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Specifications for the use of renewable energies in rural decentralised electrification

PUBLICLY AVAILABLE SPECIFICATION

INTERNATIONAL ELECTROTECHNICAL COMMISSION

EDF Electricité de France

Reference number IEC/PAS 62111

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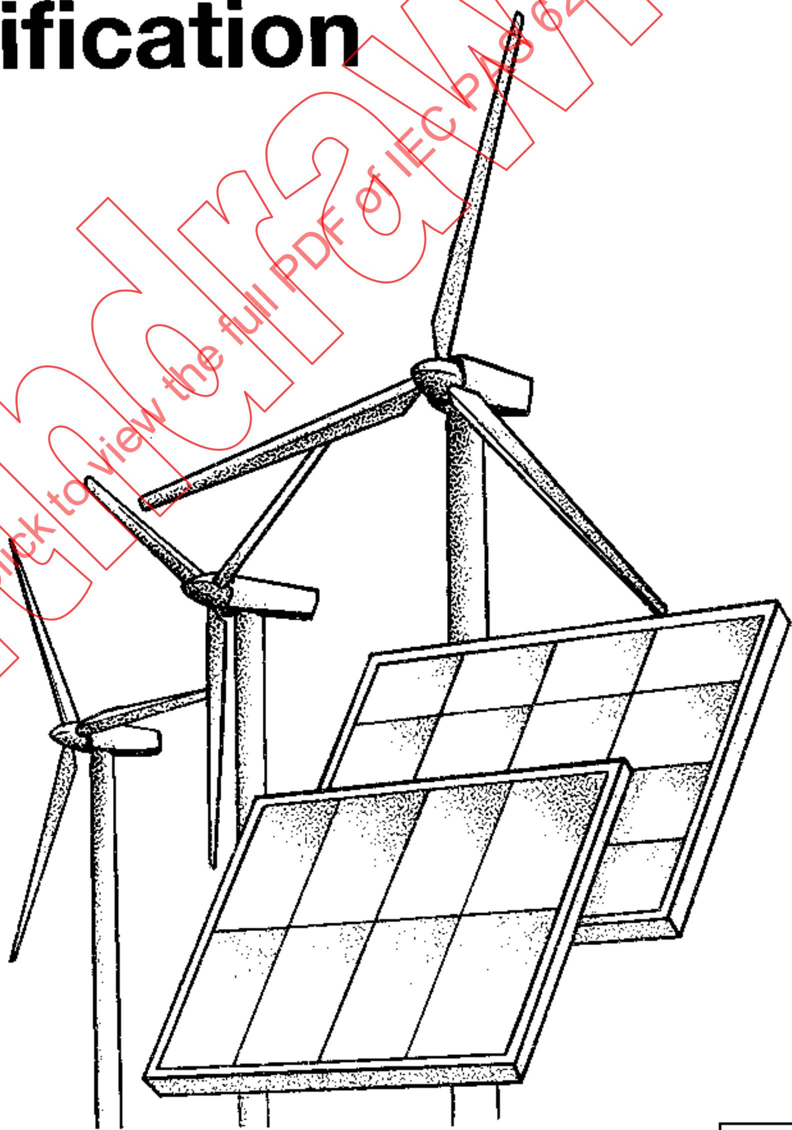

Ademe

EDF
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FOREWORD

A PAS is a technical specification not fulfilling the requirements for a standard, but made available to the public and established in an organization operating under given procedures.

IEC/PAS 62111 was submitted by Electricité de France and has been processed by IEC technical committee 82: Solar photovoltaic energy systems.

This PAS is also relevant to the activities of TC 21, Secondary cells and batteries, and TC 88, Wind turbine systems.

The text of this PAS is based on the following document:	This PAS was approved for publication by the P-members of the committee concerned as indicated in the following document:
Draft PAS	**Report on voting**
82/221/PAS	82/224/RVD

Following publication of this PAS, the technical committee or subcommittee concerned will investigate the possibility of transforming the PAS into an International Standard.

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Title

Specifications for the use of REN in Rural Decentralised Electrification

Summary

The General Directives for the use of Renewable Energies in Decentralised Rural Electrification take the form of 24 documents describing the functional specifications on which the design, implementation and exploitation of the constituent parts of these electrification systems should be based.

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SPECIFICATIONS FOR THE USE OF REN IN RURAL DECENTRALISED ELECTRIFICATION

"DRE SPECIFICATIONS"

GENERAL INTRODUCTION

Decentralised Rural Electrification projects are now being implemented in France as well as on the export market (particularly in developing countries) with no guidelines to enable those involved to establish common standards for use as a reference in assessing the quality of the installations.

It is for this reason that professionals in the area concerned have decided to pool their experience in order to establish a set of recommendations which will, when applied, provide a benchmark for the quality of the installations designed, installed and operated on this basis.

A list of those who have contributed to the content of these Directives may be found as an appendix. This document is therefore intended for the use of the **Project supervisor** and, in general, all those responsible for establishing calls for tender (e.g. : EDF - GDF Centres, Services or Electrification Syndicates in France, Independents, Development Aid Associations, etc.), as a guide to analysis of requirements and to improve the clarity of the responses they receive.

It is also intended for **Project Contractor** based in research bureaux, project planners, REN agencies in developing countries, service companies, companies involved in the electrification of villages, etc., as a guide to the presentation of their reasons for the technical options they have made in their response to the call for tender, in a format which would be comprehensible to a Project Supervisor**.**

Constructor, installers, operators and maintenance contractors will also find proposed product specifications, recommendations for the design and installation of systems, practical guidelines for operating and maintaining the installations in these Directives.

The content of these Directives is intended as a **guide** to the identification of energy requirements, of products which are technically best suited within the economic context ; it will provide a resource for :

- **selecting** an REN system suited to the installation site (adapting the solution to the needs) ;
- **specifying** a system for a pre-determined site (architecture, components, energy management, protection, etc.) ;
- **preparations** for the operation and maintenance of a REN system (guidelines to be applied).

In format, the **DRE SPECIFICATIONS** are divided into five major sections :

Part A : From Energy Requirements to Electrification System ;
Part B : Guidelines for System Design and Operation ;
Part C : Technical Specification of Components ;
Part D : Guide to Specification of a System for a Specific Site ;
Part E : Product Specifications (planned).

Table 1 provides a brief summary of each of the sections.

Table 1 : List of DRE documents

Part	Title
Series A : From Energy Requirements to Electrification System	
A 1	From the Requirements to be met to the Proposals for a Range of Electrification Systems
A 2	Results expected from the Process of System Design
A 3	Contractual Framework governing the Relationships Involved
A 4	Quality Assurance for Project Design and Implementation
Series B : Guidelines for System Design and Operation	
B 1	Architecture of Electrification Systems
B 2	Guidelines for Production Sub-System Design (planned)
B 3	Guidelines for Distribution Sub-System Design (planned)
B 4	Energy Management Guidelines
B 5	Guidelines for Data Acquisition
B 6	Guidelines for the Protection of Persons and Property from Electrical Hazards
B 7	Guidelines for Operation, Maintenance and Renewal
Series C : Technical Specification of Components	
C 1	Photovoltaic Array
C 2	Building-integration of Photovoltaic Arrays
C 3	Wind Generator
C 4	Electrogenerator Set
C 5	Battery
C 6	Converter
C 7	Energy Management
C 8	Climatic and Environmental Testing
Series D : Guide to Specification of a System for a Pre-Determined Site	
D 1	Methods for Characterising Needs (planned)
D 2	Guidelines for Selecting a System (planned)
D 3	Typical Functional Description of a Private Electrification System (planned)
D 4	Typical Functional Description of a Public Service Electrification System : Micro Power Stations
D5	Typical Functional Description of a Public Electrification System : Micro grids
Series E : Product Specifications (planned)	

The current 1997 edition will be expanded in 1998 by feedback from the application of these recommendations to **DRE** systems now being implemented throughout the world, and by the development of industrial products where the design, installation and implementation have been based on the proposed specifications.

The General Directives for the Use of REN for Decentralised Rural Electrification were drawn up for EDF by :

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DRE SPECIFICATIONS - A 1

June 1997

Title	**Part A : From Energy Requirements to Electrification System**
	Section 1 : From the Requirements to be met to the Proposals for a Range of Electrification Systems
Number of pages	14 (including appendices)
Type	Specification
Associated Document(s)	DRE - B1: "Architecture of Electrification Systems".

Summary

This document offers an initial approach to a range of systems for decentralised rural electrification, based on a theoretical analysis of user requirements and of data arising from socio-economic surveys. 8 types of system were selected as responding to three types of need. The electrification systems identified were on stream renewable energy process supply systems, private systems and service systems.

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CONTENTS

1. Vocation of Decentralised Rural Electrification Systems

Decentralised rural electrification systems are intended to supply electricity for use throughout rural areas, to sites not connected to the national grid.

The type of use is, in most cases, as follows :

- isolated private dwellings,
- dwellings in village groups,
- public service (public lighting, pumping stations, health centres, places of worship, public buildings, etc.),
- centres of economic activity (workshops, micro-industries etc.).

These systems can be sub-divided into three categories :

- process electrification systems (for example, pumping) ;
- private electrification systems (PES) for single users ;
- public service electrification systems (PSES) for public service users.

The process electrification systems and private electrification systems have only two sub-systems :

- a sub-system **producing** electrical energy ;
- a sub-system **consuming** this energy.

The public service electrification systems, on the other hand, have 3 sub-systems :

- a sub-system **producing** electrical energy.

  By convention, this section is called a **"micro power station",** the term "micro" indicating the modest levels of power produced (from a few kVA to a few dozen kVA) :
- a sub-system **distributing** this power.

  By convention, this section is called a **"micro-grid"**, the term "micro" indicating the modest levels of capacity.
- a **user** sub-system consisting of user distribution circuits and electrical equipment.

2. User Requirements

Whatever type of use is being supplied, requirements will be of two types :

- **quantitative** :
  - ◊ the **amounts of energy** required over a given period of time and providing the number of hours of use expected from the equipment installed ;
  - ◊ enough **power** to provide simultaneous use from certain installations, if not all installations.
- **qualitative** :
  - ◊ the **availability** of energy use : to be able to use energy whenever it is needed ;
  - ◊ **quality** in supply which does not affect the performance nor the life expectancy of installations.

2.1 Summary of Requirements : Supply

Appendix 1 contains an analysis of consumption typical of the devices currently installed for each of the applications mentioned in §1, and an estimated life expectancy we consider probable for these devices. This analysis was based on our experience with PV systems in France [1)] and surveys of requirements in Southern Mediterranean countries.

This analysis has lead us to propose separating quantitative requirements into 4 categories (see Table 1). For each of these categories, requirements in power and in energy have been assessed on the basis of the power specifications of equipment on the market, and on a specific number of hours use for each application.

Table 1 : Quantitative Requirements by Type

	Category	Category 2	Category 3	Category 4
Type of User and Type of Use	• **private** (lighting, audio-visual, etc.) and **low consumption public services** • (places of worship, • community centres, schools, public buildings, communications systems)	• **private** (same as category 1 + refrigeration et household appliances) and **public services** (health centres : lighting and refrigeration)	• **private** (same as category 2 + washing machines, freezers, DIY, etc.) and **public services** (public lighting)	**public services** (pumping stations, etc.) and **economic activities** (motors, etc.)
Basic Specifications	• few devices low power devices • "flat" consumer profile	• a few more devices, devices more powerful	• a lot of equipment • some powerful equipment • surge and possibly high demand on supplies • "variable" consumer profile	• powerful installations • surge and high demand on supplies
Probable installed Supply	< 200 W	150 à 500 W	0,5 à 2 kW	> 2 kW
Average Supplies required over 24h (to satisfy expected electricity consumption)	< 1 kWh	0,75 à 1,5 kWh	1500 à 4 kWh	n x 10 kWh

Category 1 : Private lighting and/or audio-visual Requirements

Power and energy requirements are low (P<200 W, E/j<1000 Wh). This category includes a certain proportion of private dwellings which can be described as "low consumers" using lighting and/or audio-visual appliances, and public services with the same type of installations. Among the latter are included places of worship, community centres, public buildings and communications systems.

Category 2 : Category 1 + Refrigeration and/or household appliances

Requirements are marginally greater (150W<P<500W et 750Wh<E/j<1500Wh).This category includes a proportion of private dwellings (lighting, audio-visual, refrigeration and household appliances) and health centres.

Category 3 : Category 2 + freezers and/or washing machine

Energy requirements are more considerable (500W<P<2000W, 1500 Wh<E/j<4000Wh).This category includes the so-called "voracious" private consumers. These consumers may have freezers, washing machines (which do not heat water), DIY equipment. Public lighting for larger villages may come under the same category. In effect, and depending on the number of lights required to operate simultaneously in a village, surge demand and energy requirements in larger villages may be compared with the third type of "private" user.

Category 4 : Process and micro-industry

Requirements for power and energy are very large (P>2000 W and E/j= n x 10 000 Wh). This category includes economic activities such as micro-industry and public services[1] such as pumping stations.

[1] 1) EDF/DER HM-55/96/025 Technical Note, October 1996 : "Feedback on Photo-Electric Systems in France - User Perception and Practice", ORHANT I, SAADAOUI L, WAERAAS de SAINT MARTIN G.

2.2 Proposing a Range of Power/Energy Ratios

Depending on the one hand, on how users wish to consume energy, and on the other, on their economic situation, several levels of service can be proposed in response to the quantitative requirements presented in Table 1, and with the following features :

- availability of daily energy levels ;
- conditions for the consumption of this energy.

A range of energy - power ratios is provided in Table 2.

Table 2 : Energy/Power Range

Requirements	**Category 1**			**Category 2**		**Category 3**				**Category 4**	
E average 24h	< 1 kWh			0,75 à 1,5 kWh		1,5 à 4 kWh				n x 10 kWh	
P installed	< 0,2 kW			0,15 à 0,5 kW		0,5 à 2 kW				> 2 kW	
Services offered	**Category 1**			**Category 2**		**Category 3**				**Category 4**	
Power Installed	10 W	50 W	100 W	200 W	200 W	500 W	500 W	1 kW	1,5 kW	2 kW	~ 4 kW
Supplies at P max. over 24 h	5 h			3 h		2 h				~ 7 - 8 h	
Max. sustainable supply over 24 h	2 W	10 W	20 W	40 W	25 W	60 W	40 W	80 W	120 W	160 W	~ 1 kW
Energy supplied over 24h	50 Wh	250 Wh	500 Wh	1 kWh	600 Wh	1,5 kWh	1 kWh	2 kWh	3 kWh	4 kWh	n x 10 kWh

2.3 Summary of Needs : Quality

Each type of use can be compared with the increasing demand shown in Table 3, by **availability period** for the energy on demand or required.

Table 3 : Types of need : qualitative

Regularity and nature of energy requirements	**Availability**
• The user needs an amount E of electric energy over a given period which extends over more than one week (weekly or monthly) • There is no quality requirement for the supply.	• He can do without energy at any time over this period of time (for example : pumping station linked with a water tower)
Every day, the user needs : • several hours of electric power supply at a constant voltage,	• He can do without electric power for several days in the year.
• to use some of the installations simultaneously	• Cannot (or will not) do without a power supply.

With regard to the **quality of the supply,** user expectation will centre on the points illustrated in Table 4.

Table 4 : Expected quality of supply

Type of equipment	Qualitative Expectations
DC	Voltage measured at equipment (U ± ΔU) Distortion of signal
AC	Voltage measured at point of supply (U ± ΔU) Frequency (F ± ΔF) Harmonics cos φ of grid

2.4 Types of Energy Production Sub-Systems

In order to begin the design of an electrification system for any given site, the technically most suitable production sub-system for the level of service required has to be selected.

In the field of decentralised rural electrification (DRE), the various production sub-systems practicable are shown in Table 5.

Table 5 : Types of production sub-systems

Type of use	Sub -system	Description of production sub-system	Constraints	Comments
Production with no storage	S1	REN, no storage, with REN availability	Random	Production is random and depends entirely on availability of the REN resources
	S2	Electrogenerator set (multi-customer systems)	Solid	This mode of production provides daily supplies over a fixed period of time
Production with buffer storage	S3	Hybrid with synchronous coupling (REN + electrogenerator set) and buffer storage	Solid	In this case, the storage associated with the REN is nothing more than a low capacity buffer battery. Resistance is S2, as the role of the battery is not to store the energy produced by the REN but to stabilise the voltage for consumption and to compensate production variations while the set is starting up.
Production with energy storage	S4	REN with energy storage	Flexible	**unreliable supplies for several days a year** With this mode of production, the storage allied to renewable energy is more flexible than for the above solutions. Because of the vagaries of the climate, this type of system may not be available for several days a year.
	S5	Hybrid (REN + Electrogenerator set) with storage of energy		**secure supplies** : The use of the electrogenerator set eliminates cuts in supplies due to climate. It guarantees continuity of supply.
	S6	Electrogenerator set with storage		

The following have not been considered :

- use of electrogenerator set only for single-user systems ;
- use of electrogenerator set in public service systems operating 24 hrs a day, linking up with a conventional power station.

The following conclusions may be drawn with regard to the various production sub-systems selected :

- The use of renewable energy alone makes for unreliable production depending on weather conditions.
- Use of the electrogenerator set provides a production unit which completely protects the user from unreliable weather. It guarantees supply. In multi-user systems, used alone (S2) or in conjunction with pseudo on-line production using REN and buffer battery (S3), it only supplies energy over a specific period of time, thus creating rigid conditions of use. (The option of diesel power stations operating 24 hours a day is not discussed in this document).
- Storage of energy adds flexibility for users :
  - ◊ combined with REN alone (S4), it means the user has adequate reserves of power to compensate for the lack of suitable natural resources. However, only over capacity from REN and storage can guarantee continued availability of supplies for the user throughout the year,
  - ◊ combined with a set with or without REN production, it enables the user to consume energy at will, without restrictions as to the period of time. The choice between a {hybrid + storage} solution (S5) and a {set + storage} solution (S6) is the result either of a political decision to use REN or of a decision to minimise operating and maintenance costs.

2.5 Matching Decentralised Production Capacities to Needs : Selection of Energy Production to Match Needs

Figure 1 illustrates how the possibilities offered by the various production sub-systems possible can be matched to user requirements.

Where user is satisfied by weekly or monthly energy supplies, with no demands as to quality, production based on renewable energy (REN) would be suitable.

Where the user requires daily supplies and accepts several days a year without operation because of weather changes, a solution consisting of storage combined with renewable energy would be suitable.

Where the user requires daily supplies completely protected from weather changes (implying the use of a set or of over capacity with REN, plus storage) several solutions would be suitable :

- an electrogenerator set (for multi-user systems) or a hybrid solution (set + REN), with synchronous coupling and buffer storage (set combined with pseudo-continuous REN). If this is the case, the user will first have to accept that supplies will be provided over a set period of time.
- production with storage, consisting either of a set on its own or of hybrid production (set + REN) or of REN alone with, in this case, over- capacity from the REN, plus storage. These solutions provide the user with operational flexibility for his system. He can consume his energy quota at will, any time of the day or night.

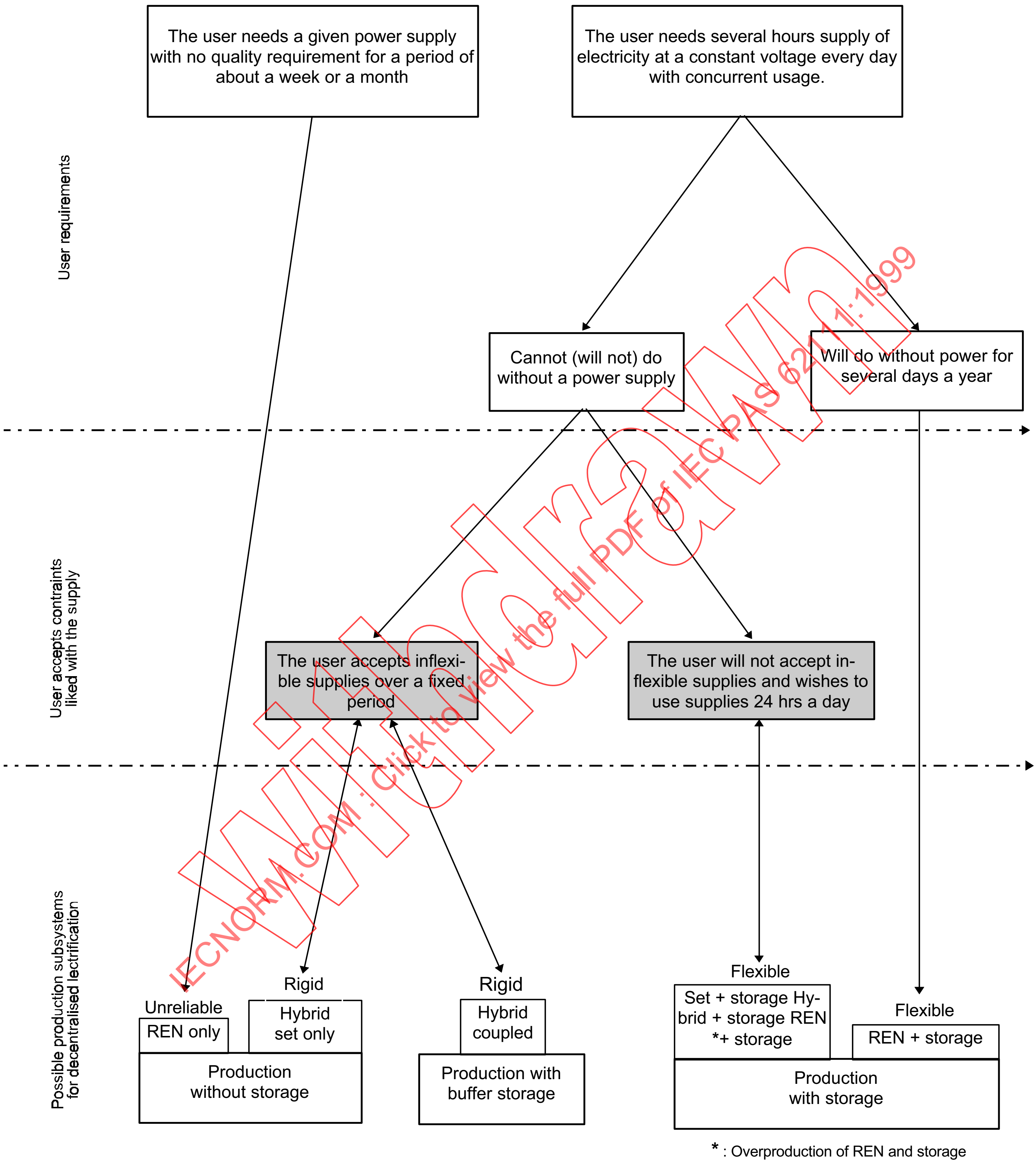

Figure 1 : Matching production possibilities to needs in decentralised systems

3. Proposing a Range of Decentralised Rural Electrification Systems

Selection of the production sub-system is carried out on the basis of the **qualitative requirements** in energy availability and acceptance by the user of the constraints connected with the proposal. Secondly, the **capacity of the production and distribution sub-systems** must be adjusted to meet **the qualitative requirements**.

Once the production sub-system matching the requirements has been selected, the type of electrification system (single or multi-user) adopted is the economically acceptable one with respect to the overall costs of investment, operation, maintenance and/or replacement, adapted to the required operational timescales. Of course, other criteria must also be born in mind, environmental protection for example.

The various types of production sub-system considered lead to the identification of eight types of **system** for decentralised rural electrification. Table 6 introduces the eight types and for each of them proposes contractual agreement to be established between Project Contractor and project designer.

The architectures of these systems are described in document DRE - B1: "Architecture of Electrification Systems". The different types of decentralised electrification systems are set out in Table 6.

Table 6 : Types of decentralised electrification systems

System Category	Type	System Description	Proposed Agreement between Site Foreman and Project Contractor
Supplies from REN sources	**T1**	REN dependent production system	Commitment to supply for x months out of 12, and y week out of 52, the contracted power supplies (or their equivalent in terms of results) every month, week, etc.
Private electrification systems (PES)	**T2**	Private REN production system with energy storage	Commitment to supply : ⇒ n days out of 365 (or n weeks out of 52) a weekly (or monthly) contractually agreed energy supply ⇒ a contractually agreed level of power.
	T3	Hybrid private production system with energy storage	
Public service electrification systems (PSES)	**T4**	REN micro-power station with energy storage, supplying a micro-grid	Commitment to supply : ⇒ n days out of 365 (or n weeks out of 52) a daily contractually agreed energy supply for a minimum of a certain number of hours. ⇒ a contractually agreed level of power
	T5	Hybrid micro-power station with energy storage supplying a micro-grid	
	T6	Hybrid micro-power station with synchronous coupling and buffer battery supplying a micro-grid.	
	T7	Diesel micro-power station with storage, supplying a micro-grid	
	T8	Diesel micro-power station supplying a micro-grid	Commitment to supply a contractually agreed power supply 365 days a year over a set timescales between time 0 and time 1.

As we have seen, a comparison of the features of the single and multi-user systems described may be summarised by the main points given in Table 7.

Table 7 : Advantages and disadvantages of the single and multi-user systems proposed

	Advantages	Disadvantages
PES systems	• the user manages his own power supply. He can vary consumption from one day to the next.	• the user runs the risk of the consequences of poor management of supplies
PEES systems	• guaranteed availability of a fixed supply of energy daily • long-term possibility (with suitable management systems) of saving on a certain amount of energy without affecting the guaranteed quota the next day	• no possibility of consuming more than the contractually agreed supply

A quantitative requirements analysis leads to the establishment of a power/energy ratio which can be proposed to customers for each of these systems, depending on the nature and the number of devices taking up the supply. These are illustrated in Table 8.

Table 8 : Proposed range of power/energy ratios

Agreed supply	10 W	50 W	100 W	200 W	200 W	500 W	500 W	1 kW	1,5 kW	2 kW	~4 kW
Energy supplied over 24h	50 Wh	250 Wh	500 Wh	1 kWh	600 Wh	1,5 kWh	1 kWh	2 kWh	3 kWh	4 kWh	n x 10 kWh

Table 9 summarises the proposed range of electrification systems. With reference to the various levels of service provided, we give :

- the type of production system recommended ;
- the type of source used by the production system ;
- the type of decentralised rural electrification system using these production systems ;
- the most probable use for each of them.

Table 9 : Initial review of decentralised electrification systems

Needs	Proposed production system			Electrification systems		Proposed contractual agreements between site foreman and Project Contractor	Comments
	REN	St	GE	PES	PSES		
The user needs an amount E of electric energy over a given period which extends over more than one week (weekly or monthly) There is no quality requirement for the supply. He can do without energy at any time over this period of time (for example : pumping station linked with a water tower)	X			T1		⇒ Commitment to supply for x months out of 12, and y weeks out of 52, the contracted power supplies (or their equivalent in terms of results) every month, week, etc.	The supplies may vary depending on the month or the season
Every day, the user needs : • several hours of electric power supply at a constant voltage, • to use some of the installations simultaneously He can do without electric power for several days in the year.	X	X		T2	T4	**PES** Commitment to supply : ⇒ n days out of 365 (or n weeks out of 52) a weekly (or monthly) contractually agreed energy supply ⇒ a contractually agreed level of power.	Days when power is cut do not include any breakdowns of the system. This includes : • either system maintenance • adjustments to the set (if there is one) • weather changes (the number of consecutive days without sun or wind) where REN production + storage is used
Every day, the user needs : • several hours of electric power supply at a constant voltage, • to use some of the installations simultaneously He cannot (will not) do without power supplies. He hopes to use energy on demand 24 hrs a day. Every days, the user needs • several hours of electric power supply at a constant voltage ; • to use some of the installations simultaneously He can do without electricity for several days in the year He accepts the restrictions of a supply during certain hours every day.	X X	X X X	 X X	T2 T3	T4 T5 T7	**PSES :** Commitment to supply : ⇒ n days out of 365 (or n weeks out of 52) a daily contractually agreed energy supply for a minimum of a certain number of hours. ⇒ a contractually agreed level of power	The PSES make it possible to offer the user savings over several days (from 3 to 5 days) in the event of the full quota not being used. This option is of interest mainly where the customer has a variable consumption profile from day to day (this generally means high power installations)>
Every day, the user needs : • several hours of electric power supply at a constant voltage, • to use some of the installations simultaneously He can do without energy for several days in a year. He accepts to only have energy at allocated times in the day	X	X	X X		T6 T8	⇒ Commitment to supply a contractually agreed power supply 365 days a year over a set time-scales between time 0 and time 1.	The hybrid system has a low capacity buffer battery. Periods of non availability are inclusive of maintenance and adjustments of the set. They do not include any breakdowns of the system.

Appendix 1 : Analysis of the types of device installed for different types of usage - Domestic use

Domestic Use : Summer							**Category I** (lighting and audio-visual)				**Category II** (**Category** I + refrigeration + household appliances)				**Category III** (**Category** II + washing machine, freezer & DIY)			
						E/j (Wh/j)	**90**	**205**	**325**	**515**	**885**	**975**	**1085**	**1175**	**1735**	**3105**	**3205**	**3555**
	Appliance	Unit Power (W)	No.	Used for : hrs/day	Power rating	Daily supply (Wh/j)												
Lighting	bulbs	10	3	3	30	90	**1**		**1**		**1**		**1**		**1**			
		10	6	3	60	180		**1**		**1**		**1**		**1**		**1**	**1**	**1**
Audio-visual	Radio	5	1	5	5	25		**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**
	TV	70	1	3	70	210			**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**
	Video	50	1	2	50	100				**1**			**1**	**1**			**1**	**1**
Cold storage	Refrigerator	70	1	8	70	560					**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**
	Freezer	160	1	8	160	1280										**1**	**1**	**1**
Labour saving	Household appliances	200	1	0,5	200	100							**1**	**1**	**1**	**1**	**1**	**1**
	Washing machine	500	1	1,5	500	750									**1**	**1**	**1**	**1**
	DIY	700	1	0,5	700	350												**1**
						P_{inst} (W)	**30**	**65**	**105**	**185**	**175**	**205**	**425**	**455**	**875**	**1065**	**1115**	**1815**

Domestic Use : Winter							**Category I** (lighting and audio-visual)				**Category II** (**Category** I + refrigeration + household appliances)				**Category III** (**Category** II + washing machine, freezer & DIY)			
						E/j (Wh/j)	**180**	**385**	**555**	**835**	**975**	**1155**	**1175**	**1355**	**1825**	**2965**	**3065**	**3415**
	Equipment	Unit Power (W)	No.	Used for : hrs/day	Power rating (W)	Daily supply (Wh/j)												
Lighting	Bulbs	10	3	6	30	180	**1**		**1**		**1**		**1**		**1**			
		10	6	6	60	360		**1**		**1**		**1**		**1**		**1**	**1**	**1**
Audio-visual	Radio	5	1	5	5	25		**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**
	TV	70	1	5	70	350			**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**
	Video	50	1	2	50	100				**1**			**1**	**1**			**1**	**1**
Cold Storage	Refrigerator	70	1	6	70	420					**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**
	Freezer	160	1	6	160	960										**1**	**1**	**1**
Labour saving	Household appliances	200	1	0,5	200	100							**1**	**1**	**1**	**1**	**1**	**1**
	Washing machine	500	1	1,5	500	750									**1**	**1**	**1**	**1**
	DIY	700	1	0,5	700	350												**1**
						P_{inst} (W)	**30**	**65**	**105**	**185**	**175**	**205**	**425**	**455**	**875**	**1065**	**1115**	**1815**

Appendix 1 (cont) - Analysis of the types of appliances installed for different types of usage : Public Service Usage

(examples of data for Mediterranean villages)

HEALTH CENTRE

Equipment	Unit power (W)	No.	Used for : (h/day)	Rated power (W)	Energy per day (Wh/day)
Bulbs	10	3	6	30	180
Refrigerator	70	1	8	70	560
Steriliser	400	1	0,5	400	200
				E/day(Wh/day)	**940**
				Pinst (W)	**500**

PLACE OF WORSHIP

Equipment	Unit power (W)	No.	Used for : (h/day)	Rated power (W)	Energy per day (Wh/day)
Bulbs	10	3	2	30	60
Mike & ampli-fier	50	1	1	50	50
				E/day (Wh/day)	**110**
				Pinst (W)	**80**

COMMUNITY CENTRE

Equipment	Unit power (W)	No.	Used for : (h/day)	Rated power (W)	Energy per day (Wh/day)
Bulbs	10	4	6	40	240
TV	70	1	5	70	350
				E/day (Wh/day)	**590**
				Pinst (W)	**110**

SCHOOL

Equipment	Unit power (W)	No.	Used for : (h/day)	Rated power (W)	Energy per day (Wh/day)
Bulbs	10	6	6	60	360
				E/day (Wh/day)	**360**
				Pinst (W)	**60**

Appendix 1 (end) - Analysis of the types of appliances installed
for each type of usage : Public Service Usage

PUBLIC BUILDINGS

Equipment	Unit power (W)	No.	Used for : (h/day)	Rated power (W)	Energy per day (Wh/day)
Bulbs	10	2	6	20	120
				E/day(Wh/day)	**120**
				Pinst (W)	**20**

COMMUNICATIONS SYSTEM

Equipment	Unit power (W)	No.	Used for : (h/day)	Rated power (W)	Energy per day (Wh/day)
System	100	1	2	100	200
				E/day (Wh/day)	**200**
				Pinst (W)	**100**

PUBLIC LIGHTING

Equipment	Unit power (W)	No.	Used for : (h/day)	Rated power (W)	Energy per day (Wh/day)
Bulbs	10	30	12	300	3600
				E/j (Wh/j)	**3600**
				Pinst (W)	**300**

PUMPING STATION

Equipment	Unit power (W)	No.	Used for : (h/day)	Rated power (W)	Energy per day (Wh/day)
Pump	1500	4	12	6000	72000
				E/day (Wh/day)	**72000**
				Pinst (W)	**6000**

DRE SPECIFICATIONS - A 2

June 1997

Title Part A - From Energy Requirements to Electrification System

Section 2 : Results expected from the Process of System Design

Number of pages 20

Type Specification

Associated Document(s)

Summary This document presents proposals for the information to be supplied with a dossier estimating the capacity of a system and submitted to a Project Supervisor in a format he is able to utilise. While leaving individual designers free choice in the method applied for estimating the system capacity, we offer a framework for a response which will improve clarity when considering the offers.

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CONTENTS

1. Implemention of Decentralised Rural Electrification Systems

Decentralised rural electrification systems are intended to supply electricity for use throughout rural areas, to sites not connected to the national grid.

The type of use is, in most cases, as follows :

- isolated private dwellings,
- dwellings in village groups,
- public service (public lighting, pumping stations, health centres, places of worship, public buildings, etc.),
- centres of economic activity (workshops, micro-industries etc.).

These systems can be sub-divided into three categories :

- process electrification systems (for example, pumping) ;
- private electrification systems (PES) for single users ;
- public service electrification systems (PSES) for public service users.

The process electrification systems and private electrification systems have only two sub-systems :

- a sub-system **producing** electrical energy ;
- a sub-system **consuming** this energy.

The public service electrification systems, on the other hand, have 3 sub-systems :

- a sub-system **producing** electrical energy.

  By convention, this section is called a **"micro power station",** the term "micro" indicating the modest levels of power produced (from a few kVA to a few dozen kVA) :
- a sub-system **distributing** this power.

  By convention, this section is called a **"micro-grid"**, the term "micro" indicating the modest levels of capacity.
- a **user** sub-system consisting of user distribution circuits and electrical equipment.

Finally, document A1 of the present directives proposes classifying the electricity supply system at isolated sites into eight categories :

Table 1 : Types of decentralised electrification systems

System Category	Type	Description of electrification system
Process supply dependent on REN	T1	REN production system "REN dependent"
Private electrification systems (PES)	T2	Private REN production system with energy storage
	T3	Private production system with energy storage
Public Service Electrification system (PSES)	T4	REN micro-power station with energy storage, supplying a micro-grid
	T5	Micro-power station with energy storage, supplying a micro-grid
	T6	Hybrid micro-power station with synchronous coupling and buffer battery, supplying a micro-grid
	T7	Diesel micro-power station with storage, supplying a micro-grid
	T8	Diesel micro-power station supplying a micro-grid

2. Purpose of this Document

This document presents proposals for the information to be supplied with a dossier estimating the capacity of a system.

While leaving individual designers free choice in the methods used for estimating the system capacity, the aim is to establish a framework for any hypotheses applied to justify estimates of capacity, and the type of results to be fed back to the principal in a format he can utilise.

The application by system designers of common rules governing the presentation of results should allow any Project Supervisor to establish an objective comparison between the various offers based on one and the same set of technical specifications,

On the other hand, the profession must be encouraged to incorporate technical and economic indicators for “good” capacity estimates so as to improve clarity in offers submitted.

3. Those Involved in Estimating Capacity

The process of estimating capacity for an installation demands the active participation of a certain number of players (see Table 2).

Care should be taken that they are required to include in the project notes on the information and decisions they provide or are responsible for.

Table 2 : Those Involved in Estimating Capacity

Nature of involvement	Responsibilities of players in the process of estimating capacity
The end user of the installation	Expresses his needs
The Project Supervisor	Defines the requirements to be met
The project designer	Establishes capacity estimate

4. Points of Comparison for Different Offers

The Project Supervisors must be given tools for comparing the various offers ; we therefore propose indicators which all designers should provide with their offer so as to improve clarity.

In this instance the fact is that the fundamental basis is provided by the establishment of technical specifications for the energy requirements to be met ; using this criteria the offer has to demonstrate, by means of the most objective data possible, that the estimated capacity of the production plant will satisfy the given energy requirements “at the right price”

In addition, it is well known that, because of uncertainty with the weather, estimates of capacity can only be based on **estimated** resources and that there is therefore a **risk** that the **reality** will differ from the forecasts.

It is the designer’s responsibility to take account of this risk without at the same time burdening the project with excessive “backup” costs.

This therefore implies that a “good” capacity estimate is one which, bearing in mind the available climatic data and the degree of uncertainty involved, minimises at the lowest possible cost the risk the customer runs of having to do without the expected supply.

We propose that comparison of the various offers should be based on the following basic points :

- the **hypotheses** on which the capacity estimates for the energy source are based ;
- the technical **data** resulting from the process of estimating the capacity ;
- the **measures** adopted to minimise the **risks** of not achieving the expected levels of service ;
- the current **cost** of the proposed installations ;
- a **guarantee** from the designer covering work on subsequent deviations in performance levels of equipment, malfunctions, costs involved after commissioning, and attributable to his work.

This proposal should mean that designers will respect the three following provisions when presenting their offer :

- **present** results and costs in accordance with a minimum list of information to be provided ;
- **explain** the major points they have based their proposals on : the hypotheses concerning consumption and the weather, provision they have made to minimise the risk of cuts in the expected levels of service.
- **agree** on the measures they will apply in the case of breakdowns (technical or economic) which cannot be ascribed to weather conditions, conditions of use, conditions of installation, maintenance or upkeep.

4.1 Presenting Results and Costs

4.1.1 Presenting the Re sults

The results are expressed as **specifications for the components** used in the system and as **agreements on supply** for the system as a whole.

◊ technical specifications for the main components (see details in Part C of the present specifications)

Table 3 : Technical specifications to be provided for the main components

• **photovoltaic panels**	number and type of panel power generated nominal voltage proportion of energy supplied daily by the photovoltaic installation
• **wind generators**	model nominal power nominal voltage
• **electro-generator set**	model power daily operating period proportion of energy supplied daily by the set
• **charger**	type power
• **batteries**	type capacity as a function of the discharge rate no of cycles
• **converter**	type power

◊ agreements regarding supply

These agreements are listed in Part A1 of the present directives ; the major points can be summarised as follows :

Table 4 : Proposed agreements

System Category	Type	Description of the electrification system	Proposed agreement between the Project Contractor and the Project Supervisor
Process supply dependant on REN	T1	REN production system "REN dependent"	Agreement to supply x months/12, y weeks /52, the contractually agreed quantities of energy (or the equivalent in terms of process results) over one month, one week, etc.
Private electrification systems (PES)	T2	Private REN production system with energy storage	Agreement to supply : ⇒ n days/365 (or n weeks/52) a weekly (or monthly) a contractually agreed quantity of energy ⇒ a given level of power
	T3	Hybrid private production system with energy storage	
Public Service electrification systems (PSES)	T4	REN micro-power station with energy storage, supplying a micro-grid	Agreement to supply : ⇒ n days/365 (or n weeks/52) a contractually agreed quantity of energy daily, at least, over a fixed timespan. ⇒ a given level of power
	T5	Hybrid micro-power station with energy storage, supplying a micro-grid	
	T6	Hybrid micro-power station with synchronous coupling and buffer battery supplying a micro-grid	
	T7	Diesel micro-power station with storage, supplying a micro-grid	
	T8	Diesel micro-power station supplying a micro-grid	Agreement to supply a contractually agreed level of power for n days/365, over a fixed time period from t0 to t1

◊ additional indicators

Additional indicators for estimating the capacity of the production sub-systems may include :

- a user "energy supply satisfaction " coefficient

  Estimates for the capacity of the installation rely on the probability of production plant generating adequate supplies of power over a given period of time to meet the energy requirements, in conformity with the hypothetical needs assessment analysis carried out beforehand.

- an estimated surcharge for REN investment.

  Bearing in mind the resource hypotheses adopted, this surcharge will be :

$$\frac{\text{probable quantities of energy the installation can produce with the REN (*)}}{\text{expected energy consumption (*)}}$$

(month by month)

(*) measured at the same point

4.1.2 Presenting the Costs

The costs supplied to the Project Supervisor must be current costs.

Rules on updating the costs are provided in Part D2 of the present Directives.

Components of these costs are as follows :

- the cost of the initial investment (equipment and installation) ;
- the cost of renewal (ditto) ;
- the operating costs (labour and consumables) ;
- the cost of recuperation and dismantling.

4.2 Explaining the Basic Hypotheses used for Estimating Capacity

Details of the hypothetical basis for estimating capacity provide information by which the Project Supervisor can appreciate the margins included by the designer to account for uncertainties.

4.2.1 Estimated Resources and Estimated Consumption Data used to Construct the Estimated Capacity

The table below illustrates various levels of detail in the knowledge of customer and REN resource consumption (in this case, sunlight).

	• **Data on consumption**
Level 1	Very precise knowledge of consumption levels over time, with information on the consumption = f (battery voltage)
Level 2	Daily consumption distributed throughout the day on the basis of day/night consumption
Level 3	Daily consumption with averages for "weekdays " and “weekends”
Level 4	Daily consumption, monthly averages
Level 5	Daily consumption, annual averages
	• **Data on resources**
• **General data on sunlight**	
Level 1	Diffuse - direct sunlight measured at short intervals on a horizontal surface with ambient temperature and wind speed - direction, at a given site.
Level 2	Daily sunlight (direct - diffuse components?) on a horizontal surface, at a given site
Level 3	Average monthly sunlight per day on a horizontal surface, at a given site
Level 4	Average monthly sunlight per day for a given geographical area, on a horizontal surface (taken from an atlas or from satellite measurements)
	• **Data on sunlight for the site concerned**
Case 1	The site is one for which general data is available
Case 2	The site is "close", from a meteorological point of view, to other sites for which general data is available (except for level 4)
Case 3	The site is as described for level 4.
	• **Background depth for data**
	N years
	• **Site specification**
	Take into account local micro-climate conditions, masking effects, albedo, inclines selected, etc.

The designer will be asked to stipulate what degree of accuracy he was working under, as each class is said to represent a uniform consumption/resource ratio with respect to the establishment of energy management schedules (see table 5).

Table 5 : Class of accuracy of consumption/resource ratio

	Level of detail for information on resources			
	Level 1	Level 2	Level 3	Level 4
	Hourly records of sunlight for a specific site	Daily sunlight levels for a specific site	Daily sunlight levels (monthly average) for a specific site	Daily sunlight levels (monthly average) indicative of a specific geographical area
Information on consumption levels	Degree of coherence in the levels of detail in resource and consumption level data used as a basis for estimating capacity			
L 1 very specific knowledge of the consumption rates over time	●	❍	□	
L 2 knowledge of daily consumption levels	❍	❍	□	⌘
L 3 average daily consumption levels	□	□	□	⌘
L 4 daily consumption, monthly averages	□	□	□	⌘
L 5 daily consumption, annual averages		⌘	⌘	⌘

●	Class 1	the most accurate
❍	Class 2	
□	Class 3	
⌘	Class 4	the least accurate
(grey)	no coherent data	

The designer is also asked to specify the productivity levels adopted for the panels, as a basis for assessing the proportion of the daily energy requirements they are destined to provide.

4.2.2 Measures taken to Minimise the Effects of Changing Weather on the Quality of the Service Provided

The designer will need to take care to specify here the precise parameters he used to estimate the capacity of the system :

◊ reduction in the estimated sunlight resources, why?

◊ selection of a specific timespan of sunlight hours, which? why?

◊ increase in the estimated consumption, why?

◊ selection of a period for autonomous operation, when? why?

◊ opting for the use of a set, why?

◊ etc.

4.3 Agreement on Measures Envisaged to Correct Possible Errors in Estimated Capacity

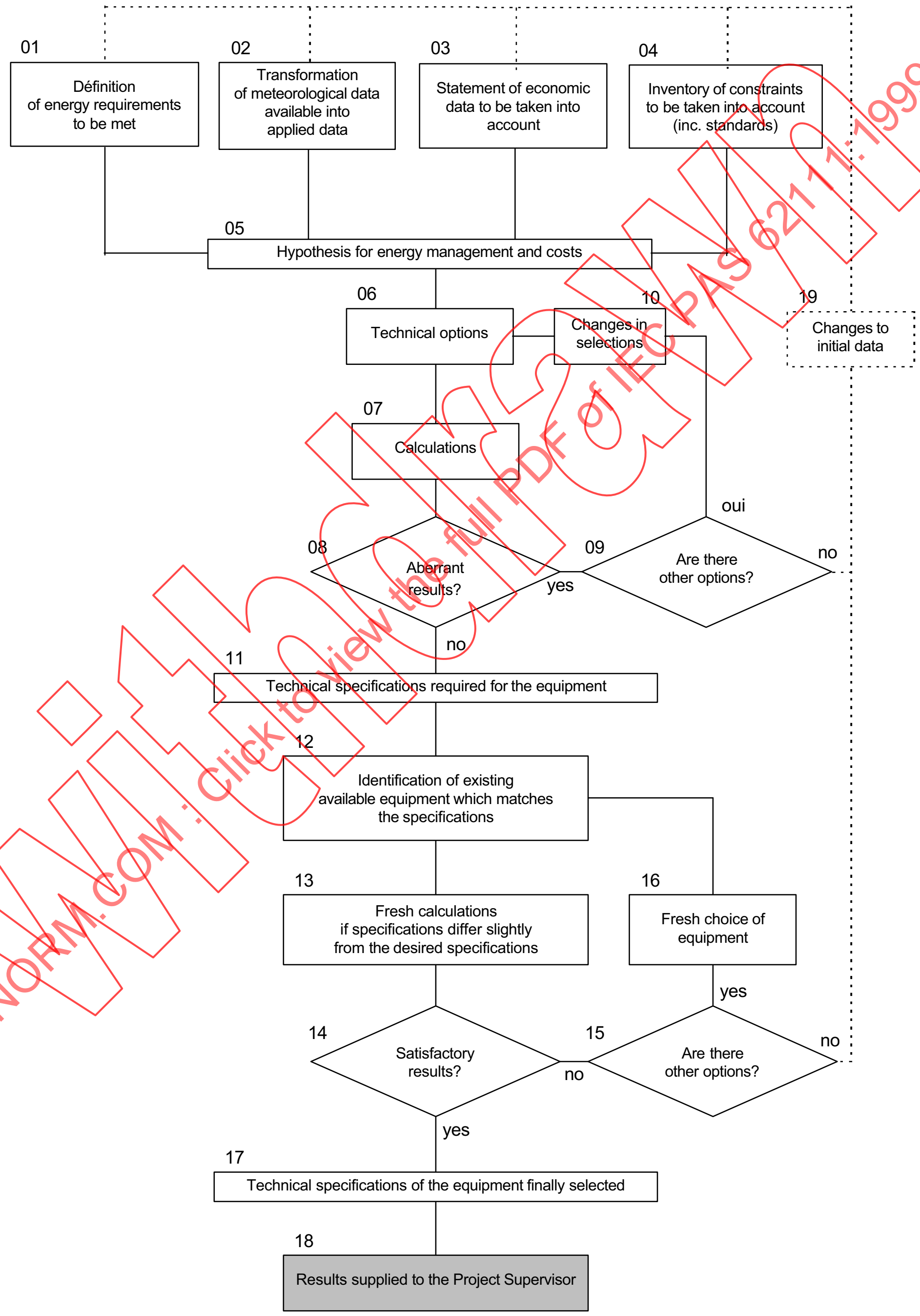
The designer will be given the opportunity to prove whether results can be guaranteed and therefore the applicability of the measures he undertakes to carry out if there is a recognised fault in estimates of capacity.

5. Proposed Procedure for Estimating Capacity

The procedures recommended for establishing an estimate of the capacity of an REN production installation is described in the diagram below.

(Each of the stages in this process has a reference number and is the subject of notes given immediately below the diagram.)

Diagram illustrating the process for estimating capacity



Comments on the proposed procedures for estimating capacity

It would be desirable for stages 01 to 05 (information gathering and establishment of working hypotheses) to be based on guidelines common to the whole of the profession.

Stages 06 to 16 provide a proposed methodology : however, the information sources and the way this information is handled are part of the skill of each designer. We cannot here propose detailed guidelines applicable to all.

It would also be desirable to base the form and content of the results provided at the outcome of the procedures for estimating capacity (stages 17 and 18) on common guidelines applicable throughout the profession.

Stage 01 : Definition of the energy requirements to be met

The energy requirements to be met are described by :

- **qualitative data** including :
  - ◊ the type of energy consumption (the types of device requiring supply) :

    We propose that the inventory of applications included in the project should be set out as described in Table 6.

Table 6 : Description of types of use requiring power supplies

Existing or potential type of customer		Type of equipment supplied
Type 1	private individuals	domestic appliances and equipment (lighting, audio-visual and cold storage equipment, etc.)
Type 2	economic activities	equipment used for professional purposes (motors, processes, etc.)
Type 3	public services	public service equipment (pumping stations, street lighting, etc.)

  - ◊ the type of energy to be supplied (based on the type of user equipment) :
    - ♦ direct current (DC)
    - ♦ and/or single phase alternative current (AC)
    - ♦ and/or three phase alternative current(AC)
  - ◊ the priority levels to be given to the various types of usage in case of conflict between demand and overall availability of power
- **quantitative data** as follows :
  - ◊ grid specifications
  - ◊ the number of supply points for each type of usage
  - ◊ specification for agreed supply
    - ♦ the maximum power levels to be connected at the point of supply, for each type of usage
    - ♦ the maximum level of energy available over a given period (e.g. 24 hrs) at each point of supply
  - ◊ specifications for consumption
    - ♦ the consumption profile (power and energy) for each supply point over a specific period

      The relevant timespan where energy management is concerned, is one hour.

      The ideal would be for the timespan used to measure consumption should be as close as possible to this.

If the real values at time H are not known, the values for time H-1 should be used.

* the timespan (over a given period of time) during which energy supplies must be provided

* For this, a choice will have to be made as described in the Table 7.

Table 7 : Example of how supplies are allocated

The overall time-span supplies are required for	Example of how supplies are allocated
24 h / 24	Supplies to all customers
12 h / 24	Supplies to economic activities during the day (8h)
	Supplies to private persons in the evening (4h)
4 h / 24	Supplies to private persons

For each point of delivery, the quantities of energy consumed (predicted) will be estimated by :

- exact assessment of consumption for each device, given the supply source ;
- as precise an assessment as possible of the length of time each device is used for, taking the season into account where necessary ;
- an assessment of the average daytime energy demand profile : the day itself may be split into periods (day/night, for example, or work/leisure), or even into hours ;
- an assessment profile for the occupation of buildings : continuous or occasional occupation (known or unknown levels of occupation) ;
- a definition of possible "peak" or "surge" consumption characterised by sudden short-term demand for power.

Stage 02 : Transformation of available meteorological data into applied data

The type of meteorological data available should be specified, from as close as possible to the installation site and with a degree of precision matching the level of knowledge of energy requirements.

In the absence of very detailed data, and with the purpose of transparency of information for all those concerned, any corrections to the available data must be indicated.

An information sheet will be established showing the data from the calculations so as to provide background information on the process of estimating capacity. This sheet could be of the type illustrated in Table 8.

Table 8 : Meteorological data used in estimating capacity

Equipment concerned	Data to be collected	Ideal data	Data available	Corrections made	Data applied in the calculations
panels	◊ Average sunlight on a horizontal surface, in kWh/m^2/j ⁎ overall ⁎ direct ⁎ diffuse ◊ Number of days per year without sun ◊ Masking effect ◊ Albedo	average/h no of consecutive days status of the panels/h coefficient/ time of year			
battery	◊ Temperatures : night-time/daytime or min/max	average/ h			
wind generator	◊ wind speed (m/s) (and height of measuring point) ◊ Average Weibull factor distribution form ◊ Wind rose ◊ No of calm days per month ◊ Site terrain (obstacles, relief over a specific area, type of vegetation) ◊ Maximum wind speed	av./mnth av./day annual no of consecutive days av. over 10 years			

Stage 03 : Statement of economic data to be taken into account

With a view to the establishment of the current overall cost of the installation at a specific date, it will be necessary to assess the cost components illustrated in Table 9 for each scenario involving an estimate of capacity.

Table 9 : Proposed types of costs to be taken into account

◊ the cost of design		◊
◊ investment costs	sources, batteries, converters, equipment for protection, management, monitoring	◊ cost of equipment utilised on site (purchases, transport, reception of materials, civil engineering) ◊ technical inspection ◊ cost of project design
◊ operating costs	operations, upkeep, maintenance of equipment, servicing	◊ cost of consumables on site (diesel, demineralised water, etc.) ◊ cost of on-site services ◊ insurance
◊ renewals	changes to equipment because of wear or modification to meet new needs	proportion of the initial costs allocated for contingencies
◊ the costs of dismantling		◊ cost of dismantling the batteries

Stage 04 : Inventory of constraints to be taken into account

Table 10 provides a list of constraints, the presence of which has to be checked in every case.

For each site, care should be taken to list the particular aspects taken into account when estimating capacity.

Table 10 : Inventory of site constraints

	Type of constraint	Features to check	Features of the site which have an impact on estimating capacity
1	Geographical environment	climatic disturbances (rain, sun, sand, frost, etc.)	
		extremes of heat and humidity	
		access routes to the site / access times	
		nature of the terrain	
		position of supply points	
2	Biological environment	fauna	
		flora	
3	Technical environment	type of grid possibly already in place (overhead, underground)	
		civil engineering	
		quality of existing buildings	
		local maintenance possible on site	
		equipment present	
4	Sociological environment	standard of living of the customers supplied	
		customary power consumption	
5	Economic environment	existing economic activities	
		solvability of customers	
		various legal provisions	
		budget limit	
6	Local government environment	site classification	
		contractual specifications	
		constraints regarding nuisance (noise, etc.)	

Stage 05 : Management hypotheses

◊ Energy management

Managing energy, means checking the production REN/consumption figures and taking the relevant action where necessary

- in the interests of the end user (to keep as close as possible to the commitment to supply energy)
- and inspecting the equipment for signs of ageing (so that the investment is exploited throughout the period it was designed to cover)

Table 11 illustrates the impact which management hypotheses can have on capacity estimates and installation.

Table 11 : Effects of energy management hypotheses on capacity estimates and installation

Hypotheses	Effects of estimates of capacity
◊ number of consecutive days without REN	expected battery life
◊ choice of battery life	type of battery
◊ expected role of the electrogenerator set	power of the set
– extra charging of the battery (included in the output)	
– source of emergency supply if the REN fails, battery or converters	
– rate of use of the set	fuel storage capacity ; battery life
◊ authorised (or not) load shedding and certain usage, under certain conditions,	battery capacity and/or GE
◊ load shedding priorities	
◊ special constraints for certain usage (e.g. : high demand for power, constraints on operating hours, etc.)	battery capacity
◊ constraints on objectives affected by the life-cycle of equipment	choice of models, equipment and battery capacity
◊ political will to use REN	

◊ Cost Management

For each case, it is desirable to seek a compromise which will work across the whole range of "investment costs + operating costs + renewal costs ".

Depending on the customer, the balance can be varied according to the technical and financial possibilities, and user requirements , in each case, care should be taken to stipulate the main objectives which the technical options sought to achieve :

- minimum cost of investment?
- minimum operating cost?
- minimum cost of renewal?

and to specify the estimated proportion of each of these overall.

Table 12 illustrates the impact cost management hypotheses can have on estimating the capacity of the installation.

Table 12 : Effects of cost management hypotheses on estimating the capacity of an installation

Hypotheses	Effects on estimates of capacity
◊ maximum / normal / minimum life of the equipment	type of battery, battery capacity, management of recharging and discharge, type of electrogenerator set
◊ normal / minimum maintenance	
– number and complexity of the maintenance operations involved	type of battery/ type of set
– frequency of maintenance operations	battery capacity and type of battery management of recharge/discharge model of set
– rate of use of the set	model of set
◊ ....*(extend list)*	

Stage 06 : Technical options

The following are covered by the term technical options :

- options with regard to architecture
  - ◊ main layout plans of the installations designed to produce, dispatch and distribute energy
  - ◊ the use or not of converters, if yes, how many, of what power, and how are they organised.
  - ◊ siting and type of circuit breakers/protection
- options relating to the technical specifications of the equipment (panels, wind generator, electrogenerator set, batteries etc.)
  - ◊ options selected from among the possible range and which are available in equipment already on the market.

Several repeat drafts will undoubtedly be necessary before settling on the option or options to be recommended to the Project Supervisor.

The initial options will be "a priori" options based on the experience of the designer.

It may be that the range of choice available is very limited, particularly when the requirement is to re-use existing equipment or to use certain brands of equipment or models (requirements described in [04] above).

Several sets of data should be used, including the conclusions drawn from analysis of the results of calculations and data testing the range of performance of one installation against options other than the initial selection.

Recommendations :

- single phase production if the output is <5 kVA
- three phase production if the output is >10 kVA
- direct current distribution if peak power (photovoltaic) < 1 kWc
- for economic activities :

  if these are marginal : it would be preferable to deal with the problem of three phase supply case by case (specific backup supply) rather than involving investment in the entire grid ;

  if these are developing or if they are to be encouraged, the possibility of three phase distribution must be looked at (over the whole grid or via a separate grid).

Stage 07 : Calculations

The calculations are carried out on the basis of the technical and economic hypotheses which have been adopted ; they are used to establish energy schedules and to assess the costs of installations which will meet these schedules.

The type of models used to demonstrate the operation of the installation and the selection of the initial data processing algorithms are left to the designers.

The calculations must demonstrate coherence and precision as well as an in-depth knowledge of the energy requirements and REN output.

Whatever tools are used, they must, establish basic values on the basis the hypotheses listed under Stages 01 - 06, including :

- estimated average rate of coverage for the installation (this value is taken into consideration for lack of anything better)
- estimated level of service for the installation (to be held in reserve until another version can be reached, since tools currently available cannot determine this value)
- budget required to obtain these values
- sensitivity of the budget to variations in these values

Stage 08 : Analysis of Results

Analysis of the results must reach a decision on whether the technical options taken can meet the technical and economic objectives required for the installation.

The results will be judged to be "aberrant" if any of the following criteria has not been followed :

- any of the stages 01 to 06 of the diagram illustrating the procedures for estimating the capacity has not been followed
- the recommendations have not been adhered to
- the investment costs exceed the budget estimated or provided

Stage 09 : Examining the viability of other options

If an unfavourable conclusion is reached about the results obtained from the calculations, the possibility will be examined of using other technical options to those already selected under [06] to meet customer requirements.

If this is so, go to stage [10] to re-examine the technical options, otherwise go to stage [19] to re-negotiate the initial conditions (where this is possible).

Stage 10 : Modifying the technical options

This is a question of modifying the specifications for the architecture or the initial estimates of capacity for the equipment, in order to bring a new set of data into the calculations.

Stage 11 : Defining the technical specifications required for equipment

These specifications formed the initial basis for the establishment (or deduction, depending on the algorithms used) of acceptable technical and economic schedules, that is.....*(please complete)*

Stage 12 : Identification of existing and available equipment which matches the specifications

Using the required specifications as a basis, a list will be made of equipment which could effectively be used in the installation, bearing in mind actual availability on the market and the timescales required for completion of the installation.

Stage 13 : Fresh calculations

This stage may be necessary if the opportunity presents itself to use equipment close to specification when compared with the equipment listed under stage [12], and which, for all sorts of reasons, is suddenly available or is offered at a good price. In this case, the calculations should be repeated to establish what the differences in results would be compared with the differences in specification between the equipment selected under stage [12] and that which is now being proposed.

Stage 14 : Analysis of results

This stage is of the same type as stage [08] :

The analysis of results must show to what extent the technical options exercised will satisfy the technical and economic objectives of the installation.

The results will be judged to be "aberrant" if any of the following criteria has not been followed :

- any of the stages 01 to 06 of the diagram illustrating the procedures for estimating the capacity has not been followed
- the recommendations have not been adhered to
- the standards have not been applied
- the investment costs exceed the budget estimated or provided
- the updated cost is not the lowest (compared with other possible solutions)

Stage 15 : Examining the viability of other options

This stage is of the same type as stage [09]

Stage 16 : Selection of other equipment

This stage is of the same type as stage [10]

Stage 17 : Technical specifications for the equipment finally selected

These specifications are for the equipment finally selected for a scenario submitted to the Project Supervisor.

Stage 18 : Results supplied to the Project Supervisor

The results of the exercise for estimating capacity must provide the Project Supervisor with the following key information :

Table 13 : Information specific to estimating the capacity of an installation as submitted to the Project Supervisor

The data on which the capacity estimate is based :	specified energy requirements taken into consideration values for REN resources used for the design (with reference to meteorological data) site constraints taken into consideration energy management hypotheses cost management scenarios
Operational features of the installation (energy, power, autonomy)	• estimated coverage rate for the installation (month by month) • autonomy of battery • autonomy of the system when supplying peak power
Operational plans of the installation	• position of each piece of equipment
Description of the main items of equipment to be installed	descriptive list of the proposed equipment
The budget required for the acquisition and the implementation of the installation over N years	• investment costs estimated operating costs renewal costs distribution in time of renewals which will have to be made

6. Technical specifications of the main equipment proposed

The tables below propose technical specifications for each main type of equipment (generators, batteries, converters) which the designer can then use as a basis for recommending models for this equipment to the Project Supervisor.

6.1 Specifications for the photovoltaic array

6.1.1 Photovoltaic Panels

Results supplied to the Project Supervisor			
◊ number and type of panels (in accordance with the requirements of the Charter Standards) ◊ unitary peaking capacity	◊ nominal voltage for the panel ◊	◊ panel surface	◊ site constraints taken into account
Technical specifications leading to the final selection of panel modules			
total peaking capacity	• nominal generator voltage	• electrical specifications I = f(V)	• site constraints taken into account

6.1.2 Support structure for the panels

Results supplied to the Project Supervisor			
◊ number of structures ◊ type of structure (roof, etc.)	◊	◊ no of panels	◊ installation of panels
Technical specifications on which the final selection of the structure is based			
• no of modules/structure • materials	• means of attachment • angle of the panels (°/horizon)	• direction of the panels (°/North) • site constraints taken into account	• area occupied

6.2 Specifications for wind generators

6.2.1 Wind generator

Results supplied to the Project Supervisor			
◊ wind-generator model ◊ rated power	◊ nominal voltage	◊ rated frequency	
Technical specifications on which the final selection of the wind generator is based			
• rotator diameter • no of vanes • output curve	• adjustment system • directional system • start-up wind speed (to start rotating)	• interrupt wind speed • destructive wind speed	• site constraints taken into account [04]

6.2.2 Support structure

Results supplied to the Project Supervisor			
◊ type of support	◊ general plan	◊ ground area covered by the installation	
Technical specifications on which the final selection of the support structures is based			
• type of support • height of support	• access to the pod for maintenance • means of attachment	• volumes of concrete	

6.3 Specifications for the electrogenerator set

Results supplied to the Project Supervisor			
◊ model of set (type and brand)	◊ set environment ◊ fuel storage method	◊ start-up ◊ operating period	
Technical specifications on which the final selection of the electrogenerator set is based			
• power in kVA • cosφ • voltage (single/three phase) • operation :	backup/emergency • Reliability : normal or with backup • speed	• type of fuel • type of cooling • environmental constraints taken into consideration [04] • safety factors taken into consideration (electrical, vandal-proofing, etc.)	• operational constraints taken into consideration • energy management constraints taken into consideration • factors governing installation

6.4 Specifications for the battery

(please complete)

Results supplied to the Project Supervisor			
(type and make)			
Technical specifications on which the final selection of the battery is based			

6.5 Specifications for the converters

Results supplied to the Project Supervisor			
model of converter	(type and make)		
Technical specifications on which the final selection of the DC/DC converters is based			
• nominal input voltage • rated input voltage • nominal output voltage • rated output voltage	• rated output power (and corresponding % load) • maximum output power (and corresponding % load) • efficiency rating with respect to load • consumption with no load	• existence and calibration of converter protection (particularly protection against polarity reversals) • conforms with standards • range of operating temperatures	• dimensions and volume • type of connections
Technical specifications on which the final selection of the DC/AC converters is based			
• nominal input voltage • rated input voltage • rated output voltage • nominal output voltage • nominal output frequency • rated output voltage	• type of output signal (wave form) • max relative harmonic content • rated output voltage (for corresponding type and % load) • voltages higher than rated and duration of effect acceptable • rated and maximum current acceptable at output	• efficiency rating as a function of the load • empty running • existence of protective devices for converter • existence of output protection for the converter • existence of a potentially adjustable "wait" mode	• conforms with standards • operating temperature range • dimensions and volume • type of connections
Technical specifications on which the final selection of reversible DC/AC converters is based (charger function)			
as above with the following in addition : • max. voltage on input • minimum input voltage	• max output current • rated output voltage	• type of load control	• existence of temperature adjustment for load control

6.6 Specifications for energy management

Results supplied to the Project Supervisor			
Technical specifications on which the final selection of energy management is based			
•	•	•	

6.7 Specifications for couplings

Results supplied to the Project Supervisor			
Technical specifications on which the final selection of couplings is based			
•	•	•	

DRE SPECIFICATIONS - A 3

June 1997

Title **Part A : From Energy Requirements to Electrification System**

Section 3 : Contractual Framework governing the Relationships Involved

Number of pages 10 (including appendices)

Type Specification

Associated document(s)

DRE - A 1 : "From the Requirements to be met to the Proposals for a Range of Electrification Systems".
DRE - A 2 : "Results expected from the Process of System Design".
DRE - A 4 : "Quality Assurance for Project Design and Implementation".
DRE - B 5 : "Guidelines for Data Acquisition".
DRE - B 6 : "Guidelines for the Protection of Persons and Property from Electrical Hazards".
DRE - B 7 : "Guidelines for Operation, Maintenance and Renewal".

Summary

This document lists the various parties involved in an electrification operation in a rural area or in isolated locations. It defines the contractual relationships between them and details the particular responsibilities which each of them must undertake in order to produce a successful outcome for the operation.

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Contents

INTRODUCTION

There are two possible solutions for the electrification of isolated locations :

1) an extension of the grid

2) the installation of stand-alone electricity generators, especially those using renewable energy

This second solution is chosen depending on its economic viability compared with the conventional solution of extending the grid.

A certain number of parties are involved in the electrification of isolated locations. These appear in the rest of this document under the designations laid out in paragraph 2.

This document deals in one part with the principal general technical clauses and in the other part with the contractual relations between the different parties involved. Its purpose is to establish clearly the responsibilities of each one of the parties listed below with regard to the construction, management and operation of stand-alone electrification installations in isolated locations. Simplified model of maintenance contracts for power stations equipped with small wind generators or photovoltaic generators are offered in document DRE - B 7 : "Guidelines for Operation, Maintenance and Renewal". In the case of a mixed installation, by starting from the proposed models it is simple to produce a contract taking both types of generator into account.

In every case a Project Contractor is appointed by the Project Supervisor and it is he who is responsible for the conformity of the installation to the specifications, even when there are several companies involved in the construction work.

The Project Supervisor is responsible for deciding whether or not to adopt quality assurance procedures (see document DRE - A 4 - "Quality Assurance for Project Design and Implementation").

Also in every case a single organisation or a single person takes charge of the operation and maintenance of the installation. This is the most important requirement for its continuing successful operation.

Note. - *In France two situations can arise :*

1) The project is eligible for assistance from FACE (Fond d'Amortissement des Charges d'Electrification - Fund for the reduction of electrification costs).

In rural areas the choice of those who are to obtain contracts for these installations is made by the Electrification Syndicates. These then become the Project Supervisors based on the following principal criteria :

(main residence, carrying on economic activity, actions of benefit to the community

•economic interest with regard to the extension or improvement of electrical supplies

The execution of the project is carried out in accordance with standard public procurement tendering procedures.

The Project Supervisor (The Electrification Syndicate) appoints an independent Project Contractor who is responsible for the call for tenders and for the construction programme. If the Project Supervisor decides to include the DRE Specifications in the call to tender, the Project Contractor is responsible for the load of these provisions.

The work is then accorded the status of an EDF concession (EDF - the French State Electricity Company).

2) The project is undertaken by another organisation or person and does not go through the public tender procedures.

If it takes place in the framework of the DRE Specifications the Project Contractor appointed by the Project Supervisor is once again responsible for the application of the provisions of the DRE specifications. In the absence of the appointment of a Project Contractor by the Project Supervisor, one of the companies concerned if there are several of them (for example the project planners or the designers) will take on this project management role by agreement with all the other partners in the project.

If only one company is involved, it will undertake the project management and the responsibility for observing the provisions of the DRE specifications.

In both cases, the Contractors, after the call for tenders, will install the equipment which will be under the control of an operating company. This will be EDF, when the installation has been financed by FACE and it has been accorded concession status, and could be a state organisation, an independent company or an person proprietor of an installation.

The operating company will sign a contract with a maintenance contractor which relates to maintenance and the replacement of live components. This contract will naturally involve fees for its performance.

1. Scope of this Document

This document describes the main general technical clauses and the relationships between the different parties in order to define their person responsibilities clearly.

2. Definitions

Project Supervisor : this is the principal developer of the electrification project. He is responsible for compiling the technical specification of the project and for the financing of the construction work.

Project Contractor : this is the person appointed by the **Project Supervisor** to ensure that the construction work is carried out as per specification. He is responsible for making sure that the installation is carried out in accordance with the specification compiled by the **Project Supervisor**.

He is also responsible for estimating the sizing of the system in accordance with the specification of the **Project Supervisor**.

Sub-contractor : responsible for certain aspects of the work as described in the call for tenders published in relation to the project ; he is responsible to the **Project Contractor** for the efficient execution of his contracted jobs.

Operator : the organisation, operator or person in charge of the operation, management and maintenance of the installation. In certain cases this party may also be a licence holder.

Maintainer : the organisation, company, operator or person entrusted by the operator with the maintenance of the installation.

User : the person who uses the installation for his domestic or professional requirements.

3. Elements of the contract

During the tendering process, the construction, the commissioning of the installation by an operating organisation or the use of this installation, the different parties must be able to check that the responsibilities of the other parties are being met.

Some items are checked by means of trackable documents which are produced throughout the entire project (see document DRE - A 4 "Quality Assurance for Project Design and Implementation"). In particular, the meteorological data which were taken into account for the Project Plan are clearly explained, as are the principles or the software used. (see document DRE - A 2 : "Results expected from the Process of System Design").

Some other items, notably those which relate to the electrical performance of the installation are provided by the instrumentation with which the site is equipped (see document DRE - B 5 : "Guidelines for Data Acquisition").

Should one of the parties not be satisfied with the performance of the installation, the documents justifying the sizing and the instrumentation of the installation by a system of measurement, will permit the cause of the non-performance to be identified :

- inaccurate sizing of the system
- over-consumption by the customer relative to forecasts
- etc.

3.1 Contract between the Project Supervisor and the Project Contractor

The Project Supervisor must ensure that the installation undertaken by the Project Contractor on his behalf conforms to the specification and that the sizing is correct, that is to say that it will fulfil the performance requirements laid out in the specification.

3.2 Contract between the Project Contractor and the subcontractors

The Project Contractor must ensure that the jobs undertaken by the various subcontractors conform to the tender documents. He is responsible for the correct sizing of the installation in regard to the specification. The subcontracting companies holding the tenders who carry out the installation must provide proof to the Project Contractor of the conformity of their installation to their tender documents with regard to performance and quality.

3.3 Contract between the Operator and the Project Supervisor

The Project Supervisor hands over to the Operator an installation which purports to be capable of certain performance standards which are those anticipated in the specification. The Operator must verify that the actual performance of the installation corresponds to that claimed by the Project Supervisor on commissioning.

3.4 Contract between the Operator and the User

With regard to the final customer, the Operator of the installation guarantees the energy output (see table 7 of document DRE - A 1 : "From the Requirements to be met to the Proposals for a Range of Electrification Systems"). The Operator must therefore have available the necessary information to ensure that the installation does in fact provide the User with the services envisaged in the contract.

In return, the User must use the installation only under the prescribed conditions. He must not consume more than he stated before the capacity of the system was estimated. In the case of a supply failure it must be possible to ascertain whether the fault is a result of the installation itself or of overconsumption by the customer.

If a generator is part of the installation it can be put down to either the User or the Operator. If it is down to the User, the Operator can ask the User to cover the cost of matching the supply with the new requirement and possibly even make a surcharge for the supply of energy, particularly during long periods without sunshine.

4. Technical guarantees

The Project Contractor is responsible for the technical guarantees which have a bearing on both the capacity estimation of the installation, which was undertaken on the basis of a functional specification approved by the Project Supervisor and the User, and on the design, provision, installation, maintenance and after-sales service of the various items of equipment.

The Maintainer is responsible for guaranteeing the upkeep of the installations.

The various volumes of DRE Specifications bring together for each element of the system and for the system itself the minimal recommendations which must be implemented. Depending on the application, the technical requirements could be more stringent.

4.1 Sizing

The results to be expected from the process of sizing are described in document DRE - A 2 : "Results expected from the Process of System Design". Analysis of demand is undertaken by an investigator, backed up, if the Project Contractor deems necessary, by a site visit which allows the particular limitations of the location to be determined.

The sizing process is carried out using computer programs or calculation methods well known in the profession, and whose principles must be clearly laid out.

4.2 Design

The design of the system must be such that it conforms to the standards and recommendations in force : CEI, ISO, CENELEC, national standards (UTE and NF in France), ISPRA or local recommendations, company specifications (such as EDF's HN in France, etc.).

In all cases, the proposed solutions must aim to obtain the best financial return on the entire equipment involved in satisfying demand (generators, storage, backup, special adaptation of the electrical appliances and promotion of successful equipment).

Performance of the system must be checkable and will be backed by guarantees.

4.3 Equipment

Components must conform with standards and recommendations in force : CEI, ISO, CENELEC, national standards (UTE and NF in France), ISPRA or local recommendations, company specifications (such as EDF's HN in France, etc.) when such exist.

They must also carry extended "parts" guarantees of a minimum of 5 years for the photovoltaic modules and a minimum of 2 years for the rest of the equipment.

Note. - *In France accumulator batteries for example will carry guarantees as specified in leaflet 564l published by the Commission Centrale des Marchés publics (Central Commission for Procurement Contracts).*

These items will be selected in accordance with the recommendations contained in the various booklets of the DRE Specifications. Their manufacture will be the subject of a Quality Assurance System designed and implemented by each manufacturer and the implementation checked by an impartial expert. Recommendations for Quality Assurance Systems are given in document DRE - A 4 : "Quality Assurance for Project Design and Implementation".

4.4 Installation

The installation of equipment must be carried out in accordance with good practice and following the procedures laid down by the Project Contractor and the manufacturers of the various components in such a way as to guarantee the ultimate correct functioning of the system and its continued operation. If necessary, this will involve the intervention of monitoring organisations.

The safety of equipment and personnel must be ensured both during and after construction. The installation must conform to the regulations of the DRE Specifications (see document DRE - B 6 : "Guidelines for the Protection of Persons and Property from Electrical Hazards") and all such provision must conform to the safety regulations in force in the country concerned.

Note. - *In France all such provision must be in conformity with the UTE C 18-510 standards, and for installations operated by E. D. F. any such provision must also be made in conformity with the Carnet de Prescription au Personnel (CPP) - Personnel Regulations Handbook.*

The installation process must also take into account the criteria for the integration of the system into the local environment. When the system is commissioned, technical documentation concerning the components and the system must be automatically passed on to the User and the Project Supervisor. These should include as a minimum the documents listed in paragraph 6.

4.5 User Training

The installer is responsible to the Project Supervisor for the provision of appropriate information to the User so that he is made fully aware of the method of operation, the day to day management and the limitations of his system. The installer will also provide training for the User concerning electrical hazards (see document DRE - B 6 - "Guidelines for the Protection of Persons and Property from Electrical Hazards").

The training given must stress the importance of the choice of electrical appliances. Documentation provided to the User must also contain this information.

4.6 Maintenance and After-Sales Service

Maintenance and after-sales service normally covers four different levels of benefits.

1) a straightforward "parts" guarantee
2) a regular inspection visit to check on the condition of the main components which are subject to possible premature failure (batteries, cabling, regulators etc.)
3) a "parts and labour" guarantee
4) an extended service guarantee covering "Parts, labour and service"

To these benefits must be added battery replacement if this is not already dealt within the guarantee.

The Maintainer is responsible for communicating at regular intervals with the other parties, particularly with the Operator and the User, and passing on important information relating to the functioning of the installation.

The Operator of the installation will be warned of any incident either by a call from the User or by a remote monitoring system in which the levels of alarm of the installation will have been pre-programmed. He will if necessary request a visit from the Maintainer. All maintenance visits must be entered in the installation's logbook which is kept permanently at the technical premises of the installation so that it is possible to keep track of events.

Regarding the after-sales service, the Maintainer will operate at intervals and under conditions set out in the contract agreed with the Operator (see paragraph 5.2).

As soon as the initial investment is made, the Project Supervisor or the Operator must set up financial arrangements of the "guaranteed fund" type which will permit the renewal and recycling of batteries and other components of the system should they fail or reach the end of their useful life.

Note. - *In France if the Operator is EDF, it will renew and recycle the batteries at its own expense. If EDF is not involved, then the former arrangements apply.*

5. Contractual responsibilities

5.1 Responsibilities of Project Contractors

The following considerations apply to all projects for which the Project Contractor stipulates conformity with the regulations of the DRE specifications.

Note. - *In France this would normally be the case for projects financed by FACE. It could also be the case for projects outside the framework of FACE for which the Project Contractor stipulates conformity with DRE specifications. This could also be the case when no recommendation is made by the Project Contractor but when the company in charge of construction declares that these specifications will be observed.*

The installer, the system designer and the manufacturers of the main components (photovoltaic modules, wind generators, accumulator batteries, electronic regulators and inverters) are bound by contract so that the performance and responsibilities of each are clearly defined. When a project has been subject to the process of public tender the Project Contractor appointed by the ***Project Supervisor*** must assume full responsibility for the observation of the regulations of the DRE specifications with regard to the design, equipment, the installation and the resulting guarantees vis-à-vis the ***Project Supervisor***, the Operator and the end User of the system.

In cases where the project is undertaken outside the public tender system but within the framework of the DER specifications, the ***Project Supervisor*** may appoint a Project Contractor but if he does not specifically do so, in all circumstances only one of the parties involved, (design office, system designer, installer etc.) as determined amongst themselves, must agree to fulfil this function and must assume this responsibility.

In short, for every project within the scope of the DRE specifications, there must be a Project Contractor responsible for the quality of the installation and for the observation of the Specifications.

Before any contracts are made, the Project Contractor must make sure that the ***Project Supervisor*** has obtained all the necessary administrative authorisations. He agrees to observe the timescales of the project and agrees to provide information and advice to the Users during the guarantee period.

5.2 Responsibilities of the Maintainer

The systems established to ensure proper maintenance will differ according to person circumstances. Maintainers must put together a service proposition which will take account of all maintenance requirements. Model maintenance contracts are provided in appendices 7 and 8 of document DRE - B 7 "Guidelines for Operation, Maintenance and Renewal".

They must agree to provide service at those intervals laid down in the contract and, if applicable, as indicated by the remote control and remote monitoring system.

They must keep a minimum stock of spares (PV modules, regulator and control devices, accessories etc.) together with a minimum of logistical and back-up equipment (vehicle, tools, generator, staff etc.)

5.3 Responsibilities of Project Supervisors and Users

In return for the guarantees of service, the User and/or the Project Supervisor agree that :

- they will not increase their energy requirement without the prior consent of the Project Contractor or the Operator.
- the installation will be used in accordance with the stipulations and instructions of the Project Contractor, the Operator and the Maintainer.
- they will honour their financial commitments.

5.4 Monitoring Procedures for Contractual Agreements

From the very beginning, installations must be designed to permit the temporary or permanent attachment of a metering or measuring system. Monitoring can be undertaken in the first place thanks to this system which will permit all parties to have access to all the energy readings of the system as well as the possible alarm signals and fault indicators (see document DRE - B 5 - "Guidelines for Data Acquisition").

Depending on the size of the system and the wishes of the Project Supervisor or of the Operator, sizing, the functioning of the system and the performance figures must be checkable by means of a recording device capable of providing the information specified in the aforementioned document.

The information must be compiled by the Operator or communicated by the Maintainer to the Operator at the prescribed intervals and in the appropriate format.

These data will permit a basic analysis of the functioning of the system to be made, in particular its coefficient of under- or over-utilisation.

5.5 Consequences of Breach of Contractual Agreements

If as a result of checks or of a complaint from the User or the Operator, it is established that the guarantee of service or any other technical guarantee specified in this document has not been observed, the Project Supervisor or an organisation mandated by him (e.g. the Operator) may, after analysing the problem, give formal notice by registered letter to the Project Contractor or the Maintainer to put matters in order.

If, following this formal notice, and force majeure excepted, the agreements made by the Project Contractor or the Maintainer are not complied with within a maximum of one month, the Project Supervisor or his representative are entitled to take whatever steps are necessary to obtain financial compensation. The terms of this compensation will have been laid down when the tender was compiled.

6. Documentation

After the installation of the equipment the subcontractor will hand over to the Project Supervisor the documents listed below in the language specified by the latter.

Note. - For France and its overseas departments all documents must be written in French.

The Project Supervisor is obliged to pass his documentation to the Operator to whom he hands over the installation who in turn passes to the User the documentation necessary for the proper use of the installation.

6.1 Project Supervisor and Operator Documentation

The documents required by the Project Supervisor are as follows :

- the sizing results, with the number of days of accumulator capacity and an estimate of the number of days of non-supply without recourse to a back-up generator.
- an operation manual, together with information on specific local factors at the moment of commissioning. This manual should include :
    - ◊ a description of how the installation works
    - ◊ a site plan
    - ◊ all the standardised wiring diagrams (single wire diagram, detailed power diagram and detailed control diagram)
    - ◊ a description and directions for use of the principal components of the system, their serial numbers as given on their identity plates and the dates of coming into service,
    - ◊ an instruction sheet for technical acceptance trials
    - ◊ directions for use and maintenance for all items of equipment and their interfaces,
    - ◊ the installation logbook (with numbered pages)
    - ◊ the normal operating limits of the system
    - ◊ the technical specifications
    - ◊ the assembly instructions
    - ◊ the commissioning procedures
    - ◊ a list of replacement parts required for two years of operation beyond the first year of the guarantee
    - ◊ maintenance instructions (checking of warning indicators, tightening of the terminals, waterproofing of the gears etc.)
    - ◊ instructions for diagnosing common faults

      a list of special tools or of all items necessary for assembling, adjusting, operating and maintaining the equipment.

6.2 User Documentation

Documents intended for the User are as follows :

- a sheet summarising the regulations for electrical safety which must be observed during operation and minor maintenance carried out by the user
- sheets setting out clearly and simply for the User the main points of the instruction manual, the safety instructions and the maintenance instructions. ;
- an installation logbook with numbered pages, possibly pre-printed with space to enter the following :
    - ◊ regular readings (voltage, battery specific gravity)
    - ◊ any incidents
    - ◊ any useful comments

If the installation is modified in any way (extension, modification, maintenance etc.) the contractor for the modification must make the documentation available.

DRE SPECIFICATIONS - A 4

June 1997

Title : **Part A : From energy requirements to electrification system**

Section 4 : Quality Assurance for Project Design and Implementation

Number of pages : 6 (including appendices)

Type : Specification

Associated document(s) : DRE - A 3 : "Contractual Framework governing the Relationships Involved"

Summary : This document deals with the general principles of quality assurance to be put into practice in decentralised rural electrification systems.

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CONTENTS

1. Objectives of Quality Assurance

The "life cycle" of a stand-alone system (single user or multi-user) for the production of electricity intended to supply an isolated location is composed of at least five principal phases :

- analysis of needs and sizing ;
- engineering and design of the installation ;
- construction and commissioning of the installation ;
- maintenance of the installation ;
- recycling and recovery of various items at the end of their useful life (e.g. batteries).

Quality assurance is the process which, by the systematic establishment of actions of prevention, checking, validation, tracking (documents, written items, progress documents etc.) brings under control the quality of the design, construction and operation of a stand-alone electricity installation and provides proof of this to the Project Supervisor, Operators and Users.

For stand-alone systems based on renewable energy, this Quality Assurance is put into practice by the parties defined in document DRE - A 3 : "Contractual Framework governing the Relationships Involved". The role of each party is laid out therein.

The process of Quality Assurance allows the various parties to provide proof of the precautions which they have taken to assure the quality of their services with regard to their partners. For example this process makes it possible for the Project Contractor, who is responsible for the quality of the execution of the project to carry out his function more effectively by involving, as necessary, other contractors or sub-contractors.

2. Basic principles of Quality Assurance

The process of Quality Assurance is a succession of programmed actions for the building and verification of quality. Each one of these actions is carried out by a clearly identified participant. This succession of actions is known as the ***Quality Plan***.

The principal phases of this process are as follows :

- analysis of customer needs ;
- monitoring of design and construction ;
- appraisal at the time of commissioning permitting the identification of lessons to be learnt (feedback) ;
- organisation of the monitoring of maintenance of the installation.

The participants responsible for putting the Quality Plan into practice will vary according to the phases of the Plan. However, the documents which record the Quality Assurance carried out in one phase must be passed on to the person responsible for the following phase. For example when an installation has been completed the Project Contractor will pass on the Quality Assurance File covering the construction phase via the Project Supervisor to the Operator who will be responsible for the Quality Assurance of the maintenance of the installation.

The various phases involved in planning, construction and maintenance must be carried out in conformity with the procedures laid down in the Quality Plan. The practices set up to assure quality operation of the installation must also conform to the contents of this Quality Plan.

The validation phase which takes place at the point of commissioning provides the opportunity to make sure that the installation conforms to customer expectations (Project Supervisor and/or Operator and/or end User).

The purpose of the Quality Assurance File is to keep track of all the Quality Assurance procedures (observations, checks, verifications etc.) which have been undertaken and to provide proof that they were in fact carried out.

It contains all the proof of the quality procedures laid down in the Quality Plan for every phase of the design, construction and maintenance of the installation.

To sum up, in order to provide Quality Assurance for the customer it is necessary to :

- put down in writing what has to be done ;
- actually carry out what has been written down ;
- record certain actions.

3. The participants in Quality Assurance

3.1 The adoption of Quality Assurance

The decision to submit the design and construction of an installation to a Quality Assurance process is the responsibility of the Project Supervisor.

It is he who will request the Project Contractor appointed for the preliminary sizing, sizing, and the design and construction of the installation, to put forward a Quality Plan.

Likewise he will also ask the Operator to put forward a Quality Plan for the maintenance of the Installation.

As a result of this the Project Supervisor becomes the guarantor of the quality of the design and construction of the installation.

Depending on the scale of the project, the Project Supervisor will decide whether or not to initiate a Quality Assurance process. If he does decide to do so, he will determine the level of Quality Assurance depending on the type of installation concerned.

3.2 Quality Assurance in design and construction

3.2.1 Preliminary sizing

Quality Assurance is put into practice by the organisation entrusted with the preliminary sizing at the request of the Project Supervisor or the Project Contractor as necessary.

3.2.2 Design and construction

The DRE Specifications lay down in document DER - A 3 : "Contractual Framework governing the Relationships Involved", that the Project Supervisor passes on to a Project Contractor the responsibility for the quality of an installation. Thus it is he who carries the responsibility for building the quality of the engineering design and of the construction works. It is he who will put forward a Quality Plan at the request of the Project Supervisor and puts it into practice.

This Quality Plan encompasses all the phases of design and construction, together with all the organisations involved in the operation. He must also request from the material or component suppliers the information required to put his Quality Plan into operation.

It is desirable that the suppliers themselves should also set up a Quality Plan for the manufacture and delivery of their equipment and should provide the appropriate documentation to the Project Contractor.

For example the Project Contractor asks the photovoltaic modules manufacturers for the progress documents showing the quality standard of the units supplied and their performance data (maximum power or energy capacity at 1000 Watts per m^2, I and V at 1000 Watts per m^2).

3.2.3 Appraisal at the time of commissioning

At the time of commissioning the Project Contractor is responsible for the presentation of the appraisal of the results from the Quality Assurance procedure. The records presented will provide proof that the installation is capable of fulfilling the needs of the customer or the end User.

3.3 Quality Assurance in maintenance

The Operator is responsible for Quality Assurance of the maintenance of the installation. However he is not permitted to alter the Quality Plan without the assistance of the Project Contractor who will put forward a proposal for a Quality Plan for maintenance which is discussed with the Operator and /or the end User.

3.4 Independent verification

This specific procedure could be adopted in the case of installations which require a very high standard of Quality Assurance, as for example certain telecommunication or data transmission installations.

This procedure is set up by a participant who is not taking an active part in the construction itself, i.e. the Project Supervisor.

3.5 Treatment of anomalies

Anomalies are dealt with as soon as they are detected. The anomalies registered and the method by which they are resolved are carefully logged so as to ensure their complete tractability and make the appraisal at the point of commissioning more effective.

4. Procedures

Before compiling a Quality Plan the following steps should be taken :

- analyse the customer's requirements and jointly produce a definition of the necessary features, the level of service and the expected performance of the installation.
- assemble the documents which relate to :
  - ◊ the sizing (or preliminary sizing) ;
  - ◊ engineering design in the installation ;
  - ◊ the supply of materials and components (Quality Assurance of suppliers) ;
  - ◊ the construction work.
- consider the points which present potential quality risks in the different phases (risk assessment) and propose methods of reducing them ;
- establish a program for carrying out the design and construction ;
- define the organisation of the operation (planning, participants, methods of implementation, suppliers, subcontractors etc.).

After this it is possible to proceed to the compilation of the Quality Plan.

5. Typical Quality Plan

Context of the operation

- Definition of the operation ;
- Definition of the quality of service and performance levels expected ;
- Risk analysis.

Organisation of the operation

- Identification of participants and implementation methods
  - ◊ Project Contractor ;
  - ◊ subcontractors ;
  - ◊ suppliers ;
  - ◊ etc.
- Data required for sizing and the associated documentation
  - ◊ meteorological data used ;
  - ◊ particular data from the Project Supervisor ;
  - ◊ calculation principles ;
  - ◊ computer programs used
  - ◊ etc.

- Progress and results in sizing
- Data required for the engineering design of the installation and associated documentation
  - ◊ features of equipment ;
  - ◊ design methods ;
  - ◊ computer programs used ;
  - ◊ etc.
- Anomalies and modifications
- Choice of suppliers and subcontractors
  - ◊ criteria ;
  - ◊ items to be bought in ;
  - ◊ subcontracted aspects.
- Quality Assurance procedures relating to :
  - ◊ program for sizing ;
  - ◊ engineering design program ;
  - ◊ choice of suppliers ;
  - ◊ choice of subcontractors ;
  - ◊ purchase of supplies ;
  - ◊ commissioning appraisal ;
  - ◊ Quality Assurance procedures relating to maintenance.

Tractability of Quality Assurance procedures, record keeping

Tables 1 to 3 should be used to record information concerning :

- analysis of requirements and definition of quality objectives ;
- risk analysis ;
- the recording of actions taken, the persons who took those actions and their results.

Table 1 :Analysis of requirements and definition of quality objectives

Identification of participants (customer)	Identification of requirements	Quality criteria and objectives

Table 2 : Risk analysis

Operation/context of risk	Factor creating risk	Level and foreseeable consequences of risk	Action for prevention of risk

Table 3 : Progress and results of action taken

Task	Contributor	Date	Results	QA (yes/no)	Action planned for quality

DRE SPECIFICATIONS - B 1

June 1997

Title

Part B - Rules on the design and operation of systems

Section 1 : Architecture of electrification systems

Number of pages 19 (including annexes)

Type Technical Specifications - Rules

Related document(s)

Summary

This document describes the architecture of electrification systems the types of which have been defined in document DRE - A 1. The diagrams provided are semi-operational flow charts and not electrical layouts. They enable the various operators (Project Supervisor, licence holder, user, etc.) to choose the system which best suits the requirements to be satisfied and the configuration desired.

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CONTENTS

Introduction

One set of decentralised rural electrification systems has been defined in table 6 of document DRE - A 1 : “Requirements to be met in providing a range of electrification systems”.

Eight types of systems have been defined and broken down into three categories :

- the electrification systems for processes (for example, for pumping) ;
- the single-user electrification systems (IES),
- the multi-user community electrification systems (CES).

The process electrification or individual electrification systems comprise only two subsystems :

- one electrical energy **production** subsystem ;
- one **user** subsystem for this power.

The community electrification subsystems, on the other hand, comprise 3 subsystems :

- one electrical energy **production** subsystem ;

  Conventionally, this part is called a **“micro-power-station”**, the term “micro” seeking to convey the modest production power level (from a few kVA to a few dozen kVA)
- a **distribution** subsystem for this power ;

  Conventionally, this is part is called the **“micro-grid”** the term “micro” seeking to convey the modest transit capacity level.
- a **user** subsystem comprising distribution circuits and electrical equipment for the user.

This document presents the architecture of eight types of systems defined within the overall category.

The diagrams shown in the figures for this specification are functional flow charts and not electrical layouts.

They are extremely general and can be adapted to a wide range of situations such as :

- a private system run and maintained by its Project Supervisor or by a subcontractor ;
- a system run by an operator (electricity company or other licence holder) ;
- a system run by two operators, one running the production and the other the distribution and supplying the power to one or several user subsystems.

The aim of these operational charts is to cover a range of systems which may be used throughout the world, both in developed and developing countries. They can be adapted to the *level of “service provided*” as required by users or Project Supervisors. The level of “service provided” determines the scale of the various elements in the system : generators, storage, cut-off points, types of protection, etc.

The cut-off points shown on the diagrams are general-purpose and do not indicate the type of equipment to be used.

The limits between the T_1 to T_8 subsystems are shown.

These subsystems may correspond to systems run and maintained by various persons or bodies. In certain cases, the whole system is owned, run and used by the same person. This is the case, for example, with a system such as a lighting kit with photo-voltaic (solar) panels which can be categorised as type T_2. The subsystems are fully geared for a micro-power-station, powering a micro-grid and classed as a type T_4 system.

The persons or organisations responsible for running these systems can choose the limit which best suits their choice of power supply for the user.

These choices may, for example, be :

- a power supply in direct current (DC) ;
- a power supply in alternating current (AC) the inverter forming part of the production subsystem ;
- a power supply in both forms (alternating and direct) ;
- one single supply point (alternating or direct) ;
- several supply points.

The generator set is, specifically, an item of electricity production equipment. For the majority of systems it is possible to envisage this element forming part of the production subsystem or user subsystem. However, for multi-user type T_4 systems, it is difficult not to categorise the generator set within the production subsystem.

Likewise, depending upon the level of service with which the system provides the user or users (since some of the systems described enable the supply of several users) some cut-off points may be removed.

1. Scope

The present specification provides an overall view of the photovoltaic or wind-driven systems for electrifying isolated sites and defines the operational types of these systems.

It also defines the limits between the various component subsystems.

This specification contains :

- a general presentation of the main subsystems ;
- a definition of the limits between the subsystems ;
- a description of the various types of subsystems (see figures 1 to 12).

2. References to standards

UTE C 18-510 : 1988 and 1994, Book of general electrical safety instructions.

EDF personnel handbook - Prevention of electrical risks (1991).

3. General presentation of sub-systems for electrification of isolated sites

An electrification system for an isolated site can be broken down into three parts :

- power production ;
- power distribution ;
- consumption (use).

3.1 Production subsystem

This comprises equipment for :

- the **production** of electricity which may be supplied by :
  - ◊ renewable energies such as sunlight or wind (photo-voltaic panels, wind generators) and even hydraulic power ;
  - ◊ fossil energy (gas oil, petrol, kerosene) as generator set fuel.
- the **storage** of electrical energy in accumulator batteries ;
- the **conversion/transformation** of power by converters :
  - ◊ DC / DC or choppers ;
  - ◊ AC / DC or rectifiers ;
  - ◊ DC / AC or inverters.
- the **protection** of persons and property ensured by :
  - ◊ circuit-breakers ;
  - ◊ fuses ;
  - ◊ neutral and earthing management devices.
- the management of energy through :
  - ◊ regulators (simple control functions) ;
  - ◊ monitoring systems (developed power management functions).
- instrumentation through :
  - ◊ gauging, storage, data processing and display equipment.

Some parts of this equipment may be installed in boxes, cupboards or other structures containing additional functions such as ventilation or alarms.

3.2 Distribution subsystem

The distribution subsystem comprises equipment enabling the distribution of power, in direct or alternating current, from the production subsystem to the user subsystem. It comprises :

- **distribution** equipment :
  - ◊ panels, boxes, etc.
- power **transmission** equipment :
  - ◊ cables ;
  - ◊ protection ;
  - ◊ boxes.
- **instrumentation** equipment.

NOTE. - This subsystem has only been defined for community electrification systems (types T_4 to T_8).

3.3 User subsystems

This subsystem is made up of all the equipment required for power consumption :

- user power control box ;
- internal installation ;
- user equipment :
  - ◊ loads operating in direct current ;
  - ◊ loads operating in alternating current.

NOTE. - This subsystem may comprise a booster unit.

4. Types of systems for the electrification of isolated sites

The systems for the electrification of isolated sites are classified into 8 types as follows :

T_1 type systems are intended for powering processes using renewable energies.

T_2 and T_3 type systems are intended to power a single user.

T_4 to T_8 type systems are micro-power stations, feeding a micro-grid and intended for supplying power to several or even large numbers of users.

4.1 "Solar, wind, water-powered" systems : Type T_1 -"REN Production"

This type of system is generally intended for powering processes "directly" in situations where it is undesirable or impossible to store energy and thus exclusively during periods of solar production (or wind production).

Examples of application : pumping water, ventilating a room, etc.

Four cases can be envisaged depending upon the source of production (PV (photo-voltaic) or wind generator) and according to the nature of the user equipment to be powered (AC or DC). These are as follows :

Type	Figure n°	Source	Use
T_{1a}	1	PV	DC
T_{1b}	2	wind generator	AC
T_{1c}	3	PV	AC (conversion)
T_{1d}	4	wind generator	DC (conversion)

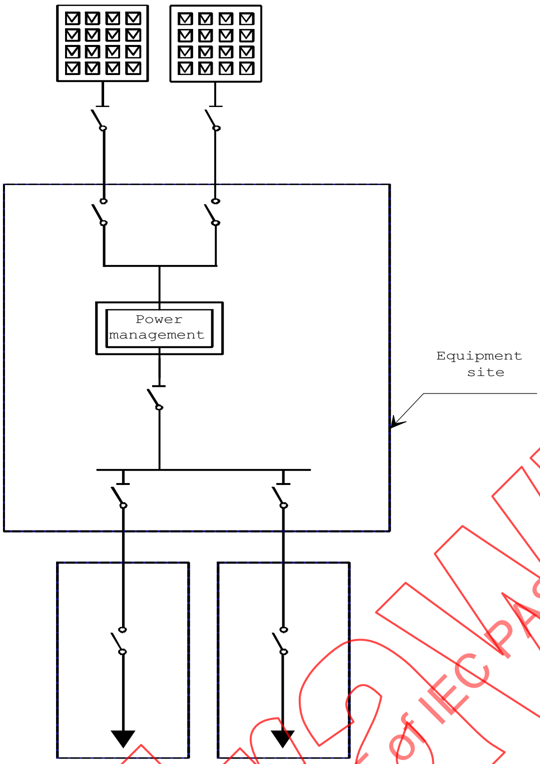


Figure 1 : T_{1a}, type system
using sunlight and supplying power in DC

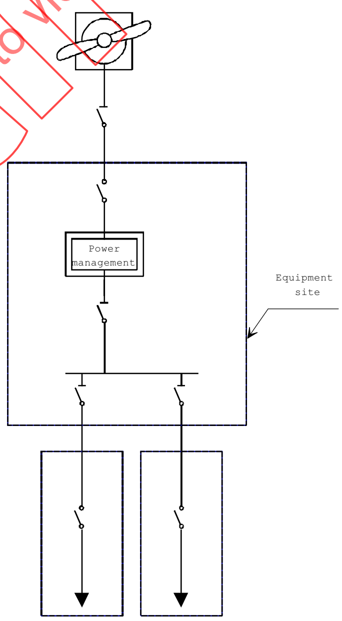


Figure 2 : T_{1b}, type system
using wind and supplying power in AC

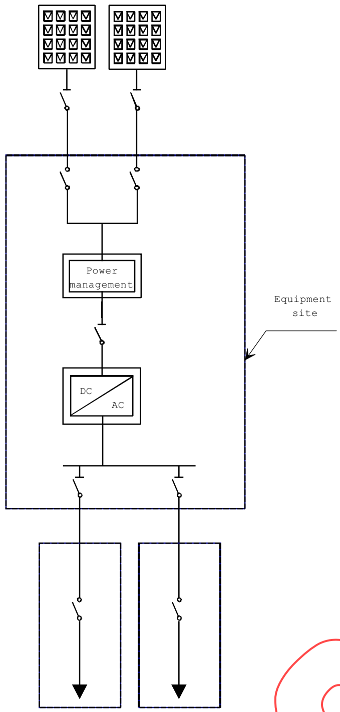


Figure 3 : T_{1c} type system
using sunlight and supplying power in AC

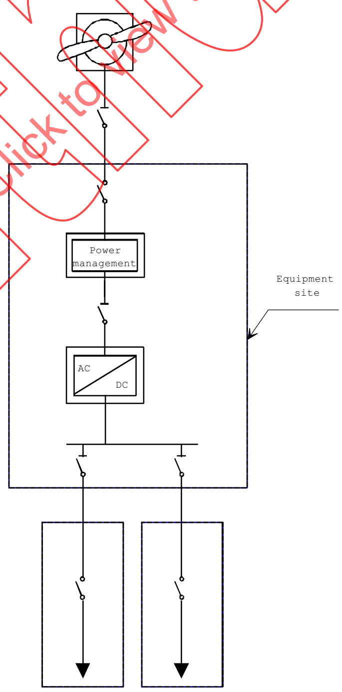


Figure 4 : T_{1d} type system
using wind and supplying power in DC

4.2 Individual electrification systems : Type T_2 - "REN production with energy storage"

This type of system, illustrated in figure 5, is intended more for users who can only obtain electrical energy when there is sunlight or wind. This system must therefore have a power storage unit. The user, however, does not need a booster unit and can simply use the electricity produced from the sources of renewable energy (PV panels and/or wind generator.

The domestic loads must be equipment which is adapted to a low-voltage supply (24 V_{DC} or 230 V_{AC}). The system must, if possible, take into account the specific restrictions of direct current : points, protection devices, earthing, etc.

The user equipment powered may be :

- exclusively direct current ;
- exclusively alternating current ;
- both types.

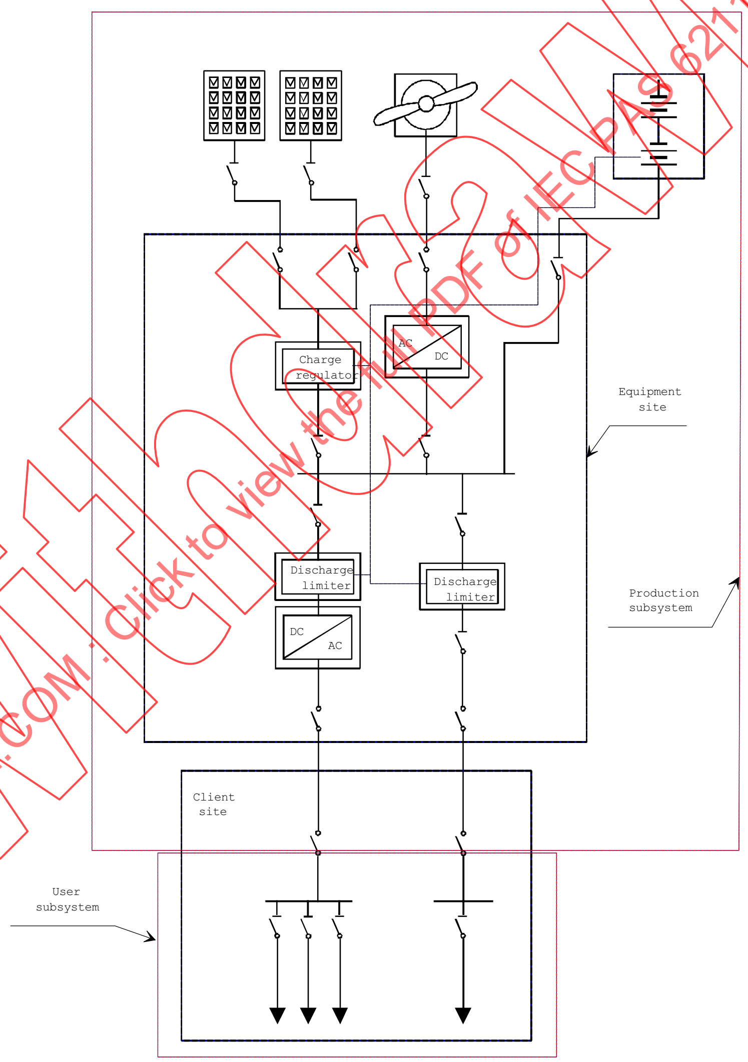


Figure 5 : T_2 type system

REN production (PV and/or wind-powered) with energy storage and power supply in DC and/or AC

4.3 Individual electrification systems : Type T_3 - "Hybrid production (REN + diesel) with energy storage"

This type of system, illustrated in figure 6, meets energy requirements, phase-shifted or otherwise, in relation to the periods of production for renewable energy sources (solar and/or wind). The presence of a booster unit enables the user to receive power in the event of unfavourable weather conditions which would have led to an exhaustion of reserve supply or an over-sizing of the system.

Two types of operation can be powered (DC and AC). If the two types co-exist, this presupposes two different distribution circuits.

The AC use is normally powered by storage batteries using an inverter. The reasons for starting up the generator set may, for example, be :

- periodical recharging of batteries (upkeep, equalisation charge) ;
- obligatory use of batteries, following notification of "battery low" from the power operator ;
- need to power an item of user equipment whilst the system is unavailable.

Advantage can thus be taken of the unit in order occasionally to supply a dedicated use where there is no wish or it is not possible to power it from renewable energy sources.

The uses powered can be :

- in direct current ;
- in alternating current. In this case, AC functions may be backed up by the unit in the event of a system failure. The uses may not be powered simultaneously by the unit and the Renewable Energy system ;
- using both. AC type operations can be backed up by the unit under the same conditions as stated for the previous case ;
- using both types to which one alternating current operation dedicated to the unit is added. Under these circumstances, in addition to the back up being identical to the two preceding types, the unit can power a dedicated operation. This operation, which is too powerful to be powered by the REN system, will be exclusively powered by the booster unit.

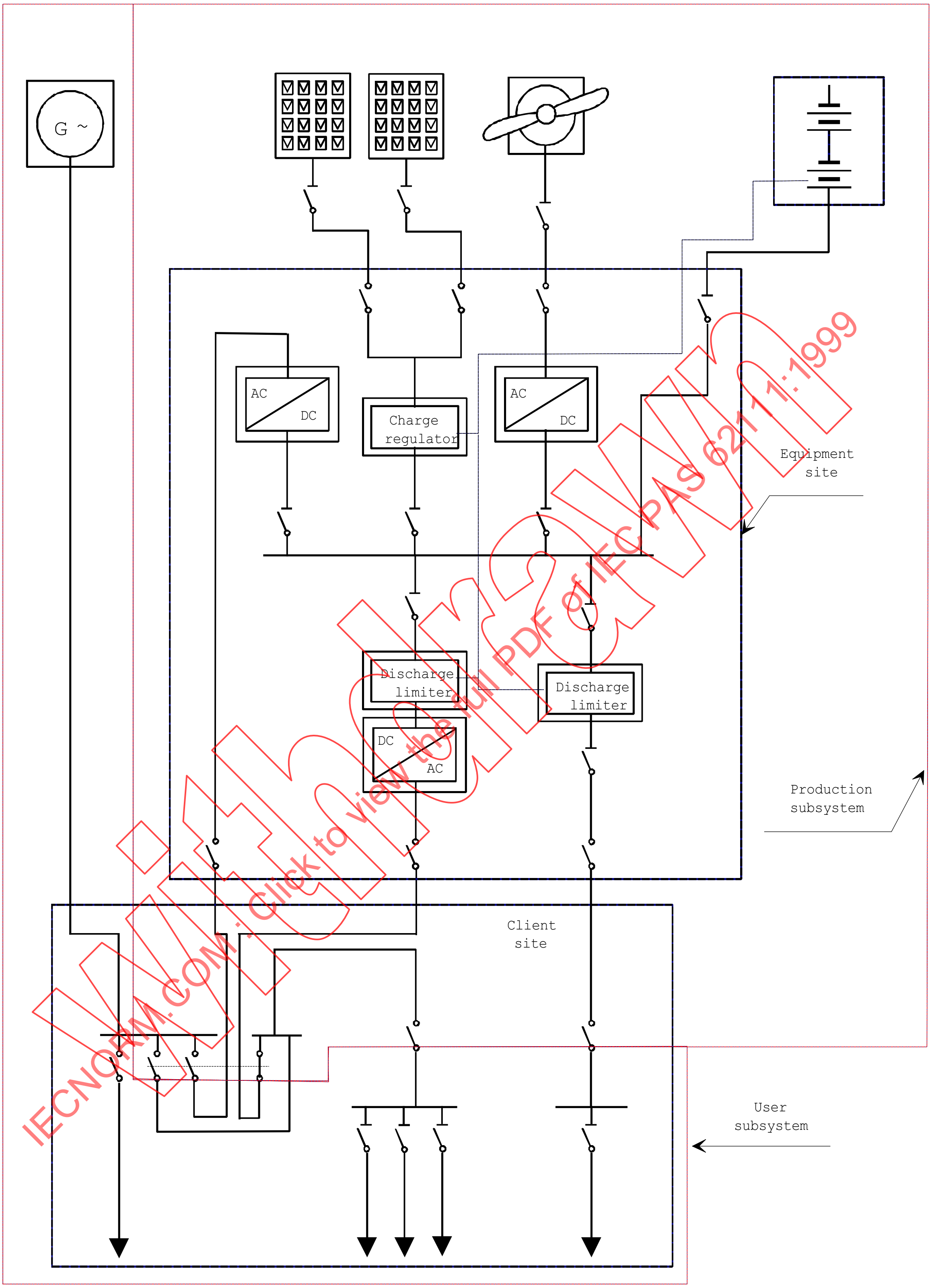


Figure 6 : T_3 type system

With storage, booster unit, power supply in DC and/or AC
and possible use dedicated to generator set

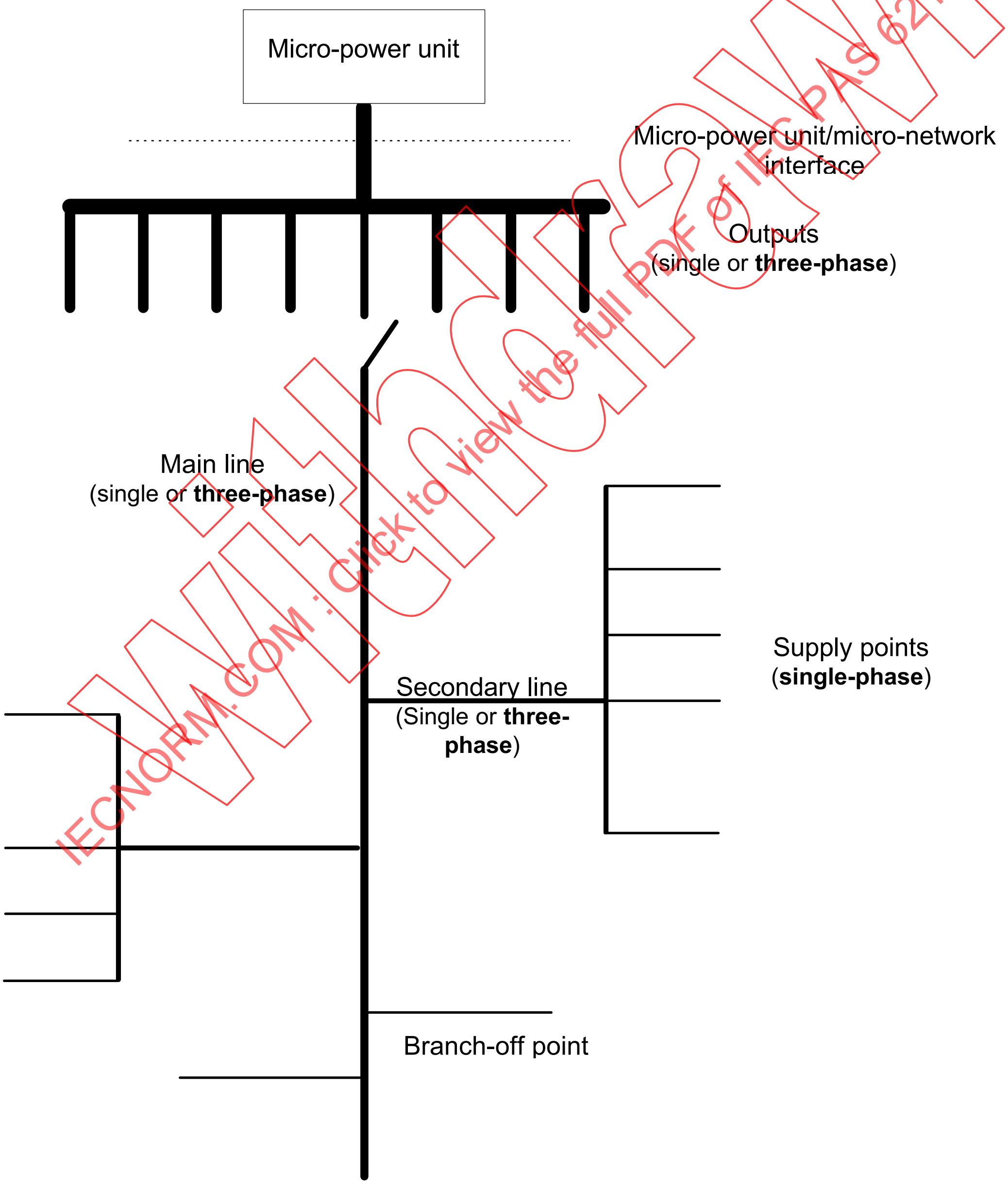
4.4 Community electrification systems : Type T_4 - "REN micro-power-station powering a micro-grid"

The T_4 type systems, illustrated in figure 7, are REN micro-power-stations with energy storage powering a micro-grid for supplying energy to several or even a large number of users, in a concentrated rural environment (groups of houses, hamlets).

The production subsystem comprises the generators (photo-voltaic and/or wind-driven), the distribution switchboards enabling the grid output and the converters enabling power supply under standard voltages (in general 230 V AC).

The distribution subsystem comprises the outputs connected to the production system distribution switchboards, the overhead lines and the underground cables and the user power supply boxes. It is organised in a radial structure illustrated by the flow chart below :

The user subsystem begins at the terminal boxes situated downstream from the user power supply box and comprises the user installations and equipment exclusively in AC.



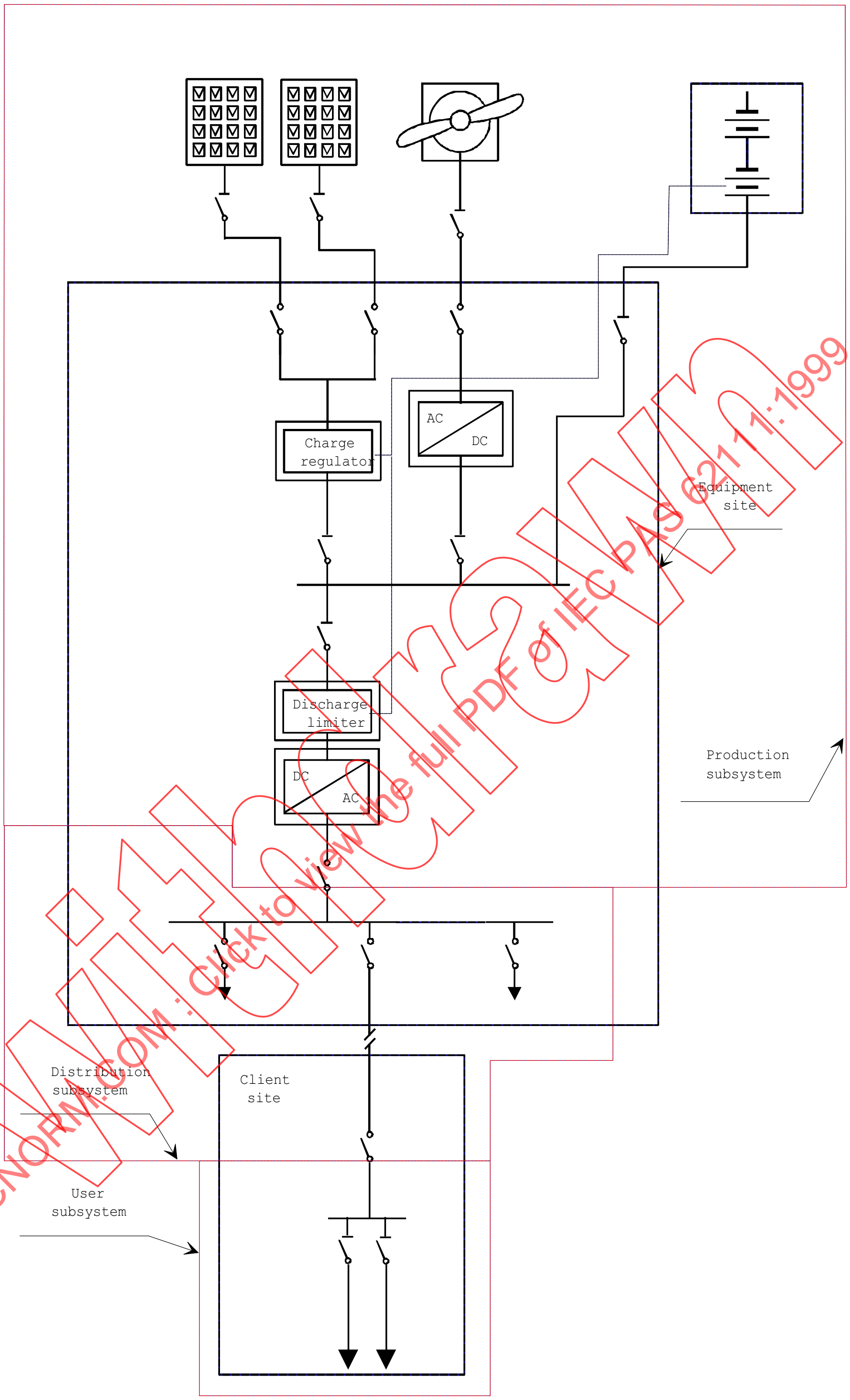


Figure 7 : T_4 type system

REN micro-power-station powering a micro-grid

4.5 Community electrification systems : Type T_5 - "Hybrid micro-power-station (REN + diesel) with energy storage powering a micro-grid"

The T_5 type systems, illustrated in figure 8, are hybrid micro-power-stations (REN + diesel) with energy storage powering a micro-grid intended to supply energy to several or even a large number of users, in a concentrated rural environment (hamlets, villages). They comprise a booster source the minimum function of which is to ensure, on a periodic basis, an equalisation charging of the batteries.

The presence of the booster unit also enables certain outlets of some importance to the community to be backed up (e.g. vaccine cooler and dispensary, school, economic and trade activities, community resources such as drinking water or irrigation). The number of uses backed up influences the size of the booster source and partly determines the level of service provided by the micro-power-station.

Activities which are not backed up are, for example, domestic uses. The proportion of backed up and non backed up activities may vary according to requirements and tends, in certain cases, to back up either a maximum number of activities or none at all.

The distribution and user subsystems are structured in the same way as T_4 type systems.

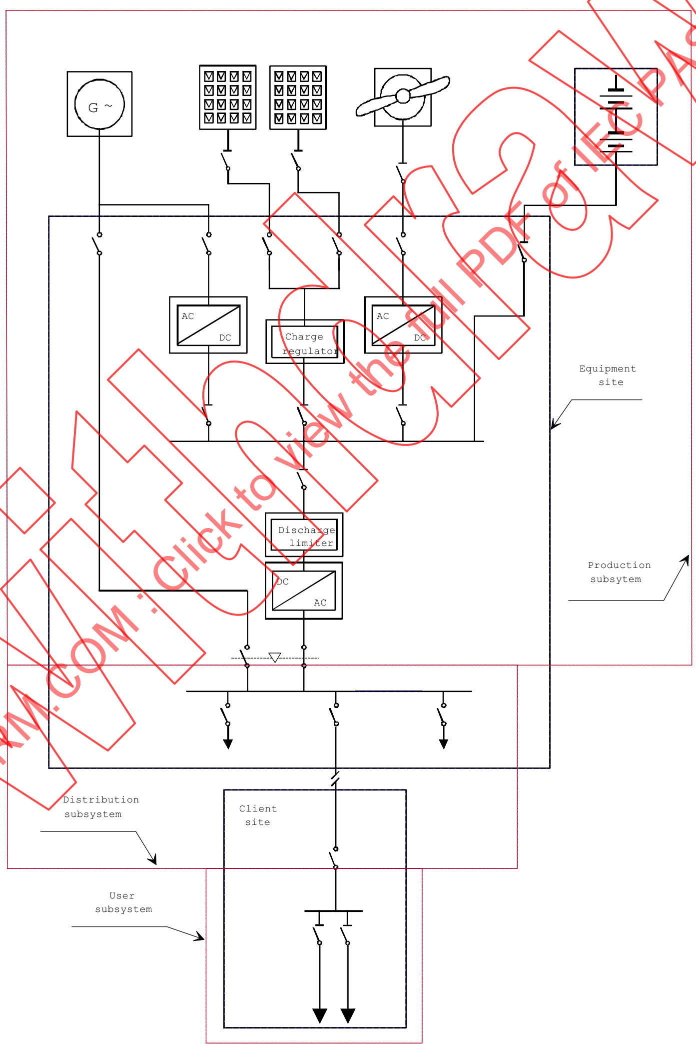


Figure 8 : T_5 type system

Hybrid micro-power-station powering micro-grid

4.6 Community electrification systems : Type T_6 - "Diesel micro-power-station powering a micro-grid with synchronous coupling to REN production"

T_6 type systems, illustrated in figures 9 and 10, are diesel micro-power-stations with synchronous coupling to production using renewable energy sources. The production subsystem comprises a buffer battery the role of which is to set the input voltage from the inverter in order to facilitate coupling and enable the system to be powered when the unit is operating.

These systems feed AC resources.

There are two scenarios, depending upon whether the renewable energy production source is PV panels (T_{6a} system) or a wind-powered generator (T_{6b} system).

The distribution and user subsystems are structured in the same way as T_4 type systems.

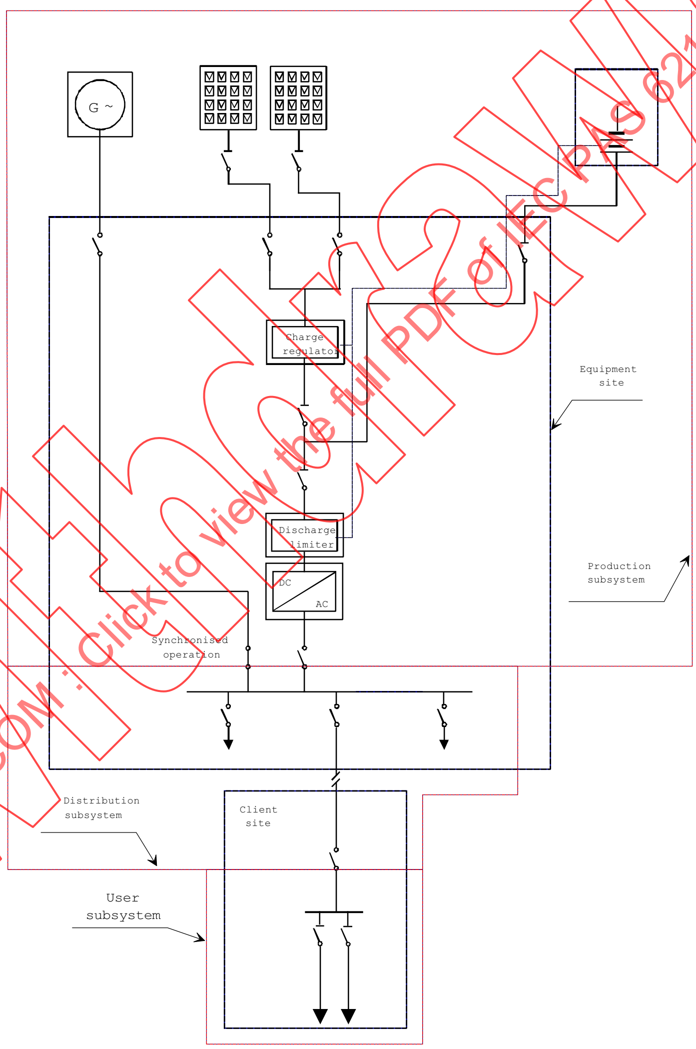


Figure 9 : T_{6a} type system

Diesel micro-power-station with synchronous coupling to solar production, powering a micro-grid

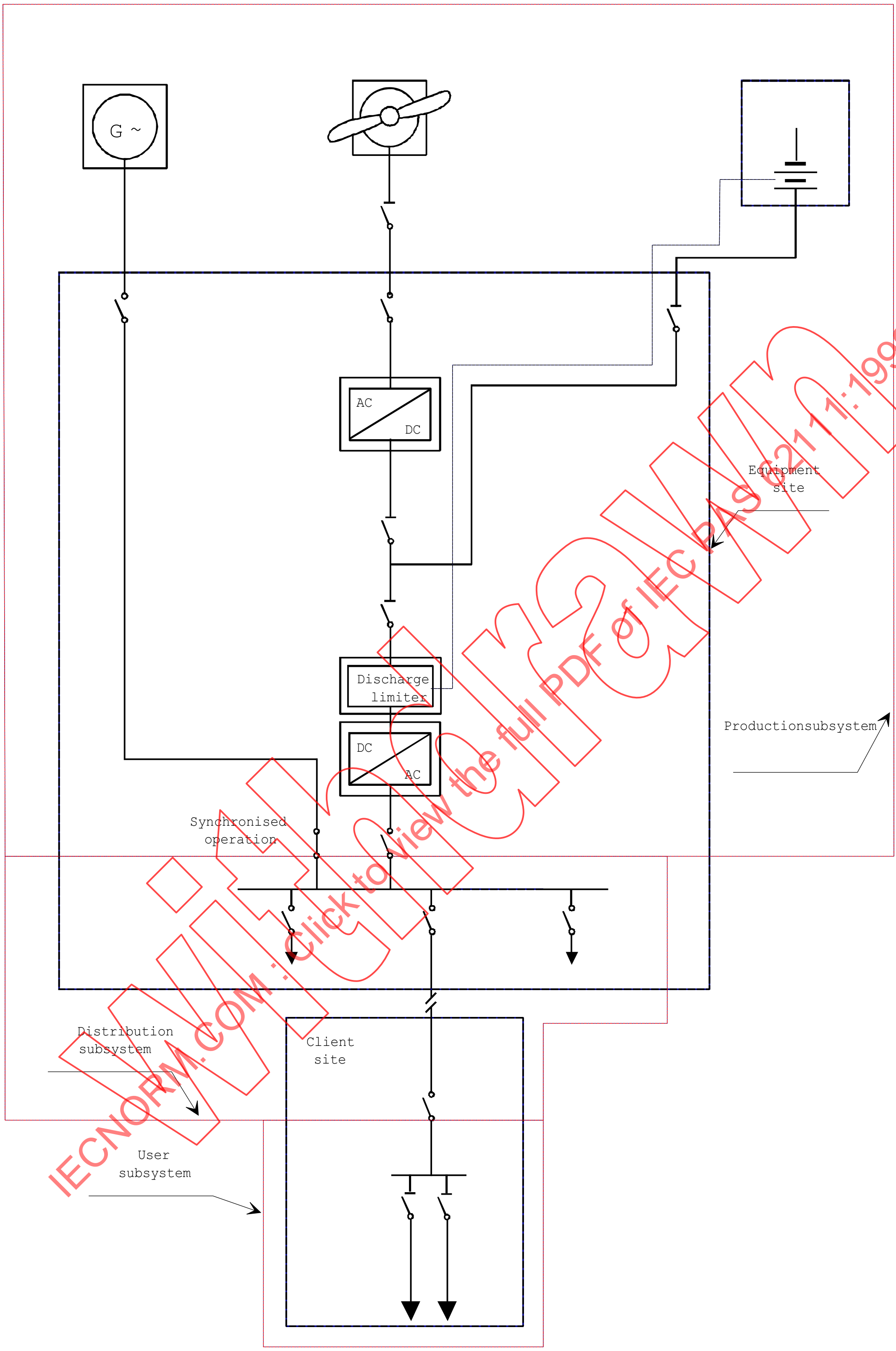


Figure 10 : T_{6b} type system

Diesel micro-power-station with synchronous coupling to wind-driven system, powering a micro-grid

4.7 Community electrification systems : Type T_7 - “Diesel micro-power-station with energy storage powering a micro-grid”

T_7 type systems, illustrated in figure 11, are diesel micro-power-stations with energy storage powering a micro-grid. The only power source is a generator set which powers the grid directly and simultaneously charges a battery. In general, the unit operates during pre-defined time slots. The battery provides the systems with an autonomy outside the unit’s operating hours.

The distribution and user subsystems are structured in the same way as T_4 type systems.

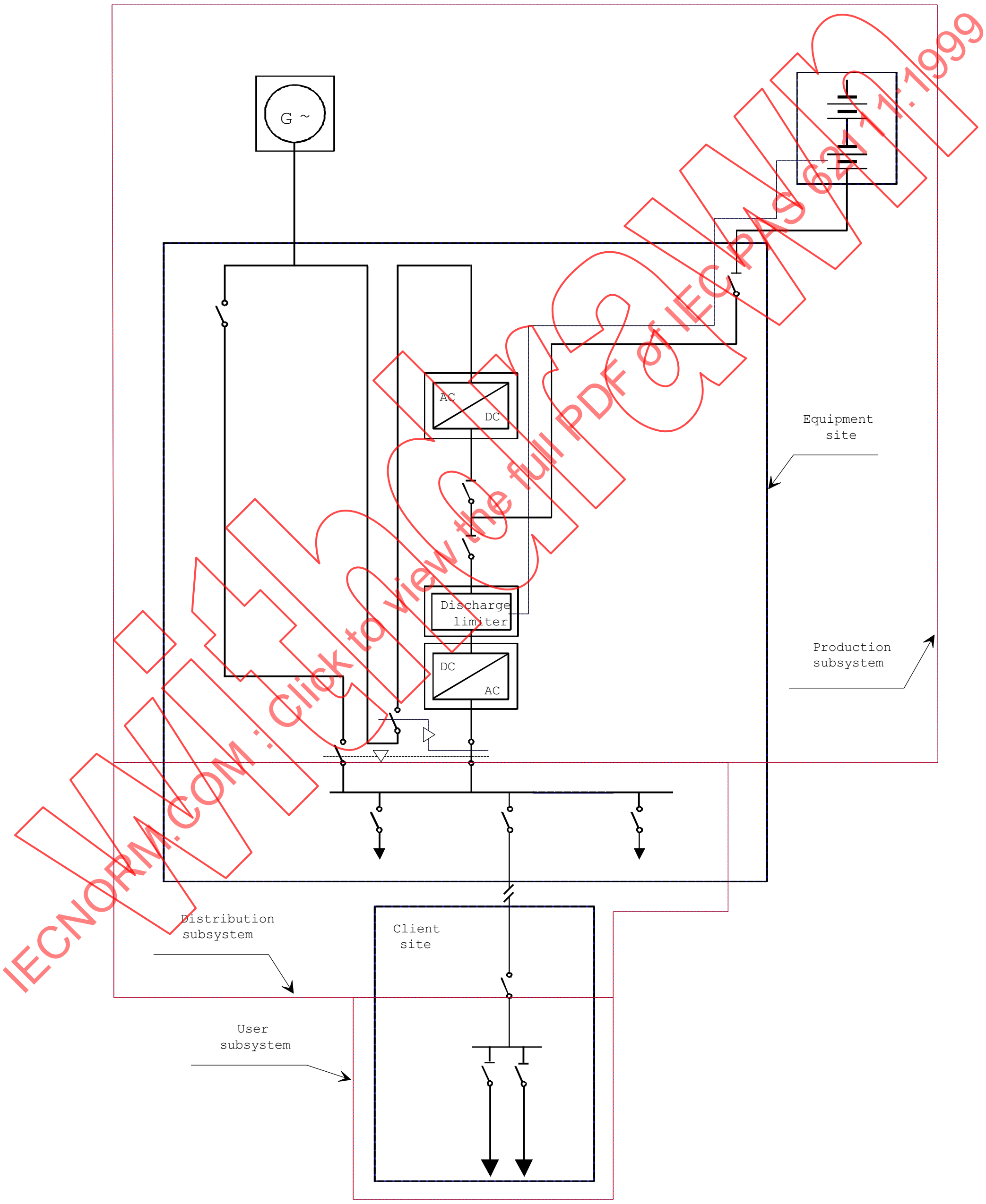


Figure 11 : T_7 type system

Diesel micro-power-station with storage powering a micro-grid

4.8 Community electrification systems : Type T_8 - "Diesel micro-power-station powering a micro-grid"

The T_8 type systems, illustrated in figure 12, are diesel micro-power-stations powering a micro-grid. The only source of energy is a generator set which supplies the grid directly. In general, the unit operates during pre-defined time slots.

The distribution and user subsystems are structured in the same way as T_4 type systems.

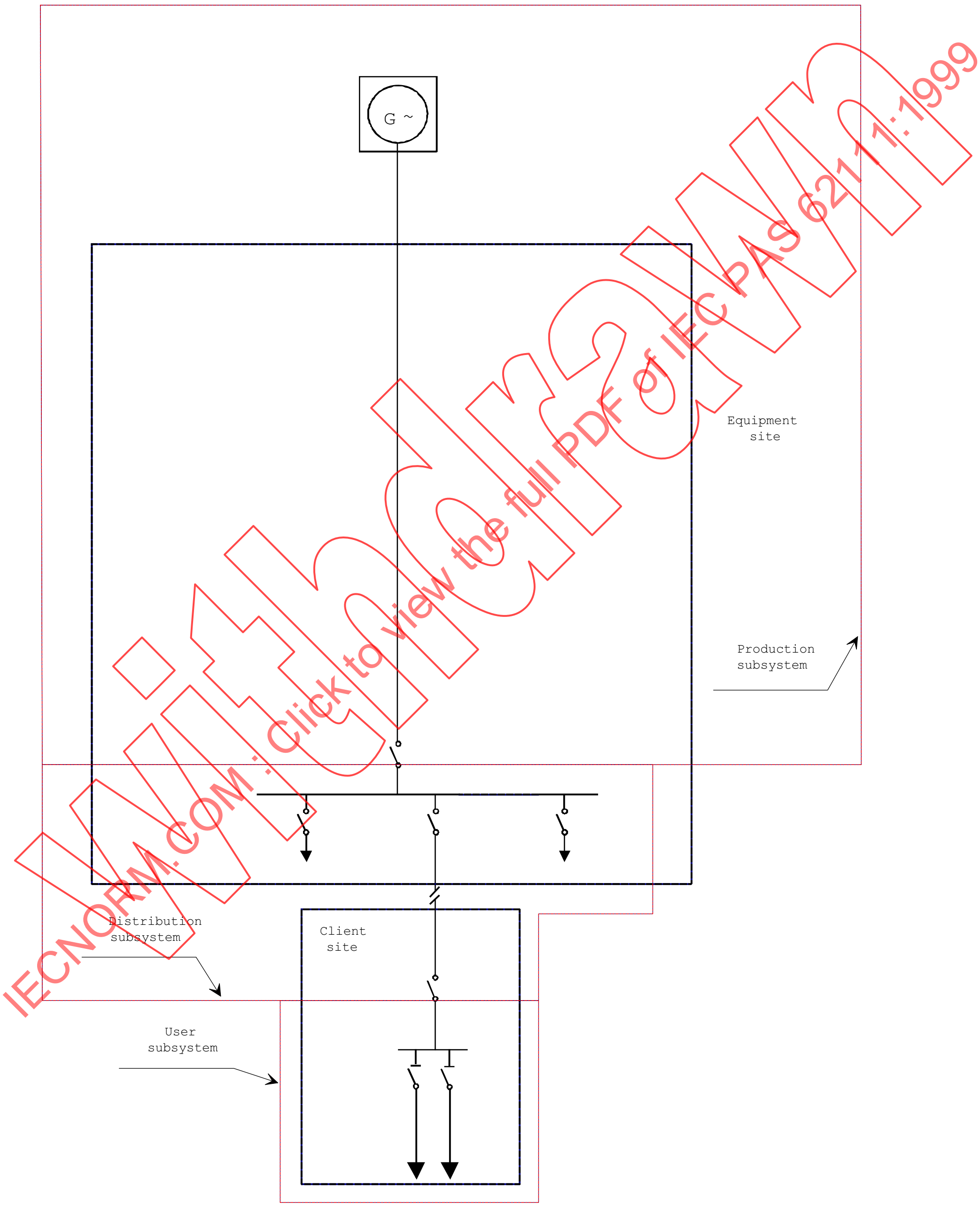


Figure 12 : T_8 type system

Diesel micro-power-station powering a micro-grid

5. Limits between the production, distribution and user subsystems The limits between the various production, distribution and user subsystems are shown in figures 1 to 12.

The various operators, where there are several of them, may choose the respective action zone limits which suit them best in relation the priorities they have set :

- one single point of supply ;
- several points of supply ;
- power supply in DC ;
- power supply in AC ;
- booster unit belonging to the user subsystem ;
- etc.

NOTE. - The supply under standard voltage to be defined (24 V_{DC}, 230 V_{AC}, for example) entails, under certain circumstances, the use of certain converters by the production subsystem operator.

The design of the systems must enable, during the operations, the observance of the safety rules imposed by the texts in force in the countries under consideration or, failing this, the rules imposed by the Project Supervisor or local operator.

NOTE. - For France, the texts governing safety operations on electrical installations are standard UTE C 18-510 and, for EDF representatives, the personnel handbook..

6. Summary of various types of electrification systems

A summary of the features of the various types of systems governing the electrification of isolated sites is shown in table 1.

Table 1 : Summary of the features of the various types of electrification systems for isolated sites

	Type of system	Energy production		Storage	Conversion	Synchronous coupling RE / unit	Use		
		PV and/or wind generator	Generator Set				DC	AC	Dedicated AC
Process powering systems using REN	T_{1a}	❋					❋		
	T_{1b}	❋						❋	
	T_{1c}	❋			❋			❋	
	T_{1d}	❋			❋		❋		
Single-user systems	T_2	❋		❋	❋		❋	❋	
	T_3	❋	❋	❋	❋		❋	❋	❋
Multi-user systems	T_4	❋		❋	❋			❋	
	T_5	❋	❋	❋	❋			❋	❋
	T_{6a}	❋	❋	❋	❋	❋		❋	
	T_{6b}	❋	❋	❋	❋	❋		❋	
	T_7		❋	❋	❋			❋	
	T_8		❋					❋	

(❋ : equipment present)

DIRECTIVES ERD - B 2

Juin 1997

Title : **Part B : Guidelines for System Design and Operation**

Section 2 : Guidelines for Production Sub-System Design

Number of pages : 1 (including appendices)

Type : Technical Specifications - Rules

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Title : **Part B : Guidelines for System Design and Operation**

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DRE SPECIFICATIONS - B 4

June 1997

Title : **Part B : Guidelines for System Design and Operation**

Section 4 : Energy Management Guidelines

Number of pages : 5 (including appendices)

Type : Technical Specifications - Rules

Associated document (s) : DRE - D 2 :"Guidelines for Selecting a System (planned"

Summary : This document explains the results expected from the sizing process and addresses the effect of energy management scenarios and technical solutions on the sizing of systems.

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CONTENTS

1. Energy management in a stand-alone solar energy-based system

Managing energy in an electricity production system utilising renewable energy sources involves the performance of a certain number of functions described below.

Managing to ensure adequacy of resources and demand

Managing energy in a stand-alone system involves balancing the production of sources using renewable energy with consumption, in other words matching resources with energy requirements and responding as a result. This system of management must be operated in the interests of the end-user in order to reconcile as far as possible the undertakings made by the competent intervener with respect to the services provided (Project Supervisor, Project Contractor, Operator).

Encouraging the use of renewable energies

Managing energy in a stand-alone system involves exercising preference for production using renewable energy in order to minimum consumption of fossil fuels.

Ensuring long service life of equipment

Managing energy in a stand-alone system involves ensuring long service life of the equipment, in other words promoting equipment safety in terms of continuity of supply in order to obtain full benefit from the investment throughout the design life of the equipment.

Managing the amount of energy

Managing energy in a stand-alone system involves managing the use of the generally limited amount of energy supplied by a system utilising renewable energy. It therefore involves management of the distribution of this amount of energy between the various users when a collective system is used.

Consequently, a certain number of precautions need to be taken in order to manage the amount of energy that is available and which can be consumed.

In a single-user system, excess consumption leads to a halt in supply after a certain length of time. The user very quickly learns to utilise the potential of the system correctly.

In a multi-user system (for example, a micro-power station linked to a micro-grid), measures need to be taken to conserve the store of energy for the benefit of the greatest number and to not jeopardise the joint installation. Several solutions are clearly possible, for example :

- the grid is only live for a restricted period of time daily, and the power for each user is limited ; in this case it is the time during which the grid is live which restricts the amount of energy distributed ;
- the grid is live for a significant part of the day which provides a better quality of service but restricts both the power available to each user and the amount of energy that he can consume for a given period of time. Depending on the sizing of the installation this amount of energy may be managed for one or several days.

In systems with electrochemical storage energy management involves taking the necessary measures in order to replenish the store of energy. In battery-less, direct coupled systems there is generally a store, but, instead of being of the electrochemical type, it is of a different nature, for example, water storage in the case of a pumping application.

In a system which produces electricity from Renewable Energy (REN) sources, therefore, it is vital that loads that are the most economical possible in terms of energy consumption are used and that all the resources in terms of Energy Demand Management (EDM) techniques are implemented.

Managing the quality of the product electricity

Energy management therefore involves managing the quality of the product electricity, supplied to the user. The criteria for defining this quality are :

- the voltage value and its range of variation ;
- the ripple rate for direct voltage ;
- the frequency and range of variation in the case of alternating voltage ;
- the harmonics rate in the case of alternating voltage.

The harmonics rate of an alternating signal supplied to the user depends directly on the quality of the DC.-AC. converter (pseudo-sinusoidal or sinusoidal) or on the generating plant used. The quality of the signal supplied must be suitable for the loads used. The designer of a system must therefore be sure to verify this point.

2. Effect of energy management scenarios on system sizing

Table 1 summarises the impact of energy management scenarios on the sizing of an installation.

Table 1 : Effect of energy management scenarios on the sizing of the system

Management scenarios	Effect on sizing
Number of days without renewable energy	Battery autonomy Choice of battery cycling Type of battery Sizing of the REN generator which must be capable of charging the batteries
Role of the generating plant • booster charge (part played in the annual energy balance sheet) • emergency supply in the event of failure of a component or exceptional period without REN, exceeding the sizing scenarios	Plant power Type of plant : • petrol ; • diesel ; • standard or industrial quality
Rate of generating plant utilisation	Fuel storage capacity Sizing of the generator utilising REN Sizing of the batteries
Cut-off of power to consumer equipment or users : • power cut-off authorisation ; • prioritisation of power cut-offs	Battery capacity generating plant power
Power constraints imposed by certain installations ; • operating hours ; • taking-up of power, etc.	Battery capacity Sizing of the DC-AC. converter
Equipment service life	Quality of components and materials selected Energy manager design

3. Effect of costs hypothesis and technical solutions choices on system sizing

The results of the sizing work must enable an acceptable compromise to be reached in each case, taking into account :

- investment costs ;
- operating costs ;
- maintenance costs ;
- renewal costs.

All these costs must be considered within the context of a discounted costing which discounts not only the various costs mentioned above but also the number of kWh produced during the life of the installation. This enables the cost of the kWh produced by the installation to be defined and the various technical solutions to be compared.

The methods used for the technical and economic costing are described in document D2 : “System selection aids”.

The scenarios for these costings must be specified by the Project Supervisor and in particular the discount rate to be used. The discounted costing is the responsibility of the Project Contractor.

The technical choices flow largely from the fixed cost targets specified by the orderer or the Project Supervisor of the installation.

By technical choices is understood :

- choice of architecture :
  - ◊ flow chart for organising the installation designed to produce and distribute the power ;
  - ◊ distribution of AC. or DC. power, therefore presence or otherwise of a converter (type, power, output signal sinusoidal or otherwise) ;
  - localisation of cut-off points for manoeuvring and type of equipment ;
  - ◊ electrical protective devises (trip switches).
- choice of quality of components and of technical characteristics (solar power modules, wind generator, batteries, power generating plant) from among the hardware available on the market..

Repeat work may be necessary in order to reach the right compromise to be proposed to the Project Supervisor of the installation. Freedom of choice may also be restricted if the budget set by the Project Supervisor of the installation is very tight. In this instance it is no longer a matter of finding the best compromise in terms of technical solutions and economic considerations but of finding the best quality of service for a given target cost.

Table 2, which is not exhaustive, summarises the main effects of technical and economic choices on the sizing of the systems..

Table 2 : Effect of cost management scenarios on system sizing

Scenarios	Effect on sizing
Target life of the equipment : • average (5 years) : • normal (10 years) : • increased (15-20 years). Equipment maintenance policy : • setting-up of maintenance structures ; • training and skills of maintenance personnel ; • type of maintenance (preventive, curative) ; stock of parts, etc. Component and equipment renewal policy : • structure for taking delivery of installations ; • renewal policy, frequency, preventive, curative, etc.	Component quality Quality of the product (electricity) supplied Type of battery Battery capacity Ability of the generator to charge the batteries Quality of the algorithms for energy management and batteries Type of generating plant Type of consumer equipment (robustness, energy consumption, etc.)

DRE SPECIFICATIONS - B 5 June 1997

Title **Part B - Rules for system design and operation**

Section 5 :"Rules for data acquisition"

Number of pages 24 (including appendices)

Type Technical specification - Rules

Associated document (s) DRE - A1 : "Requirements when submitting the proposal for a range of electrification systems".
DRE - A3 : "Contractual framework for relations with interveners".
DRE - B4 : "Rules for energy management".
DRE - B7 : "Rules for operation, maintenance and renewal"
DRE - C7 : "Energy managers".

Summary This document describes the data to be acquired in the various systems defined in document B1 : “Electrification systems architecture”. It defines a range of data acquisition systems suitable for the various types of architecture.

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CONTENTS

Introduction

This specification describes the measurements that need to be taken by the data acquisition equipment installed in systems for the electrification of isolated sites by solar power or wind generators. This specification must be consulted in conjunction with specifications A1 : “Requirements to be met when submitting the proposal for a range of electrification systems” and B4 : “Rules for energy management”, together with which this specification enables a range of seven energy managers and four types of data acquisition equipment suitable for the various types of system and requirement to be defined.

1. Scope of application

This specification defines the information to be provided for data acquisition in the systems specified for the electrification of isolated sites.

2. Definitions et abbreviations

Wind generator : system designed to convert the kinetic energy of wind into electrical energy.

REN : renewable energy (wind, sun, etc.).

PV generator : array of solar modules.

Generating set : source of alternative electrical energy with a heat engine constituting either a booster or a stand-by.

Production : set of production equipment (PV generator, wind generator, generating set).

Storage : set of accumulator batteries (state-of-the-art technology). This set may comprise one or more sets of batteries connected in parallel (battery sub-set).

Consumer equipment : consumer equipment supplied by the installation. They are five types of consumer equipment :

- **stand-by AC** : a.c. consumer equipment that can be supplied indiscriminately by battery, converters, or by the generating set.
- **non-standby AC** : a.c. consumer equipment supplied by the battery via converters. This consumer equipment can be isolated from the power source in the event of inadequate energy storage in the batteries.
- **stand-by DC : d.c.** consumer equipment that can be supplied indiscriminately by the battery or by the generating set via rectifiers.
- **non-stand by DC :** d.c. consumer equipment supplied by the battery. They can be isolated from the power source in the event of inadequate storage in the batteries**.**
- **REN pseudo-battery-less** : consumer equipment supplied by REN generators when it is no longer necessary to continue to charge the battery and when the REN is still available.

AC : alternating current.

DC : direct current.

E_T : total radiated power acting on an inclined unit area (Wm^{-2}).

I_{Bat} : battery current (plus : **+**, negative : **-**).

I_{REn} : current emitted by the REN sources (PV generator, wind generator).

I_{Gr} : current emitted by the generating set.

I_{Util} : current flowing through equipment or consumer equipment (direct : I_{DC} or alternating : I_{AC}). it is measured within the confines of the production installation and the distribution or consumer installation.

t_{Gr} : generating set powering-up time

T_{Gr} : generating set operating time.

U_{Bat} : voltage measured at the battery terminals

U_{EnR} : voltage at the REN source terminals (PV generator, wind generator).

U_{Gr} : voltage at the generating set terminals.

U_{Util} : supply voltage for the consumer equipment (direct : U_{DC} or alternating : U_{AC}). Alternatively, it is the converter output voltage.

V_{moy} : average wind speed at a height of 10 m (m/s).

W_{Bat} : amount of energy stored in the battery (charge).

W_{Gr} : generating set production(generating set coverage rate).

$W_{Réelle}$: energy actually produced by the REN sources (solar and/or wind power).

W_{Th} : energy that can be produced in theory by the installation given the REN resources (solar and/or wind power). It is the energy that could have been produced by the installation if the controls had not interrupted the battery charge when the batteries were being charged.

W_{Util} : energy consumed by the consumer equipment (DC and/or AC).

θ_{Bat} : battery temperature.

3. Information to be supplied

Four types of information may be required for a stand-alone installation supplying an isolated site with electrical energy :

- that required in order to ensure the proper functioning of the installation and of the energy manager with which the installation is equipped ;
- that required to verify compliance with the contracts between he various interveners (see document DRE - A3 : “Contractual framework for relations with interveners”) :
- that destined for the user to enable him to utilise his installation correctly ;
- that required for maintenance and diagnostics purposes.

A fifth set of information to extend knowledge of the operation of an installation can be added. This type of information is not dealt with in this document. Special devices will be used for these requirements.

The addresses for the information and their principal requirements are defined below.

3.1 Energy manager

The energy manager needs to know the physical variables associated with the status and the operation of the installation, in order to be able to make decisions regarding the production and supply of energy in accordance with the pre-defined level of quality of service whilst ensuring long service life of the equipment. The functional specification for energy managers (see document DRE - C7 : “Energy managers”) states the functions that they must perform. Table 1 shows the information the data acquisition equipment must supply to the energy manager to enable it to perform its functions. The function numbers are those stated in the said specification.

Table 1 : Information required by the energy manager

Function no.	Function description	Information required by the energy manager	Information to be provided by the data acquisition system
1	**Management of energy flows in the production - storage links**		
1.1 to 1.9	Links between REN source and storage	• Battery charge status : W_{bat} • (Schedule)	• Voltage at the REN generator terminals : U_{EnR} • Current emitted by the REN source : I_{REN} • Schedule
1.10 to 1.12	Generating set - battery link	• Battery charge status : W_{bat} • (Schedule)	• Time for powering up the generating set : t_{GR} • Schedule • Voltage at the generating set terminals U_{GR} • Current emitted by the generating set : I_{GR} • Generating set operating time : T_{GR}
2	**Management of energy flows in the storage - consumer equipment links**		
2.1 to 2.6	Storage - stand-by or non standby AC/DC consumer equipment links	• Battery charge status : W_{Bat}	• Voltage at the consumer equipment terminals : U_{util} • Consumer equipment current : I_{util}
2.3 and 2.4 2.7 and 2.8	Voltage limitation at the standby or non standby AC/DC consumer equipment terminals	• Voltage at the consumer equipment terminals : U_{util}	• Voltage at the consumer equipment terminals : U_{util}
2.9 and 2.10	REN sources - pseudo-battery-less consumer equipment links	• Battery charge status : W_{bat} • REN producible energy	• Voltage at the REN generator terminals : U_{EnR} • Current emitted by the REN source : I_{EnR}
3	**Management of energy flows in the production - consumer equipment links**		
3.1 and 3.2	Generating set - standby AC/DC consumer equipment links	• Energy produced by the generating set : W_{Gr}	• Voltage at the generating set terminals : U_{GR} • Current emitted by the generating set : I_{GR} • Generating set operating time : T_{GR}
4	**Management of the generating set start/stop commands**		
4.1 to 4.2	Generating set start, stop	• Battery charge status : W_{bat} • (Schedule)	• All data for W_{bat}, (see above) • Schedule

3.2 Installation operator

His needs are varied and are summarised in table 2. They relate to compliance with the contract and assistance with diagnostics and maintenance. The operator wishes to verify compliance of installation performance with that specified by the sizing. There may be three main reasons for a deficiency of energy in the installation :

- breakdown (converter, for example) ;
- production deficiency due to installation failure or poor weather conditions ;
- excessive consumption by the user.

In certain instances the operator must be able to teletransmit this information as well as commands to the installation. The data acquisition system must therefore be able to communicate via a telephone link in these cases.

Table 2 : Information required by the operator

Requirement	Information required
Compliance with the contract	
Verification of compliance of installation performance with the sizing specified	• Production capability of the installation : W_{Th} • Installation production : * $W_{réelle}$ * W_{Gr} Battery charge status : W_{Bat}
Check for compliance of the energy consumption limits provided for by the sizing and defined in the operator/user “contract” (see document DRE - A3 : “Contractual framework for relations with interveners”)	• Consumption of energy by the user : W_{util} • Consumption history
Diagnostics and maintenance assistance	
Knowledge of the operating conditions of the installation prior to carrying out any maintenance operation. Diagnostics in the event of failure.	• Battery charge status : W_{Bat} • Identification of breakdowns • Production history • Breakdown history

3.3 Installation user

The user of the installation may be interested in the technical monitoring of his installation and the management of energy resources. At the very least he wishes to profit by this and will want to be warned in the event of a risk of energy deficiency and of any event which might jeopardise his consumption plans. Table 3 summarises the necessary information. The information concerns compliance with the contract and assistance with use.

Table 3 : Information required by the user

Requirement	Information required
Compliance with the contract	
Verification of compliance of installation performance with the sizing specified and as promised by the operator/concessionaire	• REN production : $W_{réelle}$ • Gen. set production : W_{Gr}
Assistance with use	
Warning of any event which might jeopardise his energy consumption plans. Knowledge of the available energy and potential for consumption. Warning of risks of energy deficiency Information on how best to use the installation and manage energy resources	• Identification of breakdowns • Battery charge status : W_{Bat} • Consumption : W_{util} • REN production : $W_{réelle}$ • Gen. set production : W_{Gr}

4. Information to be provided

Tables 1 to 3 enable a list to be drawn up of the information required to meet needs. The nature and extent of the information to be supplied, possibly in various forms depending on the addressee, relate to the type of installation in question. A list of this information and the addressees is summarised in table 4.

Table 4 : Information to be provided by the data acquisition system

Information to be supplied		Utilisation of the information supplied			
		Energy management	Operational assistance		Assistance with utilisation
			"Contract" monitoring	Diagnostics maintenance	
U_{Bat}	Voltage at the battery terminals	●			
I_{Bat}	Battery current (and direction)	(●)			
θ_{Bat}	Battery temperature	(●)			
U_{EnR}	REN source voltage	●			
I_{EnR}	REN source current	●			
U_{Gr}	Generating set voltage	●			
I_{Gr}	Generating set current	●			
U_{Util}	Consumer equipment supply voltage (DC and/or AC)	●			
I_{Util}	Consumer equipment supply current DC and/or AC	●			●
t_{Gr}	Generating set powering-up time	●			
T_{Gr}	Generating set operating time	●			
	Identification of breakdowns (anomalies)		●	●	●
W_{Bat}	Battery charge status	●		●	●
$W_{Réelle}$	REN source production	●	●	●	●
W_{Th}	REN source production capability	●	●	●	
W_{Gr}	Generating set production (GS coverage rate)	●	●		●
W_{Util}	Energy consumed by consumer equipment (DC and/or AC) per day, month, year		●		●
	REN production history		●	●	(●)
	REN production capability history		●	●	(●)
	Consumption history (day, month, year)		●	●	(●)
	Breakdown history		●	●	(●)
	Battery charge status history			●	(●)
	Generating set production history		●	●	(●)

(● : compulsory information, (●) : optional information)

4.1 Information concerning the type of system

Table 5 provides useful information for each type of system (see document DRE - A1 : Requirements to be met when submitting the proposal for a range of electrification systems”).

Table 5 : Information required for the various types of installation

Information required		Type of system T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8
U_{Bat}	Voltage at the battery terminals		●	●	●	●		●	
I_{Bat}	Battery current (and direction)		(●)	(●)	(●)	(●)		(●)	
θ_{Bat}	Battery temperature		(●)	(●)	(●)	(●)		(●)	
U_{EnR}	REN source voltage	(●)	●	●	●	●			
I_{EnR}	REN source current		●	●	●	●			
U_{Gr}	Generating set voltage			●		●		●	●
I_{Gr}	Generating set current			●		●		●	●
U_{Util}	Consumer equipment supply voltage (DC and/or AC)	●	(●)	(●)	(●)	(●)		(●)	(●)
I_{Util}	Consumer equipment supply current DC and/or AC		●	●	●	●		●	●
t_{Gr}	Generating set powering-up time			●		●		●	●
T_{Gr}	Generating set operating time			●		●		●	●
	Identification of breakdowns	(●)	●	●	●	●		●	●
W_{Bat}	Battery charge status		●	●	●	●		●	
$W_{Réelle}$	REN source production	(●)	●	●	●	●			
W_{Th}	REN source production capability	(●)	●	●	●	●			
W_{Gr}	Generating set production ?(rate of coverage)				●	●		●	●
W_{Util}	Energy consumed by the consumer equipment (DC and/or AC) per day, month, year		●	●	●	●		●	●
	REN production history	(●)	(●)	(●)	(●)	(●)			
	REN production capability history	(●)	(●)	(●)	(●)	(●)			
	Consumption history (day, month, year)		(●)	(●)	(●)	(●)		(●)	(●)
	Breakdown history	(●)	(●)	(●)	(●)	(●)		(●)	(●)
	Battery charge status history		(●)	(●)	(●)	(●)		(●)	
	Generating set production history			(●)		(●)		(●)	(●)

(● : compulsory information, (●) : optional information)

Note. - Energy management for the type T_6 system is being designed. The data to be acquired will therefore be specified at a later date.

5. Range of data acquisition systems

From the information required for the various types of electrification system a range of 4 types of data acquisition as shown in table 6 can be defined.

Table 6 : Range of data acquisition systems

		Type of data acquisition system				
Information required		M_1	M_2	M_3	M_4	M_5
U_{Bat}	Voltage at the battery terminals		●	●	●	
I_{Bat}	Battery current (and direction)		(●)	(●)	(●)	
θ_{Bat}	Battery temperature		(●)	(●)	(●)	
U_{EnR}	REN source voltage	(●)	●	●		
I_{EnR}	REN source current		●	●		
U_{Gr}	Generating set voltage			●	●	●
I_{Gr}	Generating set current			●	●	●
U_{Util}	Consumer equipment supply voltage (DC and/or AC)	●	(●) (1)	(●) (1)	(●) (1)	(●) (1)
I_{Util}	Consumer equipment supply current (DC and/or AC)		●	●	●	●
t_{Gr}	Generating set powering-up time			●	●	●
T_{Gr}	Generating set operating time			●	●	●
	Identification of breakdowns	(●)	●	●	●	●
W_{Bat}	Battery charge status		●	●	●	
$W_{Réelle}$	REN source production	(●)	●	●		
W_{Th}	REN source production capability	(●)	●	●		
W_{Gr}	Generating set production (rate of coverage)			●	●	●
W_{Util}	Energy consumed by the consumer equipment (DC and/or AC) per day, month, year		●	●	●	●
	REN production history	(●)	(●)	(●)		
	REN production capability history	(●)	(●)	(●)		
	Consumption history (day, month, year)		(●)	(●)	(●)	(●)
	Breakdown history	(●)	(●)	(●)	(●)	(●)
	Battery charge status history		(●)	(●)	(●)	
	Generating set production history			(●)	(●)	(●)

(● : compulsory information, (●) : optional information)

(1) The managers of types G_{2b}, G_{3b}, G_{3d} and G_{4b} have this option (see document DRE - B7 : "Rules for operation, maintenance and renewal")

6. Correspondence between ranges of data acquisition systems, energy managers and types of system

Table 7 shows the correspondence between the range of data acquisition systems, the range of energy managers and the type of installation. The option for teletransmitting commands and/or information may be envisaged for each type of energy manager.

Table 7 : Correspondence between ranges of data acquisition systems, energy managers and types of system

		Type of data acquisition			
Type of manager	**Type of installation**	**M_1**	**M_2**	**M_3**	**M_4**
G_1	T_1	●			
G_{2a}	T_2, T_4		●		
G_{2b}	T_2, T_4		((1)		
G_{3a}	T_3			●	
G_{3b}	T_3			((1)	
G_{3c}	T_3, T_5			●	
G_{3d}	T_3, T_5			((1)	
G_{4a}	T_7				●
G_{4b}	T_7				((1)

(● : compulsory information, (●) : optional information)

(1) : consumer equipment voltage monitoring option

7. Data acquisition system functions

Four essential functions must be implemented in order to satisfy the requirements for the information described above :

- measurement of physical variables representative of the status and operation of the installation ;
- processing of measurements in order to compile data patterns of the status and operation of the installation ;
- storage of data in order to compile histories and balance sheets ;
- return to the addressees concerned (energy manager, operator, user) of the information that they are capable of utilising.

For each item of information table 8 shows the type of function that the **data acquisition** system must perform.

The characteristics of the various items of information to be gathered are shown in the function sheets in appendix 1.

Table 8 : Type of functions to be implemented in the data acquisition system

			Functions to be performed			
Information required		Sheet no.	Measurement of variables	Data processing	Storage of results	Return of information
U_{Bat}	Voltage at the battery terminals	A1	●			●
I_{Bat}	Battery current (and direction)	A2	(●)			(●)
θ_{Bat}	Battery temperature	A3	(●)			(●)
U_{EnR}	REN source voltage	A4	●			●
I_{EnR}	REN source current	A5	●			●
U_{Gr}	Generating set voltage	A6	●			●
I_{Gr}	Generating set current	A7	●			●
U_{Util}	Consumer equipment supply voltage (DC and/or AC)	A8	●			●
I_{Util}	Consumer equipment supply current (DC and/or AC)	A9	●			●
t_{Gr}	Generating set powering-up time	A10	●			●
T_{Gr}	Generating set operating time	A11	●			●
	Identification of breakdowns			●	●	●
W_{Bat}	Battery charge status			●	●	●
$W_{Réelle}$	REN source production			●	●	●
W_{Th}	REN source production capability			●	●	●
W_{Gr}	Generating set production (rate of coverage)			●	●	●
E	Energy consumed by the consumer equipment (DC and/or AC) per day, month, year			●	●	●
	Battery charge status history	A12		●	●	●
	REN production history	A13		●	●	●
	REN production capability history	A14		●	●	●
	Generating set production history	A15		●	●	●
	Consumption history (day, month, year)	A16		●	●	●
	Breakdown history	A17		●	●	●

(● : compulsory information, (●) : optional information)

8. Conditions of service

Being prepared

8.1 Conditions of storage

Being prepared.

9. Electrical characteristics

Being prepared.

10. Design characteristics

Being prepared.

Appendix A : (normative) Data acquisition function sheets

Sheet A1 : BATTERY VOLTAGE

Information to be supplied		**Performance to be achieved**		
Function to be performed	**Action**	**Performance criteria**	**Levels**	**Comments**
Measurement	U_{Bat}	Measuring range Accuracy Measuring frequency	1,5 V to 3 V per element 0,5 % 1 min	Measuring frequency : sufficient to detect : variation of 1 V on the battery voltage or the value of the battery charge status
Processing	Flag U_{Bat} maxi (counter) Flag U_{Bat} min (counter)	Calculating frequency Test period Calculating frequency Test period	1 min 0 to 24 h 1 min 0 to 24 h	
Storage	Last value U_{Bat} U_{Bat} maxi U_{Bat} min	Number of values stored Storage frequency	1 1 min	
Return	Last value U_{Bat} U_{Bat} maxi U_{Bat} min	Type of return	Local display Transmission to manager Teletransmission	

Sheet A2 : BATTERY CURRENT

Information to be provided		**Performance to be achieved**		
Function to be performed	**Action**	**Performance criteria**	**Levels**	**Comments**
Measurement	Current I_{Bat} Direction of I_{Bat}	Measuring range Accuracy Measuring frequency Measuring frequency	-100 A to +200 A 0,5 % 1 min 1 min	Measuring frequency identical to battery voltage measurement
Processing				
Storage				
Return	Module I_{Bat} Direction I_{Bat}		Local display Transmission to manager Teletransmission	

Appendix A (cont)

Sheet A3 : BATTERY TEMPERATURE

Information to be supplied		**Performance to be achieved**		
Function to be performed	**Action**	**Performance criteria**	**Levels**	**Comments**
Measurement	Temperature θ_{Bat}	Measuring range Accuracy Measuring frequency	-30 °C to + 50 °C 0,5 % 1 min	Measuring frequency identical to battery voltage measurement
Processing				
Storage				
Return	Temperature θ_{Bat}		Local display Transmission to manager Teletransmission	

Sheet A4 : REN source voltage

Information to be supplied		**Performance to be achieved**		
Function to be performed	**Action**	**Performance criteria**	**Levels**	**Comments**
Measurement	U_{EnR}	Measuring range Accuracy Measuring frequency	0-12 to 0-500 V depending on REN source 0,5 % 1 min	Measuring frequency sufficient to detect the value of the battery charge status
Processing	Compare U_{EnR} and U_{Bat}		The REN only charge the battery if $U_{EnR} > U_{Bat}$	In certain cases this is U_{EnR} after conversion
Storage				
Return			Transmission to manager	

Sheet A5 : REN SOURCE CURRENT

Information to be supplied		**Performance to be achieved**		
Function to be performed	**Action**	**Performance criteria**	**Levels**	**Comments**
Measurement	I_{EnR}	Measuring range Accuracy Measuring frequency	0-100 A depending on REN source 0,5 % 1 min	Measuring frequency sufficient to detect the value of the battery charge status
Processing				
Storage				
Return			Transmission to the manager	

Appendix A (cont)

Sheet A6 : BOOSTER GENERATOR VOLTAGE

Information to be supplied		Performance to be achieved		
Function to be performed	**Action**	**Performance criteria**	**Levels**	**Comments**
Measurement	U_{Gr}	Measuring range Accuracy Measuring frequency	0-400 V 0,5 % 1 min	Measuring frequency sufficient to detect the value of the battery charge status
Processing				
Storage				
Return			Transmission to manager	

Sheet A7 BOOSTER GENERATOR CURRENT

Information to be provided		Performance to be achieved		
Function to be performed	**Action**	**Performance criteria**	**Levels**	**Comments**
Measurement	I_{Gr}	Measuring range Accuracy Measuring frequency	0-100 A depending on REN source 5% min	Measuring frequency sufficient to detect the value of the battery charge status
Processing				
Storage				
Return			Transmission to manager	

Sheet A8 : CONSUMER EQUIPMENT SUPPLY VOLTAGE

Information to be provided		Performance to be achieved		
Function to be performed	**Action**	**Performance criteria**	**Levels**	**Comments**
Measurement	U_{Util}	Measuring range Accuracy Measuring frequency	12, 24, 48 V DC and 230 V AC 0,5 % 1 min	Measuring frequency sufficient for disconnection without damage of the loads in the event of surge or undervoltage
Processing				
Storage				
Return	Consumer equipment supply voltage	Type of return	Transmission to manager	Disconnection of consumer equipment in the event of surge or undervoltage

Appendix A (cont)

Sheet A9 : CONSUMER EQUIPMENT SUPPLY CURRENT

Information to be provided		Performance to be achieved		
Function to be performed	**Action**	**Performance criteria**	**Levels**	**Comments**
Measurement	I_{Util}	Measuring range Accuracy Measuring frequency	0/100 A depending on installation 0,5 % 1 min	
Processing				
Storage				
Return	Consumer equipment supply current	Type of return	Transmission to manager	For calculating consumer equipment consumption (with voltage)

Sheet A10 : BOOSTER GENERATOR POWERING-UP TIME

Information to be provided		Performance to be achieved		
Function to be performed	**Action**	**Performance criteria**	**Levels**	**Comments**
Measurement	t_{Gr}	Measuring time accuracy	10 s	
Processing				
Storage				
Return	Generating set operating time	Type of return	Transmission to manager	For generating set coupling after powering-up

Sheet A11 : BOOSTER GENERATOR OPERATING TIME

Information to be provided		Performance to be achieved		
Function to be performed	**Action**	**Performance criteria**	**Levels**	**Comments**
Measurement	T_{Gr}	Accuracy	10 s	
Processing				
Storage				
Return	Generating set operating time	Type of return	Transmission to manager	For minimising generating set operating time

Appendix A (cont)

Appendix A12 : BATTERY CHARGE STATUS HISTORY

Information to be provided		**Performance to be achieved**		
Function to be performed	**Action**	**Performance criteria**	**Levels**	**Comments**
Measurement	U_{bat} I_{Bat}	Measuring range Accuracy Measuring frequency Measuring range Accuracy Measuring frequency	1,5 to 3 V per element 0,5 % sufficient to detect : variation of 0,1 V in battery voltage or the value the battery charge status -100 A to +100 A 0,5 % identical to battery voltage measurement	
Processing	Determine the charge status Compare with reference charge status : - equalised - full - full-h - low1+h - low1 - low2+h - low2 - empty	Deviation from actual charge status Detect a variation in the charge status	less than 5 % less than h	Depending on algorithm used : battery voltage, energy balance sheet
Storage	Number of times the charge status was greater than a maximum value and less than a minimum value	Number of values stored	Number of times per month, or 2x12 values For a maximum period of 1 year	Assists maintenance and diagnostics, by comparing with the production value and the consumption value
Return	Battery charge status for transmission to manager Battery charge status to assist use	Transmission to manager Type of return	For each measurement Local display	Assists use (complemented by indication of instantaneous consumption)

Appendix A (cont)

Sheet A13 : REN SOURCE PRODUCTION HISTORY

Information to be provided		Performance to be achieved		
Function to be performed	**Action**	**Performance criteria**	**Levels**	**Comments**
Measurement	U_{EnR}	Measuring range Accuracy Measuring frequency	0/12 to 0/400 V dep. on REN source 0,5 % Sufficient to obtain accuracy to within 1% for determining the amount of energy produced	To be determined acc. to the data acquisition ranges (determine the P_{max} for each type)
	I_{EnR}	Measuring range Accuracy Measuring frequency	0-100 A 0,5 % Sufficient to obtain accuracy to within 1% for determining the amount of energy produced	
Processing	Calculate energy produced each month	Accuracy in relation to energy actually produced	1 %	
Storage	Energy produced each month	Number of values stored	Last 18 values	To provide the operator with a margin for annual retrieval of the values
Return	The stored values	Type of return	Local display value by value Local loading Remote loading	

Appendix A (cont)

Sheet A14 : HISTORY OF REN SOURCE PRODUCTION CAPABILITY

Information to be provided		Performance to be achieved		
Function to be performed	**Action**	**Performance criteria**	**Levels**	**Comments**
Measurement	U_{EnR}	Measuring range	0/12 to 0/400 V dep. on REN source	
		Accuracy	0,5 %	
		Measuring frequency	Sufficient to obtain accuracy to within 1% when determining the amount of energy produced	
	I_{EnR}	Measuring range	0-200 A	To be determined dep. on data acquisition ranges (determine the P_{max} for each type)
		Accuracy	0,5 %	
		Measuring frequency	Sufficient to obtain accuracy to within 1% when determining the amount of energy produced	
Processing	Calculate monthly energy production capability	Accuracy in relation to energy actually produced	1 %	
	Calculate the instantaneous production capability	Accuracy in relation to actual production capability	1 %	This information is for the energy manager
Storage	Monthly production capability of energy	Number of values stored	Last 18 values	To provide the operator with a margin for annual retrieval of the values
Return	Stored values of theoretical monthly production	Type of return	Local display value by value Local loading Remote loading	
	Instantaneous production capability	Type of return	Transmission to energy manager	

Sheet A (cont)

Fiche A15 : BOOSTER GENERATOR PRODUCTION HISTORY

Information to be provided		**Performance to be achieved**		
Function to be performed	**Action**	**Performance criteria**	**Levels**	**Comments**
Measurement	U_{Gr}	Measuring range	0-12 to 0-400 V dep. on REN source	
		Accuracy	0,5 %	
		Measuring frequency	Sufficient to obtain accuracy to within 1% when determining the amount of energy produced	
	I_{Gr}	Measuring range	0-100 A	To be determined acc. to the data acquisition ranges (determine the P_{max} for each type)
		Accuracy	0,5 %	
		Measuring frequency	Sufficient to obtain accuracy to within 1% when determining the amount of energy produced	
Processing	Calculate monthly energy production	Accuracy in relation to energy actually produced	1 %	
Storage	Energy produced monthly	Number of values stored	Last 18 values	To provide operator with a margin for annual retrieval of the values
Return	Stored values	Type of return	Local display value by value Local loading Remote loading	

Sheet A (cont)

Sheet A16 : CONSUMER EQUIPMENT ENERGY CONSUMPTION HISTORY

Information to be provided		**Performance to be achieved**		
Function to be performed	**Action**	**Performance criteria**	**Levels**	**Comments**
Measurement	U_{Util}	Measuring range	0/12 to 0/400 V dep. on REN sources	
		Accuracy	0,5 %	
		Measuring frequency	Sufficient to obtain accuracy to within 1% when determining the amount of energy produced	
	I_{Util}	Measuring range	0-100 A	To be determined acc. to the data acquisition range (determine the P_{max} for each type)
		Accuracy	0,5 %	
		Measuring frequency	Sufficient to obtain accuracy to within 1% when determining the amount of energy produced	
Processing	Calculate the energy consumed since 0 h	Accuracy in relation to energy actually consumed	1 %	Aids use by comparing with daily energy theoretically available
	Calculate the monthly energy consumption	Accuracy in relation to actual energy consumption	1 %	Compile consumption history. "Contract" verification
Storage	Monthly energy consumption	Number of values stored	Last 18 values	To provide operator with a margin for annual retrieval of the values
Return	Monthly energy consumption	Type of return	Local display value by value Local loading Remote loading	
	Energy consumed since 0 h		Local display	Information so that the user know where he is up to in terms of his potential daily consumption

Appendix A (end)

Sheet A17 : CONSUMER EQUIPMENT ENERGY CONSUMPTION HISTORY

Information to be provided		Performance to be achieved		
Function to be performed	**Action**	**Performance criteria**	**Levels**	**Comments**
Measurement				
Processing				
Storage				
Return				

NOTE. - sheet A17 will be completed when the work on document DRE-B 7 : "Rules for operation, maintenance and renewal" is complete.

DRE SPECIFICATIONS - B 6 June 1997

Title

Part B - Guidelines for System Design and Operation

Section 6 : Guidelines for the Protection of Persons and Property from Electrical Hazards

Number of pages 56 (including appendices)

Type Technical specifications - Rules

Related document(s)
DRE - A 1 : "From the Requirements to be met to the Proposals for a Range of Electrification Systems".
DRE - B 1 : "Architecture of electrification systems".
DRE - B 7 : "Guidelines for Operation, Maintenance and Renewal".
DRE - C 6 : “Converter”.

Summary The aim of this document is to describe the expected characteristics of devices for protecting persons and property against electrical hazards in decentralised rural electrification installations.

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CONTENTS

Introduction

Decentralised rural electrification systems are intended to supply electricity for users located in rural areas on sites not connected to the national grid.

These users are, in the majority of cases, as follows :

- individual isolated houses ;
- groups of houses comprising villages ;
- community services (public lighting, pumping, health centres, places of worship, administrative buildings, etc.)
- economic activities (workshops, small industries, etc.)

These systems can be classified into three categories :

- electrification systems for processes (for example, pumping) ;
- single-user individual electrification systems, also called Single Home System (SHS) ;
- multi-user community electrification systems, also called Multi Home System (MHS).

The electrification systems for processes and the SHS comprise only two subsystems :

- one electrical energy **production** subsystem ;
- one **user** subsystem for this power.

The community electrification systems (MHS), on the other hand, comprise 3 subsystems :

- one electrical energy **production** subsystem ;
  traditionally, this is called a **"micro-power station"**, the term "micro" conveying the modest production power level (from several kVA to several dozen kVA) ;
- a **distribution** subsystem for this power ;
  traditionally, this is called a **"micro-grid"**, the term "micro" conveying the modest transit capacity level ;
- a **user** subsystem comprising distribution circuits and electrical equipment for the user.

The aim of this document is to describe, in terms of the results to be attained, the expected characteristics of devices governing the **protection of persons and property** against electrical hazards in installations.

These proposals thus constitute the bases for technical specifications on the development of installations comprising the various subsystems.

1. General aspects

1.1 Summary of the types of electrification systems

In table 6 of document DRE - A 1 : "From the Requirements to be met to the Proposals for a Range of Electrification Systems", it is proposed that decentralised rural electrification systems be classified into eight types.

1, 2 and 3 type systems are dedicated to a single user (e.g. isolated house, isolated process, etc.) and are SHS types.

Systems types 4 to 8 are intended to supply several users from a community production micro-power station and are MHS types.

1.2 Effects of electric current - Protection of persons

Any person who touches a metallic element through which electric current is passing will receive a discharge which is more or less dangerous according to the circumstances. This contact can be fatal in numerous cases, in particular when the current returns directly through the earth having passed through the human body.

The causes of accidents are numerous : ground of equipment not connected to an electrical protection (EP) conductor, connection flexes in poor condition, defective or poor quality electrical installation, inept operations or makeshift DIY work (failure to observe elementary safety rules).

In a domestic environment, the household appliances mostly apparent in accidents are television sets and lighting equipment.

By definition, any accident resulting from electricity is **electrification.** Fatal electrification is **electrocution**.

1.2.1 Effects of current passing through the human body

The dangers incurred by persons receiving an electric current across their body depend essentially on its intensity and flow time.

Given that this current cannot be gauged directly, the risk is assessed in relation to the level of the contact voltage applied to this person and the impedance encountered by the current as it passes through the human body.

This relationship is not linear because the impedance depends upon the most probable trajectory of the fault current through the body (point of entry, point of exit), the moisture level of the skin and the environmental conditions, in particular with regard to the presence of water which may affect the conditions of contact between the person and the earth. Finally it also depends upon the frequency of the current.

1.2.1.1 Effects of alternating current (between 15 and 100 Hz)

The effects of alternating current depend upon the level reached by the fault current which determines the various thresholds. These thresholds correspond to the zone limits which appear in the figure 1 (flow time in relation to the current) which has been prepared by a group of medical experts, physiologists and electricians from the IEC.

Zone ① is limited to the perception threshold.

The perception threshold is the minimum current level which causes a sensation for the person through whom the current is passing. This threshold is around 0.5 mA.

In this zone, the passage of the current is not perceived.

Zone ② is limited by the non-release threshold.

The non-release threshold is the maximum level of current whereby a person holding electrodes can release them.

In this zone, the current is perceived but does not cause any reaction. It may cause a slight, more or less violent and localised jolt which disappears in a more or less short space of time.

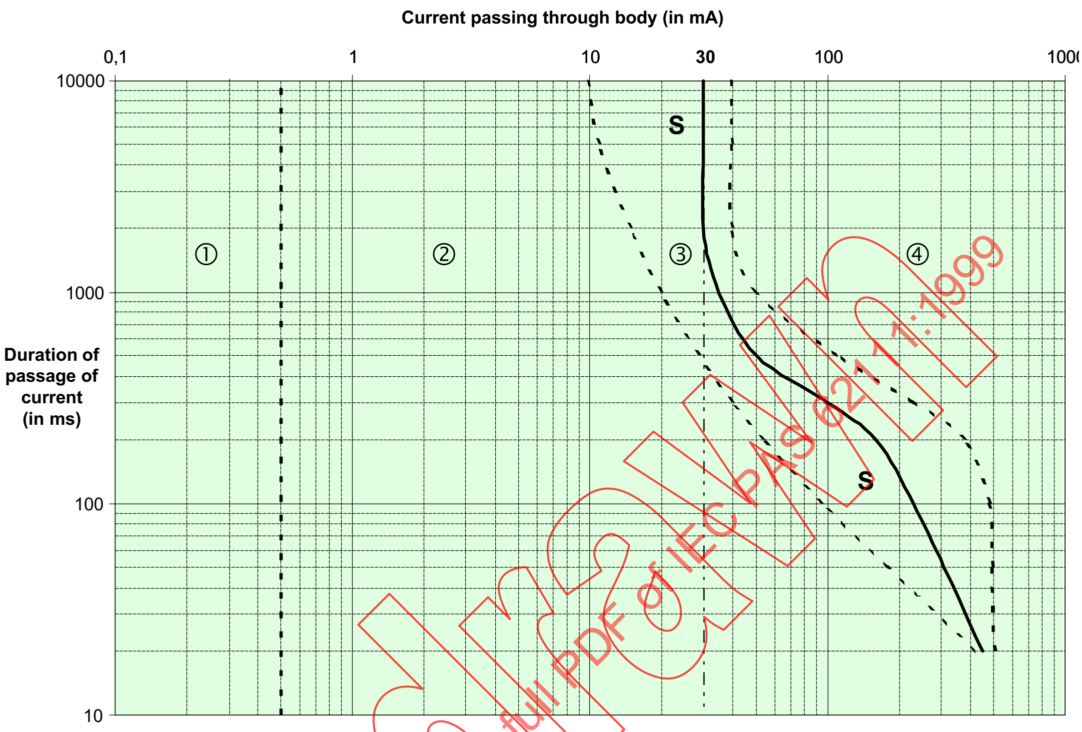


Figure 1 : Current - time zones under the effects of alternating current

Zone ③ is limited by the ventricular fibrillation threshold.

In this zone, the person holding an item of equipment cannot release it because of the phenomenon of the electrical tetanisation of the muscles. The electrical tetanisation lasts as long as the person remains in contact with the current but does not result in after-effects subsequent to the interruption of the current.

If tetanoid contracting is evident in the muscles of the thorax, it may cause the person to stop breathing. Where the victim collapses and suddenly loses consciousness, this is the result of a tetanisation of the respiratory muscles.

Under these circumstances, it is necessary for contact to be a minimum of three minutes in order for the outset of asphyxia to lead to a condition of apparent death. If, on the other hand, the passage of the current is interrupted within the following two or three minutes, the victim resumes breathing spontaneously and generally recovers very quickly.

In zone ④ the passage of the current may cause a ventricular fibrillation of the heart and may lead to cardiac arrest.

The ventricular fibrillation of the heart is a condition whereby the fibres of the cardiac muscle contract uncontrollably.

This condition leads to the complete cessation of the physiological action of the heart which no longer fulfils its role as a pump, i.e. it becomes incapable of driving the oxygenated blood around the body, in particular in terms of the brain.

The halting of the blood circulation essentially entails a loss of consciousness and subsequent cessation of breathing leading to a state of apparent death.

Within the domain of the protection of persons against electric shocks, only the risk of electrocution resulting from the ventricular fibrillation of the heart is taken into consideration.

Experiments carried out essentially on animals have enabled the possibility of establishing curve S in figure 1. This curve, located in zone ③ defines the *maximum flow time for the current in relation to the current passing through the body, to ensure safety under statistically reasonable conditions*.

To summarise, the consequences of an electric current passing through the body are comprised in table 1.

Table 1 : Effects of current passing through the body

Intensity of fault current	**Physiological effects**
1 A	cardiac arrest
75 mA	irreversible cardiac fibrillation threshold
30 mA	respiratory paralysis threshold
10 mA	muscle contraction (tetanisation)
0.5 mA	extremely slight sensation

1.2.1.2 Effects of direct current

Direct current appears to be less dangerous than alternating current ; in effect, it is less difficult to release hand-held conducting elements with direct current than with alternating current.

With direct current, the ventricular fibrillation threshold is much higher (see figure 2).

1.2.1.3 Thermal effects

Another significant electricity-related hazard is burning. Burns are extremely frequent in domestic and above all industrial accidents.

There are two types of burns :

- the arc burn which is a thermal burn caused by the intense heat radiated from an electric arc,
- the electro-thermal burn, the only real electrical burn, caused by the passing of the current through the body. This type of burn may lead to irreversible internal physical injuries.

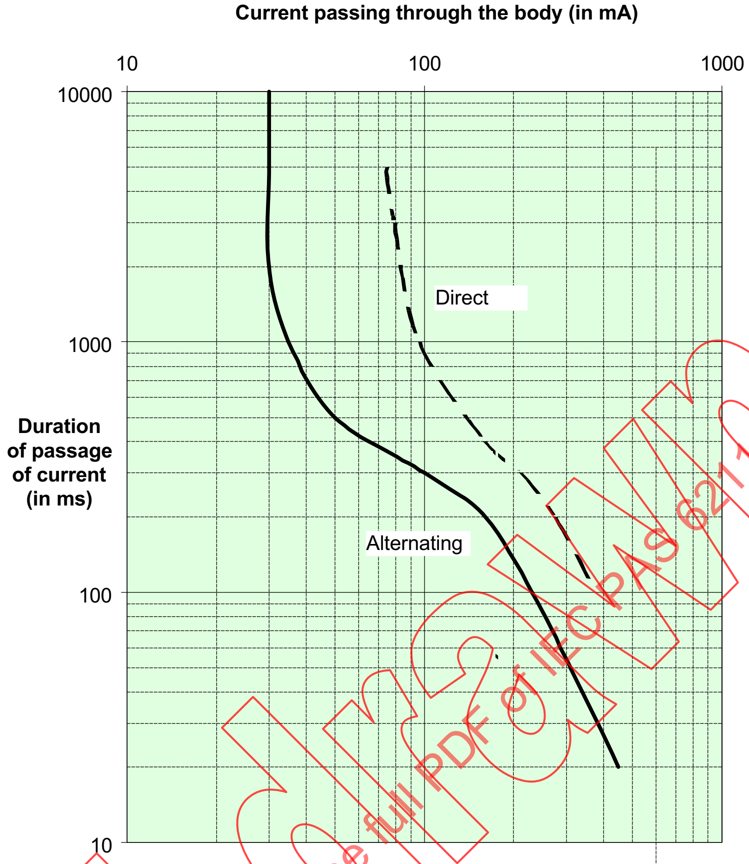


Figure 2 : Current - time zones under the effects of direct current

1.2.2 Protection against indirect contact

Indirect contact is where persons enter into contact with grounds which have been accidentally connected to a lived part, generally subsequent to faulty insulation.

These grounds may be the external casing of a household appliance, a motor, an electric panel, etc. They are metallic or conductive and include the live elements.

They are earthed using a protective conductor (PE). In the absence of faulty insulation, these electrical grounds must have a zero potential (no voltage) in relation to the earth because they are normally accessible.

In the case of faulty insulation, a ground is in contact with the live element and the current flowing through the fault and the ground meets the earth, either through a protection conductor or the person entering into contact with it.

The feature of an indirect contact is that the fault current never flows fully through the human body.

There are two types of protection measures used against indirect contact.

1.2.2.1 Protection without cut off of supply

This protection is effected :

- by using Very Low Voltage (VLV) ;
- through the electrical separation of the circuits ;
- by using class II type equipment ;
- through additional insulation of the installation ;
- through the removal or interposing of obstacles ;
- through equipotential connections not linked to the earth.

1.2.2.2 Protection through automatic cut-off of supply

Protection through the automatic cut-off of supply becomes necessary when the preceding protective measures are, in practice, only local.

It only effectively occurs subject to two conditions :

1. all the grounds and all the conductive elements which are accessible must be interconnected and linked to the earth.
   Two simultaneously accessible grounds must be linked to one <u>and the same</u> earth connection.
2. (when the first condition is apparent) the cut-off must be effected by automatically switching off the element in the installation where the insulation fault has occurred, so as not to subject a person to a U_C contact voltage over dangerous length of time.

   For example, French standard NF C 15-100 sets the cut-off time at 0.17 s for U_C = 230 V under normal conditions and 0.05 s under wet conditions.

1.2.3 Protection against direct contact

Direct contact is when a person (or domestic or farm animal) enters into contact with live elements.

The live elements may be live conductors, the coils of a motor or a transformer or the tracks of a printed circuit.

The current may flow :

- either from one live conductor to another via the human body - under these circumstances, the person must be considered as a single-phase load ;
- or from an live conductor to the earth and then the source, via the human body - under these circumstances, the person must be considered as an insulation fault.

The feature of a direct contact is the absence or non-influence of a protective conductor in the analysis of protection against direct contact to be implemented.

Regardless of the neutral system, with direct contact, the current returning to the source is the one passing through the human body.

There are several types of measures which can be implemented to protect persons against direct contact. (cf. French standard NF C 15-100).

1.2.3.1 Provision rendering direct contact not dangerous

The use of Very Low Voltage (VLV), restricted to 25 V, is the only applicable provision.

It has the disadvantage of imposing operating restrictions and can only convey low power levels.

1.2.3.2 Implementation of preventive measures

These preventive measures are intended to put live elements out of reach by :

- insulating the live elements : insulating casing for equipment, insulating the exterior of the conductor ;
- the provision of barriers or casing : boxes or cases with a minimum protection grade of IP2x or IP xxB ;
- removal in order to put out of reach : partial protection used principally on electrical service sites.

However, in spite of the implementation of the preceding provisions, some installations or the environment around the installations, may comprise specific hazards : insulation which may be defective (conductive fence, use of equipment in poor condition, DIY (makeshift work), etc.), protective conductor absence or cut off., etc.

It is necessary here to define additional protection.

This additional protection comprises highly sensitive differential-residual current devices ***($I_{\Delta n} \leq 30$ mA)*** *which ensure the protection of persons by detecting and cutting off the fault current when it occurs.*

1.3 Protection of property

1.3.1 Protection against the effects of lightning - general aspects

1.3.1.1 Fundamental rules and principles[1]

Lightning acts in two different ways depending upon whether it strikes a structure directly or indirectly.

We can therefore distinguish the following :

- direct strikes which create mechanical damage and also generate a build up in potential throughout the structures hit and around the point of impact ;
- indirect strikes which are at the source of localised overvoltage and which may cause remote destruction through the various channels of propagation (air, ground, conductors.).

NOTE. - Overvoltage may be created by resistance or inductive coupling.

◊ Resistance coupling : the lightning strikes the ground near the installation and part of the lightning current is injected into the grid of the installation through the earthing of the latter.

◊ Inductive coupling : the lightning strikes the ground near the installation and causes overvoltage induced into the conductors through magnetic coupling.

The electromagnetic effects created may have a serious impact on the structures and equipment installed therein.

These various attacks on the systems may spread in 3 fundamental ways : through conduction, radiation and coupling.

For each of these modes of propagation a series of protective measures should thus be envisaged (suitable rules and measures) in order to limit their effects to levels imposed by the safety of persons, the quality of equipment operations and the costs.

[1] REE n° 4 (April 1996). Lightning protection for ground installations, methods of implementation. Michel BAUCHET

The designing of a protection system against the effects of lightning must respect three fundamental rules.

- The uniqueness and equipotential nature of the earth grid

  This rule is required to limit the differences in potential at the various points on a site.

  It is applied by :

  ◊ interconnecting all the local earth grids,

  ◊ connecting to the earth, over the shortest distance, at the entry point of each building, all the conductive pipes and conductors (power, telecommunications) entering therein and, in particular, the cable screens.

- The uniqueness and equipotential nature of the ground grid.

  This ground grid must be interconnected with the earth grid.

  This rule is applied by :

  ◊ the creation of a ground grid layout in all directions, through the systematic interconnection of all the structure's metallic elements,

  ◊ the grounding of metallic casing, frames and structures,

  ◊ the use of cable routing to power and interconnect equipment,

  ◊ the connection to the mass grid of screened cables at both their ends.

- The systematic reduction of all the ground loops and the multiplying of interconnections between grounds.

1.3.1.2 Implementation of protective measures

The development of a protection system will entail the installation of the following two systems[2].

- An external installation for the protection of structures against direct strikes from lightning.

  This installation is intended to direct the flow of the lightning current to the earth. It shall comprise :

  ◊ one or several collector devices positioned high up (Franklin rods, extended wires, etc.) ;

  ◊ descending conductors comprising a sufficient number of fittings, inspection joints for gauging at the base and mechanical protection below these joints ;

  ◊ interconnected earth connections (preferably triangular crossbracing in type).

- The installation of protective devices against overvoltage.

  These devices are positioned on the various links between the structures and their environment (principally power grids and information transmission cables).

  This protection may comprise one or several devices (lightning arresters) installed as closely as possible to the buildings and equipment to be protected.

1.3.2 Protection against the effects of lightning in REN-based installations

The practical development of protective systems depends upon the nature of the structures to be protected.

For the electrification of isolated sites, the principal considerations are wind generators, photovoltaic (PV) (solar) panels and overhead transmission line grids.

In relation to the keraunic level (thunderstorm potential) of the sites concerned, the protection of buildings should be envisaged.

[2] International standard IEC 1024-1 (1990). Protection of structures against lightning. Part one: general principles.

1.3.2.1 Principle

The principle adopted comprises :

- the systematic, at minimum, interconnection of the grounds,
- deciding, should the case arise, to adopt specific additional measures by applying the decision criteria taking into account the value of the materials to be protected, their sensitivity, the need for their availability and the risk of the structures being struck by lightning,
- in the case of additional protection having to be installed, the measures which must be adopted.

  These measures and the related costs are listed in table 2.

1.3.2.2 Interconnection of grounds

Standards applicable

IEC 1000-5-1 : 1997, Guide to installation and current attenuation. Section 1 : General considerations ;

IEC 1000-5-2 : 1997, Guide to installation and current attenuation Section 2 : Earthing and cabling

The wind generator and panel frames must be earthed through an earth connection in the form of a triangular crossbrace and with a value under 10 Ω at 50 Hz.

These earth connections must be linked to the earth connections of the equipment site housing the other installation equipment.

In general, with LV installations, other than photovoltaic installations, lightning protection has rarely been provided for at the design stage.

In this case, two earth connections coexist in terms of the building. There is one earth connection effected by the installer at the beginning, to which the grounds are connected and one “lightning” earth connection in the form of a crossbrace with a resistance under 10 Ω.

These earth connections are then themselves connected.

In the building, the grounds of electrical equipment are still connected to the electrical protection conductor PE.

Table 2 : Lightning protection and costs

Lightning case type	Recommended measures	Cost of solution (*)
Direct strike on the mast or blades (if metallic) of the wind generator	installation of a lightning conductor and protection using lightning arresters in terms of the wind generator	20 to 30 kF F
Direct strikes on PV array frames	installation of a guard wire and lightning arrester under direct current (no guard wire if the PV array is in the collector cone of a wind generator)	to be specified
Lightning striking the ground close to the wind generator - installation connection	additional lightning arrester at the entry point of the charger	3 kF F
Lightning striking the ground close to the PV array - installation connection.	on each cable, the installation of additional lightning arresters (LA) at the control entry point : - 1 LA between + and - - 1 LA between + and earth - 1 LA between - and earth	2 kF F / lightning arrester
Protection of production installation against overvoltage from lightning spreading from the micro-grid	if sine inverter : panel lightning arrester on distribution panel otherwise lightning arrester with internal spark gap	500 FF 800 FF
Protection of user equipment against overvoltage from lightning spreading from the micro-grid	if sine inverter : panel lightning arrester on user panel or individual protected points otherwise lightning arrester with internal spark gap	500 FF / item 300 FF / point 800 FF / item
(*) the costs comprises supply and installation		

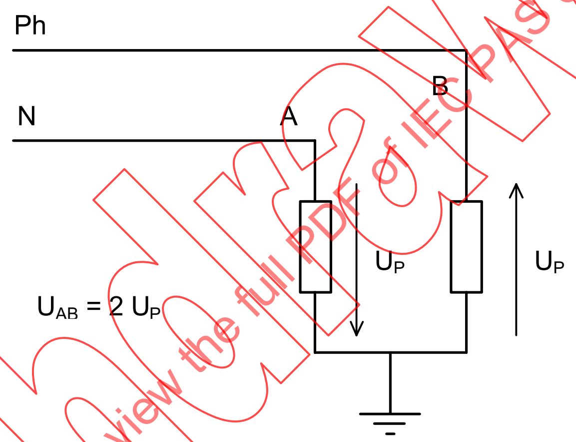
The grounds of metallic structures (wind generator, PV array frame, equipment site, water grid, telephone grid, gas grid.) must be earthed and linked to the earth connection on the equipment site.

1.3.2.3 Definition parameters for lightning arresters

The significant parameters in the definition of lightning arresters are as follows :

- U_P = level of protection for nominal current (see figure 3) ;
- U_C = permanent operating voltage which must be chosen equal at least to over 10% of the grid voltage (between phase and PE or PEN) and which is normally 1.5 times the grid voltage (example for U_C = 400 V, U_P = 1.5 kV). Under the neutral system TT, a differential current protection must be added ;
  - $I_{nominal}$ (on 8/20 wave) - Standardised values : 20 kA, 10 kA, 5 kA, (2.5 kA, 2 kA, 1.5 kA but very rare) ;
  - Imax (on 8/20 wave). Characterises the power performance of the lightning arrester.

Figure 3



(terre plus mauvaise que celle du réseau)

The use of lightning arresters poses problems in the event of the presence of harmonics, i.e. in the event of the use of non sine inverters (U_C being low, the lightning arrester wears down prematurely in the case of the presence of level 3 and 5 harmonics).

The solution consists of using lightning arresters in series with internal spark gaps (SiC or ZnO + spark gaps). Price = 800 F.

1.3.2.4 Protection of the installation against lightning striking the mast of the wind generator directly

1.3.2.4.1 Standards applicable

NF C 17-100 : 1987, Protection against lightning - Lightning conductor installations : Rules ;

NF C 17-102 : 1995, Protection against lightning - Protection of structures and exposed zones against lightning using lightning conductor with disruptive discharge device ;

IEC 1024-1 : 1990 ;

IEC 1024-1-2.

Publications NF C 17-100 and 17-102 provide the decision criteria for installing protection through lightning conductors.

Publication IEC 1024-1, article 3.2, enables the calculation of the safety distance ensuring complete isolation between the earth descent of a lightning conductor and the live conductors of the wind generator.

Publication IEC 1024-1-2 enables an estimate of the overvoltage evident at a given point (between the mast and the electrical circuit of the wind generator) and, should the need arise, whether or not to position a protective lightning conductor at this point.

1.3.2.4.2 Principle of protection adopted

The application of standards NF C 17-100 and 17-102 means that it can be decided whether or not it is worth protecting the installation below the wind generator through the installation of a lightning conductor at the top of the latter, taking into account the data relating to :

- the lightning potential of the site ;
- its geographical location ;
- the collector surface of the generator mast ;
- the price of the equipment to be protected.

If the installation of a lightning conductor is necessary[3] (cost 10 to 20,000 FF), it must be installed at the top of the mast.

Publication IEC 1024-1 enables the determining of the safety distance k_s whereby the earth descent is totally isolated from the live conductors. In the case of a wind generator, it is probable that this distance will never guarantee satisfactory isolation.

It is thus necessary to make additional provisions.

If the alternative electrical circuit is in TN-C system (neutral to earth, grounds to PEN), it will be necessary :

- to connect the neutral to the lightning conductor's earth descent at two points : at the bottom of the mast and at the top (in terms of the wind generator) ;
- to install a three-phase 20 kA lightning arrester at the bottom of the mast between each phase and the neutral ;
- possibly to install a three-phase 20 kA lightning arrester in terms of the wind generator connecting each phase to the earth descent.

  The decision criteria for installing this lightning arrester can be obtained by applying publication IEC 1024-1-2 to calculate the overvoltage which may appear at this point. It must be checked as to whether or not this is compatible with the isolation of the circuit.

If the alternative electrical circuit is in TT system (neutral to earth, grounds to earth), it will be necessary :

- to install a three-phase 20 kA lightning arrester at the bottom of the mast connecting each phase and the earth,
- to install a single-phase lightning arrester at the bottom of the mast connecting the neutral and the earth,
- possibly, to install a three-phase 20 kA lightning arrester in terms of the wind generator connecting each phase to the earth descent and a single-phase 20 kA lightning arrester connecting the neutral to the earth descent.

  The decision criteria for installing this lightning arrester can be obtained by applying publication IEC 1024-1-2 to calculate the overvoltage which may appear at this point. It should be checked as to whether or not this is compatible with the isolation of the circuit.

[3] It is not usual to fit small machines with lightning conductors even if they are not supplied with a rudder (naturally free-moving orientable wind generator) or if the rudder is lower than the blades.
There has never been any known deterioration subsequent to possible lightning striking the structures of these wind generators.
The problem is different for large machines with controlled orientation where the blades may be fitted with metallic conductors for this purpose.
As a general rule, lightning is not a concern for the mechanics and the structures and rarely for the electro-mechanics. The problems concern the electronics where applicable.

1.3.2.4.3 Cost of protection

The cost of protection is shown in table 3.

Table 3 : Cost of protection

Neutral system	Protection components	Cost of components	TOTAL
TN-C	lightning conductor 1 three-phase LA 1 three-phase LA (possible) neutral-mast connection	20 to 30,000 F 3,000 FF 3,000 F	26 to 36,000 FF
TT	lightning conductor 1 three-phase LA 1 single-phase LA 1 possible three-phase LA 1 possible single-phase LA	20 to 30,000 FF 4,000 FF 2,500 FF 4,000 FF 2,500 FF	33 to 43,000 F

1.3.2.5 Protection of the installation against lightning striking the support of PV array frame

In the event of there being both production from PV array and a wind generator, it is sufficient to position the PV array inside the wind generator's collector cone. The modules will then be protected against direct strikes from lightning.

In cases where there is only PV production, the array may be protected by adopting the following provisions :

- installation of an extended wire on the frame the collector surface of which protects the panel (see figure 4).
- installation of a direct current lightning arrester at the exit of the modules between the positive and negative polarity of the circuit. There is the possibility of protection between + and earth and between - and earth as an option on certain modules.

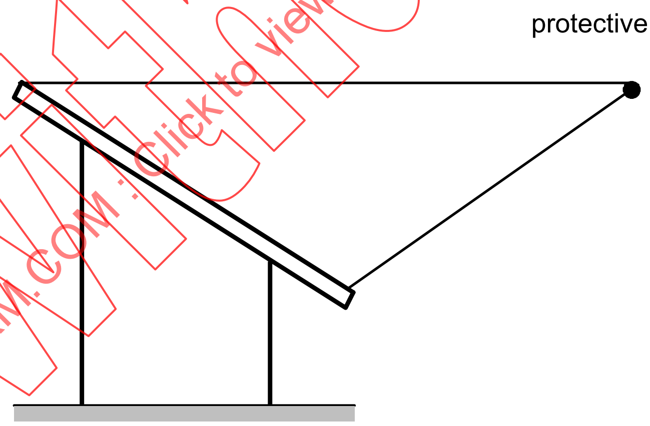


Figure 4 Protection of a photovoltaic array

1.3.2.6 Protection of the installation against lightning near conductors connecting the PV array or wind generator to the installation

1.3.2.6.1 Standards applicable

NF C 17-100 : 1987, Protection against lightning - Lightning conductor installations : Rules ;

NF C 17-102 : 1995, Protection against lightning - Protection of structures and exposed zones against lightning using disruptive discharge lightning conductor ;

UTE C 15-443 : LV electrical installations - Practical guide - Protection of LV electrical installations against overvoltage of atmospheric origin - choice and installation of lightning arresters.

The above standards offer a decision criteria regarding the possibility of protection against overvoltage. They take into account the density of the site's lightning potential, the geographical position of the constructions, the length of the overhead connection (where applicable), the value of the equipment to be protected, its sensitivity and the importance of its availability.

1.3.2.6.2 Equipment site - wind generator connection

If this connection has to be protected, the following provisions shall be implemented :

- if the alternating grid is subject to TT neutral mode this requires :
    - ◊ a three-phase lightning arrester between phases and earth on either side of the connection, i.e. one LA in terms of the wind generator (protection already provided for in the case of lightning striking the mast directly and one LA at the entry point on the charger. Price = 1,000 FF
    - ◊ a single-phase lightning arrester between neutral and earth on either side of the connection. Provision has already been made for the lightning arrester on the wind generator side for protection against lightning striking directly. Price = 1,500 FF.
- the alternating grid is subject to TN-C neutral mode.
    - ◊ a three-phase lightning arrester between phases and neutral on both sides of the connection, i.e. one LA in terms of the wind generator (protection already provided for in the event of lightning striking the mast directly and one LA at the entry point on the charger). Price = 1,000 FF

1.3.2.6.3 PV array - equipment site connection

If this connection has to be protected, the following provision shall be implemented :

a direct current lightning arrester is required on both sides, i.e. at the exit point from the modules and the entry point on the control unit. Provision has already been made for the lightning arrester at the exit point on the modules for protection against direct strikes from lightning.

1.3.2.7 Protection of the installation and user equipment against lightning striking the micro-grid (direct strikes or through coupling)

1.3.2.7.1 Standards applicable

The standards below offer a decision criteria regarding the opportunity for protection against overvoltage.

NF C 17-100 : 1987, Protection against lightning - Lightning conductor installations : Rules ;

NF C 17-102 : 1995, Protection against lightning - Protection of structures and exposed zones against lightning using a disruptive discharge lightning conductor ;

UTE 15-443 : LV electrical installations - Practical guide - Protection of LV electrical installations against overvoltage of atmospheric origin -choice and installation of lighting arresters.

They take into account the density of the site's lightning potential, the geographical position of the constructions, the length of the overhead connections (where applicable), the value of the equipment to be protected, its sensitivity and the importance of its availability.

1.3.2.7.2 Principle of protection

If applying the standards leads to deciding to adopt protection, the following provisions shall be implemented :

- installation of a panel lightning arrester (500 FF) in terms of the production installation distribution panel ;
- installation of a panel lightning arrester (500 FF / user item) in terms of the user equipment entry panel or the equipment with individual protected points (300 FF / point).

1.3.3 Protection against overcharge

Overcharge is usually a low overcurrent mostly due to an excessive number of circuits on one distribution subsystem or too many items of equipment on one user subsystem, powered simultaneously.

Protection against overcharge is ensured through fuses and circuit breakers.

The rules on protection against overcharge are summarised below and represented on the system figure 5.

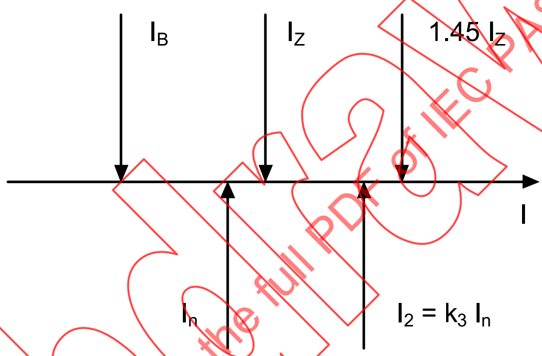


Figure 5 : rules on protection against overcharge

Where :

I_B : circuit operating current

I_n : assigned current[4] on protective device

I_Z : acceptable current in circuit conductors

k_3 : relationship of the traditional operating current[5] to its assigned current, divided by 1.45.

In practice : k_3 = 1.31 for fuses with assigned current $I_n \leq 10$ A,

k_3 = 1.21 for fuses with assigned current 10 A < $I_n \leq 25$ A,

k_3 = 1.10 for fuses with assigned current $I_n > 25$ A,

For a circuit breaker k_3 = 1.

The assigned or control current I_n of the protective device must satisfy the following two conditions :

- it must be at minimum equal to the operating current I_B of the circuit which it is protecting ;
- it must not be in excess of the acceptable current I_Z in the circuit conductors, the latter being affected by a coefficient which takes into account the nature of the protective device and the correction factors which may be necessary.

[4] The assigned current is the current by which the heating conditions and melting characteristics are determined.
[5] The traditional operating current (or melting factor) for a fuse is the current ensuring the fusion of a fuse within a maximum time equal to the traditional time which is generally one hour.

These two rules are summarised in table 4.

Table 4

Protection using fuses	**Protection using circuit breakers**
$I_n \geq I_B$	$I_n \geq I_B$
$I_n \leq I_Z \dfrac{f}{k_3}$	$I_n \leq I_Z f$

In practice, the assigned current of the protective device (fuse or circuit breaker) is chosen according to the first rule ($I_n \geq I_B$), whilst the second rule determines the cross-section of the circuit conductors.

1.3.4 Protection against short-circuiting

A short-circuit is an overcurrent which can reach a highly significant level and which is due to faults between conductors of different polarities.

Protection against short-circuiting is ensured by fuses and circuit breakers.

The rules of protection against short-circuiting are as follows :

- the cut-off power of the protective device must at minimum be equal to the assumed short-circuit current at the point of its installation ;
- the operating time of the protective device must be compatible with the thermal restrictions of the circuit conductors it is protecting.

Regardless of the nature of the protective device, these two rules are reflected in the following equations :

$$I_{PC} \geq I_{CC\ max} \quad \text{and} \quad t \leq \frac{(I^2 t)}{I^2_{CC\,min}}$$

Where :

I_{PC} : maximum current which can be cut off by the protective device (cut-off power) ;

$I_{CC\ max}$: maximum short-circuit current and the installation point of the protective device ;

t : total operating time of the protective device ;

(I^2 t) : acceptable thermal restriction of circuit conductors ;

This restriction, which depends on the nature of the conductors and their insulation, is usually indicated by the manufacturers.

$I_{CC\ min}$: minimum short-circuit current in the protected circuit, generally the single-phase short-circuit current at the end of the line.

The second condition (thermal risk of conductors) is automatically satisfied when the protective device ensures both protection against overcharges and protection against short-circuiting and it is not necessary to check it.

On the other hand, the checking of the thermal restrictions of conductors is necessary in the following cases :

- the protective device against overcharges is not installed at the beginning of the circuit it is protecting ;
- the neutral conductor or the protection conductor (PE) has a smaller cross-section than that of the phase conductors ; however, if this cross-section is not under half that of the phase conductors, this checking is not required.

The checking of thermal restrictions varies according to whether the protective device is a fuse or a circuit breaker.

The methods are described in the standards (cf. NF C 15-100 § 434.3.2, § 533.1, § 543.1) or the manufacturers' documents.

1.4 Types of system earthing (neutral systems) specified

Under alternating current, the expression "neutral system" depicts the situation of an electrical installation in relation to the earth potential. Given that this situation only concerns neutral, the standards use the expression "earth connection layouts [6].

The configuration of the earth connection layouts determines a certain number of conditions concerning the design, installation and running of the electrical installations.

Although the study of earth connection layouts relates to both Low Voltage (LV) and High Voltage (HV), we are only detailing the LV earth connection layouts (50 V < $U_n \leq 1000$ V).

By extension, these layouts can be transposed to the area of Very Low Voltage (Un ≤ 50 V).

1.4.1 Definition and classification

According to standard IEC 364, an LV earth connection system is characterised by two parameters ;

- the neutral situation in relation to the earth ;
- the situation of the grounds in the installation (user subsystem).

The system are denoted by a series of two letters corresponding respectively to the situation parameters. For each parameter, the possible situations are symbolised by a letter and illustrated in table 5.[6]

NOTE. - The codes used have the following meanings :

***First letter**. - Relationship of the power system to earth :*

T = *direct connection of one point to earth ;*

I = *all live parts isolated from earth, or one point connected to earth through an impedance.*

***Second letter**. - Relationship of the exposed conductive parts of the installation to earth :*

T = *direct electrical connection of exposed conductive parts to earth, independently of the earthing of any point of the power system ;*

N = *direct electrical connection oft the exposed conductive parts to the earthed point of the power system (in A.C. system, the earthed point is normally the neutral point).*

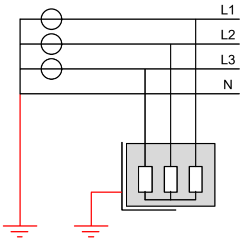
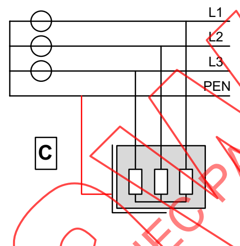
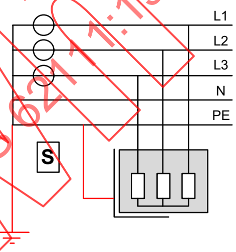
***Subsequent letter**(s) (if any). - Arrangement of neutral and protective conductors :*

S = *neutral and protective functions provided by separate conductors ;*

C = *neutral and protective functions combined in a single conductor (PEN conductor).*

[6] « HV and LV neutral systems » Claude Rémond, J35 Cahier Technique (Technical Specifications) n°20 / June 1995

Table 5 : Earth connections

First letter neutral situation	**T** (Direct earth connection)		
Second letter grounds situation			
T (Earth point connection)			
N (Neutral connection)			

TN-C system : in which neutral and protective functions are combined in a single conductor throughout the system (is called the PEN conductor).

TN-S system : having separate neutral and protective conductors throughout the system (is called the PE conductor).

Taking into account its specific aspects, in particular in terms of monitoring the insulation and resultant protection measures, the IT system is not specified in this document. It has thus not been subject to study.

1.4.2 TT system

In this system, neutral is connected directly to the earth, the neutral conductor is distributed, the grounds of the user subsystem are interconnected and linked to the same earth point using a PE protection conductor.

In the case of an insulation fault, the flow of the fault current is effected according to the figure 6 [7].

The fault loop is comprised by the generator G, the phase conductor, the fault, the PE conductor, the frame earth point on the installation A and the neutral earth point B.

[7] this diagram is strictly transposable with three-phase user subsystems and for a single-phase system.

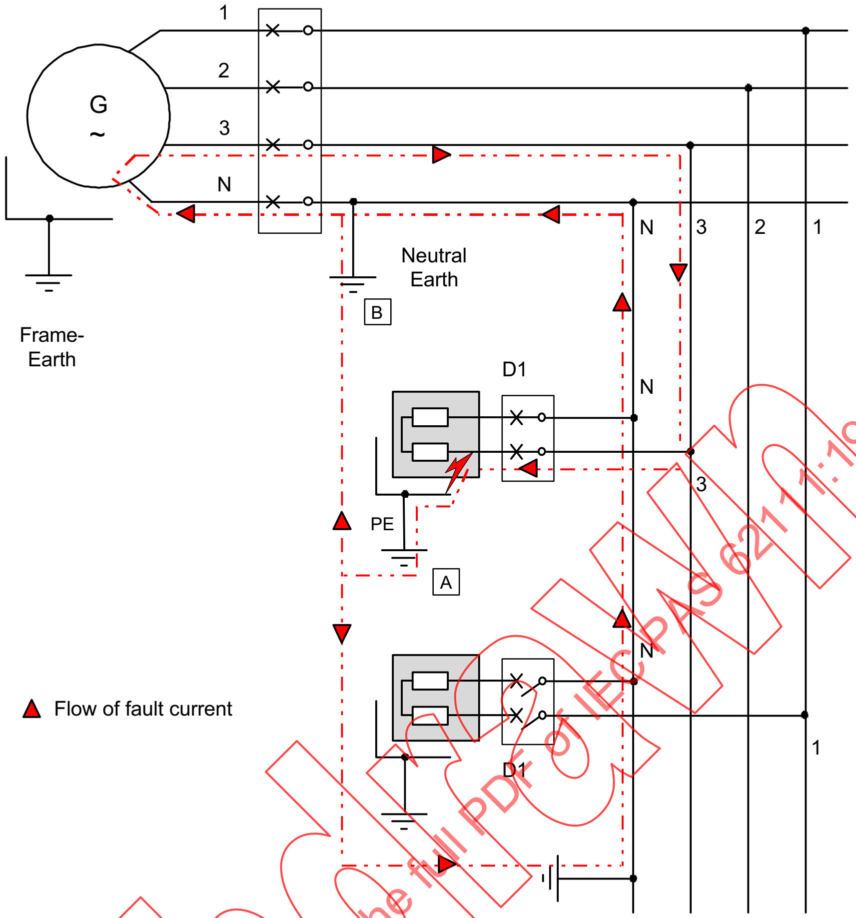


Figure 6 : Insulation fault current in TT system

The strength of the fault current is equal to :

$$I_d = \frac{U_0}{R_A + R_B}$$

with U_0 : nominal main voltage

(the terminal loop is left out using a remote earth)

Taking into account the commonly encountered values of R_A and R_B, the value of this fault current is generally insufficient to be able to ensure the operation of the protective devices for overcurrents.

In order to ensure protection against indirect contact, the cut-off should also be ensured by **differential-residual current protection devices (DR)** (cf. annex 3). The circuit breaker D1 in figure 6 will ensure the best selectivity.

Under certain conditions, cut-off can be ensured using fuses or circuit breakers with a low nominal current, provided that the resistances of the earth connections are low.

In the case of direct contact, the flow of the fault current is effected in accordance with the figure 7.

The fault loop comprises the generator G, the phase conductor, the human body, contact with the earth and the neutral earth connection B.

The strength of the fault current is equal to :

$$I_d = \frac{U_0}{R_A + R_H + R_B}$$

with U_0 : nominal voltage (phase voltage) U_0 = 230 V
R_H : resistance of human body R_H = 1500 Ω
R_A : resistance of the earth at the fault point R_A = 100 Ω
R_B : resistance of the neutral earth connection R_B = 100 Ω (excess values)

we obtain : I_d = 0.135 A.

The resultant contact voltage then exceeds 200 V.

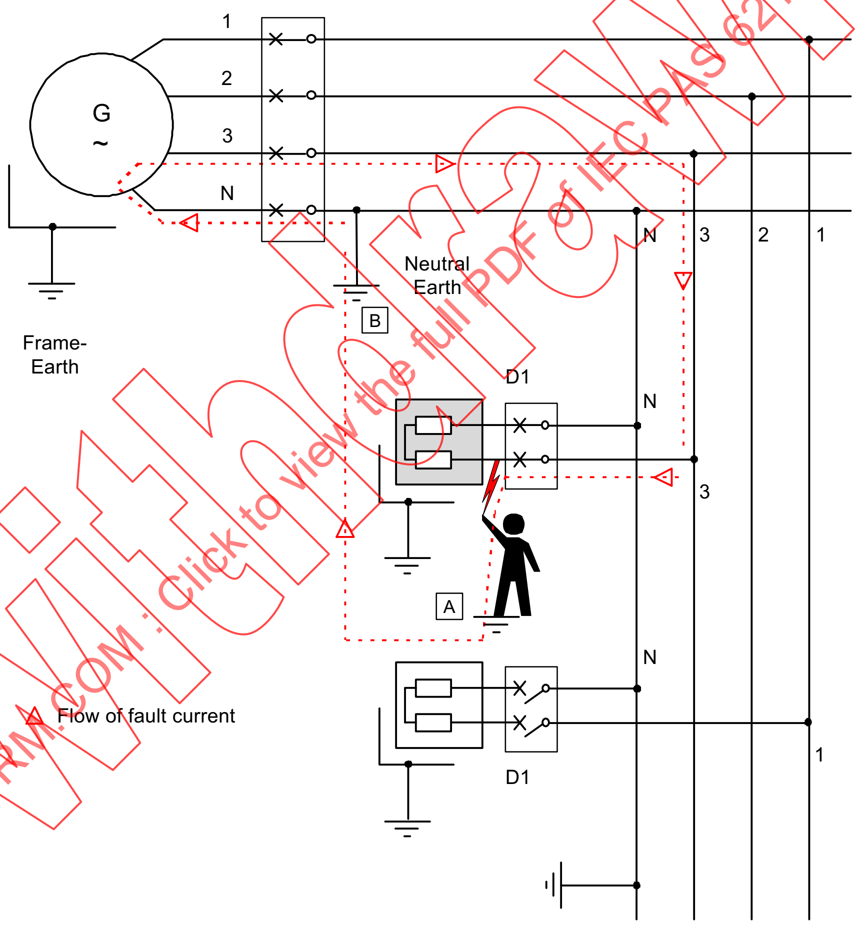


Figure 7 : Direct contact fault current in TT system

When the provisions rendering direct contact non dangerous (use of very low voltage) or the preventive measures intended to put the live elements permanently or safely out of reach (insulation, barriers or casing, removal or obstacles) additional protection must be used.

The same applies when the installations or environmental conditions of the installations present specific hazards (conductive fence, use of equipment in poor condition, etc.).

The additional protection comprises highly sensitive differential-residual current devices ($I_{\Delta n} \leq 30$ mA).

With TT system, there is no specific requirement regarding the continuity of the neutral conductor and the grid extensions can be effected without calculating the lengths of the line.

This system does not require permanent monitoring during operation but the maintenance and inspection of the earth connection are the responsibility of the users.

This is the simplest solution at the design and installation stage.

1.4.3 TN-C system

In this system, the neutral conductor and protection conductor are merged and form the PEN conductor. This conductor may be earthed regularly in the distribution subsystem.

The source neutral and PEN conductor are directly connected to the earth, the user grounds being linked to the PEN conductor.

This system is only acceptable if the distribution subsystem PEN conductor has a minimum cross-section of 10 mm².

The flow of the neutral currents through the conductive elements of the building and grounds may be a source of fires and also of disturbing voltage drops for sensitive equipment in the user subsystem (computers, medical equipment).

In the event of an insulation fault, the fault current is effected in accordance with the figure 8 [8].

The fault loop comprises the generator G, the phase conductor, the fault and the PEN conductor.

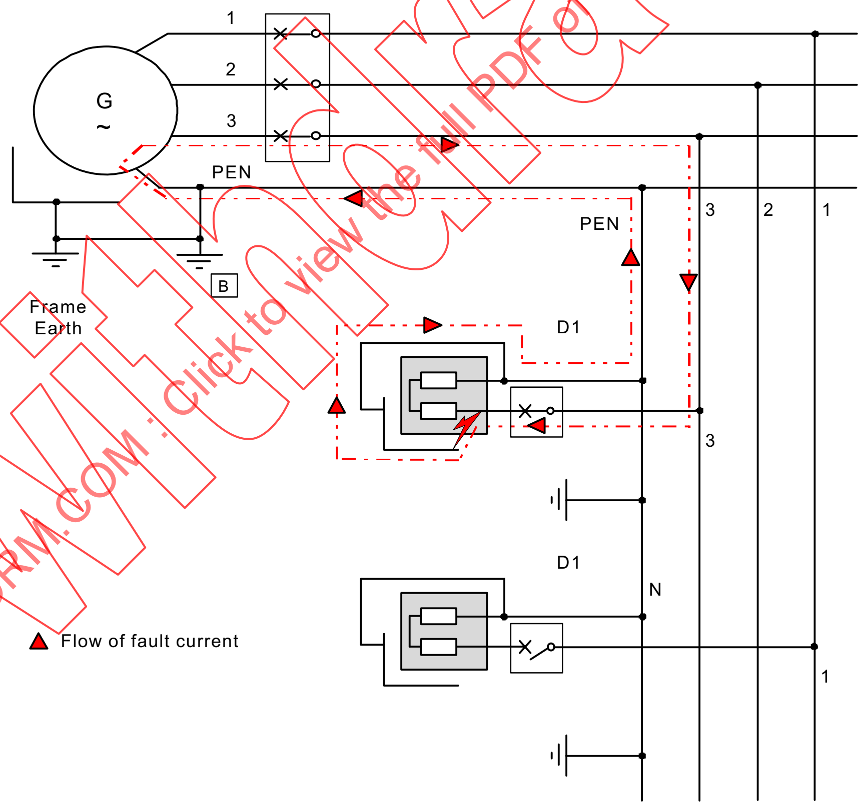


Figure 8 : Insulation fault current in TN-C system

[8] this diagram is strictly transposable with three-phase user subsystems and for a single-phase system.

The strength of the fault current, which is a short-circuit current between phase and neutral, is equal to :

$$I_d = \frac{U_0}{Z_{ph} + Z_{PEN}}$$

where U_0 : phase voltage
Z_{ph} : impedance of the phase conductor
Z_{PEN} : impedance of the conductor PEN

The strength of this fault current may reach extremely significant levels with a increased risk of causing fires and disruption.

It may be sufficient to ensure the operation of the overcurrent protection devices.

If the following is ensured :

- in the case of protection using fuses : $I_d \leq \geq I_t$ (I_t : fuse melting factor in the time specified, for example 0.4 secs for U_0=230 V) ;

in the case of protection using a circuit breaker : $I_d \geq I_m$ (I_m : instantaneous operating current of the circuit breaker)

This layout does not require any other automatic cut-off devices.

The use, however, of this protective device requires checking the release systems which must be carried out :

- at the design stage through calculation ;
- on putting into operation ;
- periodically through gauging (every year) ;
- in the case of the extension or renovation of the distribution subsystem.

Protection using differential-residual current devices may be necessary for circuits of significant length and is always recommended for the protection of persons against indirect contact in terms of the terminal distribution where the loop impedance may not be reduced ; it is thus necessary to go on to TN-S system.

In the case of direct contact, the flow of the fault current may be effected in accordance with the figure 9[9].

The fault loop comprises the generator G, the phase conductor, the human body, contact with the earth connection and the neutral earth connection B. This loop may also be created through a nearby earth connection and the conductor PEN but the human body is still crossed by all the fault current.

As in TT system (see 1.4.2) the strength of this current still reaches levels which are dangerous for human beings.

Moreover, when the provisions rendering direct contact non dangerous (use of very low voltage) or preventive measures intended to put the live elements permanently and safely out of reach (insulation, barriers or casing, removal or obstacles) cannot be implemented, additional protection must be used.

The same is applicable when installations or the environmental conditions of installations present specific hazards (conductive fence, use of equipment in poor conditions, etc.).

Additional protection comprises highly sensitive differential-residual current devices ($I_{\Delta n} \leq 30$ mA).

In general, TN system is the simplest to implement because it does not require an earth connection in the user subsystem.

Moreover, using TN-C system enables the saving of a pole on the equipment and the frame earthing conductor.

NOTE. - It is the distributor's responsibility to ensure the continuity of the conductor PEN without cut-off.

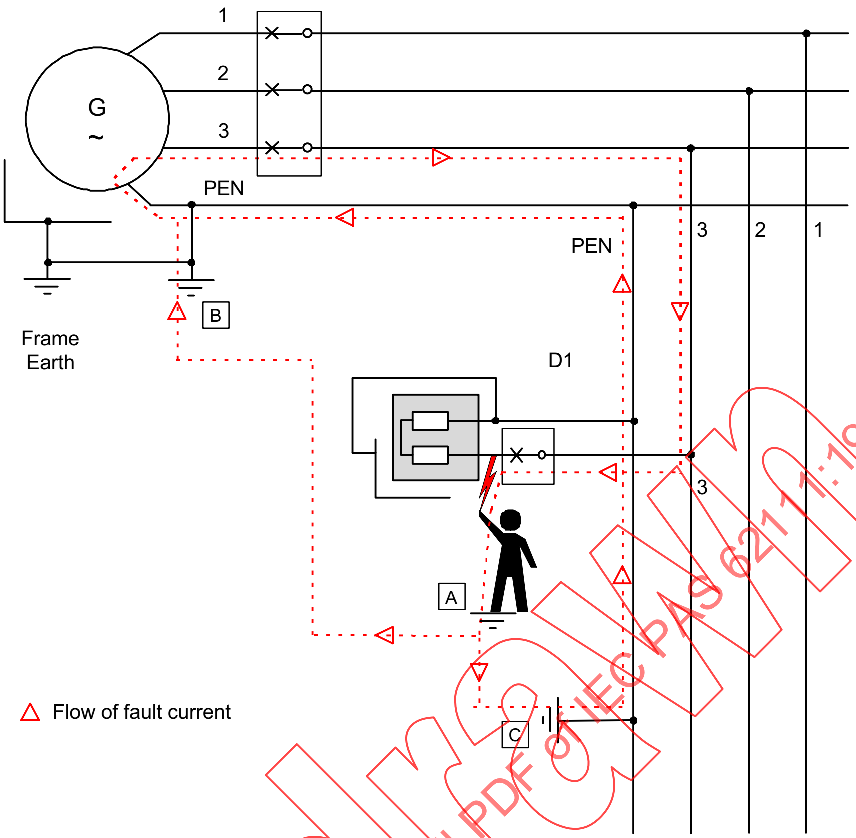


Figure 9 : Direct contact fault current in TN-C system

In TN-C system, the "protection conductor" function has priority over the "neutral" function. A conductor PEN must still therefore be connected to the "earth" terminal of a load and a bridge must be created between this terminal and the neutral terminal.

1.4.4 TN-S system

In this system the neutral conductor N and the protection conductor PE are distributed separately.

The source neutral, the distribution subsystem neutral and the conductor PE are directly connected to the earth and the user grounds are connected to the conductor PE.

There are no restrictions regarding the cross-section of the neutral conductor.

In the case of an insulation fault, the flow of the fault current is effected in accordance with the figure 10 [10].

The fault loop comprises the generator G, the phase conductor, the fault and the conductor PE.[9]

[9] this diagram is strictly transposable with three-phase user subsystems and for a single-phase system.

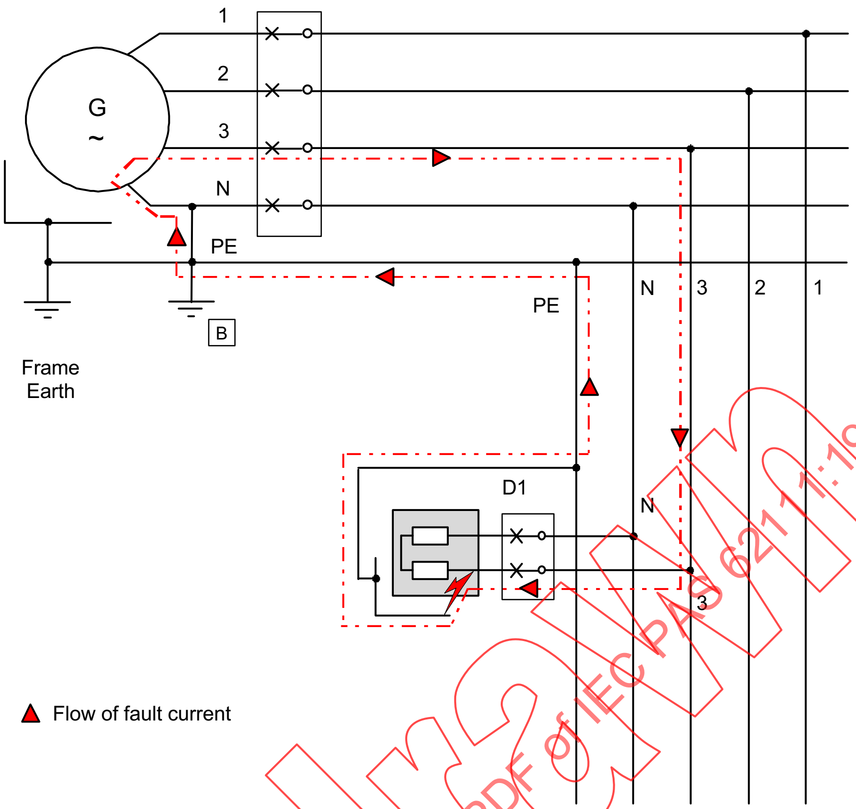


Figure 10 Insulation fault current in TN-S system

The strength of the fault current is equal to :

$$I_d = \frac{U_0}{Z_{ph} + Z_{PE}}$$

where U_0 : phase voltage
Z_{ph} : impedance of the phase conductor
Z_{PE} : impedance of the conductor PE

The strength of this fault current may reach considerable levels and be a significant risk in the cause of fires and disturbances.

It may be sufficient to ensure the operation of the overcurrent protection devices.

By taking the same precautions and imposing the same inspection restrictions as per TN-C system (see 1.4.3), this layout will not require any other automatic cut-off devices.

Given, however, that the loop impedance of the user subsystem circuits cannot be reduced, protection using differential-residual current devices is recommended.

In the case of direct contact, the flow of the fault current is effected in accordance with the figure 11.[10]

[10] this diagram is strictly transposable with three-phase user subsystems and for a single-phase subsystem.

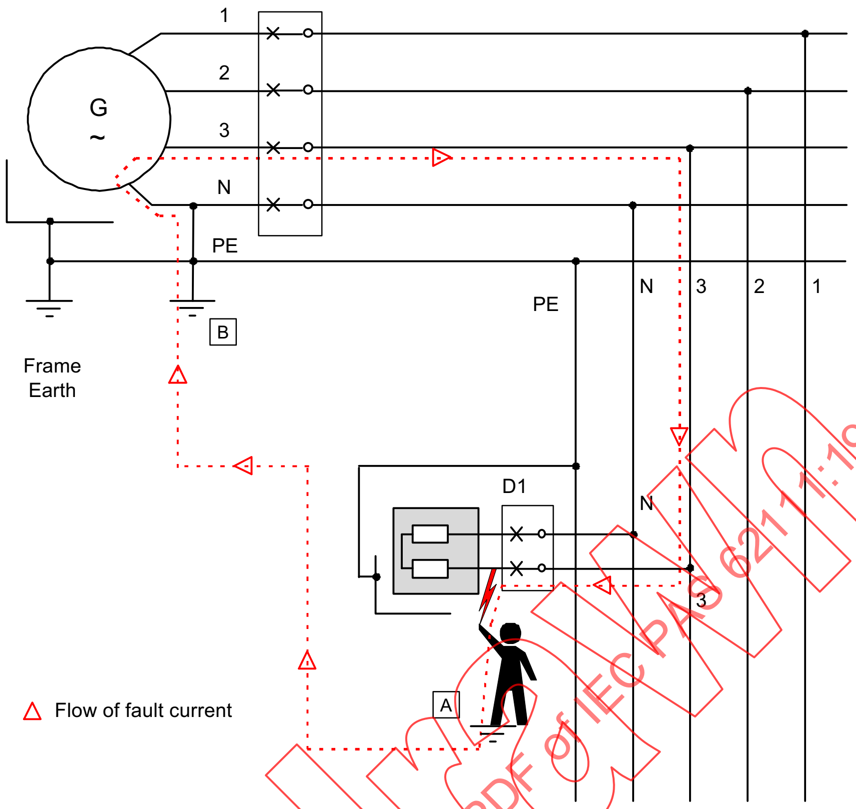


Figure 11 : Fault current under direct contact in TN-S system

The fault loop comprises the generator G, the phase conductor, the human body, contact with the earth and the neutral earth connection B.

As in TT or TN-C system (see 1.4.2 and 1.4.31.4.3) the strength of this current still reaches dangerously high levels for human beings.

Moreover, when provisions rendering direct contact non dangerous (use of very low voltage) or preventive measures intended to put the live elements permanently and safely out of reach (insulation, barriers or casing, removal or obstacles) cannot be implemented, additional protection must be used.

The same applies when installations or the environmental conditions of installations present specific hazards (conductive fence, use of equipment in poor conditions, etc.).

Additional protection comprises highly sensitive differential-residual current devices ($I_{\Delta n} \leq 30$ mA).

TN-S system is obligatory for cables with cross-sections < 10 mm² Cu or < 16 mm² Al and the conductor PE must not be cut off.

1.4.5 Combination of TN-C and TN-S systems

TN-C and TN-S systems may be used in the same installation.

TN-C system must obligatorily be above TN-S system.

An example of the combination of these two layouts appears in figure 12.

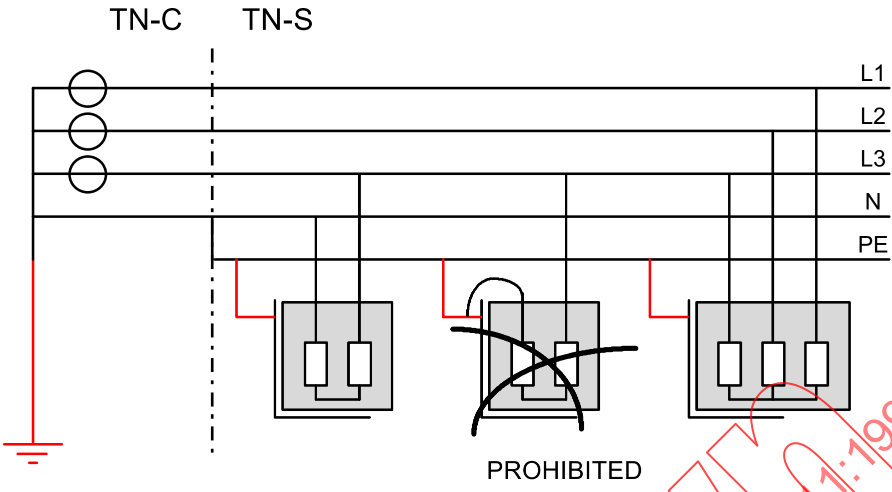


Figure 12 : Combination of TN-C and TN-S systems

1.4.6 Use of a double-coil transformer

With TN-S system, the installation of a double-coil transformer to power a user subsystem may be effected in accordance with the flow chart in figure 13.

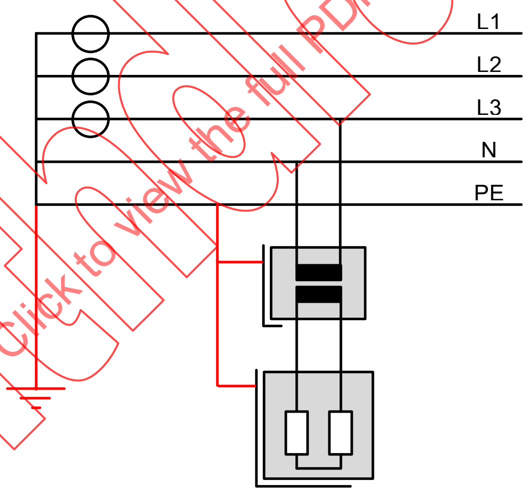


Figure 13 : TN-S system with transformer

NOTE - A subsequent more in-depth analysis of the fault diagrams may enable the possibility of specifying the characteristics and obligations relating to the use of a double-coil transformer.

1.4.7 Summary tables

Table 7 summarises the main characteristics of the components of a system and the restrictions to be observed in relation to the various earth connection layouts.

Table 6 : Summary

Characteristics	TT	TN-C	TN-S	Insulator-type transformer
Cross-section of neutral conductor	any	$\geq$ 10 mm²	any	*Under study*
Protection of neutral conductor	no except where $S_N < S_{ph}$	prohibited	no except where $S_N < S_{ph}$	
Cut-off possible through overcurrent protection devices	no	yes	yes	
Conditions governing the protection of persons against direct contact (at the source of the user subsystem)				
Differential-residual current protection - control	obligatory $I_{\Delta n} \leq \dfrac{50}{R_A}$	prohibited	recommended $I_{\Delta n} \leq \dfrac{50}{R_A}$	*Under study*
Fuses - control	no	yes $I_t \leq I_d$	yes $I_t \leq I_d$	
Circuit breaker - control	no	yes $I_m \leq I_d$	yes $I_m \leq I_d$	
Conditions governing the protection of persons against direct contact (at the source of the user subsystem)				
Highly sensitive differential-residual current protection $I_{\Delta n} \leq 30$ mA	recommended	recommended	recommended	*Under study*

Where :

- S_N : neutral conductor cross-section
- S_{ph} : cross-section of phase conductors
- $I_{\Delta n}$: differential-residual current assigned to protective device
- R_A : resistance of the installation's frame earth connection
- I_d : fault current
- I_t : fuse melting factor in time specified
- I_m : instantaneous operating current of the circuit breaker

Table 8 summarises the number of conductors which have to be protected or cut off in accordance with the neutral system.

Table 7 : Conductors to be protected

system earthing	Single-phase circuits (phase + neutral)		Three-phase circuits (3 phases + neutral)	
	Protected conductors	Cut off conductors	Protected conductors	Cut off conductors
TT	1	1	3 (4)*	3
TN-C	1	1	3	3
TN-S	1	1	3 (4)*	3

(*) An overcurrent detection system on the neutral conductor is required if the cross section of this conductor is less than that of the phase conductors and if the protective device does not ensure the protection of the neutral conductor against thermal restrictions.

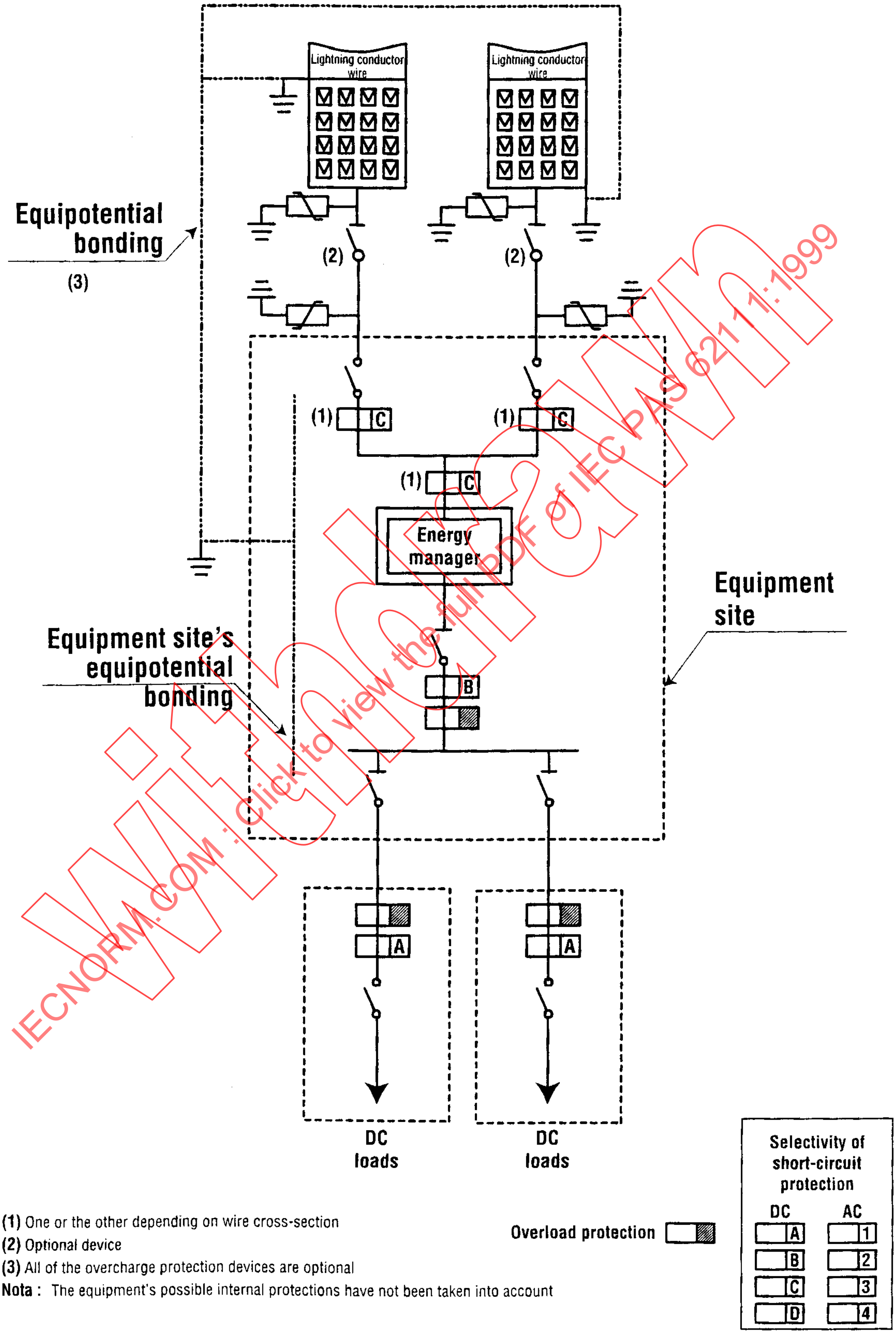
2. Implementation protection according to system

The various systems corresponding to the types defined in the document DRE - B 1 : "Architecture of Electrification Systems", are represented and described on the following pages.

The representation uses a semi-operational diagram where the operating elements correspond to the obligatory minimum requirements for maintenance operations (see document DRE - B 7 : "Guidelines for Operation, Maintenance and Renewal").

The combination of an operating element, as represented, and a protection function may lead both to the definition of a single item of equipment (circuit breaker, for example) and a choice of combination of several different items of equipment (switch + fuses, for example).

Observing all the functions, the solution to be adopted will essentially depend upon the technical and economic criteria to be defined for each installation with the Project Supervisors.



(1) One or the other depending on wire cross-section
(2) Optional device
(3) All of the overcharge protection devices are optional
Nota : The equipment's possible internal protections have not been taken into account

Figure 14 : System type T1$_a$

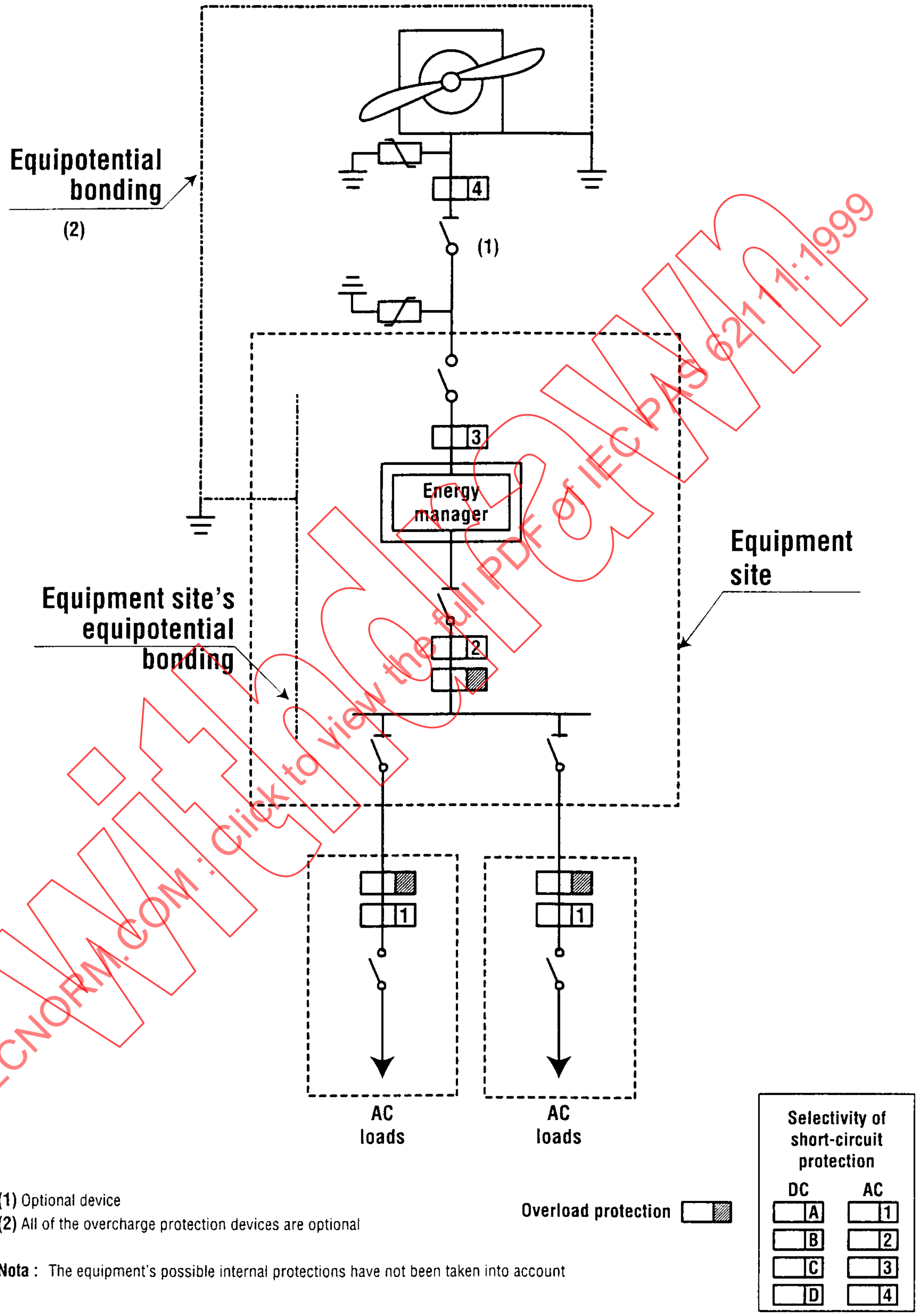
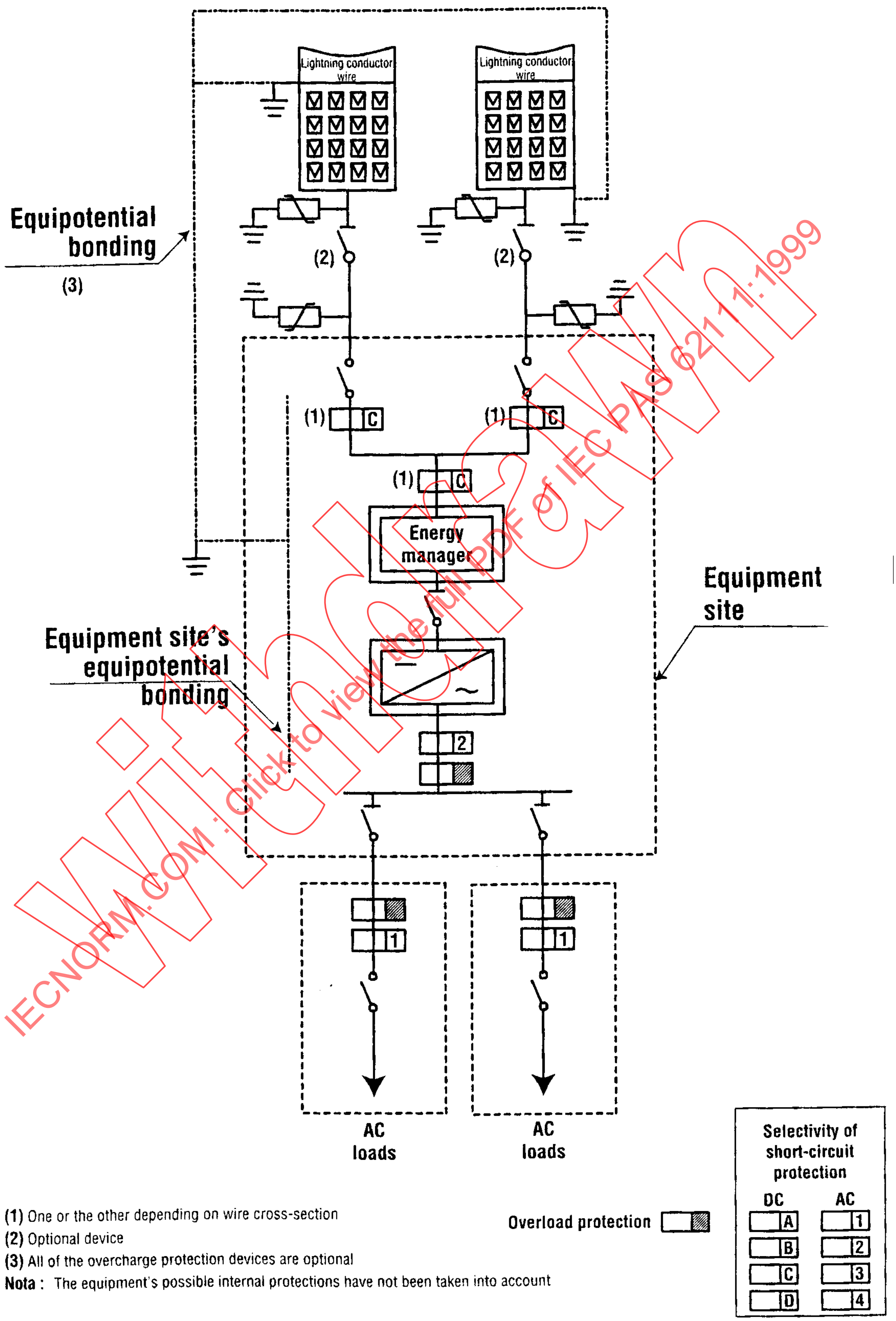
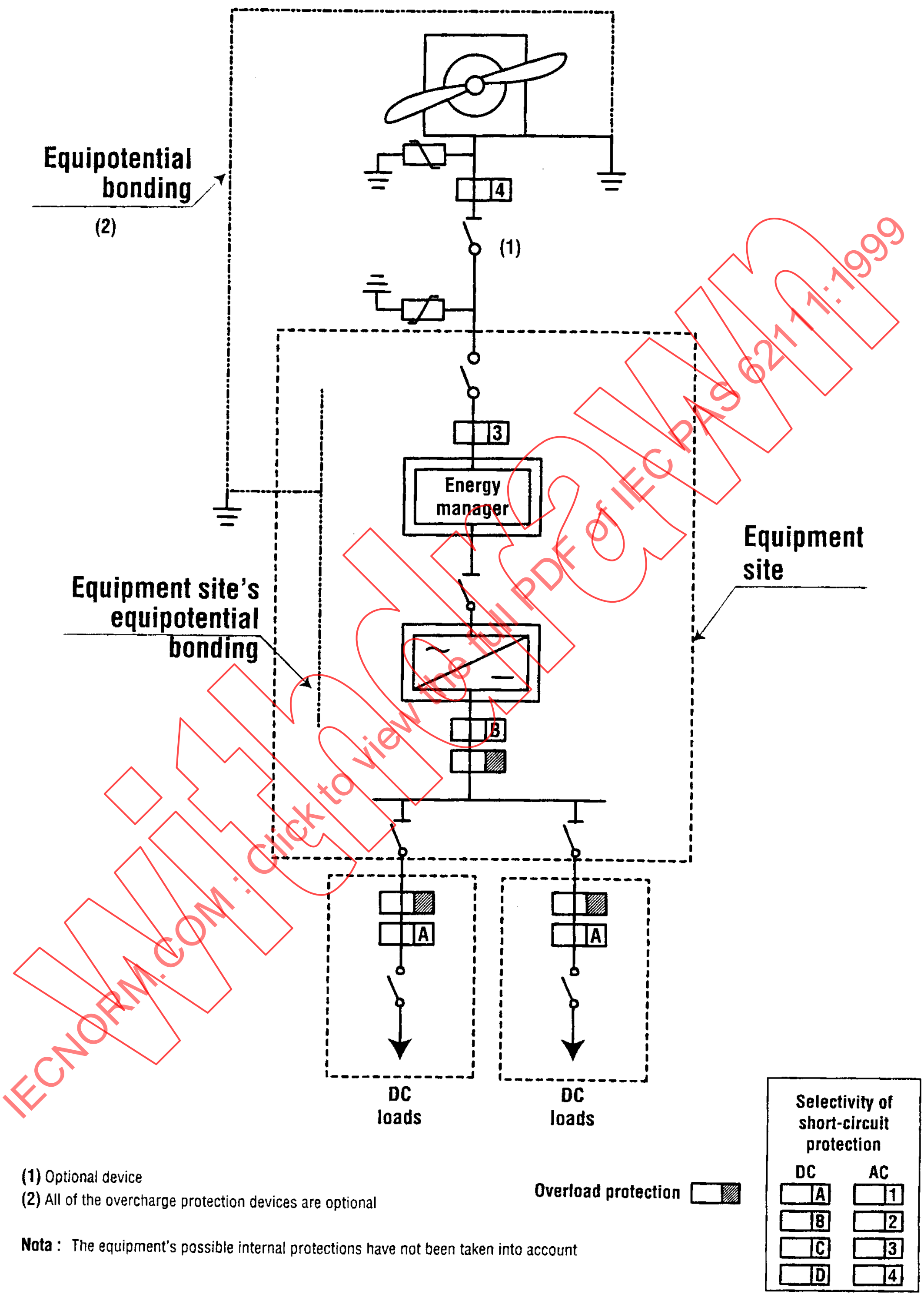


Figure 15 : System type $T1_b$



(1) One or the other depending on wire cross-section
(2) Optional device
(3) All of the overcharge protection devices are optional
Nota : The equipment's possible internal protections have not been taken into account

Figure 16 : System type T1$_c$



(1) Optional device
(2) All of the overcharge protection devices are optional

Nota : The equipment's possible internal protections have not been taken into account

Figure 17 : System type T1$_d$

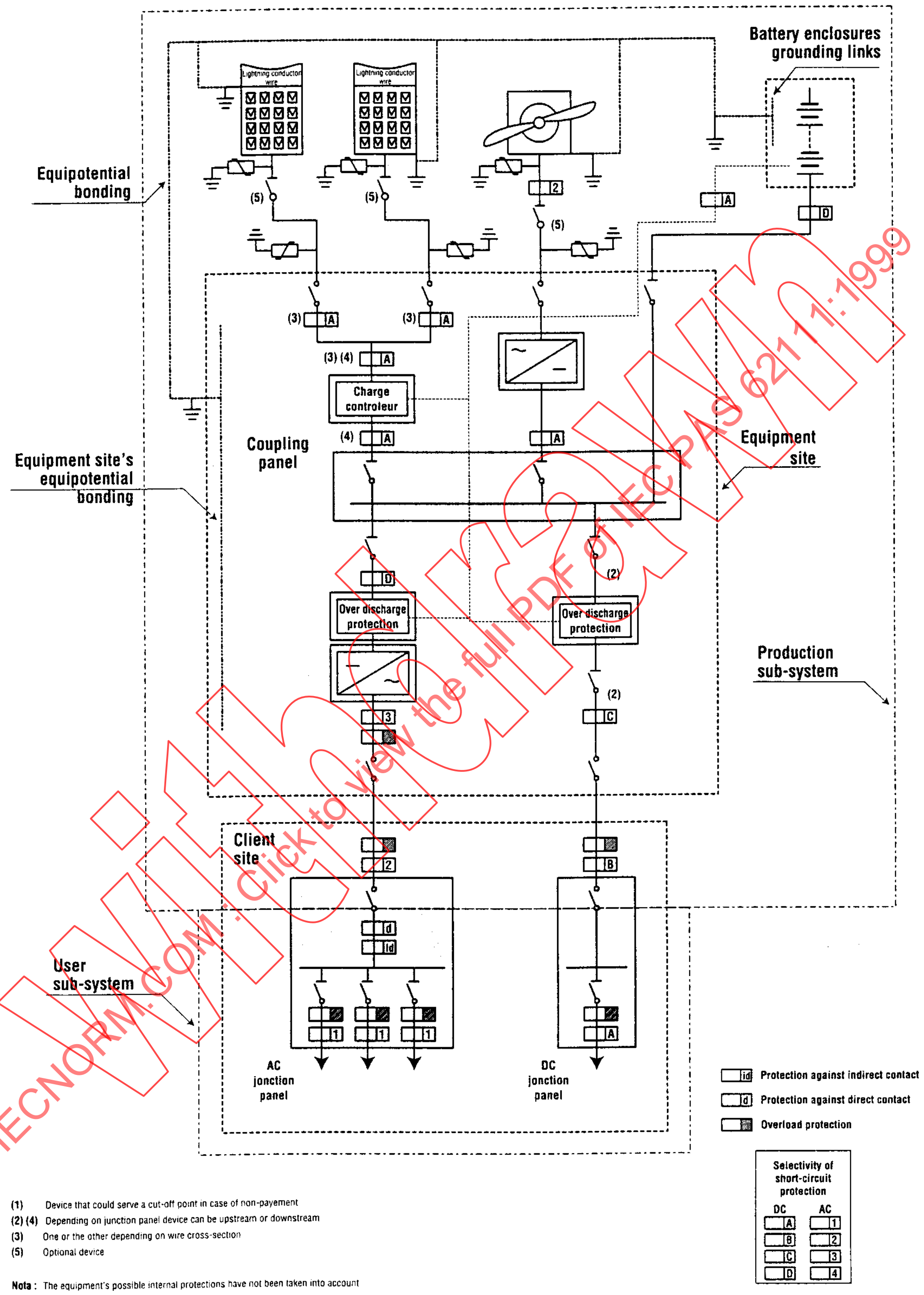


Figure 18 : System type T2

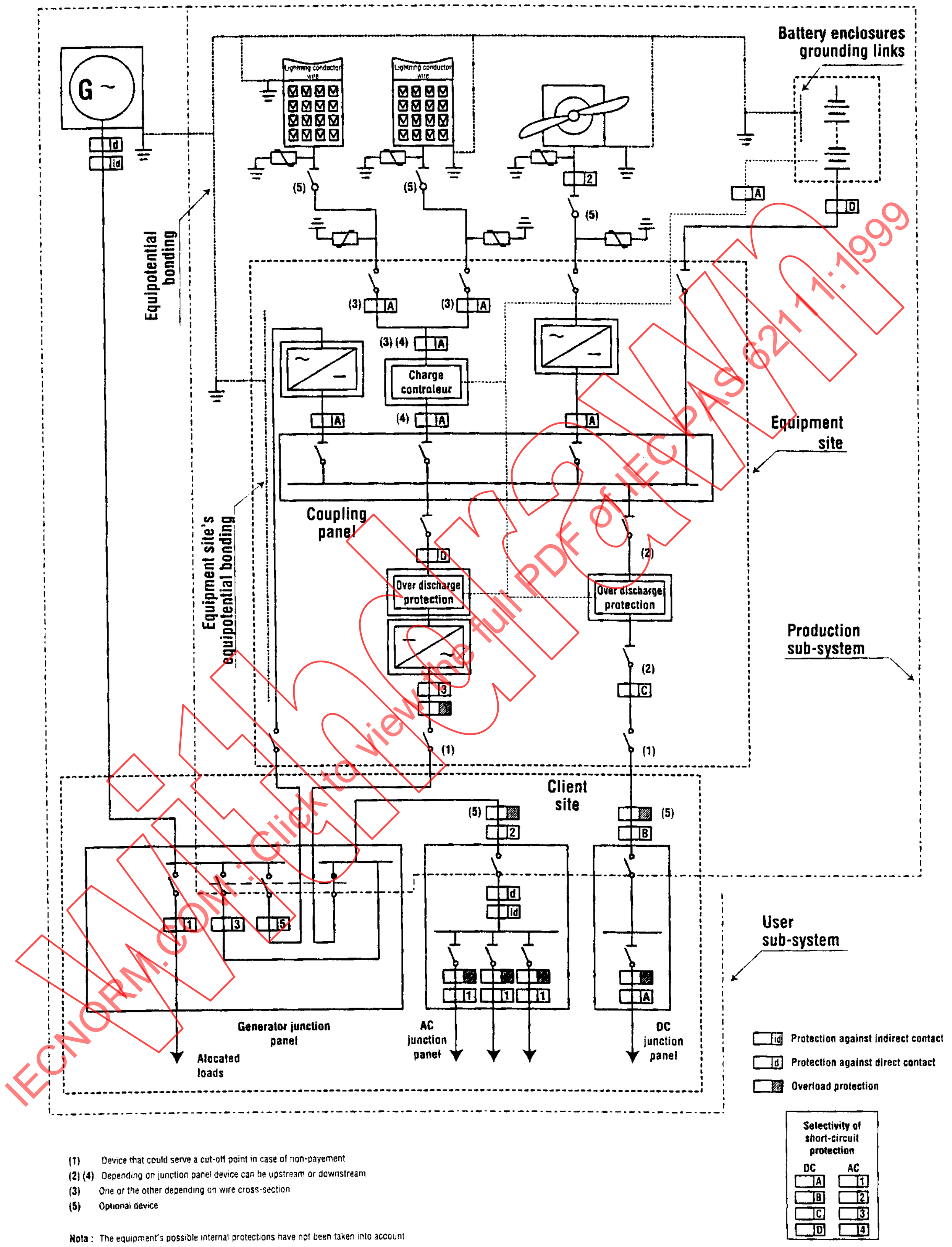


Figure 19 : System type T3

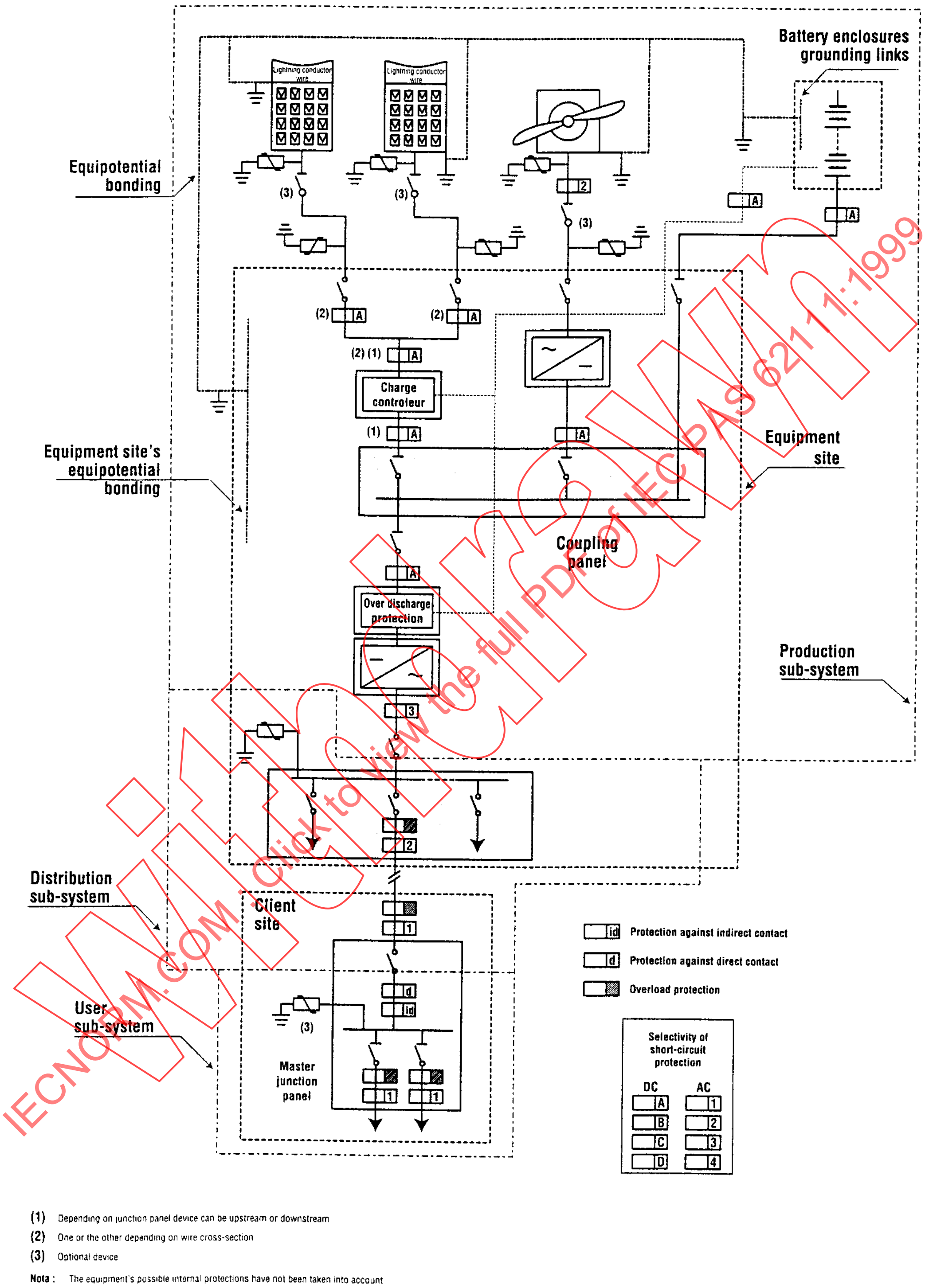
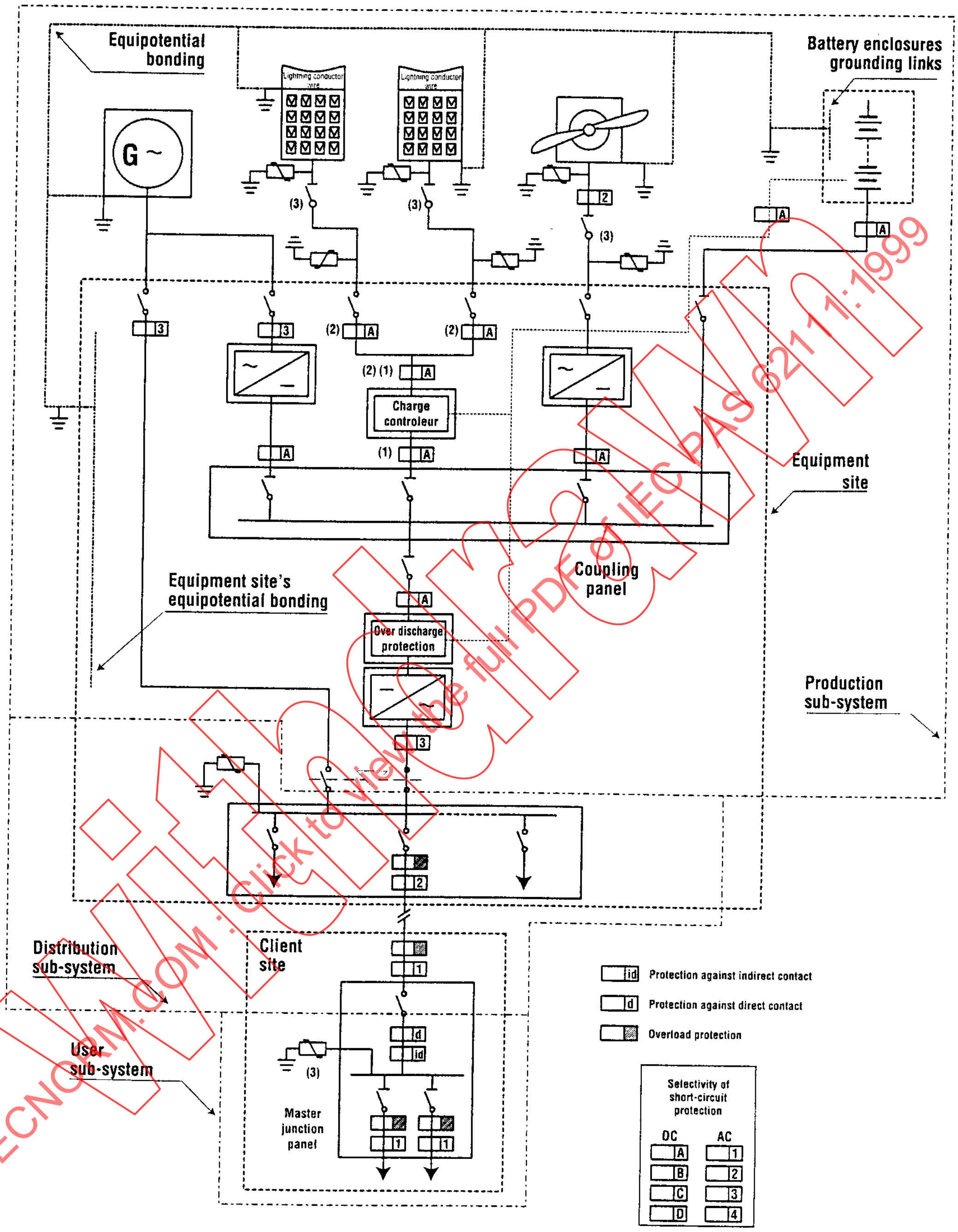


Figure 20 : System type T4



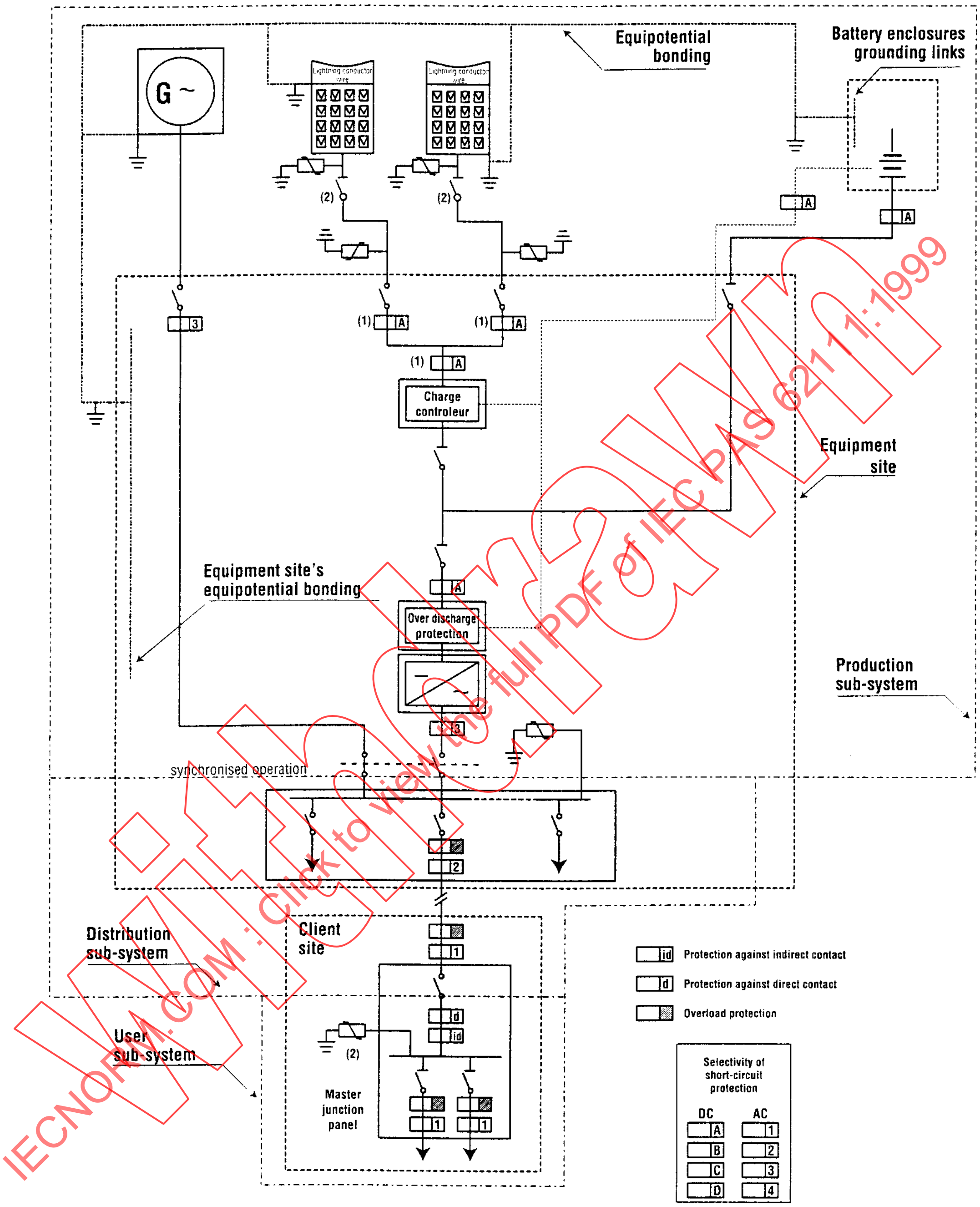
(1) Depending on junction panel device can be upstream or downstream

(2) One or the other depending on wire cross-section

(3) Optional device

Nota : The equipment's possible internal protections have not been taken into account

Figure 21 : System type T5



(1) One or the other depending on wire cross-section
(2) Optional device
Nota : The equipment's possible internal protections have not been taken into account

Figure 22 : System type T6$_a$

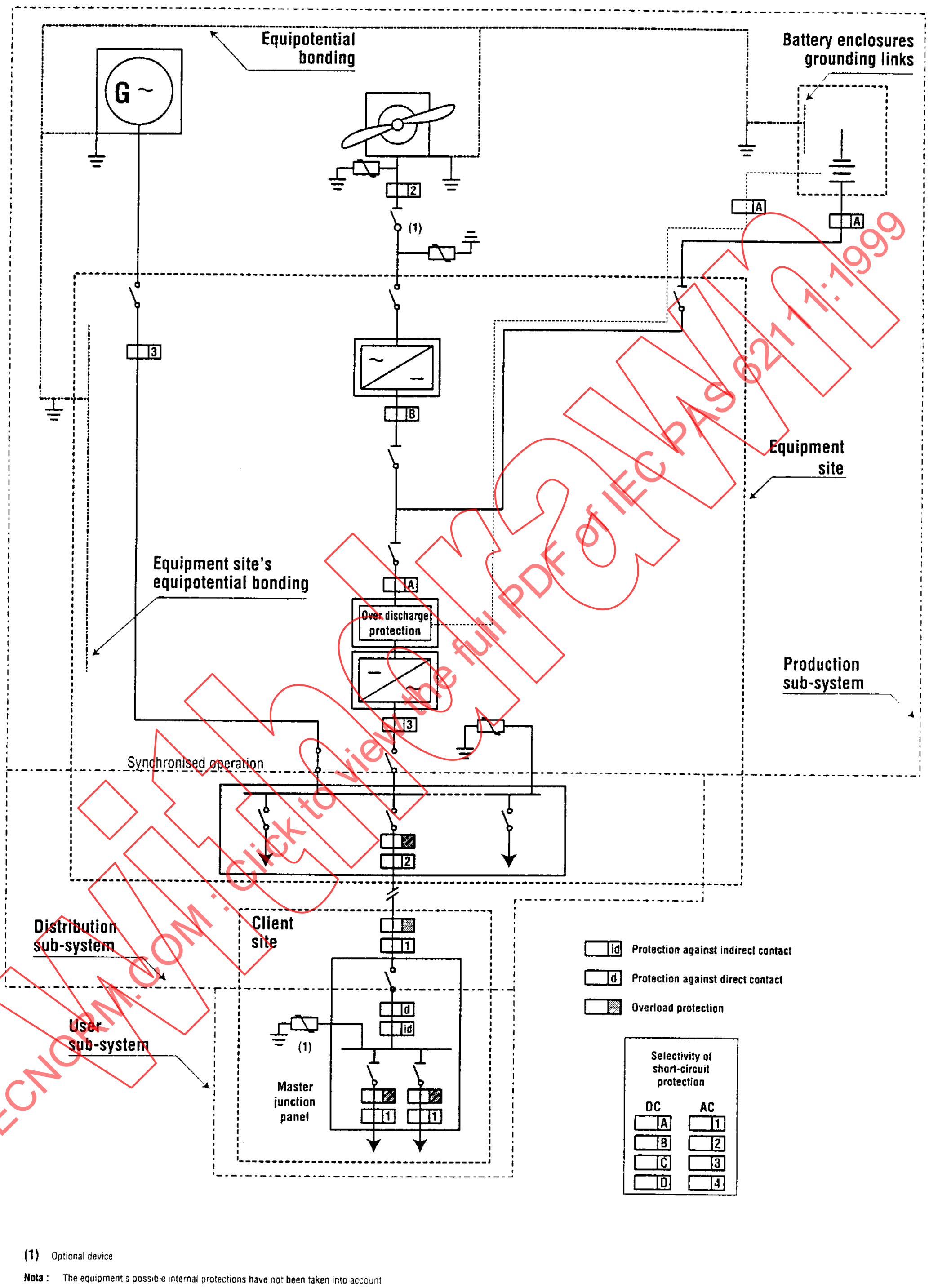


Figure 23 : System type $T6_b$

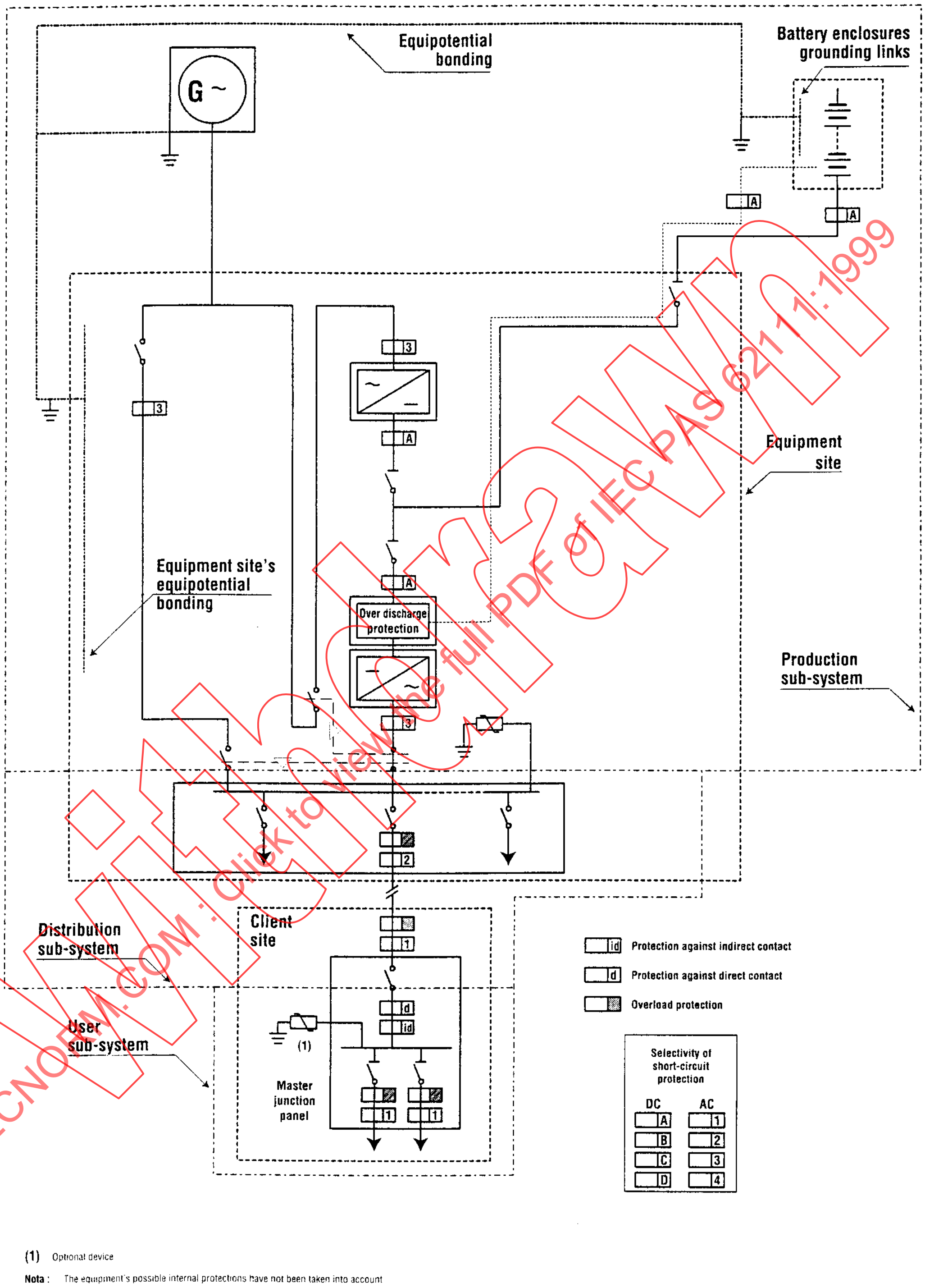
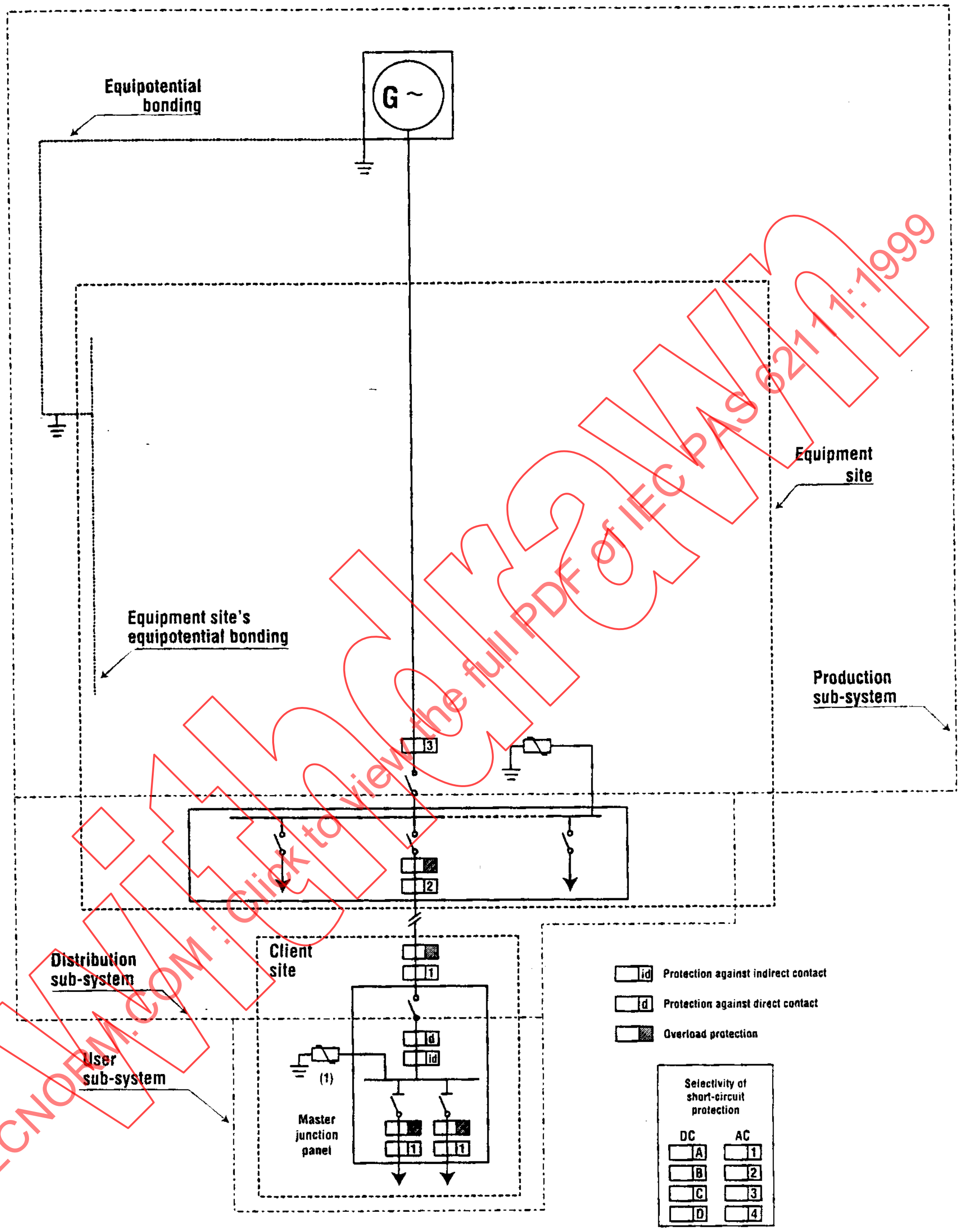


Figure 24 : System type T7



(1) Optional device

Nota : The equipment's possible internal protections have not been taken into account

Figure 25 : System type T8

Annex 1 : Earth connections

1. Definitions and characteristics

1.1. In accordance with French standard NF C 15-100

Earth connection : conductive body or series of conductive bodies, in close contact with the ground and ensuring an electrical connection to it.

Types which may be used : rods or tubes, strips or wires, plates, strips at the base of foundation ditches.

The type and depth of burying system for earth connections must be such that the desiccation of the ground and freezing do not increase the resistance of the earth connection over the limit stipulated.

The equipment used and the installation of earth connections must be such that they can withstand mechanical damage resulting from corrosion.

The design of the earthing system must take into account the possible increase of the earth connection's resistance as a result of corrosion.

1.2. In accordance with French standard NF C 17-100

The earth connection for a lightning conductor comprises, for each descent conductor :

- either conductors of the same type and cross-section as the descent conductors (in general 30 x 2 mm copper strip) arranged in the form of large-scale triangular crossbracing : 3 conductors 7 to 8 m in length, buried horizontally at a minimum depth of 60 cm ;
- or a set of 3 x 2 m interconnected vertical rods arranged on the vertices of an equilateral triangle with sides of approximately 2 m.

2. Composition of earth connections

2.1. Horizontally buried conductors (strips or wires, strips at the base of foundation ditches)

These may be :

- either solid conductors, in bare copper or with lead covering, with a minimum cross-section of 25 mm², in firm contact with the ground ;
- or solid aluminium conductors with lead covering, with a minimum cross-section of 35 mm2, in firm contact with the ground ;
- or copper strips with a minimum cross-section of 25 mm² and 2 mm thick ;
- or steel strips with a minimum cross-section of 100 mm² and 3 mm thick ;
- or galvanised steel cables with a minimum cross-section of 95 mm² ;

These conductors are either buried at the base of foundation ditches during the construction of the building or buried at a depth of around 1 m in trenches dug for this purpose.

The trenches must not be filled in with stone, clinker or similar materials and earth which can retain moisture should preferably be used.

2.2. Underground foil plates

In practice 0.5 m x 1 m rectangular plates or 1 m square plates are used and buried vertically so that the centre of the plate is at a depth of around 1 m.

The plates have a minimum thickness of 2 mm if they are copper and a minimum of 3 mm if they are galvanised steel.

2.3. Vertical rods

These can be :

- either galvanised steel pipes with a minimum external diameter of 25 mm ;
- or galvanised mild steel cross-sections with a minimum side dimension of 6 mm ;
- or copper bars with a minimum diameter of 15 mm ;
- or steel bars with a minimum diameter of 15 mm, galvanised or covered with an adherent layer of copper of appropriate thickness.

3. Recommended solution

The best solution comprises a loop at the base of a foundation ditch installed during the construction of the buildings.

This solution is, in fact, particularly advantageous as :

- it does not require any additional earth excavation work ;
- it is installed at a depth which, in general, avoids being subject to seasonal conditions ;
- it ensures effective adherence to the ground ;
- it makes practically the maximum use of the surface of the buildings and offers a minimum resistance level for the earth connection which can be obtained with this surface ;
- the resistance level obtained generally ensures the protection, in the case of TT system, with the differential circuit breakers for control panels in accordance with the standards in force ;
- it can be used, from the beginning of the construction of buildings, as an earth connection for the site installations.

It is advisable to connect to the earth connection unit - protection conductors, the conductive elements of the construction, both in terms of the metallic elements and concrete reinforcements. These connections enable, on the one hand, a reduction in the value of the overall resistance of the earthing of the ground system and, on the other hand, ensure the equipotential nature of all the grounds and conductive elements which are simultaneously accessible.

For the lightning protection of the photovoltaic array, the solution comprises creating an equipotential meshing at 15 m stages with the aid of horizontally buried conductors.

This meshing is connected by a minimum of 2 conductors to the system earth connection unit - protection conductors.

Annex 2 : The overhead and underground micro-grids
Calculation charts for determining the calibre of protection systems
(under study)

Annex 3 : Guide to the choice of circuit breakers and differential circuit breakers

In an alternating current installation comprising cable and user equipment, a circuit breaker positioned immediately upstream must :

- protect the line for all overcurrents up to the short-circuit current ;
- ensure the protection of persons against indirect contact in the case of a TN-type neutral system. With a TT neutral system, this protection must be ensured using a differential-residual current device.

In order to do this, the choice of a circuit breaker must be made in relation to :

- the characteristics of the grid on which it is installed ;
- the continuity of service desired ;
- the rules of protection to be observed ;

For a direct current grid, see chapter 5.

1. Grid characteristics

1.1. Voltage

The nominal voltage of the circuit breaker must be greater or equal to the voltage between phases for a three-phase or two-phase grid, or between the phase and neutral for a single-phase grid.

The most common rated voltages are 410 V (or 415 V) and 240 V (or 230 V).

1.2. Frequency

The nominal frequency of the circuit breaker must correspond to the nominal frequency of the grid.

The normal equipment operates indiscriminately at frequencies of 50 Hz and 60 Hz.

1.3. Intensity

The calibre of the circuit breakers release switch must be greater than the permanent current flowing in the line on which it has been installed and must be under the acceptable current level for this line.

The cable line is defined from the operating current of the loads.

The value of this current is supplied by the manufacturer of the equipment or can be easily calculated from the rating, the mains voltage and possibly the power factor. The influence of the power factor may be significant in the case of cable supplying solely fluorescent light fittings (specific PE feeder) or induction motors (individual powering for a small-scale workshop, for example).

The calibre should be selected from the following ranges :

- 80A, 100 A, 125 A, 160 A and 250 A (IEC 947-2) for a LV distribution circuit breaker ;
- 10/15/20/25/30A and 30/45/60 A for a branch circuit breaker ;
- 6A, 10 A, 16 A, 20 A, 25 A, 32 A and 40 A for a circuit breaker used on an item of household equipment.

It should be noted that the type of conductor or cable used for the line and the method of fitting (within a pipe or visible) thus influences the maximum acceptable intensity on the calibre of the circuit breaker.

The characteristics of thermal release switches on a circuit breaker are sensitive to the ambient temperature. The reference temperature is often, depending upon the manufacturers and type of circuit breaker, 30 C or 40°C.

For greater ambient operating temperatures, provision must thus be made for re-sizing the circuit breaker. There are variations of around 10% for a temperature of 50°C.

Some individual branch circuit breakers are temperature-balanced. Other circuit breakers are tropicalised.

If a circuit breaker is selected from a catalogue, it is thus necessary to study the manufacturer’s list of specifications closely.

1.4. Cut-off power level

A circuit breakers cut-off power level must at least be equal to the three-phase or single-phase short-circuit current which is likely to be present at the point where it is installed.

A simple calculation formula enables the determination of the three-phase short-circuit current I_{cc}, at a given point :

$$I_{CC} = \frac{U_n}{\sqrt{3} \times \sqrt{\left(\Sigma R_i\right) + \left(\Sigma X_i\right)}}$$

where : U_n = inter-phase rated voltage
ΣR_i = sum of the resistances upstream
ΣX_i = sum of the reactances upstream

The resistances and reactances being expressed in mΩ, the current is expressed in kA.

The usual cut-off power levels are as follows :

- around 100 kA for a LV distribution circuit breaker ;
- 4,5 kA (on cos φ = 0.7 in accordance with French standard NF C 61-420), 10 kA for two-phase and 8 kA for three-phase (in accordance with French standard NF C 63-120), for an individual branch circuit breaker ;
- 3 kA (in accordance with EN 60-898) for a circuit breaker used in a terminal installation.

NOTE. - Regardless of the make and type of circuit breaker selected, it is always essential to ensure that it is suitable for carrying out the sectioning function (12) once switched on.

1.5. Number of poles

The number of poles cut off depends upon the neutral system adopted and the relationship between the cross-section of the phase conductors and neutral in accordance with table 1.

Table 1 : Neutral system and conductor cross-section

System earthing	Distributed conductors	Cross-section of conductors	Cut-off	Conditions
TT or TN-S	3 phases		3 ph.	
	3 phases + Neutral	$S_N = S_{ph}$	3 ph. or 3 ph. + N	
	1 phase + Neutral	$S_N = S_{ph}$	ph. or ph. + N	
	3 phases + Neutral	$S_N < S_{ph}$	3 ph.	1 + 2 + 3 + 4
	3 phases + Neutral	$S_N < S_{ph}$	3 ph. + N	1 + 2 + 3
TN-C	3 phases + PEN	$S_N = S_{ph}$	3 ph.	
	3 phases + PEN	$S_N < S_{ph}$	3 ph.	1 + 2 + 3 + 4
	1 phase + PEN	$S_N = S_{ph}$	ph.	

According to the characteristics of the installation the conditions posed are as follows :

- Condition 1

The cross-section of the conductors is > 16 mm² Cu or > 25 mm² Al.

- Condition 2

  The power input between phases and neutral is < 10% of the total power conveyed by the line.

- Condition 3

  The maximum current liable to flow into the neutral is under its acceptable current.

- Condition 4

  The neutral conductor is protected against short-circuits through the provisions adopted for the phases.

NOTE. - IT system, which is not likely to be used for decentralised rural installations, has not been covered within the framework of this study.

2. Continuity of service

With regard to the obligations governing continuity of service, for a given grid, there may be a tendency to choose circuit breakers with a release trigger curve which ensures a well-defined selectivity.[11]

2.1. Release curve

A circuit breaker releases an overcharge when in one or several of the conductors in the line below, the current exceeds a given level over a certain period of time.

Two operational zones can be distinguished (figure 1 ①) :

- in the high-voltage current zones (short-circuit) the release is ensured by the "magnetic" system ; this is practically instantaneous at around 20 to 25 ms ;
- in the low overcharge zone the release is ensured by the "thermal" system ; the more significant the overcharge, the shorter the release.

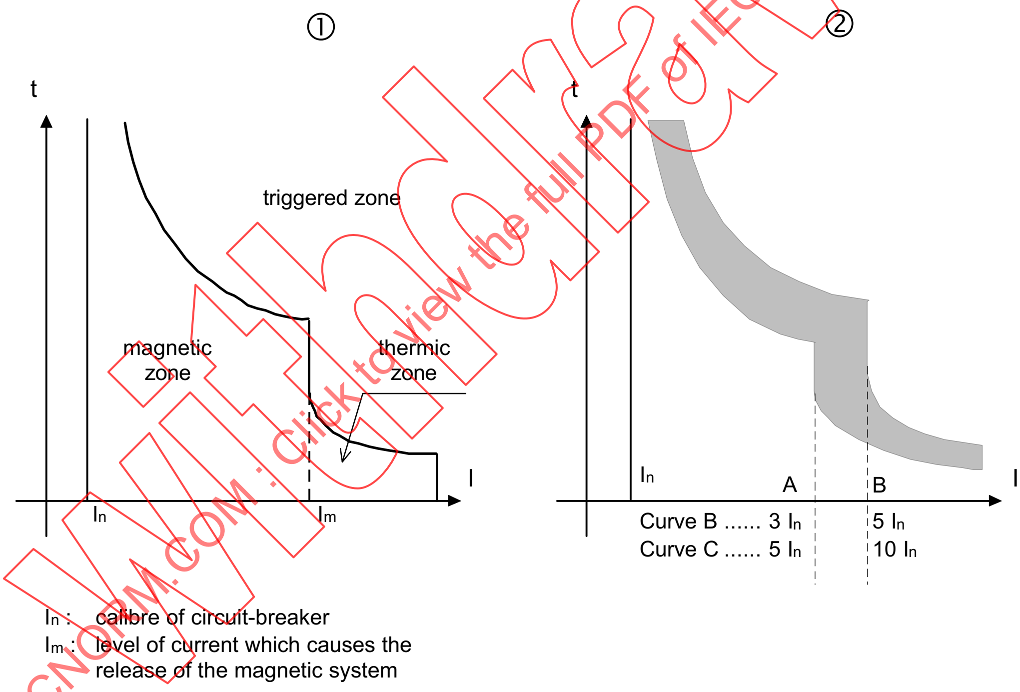


Figure 1 : Release curves

A release curve is defined according to the adjustment levels of the thermal circuit breaker and the magnetic circuit breaker.

The ideal release curve should be similar to the one shown in figure 1 ①.

In reality, there is an adjustment range (manufacturing tolerance) set by the standards or by the manufacturer for each type of curve. This is why, for each type of curve, 2 operating limits A and B (figure 1 ②) are shown.

---

[11] According to the definition given in French standard NF C 15 - 100 ξ 537-2

Between these limits, the release is ensured either by the thermal circuit breaker or the magnetic circuit breaker.

The curves shown in figure 1 (respond to European standard EN 60898 on circuit breakers for domestic and similar installations.

Curves B, C and D in accordance with standard IEC 947-2 correspond more to circuit breakers for industrial use.

U and L type curves in accordance with standards NF C 61-400 and NF C 63-120 correspond to circuit breakers which may meet more specific requirements, for example :

- avoiding untimely switch releases for weak current points ;
- allowing for the protection of persons under neutral system TN for significant lengths of cable.

The usual circuit breakers mostly operate in accordance with curve C (release level between 5 I_n and 10 I_n).

When the downstream line to be protected comprises significant lengths of cable it may be necessary to use circuit breakers which respond to curve B (release level between 3 I_n and 5 I_n).

2.2. Selectivity

Selectivity is the co-ordination of the automatic cut-off devices so that a fault, at any point on the grid, can be eliminated by the circuit breaker immediately above the fault and by it alone.

To meet this definition, it only requires two circuit breakers positioned in cascade form to have the operating curves to cover this.

To effect *total* vertical selectivity, the two circuit breakers positioned in cascade form must fulfil the following conditions :

- the relationship between the control thresholds must be :
  - ◊ > 1.6 for a distribution installation ;
  - ◊ ≥ 2 for a domestic installation with differential circuit breakers.
- the releasing of an upstream circuit breaker must be slightly time-delayed (from 40 to 50 ms for branch circuit breakers) whereas that of a downstream circuit breaker is much faster.

If the conditions are not observed, selectivity is only *partial*.

The examples given in table 2 correspond to the use of differential circuit breakers.

Table 2 : Selectivity of circuit breakers

8 **Circuit breaker upstream**	**Circuit breaker downstream**	**Selectivity**
500 mA	30 mA	partial
500 mA type S	30 mA instantaneous	total
300 mA	500 mA	not ensured
300 mA time-delayed 50 ms	30 mA instantaneous	total
500 mA	300 mA	not ensured

3. Rules on protection

3.1. Protection for persons against indirect contact

The protection measures against indirect contact using automatic power cut-off depend on the neutral system chosen.

3.1.1. TT system

In TT system, the protection is ensured by differential-residual current devices linked to the earth connection to which the grounds of the electrical equipment are connected.

The strength of the fault current must be sufficient to ensure the operation of the differential current device. The assigned differential-residual current $I_{\Delta n}$ of the device must, at maximum, be equal to the quotient of the traditional limit voltage U_L through the resistance R_A of the earth connection of the grounds protected :

$$I_{\Delta n} \leq \frac{50}{R_A} \qquad for\ U_L = 50\,V$$

In this equation the figures are drawn from table 3.

Table 3 : Assigned differential-residual current

R_A in Ω	$I_{\Delta n}$ in A
≤ 50	1
≤100	0.5
≤ 167	0.3
≤ 300	0.1
≤ 500	0.03

For individual branch circuit breakers, the usual sensitivity thresholds are as follows :

- mA for calibres from 10 to 60 A ;
- A for calibres from 30 to 60 A. The latter may be type S (selective) or time-delayed to 50 ms.

For LV distribution circuit breakers, the usual sensitivity thresholds are as follows :

- A or 3 A for calibres from 10 to 100 A.

Other calibres are available in manufacturers' catalogues.

3.1.2. TN system

In TN system the protection of persons against indirect contact is carried out using overcurrent protection devices. The releasing of a circuit breaker must occur at the first fault.

It is, however, necessary to ensure that the control current of the magnetic circuit breaker (I_m) is lower than that of the phase-ground fault current (I_d).

The level of I_d is reduced when the length of the cables in the line downstream from the circuit breaker increases. In this case, differential devices may be necessary.

The manufacturers often provide selection lists which indicate, for each cross-section of cable, the maximum length for which a circuit breaker of a given calibre will ensure protection.

3.2. Protection of persons against direct contact

The only protective measure against direct contact through automatic power cut-off requires the use of highly sensitive differential-residual current devices ≤ 30 mA.

This measure is to be adopted when there is no protection conductor and, in general, regardless of the type of neutral system.

It is effective in the case of preventive measures failing in the majority of cases of dangerous contact encountered.

This protection may be ensured for one or several circuits supplying part of an installation (or several small installations).

It should be recalled, however, that highly sensitive differential devices may be triggered off for leakage current ≤ 15 mA.

When the equipment powered has leakage current, the sum of which may exceed this level, measures must be taken to avoid the operation of differential devices in the absence of an insulation fault.

These measures may comprise :

- limiting the number of sockets, items of equipment or circuits protected by the same differential device ;
- using class II equipment ;
- using equipment comprising galvanic separation such as double-coil transformers or inverters which localise the leakage currents at the circuits powered by their secondary systems ;
- individually powering a socket or each item of equipment using a circuit isolating transformer.

NOTE. - The leakage current of a class I item of equipment is, under normal conditions, around 0.5 to 1 mA. It may reach 3.5 mA or 1 mA per kilowatt with age.

3.3. Protection against fire risks

A differential device with a differential operating current ≤ 500 mA may contribute to ensuring protection against fire risks.

It will operate in effect prior to the sum of the installation's leakage currents exceeding the level considered to be the maximum liable to cause a fire.

These devices effectively enable the monitoring of an installation's insulation level and limit the risks of fire caused through complex faults.

The most common circuit breakers used here are those with a sensitivity threshold of 300 mA. They are available in all ranges of calibres.

3.4. Protection of cables

This function forces a circuit breaker positioned upstream from a line system of cables made of CU or Al, insulated with PVC or PRC, to allow through only the power below which this cable can withstand. This is called the limiting power of a circuit breaker.

This limiting power is conveyed by its greater or lesser capacity to allow through, on short-circuit, only a current which is lower than the presumed fault current.

Where necessary, the information given in the manufacturers' catalogues should be consulted.

4. Specific characteristics

4.1. Influence of zero-sequence components

DC components stem from rectifier devices which are increasingly fitted on user equipment.

These DC components may desensitise certain differential devices and even inhibit their operation by saturating their magnetic circuit.

This is why the standards have adopted three types of differential devices, type AC, type A and type B.

4.1.1. Type AC

With type AC the release is ensured by sinusoidal alternating differential currents, whether they increase slowly or are applied abruptly.

The differential devices of this type are suitable for domestic installations in which the DC components generated by the user equipment are weak and have practically no influence on their operation.

4.1.2. Type A

With type A the release is ensured by alternating differential currents and for direct differential currents powered whether they increase slowly or are applied abruptly.

The differential devices of this type may be necessary in installations where computer and electronics equipment are installed, above all in the case of power electronics.

4.1.3. Type B

With type B the release is ensured for pure direct differential currents.

4.2. Untimely release actions

An untimely release action is any triggering of a differential-residual (DR) current protection device in the presence of a leakage current which presents no danger to persons or property.

These untimely release actions are generally due to transitory leakage currents flowing to the earth through a high operating capacity. They may occur intermittently, at random, often when a circuit is switched on and sometimes on cut-off.

They are essentially caused by three aspects :

- atmospheric overvoltage ;
- operating overvoltage ;
- the switching on of circuits presenting a high capacity with the earth.

To limit untimely release actions which may damage the credibility of the DRDs, with all the consequences which this entails, the choice of a circuit breaker must be made from those which are protected against this risk.

4.3. Installation of lightning arresters.

For the regions concerned, the choice of a circuit breaker must take into account its ability to facilitate the installation of a panel type lightning arrester.

5. Circuit breakers for a direct current grid

The choice of type of circuit breaker, for the protection of a direct current installation, depends essentially on the following criteria :

- the nominal current enabling the choice of calibre ;
- the rated voltage enabling the determination of the number of poles in series which must operate in the cut-off ;
- the maximum short-circuit current at the point of installation enabling the definition of the cut-off power level ;
- the type of grid.

The grid can be :

- either earthed : the source has an earthed polarity or comprises a middle point which is earthed ;
- or unearthed (earth insulated)

5.1. Number of poles operating in the cut-off

The number of poles which must operate in the cut-off depends on the nominal voltage and the type of grid. These poles, positioned in series on one polarity, are activated simultaneously.

In a direct current grid with an earthed polarity, a pole can be positioned on the earthed polarity to ensure the sectioning.

5.2. Calculation of the short-circuit current.

The short-circuit current at the terminals of an accumulator battery is calculated by applying the following equation :

$$I_{CC} = \frac{V_b}{R_i}$$

where : I_{cc} = short-circuit current at the terminals of the battery
V_b = maximum discharge voltage (battery 100% charged)
R_i = internal resistance equivalent to all the elements (figure generally given by the manufacturer in relation to the capacity in ampere-hours of the battery)

5.3. Choice of a circuit breaker

The choice of a circuit breaker is made with reference to the information given in the manufacturers' catalogues.

There are usually nominal current circuit breakers varying between 10 A and 250 A for voltages of from 24 V to 500 V.

6. Generator set protection circuit breakers

Generator sets are almost always fitted with their protection device. This equipment, adapted to the characteristics of the generator it is protecting, must not be modified.

Where necessary, (use of recovery equipment, for example), the choice of a circuit breaker must be made subsequent to calculating the short-circuit current at the generator terminals using :

$$I_{CC} = \frac{I_n}{X'_d}$$

where : I_{cc} = short-circuit current at the generator terminals
I_n = nominal current at nominal power
X'_d = transitory reactance between 20 and 30%

The low short-circuit current level of the generator requires the use of a low magnetic circuit breaker.

The choice of circuit breaker is made by referring to the information given in the manufacturers' catalogues which offer the appropriate equipment.

Particular attention should be paid to circuit breakers positioned in cascade form in order observe an acceptable level of selectivity.

Annex 4 : Guide to choice of other protective equipment (under study)

Annex 5 : Recommendations on the characteristics of generators and power equipment

1. General points

Generator sets and converters (see document DRE - C 6 : “Converter”) must be fitted with internal protection devices against short-circuiting and overcharges (where applicable) adapted to their characteristics.

The protective devices positioned immediately upstream from the outlet points on this equipment can only also serve as protection for the downstream cable line if the latter has a cross-section which is adapted to the maximum current conveyed.

Under study

2. Generator sets

Under study

3. Photo-voltaic panels

Under study

4. Wind generators

Under study

5. Batteries

Under study

6. Converters

Under study

Annex 6 : Safety and prevention training for operators and user information

1. Rules on operating installations

Under study

2. Rules on installation at user sites

2.1. General case

Under study

2.2. Rules on installation at single-user sites

Under study

3. Correct use of public and private equipment and installations

Under study

Annex 7 : Practical rules on sizing

1. Lightning arresters

Under study.

DRE SPECIFICATIONS - B 7 June 1997

Title

Part B - Guidelines for System Design And Operation

Section 7 : Guidelines for Operation, Maintenance and Renewal

Number of pages 74 (including annexes)

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DRE - A 1 : "From the requirements to be met to the proposal for a range of Electrification Systems".
DRE - A2 : "Results expected from the process of system design".
DRE - A 3 : "Contractual framework governing the Relationships involved"
DRE - B 1 : "Architecture of Electrification Systems".
DRE - B 6 "Guidelines for the Protection of Persons and Property from Electric Hazards".

Summary This document proposes the operating rules for the use of the various parties involved in the running, maintenance and renovation of the decentralised rural electrification systems.

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CONTENTS

1. Scope

The scope of this document is to describe the “correct operating” rules to be used by the various parties involved in the specification, design and implementation of decentralised rural electrification systems.

These rules concern the **Operation, Maintenance and Renewal** of the installations (which we shall call R. O. M. R. for convenience).

The aim is to propose that the trade adopt a process, methodology and even organisation to be implemented so that the operating, maintenance and renovation of installations are carried out under the best possible technical and economic conditions.

It also offers simplified maintenance contract models for installations fitted with photovoltaic or wind generators. In the case of a combined system, it is easy to produce a contract model, from the models offered, which will cover both types of generator.

2. General aspects

2.1 Summary of types of systems

The decentralised rural electrification systems are intended to power user equipment located in rural areas on sites not connected to national grids.

These systems can be classified into three categories :

- electrification systems for processes (for example, for pumping) ;
- single-user person electrification systems (Single Home System, SHS) ;
- multi-user community electrification systems (Multi Home System MHS).

With a view to meeting the various power requirements both in terms of quality and quantity, eight types of **systems** for decentralised rural electrification have been identified (see table 6 of document DRE - A 1 : "From the requirements to be met to the proposal for a range of Electrification Systems").

It is advisable to include the content of table 1 under Operation, Maintenance, Renewal operations.

Table 1 : R. O. M. R. operations

Operation	All operations based on : • the acceptance of the installation • monitoring the “normal” working order of the installation (“normal” working order = "the installation provides all the expected service characteristics) • managing the operation of the installation • running = effecting operations on electrical circuits (changes to configuration) • diagnosing, in the case of irregular operation, the causes of the faults • servicing = carrying out operations to restart the machine, subsequent to an “unforeseen” breakdown • repairing = restoring the defective equipment guaranteeing safety during operations on the installation
Maintenance	All operations seeking to : • avoid breakdowns = maintaining the installation in “normal” working order • avoid the deterioration of the equipment in terms of its use throughout the service life for which it has been designed
Renewal	All operations governing : • the replacement of equipment at the end of its “normal” service life • upgrading the nature of the equipment installed in order to respond to the development of power requirements

2.2 Hypothesis upon which the proposed R. O. M. R. rules are based.

2.2.1 Responsibility for system operated

A system may be operated :

- either directly by the user who is then responsible for all the R. O. M. R. operations ;
- or by an operator who is responsible for R. O. M. R.

2.2.2 Rules adopted for setting operating limits on an installation

In the case where the system is the responsibility of an operator, there are limits which set the operating domains accessible to the operator and/or user.

There are, at the end of the document, charts specifying these limits (electrical limits and equipment access limits).

2.2.3 Power supply service commitments

To meet the various power requirements at which they are aimed, the various systems are designed to attain the results objectives summarised in the key points given in table 6 of document DRE - A 1 : "From the requirements to be met to the proposal for a range of Electrification Systems".

The resources allocated to operation and maintenance must take into account the types of commitments undertaken with the Project Supervisor.

2.2.4 Choice of a neutral system

The choice of neutral system conditions the entire system, whether in terms of general design, the size of protective systems, the co-ordination of insulation or protective systems or the quality of service.

Recommendations are issued in document B6 in the present Directives “Guidelines for the protection of persons and property against electrical hazards".

This states that, in order to organise operation and maintenance, two neutral systems may be implemented : system TT and system TN.

For MHS systems, The choice entails the responsibility of the various parties in different ways :

- with system TT, the responsibility for the satisfactory operation of the earth connections lies with the user ;
- with system TN, this responsibility lies with the operator.

2.2.5 Preferred qualifications of parties responsible for R. O. M. R.

Various parties may be called upon to carry out work on the installation. The following table specifies the area of responsibility of each of these parties and a single person may assume several roles (see table 2).

Table 2 : Areas of responsibility for R. O. M. R. operatives

Nature of operative	Responsibilities in relation to R. O. M. R.
The **Project Supervisor**	From the definition of the service to be provided, they set the R. O. M. R. rules and levels, in order to ensure this service.
The **Installer (or sub Contractor)**	They carry out the installation in accordance with the Project Contractor's specifications
The **Operator** (client representative)	On acceptance of the work, the Operator issues their agreement - “satisfactory for operation”. They are then responsible for applying the R. O. M. R. rules on the ground.
The **Maintenance administrator**	They undertake to ensure the services which may take the following forms : – “parts” guarantee – regular inspections intended to monitor the condition of the main components subject to ageing (essentially battery) – “parts and workforce” guarantee – “parts, workforce, operation deadline” extended services guarantee The maintenance administrator undertakes to notify, at regular intervals, the parties concerned, in particular the Operator and User, of any significant information relating to the working order of the installation (see document DRE - A 3 : "Contractual framework governing the relationships involved")
The **User**	In applying the instructions received, they can return information to the Operator and carry out simple O. M. operations. e.g. : cleaning of PV panels, recharging of battery, emergency switch-off

With regard more specifically to operation, it is possible for a certain number of functions to be carried out by automatic systems. This may be the case with monitoring, control and diagnosis.

The **Maintenance Administrator** must have received specified training adapted to the local context or be duly qualified where there are appropriate regulations.

The **User** must observe the instructions received from the **Project Supervisor**.

3. Rules on Operation, Maintenance and Renovation according to system

The proposed rules governing operation, maintenance and renovation for type 1, 2, and 3 “single-user” isolated systems are shown below. Type 4, 5, 6, 7 and 8 “multi-user” systems are under study.

3.1 R. O. M. R. rules for type 1 systems

3.1.1 Function of a type 1 system

The type 1 system is intended to power a process under the following conditions :

- The process requires a given quantity of power, over a given period in excess of a day (week or month) ;
- There are no requirements governing quality of supply ;
- It can go without power at any point over this period of time

  (e.g. pumping for a water tower) provided that the expected results of the process over the period are attained.

3.1.2 Hypotheses upon which the proposed rules are based

3.1.2.1 System operation and responsibility

This type of system may be operated :

- either directly by the User who is then fully responsible for R. O. M. R. operations on the equipment required for the process as a whole ;
- or by another operative, appointed by the User

3.1.2.2 Production system limits

In this system, no equipment access limits have been set for operations.

The corresponding electrical layout is shown below.

3.1.2.3 Service level commitments

What matters, in the end, is that the expected result from the electrically powered process is attained.

In this type of system, the production subsystem enables the supply, x months out of 12, y weeks out of 52, of the quantity of power subscribed over a month, a week.

This quantity of power may, in certain cases, be negotiated in relation to the month or season.

3.1.2.4 Neutral system

The neutral system adopted is as follows :

AC Section	DC Section
TT or TN	an earth polarity

3.1.3 General circuit diagram

Several electrical layouts are possible. They correspond to the various scenarios relating to production sources and the type of use, in relation to the renewable energies available on the site to be equipped (see simplified layouts T_{1a} to T_{1d} in document DRE - B 1 : "Architecture of electrification systems").

3.1.4 General R. O. M. R. conditions for a type 1 system

Tables 3 and 4 show the expected results for R. O. M. R. operations on type 1 systems.

The practical methods of execution are specified in technical annexes 1 to 7.

Table 3 : General operating conditions (type 1 system)

Functions to be ensured		Proposed rules (functional content)	(technical content)	(practical rules)	(operative)	(comments)
Operation	Acceptance of the system	**checking**	◊ compliance with the operational layout specified in the Directive ◊ compliance with expected service characteristics (= the expected functions are ensured) ◊ compliance of equipment ◊ compliance with standards and trade practice ◊ compliance with the specific points requested by the Project Supervisor	see present rules in paragraph 3 see annex 6 see annex 1, files 1, 2, 4, 5 and 8 see contractual/site elements		
	Management of operation	**monitoring values**	◊ min / max. values for U compatible with the load	see power management - general conditions		
	System control	**adapting the layout to the service to be provided (on the orders of the controller)**	power cut-off (after observation of the process ;e.g. the water tower overflows)		user or automatic system linked to manager	
		diagnosing the causes of breakdowns	◊ check the condition of the equipment	see annex 2, file 1	operator	
	Servicing	**restart the system**		see annex 4, file 1	Operator	important criteria : - operating deadline - restart deadline - % change in service subsequent to servicing service guarantee after reconnection
	Repairing	**Ensure that, through identical or different means, the system assumes the same functions**			Operator	
	Guaranteeing safety	**Activate the switch-on points which enable the operations to be carried out whilst ensuring, in so far as is possible, a fully safe continuity of service for agents and third parties**		see annex 4, file 1	Operator	see circuit diagram with positions of switch-on points

Table 4 : General maintenance and renovation conditions (type 1 system)

Functions to be ensured		Proposed rules (functional content)	(technical content)	(practical rules)	(operative)	(comments)
Maintenance (preventive)	Avoiding breakdowns	**maintain the system in normal working order**	preventive operations on equipment	see annex 3, files 1, 4 and 5 see annex 4, file 1	operator	
	Avoiding the degradation of equipment aiming to use it throughout the service life for which it has been designed	d°	d°	d°		
Maintenance (curative)				see annex 4, file 1		
Renovation	Replace equipment at the end of normal service life			see annex 1, files 1,2,4,5, and 8		
	Upgrade the nature of the equipment in order to respond to developments in power requirements					if this commitment has been contractually undertaken

3.2 R. O. M. R. rules for type 2 systems

3.2.1 Function of a type 2 system

the type 2 system is a single-user system. Its function is to meet the power requirements defined as follows :

- the user requires several hours power each day at constant voltage ;
- the user has several loads and wishes to be able to use them simultaneously some of the time ;
- the user has AC and/or DC loads.

3.2.2 Hypotheses upon which the proposed rules are based

3.2.2.1 Operation and responsibility for system :

This type of system may be operated :

- either by the User who manages the consumption (within the storage limit available) and who is thus responsible for elementary maintenance operations ;
- or by an Operator who thus works within the limits of the production installation.

3.2.2.2 Production system limits

In the case where the system is subject to the responsibility of an Operator, cut-off elements limit the operational domain of the licence holder ; these elements are installed in equipment casing to which only the operator has access.

However, the production system limit passes physically through the terminals downstream from the cut-off element located on the **User** site and installed on :

- an AC distribution board ; and/or
- a DC distribution board.

3.2.2.3 Service level commitments

In this type of installation, the production system must enable the supply of, over n weeks out of 52, a daily (or monthly) quantity of power subscribed, in the knowledge that the user is limited by a max. subscribed power level.

3.2.2.4 Neutral system

The neutral system adopted is as follows :

AC Section	**DC Section**
TT or TNS	Possible choice between floating potential or earth polarity if there is galvanic insulation in the converter - otherwise floating potential

3.2.3 General circuit layout

The corresponding circuit diagram can be found in figure 5 of document DRE - B 1 : "Architecture of electrification systems".

3.2.4 General R. O. M. R. conditions for a type 2 system

Tables 5 and 6 show the expected results of R. O. M. R. operations on type 2 systems

The practical methods of execution are specified in technical annexes 1 to 6.

Table 5 : General conditions of operation (type 2 system)

Functions to be ensured		Proposed rules (functional content)	(technical content)	(practical rules)	(operative)	(comments)
Operation	Acceptance of installation	**checking**	◊ compliance with operational layout specified in the Directive	see present rule in paragraph 3.2.3	Operator's representative	
			◊ compliance with expected service characteristics (= the expected functions are ensured)	see annex 6		
			◊ compliance of equipment	see annex 1, files 1 to 5 and 8		
			◊ compliance with the recommendations of the Chart (e.g. cross-section of conductors, protection,..)			
			◊ compliance with the specific points requested by the Project Supervisor	see contractual / site elements		

Table 5 (continued) **: General conditions of operation (type2 system)**

Functions to be ensured		Proposed rules (functional content)	(technical content)	(practical rules)	(operative)	(comments)
Operation (contd.)	Monitoring the operation	**observing**	◊ condition of battery charge (U battery)	see annex 5	Operator	
			◊ does the battery recharge itself ? ◊ voltage at supply point ◊ correlation between all the charge I and sun or wind ◊ + criteria adopted with the client for service quality.	(local or remote observation) d° d° see projected consumption schedule		
		observing	◊ storage condition (battery low) ◊ performance of U battery over period	(local information and information transferred from the equipment site) minimum signal on one board	User	
	Managing the operation	**(seeking, at all times, to give priority to renewable energy sources)**		see general conditions of power management.		
	Control of installation	**adapting the layout to the service to be provided (on the orders on the manager)**	◊ charge cut-off ◊ GS start-up		User or automatic system linked to controller	

Table 5 (end) **: General conditions of operation (type 2 system)**

Functions to be ensured		Proposed rules (functional content)	(technical content)	(practical rules)	(operative)	(comments)
Operation (contd.)	Servicing	**diagnose the causes of breakdowns**	◊ checking contractual commitments ◊ checking the condition of equipment	see annex 2, file 2	Operator	
		restart the installation		see annex 4, file 2	Operator	important criteria : – operation deadline – restart deadline – % change in service subsequent to servicing service guarantee subsequent to restart
	Repairing	**Ensure that, through identical or different means, the installation assumes the same functions**			Operator	
	Guaranteeing safety	**Activate the switch-on points enabling the operations to be carried out and ensuring, in so far as is possible, a fully safe continuity of service for agents and third parties**		see annex 4, file 2	Operator	– see circuit diagram with positions of switch-on points

Table 6 : General maintenance and renovation conditions (type 2 system)

Functions to be ensured		Proposed rules (functional content)	(technical content)	(practical rules)	(operative)	(comments)
Maintenance (preventive)	Avoiding breakdowns Avoiding the degradation of equipment with a view to using it for the entire service life for which it was designed	**maintaining the installation in normal working order** d°	preventive operations on equipment d°	see annex 3, files 1 to 4 see annex 4, file 2 d°	Operator	
Maintenance (curative)				see annex 4, file 2		
Renovation	Replacing the equipment at the end of normal service life			see annex 1, files 1 to 5		
	Upgrading the nature of the equipment to respond to developments in power requirements					prevent the replacement of DSM equipment using ordinary equipment

3.3 R. O. M. R. rules for type 3 systems

3.3.1 Function of a type 3 system

A type 3 system is a single-user system the function of which is to meet the power requirements characterised by the following elements :

- The user needs an average daily quantity of power ;
- The user's consumption may vary considerably from one day to the next ;
- The user will not go without power on certain days ;
- The user needs power at any time during the day ;
- The user has AC and DC loads.

3.3.2 Hypotheses upon which the proposed rules are based

3.3.2.1 Responsibilities for the installation

In this type of installation

- the User manages the consumption (within the storage limit available) and may be responsible for elementary maintenance operations.
- an Operator is responsible for the R. O. M. R. of the production equipment, with the exception of the generator set which is the responsibility of the User.

3.3.2.2 Production system limits

In the case where the responsibility for the system lies with an Operator, the cut-off elements limit the licence holder's operational domain ; these elements are installed in equipment casing to which only the Operator has access.

However, the production system limit passes physically through the terminals downstream from the cut-off element located on the **User** site and installed on :

- an AC distribution board ; and/or
- a DC distribution board ;
- a generator set board.

The corresponding circuit diagram is shown below.

3.3.2.3 Service level commitments

In this type of installation, the production system must enable a power supply over n days out of 365 or n weeks out of 52, without the consumption restriction imposed by the user, within the limits of a max. power level.

3.3.2.4 Neutral system

It should be recalled that, in the majority of cases, the charger powered by the generator set will be fitted with galvanic insulation (see document DRE - B 6 "Protection of persons and property").

The neutral system adopted is as follows :

AC Section	DC Section
TT or TNS	Floating potential or earth polarity (*)

(*) Choice dependant upon type of converter used (see document DRE - B 6 "Protection of persons and property").

3.3.3 General circuit layout

The corresponding circuit diagram can be found in figure 6 of document DRE - B 1 : "Architecture of electrification systems".

3.3.4 General R. O. M. R. conditions for a type 3 system

Tables 7 and 8 show the expected results of R. O. M. R. operations on type 3 systems

The practical methods of execution are specified in technical annexes 1 to 6.

Table 7 : General conditions of operation (type 3 system)

Functions to be ensured		Proposed rules				
		(functional content)	(technical content)	(practical rules)	(operative)	(comments)
Operation	Acceptance of installation	**checking**	◊ compliance with operational layout specified in the Directive ◊ compliance with expected service characteristics (= the expected functions are ensured) ◊ compliance in terms of supply ◊ compliance with the recommendations of the Chart (e.g. cross-section of conductors, protection,..) ◊ compliance with the specific points requested by the Project Supervisor	see present rule in paragraph 3.3.3 see annex 6 see annex 1, files 1 to 5 see contractual / site elements		Operator's representative

Table 7 (continued) **: General conditions of operation (type 3 system)**

Functions to be ensured		Proposed rules (functional content)	(technical content)	(practical rules)	(operative)	(comments)
Operation (contd.)	Monitoring operation	**observing**	◊ condition of battery charge (U battery)	see annex 5	operator	
			◊ does the battery recharge itself? ◊ voltage at supply point ◊ correlation between all the charge I and sun or wind ◊ .+ criteria adopted with the client for service quality	(local or remote observation) d° d° see projected consumption schedule		
		observing	◊ storage condition (battery low) ◊ performance of U battery over period	(local information and information transferred from the equipment site) minimum signal on one board	user	
	Managing the operation	**(seeking, at all times, to give priority to renewable energy sources)**	isolation of the REN in order to repair as quickly as possible	see general conditions of power management.		
		providing for measures to be adopted when renewable energy sources are unavailable	◊ condition of gas oil stocks		user	
	Control of installation	**adapting the layout to the service to be provided (on the orders on the manager)**	◊ charge cut-off ◊ GS start-up		user or automatic system linked to controller	

Table 7 (end) **: General conditions of operation (type 3 system)**

Functions to be ensured		Proposed rules (functional content)	(technical content)	(practical rules)	(operative)	(comments)
Operation (contd.)	Servicing	**diagnose the causes of breakdowns**	◊ checking contractual commitments ◊ checking the condition of equipment	see annex 2, file 3	Operator	
		restart the installation		see annex 4, file 3	Operator	important criteria : – operation deadline – restart deadline – % change in service subsequent to servicing - service guarantee subsequent to restart
	Repairing	**Ensure that, through identical or different means, the installation assumes the same functions**			Operator	
	Guaranteeing safety	**Activate the switch-on points enabling the operations to be carried out and ensuring, in so far as is possible, a fully safe continuity of service for agents and third parties**		see annex 4, file 3	Operator	– see circuit diagram with positions of switch-on points

Table 8 : General maintenance and renovation conditions (type 3 system)

Functions to be ensured		Proposed rules (functional content)	(technical content)	(practical rules)	(operative)	(comments)
Maintenance (preventive)	Avoiding breakdowns Avoiding the degradation of equipment with a view to using it for the entire service life for which it has been designed	**maintaining the installation in normal working order** d°	preventive operations on equipment d°	see annex 3, files 1 to 5 see annex 4 d°	Operator	
Maintenance (curative)				see annex 4		
Renovation	Replacing the equipment at the end of normal service life			see annex 1, files 1 to 4		
	Upgrading the nature of the equipment to respond to developments in power requirements			if this engagement has been contractually undertaken		prevent the replacement of DSM equipment using ordinary equipment

3.4 R. O. M. R. rules for type 4 system

(under study)

3.5 R. O. M. R. rules for type 5 system

(under study)

3.6 R. O. M. R. rules for type 6 system

(under study)

3.7 R. O. M. R. rules for type 7 system

(under study)

3.8 R. O. M. R. rules for type 8 system

(under study)

Annex 1 - Procedures for acceptance of equipment

Equipment acceptance procedures divide into 10 files :

File 0	Identification of the installation
File 1	Acceptance of photovoltaic array
File 2	Acceptance of wind generators
File 3	Acceptance of battery
File 4	Acceptance of gauging and control equipment
File 5	Acceptance of converters
File 6	Acceptance of distribution boards
File 7	Acceptance of generator set
File 8	Acceptance of loads
File 9	Observations and approval

Annex 1 - File 0 : Identification of the installation

Proposed identification for a type 1, 2 or 3 system

Name of site or user :
Telephone no. of site or user :

Name of Project Supervisor :
Telephone no. of Project Supervisor :

Date system put into operation :
Date battery put into operation :

Peak power / battery capacity installed (C100) :
Rated voltage :

Installer or assembler :
Telephone no. of installer :
Date of inspection :
Name of inspector :

Annex 1 - File 1 : Acceptance of photovoltaic array

Photovoltaic array		**Reference Value**	**Observations**		**Comments**
			compliant	non compliant	
Panels	unit peak power				*Attach person files with Pmax, Imax and Vmax*
	technology				
	number				
	manufacturer				
	reference				
	aspect				
	sealing on branch boxes				
	presence of by-pass diodes				
Assembly	orientation				
	angle / horizontal				
	possible masking				*Masking chart if required.*
Structures	Type of structure				
	structural material				
	solidity				
	screw and bolt material				
	corrosion resistance				
	anti-theft device				
	quality of fittings				
	quality of anchoring devices				
	earthing				

Wiring		**Reference Value**	**Observations**		**Comments**
			compliant	non compliant	
Module interconnections	type of cable				
	cross-section				
	length				
	wiring on “drip”				
	protection of the connection				
	fitting of the connection				
Junction box module connections	type of cable				
	cross-section				
	length				
	number				
	protection of connections				
	fitting of connections				
Junction box	number of boxes				
	number of branches per box				
	AR diode characteristics				
	inspection of diodes				
	sealing of box and cable routing				
	securing of terminal units				
	protection of contacts (grease)				
	quality of box fitting				

Annex 1 - File 1 (contd.) : Acceptance of photovoltaic array (contd.)

wiring (contd.)		**Reference Value**		**Observations**		**Comments**
				compliant	non compliant	
Inspection of wiring according to no-load branch	Vco and Icc according to branch	Vco	Icc			*Reference sunshine level (W/m2)*
	branch 1					
	branch 2					
	branch 3					
	branch 4					
	branch 5					
	branch 6					
	branch 7					
	branch 8					
	branch 9					
	branch 10					
	branch 11					
	branch 12					
	branch 13					
	branch 14					
	branch 15					
	branch 16					
	branch 17					
	branch 18					
	branch 19					
	branch 20					
	generator total					
Regulator / solar array connections	type of cable					
	cross-section					
	length					
	number of connections					
	protection of connections					
	existence of lightning arresters					
	fitting of connections					
	fall in voltage under I max.					
Inspection of wiring according to charge regulator input point	V and I according to regulator	V	I			*Reference sunshine level (W/m2)*
	input 1					
	input 2					
	input 3					
	input 4					
	input 5					
	input 6					
	generator total					
Battery / regulator connections	type of cable					
	cross-section					
	length					
	number of connections					
	protection of connections					
	fitting of connections					
	fall in voltage at max. discharge I					

Annex 1 - File 2 : Acceptance of wind generators

Wind generators	**Reference Value**	**Observations**		**Comments**
		compliant	non compliant	

Annex 1 - File 3 : Acceptance of battery

Accumulator battery		Reference Value		Observations		Comments
				compliant	non compliant	
Type	type of battery					
	manufacturer (battery plate)					
Characteristics and condition	rated voltage					
	rated voltage according to element					
	capacity according to element C100)					
	number of elements					
	cleanliness of elements					
	condition of connections (securing)					
	level of electrolyte					
	legibility of levels presence of deposits in tanks					
Inspection of the battery	voltage and density according to element	Velt	delt			*Battery wiring layout chart*
	element 1					
	element 2					
	element 3					
	element 4					
	element 5					
	element 6					
	element 7					
	element 8					
	element 9					
	element 10					
	element 11					
	element 12					
	element 13					
	element 14					
	element 15					
	element 16					
	element 17					
	element 18					
	element 19					
	element 20					
	element 21					
	element 22					
	element 23					
	element 24					
	battery total ((voltage and Moy d)					
	ambient temperature					
Accessories	presence of densimeter/hydrometer					
	presence of thermometer					
	presence of eye-rinse					
Battery room or box	location and access					
	danger indication signs					
	ventilation					
	thermal insulation					
	acid retainer tank					
	safety locking of site					

Annex 1 - File 4 : Acceptance of gauging and control equipment

Gauging and control equipment		**Reference Value**	**Observations**		**Comments**
			compliant	non compliant	
Place of installation	location and access				
	visibility and legibility				
	ventilation of casing				
	lighting of equipment site				
Type	manufacturer				
	reference				
	rated voltage				
	serial number				
	presence of general diagram				
	identification of terminal box				
Charge control	maximum current acceptable				
	forced charge threshold				
	upper threshold				
	charge reconnection threshold				
	upper alarm threshold				
	upper alarm disappearance threshold				
	presence of upper control inspection points				
	specific voltage gauge cable				
Discharge limitation	maximum current acceptable				
	limit threshold				
	user reconnection threshold				
	lower alarm threshold				
	lower alarm disappearance threshold				
Inspection points	solar array current gauge				*Readings on the condition of the inspection points or displays linked to the regulator*
	user current gauge				
	battery voltage gauge				
	Ah/Wh production gauge				
	Ah/Wh consumption gauge				
Data acquisition	manufacturer				
	reference				
	rated voltage				
	serial number				

Annex 1 - File 5 : **Acceptance of converters**

Converters		**Reference Value**	**Observations**		**Comments**
			compliant	non compliant	
Inverter	manufacturer				
	reference				
	serial number				
	rating (power)				
	peak power and duration				
	rated input voltage				
	input voltage range				
	rated output voltage				
	output voltage range				
	peak power and duration				
	nominal output frequency				
	output frequency range				
	type of output signal (wave)				
	no-load consumption				
	own protection				
	adjustable “monitoring” mode				
DC/DC Converter	manufacturer				
	reference				
	serial number				
	power				
	no-load consumption				
	own protection				
AC/DC rectifier converter	manufacturer				
	reference				
	serial number				
	rating (power)				
	peak power and duration				
	rated input voltage				
	input voltage range				
	rated output voltage				
	output voltage range				
	rate of residual ripple				
	peak power and duration				
	no-load consumption				
	own protection				
	adjustable “monitoring” mode				

Annex 1 - File 6 : Acceptance of distribution boards

Distribution boards		**Reference Value**	**Observations**		**Comments**
			compliant	non compliant	
	location and access				
	visibility				
	max. intensity				
	earth polarity				
	solar array sectioning				
	battery sectioning				
	control power supply sectioning				.
	general power supply sectioning				
	solar array protection type				
	battery protection type				
	user equipment protection type				
	protection against direct contact				
	internal cable cross-section				*Inspection of the voltage*
General	internal cable identification				*in terms of the loads*
VLV (TBT)	terminal box identification				*(cooler, fluorescent*
Board	presence of recharge fuse				*lighting input point*
	IP grade of VLV box				*Check the value of the drop*
	presence of diagram				*in voltage in the cables*
	location and access				
	protection against indirect contact				
	VLVS				
	VLVP equipotential adaptation				
	VLVF protection measure				
	L. V. and VLV insulation				
	sectioning				
	protection against overcharge				
	protection against direct contact				
	neutral earthing				
	cable identification				
	terminal box identification				
	IP grade of L. V. box				
	presence of diagram				

Annex 1 - File 7 : Acceptance of the generator set

Generator set		**Reference Value**	**Observations**		**Comments**
			compliant	non compliant	
Generator set	manufacturer				
	type				
	reference				
	power				
	output voltage				
	protections				
	source inverter				
	protective circuit breaker				
	general cut-off including GS				
Charger	manufacturer				
	type				
	nominal charge current				
	presence of voltage control				
	length of battery connection				
	cross-section of battery connection				

Annex 1 - File 8 : Acceptance of loads

Loads		**Reference Value**	**Observations**		**Comments**
			compliant	non compliant	
Lighting					
	ratings (power)				
	phi cosine (strip lamps, LBC)				
	refrigerator type				
	capacity				
	insulation quality				
Cold	compressor power				
	freezer type				
	capacity				
	insulation quality				
	compressor power				
Other loads					
(pumps,					
motors,.)					

Annex 1 - File 9 : Observations and approvals

Observations of user

Observations of Project Supervisor - Any compliance operations required.

Prepared in : on				
Signature of Project Supervisor	Signature of Project Contractor representative	Signature of Project Contractor	Signature of Licence holder	Signature of Assignee

Annex 2 - Fault search algorithms

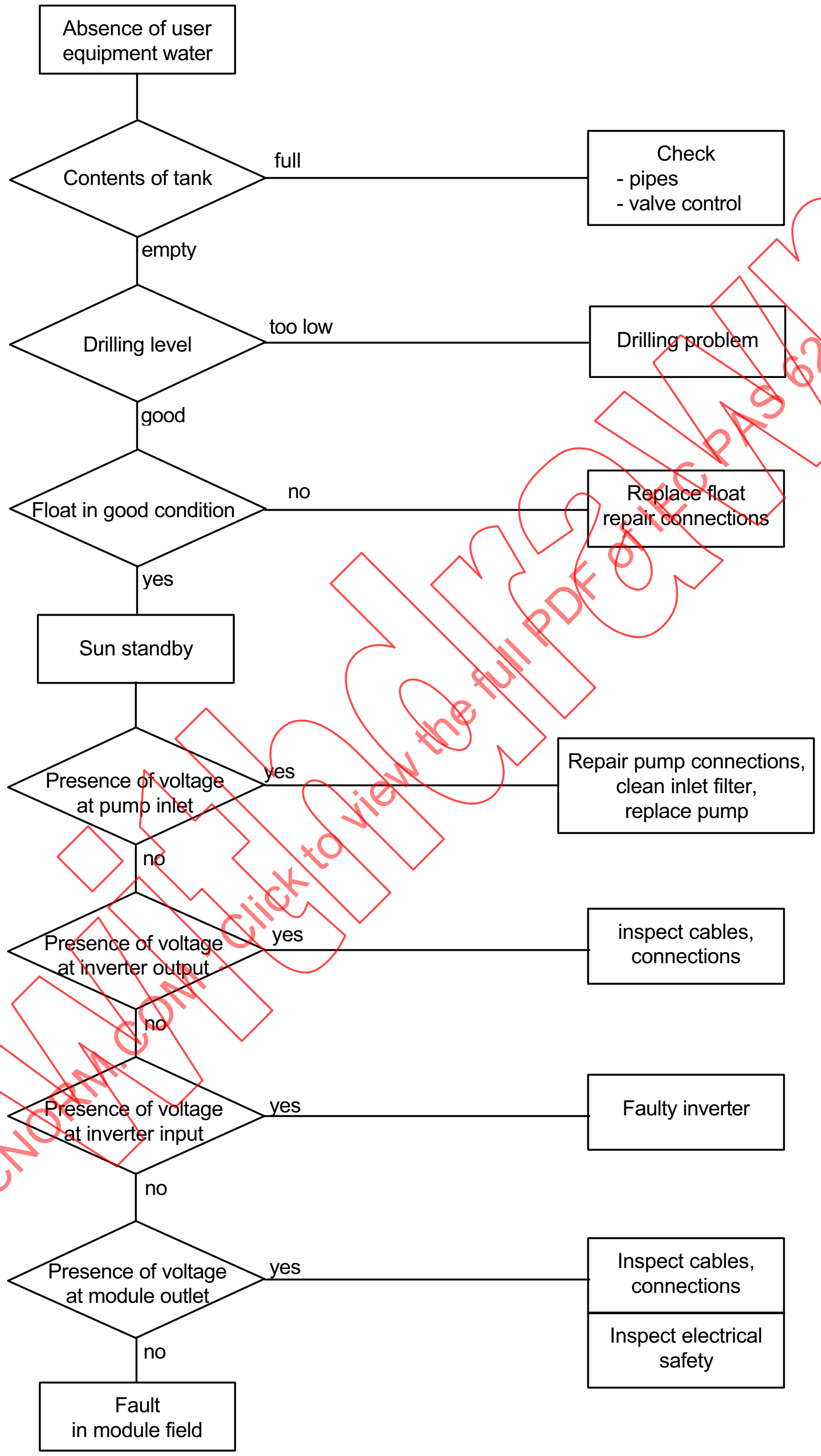
Fault search procedures divide into 8 files :

File 1	Fault searches on type 1 installations
File 2	Fault searches on type 2 installations
File 3	Fault searches on type 3 installations
File 4	Fault searches on type 4 installations (under study)
File 5	Fault searches on type 5 installations (under study)
File 6	Fault searches on type 6 installations (under study)
File 7	Fault searches on type 7 installations (under study)
File 8	Fault searches on type 8 installations (under study)

Annex 2 - File 1 : Fault searches on type 1 installations

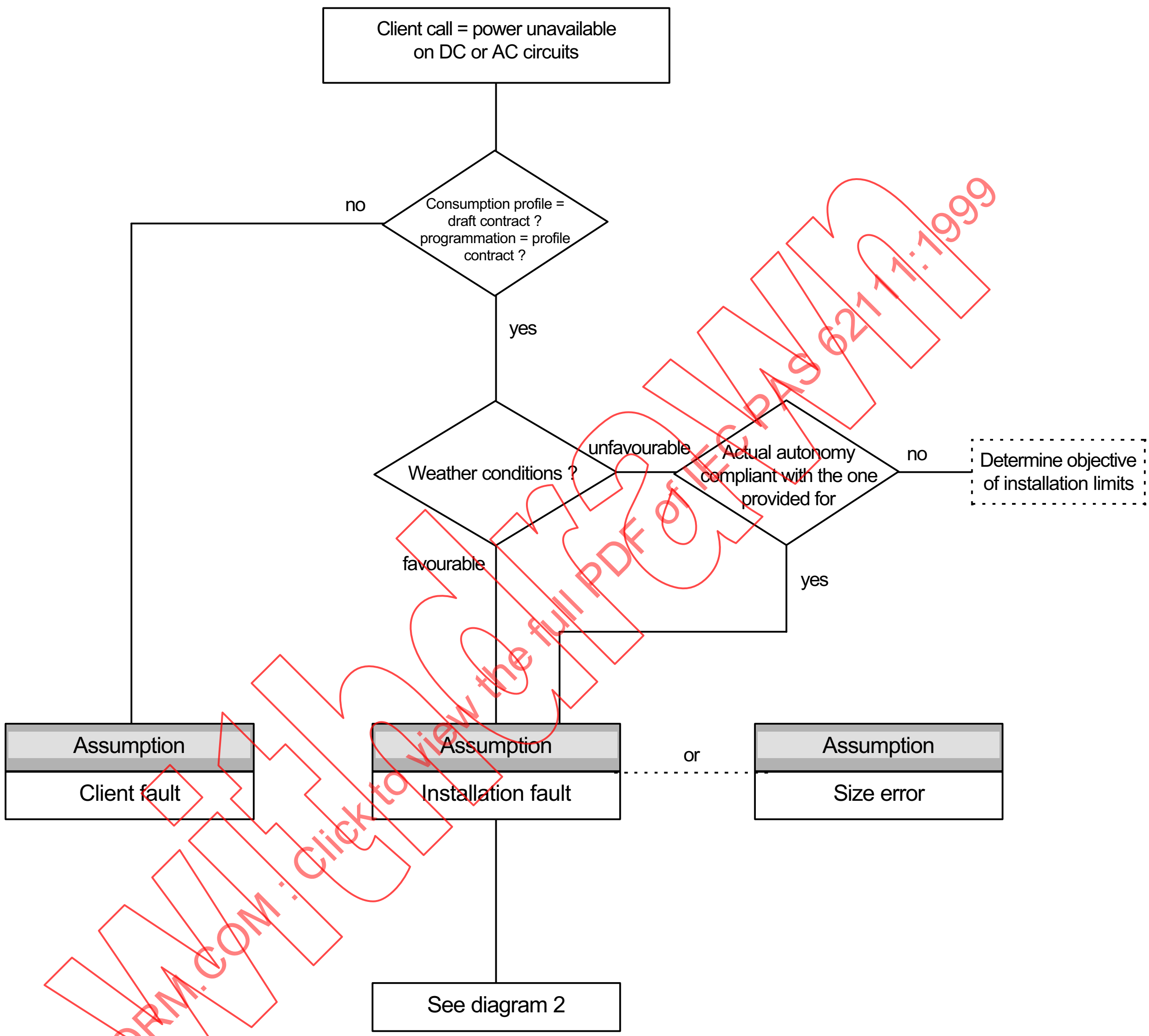
Diagram 1 : Analysis of probable causes of faults

(example of “solar-powered” water pumping type process)



Annex 2 - File 2 : Fault searches on type installations

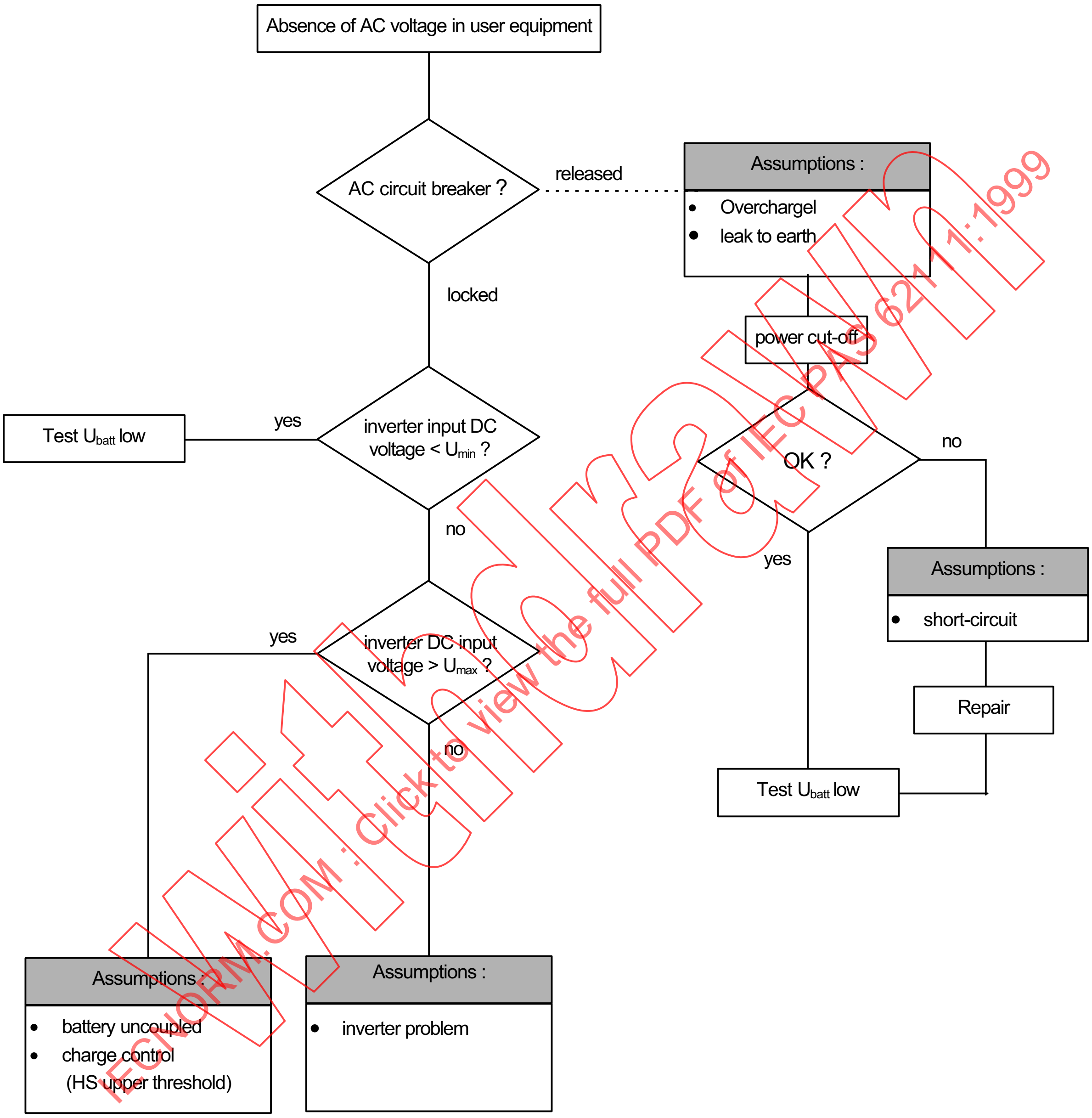
Diagram 1 : Analysis diagram relating to clauses in operator/client contract



Annex 2 - File 2 (cont) : Fault searches on type 2 installations

Diagram 2 : Diagram analysing probable causes of installation faults

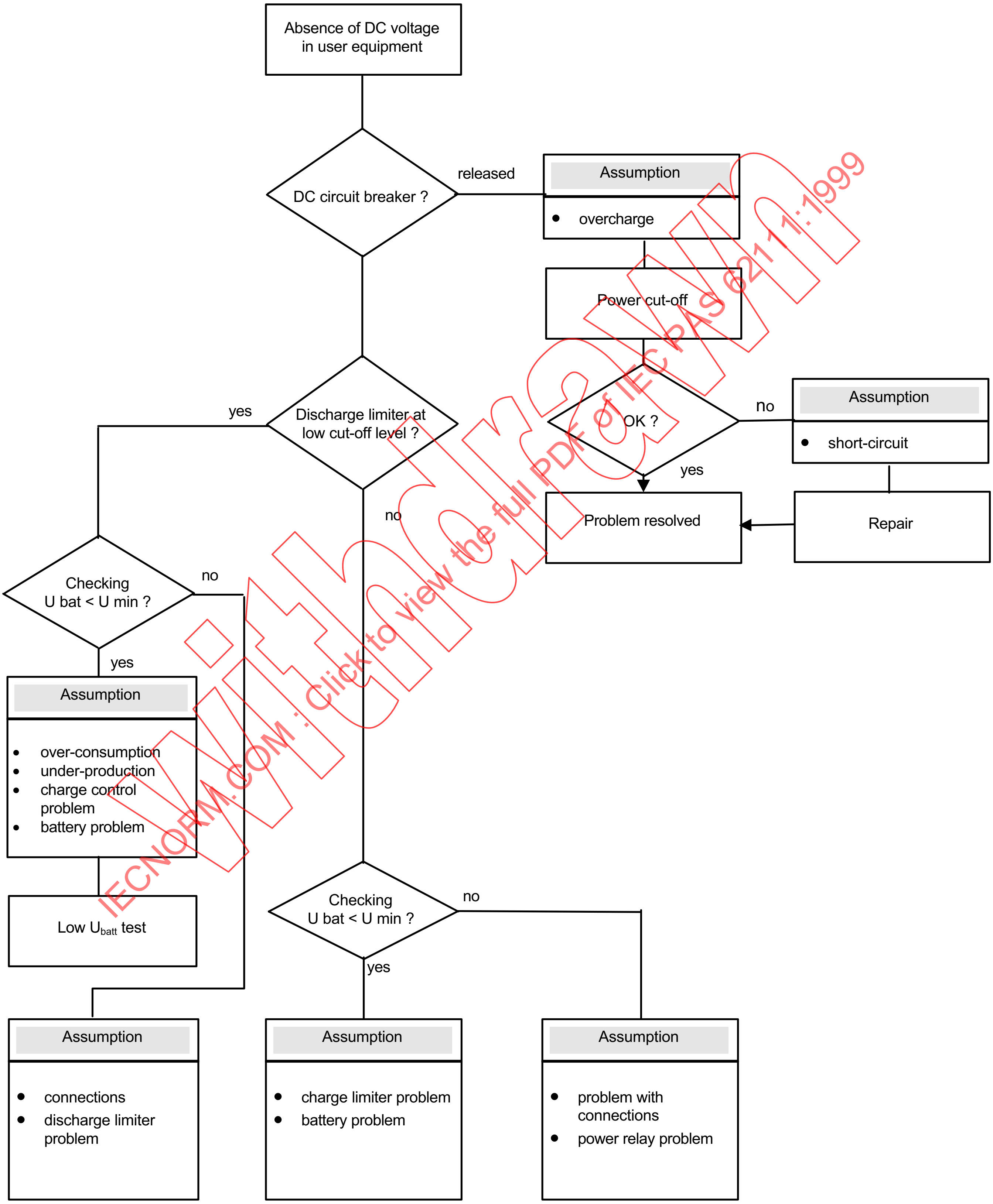
Type 2 (AC user equipment)



Annex 2 - File 2 (contd.) : Fault searches on type 2 installations

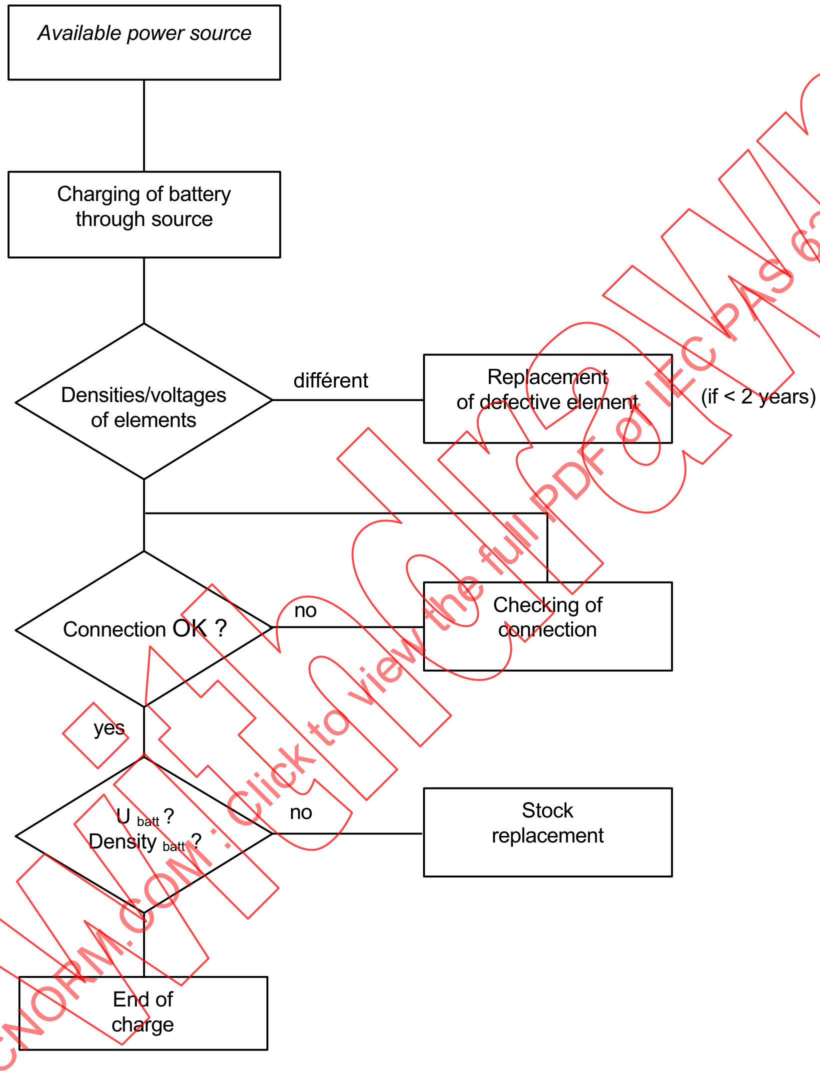
Diagram 2a : Diagram analysing probable causes of installation faults

Type 2 (DC user equipment)



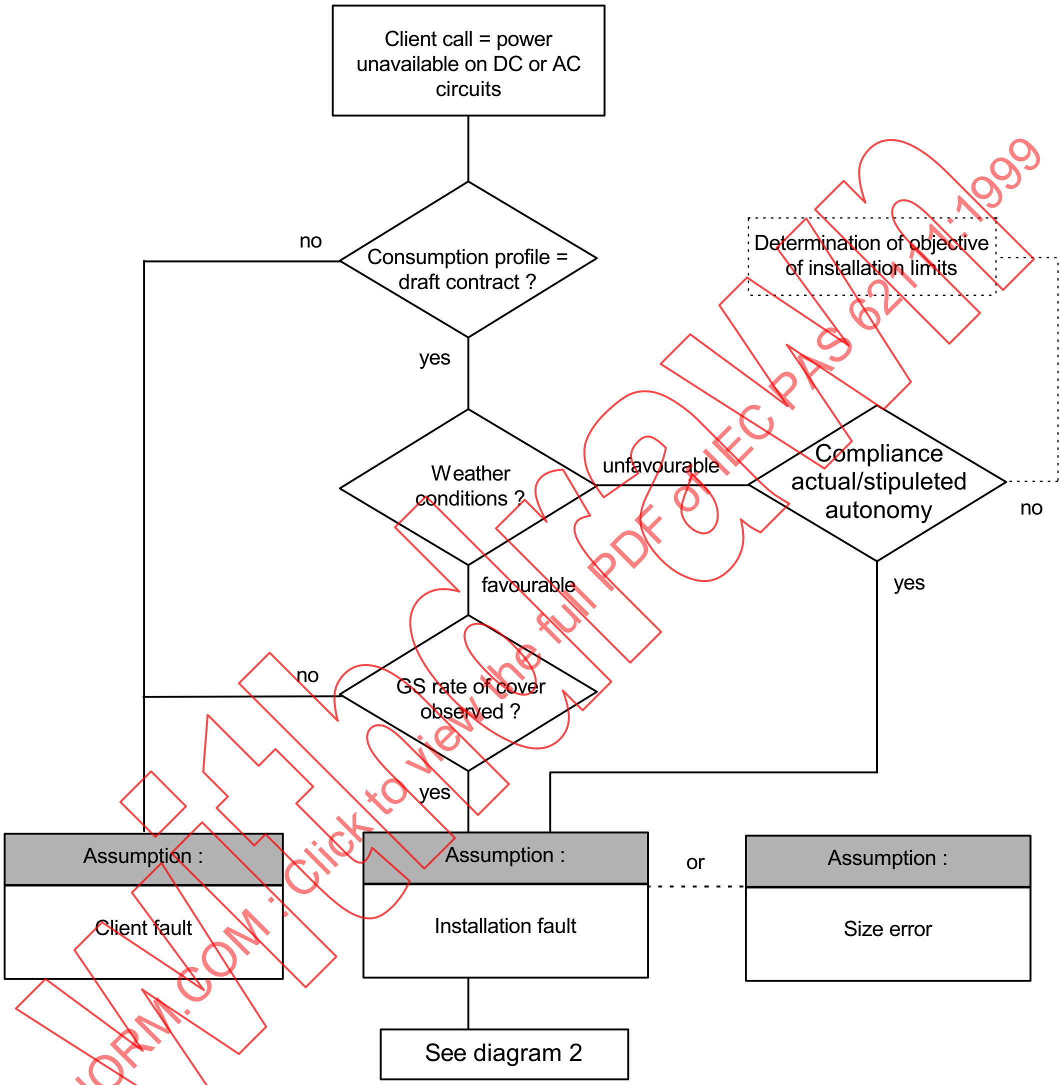
Annex 2 - File 2 (end) : Fault searches on type 2 installations

Diagram 3 : Inspection of *battery* stocks



Annex 2 - File 3 : Fault searches on type 3 installations

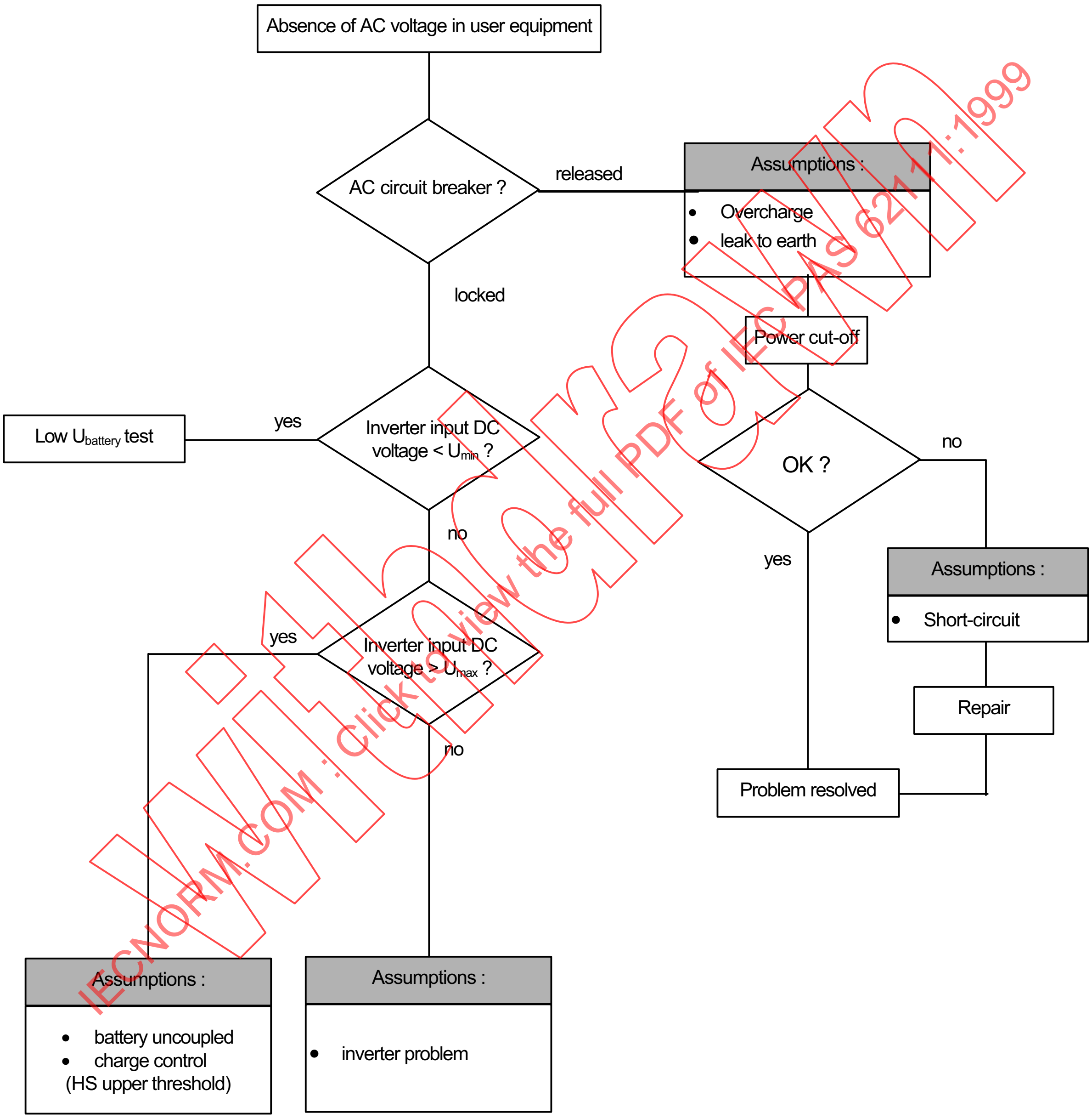
Diagram 1 : Diagram analysing observance of operator /client contract clauses



Annex 2 - File 3 (contd.) : Fault searches in type 3 installations

Diagram 2 : Diagram analysing probable causes of installation faults

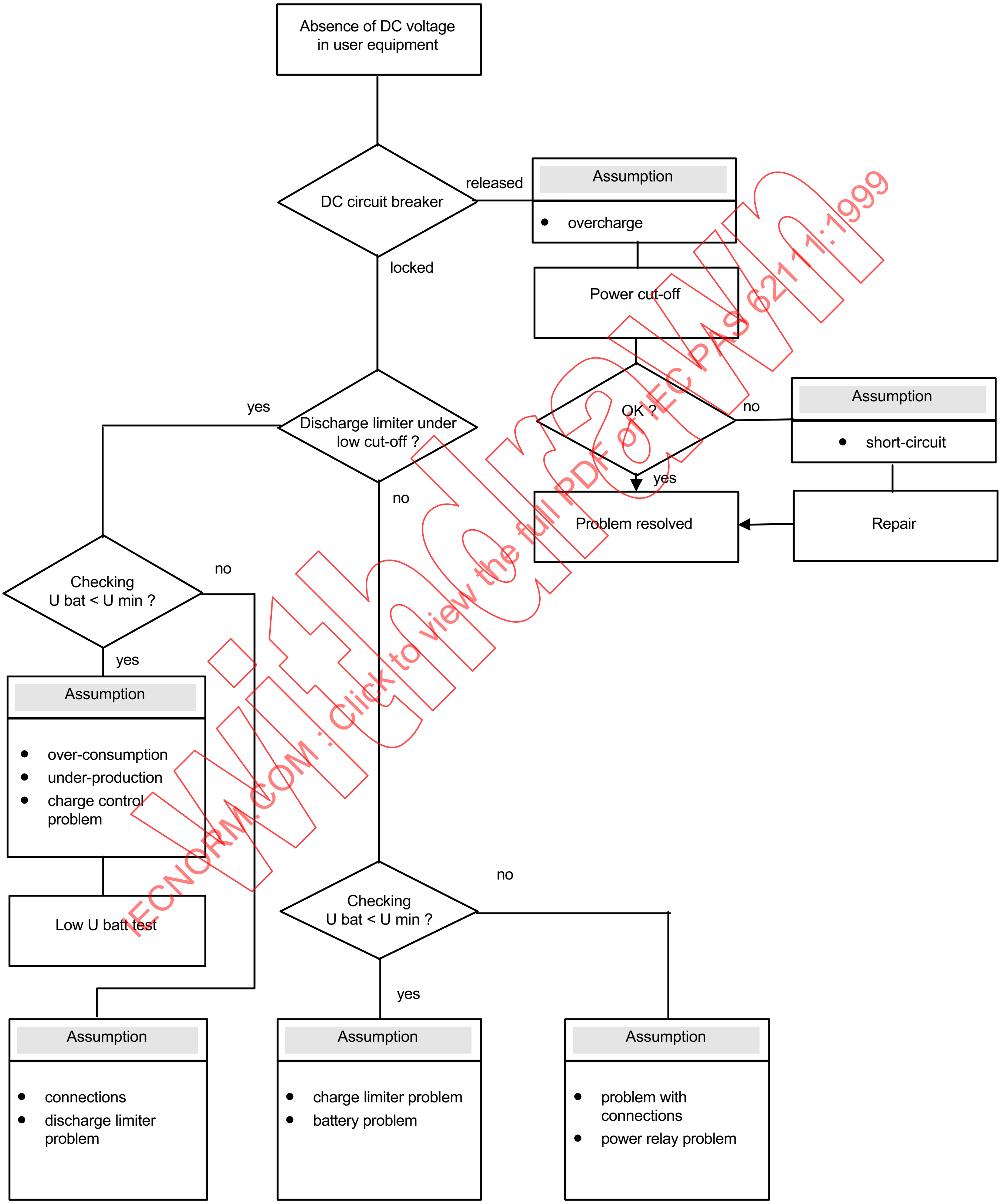
Type 3 (AC user equipment)



Annex 2 - File 3 (contd.) : Fault searches on type 3 installations

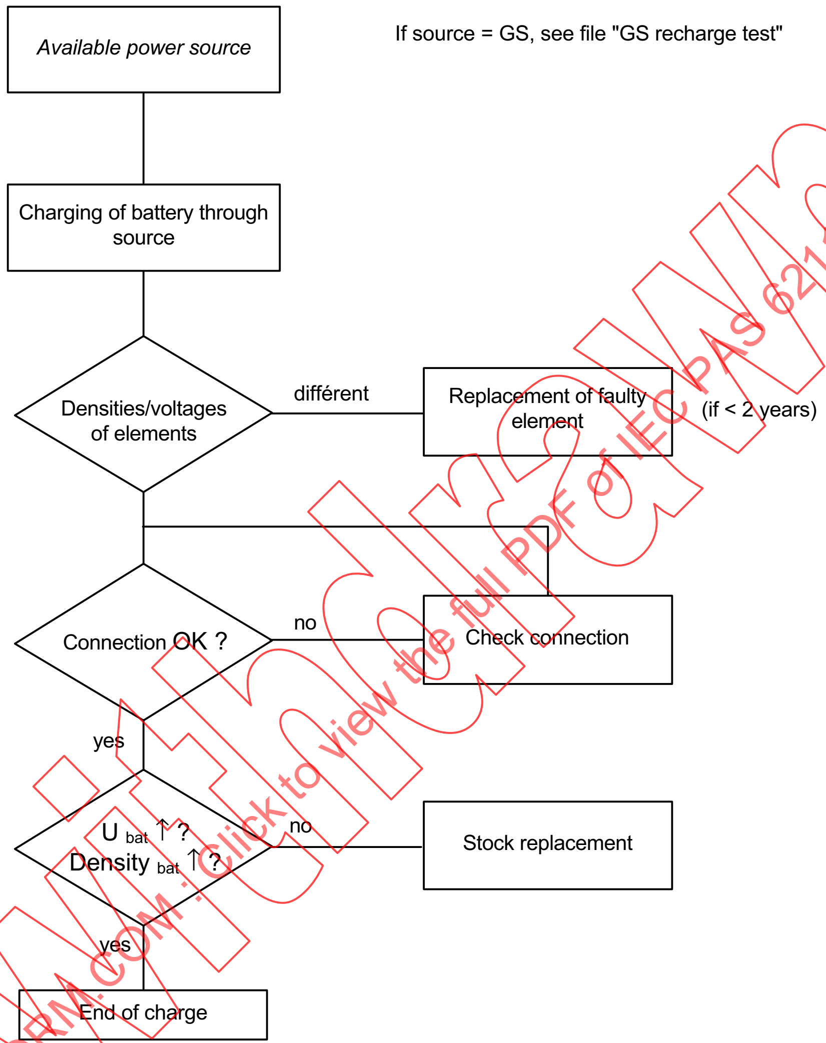
Diagram 2a : Diagram analysing probable causes of installation faults

Type 3 (DC user equipment)



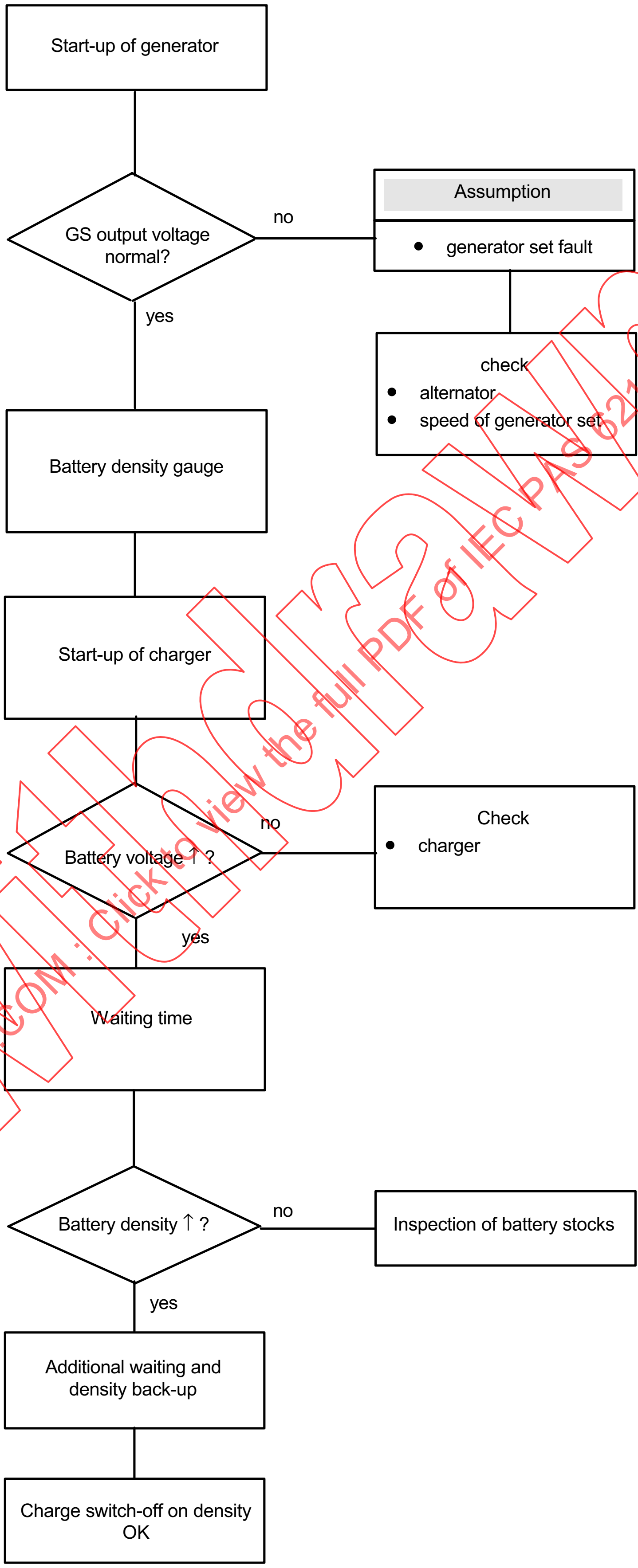
Annex 2 - File 3 (cont) : Fault searches on type 3 installations

Diagram 3 : Inspection of battery stocks



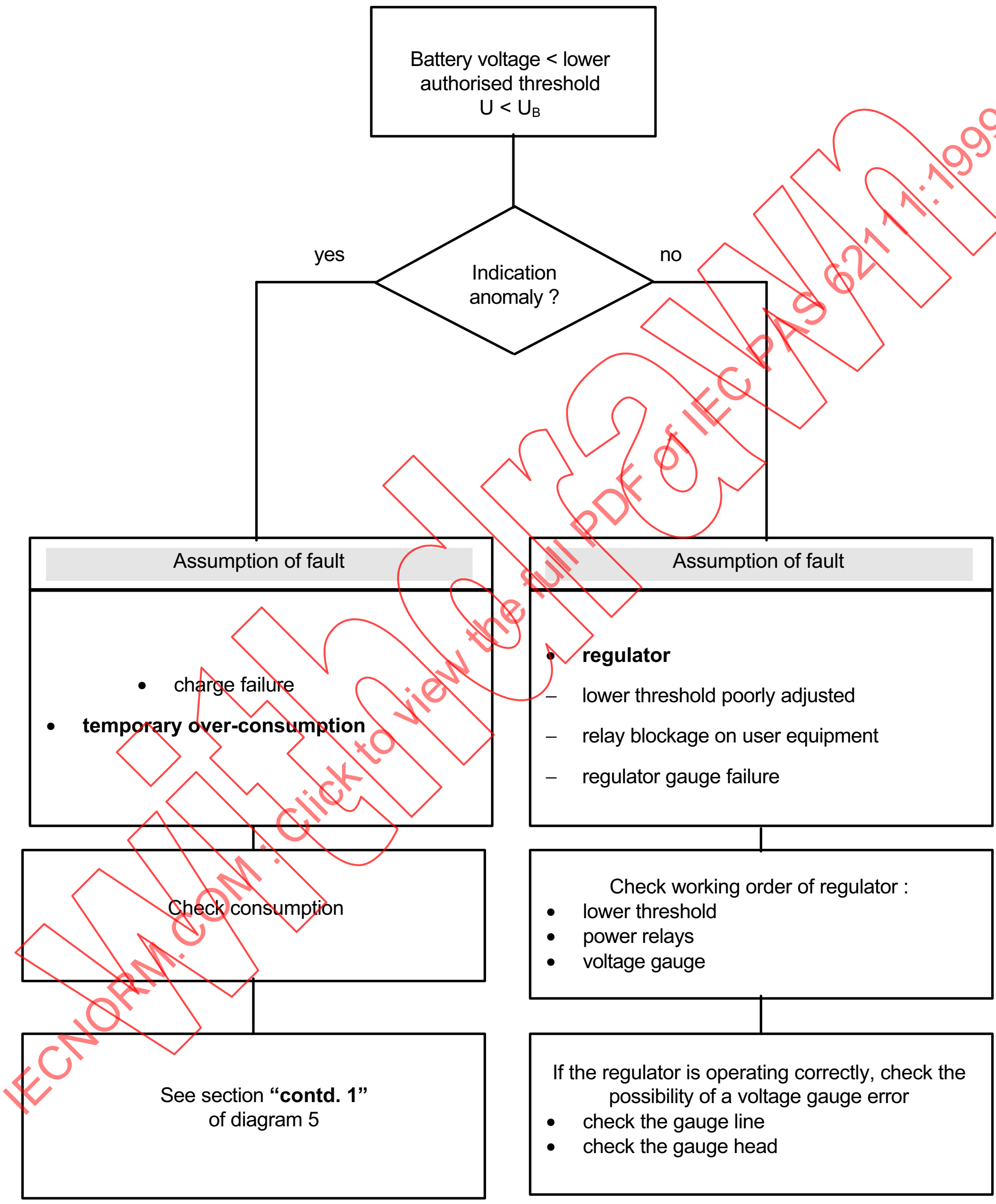
Annex 2 - File 3 (contd.) : Fault searches on type 3 installations

Diagram 4 : Battery recharge test for a generator set



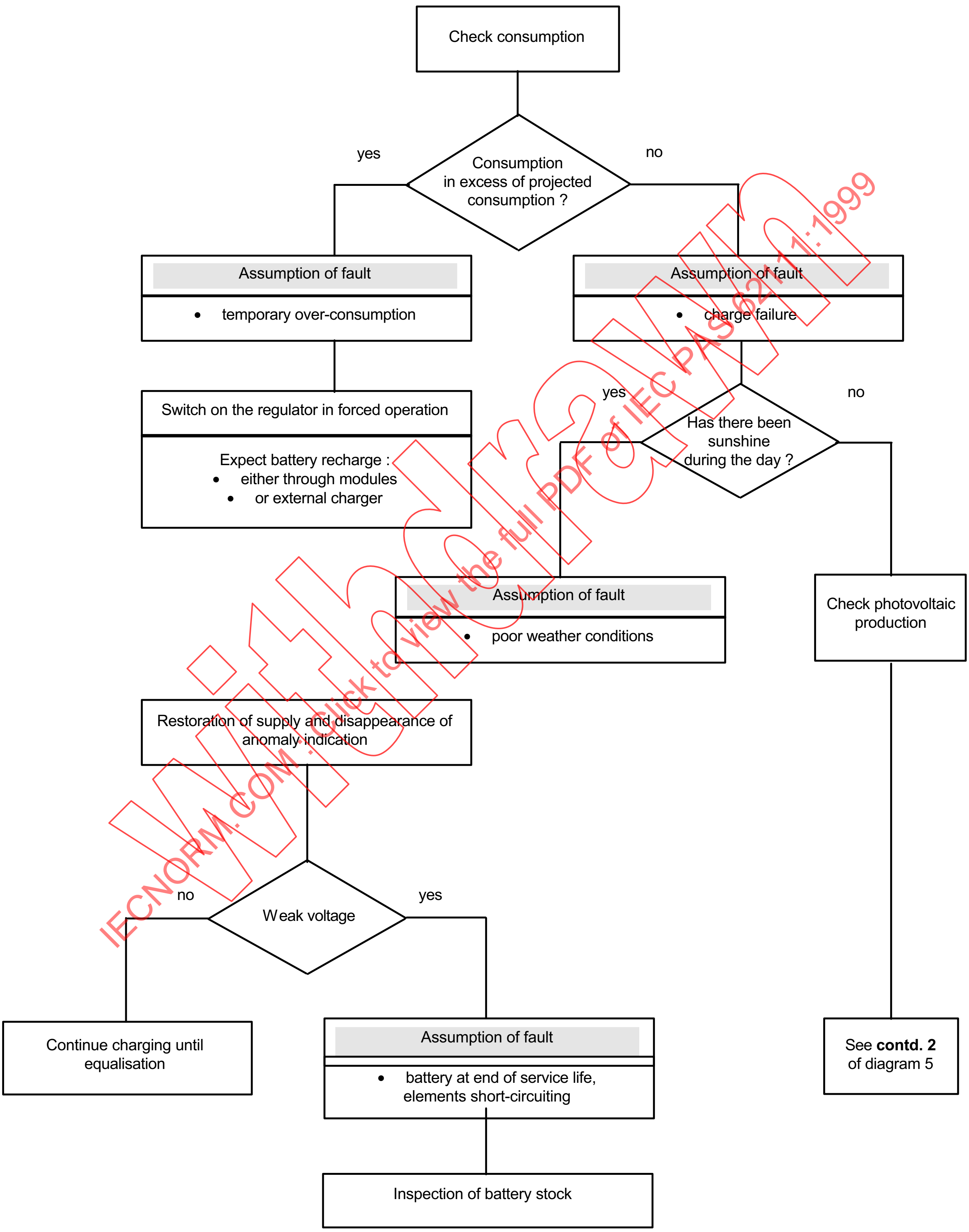
Annex 2 - File 3 (contd.) : Fault searches on type 3 installations

Diagram 5 : Low voltage battery test



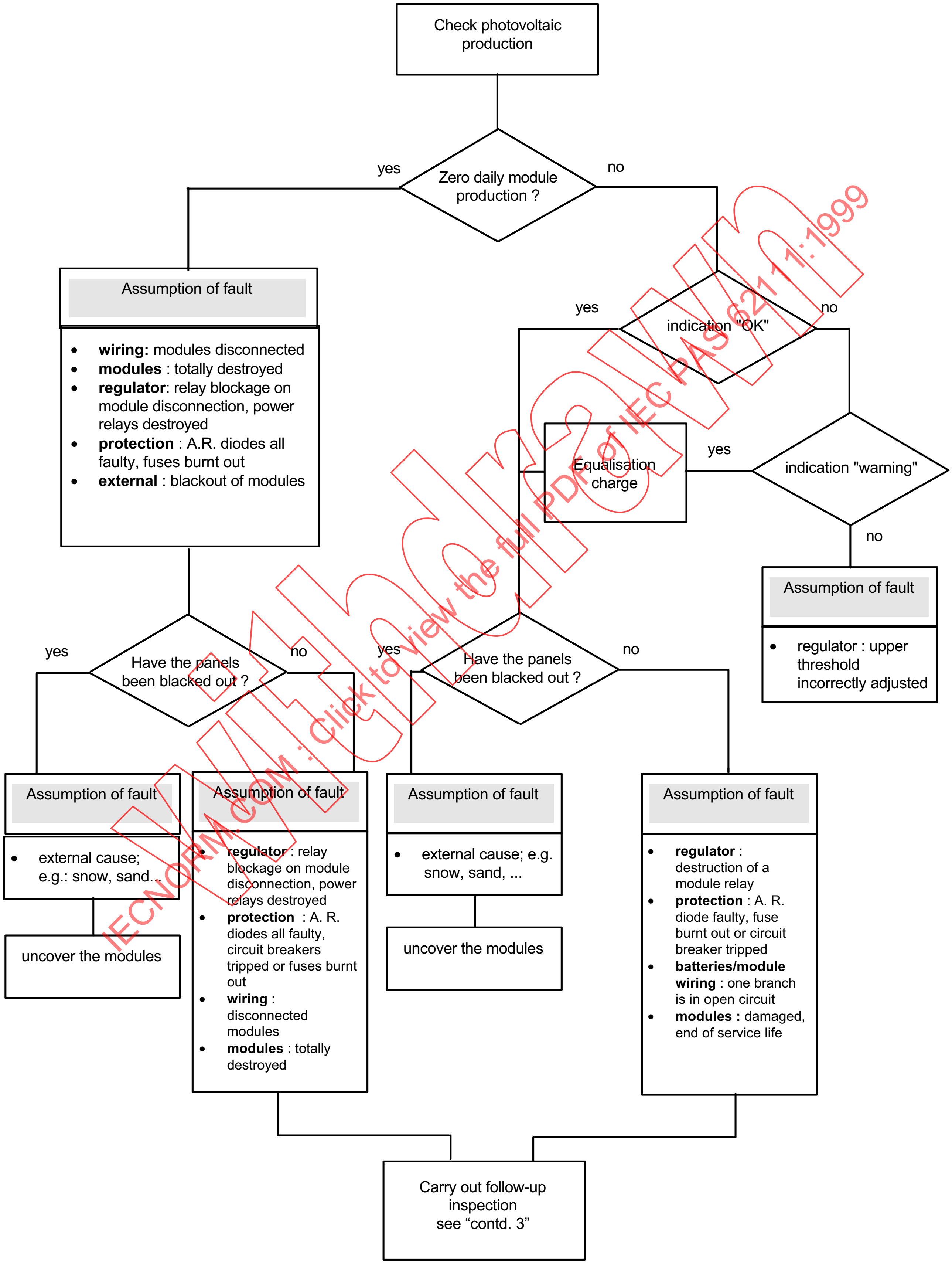
Annex 2 - File 3 (contd.) : Fault searches on type 3 installations

Diagram 5 (contd. 1) : Low voltage battery test



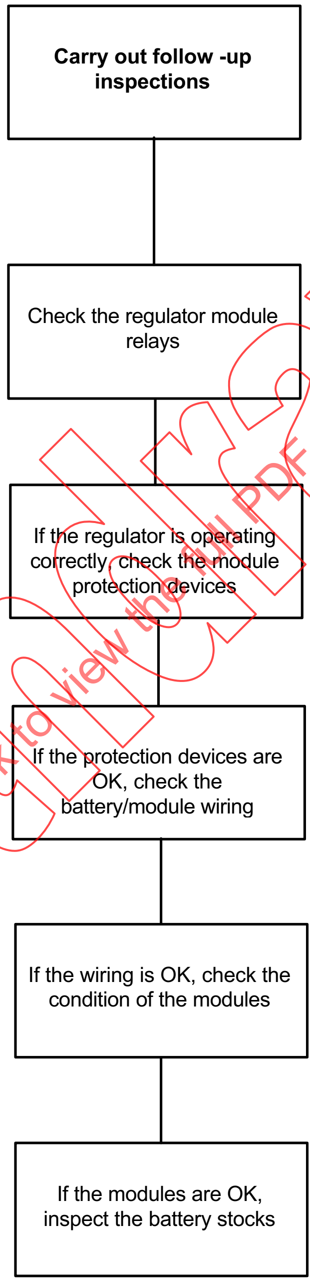
Annex 2 - File 3 (contd.) : Fault searches on type 3 installations

Diagram 5 (contd. 2) : Low voltage battery test



Annex 2 - File 3 (end) : Fault searching for type 3 installations

Diagram 5 (contd. 3) : Low voltage battery test



Annex 3 : Equipment maintenance operations

The maintenance procedures for equipment divide into 7 files :

File 1	Maintenance of photovoltaic array
File 2	Maintenance of wind generators (under study)
File 3	Maintenance of battery
File 4	Maintenance of gauging and control equipment
File 5	Maintenance of converters (under study)
File 6	Maintenance of distribution boards
File 7	Maintenance of generator set

Any operations on equipment must observe the stipulations of annex 4.

Annex 3 - File 1 : Maintenance of photovoltaic array

	Tasks to be carried out			Comments
Items	**inspections**	**operations**	**frequency**	
Panels (modules)	• inspection of cleanliness of each module	• any cleaning with clear water using a sponge	on sight	
	• visual inspection of the sealing on each module		1/year	migration of moisture and oxidising of the connections may occur : indicate this to the installer (to report to the manufacturer)
	• internal inspection of the boxes on each module	• open the boxes • retighten or change the cable gland • seal or change the terminal box • check the diodes if necessary (wing inspection) • check the connection tightening and silicon greasing		
	• inspection of cable clips	• to be replaced if necessary		this inspection must concentrate particularly on the high altitude generators ; do not hesitate to double the cable clips
	• inspection of cable covering	• if change necessary, change it using a cable with the same cross-section and of the same type		cable split or damaged (friction, for example) may have started and ultimately blow N.B. :the external cable routing must preferably be carried out on the north side of the constructions and structures to minimise the attack of solar UV radiation
	• inspection of any underground connections between the generator and the equipment site	• the mechanical protective sleeve allows water in at the ends, seal with silicon		
	• inspection of the interconnection of metallic masses (modules, structures, supports,...)	• if contacts are oxidising, brush them and coat with neutral grease and earth connection gauging		

Annex 3 - File 1 (contd.) : Maintenance of the photovoltaic array

	Tasks to be carried out			Comments
Elements	**inspections**	**operations**	**frequency**	
Panels (fittings)	• inspection of fittings of each module on its support	• retighten the fittings ; in the case of changing the fittings, choose stainless steel bolts with locking devices		the oxidising of the fittings may stem from failing to observe the inter-compatibility of the various metals (:e.g. : galvanised steel on aluminium) ; if necessary change the bolts with stainless steel bolts
	• inspection of fittings of each support	• retighten the fittings of each support between each other and on the ground (or side, post, section, wall..) depending upon the type of assembly chosen		
	• inspection of anchoring on each support	• on the ground or the wall : if the concrete is cracking this indicates the deterioration of the support (concrete incorrectly measured out, for example)		
	• inspection of correct ageing of each section	• arrow gauge • any rust-inhibiting paint or spray galvanisation, where required, after brushing and cleaning the support.		
	• inspection of satisfactory movement of mobile parts	• any greasing (joints, axles..)		
Junction boxes	• checking of the mechanical behaviour of the boxes and their fittings	• re-tightening of fittings		
	• check securing of << branch input >> and << equipment site output >> terminals	• re-securing of terminals		
	• gauge no-load and I_{cc} voltages for each branch			**this measure is effected with the battery circuit breaker open**
	• gauge no-load voltages for each branch module with values different from the others	• also test connection		**see annex 5, file**
	• gauge return and direct voltages for each diode	•		
	• gauge charging voltage of the generator on battery	•		
	• inspect protection against overvoltage	•		

Annex 3 - File 3 : Maintenance of battery

	Tasks to be carried out			Comments
Elements	inspections	operations	frequency	
Battery room	• checking of ventilation systems • checking of securing devices at door entrance • checking of site lighting	• remove any obstructive element • check that it is actually flame/explosion proof in type		
Battery	• cleaning of elements and connections • examination of plates • gauge voltage condition of each element • gauge condition of charge • additional level if necessary • checking of correct behaviour of cables and their identification • restart an equalisation charging sequence on the battery (forced charge) or check the automatic operation of this sequence	• cleaning of lugs and bolts with clear water • re-tightening, greasing • densimeter and thermometer • only distilled water		See annex 5, file 2

Annex 3 - File 4 : Maintenance of gauging and control equipment

	Tasks to be carried out			Comments
Elements	**inspections**	**operations**	**frequency**	
Control box	• internal and external cleaning • re-tightening of power terminals and checking of control terminals • inspection of identification • testing of voltage controller • reading of data acquired • testing of functions • inspection of equipotential connections	• according to type of layout : circuit breaker tests, release coil tests		
Equipment	• inspection of measuring equipment • inspection of regulator	• checking of voltages and currents during connection of modules to the battery (switching on and off of panel circuit breaker) • inspection of threshold adjustment • inspection of fuses and circuit breakers inside the control box • check the operation of the control system • carry out equalisation charging on the battery by locking this function manually on the regulator		This inspection should be carried out on a natural scale by bringing the regulator to the battery voltage level. To do this, a variable autonomous power supply (or power supply installed on the generator inverter, where applicable) is used which will be connected to the regulator's voltage gauge input (control voltage). By exploring the range of voltages liable to be adopted by the battery, an inspection of the correct switching of the discharge limitation and charge relays can be carried out and the validity of the switching thresholds can be checked. The thresholds generally adopted for normal operating conditions are : • forced charge threshold : 2.5 V per element • charge regulating threshold : 2.4 V per element • charge reconnection threshold : 2.15 V per element • discharge limitation threshold : 1.9 V per element • user equip. reconnection threshold : 2.15 V per element

Annex 3 - File 6 : Maintenance of distribution boards

	Tasks to be carried out			Comments
Elements	**inspections**	**operations**	**frequency**	
VLV and LV boxes	• inspection of power and control terminals • inspection of identification tags • testing of all circuit breakers, cut-off elements, source inverters,... • inspection of relay system • checking of calibre of fuses • inspection of equipotential connections	• retighten the terminals • e.g. : start-up test		

Annex 3 - File 7 : Maintenance of generator set

	Tasks to be carried out			Comments
Elements	**inspections**	**operations**	**frequency**	
	• Ensure compliance with generator manufacturers' instructions			

Annex 4 : Operating and maintenance methods

The operating and maintenance methods divide into 8 files :

File 1	Operating and maintenance methods for type 1 installations
File 2	Operating and maintenance methods for type 2 installations (under study)
File 3	Operating and maintenance methods for type 3 installations
File 4	Operating and maintenance methods for type 4 installations (under study)
File 5	Operating and maintenance methods for type 5 installations (under study)
File 6	Operating and maintenance methods for type 6 installations
File 7	Operating and maintenance methods for type 7 installations (under study)
File 8	Operating and maintenance methods for type 8 installations (under study)

Annex 4 - File 1 : Operating and maintenance methods for type 1 installations

The operation and maintenance of type 1 installations cover all operations on the constructions which constitute them, regardless of their nature.

These operations may comprise work of an electrical nature, work of a non-electrical nature, interventions, manoeuvres, measuring, tests, inspections and operations specific to certain constructions.

These operating methods describe and illustrate the rules to be applied for the overall control of the equipment. They should be combined with the diagrams shown in chapter 3.1 of this document.

Type 1 installations can, in the main, operate either :

- with photovoltaic panels and direct current equipment (type T_{1a}) ;
- with a wind generator and alternating current equipment (type T_{1b}) ;
- with photovoltaic panels and alternating current equipment (type T_{1c}) ;
- with a wind generator and direct current equipment (type T_{1d}).

1. General points

Work of an electrical and non-electrical nature is normally carried out with the equipment switched off.

Breakdown repair operations are normally carried out with the equipment switched off.

Some conductor connection and disconnection operations on low power circuits (auxiliary, control, …) may be carried out with the equipment switched on.

No isolation of part of an installation must carried out solely for the purposes of disconnecting power conductors on a terminal.

Any equipment where operating the isolation elements should be prohibited must be provided for through the construction of a device enabling separation.

2. Rules of instruction for type T_{1a} installation equipment

The constructions concerned are either :

- Extra-Low voltage (ELV) in even direct current with : Un (120 V ;
- Low Voltage (LV) in even direct current with : 120 V < Un (750 V.

2.1. Branch of photovoltaic array with dedicated sectioning equipment

The installation parts concerned are : a module, a complete panel or entire branch.

✹ Isolation

1. switch off and lock the cut-off equipment in the array concerned located in the equipment casing immediately above the power controller ;
2. switch off and lock the sectioning equipment from the branch of the array concerned ;
3. check the presence of voltage on the terminals above the sectioning equipment ;
4. cover the array branch concerned ;
5. check the absence of voltage on the terminals above the sectioning equipment.

✹ Repair

1. uncover the array branch concerned ;
2. check for the presence of voltage at the terminals above the sectioning equipment (value and polarity) ;
3. unlock and close the sectioning equipment on the array branch concerned ;
4. unlock and close the cut-off equipment on the array concerned.

2.2. Photovoltaic array

The installation parts concerned are : a module, a complete panel or an entire array and the cable connection.

✹ Isolation

1. switch off and lock the cut-off device of the array concerned located in the equipment casing immediately above the power controller ;
2. check the presence of voltage on the terminals above the cut-off device ;
3. cover the array concerned ;
4. check for the absence of voltage on the terminals above the cut-off device.

✹ Repair

1. uncover the array concerned ;
2. check for the presence of voltage on the terminals above the cut-off device (value and polarity)
3. unlock and close the cut-off equipment on the array concerned.

2.3. *Cable connection between the cut-off device and an item of sectioning equipment dedicated to a photovoltaic array branch*

✹ Isolation

1. switch off and lock the cut-off device of the array concerned located in the equipment casing immediately above the power controller ;
2. switch off and lock the sectioning equipment concerned ;
3. check for the absence of voltage on the terminals above the cut-off device.

✹ Repair

1. unlock and switch on the sectioning equipment concerned
2. unlock and switch on the cut-off equipment concerned

2.4 Sectioning equipment dedicated to a branch of photovoltaic array

✹ Isolation

1. switch off and lock the cut-off device of the array concerned located in the equipment casing immediately above the power controller ;
2. switch off and lock the sectioning equipment of all the branches of the array concerned,
3. cover the branch of the array concerned ;
4. check for the absence of voltage on the terminals above the sectioning device.

✹ Repair

1. uncover the array concerned ;
2. check for the presence of voltage on the terminals above the cut-off device (value and polarity)
3. unlock and switch on the cut-off equipment on the array concerned.

2.5 Power controller

✹ Isolation

1. switch off and lock the cut-off device of the photovoltaic arrays located in the equipment casing immediately above the power controller ;
2. switch off and lock the sectioning equipment located in the sectioning equipment immediately below the power controller ;
1. check for the absence of voltage on the terminals above and below the power controller.

✹ Repair

1. unlock and switch on the sectioning equipment concerned ;
2. unlock and switch on the cut-off equipment on the photovoltaic arrays concerned.

3. Instruction rules on type T_{1b} installation equipment

The constructions concerned are Low Voltage (LV) alternating current in type with : 50 V < Un (500 V.

3.1. Wind generator with or without a dedicated sectioning device

The installation parts concerned are the wind generator, the possible dedicated sectioning device and the connection cable

✸ Isolation

1. reduce the speed of and switch off the wind generator (a wind generator must not run light) ;
2. implement the locking brake ;
3. lock the locking brake ;
4. switch off and lock the cut-off device concerned located in the equipment casing immediately above the power controller ;
5. check for the absence of voltage on the terminals above the cut-off device.

✸ Repair

1. unlock and switch on the cut-off device concerned ;
2. unlock the locking brake ;
3. remove the locking brake.

3.2. Power controller

✸ Isolation

1. reduce the speed of and switch off the wind generator (a wind generator must not run light) ;
2. implement the locking brake ;
3. lock the locking brake ;
4. switch off and lock the cut-off device concerned located in the equipment casing immediately above the power controller ;
5. switch off and lock the sectioning device located in the equipment casing below the power controller ;
6. check for the absence of voltage on the terminals above and below the power controller.

✸ Repair

1. switch off, if necessary, the cut-off devices on the AC user equipment ;
2. unlock and switch on the sectioning device concerned ;
3. unlock and switch on the cut-off device concerned ;
4. unlock the locking brake ;
5. remove the locking brake ;
6. switch on the cut-off devices on the AC user equipment as necessary.

4. Instruction rules for type T_{1c} installation equipment

The constructions concerned are either :

- even direct current Extra-Low voltage (ELV) in type with : Un (120 V ;
- even direct current Low Voltage (LV) in type with : 120 V < Un (750 V,

with regard to some,

or alternating current Low Voltage (LV) in type with : 50 V < Un (500 V for others.

4.1. Branch of photovoltaic array with dedicated sectioning equipment

The installation parts concerned are : a module, complete panel or entire branch.

- Isolation
  1. switch off and lock the cut-off device of the array concerned located in the equipment casing immediately above the power controller ;
  2. switch off and lock the sectioning device on the branch of the array concerned ;
  3. check for the presence of voltage on the terminals above the sectioning device ;
  4. cover the branch of the array concerned ;
  5. check for the absence of voltage on the terminals above the sectioning device.
- Repair
  1. uncover the branch of the array concerned ;
  2. check for the presence of voltage on the terminals above the sectioning equipment (value and polarity) ;
  3. unlock and switch on the sectioning equipment on the branch of the array concerned ;
  4. unlock and switch on the cut-off device on the array concerned.

4.2. Photovoltaic array

The installation parts concerned are : a module, a complete panel or an entire array and a connection cable

- Isolation
  1. switch off and lock the cut-off device of the array concerned located in the equipment casing immediately above the power controller ;
  2. check for the presence of voltage on the terminals above the cut-off device ;
  3. cover the array concerned ;
  4. check for the absence of voltage on the terminals above the cut-off device.
- Repair
  1. uncover the array concerned ;
  2. check for the presence of voltage on the terminals above the cut-off device (value and polarity) ;
  3. unlock and switch on the cut-off device on the array concerned.

4.3. Connection cable between the cut-off device and an item of sectioning equipment dedicated to a branch of photovoltaic array

- Isolation
  1. switch off and lock the cut-off device concerned located in the equipment casing immediately above the power controller ;
  2. check for the presence of voltage in the terminals above the cut-off device ;
  3. cover the array concerned ;
  4. check for the absence of voltage on the terminals above the cut-off device.
- Repair
  1. uncover the array concerned ;
  2. check for the presence of voltage on the terminals above the cut-off device (value and polarity)
  3. unlock and switch on the cut-off device on the array concerned.

4.4. Branch of photovoltaic array with dedicated sectioning equipment

The installation parts concerned are : a module, complete panel or entire branch.

✸ Isolation

1. switch off and lock the cut-off device of the array concerned located in the equipment casing immediately above the power controller ;
2. switch off and lock the sectioning devices on the branches of the array concerned ;
3. cover the branch of the array concerned ;
4. check for the absence of voltage on the terminals above the sectioning device.

✸ Repair

1. uncover the branch of the array concerned ;
2. unlock and switch on the sectioning equipment on all branches of the array concerned ;
3. unlock and switch on the cut-off device on the array concerned.

4.5. Power controller

✸ Isolation

1. switch off and lock the cut-off device of the photovoltaic arrays concerned located in the equipment casing immediately above the power controller ;
2. switch off and lock the sectioning equipment located in the equipment casing immediately below the power controller ;
3. check for the absence of voltage on the terminals above and below the power controller.

✸ Repair

1. unlock and switch on the sectioning equipment concerned ;
2. unlock and switch on the cut-off devices on the photovoltaic arrays concerned.

4.6. DC/AC converter (inverter)

✸ Isolation

1. switch off and lock the cut-off devices concerned located in the equipment casing immediately above the power controller ;
2. switch off and lock the sectioning device(s) in the equipment casing immediately above the inverter ;
3. switch off and lock the sectioning device(s) in the equipment casing immediately below the inverter ;
4. discharge the condensers in the DC section of the inverter ;
5. check for the absence of voltage on the terminals above and below the inverter.

✸ Repair

1. unlock and switch on the sectioning device located immediately above the inverter ;
2. unlock and switch on the sectioning device(s) located immediately below the inverter ;
3. unlock and switch on the cut-off devices on the photovoltaic arrays concerned.

5. Instruction rules for type T_{1d} installation equipment

The constructions concerned are either :

- even direct current Extra-Low voltage (ELV) in type with : Un (120 V ;
- even direct current Low Voltage (LV) in type with : 120 V < Un (750 V,

with regard to some,

or alternating current Low Voltage (LV) in type with : 50 V < Un (500 V for others.

5.1. Wind generator with or without a dedicated sectioning device

The installation parts concerned are the wind generator, the possible dedicated sectioning device and the connection cable

✸ Isolation

1. reduce the speed of and switch off the wind generator (a wind generator must not run light) ;
2. implement the locking brake ;
3. lock the locking brake ;
4. switch off and lock the cut-off device concerned located in the equipment casing immediately above the power controller ;
5. check for the absence of voltage on the terminals above the cut-off device.

✸ Repair

1. unlock and switch on the cut-off device concerned ;
2. unlock the locking brake ;
3. remove the locking brake.

3.2. Power controller

✸ Isolation

1. reduce the speed of and switch off the wind generator (a wind generator must not run light) ;
2. implement the locking brake ;
3. lock the locking brake ;
4. switch off and lock the cut-off device concerned located in the equipment casing immediately above the power controller ;
5. switch off and lock the sectioning device located in the equipment casing below the power controller ;
6. check for the absence of voltage on the terminals above and below the power controller.

✸ Repair

1. switch off, if necessary, the cut-off devices on the DC user equipment ;
2. unlock and switch on the sectioning device concerned ;
3. unlock and switch on the cut-off device concerned ;
4. unlock the locking brake ;
5. remove the locking brake ;
6. switch on the cut-off devices on the DC user equipment as necessary.

5.3. AC/DC converter (rectifier)

✸ Isolation

1. reduce the speed of and switch off the wind generator (a wind generator must not run light) ;
2. implement the locking brake ;
3. lock the locking brake ;
4. switch off and lock the cut-off devices concerned located in the equipment casing immediately above the power controller ;
5. switch off and lock the sectioning device in the equipment casing immediately above the rectifier
6. switch off and lock the sectioning device(s) in the equipment casing immediately below the rectifier ;
7. discharge the condensers in the DC section of the rectifier ;
8. check for the absence of voltage on the terminals above and below the rectifier.

✸ Repair

1. switch off, if necessary, the cut-off devices on the DC user equipment,
2. unlock and switch on the sectioning device located immediately above the rectifier ;
3. unlock and switch on the sectioning device(s) located immediately below the rectifier ;

4. unlock and switch on the cut-off device concerned ;
5. unlock the locking brake ;
6. remove the locking brake ;
7. switch on the cut-off equipment on the DC installations as necessary.

Annex 4 - File 3 : Operating and maintenance methods for type 3 installations

The operation and maintenance of type 3 installations cover all operations on the constructions which constitute them, regardless of their nature.

These operations may comprise work of an electrical nature, work of a non-electrical nature, interventions, manoeuvres, measuring, tests, inspections and operations specific to certain constructions.

These operating methods describe and illustrate the rules to be applied for the overall control of the equipment, the changing of the operating layout and cut-off for non-payment. They should be combined with the diagrams shown in chapter 3.13 of this document.

1. Rules of instruction for equipment

The constructions concerned are either :

- even direct current Extra-Low voltage (ELV) with : Un (120 V ;
- alternating current Low Voltage (LV) with : 50 V < Un ≤ 500 V ;
- even direct current Low Voltage (LV) with : 120 V < Un (750 V.

Work of an electrical and non-electrical nature is normally carried out with the equipment switched off.

Breakdown repair operations are normally carried out with the equipment switched off.

Some conductor connection and disconnection operations on low power circuits (auxiliary, control, …) may be carried out with the equipment switched on.

No isolation of part of an installation must carried out solely for the purposes of disconnecting power conductors on a terminal.

Any equipment where operating the isolation elements should be prohibited must be provided for through the construction of a device enabling separation.

1.1. Branch of photovoltaic array with a dedicated sectioning equipment

The installation parts concerned are : a module, a complete panel or entire branch.

✹ Isolation

1. switch off and lock the cut-off equipment in the array concerned located immediately above the charge regulator in the equipment casing ;
2. switch off and lock the sectioning equipment from the branch of the array concerned ;
3. check the presence of voltage on the terminals above the sectioning equipment ;
4. cover the branch of the array concerned ;
5. check the absence of voltage on the terminals above the sectioning equipment.

✹ Repair

1. uncover the array branch concerned ;
2. check for the presence of voltage at the terminals above the sectioning equipment (value and polarity) ;
3. unlock and switch on the sectioning equipment on the branch of the array concerned ;
4. unlock and switch on the cut-off equipment of the array concerned.

1.2. Photovoltaic array

The installation parts concerned are : a module, a complete panel or an entire array and the cable connection.

✹ Isolation

1. switch off and lock the cut-off device of the array concerned located immediately above charge regulator in the equipment casing ;
2. check the presence of voltage on the terminals above the cut-off device ;
3. cover the array concerned ;
4. check for the absence of voltage on the terminals above the cut-off device.

- Repair
  1. uncover the array concerned ;
  2. check for the presence of voltage on the terminals above the cut-off device (value and polarity)
  3. unlock and switch on the cut-off equipment on the array concerned.

1.3 Cable connection between the cut-off device and an item of sectioning equipment dedicated to a photovoltaic array branch

- Isolation
  1. switch off and lock the cut-off device of the array concerned located immediately above the charge regulator in the equipment casing ;
  2. switch off and lock the sectioning equipment concerned ;
  3. check for the absence of voltage on the terminals above the cut-off device.
- Repair
  1. unlock and switch on the sectioning equipment concerned
  2. unlock and switch on the cut-off equipment concerned

1.4 Sectioning equipment dedicated to a branch of photovoltaic array

- Isolation
  1. switch off and lock the cut-off device of the array concerned located immediately above the charge regulator in the equipment casing ;
  2. switch off and lock the sectioning equipment of all the branches of the array concerned,
  3. cover the branch of the array concerned ;
  4. check for the absence of voltage on the terminals above the sectioning device.
- Repair
  1. uncover the branch of the array concerned ;
  2. unlock and switch on the sectioning equipment of all the branches of the array concerned ;
  3. unlock and switch on the cut-off equipment on the array concerned.

1.5. Wind generator with or without a dedicated sectioning device

The installation parts concerned are the wind generator, the possible dedicated sectioning device and the connection cable

- Isolation
  1. reduce the speed of and switch off the wind generator (a wind generator must not run light) ;
  2. implement the locking brake ;
  3. lock the locking brake ;
  4. switch off and lock the cut-off device concerned located immediately above the charge regulator in the equipment casing ;
  5. check for the absence of voltage on the terminals above the cut-off device.
- Repair
  1. unlock and switch on the cut-off device concerned ;
  2. unlock the locking brake ;
  3. remove the locking brake.

1.6. Battery

✸ ✸ ✸ Isolation

1. switch off and lock the cut-off devices of the photovoltaic arrays located immediately above the charge regulator in the equipment casing ;
2. switch off and lock the sectioning device of the photovoltaic arrays located in the coupling board[1] below the charge regulator ;
3. switch off and lock the sectioning equipment of the battery located in the equipment casing.

✸ Repair

1. unlock and switch on the sectioning equipment of the battery located in the equipment casing ;
2. unlock and switch on the sectioning equipment of the photovoltaic arrays located in the coupling board ;
3. check for the presence of voltage on the terminals below the cut-off devices of the photovoltaic arrays located immediately above the charge regulator in the equipment casing ;
4. unlock and switch on the cut-off device on the photovoltaic arrays.

1.7. Charge regulator

✸ Isolation

1. switch off and lock the cut-off devices on the photovoltaic arrays located immediately above the charge regulator in the equipment casing ;
2. switch off and lock the sectioning equipment of the photovoltaic arrays located in the coupling board below the charge regulator ;
3. switch off the charge regulator gauge circuit ;
4. check for the absence of voltage on the terminals above and below the charge regulator.

✸ Repair

1. switch on the charge regulator gauge circuit ;
2. unlock and switch on the sectioning devices of the photovoltaic arrays located in the coupling board above the charge regulator ;
3. unlock and switch on the cut-off devices of the photovoltaic arrays located immediately above the charge regulator in the equipment casing.

[1] According to the functions and layout of the control system

1.8. AC/DC converter of the wind generator

✸ Isolation

1. reduce the speed of and switch off the wind generator (a wind generator must not run light) ;
2. implement the locking brake ;
3. lock the locking brake ;
4. switch off and lock the cut-off devices concerned located immediately above the rectifier in the equipment casing ;
5. switch off and lock the sectioning device of the wind generator located in the coupling board below the rectifier ;
6. check for the absence of voltage on the terminals above and below the rectifier ;
7. switch off the possible gauge circuit ;
8. discharge the DC converter section condensers.

* Repair
    1. switch on the possible gauge circuit ;
    2. unlock and switch on the sectioning device on the wind generator located in the coupling board below the rectifier ;
    3. unlock and switch on the cut-off device on the wind generator located immediately above the rectifier in the equipment casing ;
    4. unlock the locking brake ;
    5. remove the locking brake.

1.9. AC/DC converter on the generator set (battery charger)

* Isolation
    1. switch off and lock the cut-off device of the generator set located immediately above the rectifier in the equipment casing ;
    2. switch off and lock the sectioning device of the generator set located in the coupling board below the rectifier ;
    3. check for the absence of voltage on the terminals above and below the rectifier ;
    4. switch off the possible gauge circuit ;
    5. discharge the DC section condensers of the charger.

* Repair
    1. switch on the possible gauge circuit ;
    2. unlock and switch on the sectioning device of the generator set located in the coupling board below the rectifier ;
    3. unlock and switch on the cut-off device of the generator set immediately above the rectifier in the equipment casing ;

1.10 Coupling board

* Isolation
    1. switch off and lock the cut-off equipment on the power supply for the AC and DC boards located in the equipment casing ;
    2. switch off and lock the cut-off equipment in the photovoltaic arrays located immediately above the charge regulator in the equipment casing ;
    3. switch off and lock the sectioning equipment of the photovoltaic arrays located in the coupling board below the charge regulator ;
    4. switch off and lock the cut-off equipment of the generator set located immediately above the rectifier in the equipment casing ;
    5. check the absence of voltage on the terminals above the sectioning equipment of the generator set located in the coupling board ;
    6. reduce the speed of and switch off the wind generator ;
    7. implement the locking brake ;
    8. lock the locking brake ;
    9. switch off and lock the cut-off device of the wind generator immediately above the rectifier in the equipment casing ;
    10. check for the absence of voltage on the terminals above the sectioning equipment of the wind generator located in the coupling board ;
    11. check for the absence of voltage on the terminals above the sectioning equipment of the photovoltaic arrays located in the coupling table ;
    12. switch off and lock the sectioning device of the battery located in the equipment casing ;
    13. check for the absence of voltage below the coupling board.

✸ Repair

1. unlock and switch on the sectioning device of the battery located in the equipment casing ;
2. unlock and switch on the cut-off device of the wind generator located immediately above the rectifier in the equipment casing ;
3. unlock the locking brake of the wind generator ;
4. remove the locking brake ;
5. unlock and switch on the cut-off device of the generator set located immediately above the rectifier in the equipment casing ;
6. unlock and switch on the sectioning device of the photovoltaic arrays located in the coupling board below the charge regulator ;
7. check for the presence of voltage on the terminals below the cut-off devices of the photovoltaic arrays located immediately above the charge regulator in the equipment casing ;
8. unlock and switch on the cut-off devices of the photovoltaic arrays ;
9. unlock and switch on the sectioning devices of the power supply for the AC and DC boards located in the equipment casing.

1.11 DC/AC converter (inverter)

✸ Isolation

1. switch off and lock the cut-off device of the power supply of the AC board located in the equipment casing ;
2. switch off the cut-off equipment of the power supply of the DC board located in the equipment casing ;
3. switch off and lock the cut-off equipment in the photovoltaic arrays located immediately above the charge regulator in the equipment casing ;
4. switch off and lock the sectioning device of the photovoltaic arrays located in the coupling board below the charge regulator ;
5. switch off and lock the cut-off equipment of the generator set located immediately above the rectifier in the equipment casing ;
6. check for the absence of voltage on the terminals above the sectioning equipment of the generator set located in the coupling board ;
7. reduce the speed of and switch off the wind generator ;
8. implement the locking brake ;
9. lock the locking brake ;
10. switch off and lock the cut-off devices on the wind generator located immediately above the rectifier in the equipment casing ;
11. check for the absence of voltage on the terminals above the sectioning equipment of the wind generator located in the coupling board ;
12. check for the absence of voltage on the terminals above the sectioning equipment of the photovoltaic arrays located in the coupling board ;
13. switch off and lock the sectioning equipment of the battery located in the equipment casing ;
14. check for the absence of voltage below the coupling board ;
15. switch off and lock the sectioning device located immediately above the inverter ;
16. discharge the condensers in the DC section of the inverter ;

✹ Repair

1. unlock and switch on the sectioning device located immediately above the inverter ;
2. unlock and switch on the sectioning device of the battery in the equipment casing ;
3. unlock and switch on the cut-off device of the wind generator located immediately above the rectifier in the equipment casing ;
4. unlock the locking brake of the wind generator ;
5. remove the locking brake ;
6. unlock and switch on the cut-off device of the generator set located immediately above the rectifier in the equipment casing ;
7. unlock and switch on the sectioning device of the photovoltaic arrays located in the coupling board below the charge regulator ;
8. check for the presence of voltage on the terminals below the cut-off devices of the photovoltaic arrays located immediately above the charge regulator in the equipment casing ;
9. unlock and switch on the cut-off devices in the photovoltaic arrays ;
10. switch on the cut-off equipment on the DC board power supply located in the equipment casing ;
11. unlock and switch on the cut-off device of the AC board power supply located in the equipment casing

Note. - In order to maintain the power supply of the DC board during operations on the DC/AC converter (to power the safety equipment, for example), it is possible to reconnect the battery to the coupling board (operations 2 and 10 of the "Repair" phase.

It is, however, necessary to carry out operations 2 and 13 of the "Isolation" phase prior to full repair by in following the entire procedure.

2. Changes to the operating layout

The changes to the operating layout are made from the GS board located in the user site. The inter-locking devices of the cut-off equipment on the GS board are designed so that, regardless of the layout adopted, under no circumstances can the GS convert to the AC board via the rectifier and inverter of the renewable energy-based production installation.

The basic operating layout is the one corresponding to the AC and DC boards power supply effected solely from the renewable energy-based production installation.

The corresponding position of the cut-off equipment on the GS board is shown in figure 1.

The power supply of the dedicated user equipment is independent of the various operating layouts applied.

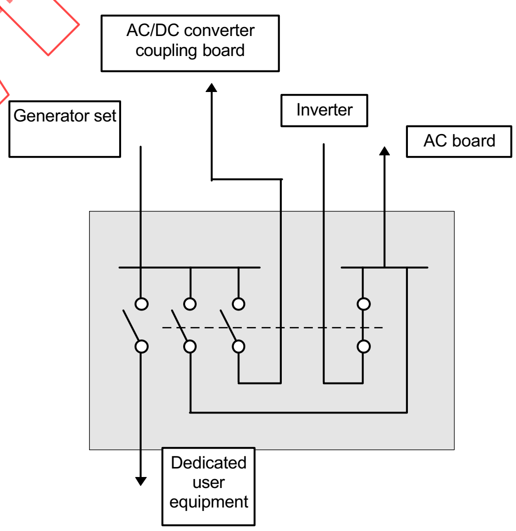


Figure 1 : Position of the GS board cut-off equipment in the basic operational layout

2.1. Power supply of the AC board from the generator set alone

This configuration may be required through the unavailability of the renewable energy-based production installation for work, maintenance operations or cut-off for non payment.

The corresponding position of the GS board cut-off equipment is shown in figure 2.

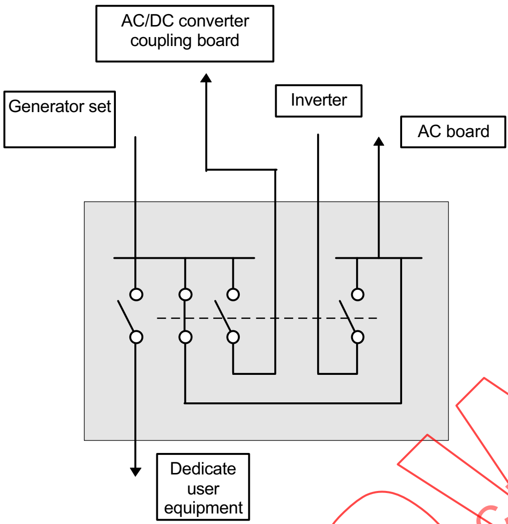


Figure 2 : Position of the GS board cut-off equipment for an AC board power supply from the GS alone.

2.2. Battery charging and possible powering of the DC board

This configuration may be used when the battery has to be recharged after a long period during which renewable energy sources are unavailable, for example.

In relation to the requirements, the DC board in the user site must also be powered.

The corresponding position of the GS board cut-off equipment is shown in figure 3.

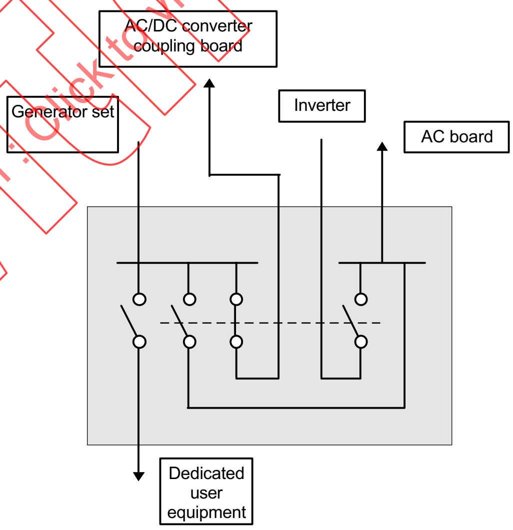


Figure 3 : Position of the GS board cut-off equipment for charging the battery from the GS alone

2.3 Powering the AC board and charging the battery

This configuration comprises the two preceding configurations simultaneously.

The corresponding position of the cut-off equipment of the GS board is shown in figure 4.

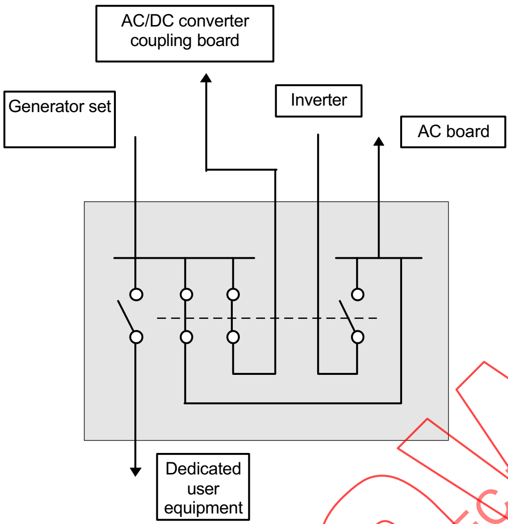


Figure 4 : Position of GS board cut-off equipment
for powering the AC board and charging the battery from the GS alone

By agreement with the operations administrator, during work or maintenance operations, other configurations enabling the partial re-powering of the installation may be used.

They should be subject to a specific study and specific operating methods must be prepared.

3. Cut-off (disconnection) for non-payment

Cut-off for non-payment is carried out by a duly authorised operator using the cut-off equipment positioned above the user site on the power supply of the AC and DC boards.

This cut-off equipment is located in the equipment casing and must be lead-sealable.

The equipment casing is closed by an appropriate device (lock for a room or cupboard, triangle or square for a box). It must be accessible under any circumstances without the operator being forced to enter private property.

The re-setting of the power supply can only be carried out from the cut-off equipment by an equally authorised operator.

Annex 5 : Operating methods for testing the condition of equipment (under study)

Annex 6 : Analysis procedure for service provision compliance

The analysis of the compliance of the service provided comprises :

- the checking of the dynamic operation of the installation on acceptance
- the checking of the observance of the contractual engagements in the event of a complaint on the part of the clients.
-

1. Dynamic operation of the installation on acceptance

This paragraph is covered by the annex on acceptance tests for installations.

2. Observance of contractual engagements in the event of a complaint on the part of the clients

Table 4 of document DRE - A2 : "Expected results of the sizing process of a system" shows the contractual engagements between the Project Supervisor and the Project Supervisor in relation to the various types of systems defined for the installation categories.

The checking of the observance of the engagements presupposes the capability of preparing an energy balance report for the period covered by the contract. The actual operation relevant to this are detailed in table 7 in relation to the type of system.

Table 1 : Checking of the observance of contractual engagements

Type of system	Action
T1	• Comparison between the weekly (or monthly) power gauged with that defined in the contract. This comparison requires metering the power consumed through the renewable energy powered process or gauging the results from the process, e.g. water metering.
T2	• Comparison between the weekly power gauged with that defined in the contract. This comparison requires metering of the AC power and DC power consumed by the client
T3	• Comparison between the weekly power gauged with that defined in the contract. This comparison requires metering of the AC power and DC power consumed by the client • Comparison of the portion produced by the generator set in relation to that produced from the renewable energy sources. This comparison requires the metering of the DC power produced from the generator set and rectified and the DC power produced from the renewable energy sources : what is the share of fuel used to charge the battery then consumed and metered as electricity ? This share must be identified in order to be deducted from the total DC power consumed.
T4	to be defined
T5	to be defined
T6	to be defined
T7	to be defined
T8	to be defined

DRE SPECIFICATIONS - C 1

June 1997

Title

Part C - Technical specification of components

Section 1 : Photovoltaic array

Number of pages 15 (including annexes)

Type Technical specification of components

Associated document(s)

Abstract This document contains all the certification and implementation conditions for photovoltaic arrays used in decentralised rural electrification.

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CONTENTS

1. Scope of application

This document defines the main specifications to be met by photovoltaic arrays used for providing power at isolated locations.

The photovoltaic arrays involved consist of photovoltaic modules with neither concentrator nor reflector.

2. Reference standards and regulations

2.1 Standards established by the CEI

CEI 68-2-1 : 1990, Fundamental climatic and mechanical strength tests - 2nd Part - Tests - Test A : Cold (NF C 20-701) ;

CEI 68-2-2 : 1974, 1976, Fundamental climatic and mechanical strength tests - 2nd Part - Tests - Test B : Dry heat (NF C 20-702) ;

CEI 68-2-3 : 1969, Fundamental climatic and mechanical strength tests - 2nd Part - Tests - Test Ca : Continuous humid heat test (NF C 20-703) ;

CEI 68-2-11 : 1981, Fundamental climatic and mechanical strength tests - 2nd Part - Tests - Test Ka : Salt mist (NF C 20-711) ;

CEI 68-2-13 : 1983, Fundamental climatic and mechanical strength tests - 2nd Part - Tests - Test M : Low atmospheric pressure (NF C 20-713) ;

CEI 68-2-14 : 1984, 1986, Fundamental climatic and mechanical strength tests - 2nd Part - Tests - Test N : Temperature variations (NF C 20-714) ;

CEI 68-2-21 : 1983, 1991, 1992, Fundamental climatic and mechanical strength tests - 2nd Part - Tests - Test U : Strength of outputs and fixing devices (NF C 20-721) ;

CEI 68-2-30 : 1980, 1985, Fundamental climatic and mechanical strength tests - 2nd Part - Tests - Test Db and guide : Cyclic humid heat test (12 h + 12 h) (NF C 20-730) ;

CEI 68-2-38 : 1974, Fundamental climatic and mechanical strength tests - 2nd Part - Tests - Test Z/AD : Composite cyclic temperature and humidity test ;

CEI 68-2-61 : 1991, Fundamental climatic and mechanical strength tests - 2nd Part - Tests - Test Z/ABDM : Climatic sequence (NF C 20-761) ;

CEI 167 : 1964, Measurement of full insulation resistance (NF C 26-210) ;

CEI 529 : 11/89, Grade of protection provided by covering (Code IP) ;

CEI 695-2-1 : 1994, Tests relating to fire hazards - Test methods - Incandescent wire test and guide (NF C 20-455) ;

CEI 721-2-1 : 1982, 1987, Classification of environmental conditions - 2nd Part - Environmental conditions occurring in nature : Temperature and humidity (NF C 20-000) ;

CEI 891 : 1987, 1992, Procedures for corrections according to temperature and irradiance to be applied to the measured I-V characteristics of crystalline silicon photovoltaic devices (NF C 57-104 02/1995) ;

CEI 904-1 : 1987, Photovoltaic devices - 1st part : Measurement of current-voltage characteristics of solar photovoltaic devices (NF C 57-321) ;

CEI 904-3 : 1989, Photovoltaic devices - 3rd part : Measurement principles for solar photovoltaic (PV) devices for surface use, including reference data for spectral irradiance (NF C 57-323) ;

CEI 904-4 : 1994, Photovoltaic devices ;

CEI 904-5 : 1993, Photovoltaic devices - 5th part : Determination of equivalent cell temperature (ECT) of photovoltaic devices (PV) by the open circuit voltage method (NF C 57-325 de 09/1996) ;

CEI 904-6 : 1994 Photovoltaic devices - 6th part : Requirements relating to solar reference modules (NF C 57-326 de 09/1996) ;

CEI 904-7 : 1995, Photovoltaic devices - 7th part : Calculation of mismatch error for spectral responses in tests on a photovoltaic device ;

CEI 904-8 : 1995, Photovoltaic devices - 8th part : Guide for measuring spectral response of a photovoltaic device (PV)

CEI 904-9 : 1995, Photovoltaic devices - 9th part : Requirements for operation of solar stimulators ;

CEI 1006 : 1991, Test methods for establishing vitreous transition temperature of electrical insulating materials (NF EN 61006) ;

CEI 1173 : 08/1992, Protection against voltage surges on photovoltaic (PV) energy production systems- Guide (NF EN 61173, classification C 57-331) ;

CEI 1194 : 12/1994, Descriptive parameters of independent photovoltaic systems ((UTE C 57-300) ;

CEI 1215 : 04/1993, photovoltaic modules (PV) in crystalline silicon for terrestrial applications - Qualification of design and certification ;

CEI 1277 : 1995, Surface-based photovoltaic systems (PV) - General points and guide ;

CEI 1646 : 1996, Thin film photovoltaic modules (PV) for terrestrial applications - Qualification of design and certification ;

CEI 1701 : 03/1995, Salt mist corrosion test on photovoltaic modules (PV) ;

CEI 1721 : 03/1995, Sensitivity of a photovoltaic module to damage through accidental impact (resistance to impact test) ;

CEI 1829 : 03/1995, crystalline silicon photovoltaic modules (PV) arrays - Measurement of characteristics I-V on site.

2.2 ISO standards

ISO 62 : 01/1980, Plastics - Determination of water absorption (NF T 51-166) ;

NF EN ISO 75-1 à 75-3 : 03/1996, Plastics - Determination of flexing temperature under load (NF T 51-005) ;

ISO 178 : 05/1993, Plastics - Determination of bending properties (NF T 51-001) ;

ISO 179 : 08/1993, Plastics - Determination of resistance to Charpy impact test (NF T 51-035) ;

ISO 1183 : 02/1971, Methods for determining the density of solid state products, apart from cellular products (NF T 51-063) ;

NF ISO 1210 : 09/1993, Plastics - Determination of burning behavior of horizontal and vertical test pieces in contact with a small flame as the ignition source (NF T 51-072) ;

ISO 3451-1 : 01/1981, Plastics - Determination of ash content (NF T 51-040) ;

NF EN ISO 4589-3 :11/1996, Plastics - Determination of burning behavior at mean oxygen index (NF T 51-071-3) ;

ISO 7111 : 02/1987, Plastics - Thermogravimetry of polymers - Method using temperature study.

2.3 French standards set by the UTE

NF C 15-100 : 05/1991, 12/1994, 12/1995, Low voltage electrical installations. Rules ;

UTE C 18 510 : 11/1988, update 1991, Set of general electrical safety instructions ;

UTE C 18 530 : 05/1990, Electrical safety instruction booklet for authorised personnel ;

NF C 32-102-1 à 4 : 12/1993, Conductors and rubber-insulated cables with maximum rated voltage of 450/750 V - Parts 1 to 4 ;

NF C 32-321 : 10/1982, 04/1993, Conductors and insulated cables for installations - Rigid cables, insulated with cross-linked polyethylene, with polyvinyl chloride protective sleeve - Series U-1000 R2V ;

NF C 32-322 : 04/1982 et 07/1988 et 11/1993, Rigid conductors insulated with cross-linked polyethylene, with reinforced polyvinyl chloride protective sleeve - Series U-1000 RVFV ;

NF EN 50102 : 06/1995, (classification NF C 20-015) Protection grades provided by electrical equipment coverings against external mechanical impacts (Code IK) ;

NF C 57-100 : 07/1986, Direct transformation of solar energy to electrical energy - Photovoltaic modules for terrestrial applications - Generic standard ;

UTE C 57-100 : 01/1985, 04/1986 et 10/1990, Direct transformation of solar energy to electrical energy - Photovoltaic modules for terrestrial applications - Set of particular specifications relating to standard NF C 57-100 ;

NF C 57-101 : 07/1986, Photovoltaic modules for terrestrial applications in equatorial zones - Intermediate standard ;

NF C 57-102 : 07/1986, Photovoltaic modules for terrestrial applications in tropical zones - Intermediate standard ;

NF C 57-103 : 07/1986, Photovoltaic modules for terrestrial applications in temperate zones - Intermediate standard ;

NF C 57-104 : 02/95, Procedures for corrections according to temperature and irradiance to be applied to the measured I-V characteristics of crystalline silicon photovoltaic devices (NF EN 60891, CEI 891 - 1987 and modification 1 - 1992) ;

UTE C 57-300 : 05/1987, Descriptive parameters of an on-site photovoltaic system ((CEI 1194) ;

NF C 57-321 : 08/94, Photovoltaic devices - 1st part : Measurement of current-voltage characteristics of solar photovoltaic devices (NF EN 60904-1, CEI 904-1 - 1987) ;

NF C 57-322 : 08/94, Photovoltaic devices - 2nd Part : Requirements relating to solar reference modules NF EN 60904-2, (CEI 904-2 - 1989) ;

NF C 57-323 : 08/94, Photovoltaic devices - 3rd part : Measurement principles for solar photovoltaic devices (PV) for terrestrial use, including spectral irradiance reference data (NF EN 60904-3, CEI 904-3 - 1989) ;

NF C 57-331 : 02/95, Protection against voltage surges on photovoltaic systems (PV) for energy production - Guide (NF EN 61173, CEI 1173 - 1992) ;

NF C 57-332 : 09/96, Descriptive parameters of independent photovoltaic systems (NF EN 61194, CEI 1194 - 1992) ;

NF EN 60529 : 10/1992, (classification NF C 20-010) Grades of protection provided by coverings (Code IP) ;

NF EN 61173 : 02/1995, (classification UTE C 57-331) Protection against voltage surges on photovoltaic systems (PV) for energy production - Guide (CEI 1173).

2.4 Regulatory texts applicable in France

Decree 88-1056, 14 November 1988, relating to worker protection in establishments using electrical currents

Circular **DRT 89-2**, 6 February 1989, Application of decree 88-1056.

3. Definitions

Solar cell : basic photovoltaic device which generates electricity when exposed to solar radiation.

Module array : mechanical assembly of modules or panels, with their supporting structure, apart from foundations, steering devices and thermal control devices, or others of this type, connected together to form a direct current generating unit.

Photovoltaic array : set of all the solar module arrays forming part of a given photovoltaic system.

Load current (I_L) : current supplied by the photovoltaic generator, for a particular temperature and irradiance in a load connected to its terminals.

Short-circuit current (I_{SC}) : output current from a photovoltaic generator under short-circuit conditions for a particular temperature and irradiance.

Bypass diode(s) : diode(s) connected in the direction of current flow from one side to another of one or more cells, modules or panels, to allow current to be shunted from these cells, modules or panels.

Blocking diode : diode connected in series with the module or panel, or modules or panels concerned, to prevent a reverse current in these modules or panels. It may or may not be integrated into the modules or panels concerned.

Standard test conditions (STC) : reference values for the temperature of a module, the irradiance in the plane of a module and the spectral distribution, used for indoor measurements (temperature of the module : 25 °C (2 °C, irradiance in the plane of the modules : 1 000 W.m^{-2}, air mass : 1.5).

Energy irradiance (E) : at a point on the surface, quotient of energy flow received by an element on the surface, by the area of that element. Unit : Watt per square meter (W.m^{-2}).

Solar reference irradiance : solar irradiance whose spectral distribution is defined in standard CEI 904-3.

Air mass (AM) : length of the path travelled by a ray from the sun directly through the Earth's atmosphere expressed as a multiple of the path travelled to a point at sea level when the sun is vertical to this point.

Module : smallest assembly of interconnected solar cells, completely protected from the environment.

Panel : group of modules fixed together, pre-assembled and interconnected, to be incorporated into a unit of an assembly or a sub-assembly.

Load power (P_L) : power supplied in a load connected to the terminals of a photovoltaic generator for a particular temperature and irradiance, namely $P_L = V_L \times I_L$.

Maximum reference power (P_S) : for standard test conditions STC, P_S corresponds to the electrical power which the specimen can supply. The voltage and current pair V_S and I_S correspond to this power P_S.

Nominal operating photovoltaic cell temperature (NOCT) : average stabilised cell junction temperature obtained for the following operating conditions of the module concerned : open circuit, energy irradiance 800 W.m^{-2}, ambient temperature 20 °C, windspeed 1 m.s^{-1}.

Junction temperature (T_j) : temperature measured by a thermal sensor in contact with the rear of the cell, or deduced from measurement of V_{OC} or after thermal distribution calculations. It differs only slightly from the temperature on the exposed surface of the cell.

Ambient temperature (T_{amb}) : calm air temperature measured beneath the module at a distance from it equal to its largest dimension at least.

Open circuit voltage (V_{OC}) : voltage present at the terminals of a photovoltaic generator off load (open circuit) at a particular temperature and irradiance

Load Voltage (V_L) : voltage appearing at the terminals of a load connected to a photovoltaic generator for a particular temperature and irradiance.

4. Symbols and abbreviations

ELV : Extra-Low Voltage, whose nominal value is no more than 120 V in smoothed direct current.

SELV : Safety Extra-Low Voltage, providing power to installations in which :

1) all the active parts are separated from the active parts of any other installation by class II isolation (double or reinforced) ;
2) the active parts are isolated from earth, as well as from any other protective conductor belonging to other installations.

PELV : Protection Extra-Low Voltage which meets condition 1) of PELV but not 2).

FELV : Functional Extra-Low Voltage for installations powered by ELV but which do not meet the conditions of PELV, nor those of SELV.

5. Climatic conditions

The climatic stresses for long-term use of the photovoltaic array are those defined in standard CEI 1215. The climate under consideration are those general climates which include all statistical open air climates, apart from extremely cold and extremely hot conditions.

The naturally-occurring environmental conditions are as defined in standard CEI 721-2-1 which gives the extreme absolute values of temperature and humidity shown in table 1.

Table 1 : Extreme absolute values of temperature and humidity in the "general" group of climates, according to CEI 721-2-1

Low temperature (°C)	High temperature (°C)	Max temperature for which r. h.. (95% (°C)	Max absolute humidity (g.m^{-3})
-60	+45	+37	40

6. Constructional conditions

6.1 Photovoltaic modules

The photovoltaic modules must comply with the certification conditions defined in standards CEI 1215 and CEI 1646. The certification tests are summarised in item **Erreur! Source du renvoi introuvable.**.

NOTE. - It is presently impossible to comply with Standard NF 57-100, whose conditions are incidentally only slightly different from those of standards CEI 1215 and 1646, insofar as it refers to cancelled or incorrect NF standards.

They must withstand the following climatic ambient conditions :

- temperature from -40°C to +85° C ;
- relative humidity up to 100 % ;
- windspeed up to 190 km/h (gusts) ;
- continuous driving wind or hail (hailstones ≤25 mm) ;
- salt atmosphere.

The modules should be suitable for installation without a frame, so that they may be built into a roof easily, if necessary. All other characteristics and the guarantee remain unchanged. In this event, in order to avoid having to carry out work on their underside, modules are accepted without connecting unit, but with output cable connected to the module by a sealed, molded unit. This device must be pull-resistant.

During the first ten years of operation, any drop in power of more than 10 % or the appearance of any faults as stated in the CCE Specifications n° 503 requires that the modules concerned should be replaced.

6.2 Photovoltaic array

The parameters required for characterisation of a photovoltaic array, its operation and its performance at a given site are described in standard CEI 1194 (or UTE C 57-300).

The photovoltaic array consists of modules or panels assembled on metal supporting structures which are then fixed at the installation site concerned (roof, concrete slab, etc.). All the modules forming the photovoltaic array are identical or interchangeable.

The modules are connected together to provided one or more sections whose overall voltage is the nominal operating voltage.

Only modules manufactured using the same manufacturing techniques may be used, though they may vary in certain electrical characteristics. Modules may be used whose cells have the same technology, the same shape, dimensions which may vary within a range of 10 % (dimension = diameter or diagonal) connected together using the same procedure, and with identical encapulsation.

The photovoltaic array may be installed either on the elevation or roof of a building, or on the ground.

The rules to be observed in constructing assembly and support structures for the photovoltaic modules for this installation are described in the specification "Integration into framework" (Cf. part 12 of the General Directives).

6.2.1 Installation of photovoltaic array on roof

Where the photovoltaic array is to be installed on the roof of a building, an air-gap of at least 5 cm, must be maintained between the roof and the underside of the modules (Cf. part 12 of the General Directives). In this case, and if the modules have a connecting box on the rear surface, the frameworks must be able to pivot to allow easy access to the underside. This is not applicable if the modules are built into the roof, instead and in place of the normal roofing. Care must be taken with waterproofing of the roof.

6.2.2 Installation of the photovoltaic array on the ground

6.2.2.1 Mounting structure

The junction between the module and the structure is the subject of special precautions taken against galvanic corrosion (Cf. part 12 of the General Directives).

The frames are designed to inhibit, or even prevent, if possible any attempt to steal the modules. Theft-proof screws and fittings are used.

6.2.3 Electrical connections

Connections on the rear of the modules are protected from splashing or running water. They are designed to avoid any condensation or water retention near live conductors.

Connection or junction boxes are used for making the electrical connections between modules or panels.

In all cases, cable glands are used for cable entries and exits on the underside of the boxes.

The covers and closing panels of these boxes are fitted with suitable devices (locks, specific screws, etc.) to hold them firmly in their "closed" position.

6.2.3.1 Connection boxes

Modules are connected together by electrical connection boxes, or intermediate connection units when modules do not have their own connection boxes.

These boxes shall have :

- protection level IP55, in accordance with standard CEI 529 (NF EN 60529) ;
- protection level IK09, in accordance with standard NF EN 50102.

6.2.3.2 Junction boxes

Sections are individually connected to interconnection boxes which connect them in parallel. The branches are separated by a diode series on each section.

Wiring at a nominal voltage of 12 or 24 V does not have parallel diodes.

6.2.3.3 Blocking diode

The blocking function is intended to prevent the discharge of the batteries in the photovoltaic array. This function is provided by a diode selected for its low direct voltage drop characteristics.

For a photovoltaic array with a small number of modules (< 6), the blocking diode is normally placed in the regulator. In all other cases, it is placed in the junction box described in 6.2.3.2.

6.2.3.4 Cables

All connecting cables for outdoor use comply with the standards suitable for the installation and environment conditions required by the installation site concerned :

- series NF C 32-102 ;
- NF C 32-321 ;
- NF C 32-322.

Their individual section is determined according to the rules in NF C 15-100, giving particular attention to the stresses of voltage drops between the photovoltaic array and the power control system, which drop must not 3 % of the nominal voltage in relative values for a current of not less than 0.7 times the short circuit current set by the manufacturer.

6.2.3.5 Electrical hazard plate

If the photovoltaic array supplies a nominal voltage of more than 60 V, an appropriate information plate must be placed on the outside of the boxes containing live parts.

6.2.3.6 Neutral point of the photovoltaic array

The neutral point of the photovoltaic array is covered in part 11 of the General Directives (protection of people and property).

6.2.3.7 Grounding of frames

All the metal frames comprising the supporting structure of the photovoltaic array shall be individually grounded via a specific green-yellow conductor, whose section shall be equal to that of each of the output conductors from the photovoltaic array, with a minimum of 16 mm^2.

6.2.4 Screws and fittings

All screws and fittings shall be unaffected by natural conditions, or shall be protected against atmospheric damage. The screws must be fitted with lock-washers or other devices to prevent their release.

6.2.5 Protection against birdlife

Suitable devices shall be installed on the photovoltaic array to reduce marking caused by bird droppings.

6.2.6 Protection against wind-borne sand and ground-living animals.

To restrict the effects of wind-borne sand and ground-living animals, the photovoltaic array shall be installed at a suitable height above the ground, between 1.5 and 2 m.

6.3 Service life

The service life for the environmental conditions (transport, storage, use) compliant with those for which the equipment has been specified, is counted from delivery by the Supplier.

6.3.1 Unfinished metal parts

The level of rust, after 10 years, shall be less than the degree of rust of value Ri_2 defined by the reference plate in standard ISO 4628/3 or less than the degree of value Re_2 defined by plate 8 of the European scale of degrees of rusting for rust-proof paint finishes.

6.3.2 Synthetic materials

For synthetic materials, the service life, criteria and acceptance thresholds are as defined by the tests used in this specification.

Synthetic materials, apart from elastomers, used to produce a photovoltaic array shall have passed the tests described in the following standards :

- CEI 167 : full isolation resistance (NF C 26-210) ;
- CEI 695-2-1 : fire behavior ;
- CEI 1006 : thermal endurance ;
- ISO 62 : establishing water absorption ;
- NF EN ISO 75-1 à 75-3 : bending under load ;
- ISO 178 : bending characteristics ;
- ISO 179 : impact resistance ;
- ISO 1183 : establishing density ;
- NF ISO 1210 : fire behavior ;
- ISO 3451-1 : ash content ;
- NF EN ISO 4589-3 : oxygen index ;
- ISO 7111 : thermogravimetric analysis.

6.4 Marking

In accordance with standards CEI 1215 and CEI 1646, each module must show clearly and indelibly the following information :

- identification of the manufacturer (name, logo or symbol) ;
- type or reference of the model ;
- serial number ;
- date and place of manufacture, or failing that, this information must be deducible from the serial n° ;
- polarity of each terminal or output conductor (colour code possible) ;
- maximum voltage of the system for which the module is suitable.

6.5 Identification dossier

The Identification Dossier (ID) is used to guarantee compliance of the equipment supplied with the properties of the equipment which has undergone standard tests. This is applied to sub-assembly level on the equipment.

The ID is referenced, and includes an issue number for controlling updates. It includes at least the documents and information described in this section.

6.5.1 General constructional characteristics

The D I shall include :

- the list of components used and their source, their name and location plan ;
- the list of materials used, source and temperature and fire behavior.
- drawings required for visual inspection and testing.

6.5.2 Functional characteristics of the photovoltaic array

The ID shall supply :

- a user manual for the photovoltaic array ;
- an installation manual for the photovoltaic array (power supply, connections, etc.).

6.5.3 Electrical constructional characteristics of the photovoltaic array

The ID shall provide or indicate :

- references to standards concerned ;
- description of the model(s) of module ;
- the type of semi-conductor ;
- the climate category ;
- the box, dimensions, weight, output markings ;
- the number of cells comprising the module ;
- the limit values of ambient temperature, junction temperature, wind, as set ;
- the number of cells linked by a bypass diode ;
- essential electrical characteristics :
    - power supplied by a given output voltage, junction temperature, energy irradiance and air mass,
    - maximum reference power corresponding to a maximum output voltage ;
    - short-circuit current ;
    - nominal current ;
    - nominal voltage ;
- the reference, electrical characteristics and position of blocking diodes ;
- list of circuits connected to ground and the means whereby ground continuity is achieved within the array ;
- the position of the connecting point for the grounding, and the method used ;
- insulation strength between each electrically independent circuit or group ;
- dielectric insulation level (50 Hz and shock 1.2/50 µs) ;
- list of protections.

6.5.4 Mechanical constructional characteristics of the photovoltaic array

The ID shall include or indicate :

- dimensions and weight of the equipment (as a whole and for each sub-assembly) ;
- floor space plan ;
- reference position in normal operation ;
- fixing device ;
- protection level provided by covering (boxes, etc.) ;
- installation and connection plan.

6.5.5 Test file

The test file provides the methods and results of standard tests performed by the manufacturer for investigation or certification, and also the results of tests performed by users or independent laboratories, with references for the test laboratory.

Standard acceptance tests are those performed on the prototypes and/or first production models. They may be repeated, as a whole or in part, at the Purchaser's request.

6.6 Quality assurance procedure

The ID shall give the list of components in the equipment manufactured using Centralised Quality Control, or Quality Assurance.

It must also contain copies of the confirmation and/or certification certificates supplied by the Standards Committee or identified test laboratories.

The manufacturer must describe, in the ID, the checks carried out before and during manufacture (checks on components and on raw materials).

The description of these operations relates to :

- sampling procedures ;
- test and measurement methods ;
- sanctions applied.

7. Standard acceptance procedure

The standard acceptance procedure for the equipment includes :

- Study of its compliance with the ID ;
- performance of standard acceptance tests.

Sanction

Any equipment which does not pass all the tests is rejected.

Note : Investigation tests may be performed within the acceptance procedure.

8. Standard tests

8.1 Certification tests for photovoltaic modules

In order to be accepted, the photovoltaic modules must have passed the test procedure described in standards CEI 1215, CEI 1646, CEI 1701 and CEI 1721. Table 2 gives a chronological list of the tests.

Table 2 : Tests on photovoltaic modules

TEST	STANDARD	TEST CONDITIONS
Visual inspection **Performance in STC** **Insulation**	CEI 1215 CEI 1646 NFC 57-100	Appearance conditions other than the following major visual defects may be accepted : - torn, cracked or broken surfaces - in a cell, a crack, whose propagation may isolate more than 10 % of the surface of the cell of the electrical circuit of the module - bubbling, or delamination forming a continuous path between any part of the electrical circuit and the edge of the module - loss of mechanical continuity causing damage to the insulation and/or operation of the module Cell temperature : 25 °C ; irradiance 1 000 $W.m^{-2}$ with reference spectral distribution of solar irradiance according to CEI 904-3 1 000 V DC + twice the system voltage at STC for 1 min
Temperature coefficients	CEI 1215 CEI 1646	
NOCT **Performance in NOCT**	CEI 1215 CEI 1646 NFC 57-100	Total solar irradiance : 800 $W.m^{-2}$; ambient temperature : 20 °C ; windspeed : 1 $m.s^{-1}$ I-V characteristics according to CEI 904-1 with : cell temperature NOCT ; irradiance 800 $W.m^{-2\ 2}$ with reference spectral distribution of solar irradiance
Performance under low irradiance **Exposure in natural site**	CEI 1215 CEI 1646	I-V characteristics according to CEI 904-1 with : cell temperature : 25 °C ; irradiance : 200 $W.m^{-2\ 2}$ and reference spectral distribution of solar irradiance Total energy exposure : 60 $kWh.m^{-2}$
Performance with local heating	CEI 1215 CEI 1646 NFC 57-100	5 exposures of 1 h ; irradiance 1 000 $W.m^{-2}$ in worst case localised heating
UV **Humidity - freeze**	CEI 1215 CEI 1646	under study 10 cycles of +85 °C, 85 % RH at -40 °C (CEI 68-2-38, test Z/AD)
Humid heat (continuous) **Thermal cycles** **Strength of outputs** **Twisting** **Mechanical load**	CEI 1215 CEI 1646 NFC 57-100	1 000 h at +85 °C, 85 % RH, (CEI 68-2-3, test Ca) 50 and 200 cycles of -40 °C at +85 °C (CEI 68-2-14, test Nb) According to CEI 68-2-21, test U Angle of distortion : 1.2 degree 2 cycles with uniform load of 2400 Pa applied for 1 h successively on the front then rear surface
Hail or **Impact**	CEI 1215 CEI 1646 CEI 1721 NFC 57-100	hail stone moving at 23 $m.s^{-1}$, directed at 11 points of impact or pendulum test Hardened steel ball pendulum ((40 mm, hardness R62), height of drop 1 m
Salt mist	CEI 1701 NFC 57-100	Duration 96 h, angle 15 to 30° (CEI 68-2-11, test Ka)
Dry heat **Climatic composite**	NFC 57-100	Duration 96 h, temperature 85 °C ±2 °C (CEI 68-2-2, test Bb) According to CEI 68-2-61, sequence Z/ABDM : dry heat 85 °C ±2 (CEI 68-2-2, test Bb), then humid heat (CEI 68-2-30, test Db), then cold -40 °C ±2 (CEI 68-2-1, test Aa) and low atmospheric pressure if required (CEI 68-2-13, test M),
Prolonged exposure to light radiation **Annealing** **Leakage current in humid environment**	CEI 1646	Exposure from 800 to 1 000 $W.m^{-2}$ to stabilisation of P_{max} within ±2 % Prolonged exposure to thermal radiation at 85 °C to stabilisation of P_{max} within ±2 % Water spraying on outputs, and immersion of the edge with application of 500 V DC to determine leakage current

8.2 Tests on photovoltaic array

After installation of the photovoltaic array, its current voltage characteristics shall be measured on site, according to the procedure described in standard CEI 1829.

Other tests under study.

9. Operating conditions on a photovoltaic array

Under study.

DRE SPECIFICATIONS - C 2

June 1997

Title

Part C - Technical Specification of Components

Section 2 : Building-integration of Photovoltaic Arrays

Number of pages 18 (including annexes)

Type Technical specification of components

Associated document(s)

Summary : This document covers all the conditions for installing photovoltaic arrays in buildings. It restates the rules enacted by the CSTB.

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CONTENTS

INTRODUCTION

In the past few years, the number of photovoltaic installations in buildings has been increasing in neighbouring countries, mainly Switzerland and Germany. The problem of integrating photovoltaic installations into the architecture of a building is highlighted in the European program "Solar house" from Joule II and is the subject of task 16 of the "Solar heating & cooling program" of the International Energy Agency. Several European manufacturers (mainly German) have subsidiaries or distributors in France and are beginning projects there.

Table 1 : A new approach to fitting photovoltaic modules in urban sites coexists with the old approach

	Isolated Site	**Urban**
Building	existing	new
Motivation of main contractor	need for electricity	architectural + energy saving
Design	function of need	function of the architectural part
Type of installation	independent collectors on supports linked to a frame	collectors built into the building shell
Principle operator	photovoltaic company	roofing company or manufacturer

The problem of integrating frame-mounted photovoltaic modules is therefore different from the situation some years ago, when photovoltaic systems were only envisaged in isolated sites. It was necessary to repeat and complete the work carried out almost ten years ago at the CSTB on professional standards in this subject 1. This was done with support from ADEME.

The requirement is to ensure provision of elements for correct implementation of photovoltaic modules on a building by the professionals involved. The following text is intended as a guide to installation of the collectors ; it was drawn up from the existing rules regarding photovoltaic systems and the building shell, making use also of texts relating to thermal collectors, and finally with regard for practices in other countries.

The design of the photovoltaic installation is not covered by this document. When this design is a function of need, as for an isolated site, there are several available methods none of which are treated as the reference. The manufacturer suggests one in general terms.

The text forms part of French regulations ; it refers to Unified Technical Documents (DTU), design rules and standards. Most of these documents are produced by the CSTB and may be consulted in REEF or CD-REEF.

1"Frame-mounted photovoltaic systems ", *Cahiers du CSTB* 2230, April 1988

1. Scope of application

This specification defines rules for incorporating photovoltaic modules into buildings.

2. Standard references

2.1 Standards established by the ISO

ISO 2813 : 1994, Paint and varnish - Determination of specula reflection of non-metallic paint layers 20 °C, 60 °C and 85 °C ;

ISO 7599 : 1993, Anodisation of aluminium and its alloys - General specifications for anodic layers on aluminium ;

3. French standards

3.1 AFNOR standards

3.1.1 Standards

NF A 36-321 : 12/96, Hot-dip galvanised continuous-process mild steel sheets and strips for cold forming - technical delivery conditions (NF EN 10142) ;

NF A 91-121 : 08/87, Galvanisation by immersion in molten zinc (hot-dip galvanisation) - finished products in iron, steel, cast iron ;

A 91-122 : 08/87, Metallic coatings - Finished products in hot-dip galvanised steel - Recommendations relating to design and use of galvanised products ;

NF A 91-201 : 01/94, Metallic and inorganic coatings, thermal spraying, zinc, aluminium and their alloys (NF EN 22063) ;

NF P 01-012 : 07/88, Dimension of handrail. Safety rules. Staircase handrails ;

NF P 06-001 : 06/86, Construction design calculations - building operational loads ;

P 08-302 : External walls of building - Resistance to impacts - Test methods and criteria ;

NFP 24-351 : 04/82, Metal frameworks - Protection against corrosion and preservations of surface condition of windows and doors - metal-framed windows ;

NF S 31-010 : 12/96, Properties and measurement of environmental noise - Instruction on complaints about noise in residential areas ;

NF S 31-051 : 12/85, Measurement of sound insulation capacity of construction elements and building insulation - laboratory measurements of the sound insulation properties against airborne noise of construction elements ;

NF S 31-055 : 08/82, Measurement of sound insulation capacity of construction elements and building insulation - investigation method for measuring in situ against airborne noise of premises with respect to road traffic noise ;

NF S 31-057 : 10/82, Verification of acoustic quality of buildings ;

3.1.2 Unified Technical Documents

DTU 33.1 Lightweight frontages (coming out shortly)

DTU 39 : 05/93, Mirrors - glazing

Schedule of technical clauses (NF P 78-201-1) ;

Schedule of special clauses (NF P 78-201-2) ;

DTU 40.11 : 05/93, Slate tile roof
Statement of works (NF P 32-201-1)
Schedule of special clauses (NF P 32-201-2) ;

DTU 40.12 : 05/93, Asbestos-cement slate tile roof
Schedule of technical clauses (NF P 33-202-1) ;
Schedule of special clauses (NF P 33-202-2) ;

DTU 40.14 : 05/93, Bituminised shingle roof
Schedule of technical clauses (NF P 39-201-1) ;
Schedule of special clauses (NF P 39-201-2) ;

DTU 40.21 : 06/79, Terracotta grooved or sliding roof tiles
Statement of works ;
Schedule of special clauses ;

DTU 40.22 : 05/93, Curved terracotta roof tiles
Schedule of technical clauses (NF P 31-201-1) ;
Schedule of special clauses (NF P 31-201-2) ;

DTU 40.23 : 09/96, Flat terracotta roof tiles
Statement of works (NF P 31-204-1) ;
Schedule of special clauses (NF P 31-204-2) ;

DTU 40.24 : Concrete sliding or longitudinal grooved roof tiles
Schedule of technical clauses (NF P 31-207-1) ;
Schedule of special clauses (NF P 31-207-2) ;

DTU 40.25 : Flat concrete roof tiles
Schedule of technical clauses (P 31-206-1) ;
Schedule of special clauses (P 31-206-2) ;

DTU 40.31 : Asbestos-cement corrugated sheet roofing
Schedule of special clauses ;
Statement of works ;

DTU 40.32 : 04/82, Corrugated metal sheet roofing
Statement of works (P 34-201-1) ;
Schedule of special clauses (P 34-201-2) ;

DTU 40.35 : 09/83, Ribbed sheet roofing, made from pre-painted galvanised sheet steel, or galvanised sheet steel
Schedule of technical clauses (P 34-205-1) ;
Schedule of special clauses (P 34-205-2) ;
DTU 40.36 : 05/93, Ribbed aluminium sheet roofing, pre-painted or not
Schedule of technical clauses (NF P 34-206-1) ;
Schedule of special clauses (NF P 34-206-2) ;

DTU 43.1 : 07/94, Waterproofing of flat roofs with masonry load-bearing elements
Statement of works (NF P 84-204-1) ;
Schedule of special clauses (NF P 84-204-2) ;

DTU 43.2 : 05/93, Waterproofing of roofs with masonry load-bearing elements, with slope of at least 5%

Schedule of technical clauses (NF P 84-205-1) ;

Schedule of special clauses (NF P 84-205-2) ;

DTU 43.3 : 06/95, Roofing in ribbed sheet steel with waterproof coating

Statement of works (NFP 84-206-1) ;

Schedule of special clauses (NFP 84-206-2) ;

DTU 43.4 : 05/93, Roofs with wooden load-bearing elements and panels from wood with waterproof coating

Schedule of technical clauses (NF P 84-207-1 + addendum of 12/95) ;

Schedule of special clauses (NF P 84-207-2) ;

DTU 59.1 : 10/94, Building paintwork

Schedule of technical clauses (NF P 74-201-1) ;

Schedule of special clauses (NF P 74-201-2) ;

DTU 65.12 : 05/93, Construction of flat solar collectors with water circulation for heating and production of hot water for domestic use.

Schedule of technical clauses (NF P 50-601-1) ;

Schedule of special clauses (NF P 50-601-2) ;

DTU 95.1 : 05/93, Construction of buildings to carry mechanically-driven, hanging pods for maintenance and cleaning of frontages, construction of these pods and implementation - Statement of works (NF P 95-201) ;

3.2 Standards produced by UTE

NF C 15-100 : 05/1991, 12/1994, 12/1995, Low voltage electrical installations. Rules ;

UTE C 57-100 : 01/1985, 04/1986 et 10/1990, Direct transformation of solar energy to electrical energy - Photovoltaic modules for terrestrial applications - Set of particular specifications relating to standard NF C 57-100 ;

NF C 57-101 : 07/1986, Photovoltaic modules for terrestrial applications in equatorial zones - Intermediate standard ;

NF C 57-102 : 07/1986, Photovoltaic modules for terrestrial applications in tropical zones - Intermediate standard ;

NF C 57-103 : 07/1986, Photovoltaic modules for terrestrial applications in temperate zones - Intermediate standard ;

NF C 57-104 : 02/95, Procedures for corrections according to temperature and irradiance to be applied to the measured I-V characteristics of crystalline silicon photovoltaic devices (NF EN 60891, CEI 891).

3.3 Design rules

Rules NV 65 : 01/94, Rules defining the effects of snow on constructions (DTU P 06-002) ;

Rules N 84 : Actions of snow on constructions (DTU P 06-006) ;

Rules PS-MI 89 : 03/95, revised 1992, Earthquake-resistant construction of private houses and similar buildings. Scope. Design. Execution. (NF P 06-014) ;

Rules CB 71 : Design rules for wooden frameworks (DTU P 21-701) ;

Rules CM 66 : Design rules for steel constructions (DTU P 22-701) ;

Rules AL : 07/76, Design rules for aluminium alloy frameworks (DTU P 22-702) ;

Rules Th-K 77 : 01/90, Design rules for effective thermal characteristics of construction walls (DTU P 50-702).

3.4 CSTB Documents

CHEVALIER J.L., FILLOUX A., LYONNET C., "Frame-mounted photovoltaic systems", *Cahiers du CSTB* 2230, delivery 288, April 1988 ;

"UEATc technical guide for Approval of insulation systems for external frontages with mineral coatings", *Cahiers du CSTB* 2602, delivery 331, July-August 1992 ;

" UEATc technical guide for Approval of external glued glazing", *Cahiers du CSTB* 2655, delivery 339, May 1993.Legislative and regulatory texts

Decree 65-48 of 8 January 1965 providing public administration regulations for execution of the conditions of volume II of the labour regulations (heading II : Health and safety of workers) as regards particular steps for protection and health applicable to establishments whose personnel perform building work, public work, and all other work relating to buildings.. Modified and supplemented by decrees 81-989 of 30 October 1981, 92-767 of 29 July 1992, 93-41 of 11 January 1993, 94-1217 of 29 December 1994 and 95-608 of 6 May 1995 (J.O. of 23 January 1965, 4 February 1965, 5 November 1981, 7 August 1992, 13 January 1993, 31 December 1994, 7 May 1995) ;

Decree 75-848 of 26 August 1975 relating to safety of personnel, animals and goods during the use of electrical equipment for use within certain voltage limits. Modified by decree 81-1237 of 30 December 1981 (J.O. of 12 September 1975, 21 January 1976, 10 January 1982) ;

Notification relating to application of decree 75-848, modified by decree 81-1237 of 30 December 1981, relating to safety of personnel, animals and goods during the use of electrical equipment for use within certain voltage limits (J.O. of 2 April 1995) ;

Decree 88-1056 of 14 November 1988, passed for volume II of the labour regulations (heading III : Health, safety and working conditions) as regards protection of workers in establishments using electrical currents.. Modified by decree 95-608 of 6 May 1995 (J.O. of 24 November 1988 and 7 May 1995) ;

Fire protection. Residential buildings. Regulatory texts with illustrations (J.O. department, brochure 1603, 1989).

Decree 91-461 of 14 May 1991, relating to earthquake protection (J.O. of 17 May 1991) ;

Fire protection. Volume 1 General risk prevention. Legislative and regulatory texts (J.O. department, brochure 1540, 1992) ;

Fire protection : buildings open to the public (ERP) : general texts (J.O. department, brochure 1477-1, 1993) ;

Very tall buildings. Fire protection (J.O. department, brochure 1536 , 1993) ;

4. DEFINITIONS

Independent collectors : independent collectors are fixed to the outside of the building with supports. They do not provide any enclosure or covering function ; these are building equipment components.

Integrated collectors : integrated collectors are components of the building shell, either the roof or the frontage. They do provide an enclosing or covering function.

This distinction between elements which are part of the building shell and elements which are equipment means that, among other consequences, integrated collectors are included in the ten-year guarantee, while independent collectors can only have a two year operating guarantee. Another consequence is that part of the cost of the collectors is included in the building shell, or even in the heating system, in the case of "multifunction" modules, which reduces proportionately the initial cost of the photovoltaic generator.

5. General points

The implementation conditions for the photovoltaic modules are summarised in table 2.

Table 2 - Implementation of building-integrated photovoltaics

Photovoltaic modules	Independent	Integrated
Installation configurations	• on sloping roof with covering of discontinuous elements • on flat roof or roof covered with waterproof coating • fixed to a wall without external insulation • fixed to a wall with external insulation • fixed to a light frontage • balcony shade or sun-canopy • collectors on balcony railing	• component of sloping roof with covering of discontinuous elements • component of glass roof • opaque outside wall of a filling of a curtain wall • more or less opaque outside glass element of an insulating glazing unit • full thickness of wall element of a more or less opaque part of the façade • cladding element in front of a concrete wall
Equipment	collectors, supports	PV shell elements
Implementation Rules	Rules relating to function or performance of collectors : - exposure to sun - cooling of collectors Rules relating to safety : - stability (fixing of supports) - electrical hazard - safety of workers Rules relating to retention of functional characteristics of building shell : - maintenance of roof or façade - penetration of supports through plane of roof - penetration of electrical cables through the building	Rules relating to function or performance of collectors : - exposure to sun - cooling of collectors Rules relating to safety : - stability - impacts - fire - electrical hazard - intrusion, explosion - safety in use Rules relating to habitability : - stability - waterproofing and airtightness - hygrothermal comfort - acoustic comfort - appearance - health Rules relating to durability : - accidental impacts - maintenance - hygrothermal - occurrence of - solar protections

6. Independent modules

6.1 Installation configurations

a) independent modules on sloping roof covered in discontinuous elements ;
b) independent modules on flat roof or waterproofed roof ;
c) independent modules fixed to a non-insulated outside wall ;
d) independent modules to an insulated outside wall ;
e) independent modules fixed to a light frontage ;
f) modules on balcony shade or sun-canopy ;
g) modules on balcony railing.

6.2 Collectors

The photovoltaic modules are the subject of test standards and specification sheets intended to guarantee their suitability for use (standards NF C 57-100, NF C 57-101, NF C 57-102 and NF C 57-103).

6.3 Supports and fixing components

Supports and fixing components shall be suitably protected against corrosion, for example :

- paint protection defined in DTU 59.1 "Painting" ;
- hot-dip galvanised steel defined by standard NF A 91-121 at 600 g/m2 ;
- continuous-process galvanised sheet steel, defined by standard NF A 36-321, class Z 350 ;
- zinc-coated steel defined by standard NF A 91-201, Zn 120 (apart from industrial or marine environments : Zn 200 or Zn Al 120) ;
- aluminium alloy ;
- stainless steel (mainly for screws and fittings).

Support calculations are performed according to the relevant rules :

- Rules CB 71 (DTU P 21-701 - wooden frameworks) ;
- Rules CM 66 (DTU P 22-701 - steel constructions) ;
- Rules AI (DTU P 22-702 - aluminium alloy frameworks).

6.4 Implementation rules

A distinction is made between functional or performance aspects of the collectors, those relating to safety and those for preservation of the functional characteristics of the building shell.

6.4.1 Functional rules

Two parameters relating to installation are deciding factors in the performance of the collectors. These are exposure to the sun on the one hand, and cooling of the collectors on the other.

Exposure to sun of the collectors depends on their orientation, their gradient and any shadows. In some cases - independent collectors on supports on a flat roof - the collectors may be oriented to the south, with optimal gradient according to changes over the year, and all shade avoided.

In other cases - installation on the building frontage, for example - orientation and gradient of the collectors shall not be optimised, and there may be some shadow, but this may be permissible, bearing in mind architectural constraints.

The performance of the photovoltaic modules depends on their temperature. To give some idea of the order of magnitude, dropping the collector temperature by 10 degrees increases the collected power by about 5 %. Since the temperature of a collector insulated on its underside may exceed the ambient temperature by about fifty degrees, this difference is easily halved if the rear surface is ventilated giving a power increase of more than 10 %.

It is therefore strongly recommended that natural or forced ventilation is used to cool the underside of the collectors. Independent collectors shall be naturally ventilated by wind and thermal draft. In all configurations, an air-gap of at least 5 cm should be kept behind the modules.

6.4.2 Rules related to safety

6.4.2.1 Safety of workers

Installation of the collectors, maintenance operations on them or on parts of the roof or building façade which they cover shall always be performed in accordance with the conditions of the decree of 8 January 1965 on general safety rules for workers, and those of the decree of 14 November 1988 regarding protection of workers in establishments using electrical currents.

Workers installing photovoltaic modules on the roof or façade of a building are mainly exposed to risks of falling and of electrocution. The first risk is not specific to this type of installation but it should be mentioned ; independent collectors shall not actually be installed by building workers (roofers aware of safety rules on a roof, for example).

Risk of electrocution is specific to photovoltaic installations. Collectors are powered up as soon as they are exposed to light. It is recommended that modules should not be connected until they are all in place. The level of care taken during this operation shall depend on the voltages concerned, because of the number of modules in series. The module field could be covered, but this is not normally necessary.

6.4.2.2 User safety

User safety is not threatened in principle by correctly installed, independent photovoltaic modules. As a reminder, we can mentioned the specific risks (outside the scope of this document, relating to collector installation) of photovoltaic installations in isolated sites, which have accumulator batteries located in residential premises.

6.4.3 Rules relating to retention of functional characteristics of the building shell

6.4.3.1 Maintenance of roof or building façade

Collectors on or in front of an element of the shell should not prevent maintenance of this element. The frequency of maintenance operations on the building shell depends on the type of element and the site ; it varies from a few months to one year or several decades. The presence of collectors on or in front of an element of the shell may encourage the growth of moss or the accumulation of rubbish, and therefore require more frequent maintenance.

There are several possible solutions for carrying out this maintenance.

Either the presence of collectors and their supports does not block access to any part of the shell, as is generally the case on flat roofs or on the building façade when the line of the collectors is different from that of the flat roof or the façade.

Or the collectors do block access to the nearby parts of the shell, as generally happens for sloping roofs when the collectors are parallel to the roofing, and very close to it. The part of the shell required is therefore reached by moving (by a mobile system, a pivot for example) or removing the collector. Removal is permitted if only a single modules needs to be moved, and where no specific tool is required and there is no risk of electrocution.

6.4.3.2 Retention of waterproofing and stability of the building envelope

a) independent modules on sloping roof covered in discontinuous elements :

The supports are fixed to stronger elements of the framework (rafters, purlins), by joint beams if required, and never to the wood parts of the roofing (battens, lathes, chipboard). Figure 21 of the schedule CSTB 2230 shows the fixings for the supports for the independent collectors on the roofing ;

The supports penetrate the roofing in accordance with the various roofing DTUs, DTU 40.11 to 40.36 (see illustration on figure 22 of schedule CSTB 2230).

b) independent modules on flat-roofing or waterproofed roofing :

Installation work for collector supports shall be carried out in accordance with DTU 43.1 and 43.2, for a roof whose load-bearing component is made of concrete, or DTU 43.3 or 43.4, for a roof whose load-bearing component is not concrete ;

In general, penetration of the roof is avoided. The collector support is anchored in a concrete block, for ballast, placed on the waterproofing with an intervening layer (expanded polystyrene, for example) whose density is at least 25 kg/m^2 with a minimum thickness of 3 cm (see illustration on figure 1e of DTU 65.12).

This solution is permitted if the gradient of the roof is less than 5%. The overload on the waterproofing shall be no more than 1 N/cm^2 bearing in mind the weight itself and climatic overloads. The concrete mass shall be movable, with no need for lifting gear, to allow the waterproof covering to be repaired if necessary.

c) independent modules fixed to a non-insulated outside wall :

The supports are fixed to the wall, either by penetrating screws or, more often, by metal brackets fastened to the wall. The strength of the fastenings is determined either according to the known values for heavyweight aggregate concrete walls or by tests in situ.

d) independent modules fixed to an insulated outside wall

The supports are either fixed to the wall as above, or to the secondary framework, with the agreement of the designer.

The external coating is penetrated according to the code of practice for a traditional system, or the technical notification for a non-traditional system.

e) independent modules fixed to a light building frontage

The supports are fixed to the secondary framework of the light frontage with the agreement of the designer

f) modules on balcony shade or sun-canopy

Depending on the type of façade concerned, one of the three previous examples is used.

g) modules on balcony railing

Collectors are installed instead of, and in the place of railings in accordance with standard NF P 01-012 "Dimensions of handrails. Safety rules. Staircase handrails". In applying this standard, collectors are classed as narrow handrails.

7. Integrated collectors

Integration consists of using a "specific" collector, in dimension and composition, as a roofing or cladding element, or as a more or less opaque filler for part of a light façade.

7.1 Installation configurations

a) sloping roof element covered with discontinuous elements ;

b) glazing element ;

c) opaque external wall of a curtain wall filler ;

d) external glazing element, more or less opaque, of an insulating glass panel ;

e) whole thickness of a wall element of a more or less opaque part of a light façade ;

f) cladding element in front of a concrete wall.

7.2 Equipment

Integrated collectors are parts of the building shell, acting as an enclosing or roofing part. They are included in the ten-year guarantee.

They are non-traditional roofing or façade elements, which shall therefore be covered by the relevant technical Recommendation :

- by specialist Group n° 5 (roofs, roofing, waterproofing) if they are roofing elements ;
- by Group n° 2 (construction, façades and light panels) if they are light façade elements ;
- by Group n° 7 (additional waterproofing and insulation products and systems for vertical walls) if these are attached cladding elements.

Bearing in mind, however, the innovative nature of the techniques for integrating photovoltaic modules into the building shell, the ATEx procedure (experimental technical evaluation) is the best to use in the first place. ATEx is located upstream of the technical Recommendation, and is intended to assist the initial experimental operations for a new technique. Many ATEx also cover the use of glass in the building shell (façades, glass roofs).

7.3 Design and implementation rules

There are two types of rules to follow : those relating to the photovoltaic function (see 6.4.1) and those relating to the building shell function (see 6.4.2 to 7.3.4). These are mainly included in the DTUs relating to the roof and the façade, mentioned in section 0. As regards light façades, a DTU (33.1) is presently being drawn up. The content of sections 6.4.2 to 7.3.4 are inspired by the draft of this DTU.

7.3.1 Rules relating to operation or performance of the collectors

Two parameters relating to installation are deciding factors in the performance of the collectors. These are exposure to the sun on the one hand, and cooling of the collectors on the other.

Exposure to sun of the collectors depends on their orientation, their gradient and any shadows.

For integration on the roof or building frontage, orientation and gradient of the collectors shall probably not be optimal, but this may be permissible, bearing in mind the architectural part and the "multi-functional" nature of the collectors.

The performance of the photovoltaic modules depends on their temperature. To give some idea of the order of magnitude, dropping the collector temperature by 10 degrees increases the collected power by about 5 %. Since the temperature of a collector insulated on its underside may exceed the ambient temperature by about fifty degrees, this difference is easily halved if the rear surface is ventilated giving a power increase of more than 10 %.

It is therefore strongly recommended that natural or forced ventilation is used to cool the underside of the collectors. A ventilated air-gap (in the sense of Th-K rules) of at least 5 cm should be kept behind the modules. Forced ventilation using fans may be used for sealed elements ; it will then help in heat recovery.

When making provisional performance calculations for the photovoltaic installation, consideration must be given to the cooling method of the collectors, empirical formulae giving the effect of temperature on existing performance. Current research programs, especially in Europe, will allow the effect of the mounting method on performance to be quantified.

7.3.2 Rules relating to safety

7.3.2.1 Stability

The photovoltaic component of the shell shall not break down or deteriorate under all the operations which may cause stress to it, resulting from weight, atmospheric agents, stresses generated and suffered by the main structure, and operating loads on the roof or the façade.

The photovoltaic component of the shell including its fixings is designed so that :

- under all normal stresses, according to NV rules (section 3.1.), the mechanical strength is satisfied and distortion (bending, twisting, movements of support) of the framework elements, joinery and filling are such that the fillings are held in place at all times and the performance of the waterproof claddings is not compromised ;
- under all extreme stresses according to NV rules(section 3.1.), the photovoltaic component of the shell shall not be put "out of service", always according to the same rules.

The mechanical stresses, either permanent or momentary, must be determined, as well as their possible combinations, and then verifications made to ensure that the effects of each stress or combination of stresses does not exceed permitted values.

The stresses to be considered are : weight, wind and snow, variations in temperature and humidity, operating loads, earthquake, and as required, in general, any stress such as that on the main structure (operating overload, differential settlement, vibration, etc.).

7.3.2.1.1 Effects of wind and snow

Values of pressure, depressions and vibrations caused by the action of wind are calculated by applying current rules in force (DTU 39, rules NV 65) defining the effects of wind on constructions or determined by measurements in a wind tunnel, where conditions of exposure, height and/or the shape of the building do not allow these rules to be applied.

Loads caused by snow must be considered for roofs and any fittings on the building façade. The design rules applicable are the snow rules N 84.

7.3.2.1.2 Effect of variations of temperature and humidity

By exemption from rules AL and CM and to evaluate the effects on dimensions of variations of temperature and humidity, the limiting temperatures of materials to be considered are - 20°C and + 80°C, subject to climatic conditions or particular circumstances.

Dimensional variations in elements, and the resulting clearances, accommodated in assembly are evaluated by reference to experience, and if necessary, by calculation. Moreover, a sharp variation (of around 50°C) in the temperature of the outside wall, resulting for example from prolonged insolation followed by a sudden downpour should not cause any problems on the façade or the glass roof.

Some construction conditions, those relating to air-gaps, even ventilated, or breathing, behind non-opaque glass for example, need the range of extreme temperatures which may be reached on the ground to be established. The consequences, especially for insulation, filler components, and waterproof cladding, must be considered, both as regards safety and durability.

7.3.2.1.3 Effects of operating loads

These are static or dynamic temporary loads.

For loads from human pressure on the wall, similar to the handrail rules, refer to NF P 06-001.

Pods and cleaning equipment are covered in DTU 95.1. Exceptional dynamic loads, or pressure other than human on the wall, must be specified by the main contractor.

7.3.2.1.4 Effects of earthquake

There is no specific text at present. Earthquake protection requirements for structures are the responsibility of the main contractor, and may be supported by application of the PS 69 rules.

NOTE : New rules, PS 89, are being developed, which may be applied to support requests of Main Contractors. These new rules shall be made regulatory when the application decrees are published.

The decree 91-461 of 14 May 91 makes the new earthquake areas of France official, and shows that, in considering earthquake risk, buildings, equipment and installations are divided into two categories, called normal risk or special risk.

Preventative measures on normal risk buildings are covered by the application decree signed on 16 August 1992. This decree defines, in particular, the classification rules for new, so-called normal risk buildings, the construction rules to be applied to these buildings and the date of application of these rules. The decree of 10 May 1993 covers special risk installations.

7.3.2.1.5 Combination of stresses

In order to verify constraints by calculation, combinations are made according to rules CM†66 for steel and AL 76 for aluminium. For general verification of bending and movement, and subject to particular specifications, weight, wind and snow, if any, shall be combined. In the particular case of the effects of earthquakes, the combination of stresses must comply with the specific regulatory texts.

It is then necessary to check that the effects of each stress or combination of stresses does not exceed the permitted values for mechanical strength and distortion.

The mechanical strength of the façade or glass roof elements and connecting components is confirmed by application of rules AL 76 and CM 66. For stresses, the characteristic stress under extreme wind conditions, bearing in mind the weightings for calculating rules CM 66 or AL 76, shall be less than the elastic limit. The admissible bending of secondary structures and frameworks shall be 1/300th of the range, at a pressure PN corresponding to the resulting unitary action under normal pressure, bearing in mind local action, depending on the location concerned. Moreover, DTU 39 must be observed when calculating thickness of glass. For constructions not covered by regulations, in the sense of the NV rules, refer to section 6.4. of these rules.

7.3.2.2 Safety in the event of impacts

Personnel safety must always be ensured in the event of exceptional impacts arising from normal occupation, the risk of which may reasonably be expected.

Under the effect of these exceptional impacts called "safety impacts" the photovoltaic component of the shell, within the regulation safety height, may be damaged, but any damage must not jeopardise, in particular, the safety of persons (not being the cause of the impact) whether internal or external, among others, caused by the dropping of blunt or cutting debris, or items which could cause serious injury to these people. After this impact, there is no longer any requirement for personnel safety to be ensured by this structure. The person causing the impact should not be able to cross the façade.

A requirement is applicable for a residual protection in the sense of NF P 01-012. Levels of impact energy which components must be capable of resisting shall comply with standard NF P 08-302. The energy level depends on the position of the structure in the building, and the type of activity zone.

NOTE. - The main contractor is recommended, for light façades on the ground floor, likely to be exposed to very severe accidental impacts (vehicles, mobile plant), to provide independent devices for restricting the effects of these impacts.

7.3.2.3 Fire protection

In the event of fire, the occupants must be able to escape, and sick or disabled people must be able to be transported without suffering bodily injury resulting mainly from projections of material or discharge of toxic gases.

Quality rules are to be modified according to the intended use of the building. For example these rules may be slightly different, depending on whether the building is for residential use or is an E.R.P.

The materials forming the photovoltaic component of the shell or the gases which it may discharge should not encourage, either directly or indirectly, the development or the propagation of fire.

Toxic, or simply noxious gases must not be produced in dangerous quantities by the photovoltaic component of the shell.

The fixing devices of the photovoltaic component in the main structure must resist a fire limited to one apartment or one floor.

The façades must not constitute a serious risk of transmitting fire to an upper floor.

The structures should, depending on the types of building or activity involved, comply with the rules in force : brochures of the official Journal n°1477 (E.R.P.), n°1540 (general and various texts), n°1536 (Very Tall Buildings), n°1603 (residential buildings), and labour laws.

7.3.2.4 Electrical safety

The occupants should not suffer any bodily injury which may result from the use of the electrical installations under conditions which may reasonably be expected.

Unless otherwise specified, metal parts of the photovoltaic components of the shell are not earthed.

Electrical equipment, fitted on or in photovoltaic components of the shell, must be chosen according to service conditions and external influences specified in section 32 and section 512 of standard NF C 15-100.

The choice of electrical ducting shall comply with the regulations in force (section 521 of standard NF C 15-100) particularly for ducting embedded in the walls. Electrical ducting may not pass from floor to floor through the façade.

7.3.2.5 Security measures against intrusion or explosion

Unless otherwise specified, the photovoltaic component of the shell is not involved in safety of goods and persons against deliberate attacks. It is therefore not intended to resist either intrusion or stresses caused by explosions or vandalism.

7.3.2.6 Safety in use

Normal cleaning and maintenance operations should cause no risk to operators or third parties.

For cleaning and maintenance equipment, the pod for example, user safety may not always be achieved by design of the façades, and depends on the conditions of use of the said equipment.

Safety in use of glazed parts is supported by application of the regulatory texts (especially DTU 39).

7.3.3 Rules relating to habitability

7.3.3.1 Air-tightness and waterproofing

The building shell, under the conditions relating to implementation and bearing in mind effects of stress listed in 7.3.2, must ensure waterproofing and air-tightness between the internal and external environments. The concept of air-tightness is understood as a limitation to permeability, that is control of unavoidable air flow (therefore including dust, snow, insect penetration, etc.), and that of waterproofing is considered to be the absence of moisture caused by rainwater in parts accessible to the user, and elements of both the façade or the glass roof or neighbouring components, which could be damaged by this.

If the photovoltaic component is a sloping roof element covered with discontinuous elements or a cladding element, only the waterproofing function applies. If it is an element of the light façade or the glass roof, air permeability is also involved.

7.3.3.1.1 Air permeability

The wall, when subject to a pressure difference between the outside environment and the inside environment caused by wind action and/or pressurisation or depressurisation of the building, should not cause intake of an air flow which could :

- reduce the comfort of the occupants ;
- represent a source of excessive cost to maintain the temperature of the premises.

At a pressure P1 of 25 % of the resulting unitary action corresponding to normal pressure, without considering local actions, permeability must be no more than 1.5 $m^3/h.m^2$. At a pressure P2 equal to the resulting unitary action corresponding to normal pressure, without considering local actions, permeability must be no more than 4 $m^3/h.m^2$. These performance levels are to be considered under both positive and negative pressure.

The air permeability performance may only be evaluated by reference to an approved classification or by conventional bench tests.

7.3.3.1.2 Waterproofing

The façade or the roof is designed such that, subject to a pressure difference P3 corresponding to 50% of the pressure equal to the resulting unitary action corresponding to normal pressure, without considering local actions, it remains proof against rain, with the criteria required listed below :

- internal areas accessible to the user are not dampened by rain water ;
- the thermal characteristics, air permeability, mechanical strength are not degraded ;
- the parts of materials of the façade or glass roof which could be degraded by a rapid drop in temperature associated with standing water are properly drained.

Performances are to be considered only under pressure. The waterproofing performance can only be evaluated by reference to an approved classification and/or tests, or by conventional bench tests.

7.3.3.2 Hygrothermal comfort

7.3.3.2.1 Thermal comfort

The design and realisation of the building shell, must contribute to the energy saving requirement and the overall thermal insulation of the building.

The photovoltaic components of the shell in their contribution, must comply with the thermal regulations in force (design rules in the C.S.T.B.'s R.E.E.F.).

7.3.3.2.2 Condensation

The internal walls must remain within a humidification level, above which the comfort of the occupants would be compromised.

Condensation on internal walls, under the conditions in which the room is correctly heated and properly ventilated or air-conditioned, must be limited.

Condensation is directly linked to the effective internal hygrothermal conditions. The statement of works shall therefore specify the hygrothermal operating conditions of the building, and the external temperatures to be considered.

If these details are not available, the following internal conditions shall be used in the design of the photovoltaic component of the shell :

Winter : 18°C - RH : 50%

Before stabilisation of the main structure (concrete, plaster, etc.) a higher level of relative humidity in the air may temporarily cause greater condensation to occur.

Unless otherwise particularly specified, where filling of low thermal resistance is used (less than 0.05 m^2K/W such as that for single glazing), a condensation water collecting device must be included.

7.3.3.3 Acoustic comfort

The external walls shall be such that, bearing in mind the links to the main structure :

- normal air-borne noise outside the building shall not be excessively annoying for the occupants ;
- the sound of external impacts (hail) shall be adequately deadened so that it is not intolerable for the occupants ;
- no unpleasant noise shall be caused by the structure when subject to normal internal and external actions.

It is assumed that these walls comply with the acoustic requirements if they are in accordance with regulations in force (Decree of 6 October 1978 modified by the decree of 23 February 1983, relating to acoustic insulation of residential buildings against noise for the internal space, and standards NF S 3-010, NF S 31-051, NF S 31-055, NF S 31-057).

7.3.3.4 Appearance

The external walls shall have a normal appearance both outside and inside, without visible abnormal complexity, with respect to that requested by the call for tenders. The continuous lines shall be suitably straight. The appearance of the shell of a building and its durability may not be judged without reference to its normal maintenance (see 7.3.4).

The appearance of the anodised aluminium shall meet all the specifications of standard ISO 7599. Unless specifically required otherwise, the reflectance of the anodised aluminium measured according to standard ISO†2813 at 60° shall be between 13 and 21. Deviations in shade of the anodised aluminium shall correspond as a maximum to grade 3 on the grey scale, according to document ISO R 105/1, part 2.

Reflectance of enamelled products shall be measured according to Standard ISO 2813 at an angle of 60°. There are 3 possible categories for this reflectance :

- Category 1 : 0 - 30 ± 45 units
- Category 2 : 30 - 70 ± 7 units
- Category 3 : 70 - 100 ± 10 units

Anodised and enamelled products shall comply with Standard NF P 24-351. Current certifications for anodised and enamelled products are QUALANOD and QUALICOAT.

Evaluation of the quality of appearance of other products, especially glazing used for the façade, depends on these products and shall be made according to the stated criteria for these products. This evaluation shall be made at a distance no closer than 3 m.

7.3.3.5 Health

The component materials of the photovoltaic components of the shell shall not be likely to emit, in normal operational conditions, noxious gases, radiation or noxious dust. They shall also have, independently or together (composite fillings for example), a suitable physico-chemical stability in normal operational conditions, and especially under the influence of permitted extremes of temperature.

7.3.4 Rules relating to durability

Bearing in mind normal degradation factors (corrosion, insects, fungus, etc.) and with normal maintenance and use (impacts resulting from occupation etc.) the structure shall retain all its qualities resulting from the previously-mentioned functional requirements for safety and habitability, throughout the life span normally expected, according to the type of building concerned.

A photovoltaic component of the shell must retain all its functional characteristics (component parts and fixings), including its appearance and performance. It shall not be a cause of excessive nuisance to the occupant, under the effects of accidental shocks, without exceptions, arising from normal occupation.

7.3.4.1 Accidental impact

The requirement with respect to these accidental impacts is considered satisfactory if the photovoltaic component of the shell performs properly under the effect of conventional impacts known as "performance conservation impacts ".

The energy level of the shock, which the structures of the building façade must be able to withstand shall comply with standard NF P 08-302. The energy level depends on the position of the structure in the building, and the type of activity zone.

7.3.4.2 Maintenance

The photovoltaic modules shall be maintained according to the manual provided by the manufacturer.

The photovoltaic component of the shell shall be regularly maintained, to retain its qualities of appearance. In order to do this, annual cleaning is recommended.

7.3.4.3 Hygrothermal

Some constructional conditions, for example those requiring ventilated or breathing air gaps behind non-opaque glazing, require the maximum temperature levels which may be reached in sunshine to be determined. The consequences, especially for the insulation and the filling elements, shall be considered from the point of view of security requirements and durability requirements.

DRE SPECIFICATIONS - C 3 **June 1997**

Title **Part C - Technical Specification of Components**

Section 3 : Wind generator

The IEC committee of action decided to withdraw section C.3 on wind turbines at the request of IEC technical committee 88, Wind turbine systems (see documents CA/1549/R and CA/1587/RV).

Reference is made to the publications developed by technical committee 88, issued in the IEC 61400 series, particularly to the following standards:

IEC 61400-1, 1999: Wind turbine generator systems - Part 1: Safety requirements

IEC 61400-2, 1996: Wind turbine generator systems - Part 2: Safety of small wind turbines"

DRE SPECIFICATIONS - C 4

June 1997

Title

Part C - Technical Specification of Components

Section 4 : Electrogenerator set

Number of pages 26 (including Annexes)

Type Technical specification of components

Associated document(s) DRE - C 3 "Wind generator".

Summary The aim of this document, in the context of decentralised rural electrification, is to provide users with the appropriate levels of reliability and safety in this equipment throughout its estimated service life.

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CONTENTS

1. Scope

The present specifications apply to electrogenerator sets intended for emergency or backup use in installations for the electrification of isolated sites.

Its aim is to provide users with the appropriate levels of reliability and safety in this equipment throughout its estimated service life.

It applies to any electrogenerator set powered by a combustion engine, having a low-voltage output with a nominal output power between 1 kW and 50 kW, and intended to provide electrical power to isolated sites used in the systems whose typologies are described in Part 2 of the Quality Charter.

It describes the minimum safety requirements and is not claimed to be an exhaustive manual of instructions or design specifications.

Compliance with this document does not absolve any person, organisation or corporation from the responsibility of complying with all other appropriate regulations.

NOTE. - Certain provisions contained in this document arise from standardisation at the international or French level. In the latter case, an explicit statement to that effect is made. Obviously, local regulations must be observed.

2. References to regulations and standards

2.1 ISO Norms

ISO 3046-1 :1986 Reciprocating internal-combustion engines - Performance - Part 1 : Normal reference conditions and statements of power and of fuel and lubricant consumption figures.

ISO 3046-2 :1989 Reciprocating internal-combustion engines - Performance - Part 2 : Test methods.

ISO 3046-3 :1989 Reciprocating internal-combustion engines - Performance - Part 3 : Test measurements.

ISO 4628/3 : 1982, Paints and varnishes - Evaluation of the degradation of painted surfaces - Designation of the intensity, quantity and dimension of current types of defects - Part 3 : Designation of the degree of rusting.

ISO 8528-1 : 9/94, Alternating-current electrogenerator sets driven by reciprocating internal-combustion engines - Part 1 : Application, characteristics and performance (E 37-301).

ISO 8528-2 : 9/94, Alternating-current electrogenerator sets driven by reciprocating internal-combustion engines - Part 2 : Engines (E 37-302).

ISO 8528-3 : 9/94, Alternating-current electrogenerator sets driven by reciprocating internal-combustion engines - Part 3 : Alternators for electrogenerator sets (E 37-303).

ISO 8528-4 : 09/94, Alternating-current electrogenerator sets driven by reciprocating internal-combustion engines - Part 4 : Control and switching equipment (E 37-304).

ISO 8528-5 : 09/94, Alternating-current electrogenerator sets driven by reciprocating internal-combustion engines - Part 5 : Electrogenerator sets (E 37-305).

ISO 8528-6 : 09/94, Alternating-current electrogenerator sets driven by reciprocating internal-combustion engines - Part 6 : Testing methods (E 37-306).

ISO 8528-7 : 08/95, Alternating-current electrogenerator sets driven by reciprocating internal-combustion engines - Part 7 : Technical declarations for specification and design (E 37-307).

2.2 IEC Norms

IEC 364 (series) : Low-voltage electrical installations Regulations (NF C 15-100 and HD 384 series).

IEC 529 : 1989, Degrees of protection procured by envelopes (IP Code) (NF EN 60529, classification NF C 20-010).

IEC 536 : 1976, 1992, Low-voltage electrical equipment. Protection against electric shock. Safety regulations (NF C 20-030).

IEC 34-1 : Electrical rotating machines - Assigned characteristics and operating characteristics (10th edition 1996-11).

IEC 34-2 : Methods for the determination of the losses and output of electrical rotating machines based on testing (excluding machines for traction vehicles).

IEC 34-5 : Classification of the degrees of protection procured by the envelopes of electrical rotating machines (IP code).

IEC 34-6 : Methods of cooling rotating machines.

IEC 34-7 : Classification of the structural shapes and mounting arrangements for electrical rotating machines (IM Code).

IEC 34-8 : Extremity and direction-of-rotation markings of rotating machines.

IEC 34-9 : Electrical rotating machines - Noise limits.

IEC 34-14 : Mechanical vibrations of certain machines with axis height exceeding or equal to 56 mm - Measurement, evaluation and limits of vibrational intensity.

IEC 34-16-1 : Systems of excitation for synchronous machines. Chapter 1 Definitions : (first edition 1991-02).

IEC 34-16-2 : Systems of excitation for synchronous machines. Chapter 2 Models for the study of grids (first edition 1991-02).

IEC 34-16-3 : Systems of excitation for synchronous machines. Chapter 3 Dynamic performance (first edition 1996-01).

IEC 34-22 Electrical rotating machines - Alternating-current generators for internal-combustion engines with pistons (1996).

IEC 38 Normal voltages of the IEC (1983).

IEC 72-1 : Dimensions and series of powers of electrical rotating machines - Part 1 : Designation of bodies between 56 and 400 and straps between 55 and 1080 (sixth edition 1991-2).

IEC 245 Conductors and cables insulated with rubber, with a nominal voltage not exceeding 450/750V.

IEC 287 Calculation of current continuously acceptable in cables (100% load factor).

IEC 439-1 : Assembly of low-voltages equipment - First part : Regulations for series and series-derived assemblies (NF EN 60439-1, classification C 63-421).

IEC 364 : Electrical installations in buildings.

IEC 529 : 1989 : Degrees of protection procured by envelopes (IP Code).

IEC 721-2-1 1982 Classification of environmental conditions - Second part Environmental conditions present in nature - Temperature and humidity (NF C 20-000).

IEC 947-1 :1988 Low-voltage equipment - First part : General regulations (NF EN 60947-1, classification C 63-001).

IEC 1000 : Electromagnetic compatibility.

IEC CISPR 11 : 1990 : Limits and measurement methods for the characteristics of industrial, scientific and medical (ISM) equipment subjected to radiofrequency electromagnetic interference.

IEC 1024-1 : 1990 : Protection of structures against lightning - First part : General principles.

2.3 CEN and CENELEC Norms

EN 12601 pr : 09/96, Electrogenerator sets driven by reciprocating internal-combustion engines - safety (AFNOR draft : E 37-351).

2.4 Regulations applicable in France

2.4.1 Laws

76-663 of 19 July 1976, relating to installations classified for the protection of the environment.

2.4.2 Decrees

88-1056 of 14 November 1988 relating to the protection of workers in establishments using electrical currents.

93-1412 of 29 December 1993 relating to the general provisions applicable to installations classified for the protection of the environment subject to declaration under the heading 2925.

2.4.3 Orders

25 June 1980 approving the general provisions of the safety regulation against the risks of fire and panic in establishments admitting the public (see 2.2 for the norm UTE C 12-201).

2 January 1986 relating to the limitation of the sound level of airborne noise emitted by electrogenerator sets (EEC Directive 84/536).

2.4.4 Circulars

DRT 89-2 of 6/2/89, as amended on 29 July 1994, relating to measures intended to ensure the protection of workers in establishments using electrical currents (comments on the Decree 88-1056).

2.4.5 Other regulatory texts

Technical specifications of the *Groupe d'Etudes de Marchés des Matériels Mécaniques, Electriques et Electroniques* (GPEMMEE) [Study Group on the Markets for Mechanical, Electrical and Electronic Equipment]

2.5 Norms applicable in France

2.5.1 AFNOR Norms

XP E 37-309 : 11/90, Internal-combustion engines - Alternating-current electrogenerator sets driven by reciprocating internal-combustion engines - measurement of mechanical vibrations.

NF ISO 8528-1 (classification E 37-301) 09/94 : Alternating-current electrogenerator sets driven by reciprocating internal-combustion engines - Part 1 : Applications, characteristics and performance.

NF ISO 8528-2 (classification E 37-302) 09/94 : Alternating-current electrogenerator sets driven by reciprocating internal-combustion engines - Part 2 : Engines.

NF ISO 8528-3 (classification E 37-303) 09/94 : Alternating-current electrogenerator sets driven by reciprocating internal-combustion engines - Part 3 : Alternators for electrogenerator sets.

NF ISO 8528-4 (classification E 37-304) 09/94 : Alternating-current electrogenerator sets driven by reciprocating internal-combustion engines - Part 4 : Control and switching equipment.

NF ISO 8528-5 (classification E 37-305) 09/94 : Alternating-current electrogenerator sets driven by reciprocating internal-combustion engines - Part 5 : Electrogenerator sets.

NF ISO 8528-6 (classification E 37-306) 09/94 : Alternating-current electrogenerator sets driven by reciprocating internal-combustion engines - Part 6 : Test methods.

NF ISO 8528-7 (classification E 37-307) 08/95 : Alternating-current electrogenerator sets driven by reciprocating internal-combustion engines - Part 7 : Technical declaration for specification and design.

2.5.2 UTE Norms

UTE C 12-201 : 4/92, 2/96, Official texts relating to protection against the risks of fire and panic in establishments admitting the public (extracts concerning electrical installations (see 2.4.3 for Order of 25 June 1980).

NF C 15-100 : 05/1991, 12/1994, 12/1995, Low-voltage electrical installations. Regulations.

UTE C 15-401 concerning installations of combustion-engine groups - generators. Practical guide.

NF EN 50102 : 6/95, Degrees of protection procured by the envelopes of electrical equipment against external mechanical impact. IK Code. (NF C 20-015).

NF C 15-100 : 05/91, Low-voltage electrical installations. Regulations (equivalent to IEC 346 and HD 384).

UTE C 18 510 Collection of general safety instructions relating to electricity.

UTE C 18 530 Electrical safety notes intended for qualified personnel.

NF C 32-102-1 à 4 : 12/1993 Conductors and cables insulated with rubber, with an assigned voltage not exceeding 450/750V Parts 1 to 4.

NF C 32-321 : 10/1982 Insulated conductors and cables for installations - Rigid cables insulated by cross-linked polyethylene with a polyvinyl chloride protective sheath - Series U-1000 R2V.

NF C 32-322 : 04/1982 Rigid cables insulated by cross-linked polyethylene with a reinforced polyvinyl chloride protective sheath - Series U-1000 RVFV.

NF EN 60529 (classification NF C 20-010) Degrees of protection procured by envelopes (IP Code).

NF EN 60947-1 (Classification NF C 63-001) Low-voltage equipment - First part : General rules.

NF C 51-104 January 1974 "Electrical rotating machines - Fixing studs - Connection"

NF C 51-105 September 1971 "Electrical rotating machines - Cylindrical shaft ends of the long series with keying".

NF C 51-110 February 1977 "Electrical rotating machines - Normal values of nominal power".

NF C 51-111 "Electrical rotating machines - Regulations for the installation of electrical rotating machines" (equivalent to the norm IEC 34-1).

NF C 51-112 November 1975 "Electrical rotating machines - Method for the determination of the losses and yield of electrical rotating machines based on testing".

NF EN 60 034 part 5 (NF C 51-115) "Electrical rotating machines - Classification of the degrees of protection procured by the envelops of rotating machines" (equivalent to IEC 34-5).

NF C 51-117 April 1976 "Electrical rotating machines - Symbols for the structural shape and mounting arrangements for electrical rotating machines".

NF C 51-118 February 1996 "Electrical rotating machines - part 8 : Extremity and direction-of-rotation markings of rotating machines.

NF EN 60034-9 (classification C 51-119) : Electrical rotating machines - Ninth part : noise limits (equivalent to IEC 34-9).

NF EN 61000 : Electromagnetic compatibility.

3. Definitions

Environmental conditions : Characteristics of the environment (altitude, temperature, humidity etc.) that may affect performance.

Lifetime : Effective operating time taking account of the probability of the occurrence of a catastrophic failure.

Assigned frequency : ratio of the assigned power to the apparent assigned power.

Electrogenerator set : equipment producing electrical energy with the aid of a fossil fuel ; it consists mainly of a reciprocating internal-combustion engine producing mechanical energy, a generator converting the mechanical energy into electrical energy, and components for mechanical transmission, support and mounting.

Scheduled maintenance : Preventive maintenance performed in accordance with a laid-down plan.

Unscheduled maintenance : Necessary maintenance in addition to that provided for in advance.

Assigned power (apparent assigned or nominal power) : Maximum apparent electrical power continuously provided by a electrogenerator set in accordance with its specifications and under normal operating conditions. It is expressed in VA (voltamperes) or, more commonly, in kVA.

Assigned active power (nominal active power) : Maximum active electrical power continuously provided by a electrogenerator set in accordance with its specifications and under normal operating conditions. It is expressed in W (watts) or, more commonly, in kW.

Assigned reactive power : vector difference between apparent assigned power and active assigned power, expressed in VAR.

Assigned voltage : voltage between phases at the alternator terminals at the assigned frequency and assigned power.

Assigned speed of rotation : speed of rotation required of the alternator for the production of voltage at the assigned frequency.

4. Symbols and abbreviations

GS : Standby electrogenerator set.

5. Conditions related to the environment

5.1 Normal reference conditions

The reference environmental conditions applicable to the main components of a electrogenerator set in order to define its assigned performance figures, in accordance with the norm NF ISO 8528-1, are as follows.

Engine : the following conditions apply for the definition of the nominal power of the engine in accordance with the norm ISO 3046-1 :

- total barometric pressure 100 kPa (1000 mbar) ;
- air temperature 25°C (298 K) ;
- relative humidity 30% ;
- temperature of coolant for the supercharging air 25°C (298 K).

Alternator : the following conditions apply for the definition of the apparent assigned power of the alternator, in accordance with the norms NF C 51-111 and NF ISO 8528-3 (France) or IEC 34-1 and ISO 8528-3 (international) :

- ambient air temperature below 40°C (313K) ;
- cooling air temperature below 40°C (313 K) ;
- cooling water temperature below 25°C (298 K) ;
- altitude less than 1000 m above sea level.

Control and switching equipment : the following normal reference conditions apply for the adjustment of the control and switching equipment, in accordance with the norms NF C 64-439-1 (France) or IEC 439-1 (International) :

- maximum temporary ambient temperature : 40°C (313K) ;
- relative humidity : 50% at 40°C (313 K) ;
- altitude less than 2000 m above sea level.

5.2 Normal extreme conditions

The extreme reference environmental conditions applicable to the main components of a electrogenerator set are as follows.

Engine : the extreme conditions for the use of the engine in accordance with the norm ISO.... are as follows : *to be completed (if a usable reference document exists)*

- total barometric pressure : minimum 100kPa (1000 mbar), maximum.... ;
- air temperature : from...°C to...°C ;
- relative humidity : from..% to.. % ;
- temperature of coolant for the supercharging air : from..°C to..°C.

Alternator : the extreme conditions for the use of the alternator in accordance with the norms NF C 51-111 (France) or IEC 34-1 (international) are as follows :

- ambient air temperature : between -15°C and +40°C for machines whose power exceeds 600VA and between 0°C and +40°C for machines whose power is less than 600VA ;
- temperature of the cooling air : as for ambient air ;
- temperature of cooling water between +5°C and 25°C ;
- altitude less than 1000 m above sea level.

These conditions should be considered as reference conditions that should not be exceeded for the installation of the electrogenerator set.

Any foreseeable operating conditions going outwith the limit values may cause a significant change in equipment (excessive dimensions, even technical impossibility), and should therefore be included in the technical specification communicated to the Manufacturer of the electrogenerator set.

5.3 Site conditions

The site conditions under which the electrogenerator set is called upon to operate, whatever be its mode of installation, may affect certain of its characteristics. They must be taken into account by the Contractor and the Manufacturer of the electrogenerator set. They must be clearly defined by the Contractor and any particularly dangerous condition must be the subject of a description.

5.3.1 Climatic conditions

The Contractor must inform the Manufacturer of the electrogenerator set of the upper and lower extreme ambient temperatures and the conditions of relative humidity under which the electrogenerator set must operate, no matter what its mode of installation.

When the site conditions are unknown, and unless otherwise specified, the following nominal site conditions should be used (see NF ISO 8528-1) :

- total barometric pressure 89.9kPa (1000 mbar) ;
- air temperature 25°C (298 K) ;
- relative humidity 30% ;
- temperature of coolant for the supercharging air 25°C (298 K).

The external climatic conditions shall be notified in all cases to the Manufacturer of the electrogenerator set, whether this be installed indoors or outdoors.

The default conditions to be taken into consideration are as follows :

- variations in normal operating temperature of the system from -10°C to +40°C ;
- maximum relative humidity 95 % ;
- atmospheric composition equivalent to that of an unpolluted continental atmosphere ;
- altitude less than 1000 m.

NOTE. - In the absence of a normative reference specific to electrogenerator sets, the latter specifications are those used to define the normal external conditions for wind generators (see document DRE - C 3 "Wind generator")

5.3.2 Other environmental conditions :

The Contractor must inform the Manufacturer of the electrogenerator set of the other environmental conditions affecting the design, dimensions and maintenance of the electrogenerator set in accordance with the norm NF ISO 8528-1 :

- altitude (if over 1000 m) ;
- presence of sand, dust or other physical pollutants of the atmosphere of the electrogenerator set
- marine environment (electrogenerator sets operating at coastal sites) ;
- shock and vibrations (earth tremors, presence of another rotating machine) ;
- presence of chemical pollution.

No minimum specification is given in the present document concerning these environmental conditions.

6. Performance and constructional arrangements

6.1 Regulations for design

The safety regulations to be used in the design and construction of a electrogenerator set are those of the draft norm CEN EN 12601. They concern mainly the following :

- the starting device ;
- normal or emergency stop ;
- manual or automatic controls ;
- monitoring devices ;
- protection against mechanical risks ;
- protection from hot surfaces ;
- conveyance ;
- protection against fire ;
- protection against direct and indirect contact ;
- noise ;
- emissions of gas and particles ;
- oil changes ;
- etc.

6.2 Conditions of use - Classification of electrogenerator sets

6.2.1 Conditions of use

The two main types of use of electrogenerator sets that are described in Part 2 of the Quality Charter are single-user (type-T3 topology) and small power station (type-T4 topology) systems.

In these two topological categories, electrogenerator sets are used for the following purposes :

- solely for charging secondary batteries ;
- for charging batteries and standby power supply for all or part of AC loads and for the supply of dedicated AC loads.

The nature of the utilisation of the standby electrogenerator set must be clearly identified by the Contractor and notified to the supplier.

6.2.2 Classification of services

Electrogenerator sets are classified by the service they provide. These services, of which there are four, define an acceptable power for an annual number of running hours. They are shown in Table 1.

Table 1 : Classification of electrogenerator sets

Service	A	B	C	D
Power	maximum continuous	variable continuous	variable	variable
Number of hours	unlimited	4 000	2 000	500
Overload	no	10 % single-hour	10 % single-hour	no
Number of hours/day	24	24	12	*

* : to be studied case by case (emergency, peak smoothing etc.)

6.2.3 Classes of load and charging conditions

The classes of application are defined by the norm NF ISO 8528-1 (article 7). The following classes are used for the area of application of the present compilation of specifications :

Class G1 : utilisations in which the equipment supplied is such that only minor voltage or frequency constraints need be specified. General use (lighting and other electrically simple loads) ;

Class G2 : utilisations in which the voltage characteristics required are virtually the same as those on the public grid. When load fluctuations occur, temporary fluctuations in voltage and frequency can be accepted. Systems for lighting, pumping, fans and hoists ;

Class G3 : utilisations in which the equipment supplied may impose stringent requirements as to frequency, voltage and waveform. Telecommunications and loads controlled by thyristors (battery chargers).

NOTE. - Class G4, the most stringent, which is applicable to computer systems, is not used in this context.

The default application class used here is G1 *or G2?*

The (normalised) reference load conditions are defined by the norm IEC 34-1 article 6.2.2 : they correspond to a quasi-linear load, i.e. one which :

- when supplied with a perfectly sinusoidal voltage consumes a current whose instantaneous value never deviates by more than 5% from the fundamental waveform ;
- when supplied with a balanced three-phase voltage system, neither the negative nor the homopolar component exceeds 5% of the positive component.

These conditions enable the assigned power of the alternator of the electrogenerator set to be defined to allow compliance with the supplied voltage conditions specified below. If the electrogenerator set load does not comply with these criteria, the Contractor must so inform the Supplier of the electrogenerator set so that they correctly dimension the alternator in electrical and thermal terms. In fact a non-sinusoidal current tends to deform the voltage supplied by the electrogenerator set and to create additional losses in the alternator which lead to additional heating of the windings.

As a general rule, battery chargers do not respect the criterion of the reference load (the current absorbed is not sinusoidal). In consequence the current characteristics of chargers must be notified very precisely to the supplier of the electrogenerator set.

Several modes of operation can be envisaged for standby electrogenerator sets, in accordance with the norm ISO 8528-1 :

- used alone : the electrogenerator set operates without direct connection to another source of energy ;
- coupled (grouped in parallel) : in this mode of operation, two or more electrogenerator set are electrically connected ;
- on the grid : operate for the supply of a public distribution grid ; this mode of operation does not apply to the present document.

6.2.4 Technical definition of the standby electrogenerator set

It is therefore the responsibility of the Contractor to define precisely the minimum conditions of utilisation of a standby electrogenerator set :

- the environmental conditions ;
- the maximum useful power levels and the corresponding duration and frequency of loading ;
- the characteristics of the electrical loads (power factor, acceptable voltage range, harmonic content of current etc.).

The technical declarations for the specification and design of electrogenerator sets recommended by the norm NF ISO 8528-7 (or ISO 8528-7 for international implementation) shall be made :

- the Contractor shall express his requirements in a technical questionnaire complying with Annexe A to the norm NF ISO 8528-7 (or ISO 8528-7 respectively) ;
- The specifications approved by the Manufacturer of the electrogenerator set and the Contractor shall be expressed in a technical form complying with Annexe C to the norm NF ISO 8528-7 (or ISO 8528-7 respectively).

Since the assigned dimensions of the electrogenerator set are usually defined for the normalised reference conditions specified in section 5.1, it is therefore necessary for the effective environmental conditions of use of the electrogenerator set to be clearly defined. It must be noted in particular that, beyond the reference conditions (temperature of 25°C and pressure <100kPa), it is necessary to provide for a declassification of the power of the engine.

6.3 Assigned dimensions

The assigned dimensions defining a electrogenerator set are as follows :

- the assigned voltage ;
- the assigned frequency ;
- the assigned power and the corresponding regime of operation in compliance with the norm ISO 8528-1 ;
- the class of application ;
- the assigned current ;
- the assigned power factor ;
- the maximum ambient temperature ;
- the maximum altitude for utilisation ;
- the nature of the fuel.

6.4 Characteristics of the voltage supplied by the electrogenerator set

The voltage supplied by the electrogenerator set to power a reference load complies with the norms IEC 34-22 and NF ISO 8528-3 (ISO 8528-3), depending on the application class (G1, G2 or G3).

The main performance figures for a generating-set alternator in the application class G1 supplying a reference load and powered at the assigned speed are as follows :

- voltage deviation in continuous operation : <±5% ;
- maximum potential drop under transient conditions : <30% ;
- maximum transient overvoltage : <35% ;
- maximum time for restoration of voltage : 2.5s ;
- maximum voltage unbalance : 1% ;
- harmonic factor of phase voltages : <8%.

If the load of the electrogenerator set does not display the characteristics of a reference load, the specifications for the voltage supplied by the electrogenerator set will have to be defined by agreement between the Contractor and the supplier of the electrogenerator set, particularly for battery-charging applications.

6.5 Noise emissions

Where noise emissions are concerned, electrogenerator sets must comply with the limits on acoustic power of airborne noise shown in Table 2[1].

Table 2 : Acceptable acoustic power levels for electrogenerator sets

Electrical power of electrogenerator set (P)	Acceptable acoustic power level (dB (A)/1 pW)
P (2 kVA	102
2 kVA < P < 240 kVA	100

Respect for these limits may require the use of a sound baffle.

The noise emissions of the alternator of the electrogenerator set comply with the norms NF EN 60034-9 or IEC 34-9 (international) as a function of its mode of cooling and its assigned speed of rotation.

NOTE. - The future norm ISO 8528-10 will deal with the measurement of the airborne noise from electrogenerator sets.

6.6 Characteristics of the combustion engine

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[1] *In France, the limiting levels were fixed by the Order of 2 January 1986 (EEC Directive 84/536).*
Note: This Order imposes a specific marking indicating acoustic power level in A-weighted decibels.

6.6.1 Nature

The engines of electrogenerator sets are reciprocating internal-combustion engines and are of two types :

- compression-ignition engines ;
- spark-ignition engines.

Unless specified by the Contractor, the nature of the engine is selected by the Supplier of the electrogenerator set.

6.6.2 Fuel

The fuel used by the electrogenerator set shall display an ignition point greater than or equal to 55°C.

The nature of the fuel to be used is specified by the Supplier of the electrogenerator set.

If the Contractor wishes to impose or exclude a particular type of fuel he must so inform the supplier of the electrogenerator set.

6.6.3 Fuel tank

The electrogenerator set shall be provided with a fuel tank having a minimum volume V based on the following criterion :

V (0,25 l per kVA and per hour of daily operation.

A return pipe shall be provided from the engine to the tank.

6.6.4 Exhaust

Hot parts (exhaust pipes) must be put out of reach or heat-insulated.

6.7 Characteristics of the alternator

The alternator of the electrogenerator set complies with the norms NF ISO 8528-3 (ISO 8528-3 international) and IEC 34-22.

It is defined by the following assigned dimensions for basic continuous operation (service S1) and, if necessary, for peak continuous operation (service type S10) in compliance with the norm IEC 34-22 :

- Assigned apparent power :
- Assigned frequency ;
- Assigned voltage ;
- Assigned current ;
- Assigned power factor ;
- Maximum ambient temperature ;
- Maximum altitude.

For continuous service, the heating of the stator and rotor windings of the alternator comply with the limit values of the norm IEC 34-1 depending on the mode of cooling and the insulation class of the insulating materials.

For continuous peak service, the heating of the stator and rotor windings of the alternator comply with the limit values of the norm IEC 34-22.

When used on a load that draws a non-sinusoidal current (battery charger, low-power lamps), the alternator dimensions shall be such that the heating of the stator and rotor windings does not exceed the limit values corresponding to the insulation class of the insulating materials defined by the norms NFC 51-111, IEC 34-1 and IEC 34-22, for all regimes of utilisation specified in the environmental conditions. Moreover, the electrical dimensions of the alternator must take account of the presence in the utilisation grid of a significant proportion of electrical motors, particularly asynchronous motors.

The alternator has the capacity for an occasional overvoltage in compliance with the norm IEC 34-1, i.e. 1.5 times the assigned current for 30 s.

The alternator is capable of bearing a short-circuit at its terminals for a sufficient time to allow the operation of protective arrangements (ISO 8528-3 art. 10)

Rotating parts shall be protected by casings.

6.8 Mode of intervention and control

The modes of intervention and control involved in the operation of a electrogenerator set are normally as follows :

- starting ;
- monitoring ;
- regulation of voltage and frequency ;
- switching ;
- stopping.

These may be entirely or partially manual or automatic.

Intervention periods (starting and loading) for a electrogenerator set may be specified if necessary. They shall be agreed with the Supplier of the electrogenerator set.

6.9 Means of starting

Various starting means can be used, depending on the source of energy and the size, design and application of the electrogenerator set :

- mechanical means (manual starting) ;
- electrical means (electric starting motor) ;
- pneumatic means (injection of compressed air into the cylinders, or pneumatic starting engine).

Where electrical starting is used, lead-acid or nickel-cadmium accumulator batteries (optionally) should be placed as close as possible to the electrogenerator set with a protective cover.

6.10 Control and switching equipment

The electrical control and switching equipment of the electrogenerator set complies with the norms NF ISO 8528-4, NF EN 60947 (ISO 8528-4, IEC 439-1, IEC 947-1 international).

The electrical protection of the alternator must have the latter's short-circuit characteristics.

6.11 Vibrations

The Manufacturer of the electrogenerator set must show that, for the vibrating system (engine, coupling, generator, frame), the vibration characteristics throughout the normal operating zone are sufficiently distant from the range of critical values.

The vibrations due to other parts of the electrogenerator set (exhaust) should be taken into account.

The limits on the vibrations of the alternator comply with the norm IEC 34-14.

6.12 Configuration of the electrogenerator set, mounting and types of installation

The possible types of configuration for a electrogenerator set are as follows (cf. NF ISO 8528-1) :

A : without chassis ;

B : with chassis ;

C : with chassis, control and switching equipment and integral auxiliaries ;

D : C with soundproof cover ;

E : C with integral conveyor system or mounted on a trailer.

Several types of mounting can be envisaged for a electrogenerator set and chosen by agreement between the Contractor and the supplier of the electrogenerator set (cf. norm NF ISO 8528-1) :

- rigid mounting ;
- elastic mounting ;
- totally elastic mounting ;
- semi-elastic mounting ;
- mounting on anti-vibration arrangement.

The nature of the link between the engine and the alternator is defined by the supplier of the electrogenerator set.

Several modes can be envisaged for the installation of the electrogenerator set (cf. norm NF ISO 85281) :

- indoor installation ;
- outdoor installation with weather protection ;
- open-air installation.

The choice of a weather-protected outdoor or open-air mode of installation must be agreed between the Contractor and the Supplier of the electrogenerator set.

6.13 Marking

Every electrogenerator set must bear the following indicator plates, in accordance with the norm NF ISO 8528-5 :

a. Electrogenerator set :

- the designation "Electrogenerator set complying with norm etc." ;
- the name or trade mark of the manufacturer ;
- the reference and name of the product ;
- the serial number and the date and place of manufacture ;
- the assigned power of the electrogenerator set in kW, and a statement of the corresponding type of operating regime ;
- the class of application in compliance with ISO 85281 :1993 ;
- the assigned power factor ;
- the maximum altitude for utilisation ;
- the maximum ambient temperature ;
- the assigned voltage per phase ;
- the assigned frequency ;
- the assigned current ;
- the mass.

b. Engine

c. Alternator :

- the alternator must bear an indicator plate complying with the norms NF C 51-111 (IEC 34-1 international) and 34-22, containing at least the following information :
  - ◊ the name or trade mark of the manufacturer ;
  - ◊ serial number and machine code ;
  - ◊ year of manufacture ;
  - ◊ reference norm ;
  - ◊ degree of protection of envelopes (IP code) ;
  - ◊ thermal classification or heating limit ;
  - ◊ type of service (S1 to S10) ;
  - ◊ assigned power ;
  - ◊ assigned voltage ;
  - ◊ assigned frequency ;
  - ◊ assigned current ;
  - ◊ assigned speed of rotation ;
  - ◊ assigned power factor ;
  - ◊ maximum altitude for utilisation ;
  - ◊ maximum ambient temperature ;
  - ◊ direction of rotation (if unique).

d. Switch-off equipment

6.14 Lifetime

Electrogenerator sets are designed for an operating lifetime of 20 years.

6.14.1 Lifetime of painted metal parts

The degree of rusting of the whole after 10 years must be less than the degree of rusting of value Ri2 defined by the reference plate of the norm ISO 4628/3 or less than the degree of value Re2 defined by plate 8 of the European scale of degrees of rusting for antirust paint.

6.14.2 Lifetime of sheathing systems

A sheathing system is considered satisfactory no matter what the support if :

- after 10 years the modifications in appearance characterised by bubbling, deep cracking followed by scaling, glazing and chalking, isolated or cumulated, do not exceed a limit of 1% per square of side 1m ;
- after 6 years, the alteration of the colour or the attenuation of the gloss is uniform and does not spoil aesthetic appearance. This provision also applies to coloured materials in the ground coat.

6.14.3 Lifetime of synthetic materials

For synthetic materials, the lifetime, criteria and acceptance thresholds are those defined by the tests contained in the present specification.

6.15 Earth connection

At the time of manufacture, the electrogenerator set and its cabinet are fitted with an equipotential connection between all components, connected to a connecting point on the chassis of the electrogenerator set.

6.16 Maintenance and periodic checks

Scheduled maintenance operation (nature and frequency) are defined by the supplier of the electrogenerator set and notified to the user.

6.17 Documentation

The Manufacturer of the electrogenerator set should provide the following with each machine :

- the instruction manual for the operator ;
- the maintenance manual, which will include the maintenance requirements ;
- the documentation, that includes overall plans, electrical diagrams, specifications and instructions for assembly, installation and setting up.

This documentation must state details relating to loads, weights, lifting lugs, and the specific tools and procedures required for maintenance, installation and operation of the electrogenerator set.

Manuals must be produced in French for electrogenerator sets installed in France and in a language that can be read and understood by operators for electrogenerator sets installed in other countries.

The documentation should include the following points :

For installation :

- details of specific tools, equipment and arrangements for securing, and other equipment for safe installation ;
- instructions for correct lubrication and the conditions of all components before taking into service ;
- the assembly procedures recommended by the manufacturer ;
- identification of critical fasteners and the procedures relating to tightening torque and other recommendations ;
- a set of plans relating to assembly on the site and installation ;
- a complete diagram of cabling and interconnections.

For operation :

- limits on safe operation and descriptions and procedures for starting and stopping ;
- procedures for operational checks on all protection subsystems ;
- a description of the subsystems of the electrogenerator set and their operation.

For inspection and maintenance :

- intervals and procedures for inspection and maintenance ;
- lubrication intervals, frequency of lubrication, types of oil and other special fluids to be used ;
- procedures for unscheduled and emergency maintenance ;
- diagnostic procedures and a guide to fault tracing.

7. Regulations for the installation of electrogenerator sets

7.1 French regulations

Under the safety regulations of 25 June 1980 (see Book II, Chapter V), premises containing electrogenerator sets are classified in France as boiler plant.

Electrogenerator sets must not be located in a boiler room or premises directly accessible to the public.

7.2 Mode of installation

Several modes can be envisaged for the installation of the electrogenerator set (cf. norm NF ISO 8528-1) :

- indoors : electrogenerator set located in a building and therefore not exposed to direct effects of weather ; minimum and maximum temperatures of the room should be taken into account ;
- outdoors, with weather protection : installation in a protective enclosure or under crude shelter ;
- in the open air : electrogenerator set entirely exposed to weathering.

The installation and implementation of the electrogenerator set are the responsibility of the Contractor.

7.3 Civil engineering works

The civil engineering works shall permit easy introduction of the equipment.

Electrical ducts (for cables) and mechanical ducts (for fluids) shall be separated.

An anchoring block weighing one and one-half times the weight of the electrogenerator set shall be provided, supported by an insulator or rubber blocks.

Metal fittings shall be connected to earth.

A source of water and a drain for it shall be provided.

7.4 Ventilation

The premises in which the electrogenerator set is installed shall permit the engine to be correctly supplied with air for combustion and for cooling and shall maintain the electrogenerator set within the ambient temperature limits for which it has been specified.

The air consumption of the electrogenerator set is notified by the Manufacturer. By default, the following values may serve as a reference.

The cross-section of the air intake shall be the same as that of the return and shall be determined as follows :

- electrogenerator set ventilated by its radiator or air cooler : 80 m^3/h per kVA ;
- electrogenerator set with heat exchanger, provide for a standby fan : 40 m^3/h per kVA ;
- speed in jackets : 4 m/s ;
  - Example : 30 kVA electrogenerator set, flow rate 30 x 80 = 2400 m^3/h = 0.67 m^3/s ;
    cross-section = 0.67 m^3/s / 4 m/s = 0.17 m².

The ventilation of the premises in which the electrogenerator set is installed should be of such dimension as to comply with the limits on acceptable ambient temperature for the electrogenerator set, engine and generator, under all specified conditions of use and environmental conditions.

To achieve this, the Supplier of the electrogenerator set shall notify the Contractor of all information necessary for the thermal dimensioning of the premises accommodating the electrogenerator set :

- losses via the exhaust (radiated heat) ;
- engine losses evacuated by the radiator ;
- losses directly emitted to the surroundings (losses from the alternator, convection losses of the engine).

7.5 Exhaust of burnt gases

Combustion gases must be exhausted directly to the exterior of the premises.

The cross-section of the piping for exhausting the burnt gases can be determined by the following calculation :

$$\text{diameter in cm} = \sqrt{kVA * 1{,}2}$$

The chosen diameter shall be the nearest standard diameter.

This piping may be thermally insulated or otherwise and may be made in stainless or ordinary steel.

7.6 Storage of fuel

The premises containing the electrogenerator set must not be used for the storage of fuel exceeding an amount of 500 litres[(2)].

A container with a capacity of 600 litres shall therefore be installed in the premises housing the electrogenerator set.

If the quantity stored exceeds 500 litres, storage must be effected in specific premises[(2)]. The following points shall be respected :

- double wall if the tank is buried ;
- anchoring to a block weighing 1 200 kg per 1 000 litres of capacity ;
- vent pipe taken to a high point ;
- external "fireman's" valve for filling the tank of the electrogenerator set ;
- supply to the electrogenerator set by electric or manual pump ;
- overflow return sloping down to the tank ;
- level contact for pump control and alarm ;
- earthing of the tank.

7.7 Electrical connections

The conditions for the installation of electrogenerator sets, particularly as regards protection against indirect contact and the plan of earth connections, are given in the document on the protection of persons and goods (DIGELEC, part 11).

The neutral system of the electrogenerator set shall be that of the installation that it powers.

Emergency distribution to an installation normally powered from another source must be effected via a Normal / Emergency change-over switch fitted with mechanical and electrical locks that prevent the accidental connection in parallel of the electrogenerator set and the other source.

7.7.1 Cables and connections

For compact versions of electrogenerator sets, no cable between the electrogenerator set and its controls should be provided. In the case of a electrogenerator set with a separate cabinet, a 19x1.5 mm² cable should be provided for the transmission of controls and commands, a 2x6 mm² cable for charging the battery, and a 4x4 mm² cable for preheating.

Power cables shall be thermally dimensioned (the short-circuit power of a electrogenerator set is only three times its nominal power) in accordance with Table 3, which shows the cross-section of connecting cables for a three-phase 230/400 V electrogenerator set, a cable length of 10 m and an ambient temperature of 40°C.

[(2)] In France, safety regulation of 25 June 1980 (article EL 10)

Table 3 : Cross-section of power cables

Power (kVA)	Section / phase (mm²)	Power (kVA)	Section / phase (mm²)
20 and 30	6	300	2 x 150
40	16	325	2 x 150
50	16	350	2 x 185
60	25	400	2 x 240
80	35	450	2 x 240
100	50	500	3 x 185
125	70	550	3 x 240
150	95	600	3 x 240
175	120	650	3 x 300
200	150	700	4 x 185
225	185	750	4 x 240
250	240	800	4 x 240
275	240	850	4 x 300

7.7.2 Earthing

The earth connection shall be made in accordance with the requirements of the document on the protection of persons and goods (DIGELEC, part 11).

All metal masses shall be connected to the earth connection of the installation :

- the electrogenerator set ;
- its cabinet, if any ;
- tanks and pipes ;
- cable ducts and metal covering plates ;
- fittings.

7.8 Noise nuisances

Electrogenerator sets installed indoors must be such or must be installed in such a way that they do not cause a noise level exceeding 30 dB (A) in the adjoining premises if the latter are considered to be inhabited premises.

The performance figures for the means to be implemented in order to reduce this level are as follows :

- full concrete walls 30 to 45 dBA ;
- noise screening by sheath 30 to 50 dBA ;
- soundproofed door 15 to 43 dBA ;
- exhaust silencer 9 to 32 dBA ;
- soundproof covers 20 dBA ;
- wall coverings 10 to 40 dBA.

7.9 Special provisions

In the case of establishments admitting the public, the walls of the premises accommodating the electrogenerator set shall be fire-retarding for two hours.

A stop device that cuts off the fuel supply shall be accessible from the outside of the premises.

Fire-fighting means (extinguisher and container of sand) shall be provided.

Access doors shall open outwards and shall be fitted with anti-panic devices.

7.10 Auxiliary equipment

7.10.1 Auxiliary equipment for monitoring

This auxiliary equipment has no control linked with the running of the electrogenerator set, but ensures it is kept ready :

- preheating ;
- battery charging ;
- lighting ;
- heating of premises (if any) ;
- compressor.

7.10.2 Auxiliary equipment for operation

This auxiliary equipment operates simultaneously with the electrogenerator set :

- air cooler (electric motor for driving the fan when it is not driven by the engine of the electrogenerator set) ;
- room fan (if any) ;
- pump for untreated water.

7.11 Pneumatic starting

Where there is (optional) supplementary starting by compressed air, an electric compressor and a supply of compressed air shall be provided in the premises.

A supply consisting of two containers should be selected in order to avoid neutralising the device during inspections for the five-yearly check (see 10.1.3).

7.12 Installation and assembly on site

Transportation to the site, installation and commissioning of the electrogenerator set are effected in accordance with the recommendations of the Supplier of the electrogenerator set.

7.13 Documentation for the installation

The Contractor for the installation supplies the operator with the technical documents relating to the installation of the electrogenerator set :

- site plan
- plan of installation of the electrogenerator set (frame, ventilation sheath etc.)
- plans of the electrical connection of the electrogenerator set
- notice re. the servicing and maintenance of the installation (cleaning and replacement of filters, servicing of secondary batteries etc.)

8. Type acceptance procedure

The type acceptance procedure for the equipment includes the following :

- examination of its conformity with the Identification Dossier ;
- the performance of type acceptance tests.

Penalty

Any equipment not satisfying all tests is rejected.

NOTE - Investigative tests may be carried out in the context of the acceptance procedure.

8.1 Identification Dossier

The purpose of the Identification Dossier is to guarantee conformity of the supplied equipment with that which underwent type testing. The level of detail goes down to the subassemblies composing the equipment.

The Identification Dossier contains references and an index to enable the handling of updates. It contains at least the documents and information described in this chapter.

8.1.1 General constructional characteristics

The Identification Dossier must include the following :

- the plans necessary for visual examination and the performance of tests ;
- a list of the components used and their origin, nomenclature and location plan ;
- a list of the materials used, their origin and capability of withstanding temperature.

8.1.2 Functional characteristics

The Identification Dossier must include the following :

- a notice about the use of the electrogenerator set ;
- a dossier for the installation of the electrogenerator set (supplies, connections, assembly etc.).

8.1.3 Electrical constructional characteristics

The Identification Dossier must provide or state the following :

- the essential electrical characteristics :
  - ◊ assigned and maximum power ;
  - ◊ assigned voltage ;
  - ◊ assigned frequency ;
  - ◊ assigned current ;
  - ◊ assigned power factor ;
  - ◊ short-circuit current ;
  - ◊ nature of the reference load ;
- engine characteristics (power, cubic capacity, consumption of fuel, air, oil etc.)
- a list of circuits connected to earth and the way in which earthing continuity is effected within the equipment ;
- the location of the earth connection point and the means of connecting to it ;
- references to the norms complied with ;
- a list and diagrams of the electrical circuits defined as independent ;
- the insulation resistance between each electrically independent circuit or set ;
- the level of dielectric insulation (50 Hz and shock 1.2/50 µs) ;
- a list of fuses ;
- protection indices of the envelopes of the main components ;
- limit values of ambient temperature.

8.1.4 Mechanical constructional characteristics

The Identification Dossier must provide or state the following :

- the dimensions and weight of the equipment (in total and for each subassembly) ;
- floor plan ;
- the reference position in normal operation ;
- the fixing device ;
- the installation and connection plan.

8.2 Test dossier

The test dossier provides the modes and results of the type testing carried out by the manufacturer for investigation or homologation and the results of tests made by users or independent laboratories, with references to the test laboratory.

Type acceptance tests are the tests carried out on prototypes and on early products. They may be renewed in whole or in part at the request of the Purchaser.

9. Quality assurance procedure

The Identification Dossier should give a list of the components of the equipment that have been made under Centralised Quality Control or under Quality Assurance.

It should also include copies of attestations and/or homologation certificates issued by the *Comité de la Marque* [Trade Mark Committee] or identified test laboratories.

In the Identification Dossier, the manufacturer should give a description of the checks made before and during manufacture (checking on components and raw materials).

A description of these operations covers the following :

- sampling procedures ;
- methods of testing and measurement ;
- the sanctions applied.

10. Type tests

10.1 Tests on components

The aim of tests on components is to check by means of laboratory testing the dimensions and main performance figures of the electrogenerator set (engine, alternator etc.). The selection of the test conditions, including the test loads, should take account of the appropriate safety level.

10.1.1 Engine tests

The engine is tested in accordance with the norms ISO 3046-2 and ISO 3046-3.

To be completed

10.1.2 Tests on the alternator

The tests on the alternator are shown in Table 4.

Table 4 : Tests on the alternator

Test	Norm	Test conditions
Visual examination Check on the IP (protection index)	IEC 34-5 NF EN 60 034	
Insulation resistance	IEC 34-1 NF C 51-111	Measured under a voltage of 500 V DC
Dielectric strength	IEC 34-1 NF C 51-111	under DC voltage or AC voltage at industrial frequency
Direction of rotation	IEC 34-8 NFC 51-118	test with machine uncoupled (operating as an engine)
Unloaded test	IEC 34-2 NF C 51-112	test with machine uncoupled (operating as an engine), at variable voltage for separation of losses
Measurement of output	IEC 34-2 NF C 51-112	method of separation of losses or by calibrated engine
Test of heating on load	IEC 34-1 IEC 34-22 NF C 51-111	test with excitation capacitors if any and a generator load representative of the useful load ; particular attention will be paid to whether the harmonic content of the currents under test is close to that of the currents drawn by the electrical load on the electrogenerator set.
Vibrations of bearings	IEC 34-14 NF EN 60034-14	test with machine uncoupled (operating as an engine)
Measurement of noise	IEC 34-9 NF EN 60034-9 ISO 1680-1	test with machine uncoupled (operating as an engine)

10.1.3 Check test on containers of compressed air

(In preparation)

10.2 Overall tests

Overall tests shall be performed on the electrogenerator set in accordance with the norm NF 8528-5.

The basic operating parameters to be checked are as follows :

- the stability of voltage and frequency for different load conditions in steady state ;
- the voltage and frequency for different load conditions in transient state ;
- heating of the alternator ;
- fuel consumption of engine ;
- vibrations by the engine, the alternator and the chassis.

The tests on operation should also be performed in order to check the correct operation of the protection and control systems.

Where possible, tests should be performed under the limiting environmental conditions specified for the electrogenerator set.

DRE SPECIFICATIONS - C 5

June 1997

Title

Part C - Technical Specification of Components

Section 5 : Battery

Number of pages 27 (including Annexes)

Type Technical specification of components

Associated document(s)

Summary This document summarises the conditions of installation and the statutory requirements to be observed to ensure a long working life and proper operation of the installations and the security of neighbours and operators. It will be very thoroughly revised within a few months on the basis of the results of work in hand on the batteries.

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CONTENTS

1. Scope of application

This document applies to lead accumulator batteries intended for use in a fixed position in decentralised rural electrification installations to fulfil a direct current requirement.

The regulations and standards referred to in this document apply in France. Their use may be suggested in other countries where no equivalent local provisions exist.

NOTE. - This document is not a specification strictly speaking but rather a selective recapitulation of statutory requirements and installation conditions to be observed in order to ensure a long working life and effective operation of installations and also security for neighbours and operators. Having regard to the extremely varied conditions encountered on site, the list of batteries that might be selected covers almost all open lead batteries and several models of nickel cadmium battery.

Work on hand on batteries and especially on the way they are administered will probably result in a thorough review of the contents of this document within a few months.

2. References to laws and regulations

2.1 CEI standards

CEI 68-2-11 : 1981, Fundamental climatic and mechanical strength tests - part 2 - tests - test KA : salt fog

CEI 68-2-31 : 1980, Fundamental climatic and mechanical strength tests - part 2 - tests - test EC : falling and tipping, test intended primarily for hardware

CEI 364 (series) Low voltage electrical installations. Rules (series HD 384)

CEI 529 : 1989, degrees of protection required for sheathing (IP code).

2.2 Standards applicable in France

2.2.1 AFNOL standards

NFT 23-001 : 09/53, Sulphuric acid

2.2.2 UTE standards

NF C 15-100 : 05/1991, 12/1994, 12/1995, Low voltage electrical installations. Rules (equivalency series CEI 364 and HD 384)

NFC 20-711 : 05/87, Fundamental climatic and mechanical strength tests - part 2 - tests - test KA : salt fog (identical to CEI 68-2-11)

NF C 20-731 : 01/94, Fundamental climatic and mechanical strength tests - part 2 - tests - test EC : falling and typing, test intended primarily for hardware (identical to CEI 68-2-31)

NF C 58-311 : March 1990, type test procedure for accumulator rectifier - charger - battery units

UTE C 12-201 : 496, 296, Official publications concerning protection against the risks of fire and panic in establishments open to the public (excerpts regarding electrical installations, see 2.3.3. statutory order of 25 June 1980)

UTE C 15-103 : 992, Choice of electrical equipment (including ducting) in relation to external influences

UTE C 90-511 : 03/91, General - production date coding

2.2.3 European standards

NF EN 50102 : 695, Degrees of protection required by jackets for electrical equipment against external mechanical impact. Code IK (classification C 20-015)

NF EN 60529 : 10/92, Degrees of protection required for sheathing (IP code) (identical to CEI 529, classification C 20-010)

2.3 Regulations applicable in France

2.3.1 Laws

76-663 of 19 July 1976, concerning installations classified for environmental protection

2.3.2 Decrees

88-1056 of 14 November 1988 concerning protection for workers in establishments where electrical currents are applied

93-1412 of 29 December 1993 concerning general provisions applicable to installations classified for environmental protection subject to the declaration under heading 2925.

2.3.3 Statutory orders

31 March 1980 concerning electrical installations in regulated establishments by virtue of the laws concerning classified installations and those likely to harbour a risk of explosion.

25 June 1980 concerning approval of the general provisions of the security regulations against the risks of fire and panic in establishments open to the public (ERP).

9 December 1988 laying down special provisions applicable to certain premises or working locations earmarked for the production, conversion or distribution of electricity (application of decree 88-1056).

19 December 1988 concerning conditions for installing electrical equipment at installations harbouring an explosion risk (application of decree 88-1056).

2.3.4 Circulars

DRT 89-2 of 6.2.89 as amended on 29 July 1994 concerning measures intended to provide protection for workers in establishments where electrical currents are applied (commentaries on the decree 88-1056).

3. Definitions and abbreviations

3.1 Components

Accumulator : electrical element that may pass successively from charged stated to uncharged state and vice versa through circulation of electrical current in inverse direction.

Battery : set of two or more connected elements for the supply of electrical energy.

Body : receptacle of a material neutral to electrolyte and containing the block of plates and the electrolyte.

Terminals (poles) : articles to which the external electrical circuit is connected.

Couple : part of the accumulator consisting of two plates, one positive and one negative. Also applies to an interlinked positive plate and a negative plate belonging to two neighbouring elements.

Density : abstract quantity expressed by the ratio of the mass of electrolyte to the mass of water occupying the same volume at 4°C.

Electrolyte : a mixture of pure water (distilled or demineralised) and sulphuric acid, the preparation of which is characterised by the density of the mix.

Gelled electrolyte (sealed elements) : the electrolyte is immobilised in the form of a silicate gel.

Element : practical shape in which a galvanic cell used for the production of current is implemented.

Open accumulator element : element provided with a filling opening permitting a reduction in the electrolyte reserve to be made good by adding distilled or demineralised water.

Sealed (or recombined) accumulator element : element remaining sealed provided that the specified operating limits are observed. It is fitted with a safety valve operating in the event of internal over-pressure.

NB : This type of element displays a recombination rate for gases greater than 95%. There is therefore no need to add water during operation.

Felt (sealed elements) : the electrolyte is maintained by capillarity in a felt of partly impregnated (approx. 80%) glass microfibre.

Grille : conductive support used in lead accumulators to maintain the active component.

Active component : material of plates reacting chemically to produce electrical energy when the accumulator discharges and re-established to its initial state when charged.

Fritted plate : electrode consisting of a sheet of perforated nickel plated steel on which a specific nickel powder is deposited by fritting. The active component is incorporated by precipitation in this extremely porous fritted mass.

Flat plate : electrode comprising a conductive support of a lead-based alloy and deposited active components.

Set plate (plate with large surface) : electrode generally of soft lead with a highly developed surface and whose active component is obtained as a thin layer at the expense of the lead itself.

Pocket plate : electrode comprising an assembly of pockets of perforated steel, these pockets being interlinked and containing the active component.

Tubular plate : electrode comprising an assembly of porous tubes filled with active component.

Separator : device inserted between the plates, avoiding short circuits, retaining the active component and the texture or porosity of which permits ions to pass, the acid to diffuse and the gas to be released.

Valve : mechanism which opens to limit the internal pressure in the element. This mechanism prevents air from entering and operates at a pressure lower than that which could damage the element.

3.2 Electrical quantities

Autonomy : on being completely charged the autonomy of an accumulator element is the time at the end of which the stop voltage is reached (U_a) under specified conditions (temperature and discharge ratio).

Auto discharge : a discharge reaction associated with electrolysis of the water (dissociation of hydrogen and oxygen) within the elements of an accumulator. This reaction exists in an open circuit but also on charging and discharging. The auto discharge current varies with the voltage applied at the terminals of the elements, temperature, age and the nature of the elements.

Assigned capacity (C) : quantity of electricity expressed in amperes-hours (Ah) that an accumulator may discharge after being fully charged under standard conditions of temperature, operation and final voltage. It is designated by the letter C together with an index (T) relating to the duration of the discharge expressed in hours.

Nominal capacity : capacity defined by the reference conditions specified (temperature, operating conditions and final voltage). It is designated by C_{nt}, replacing C_n by the number of watt hours and T by the duration of discharge expressed in hours.

Nominal energy (E_{nt}) : energy defined under the specified reference conditions (temperature and final voltage) replacing E_n by the number of watt hours and T by the duration of the discharge expressed in hours.

Electromotive force (EFM) : difference in potential existing across the connecting devices of an element or of an open circuit battery.

Charging or discharging rate : constant output of the charging or discharging current expressed in relation to the capacity of an accumulator.

Initial voltage : voltage appearing immediately at the terminals of the element after the operating circuit is closed.

Operating voltage in floating operation (U_{fl}) : voltage applied at the terminals of an element for the purpose of maintaining the charged state. The current produced must be greater than the auto discharge current.

Final voltage (U_a, stop voltage) : voltage in respect of which the discharge from the element is regarded as terminated.

Nominal voltage : conventional value used as a reference. The nominal voltage of a lead element is fixed a 2 volts.

The following notations are taken from the French standards NFC 15-100 and NF C 58-311 :

- I_{bL} : maximum value of direct current likely to be supplied at the battery under normal operation and on set conditions by the charging system. This value is declared by the manufacturer of the charging system ;
- I_{bS} : value of the direct current supplied to the battery triggering intervention of the current monitoring facility in the battery connection under operating conditions ;
- I_c : value of the current carrying the charge corresponding to current I_n, this current being generally higher than the nominal current supplied by the charger under normal operation ;
- I_n : value of direct current of the facility supplying the charging system ;
- I_2 : value of the current effectively ensuring operation of the facility protecting the supply to the charging system ;
- U_{ds} : value of the direct current applied at the battery triggering operation of the facility monitoring the battery voltage under set operating conditions ;
- U_{ln} : nominal voltage at the supply side of the charger.

4. Environmental conditions

Unless specified otherwise by the Purchaser signing the contract, batteries will be transported, stored and operated within the climatic and atmospheric limits set out in table 1.

Table 1 : Climatic and atmospheric limits

	Transportation (1)	Storage (1)	Operation
Ambient temperature (°C)	-30 to +50	-20 to +45	-15 to +40
Relative humidity (%)	5 to 95		10 to 90
Atmospheric pressure (hPa)	700 to 1060		

(1) applies to accumulators protected by their original packaging

5. Choice, monitoring and maintenance of a lead battery

A guide to the choice of control and maintenance for lead accumulator batteries is given in Annex A to this document.

6. Electrical characteristics

6.1 Electromotive force

The quality of a product is characterised by the weak dispersion of voltage measured in open circuit on fully charged elements. The value of the EMF indicated by the Supplier must be respected with a tolerance of ± 1%.

6.2 Capacity

The nominal capacity CNT is specified for a reference discharge period (hours), an element temperature of 20°C and a conventional stop voltage of 1.80 V per element.

The assigned capacity CT is guaranteed by the Supplier for a discharge period T (hours), an element temperature of 20°C and a stop temperature specified in relation to the discharge rate.

NB : The assigned capacity over 10 hours (C_{10}) is always stated by the Supplier and in that case the stop voltage is fixed at 1.80V.

For each type of accumulator, whether open or sealed, the nominal capacity and assigned capacities used as reference are specified with the discharge parameters appearing in table 2.

Table 2 : Discharge parameters

Accumulated type	Capacity (Ah)	Discharge period (h)	Discharge ratio (A)	Stop voltage (V)
Stationary compact lead sealed	CN_{10}	10	$CN_{10}/10$	1.8
	CN_5	5	$CN_5/5$	1.75
	CN_3	3	$CN_3/3$	1.70
Stationary compact lead rapid discharge	CN_3	3	$CN_3/3$	1.8
	$CN_{1.5}$	1.5	$CN_{1.5}/1.5$	1.75
	CN_1	1	$CN_{1}/1$	1.70
Stationary compact lead extra-rapid discharge sealed	CN_1	1	$CN_1/1$	1.8
	$CN_{0.5}$	0.5	$CN_{0.5}/0.5$	1.75
	$CN_{0.25}$	0.25	$CN_{0.25}/0.25$	1.70

The capacities shown are required after five operating cycles applying the corrections for temperature where applicable. Capacities of $0.9C_{10}$ (or $0.9C_{NT}$) are therefore permitted during a pre-delivery check.

7. Endurance characteristics

7.1 Storage capacity

After complete charging, an element or solid block stored in open circuit in premises with a prevailing temperature of between 20 and 25°C must preserve its charge.

The loss of capacity recorded at the end of an idle period equal to 6 months should not exceed the following values :

- 35% for a stationary compact lead sealed type ;
- 50% for a stationary compact lead rapid-discharge type ;
- 75% for a stationary compact lead sealed ultra-fast discharge type.

Besides, it must withstand such storage for 6 months without irreversible deterioration of the initial characteristics (voltage, density and capacity) which must be present after full recharging and five cycles of operation.

The sealed elements must be able to withstand 6 months' storage in recumbent position. No seepage of electrolyte or trace of corrosion may be observed during this period.

7.2 Operating capacity

The operating capacity of a battery is characterised by :

- homogeneity of tensions (gap less than 0.03 V in relation to the average of elementary tensions) ;
- a negligible density drop for open elements (drop of less than 0.02 in relation to average value) ;
- reduced capacity loss (restitution greater than 0.80 CNT).

The battery is regarded as defective if at least 2 of the above parameters are located outside the tolerances.

7.3 Cyclic capacity

The cyclic capacity of an accumulator is defined by the number of charging and discharging cycles at constant intensity that it can withstand under the following conditions :

- discharge for 4 hours at a ratio of 0.10 C10 (A) ;
- recharging for 20 hours at a ratio of 0.03 C10 (A).

The voltage can be limited on completion of charging to reduce the release of gas.

In these circumstances, accumulators must withstand at least 400 cycles.

7.4 Overloading capacity

The capacity for overloading under constant voltage is defined by the period during which an accumulator can withstand an unlimited overload current produced by a constant voltage of 2.35 V per element imposed at its terminals for 400 days. This overloading capacity is also characterised by the release of gas :

A) Open elements : the gas is released by the elements fitted with their plug should contain no harmful or corrosive substances (sulphuric acid, chloride, etc.) ;

B) Sealed elements : the recombination rate of oxygen and hydrogen must be at least 0.95 throughout the test period. The recombination rate for an element under an overloading test is obtained by the formula :

$$\mathrm{Rr} = 1 - 3000\left(\frac{M_2 - M_3}{Q}\right)$$

where :

M_2 (kg) represents the mass of the element before the test ;

M_3 (kg) represents the mass of the element at the end of the test ;

Q (Ah) represents the quantity of electricity recorded during the test.

8. Mechanical characteristics

8.1 Electrolyte reserve

8.1.1.1 Open elements

The electrolyte reserve corresponds to the volume delimited by the vertical walls of the body and the maximum and minimum levels.

At maximum level, the free space beneath the top should suffice for the normal release of gas without the projection of acid bubbles to the outside. Under such conditions, the electrolyte reserve should permit an ongoing overload as stated in 7.4 for a period of 100 days.

8.1.2 Sealed elements

The electrolyte reserve is influenced by the initial volume, the density, the recombination rate and tightness.

Under normal operating conditions the electrolyte loss should not affect the working life of a sealed element.

At the end of the overloading capacity test (see 7.4) the loss of mass (M_2 M_3) should be less than 10% of the initial electrolyte mass (M_2 M_1) were :

M_1 (kg) represents the mass of the element (or solid block) before filling ;

M_2 (kg) represents the mass of the element (or solid block) after filling ;

M_3 (kg) represents the mass of the element (or solid block) at the end of testing.

8.2 Fall resistance

The elements or solid blocks whose mass is less than 60 kg must offer resistance to falling that may occur during handling. This resistance is assessed in accordance with standard CEI 68-2-31 (variant B) ; the height of the fall is fixed at 10cm.

9. Other characteristics

9.1 Body

The body must be so dimensioned as to meet the requirements regarding the electrolyte reserve (cf. 8.1) and to avoid potential short circuiting due to the falling of active components. It must withstand the following tests, described in item 19 :

- dielectric resistance ;
- resistance to heat ;
- resistance to temperature variations ;
- resistance to mechanical shock ;
- cracking.

9.2 Separators

Separators should be acid proof and may not affect the electrolyte or modify its composition. Separators, sheaths and other internal components may not therefore be made of micro-porous polyvinyl. Separators must cover or protect the plates to prevent leak currents.

9.3 Top

The top is designed to ensure perfect tightness of the body. It comprises :

- openings for the terminals with a tightness facility and the polarity markings "+" and "-" ;
- openings for plugs and level indicators, if used.

The design of the top should permit the plugs and level indicators to be inverted to facilitate filling after the batteries have been in operation.

The top should withstand the following tests described in item 19 :

- heat resistance ;
- resistance to mechanical shock ;
- cracking.

9.4 Plugs

Plugs on open elements should permit the normal release of gas. The design should take account of the following prerequisites :

- "paracid" protection : an expansion chamber with filter and/or chicanes preventing release of bubbles of acid to the outside ;
- "fireproof" protection : the nature of the walls and material used should eliminate the risks of explosion that could be caused by proximity of a flame or spark.

9.5 Level indicator

Open elements must be marked to indicate the electrolyte levels MAX, AVE, and MIN.

If the body is transparent or translucent, these markings must remain visible after the battery has been installed. If it is of opaque material, they must appear on an external indicator.

9.6 Electrolyte

The electrolyte is prepared from special sulphuric acid for accumulators[(1)]. It must be clear and devoid of any deposit of insoluble material.

9.7 Element

The element must be designed to take account of the following requirements :

- the upper part of the plate block must be protected to prevent any deterioration of the separators ;
- tightness of the body, top and joints will be so ensured that the electrolyte cannot spread during handling or during use.

10. Accumulator range

The proposed range includes functional and dimensional characteristics proper to each type of element to meet certain criteria for installation and use such as space, discharge rate, operational autonomy, final voltage, maintenance, etc. The three types of accumulator are as follows :

a) the "stationary compact lead" type designed for discharge at a normal rate : the reference discharge period (T) is fixed at 10 hours ;

b) the "stationary compact lead rapid discharge" type designed for heavy duty discharge : the reference discharge period (T) is fixed at 3 hours ;

c) the "stationary compact lead ultra-rapid discharge" type designed for discharges at special rates : the reference discharge period (T) is fixed at 3 hours.

11. Marking

Elements supplied bare must legibly and indelibly carry the following information :

- manufacturer's name and trademark ;
- coding index and nominal capacity ;
- manufacturing date : year, week[(2)] [2].

[(1)] In France, NF T 23-001
[(2)] In France, NF C 90-511

12. Starting up

12.1 Connections

Connections between elements or solid blocks will be sized to ensure good mechanical resistance and the lowest possible voltage drop. This voltage drop should not exceed 0.01 V between two elements and 0.02 V between two arrays of elements.

Connections will be acid-proof by nature or by treatment and will not require preventive maintenance such as greasing.

Connections will be protected by an insulating material to avoid any risk of accidental short-circuiting.

Connections will be so made that the replacement of a defective element or solid block requires neither welding nor special tools.

12.2 Grouping

Elements or solid blocks will be grouped with means of attachment if the mass is less than 60 kg or handling eyes if the mass is greater.

12.3 Identification

Battery groups will be identified by an information plate bearing at least the following particulars :

- supplier's name and address ;
- coding index ;
- nominal capacity and capacity over 10 hours ;
- end of charge density (open elements) ;
- delivery date.

If start-up is undertaken by the Supplier, the latter must number the elements (from 1 onwards) as from positive polarity.

12.4 Post-installation checks

Post-installation checks will cover the following points :

- visual check of elements and connections ;
- position, alignment and level check ;
- electrolyte density and level check (open elements) ;
- check of individual tensions on a floating battery ;
- voltage drop check at connections ;
- numbering of accessories and spares ;
- examination of documentation.

13. Packaging and transportation

The Supplier will take all necessary steps to ensure the elements arrive in perfect state at destination. In particular, the base and cover of the packaging will be so marked as to prevent overturning.

In addition to the address of the consignee and customary markings for fragile and dangerous hardware, each packaging will indicate the following in indelible characters :

- supplier's name ;
- coding index for the elements.

The packaging may show additional information at the Purchaser's request (date and contract reference, etc.).

14. Technical documentation

Each battery of accumulators is supplied with the accompanying file containing at least the following documents :

- a battery specification providing instructions for starting up, maintenance and safety and the general guarantee conditions. This file also includes tables for measuring the appropriate parameters ;
- a wall poster drawing the user's attention to the danger of explosion (open elements), to be affixed inside the battery room. The Purchaser will when ordering indicate the language in which the poster will be drafted.

15. Installation rules

15.1 Administrative formalities

The legal provisions of each country must be observed[(3)] [3]. It is desirable for a list of these installations to be kept by an administrative body in order to prevent the lead or acid from being scattered in the environment at the end of their useful life.

15.2 Location

The conditions for installing a stationary accumulator battery depend largely on the gases released during charging (open battery). An accumulator battery must be installed in an engineering room which may be an ordinary one[(4)] [4].

However :

- the battery must be installed in premises **not accessible to the public** if the CU_a of the capacity (Ah) produced by the discharge voltage is less than or equal to 1000 and in the case of those whose CU_a product exceeds 1000, it must be placed in a **jacket**, which may be opened only by an authorised person ;
- it may be installed in **any premises** if the CU_a produced is less than or equal to 1000 and if it is placed in a **jacket** meeting the above requirement.

The installation conditions are summarised in table 3.

Table **3** : Battery location

Battery	Location
CU_a £ 1000 and CU_a > 1000 in jacket	room not accessible to the public
CU_a > 1000	ordinary electrical engineering room
CU_a =< 1000 in jacket	any room

15.3 Ventilation

The room and the jacket for the three types of installation described in 15.2 must be ventilated[5].

The premises and the jacket must be naturally or mechanically ventilated according to the specific requirements for each type of battery (see 15.3.1 and 15.3.2). Where a battery is placed in a jacket, ventilation openings placed at the upper and lower parts will suffice to create satisfactory ventilation provided that the output pipe opens on the outside of the building.

[(3)] In France, battery installations with charging power of over 10 kW are considered installations classed for environmental protection, and must therefore be declared at the departmental Prefecture (law 76-663, decree 77-1133 and 93-1412)

[(4)] In France, statutory order (25 June 1980)

15.3.1 Ventilation of an open battery

The volume of air to be renewed in an open battery is 0.05 NI m^3/h, where :

N = number of elements of the battery

$I = I_{bL}$ or I_{bS} (6)

or $I = I_c \frac{I_2}{I_n}$ (5)

In the case of mechanical ventilation, charging should cease as soon as ventilation stops.

15.3.2 Ventilation of a recombination battery

A recombination battery must normally be linked to a charger dedicated to it[6]. In these circumstances, the volume of air to be renewed is 0.0025 NI m^3/h, where :

N = number of elements of the battery

$I = I_{bL}$ (6) 6

If the charger is not specifically adapted to the recombination battery the volume of air to be renewed will be calculated by the method applying to an open battery.

The maximum charging period after mechanical ventilation ceases is obtained from :

$$T = 400 \frac{V}{N.I_{bL}}$$ where,

T = in hours

V = volume of the room (in m^3)

N = number of elements in the battery

I_{bL} = (6)

15.4 Characteristics of the place of battery storage

15.4.1 Specific battery room

If a battery is installed in a specific room, the latter must comply with the following characteristics in particular[3] :

- built from incombustible materials ;
- lightweight roof without a floor above (no basement permitted) ;
- door opening to the outside and normally locked ;
- ventilation along the upper parts ;
- room used for no other purpose ;
- waterproof floor ;
- walls covered with a watertight coating adapted to the type of battery electrolyte, up to 1m above floor level (or more if batteries are in racks) ;
- retention basin (no discharge to sewers) of a capacity equal to the larger of the following two values :
  - ◊ either 100% of the largest body ;
  - ◊ or 50% of the global capacity of the bodies ;
- room to be heated exclusively by circulation (air, water, water vapour) ;

(5) In France, NF C 58-311
(6) In France, NF C 15-100 (section 554 and annex)

- no toxic or corrosive gases may be emitted to the atmosphere (special channelling) ;
- equipment for rinsing the eyes ;
- firefighting equipment (sand, fire extinguisher for electrical fires).

15.4.2 Battery box

- If the battery is installed in a box (see 15.2) the latter must display the following characteristics in particular[3] :
- built of non-flammable materials ;
- ventilated at the top and bottom with evacuation to the outside of the room ;
- retention basin (no discharge to sewers) of a capacity equal to the larger of the following two values :
  - ◊ either 100% of the largest body ;
  - ◊ or 50% of the global capacity of the bodies ;
- no toxic or corrosive gases to be released to the atmosphere (special channelling) ;
- equipment for rinsing the eyes immediately to hand ;
- firefighting equipment immediately to hand (sand, fire extinguisher for electrical fires).

15.5 Electrical equipment

The electrical equipment is limited to that strictly necessary. External influences (see CEI 364-3) are classified as : AA4, AD3, AE1, AF3, AG1, BA5, BB2, BC3 and BE3 if ventilation is non-conforming.

The degrees of protection to be installed are :

- IP03 for the battery and IP33 for other hardware (see CEI 529) ;
- IK02 or IK07 for the battery and other hardware[(7)].

If a battery producing a voltage in excess of 150 V has exposed active parts[(5)] :

- an insulating floor must be installed within a perimeter of 1 metre around the battery ;
- simultaneous contact between a person and two active exposed parts whose voltage differs by more than 150 V must be prevent.

All components of the electrical installation must be adapted to the risk of corrosion and, if applicable, to the mechanical risk (no corrodable metallic parts such as plates, reinforced rigid metal pipes, etc.).

Electrical conduits may not result in the ignition of a possible explosive atmosphere[(8)].

A facility must be installed for cutting and sectioning the battery. It must be easily accessible and marked as an emergency cut-off[(9)].

Manually operated emergency lighting must be installed per independent block.

15.6 Safety precautions

The following signs must be put up :

- no entry to any unauthorised person ;
- no smoking ;
- no entry with a flame ;
- signs showing access to unprotected active parts ;
- first aid following shock.

16. Maintenance accessories

(7) In France NF EN 50102 and UTE C 15-103
(8) In France, statutory order (19December 1988)
(9) In France, decree 88-1056

The accessories described below are provided solely for the maintenance of open batteries. Unless indicated otherwise, a set of accessories will be provided per battery or per batch of 24 elements if the number of batteries is indeterminate. A set of accessories includes a densimeter, a filler and a thermometer. It will be supplemented with two plugs of each type used and two level indicators if the batteries are provided with these.

A) Densimeter

The densimeter comprises :

- a heavy duty transparent pipette whose geometrical shape permits rapid balancing of the areometer without any adhesion to the walls ;
- a bulb of pure rubber or material of equivalent quality with sufficient volume to take measurements in a single manoeuvre ;
- a fitting serving as shock absorber for the areometer and fitted with tubing at least 150mm in length ;
- an areometer graduated for densities of 1.10 to 1.30 graduated in hundreds and with an extended reading scale (minimum spacing 2.5mm per 0.01).

The densimeter will be supplied in strong packaging designed for transit and storage.

B) Filler

The filler includes a reservoir made of plastic containing at least 10 litres, a rubber pipe at least 2 metres in length and a filling nozzle similarly of a plastic material. The nozzle will include a grip acting as stop-cock.

C) Thermometer

The thermometer is graduated from -20 to +60°C ; the gradations will be acid proof.

The thermometer will be supplied in strong packaging designed for transit and storage.

17. Reliability, maintainability and availability

17.1 Reliability

At the Purchaser's request, the Supplier will indicate :

- the standards that the materials used must meet ;
- the failure rate of any battery element : rate guaranteed or inferred from the official documents ;
- the result of the operating reliability statistics for an identical battery.

17.2 Maintainability

The maintenance requirements have an important effect on the cost of operating the equipment. The Supplier must therefore indicate the frequency and nature of maintenance operations.

At the Purchaser's request, the Supplier will substantiate the average replacement or repair time for an element and the average intervention time. The total of these two times will constitute the mean time between technical repairs (MTTR).

17.3 Availability

The availability rate $\left(\frac{MTBF}{MTBF + MTT} x100\right)$ is the probable percentage of time during which the equipment will be able to function normally, where MTBF is the average period of fault-free operation.

18. Technical guarantee

The guarantee applies to equipment transported, in store and used in accordance with this document. The guarantee takes effect on the date of receipt and applies under the following conditions :

- for a period of two years, elements and mechanical parts that display a defect of material or manufacture or poor operating resistance (cf. 7.2) will be reinstated or replaced free of charge by the Supplier. The latter will take steps to ensure continuity of service during operation ;
- beyond these first two years, the defective equipment will similarly be replaced or repaired under the stated conditions. However, the replacement supply will be invoiced by the Supplier on the basis of the original updated price by applying to it a rebate calculated in the following way :

$$A\% = 100\,\frac{0{,}6V - U}{V} \quad \text{where,}$$

V is the reference working life expressed in months ;

U is the period of use expressed in months, counting as from the date of receipt.

When the above rebate reaches zero value the guarantee will become superfluous.

NOTE. - If the contract provides for a battery to be installed, the guarantee will become effective on the date on which the installation is received. However, if the Purchaser is held responsible for a delay in delivery, the guarantee will take effect as from the contractual installation date.

19. Checks and tests

Checks will be made to ensure that the supply conforms to this document.

The checks made by the Purchaser or by an organisation appointed by it will be independent of the quality controls that the Supplier must undertake at the various stages of production.

To quality, a specimen must meet all conditions imposed by this document (suitability for cycling, overloading, storage, etc.).

The necessary tests for qualification will be made on each product type. A product type is defined by :

- the nature of the body (ebonite, plastic, etc.) ;
- the nature and dimensions of the positive and negative plates ;
- the nature and dimensions of the separators.

The Supplier will submit 9 specimens of each production type for qualification together with the identification file for these products. Specimens will be tested as follows :

- 3 will undergo cycling aptitude tests ;
- 3 will undergo overloading aptitude tests ;
- 3 will undergo miscellaneous tests (storage, salt fog, form, etc.).

NOTE. - A qualified element on solid block may not be changed in any way without the Purchaser's prior consent.

19.1 Capacity measurement

The test will be carried out on elements or batteries that have received a charging current limited to 0.04 CNT (A) until the end of charge indicators appear. Open elements will first be filled up to the average level before this operation.

A) Nominal capacity

The battery will be discharged at a constant intensity equal to CNT/T (A). The test will be stopped when the battery voltage of n elements reaches n x 1.80 V.

B) Assigned capacity

The battery will be discharged at a constant intensity equal to CT/T (A). The test will be stopped when the average value of the individual voltages reaches the stop voltage specified in relation to the discharge scheme (cf. 6.2).

NOTE. - If the initial average temperature of the electrolyte differs from 20°C, the measured capacity will be increased by 0.75% per degree below 20°C or reduced by 0.75% per degree above 20°C. However, if the average temperature exceeds 30°C or is less than 10°C, the test will be deferred to another date.

19.2 Cycling aptitude test

Elements will be charged and then discharged under the conditions laid down in 19.1 to ensure that they are returned to their nominal capacity.

They will subsequently be subjected to a series of successive charging and discharging cycles for a total period of 24 hours under the schemes described in 7.3.

The bodies will be positioned or immersed in a thermostatically controlled environment with a maintained temperature of 25°C ± 1°C.

The capacity will be measured every 100 cycles after the charging operation.

After each capacity measurement, the elements will each be given a quantity of electricity equal to 1.3 times the number of Ah supplied and the cycling test will then be continued.

The test will be stopped when the capacity noted during a control discharge falls below 0.8 CNT.

19.3 Overloading aptitude test

The elements are fitted in series to the terminals of a stabilised supply source providing a voltage of n x 2.35 V with a tolerance of ± 0.5%.

The bodies will be positioned or emersed in a thermostatic environment with a maintained temperature of 25°C ± 1°C.

The capacity will be measured every 100 days under the conditions described above.

The test will be stopped when the capacity noted during a control discharge falls below 0.8 C_{NT} or when the intensity of the current absorbed reaches 0.10 C_{10} (A).

This test will also permit the recombination rate and the electrolyte reserve of sealed elements to be checked by the weighing method (cf. 7.4 and 8.1) or an equivalent method.

19.4 Resources for electrical testing

For the cycling test :

- a constant current input (± 5%) with volt meter and ammeter incorporated ;
- a constant input (± 5%) electronic discharge "resistance" with volt meter and ammeter incorporated ;
- a double Ah counter monitoring and totalling the cycles ;
- auxiliary control, monitoring and protection circuits ;
- a cooling tank with thermostat, electric valve and resistance (if necessary).

For the constant voltage overloading test :

- a constant current input (± 5%) with volt meter and ammeter incorporated.

For the discharge tests before and during cycling and overloading tests :

- a constant input (± 5%) electronic discharge "resistance" with volt meter and ammeter incorporated ;
- auxiliary control, monitoring and protection circuits.

For all tests, a measurement unit to record the :

- voltage at the element terminals ;
- current input to each circuit ;
- quantity of electricity passing through each circuit ;
- temperature of each element ;
- date and time of readings.

NOTE. - All measurement appliances offer a level of accuracy of 0.5.

19.5 Body tests

19.5.1 Dielectric resistance test

The body is subjected to a dielectric resistance test under a voltage U corresponding to 1000 V per mm of thickness of the thinnest wall.

Before the test, the body is filled with water and immersed for 48 hours in such a way that any pores have time to fill. At the point of testing the levels will be adjusted to 1cm below the upper crest.

The test will be made by dipping one electrode inside the body and another electrode outside it ; no current build up should be noted.

19.5.2 Heat resistance test

The selected bodies to be filled with water with the top in position.

The water will be maintained at a constant temperature of 65°C for 4 hours.

After cooling and emptying the body, the lateral arrows on the body will be measured. None of these arrows may exceed 1.5% of the dimension of the corresponding wall.

19.5.3 Cracking test

The selected body is filled with white spirit. After one minute it is emptied and allowed to drain without prior drying for at least one hour. The body should show no distortion or cracking in the thickness of the material.

19.5.4 Temperature variation resistance test

The selected bodies are dipped alternatively for 2 minutes into two tanks filled with water, the one with ambient temperature T, the other with a temperature of T + 30°C ; the transfer will be made in less than 120 seconds and twice consecutively.

No deterioration in the bodies may be evident after testing.

19.6 Element tightness

The tests described below allow the tightness of open elements to be verified.

19.6.1 Inclination test

Elements filled with electrolyte up to the maximum level are tilted at 30° towards each of their sides for 5 minutes.

No escape or any seepage of electrolyte may be noted.

19.6.2 Over pressure test

An over pressure of 100 hPa is maintained within the elements for 15 seconds.

No leakage may be noted during this test.

19.7 Plug efficiency

19.7.1 *Paracid efficiency*

The plugs to be tested will be fitted to the elements subjected to the overloading test. Reactive paper (litmus or methyl orange) are placed 2cm above the openings in these plugs.

No change may be noted in the reactant after one week's observation.

19.7.2 *Fireproof efficiency*

The plugs will be tested under a gasflow identical to that resulting from overloading. They will be fitted to real elements or equivalent facility. Every precaution having been taken for the protection of the observers, a flame (or spark) induced at approx. 1cm from the plug should not cause an explosion.

19.8 *Falling test*

The element or the solid block is placed in its normal operating position on a smooth, hard, rigid surface of concrete and steel as provided under standard CEI 68-2-31 (variant B). It is then lifted above the surface, a wood block 10mm high being placed beneath one corner and a wood block 20mm high being placed beneath the adjacent corner of one of the lower edges.

The article is then swung above the test surface while turning round the edge resting on the two blocks until the corner adjacent to that placed on the 10mm block is raised 100mm until the angle created by the article and the test surface is 30°, the latter condition being less stringent. It is then allowed to fall freely onto the test surface.

The article is allowed to fall from the 4 lower corners by applying the test to the 4 lower edges successively, the latter being selected by turning in the one or other direction.

19.9 *Salt fog test*

The elements or solid blocks equipped with their connections will be subjected to a salt fog test in accordance with standard CEI 68-2-11 for 48 hours :

initial conditions : floating battery voltage applied at the terminals of the elements ;

final checks : absence of rust, lead sulphate or corrosion.

Annex A : Guide to choosing a lead accumulator battery

A.1. Parameters determining the choice of accumulators

A.1.1. Parameters for use

A.1.1.1 Environmental constraints

storage (supervised or not) ;

extreme operating temperatures ;

- atmosphere (tropical, corrosive, etc.).

A.1.1.2 Installation constraints

- space occupied ;
- acclimatisation of the premises (ventilated or not).

A.1.1.3 Operating level under voltage and under floating voltage

- U_{max}, U_{min} maximum and minimum values of voltage (often imposed by the user) ;
- U_{fl}.

A.1.1.4 Autonomous period

A.1.1.5 Operating currents

- *I permanent ;*
- charging impact, if any (position in time : start, middle or end of autonomy).

A.1.1.6 Renewal frequency (working life)

A.1.2 Battery parameters

A.1.2.1 Technology

Open lead :

- types of plate ;
- alloys for the positive plate, e.g. lead-antimony, lead-calcium.

Sealed lead :

- felt or gelled electrolyte type ;
- alloys for the positive plate ; e.g. lead-antimony, lead-calcium.

A.1.2.2 Capacity

The capacity of an accumulator is selected in relation to :

- the operating current ;
- the period of autonomy ;
- the final voltage ;
- the ambient temperature ;
- the degree of "security".

A.1.2.3 Number of elements

- N = U_{max} of use/U_{charge} per element

A.1.3 Effect of the choice of battery on the choice of charger

A.1.3.1 Voltage

The range of output voltage from the charger should cover the range of operating voltage.

A.1.3.2 Current

The calibre of the charger is determined by the following ratio :

$$I_{charger} = I_{use} + I_{battery}$$

The limitation of the charging current (Ibattery) at present recommended by the makers is 0.1 to 0.2 C but is not rigorously applied. The figures adopted by EDF for uninterrupted supply show that the maximum charging current may reach levels of approx. 0.4 C. A level of this kind should not affect the ageing of the accumulators. In addition, this high level of current has the advantage of reducing the charging time and, as a corollary, of increasing the battery availability.

A.2 Stationary lead accumulators and specific features

A.2.1 Type of plate

Planté plate :

- substantial working life ;
- sometimes used for high capacities ;
- unsuitable for rapid discharge (period of autonomy several hours) ;
- unsuitable for overloading and cycling ;
- high cost.

Smooth plate :

- unsuitable for frequent cycling ;
- suitable for rapid discharges ;
- low cost.

Tubular plate :

- suitable for cycling ;
- suitable for overloading ;
- resistant to vibration, mechanically strong ;
- unsuitable for rapid discharging.

A.2.2 Packaging

Single element

Fixed top design

Solid block

Design consisting of separate elements fitted in the same integral body with connections (apparent) between external or internal elements through the walls.

Open battery

A design permitting the free escape of electrolytic gas. A facility is included for topping up the water and measuring the level and volumetric mass of the electrolyte.

Valve regulated (sealed element)

A design for recombining the electrolytic gases. No facility is included for topping up the water. The electrolyte is immobilised and limited in volume. A safety valve permits gas to escape in the event of internal over-pressure.

A characteristic of these batteries is that they are of a "recombination" type. This means that the breakdown of water into oxygen and hydrogen, which is the normal electrochemical reaction on re-charging and on floating, is accompanied by a parallel chemical reaction recombining these gases into water in a sealed battery.

A.2.3 Alloys

Lead antimony (PbSb)

Advantages :

- improvement in suitability for fund recasting ;
- increased mechanical strength of the lead ;
- effective resistance to corrosion.

Disadvantages :

- substantial water consumption (affects the frequency of checks) ;
- loss of capacity through poisoning of the negative plate (migration of antimony ions from the positive plate to the negative plate) so reducing the working life.

Over the past ten years, the ratio of antimony in the positive plate has been reduced (from 10% to less than 3%). The effect of this trend has been to increase the working life of accumulators and reduce maintenance work (topping up with water).

Lead-calcium (PbCa)

Advantages :

- low water consumption ;
- slight increase in floating operating current during the life of the accumulator ; replacing defective elements is less of a problem compared with a lead-antimony battery.

Disadvantages :

- less effective mechanical resistance to corrosion compared with the PbSb alloy.

A.2.4 Temperature operating range

The ranges described below are indicative and apply to stationary batteries where the operating current is at least 0.1 C. They do not apply, in particular, to batteries for photovoltaic applications where the operating current is less than 0.01 C. Use below -10°C remains possible by selecting special types of battery (electrolyte volume increased for a same given capacity).

Open accumulators

- charged state : -50°C to +50°C
- discharged state : -10°C to +50°C

Sealed accumulators

- charged state : -50°C to +40°C
- discharged state : 0°C to +40°C

To determine autonomy in relation to temperature, the reference value must be increased by 1% to 25°C per additional degree and reduced by 1% for each degree less.

A.2.5 Charging methods

The charging methods most commonly used for lead batteries of the stationary type are as follows :

- Single step : this method is used more especially for fixed type accumulators and gas recombination sealed accumulators. It consists of recharging the battery under floating regulating conditions. The simplicity of this technique has the advantage of greater charger reliability and lower cost. For batteries of the fixed type, the choice of single step lies in the fact that they will not withstand high charges. In the case of sealed batteries, the same choice is due to the fact that charges (single and double step) have comparable efficiency.
- Voltage double step : This method is used for open accumulators. Initially, a stabilised direct current greater than the floating battery voltage is applied at the terminals of the battery to accelerate or complete, where applicable, charging of the elements. The charging period must be determined in consultation with the manufacturer. After this period of time the voltage at the

battery terminals is reduced to the level provided for operating in floating mode. For open accumulators, this method of charging is intended to reduce the charging time and improve homogeneity of the electrolyte through agitation by the gases emitted.

The ranges of the voltages used for the various methods of charging must be decided by manufacturer.

A.3 Choice of battery and space used

A.3.1 Choice of battery and dimensioning

The choice of technology is made in relation to the criteria explained above. Account will be taken of the following broad trends :

- cost (cost price and allowing for maintenance and servicing) ;
- environmental constraints (e.g. temperature) ;
- installation constraints (the need for an expensive fireproof room for open technology) ;
- operating range under voltage ;
- period of autonomy ;
- operating current (charging impact, if any) ;
- frequency of renewal.

A.3.2 Dimensioning of an open lead battery

The decisive criteria with regard to dimensions are as follows :

- use (charging impact and position in time) ;
- period of autonomy (taking account of ageing[1] ;
- final level of voltage (U_a) ;
- size of the voltage pocket on commencement of discharging.

A.3.2.1. Special cases of dimensioning

A.3.2.1.1 High final voltage level

A brief supplementary drop in voltage known as a "voltage pocket" is noted on commencement of discharging.

For a period of time equal to approx. 1 or 2% of the discharge of nominal capacity, the battery voltage falls to a minimum and then rises according to the intensity of the discharge current by approx. 20 to 50 mV per element.

When discharging under a high current, care should be taken that the brief fall in voltage occurring at the start of discharging does not fall below the prescribed final discharge voltage. If it does, the coefficient of the discharge current should be reduced which will result in the battery being overdimensioned.

A.3.2.1.2 Surge on discharging

If the discharge current rises, the battery voltage will develop according to the equation :

$$(U = \Delta I \times R_{int} \qquad \text{with,}$$

R_{int} = internal resistance of the battery elements immediately before the current impact.

By way of example, the voltage in a 400 Ah element subjected to a discharge of 120 A for 2 hours may fall by approx. 50 t 75 mV on an increase of current of 50%.

This voltage drop should be taken into account when dimensioning the battery by establishing a new level for the final voltage (Ua_2) which integrates the variation in voltage due to the surge. We then have :

$$U_{a2} = Ua + \Delta I \times R_{int}.$$

The quantities required for calculating the dimensioning should be advised by the manufacturer.

A.4 Monitoring and maintenance

A.4.1 Monitoring accumulator batteries

The availability of accumulator batteries is one of the main concerns of users. Present monitoring operations rely on measuring the individual voltage of the elements, the density of their electrolyte (open lead elements) and their autonomy.

A.4.1.1 Measurement of individual voltage in floating mode

When functioning in floating mode, the charger applies the voltage at the battery terminals. Two types of findings are possible during measurement of individual voltage at the elements constituting a battery :

- tensions measured are the same for each element. It is therefore impossible to assess the battery status unless all elements are in the same condition ;
- imbalance is observed. In that case, this may be due either to non-homogeneous ageing of the elements or to defects in manufacturing one or more elements. Whatever the reason, operation on an unbalanced basis is undesirable. If the battery is new and consists of essentially identical elements, the suspect elements should be replaced. Otherwise, if the battery has already been in operation for several years, replacing prematurely aged elements with new ones could have the effect of increasing the imbalance. The proportion of elements that may be replaced in a battery depends on their technology. In the case of accumulators with a high antimony ratio, a large number of elements should not be replaced simply because the floating current increases after several years of operation.

In the case of accumulators with a low ratio of antimony or of lead-calcium accumulators, the proportion of elements that may be replaced is greater by comparison with elements with a high ratio of antimony.

A.4.1.2 Density measure

The density of the electrolyte in an accumulator is essentially a good indication of the state of its charge.

This parameter can be measured by traditional means, exclusively within the electrolyte reserve located above the accumulator plates. For this measurement to be taken, the electrolyte must be rendered homogeneous, which can be achieved by a charge resulting in "boiling". In fact, the level of charging voltage adopted is often less than 2.33 V, a level as from which boiling can be observed. This density measurement can be applied, especially after topping up with water, only by preceding it with a charge at 2.33 V per element or, failing this, by a charge at a lower level but over several days. Precautions must be taken, by taking account of the level of the electrolyte, which must be the same for all elements.

A.4.1.3 Measuring the autonomy

The autonomy is the best parameter for functional control of the state of a battery charge. In fact, measuring the autonomy or period of discharge at constant current up to the final specified discharging voltage allows for a perfect check on the "reconstitutable" capacity of a battery under the given conditions. During this check, the battery should be discharged to as low a level as possible within the permitted limits in order to compare the reconstituted capacity of each of its elements at the same stop voltage. The recommended level of voltage at the end of discharging must be close to 1.8 V per element. This level permits the doubtful elements to be identified where loss of capacity will result in inflection on their polarisation curve.

A.4.1.4 Measurement of the internal resistance of elements

A study is in progress into the characterisation of accumulators on the basis of the measurement of the internal resistance of the elements. Initial results show that this method can be applied on a relative basis. In fact, a comparison of measurements made on all elements of a battery at a given point in time should permit defective elements to be identified where a substantial difference is noted in the values measured for internal resistance. A finding of this kind allows the operator to be warned. If a battery cannot be discharged, the autonomy check can be made at just one of the doubtful elements ; this specimen element can then be recharged.

A.4.2 Maintenance

Accumulator batteries should be maintained along the lines laid down by the manufacturer. Following the latter's instructions may in fact be a condition under the guarantee agreement.

A.4.2.1 Open accumulators

In the case of open accumulators, it must be remembered that the maintenance intervals depend on the temperature, the voltage parameter under floating operation and the age of the battery. An increase in these parameters may result in increased consumption of water in the electrolyte reserve (3 Ah supplied to the battery while operating in floating mode produces a loss of 1 gram of water per element).

A.4.2.2 Sealed accumulators

The standards for sealed accumulators state that the recombination rate must exceed 95% ; this is ordinarily 98 to 99% in practice. The result is that the residual water loss is negligible even at the end of these batteries' working lives, which is why they are justifiably called "maintenance" free batteries.

Sealed accumulators are maintenance-free but special precautions must be taken. Their floating mode voltage is generally 2.27 V per element at around 25°C. They are sensitive to temperature increases. This is so for two reasons :

- the recombination reaction is exothermic, i.e. they initiate supplementary heating independently of ohmic losses ;
- the quantity of electrolyte is reduced and so consequently is their thermal inertia ; i.e. an equivalent quantity of heat communicated to two batteries of the same capacity, the one being sealed the other open, will result in appreciably greater heating of a sealed battery.

The need to adjust the floating voltage in relation to temperature is therefore more important than for similar open batteries. Besides, sufficient ventilation must be provided to avoid excessive heating during normal operation.

DRE SPECIFICATIONS - C 6

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Title

Part C : Technical Specification of Components

Section 6 : Converter

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Type Technical specification of components

Associated document(s) DRE - C 8 : "Climatic and environmental testing".

DRE - B 5 : "Guidelines for Data Acquisition".

Abstract This document constitutes a framework of specifications for electronic converters designed for the supply of power for isolated sites supplied by renewable energy. The specification concerning the inverter (DC-AC converter) is the most detailed. This specification will be used as a basis for completing the specifications for other converters such as the battery charger, the output DC-DC converter or the solar panel / battery conditioning unit.

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CONTENTS

1. Scope of application

The term “energy converter” covers the various devices that can be used to obtain the following specific functions :

A. Conversion of DC-AC electrical energy between the storage battery and AC utilisations (**inverter**).
B. Conversion of DC-DC electrical energy between the storage battery and DC utilisations (**DC-DC converter**).
C. Conversion of AC-DC electrical energy between AC electric circuits (diesel, electric grid) and the storage battery (**battery charger**).
D. Conversion of DC-DC electrical energy between solar panels and the storage battery (**conditioning unit adapting the solar panel voltage to the battery voltage** or power maximising device).
E. Conversion of AC-DC electrical energy between the wind generator and the storage battery (**battery charger supplied with power by the wind generator**).
F. “Battery-less energy conversion”. This concerns the conversion of energy between solar panels and a wind generator generally supplying power to pumping devices without solar panels, or a wind generator generally supplying power to pumping devices without any intermediate battery storage (**battery-less converters**).

Note : Converters designed to supply power to fluorescent tubes (ballasts) are not included within the defined scope.

Some manufacturers offer devices which can include a number of the specific functions mentioned above as well as certain functions for the management of energy (protection of the battery, in particular) and instrumentation. In this case, reference will be made to the specifications specific to those two functions if a single device is required.

The functions of converters have been classified into five main categories in order to :

1. Ensure conversion (type of electrical energy conversion, from A to F as stated above) ;
2. Protect the operation and long service life of the converter in environmental conditions ;
3. Protect the environment of the inverter ;
4. Facilitate maintenance (also including the availability of consumables) ;
5. Limit the consumption of electrical energy.

2. Converter functions

The specifications on the functions of **inverters** (type A) are described in detail in Section 6 (Specification on energy conversion by the inverter), Section 7 (conditions related to the inverter environment) and Section 8 (constructive provisions regarding the inverter).

For the **other types of converter** (types B to F), a brief description of their specific energy conversion functions is given in Section 9 (specific functions of conversion excluding the inverter). The specifications of functions 2 to 5 defined for the inverter (type A) in Sections 7 and 8 can be taken as a basis for the specification of other functions of these other types of converter. For example, function 2 (Protect the operation and long service life of the converter in environmental conditions) should be modified in its section on electrical conditions. Similarly, function 3 (Protect the inverter environment) should be modified as regards the specific protection of the relevant energy source, especially with respect to the harmonic currents that it absorbs owing to the converter (the energy source being a battery, a diesel generator, a wind generator or solar panels, as applicable).

This document describes the minimum safety requirements and is not intended as an exhaustive manual of instructions or design specifications. Ensuring compliance with this document does not release any person, organisation or corporation from the responsibility of complying with any other relevant regulations.

3. References to standards

3.1 Standards drawn up by UTE and AFNOR

NF C 15-100 : 05/91, Low-voltage electrical installations. Rules (equivalent to IEC 346 and HD 384).

UTE C 15-402 : 09/1995, Practical guide, Static type uninterruptible power supplies (UPS) - Installation rules.

UTE C 18 510 : Collection of general electrical safety instructions.

UTE C 18 530 : Book of electric safety instructions for approved personnel.

3.2 Standards drawn up by CENELEC

NF EN 50081-1 (NF C 91081-1 classification) : Electromagnetic compatibility - Generic transmission standards - First part : Residential, commercial and light industry.

NF EN 50082-1 (NF C 91082-1 classification) : Electromagnetic compatibility - Generic immunity standards - First part : Residential, commercial and light industry.

NF EN 50091-1 (NF C 42-810-1 classification) : Uninterruptible power supplies (UPS) - Part 1 : General instructions and safety rules.

NF EN 50091-2 (NF C 42-810-2 classification) : Uninterruptible power supplies (UPS) - Part 2 : Instructions regarding magnetic compatibility

NF EN 50091-3 (NF C 42-810-3 classification) : Uninterruptible power supplies (UPS) - Part 3 : Performances.

NF EN 60146-1-1 (NF C 53-211, IEC 146-1-1 classification) : Semiconductor type converters - Common specifications and grid switched converters - Part 1-1 : Specification of basic technical clauses.

NF EN 60529 (NF C 20-010 classification, equivalent to IEC 529-1989) : Degrees of protection provided by casings (Code IP).

NF EN 60947-1 (NF C 63-001 classification) : Low-voltage equipment - First part : general rules.

NF EN 60950 (NF C 77-210 classification, equivalent to IEC 950) : and amendments, Safety of information processing hardware including electrical office equipment.

Series of standards NF EN 61002-x, 61003-x and 61004-x (NF C 9100y-x and IEC 100y-x classification in certain cases) concerning electromagnetic compatibility.

3.3 Standards drawn up by IEC

IEC 146-2 (NF C 53-221 classification) : Semiconductor type converters.

IEC 146-3 (NF C 53-223 classification) : Direct semiconductor type DC converters (DC-DC converters).

IEC 1000-2-2 : Electromagnetic compatibility - Part 2 : Environment - Section 2 : Compatibility levels for low-frequency control interference and signal transmission on low-voltage on public electric power grids.

3.4 French statutory texts

- Worker protection :

  Decree 88-1056, November 14, 1988, regarding the protection of workers in establishments implementing electric currents.

  Circular DRT 89-2, February 6, 1989, Application of decree 88-1056.

- Low-voltage directive :

  Decrees 75-848, 81-1237 and 95-1081.
- EMC directive :

  Decree 92-587 of June 26, 1992.

4. Definitions

The vocabulary used is, unless otherwise specified, that defined by standards IEC 146-1-1, IEC 146-2, IEC 146-3.

5. Abbreviations

UPS : Uninterruptible power supply.

AC : Alternating current.

DC : Direct current.

6. Specification of energy conversion by the inverter

The main function of the inverter is to supply alternating current power to cater for the electrical load of consumers in service conditions.

6.1 Specification of electrical loads

It is essential to describe as accurately as possible the electrical loads for which power is to be supplied in order to avoid any malfunction.

6.1.1 Load supply voltage

The number of phases (generally 1 or 3) will be stipulated as well as whether there is a neutral conductor.

The rms voltage rating between neutral and phase is 230 V and the rated output frequency is 50 Hz unless otherwise specified.

6.1.2 Description of loads

The value that best describes the characteristics of an inverter is not the active power that it can supply but the rms current and, thus, the apparent power, as the value of the output voltage remains close to the rms voltage.

The inverter is dimensioned for a given current and for a given time. Three different current values will therefore be specified :

- constant rms rated output current ;
- long-duration rms rated output current. The duration is specified in minutes and is generally 30 minutes. This current corresponds to permissible temporary overloads ;
- short-duration rms rated output current (duration expressed in seconds). This current corresponds to the starting of motors in particular (s...) ;
- maximum output current.

The range of variation of the load's power factor will be specified.

In the case of a 3-phase inverter, the maximum unbalance of the load will be specified.

In the case of non linear loads (especially electronic type loads such as television, radio, microcomputers, fax machines, telephone answering machines, certain types of low-consumption lighting), at least, the power factor of each of the loads will be given as well as, as far as possible, the value of the harmonic components of the currents produced by the load. If necessary, the basis of an experimental characterisation of the load can be taken.

6.2 *Quality of supply for the designated loads*

6.2.1 Static performances

- The following ranges of variation are permitted in normal service conditions and in continuous service : rms output voltage : ±5%.

  Note : +6%, -10% can be accepted in certain cases, particularly when the inverter is reserved for non-simultaneous applications of limited range.

- output frequency : ±2%.

In order to ensure satisfactory operation of the loads, whether they are linear loads, motor loads or electronic loads, it is highly desirable to specify power supply of the “sine wave” type. For the limits, reference should be made to the standards regarding uninterruptible power supplies and to IEC 1000-2-2 (see Appendix I, Table 1).

However, after checking the compatibility with the load, it may be possible to use trapezoidal type power supplies. It is, thus, preferable to limit dV/dt to 10 V/µs. The term “pseudo-sinusoidal” is sometimes used to refer waves of the rectangular type.

6.2.2 Dynamic performances

There may be dynamic phenomena on the output voltage in the case of load impacts or the loss of the supply voltage (overvoltage or undervoltage).

Overvoltages must be limited in order to protect the equipment downstream of the inverter. Undervoltages can also be limited according to the installation’s desired level of performance. Standard NF EN 50091-X will be used as the basis for specifications on the dynamic tolerance range for the control of output voltage.

7. Conditions related to the inverter environment

A distinction is drawn between the conditions in which the inverter operates or is transported and the effect of the inverter on its environment.

7.1 *Protection of the converter*

7.1.1 Normal service conditions

The inverter must operate in the following service conditions :

- **Electrical conditions**

  The range of variation of the battery voltage must be specified. This is usually between -15% and 25% of the battery’s rated voltage.

  Transient supply overvoltages are liable to occur on input to the appliance (see Appendix II).

- **Climatic conditions**

  The conditions regarding cold, heat, humidity, salt spray and fungal hazard must be specified, on the basis of document DRE -C 8, “Climatic and Environmental Testing” and assuming that the inverter is generally located in a shelter, the protection level of which must be ensured.

- **Electromagnetic field immunity (EMC)**

  Document DRE - C 8 : "Climatic and Environmental Testing" will be used as a basis. The values specified below are for guidance and can be modified in compliance with the European EMC directive.

  ◊ Rapid transients in bursts :

  - direct 2 kV - 5 kHz (supply), capacitive 1 kV and 5 kHz (monitoring and control) in accordance with IEC 1000-4-4.

  ◊ Shock waves :

  - 3 kV in common mode, 1 kV in differential mode in accordance with IEC 1000-4-5.

  ◊ Electromagnetic field :

  - In accordance with IEC 1000-4-3.

  ◊ Electrostatic discharge :

  - 6 kV in contact, in accordance with IEC 1000-4-2.

- **Flora and fauna**

  Fungal hazards may be encountered in certain environments (see document DRE - C 8 : "Climatic and Environmental Testing").

  Some animals such as rodents or insects (ants, termites) may also be encountered. Specific measures must then be taken.

7.1.2 *Abnormal electrical conditions*

- **External short circuits** (on inverter input and output)

  There must be no damage, even partial, of the converter other than to consumables (fuses). This function can also be provided by external devices recommended by the manufacturer (fuses, circuit breakers, etc.).

  The protection must allow a certain selectivity with regard to protective devices located downstream. The solutions that the manufacturer can offer are current limitation or specific operating sequences (delay before the triggering of certain protective devices, etc.).

- **Converter overload**

  A converter monitoring and shutdown device must be installed in order to prevent damage in case of overload.

- **Battery voltage not in compliance with specifications**

  If the battery voltage is not in compliance with specifications, the converter must be shut down.

- **Battery polarity reversal**

  According to the skill level of the personnel installing the inverter, it may be necessary to specify non-destruction of the inverter in the event of reversal of the battery polarity. This, however, results in a reduction in efficiency.

7.2 *Protection of the inverter environment*

7.2.1 *Protection against direct contacts (with or without tool)*

The IP degree of protection of the casing must be specified and comply with at least IP2X.

7.2.2 *Protection against indirect contacts*

Protection against indirect contacts must be ensured in keeping with the safety measures taken in the installation. For all these specifications, reference can be made to document DRE - C 8 : "Climatic and Environmental Testing".

- **Earth continuity**

  The value of the resistance of earth connections must be equal to or less than 0.01 Ohms.

- **Insulation resistance**

  The value of the insulation resistance must be greater than 100 M(at 500 V. It is also possible to specify whether the inverter is in insulation class I or II, if this is required for the selected electric shock protection system.

- **Presence of an isolating transformer or not**

  It must be specified by the user whether an isolating transformer is installed so that an appropriate electric shock protection system can be installed. The transformer can be at 50 Hz or high frequency. If there is no electrical isolation, the existing electrical links must be known for safety purposes (continuity of the neutral conductor, for example).

7.2.3 *Limiting of converter input and output overvoltages*

The overvoltages produced by the converter and that are allowable by the other components of the system must be specified. The overvoltage value is specified with respect to time, according to the other equipment used (relays, utilisations, other converters, battery regulator, etc.).

These overvoltages can normally occur in the event of sudden cut-off of the power supply or the load due to the inductive behaviour of the cables or components (smoothing choke).

7.2.4 *Limiting of harmonic current produced in the battery by the converter*

If specified by the battery manufacturer, it is necessary to limit the value of harmonic currents of the converter input current (battery).

As regards protection of the battery, the inverter can perform certain energy management functions (management of the battery / load connection, in particular). In this case, the specific documents containing DRE Specifications must be consulted.

7.2.5 *Limiting fire hazards*

- **Internal short circuits**

  Protective devices (fuses) can be fitted inside the converter in order to avoid the start of a fire in the event of internal short circuit.

- **Materials**

  Materials (wires and connections) that limit fire risks will be used. Incandescent wire tests can be specified for synthetic materials or a manufacturer's guarantee can be demanded.

7.2.6 *Limiting electromagnetic field emissions*

- Emission by high-frequency conduction (10 kHz to 30 MHz), electrical field emission (30 MHz to 1,000 MHz).

The generic standard, EN 50081-1, will be used as a basis. Limits on low-frequency emission by conduction are not applicable and correspond to the voltage harmonic limits defined in Section 6.

7.2.7 *Noise*

The noise limits at rated power can be specified, if necessary. In particular, the converters can produce sounds at 50 Hz or at higher frequency (a few kHz) according to their operating mode.

8. Constructive provisions regarding the inverter

8.1 General

The required items of equipment are generally installed in isolated locations where there are few personnel qualified in the electrical field.

Strong and reliable equipment backed by sound references is therefore required both for the main components and for fitting accessories, in order to ensure the minimum possible maintenance and long-term resistance to damage.

8.2 Facilitating maintenance

It must be possible to change all the subassemblies easily without specific tools

- **Cut out the system's power supply on user requests**

  Elimination of dangerous voltages inside the appliance (capacitors with a voltage of >120 V, output voltage, etc.) in a short time (a few seconds, for example). Otherwise, clear marking (by means of labels on the converter and in the maintenance manual) must indicate the required lapse of time before undertaking any servicing and the voltage presence checking procedure.

  Opening of power circuits on input and output.

  This can be provided by external components (contactors or circuit breakers).

- **Allow the easy replacement of consumables (fuses, lamps, etc.)**

  Easy manual operation : easily replaceable withdrawable boards, power components, fuses and lamps.

  Availability of the previously stated spare parts and description of their characteristics.

- **Facilitate converter / environment connections**

  Specify the type of connection (pinning, screws, etc.).

  The wiring is installed using flexible copper conductors with thermoplastic insulation. It is arranged in such a way as to avoid masking the distinctive markings of functional components. Every precaution should be taken to minimise inductive and capacitive couplings between different circuits.

- **Provide information for maintenance and users**

  Input voltage and output voltage presence indicator

  Note : Document DRE - B5, "Data acquisition rules", describes the functions of the instrumentation system. Some functions can be provided by the converter, as an overload indicator on the user side, an indicator light showing correct operation of the converter.

8.2.1 Service life

An MTBF calculation can be carried out. In general, the inverter operates 24 hours a day.

All the attaching hardware must be resistant to deterioration by nature or protected against atmospheric agents. Clamping screws must, imperatively, be fitted with washers or devices preventing them from becoming loosened.

8.2.2 Mechanical stresses during transportation

Mechanical stresses during transportation, according to the means of carriage provided for (ship, aircraft, bush taxi, etc.), must be specified (see document DRE - C8 : "Climatic and environmental tests"). The packaging must be included in these tests.

8.3 Efficiency and energy consumption

This is an important point in order to avoid overdimensioning the solar panels. A compromise will be sought between the cost of the converter and "efficiency". It is possible to use the efficiency calculated by weighting according to the load, using the efficiency curve, and to make comparisons with a resistive load (see example of coefficient in Table 2, Appendix III).

The maximum efficiency is not enough information in itself.

The maximum no-load losses and standby losses can be specified, where applicable. However, the exact definition of these terms must be discussed with the manufacturers. In particular, the operation of switching to standby must be explained (power level, operation, switching from one mode to another, etc.). It may also be required that this device should be desactivatable.

8.4 Documents to be supplied

The manufacturer must supply :

- the instruction manual for the operator,
- the maintenance manual containing maintenance requirements,
- documentation including assembly drawings, wiring diagrams, specifications and instructions for assembly, installation and setting up.

Note : The manuals must be written in the French language in the case of converters installed in France in a language that can be read and understood by operators in the case of converters installed in other countries.

The documentation must cover the following points :

- For installation :
  - ◊ details on specific tools, attaching equipment and devices and other equipment for installation in complete safety,
  - ◊ the fitting procedures recommended by the manufacturer,
  - ◊ the identification of critical attachments and procedures regarding tightening torques and other recommendations,
  - ◊ a set of drawings for fitting on site and installation,
  - ◊ a complete wiring and interconnection diagram.
- For operation :
  - ◊ safe operating limits and descriptions, including start-up and shutdown procedures,
  - ◊ procedures for the functional verification of all protection subsystems.
- For inspection and maintenance :
  - ◊ inspection and maintenance periods and procedures,
  - ◊ unscheduled and emergency maintenance procedures,
  - ◊ diagnosis procedures and a fault tracing guide.

9. Specific conversion functions excluding the inverter

9.1 DC-DC converter

The specific function of the DC-DC converter is to supply consumers with DC voltage at fixed value from the battery. The designated loads and supply quality must be specified.

Note : In the case of low voltage (<48 V) from a battery that also has a low voltage (<48 V), an isolating transformer is not required.

9.2 Battery charger

The specific function of the battery charger is to supply the battery with electrical energy. The values of the voltage and capacity of the battery and of the charging current must be specified.

It must be specified whether the battery charger is a supplementary charger used for emergencies or if its operation is usual.

In the case of a battery charger intended to be used on a usual basis on a electrogenerator set, compatibility between the operation of the battery charger and operation of the electrogenerator set must be checked. In particular, controls of the wave train type (operation in on/off mode for periods of between 20 ms and several seconds) can be damaging.

Notes :

1. - It must be specified whether the value of the charging current can be adjusted by the user.

2. - It must be specified whether the battery charger can also make allowance for the state of charge of the battery (current limitation at the end of battery charging, in particular) or whether the battery protection function is provided by the system's charging regulator or by the user, personally.

9.3 Conditioning unit adapting the solar panel voltage to the battery voltage

The power-conditioning unit can have three specific functions in addition to the function of supplying power to the battery :

- Adapting the voltage of the solar panels to the battery voltage in order to simplify installation operations ;
- Allow easier changing of the specified limits of the solar panels configuration (addition of a number of panels, destruction of a number of panels) without any risk of losing energy produced by the panel due to incorrect control of the solar panel / battery voltage ;
- Optimise the peak power of the solar panels by maximising the energy supplied to the battery. The principle is based on constantly adapting the output voltage from the solar panels in order to remain at the maximum power point.

For the purposes of these three functions, the limits of each function must be clearly specified in agreement with the manufacturer (rated values, permitted voltage and current ranges, type of monitoring used to locate the maximum operating point, etc.).

9.4 Battery charger for the wind generator

The principal specific function of the battery charger is to supply electrical energy to the battery. The voltage and current values of the battery must be specified. There may be, however, another specific, optional function. This depends on the type of wind generator monitoring. Indeed, it may be necessary to monitor the rotating speed of the wind generator by means of the converter. In this case, the converter monitoring required to ensure satisfactory operation of the wind generator is specified by the wind generator manufacturer.

Note : Wind generators monitored by mechanical regulators do not require any specific functions from the converter.

10. Tests

As regards tests, reference can be made to the existing standards concerning converters (see Section 3). Depending on the specific nature of the specification drawn up, however, it may be useful to carry out various tests, described in document DRE - C8 : "Climatic and environmental tests", such as climatic tests, and to add tests concerning, for example, the functions of energy management, display, protection selectivity and ease of maintenance.

Appendix I : Compatibility levels for individual harmonic voltages on low-voltage systems

Table 1 : Compatibility levels in IEC 1000-2-2

Odd harmonics not multiples of 3		Odd harmonics multiples of 3		Even harmonics	
Harmonic rank (n)	Harmonic voltage (%)	Harmonic rank (n)	Harmonic voltage (%)	Harmonic rank (n)	Harmonic voltage (%)
5	6	3	5	2	2
7	5	9	1.5	4	1
11	3.5	15	.3	6	.5
13	3	21	.2	8	.5
17	2	>21	.2	10	.5
19	1.5			12	.2
23	1.5			>12	.2
25	1.5				
>25	0.2+.5x25/n				

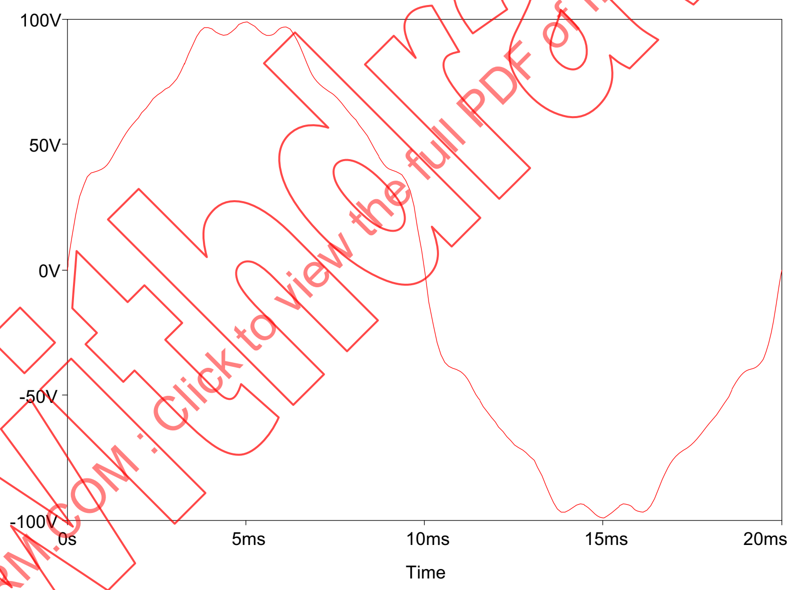

Figure 1 : Example of voltage comprising harmonics (see Table 2)

Table 2

Harmonic rank	3	5	7	9	11	13	17
Voltage as %	5	6	5	1.5	3.5	3	2

Appendix II : Maximum voltages planned on battery side

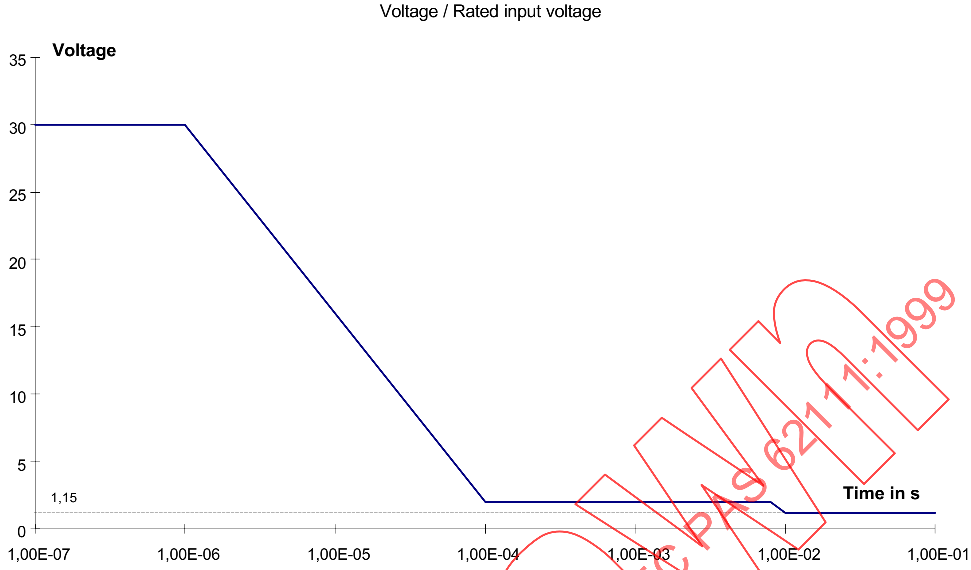

Figure 2 : Maximum voltages planned according to duration of transient (IEC 146-2, 3.1.j)

Note : These values are intended for battery rated voltages of less than 50 V. For higher voltages, the curve is cut at the specified voltage obtained using the following formula :

$$U_{limit} = 1400V + 2.3\ U_{batt}.$$

Appendix III : Weighted efficiency of an inverter

In order to be able to compare the efficiency of converters and to allow for the efficiency over the whole power range, it is possible to weight the load factor with respect to time. We obtain a more consistent efficiency value than the efficiency in rated conditions. The efficiency is, of course, given for a precise type of load : generally, for a resistive load. Table 3 shows the values currently used in various publications.

Table 3 : Inverter operating time with respect to the load factor

Load factor (%)	5	10	20	30	50	100
Operating time (%)	3	6	13	10	48	20

DRE SPECIFICATIONS - C 7 June 1997

Title **Part C - Technical Specification of Components**

Section 7 : Energy Management

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Type Technical specification of components

Associated document(s) DRE - B 1 : "Architecture of Electrification Systems".

Abstract This document gives the Functional Specifications for energy management in independent installations designed for decentralised rural electrification. It also describes an operational range of energy controllers suitable for various types of installations described in the associated document which covers the types available.

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CONTENTS

Introduction

An electrification system for isolated sites comprises the following items of equipment :

- sources : sources for production of electricity from renewable resources (sun, wind, water) and/or fossil fuels ;
- storage methods for the energy produced (accumulator batteries) ;
- loads (lighting, electric motors etc.)

In principle, the amount of energy available to users of these systems is not unlimited, because of the simple fact of the availability of the primary power source (sun or wind), the power of the generators, and the storage capacity for the energy collected.

It is therefore essential to manage the use of the available resources, in order to :

- optimise the use of the available energy provided by sources ;
- to save as much of the stored energy as possible (minimum loss) ;
- to manage the amount of "consumable" energy in the best interests of the immediate energy needs of the customers, and in order to prolong the life of the equipment.

The need to manage leads to the installation of equipment intended to control the configuration and operation of the electrification systems.

This document does not, by convention, deal with protection for people and equipment against electrical hazard. This point is covered in part B 6 of the DRE Specifications.

Protection of the electrification system against aberrant operation, in the power sense, is analysed, for example :

- complete discharge of the battery ;
- battery overload ;
- wasting energy ;
- over-production of energy ;
- over-consumption of energy.

The protections described are therefore essentially intended to optimise the durability of the performance of the electrification system.

Any joint inter-use interference is not taken into account by the energy controller.

The functional description of the services provided by the energy controller is independent of the technologies used, especially for the batteries.

The priorities managed by the energy controller may vary significantly from one load to another. For example, for supply of energy for business use, continuity of supply would doubtless be valued, even if it means the reserve generator working a little harder and the cost of production being slightly higher. For domestic use, the return cost per kWh needs to be minimised and the durability of storage methods encouraged, for everyone's benefit, even if it means cutting supply for short periods.

1. Scope of application

This specification defines a functional range of energy controllers suitable for the type of electrification in isolated sites.

2. Definitions and abbreviations

Wind-generator : wind-powered electricity generator.

REN : renewable energy (wind, sun, etc.).

PV generator : field of photovoltaic modules.

Electricity generator set : alternative electrical energy source with a thermal motor, providing either a booster or a back-up power source

Production : complete set of production equipment (PV generator, wind generator, generator set).

Solar pseudo-battery-less : loads which are only powered by REN sources and only when the storage is full.

Storage : set of accumulator batteries (using state-of-the-art technology). This set may consist of one or more groups of batteries, connected in parallel (sub-set of batteries).

Loads : user equipment powered by the electrification system.

Battery-dedicated loads : loads provided by the storage and which are never cut, since they involve vital safety elements (ground lighting of a generator wind generator, etc.)

Non-backed up AC loads : these AC loads are supplied from the battery via inverters. These loads may be jettisoned in the event of a scarcity of power from the batteries.

Backed-up AC loads : AC loads which may be powered either by the battery, via inverters, or by the generator set.

Non-backed up DC loads : DC loads which are powered by the battery. They may be jettisoned in the event of a scarcity of stored power in the batteries.

Generator-dedicated loads : loads powered directly by the generator set.

Pseudo-battery-less loads of RENs : loads powered by the REN generators when the battery no longer needs charging and the RENs are still available.

Safety loads : special arrangements (e.g. : wind-generator brake).

AC : alternative current.

DC : direct current.

I_{Bat} : incoming/outgoing current for the battery.

U_{Bat} : voltage measured at the terminals of the battery.

U_{Ond} : voltage measured at the output terminals of the inverter.

U_{nom} : Nominal usage supply voltage.

U_{max} : maximum permitted voltage at the terminals of the loads.

U_{min} : minimum acceptable voltage at the terminals of the loads.

U_{Pv} : voltage measured at the terminals of the photovoltaic generator.

3. Functions of the energy controller

The main functions of the energy controller relate to the configuration and operation of the electrification system in order to :

- manage energy fluxes in production storage links ;
- manage energy fluxes in storage load links ;
- manage energy fluxes in production load links ;
- manage "on off" commands for the generator set ;
- configure the set of batteries ;
- manage information.

The general functional architecture of an energy controller is shown in figure 1 :

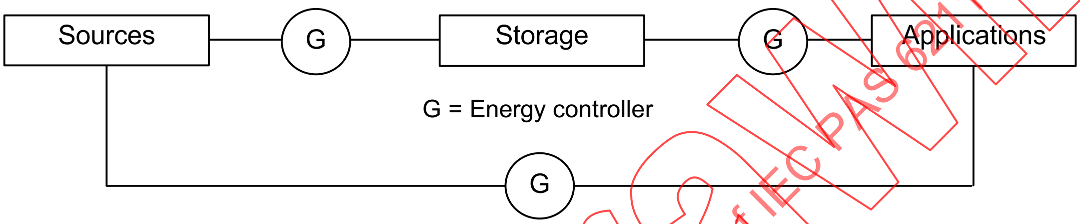

Figure 1 : General functional architecture of an energy management system

3.1 Energy fluxes controlled

The energy fluxes considered in energy management are classified as follows :

- production - storage flux : $\mathbf{P \rightarrow St}$
  - $\mathbf{P_{Pv} \rightarrow St}$ or $\mathbf{P_{Wind} \rightarrow St}$: REN - Storage links
  - $\mathbf{P_{Gr} \rightarrow St}$: generator set - storage links
- production - loads flux : $\mathbf{P \rightarrow U}$
  - $\mathbf{P_{Gr} \rightarrow U_{ACb}}$: generator set - backed-up AC loads links
- storage - loads flux : $\mathbf{St \rightarrow U}$
  - $\mathbf{St \rightarrow U_{ACb}}$: storage - backed-up AC loads links
  - $\mathbf{St \rightarrow U_{ACnb}}$: storage - non-backed up AC loads links
  - $\mathbf{St \rightarrow U_{DCnb}}$: storage - non-backed up DC loads links
  - $\mathbf{St \rightarrow U_{Pbl}}$: storage - "REN pseudo-battery-less" loads links

Note : The following links are not managed :

- *storage (any dedicated battery loads ;*
- *generator set (dedicated generator loads ;*
- *wind generator (braking load. This link becomes operational as soon as the* $\boldsymbol{P_{wind} \rightarrow St}$ ***link is jettisoned****.*

The energy fluxes taken into account by the energy controller are shown in figure 2.

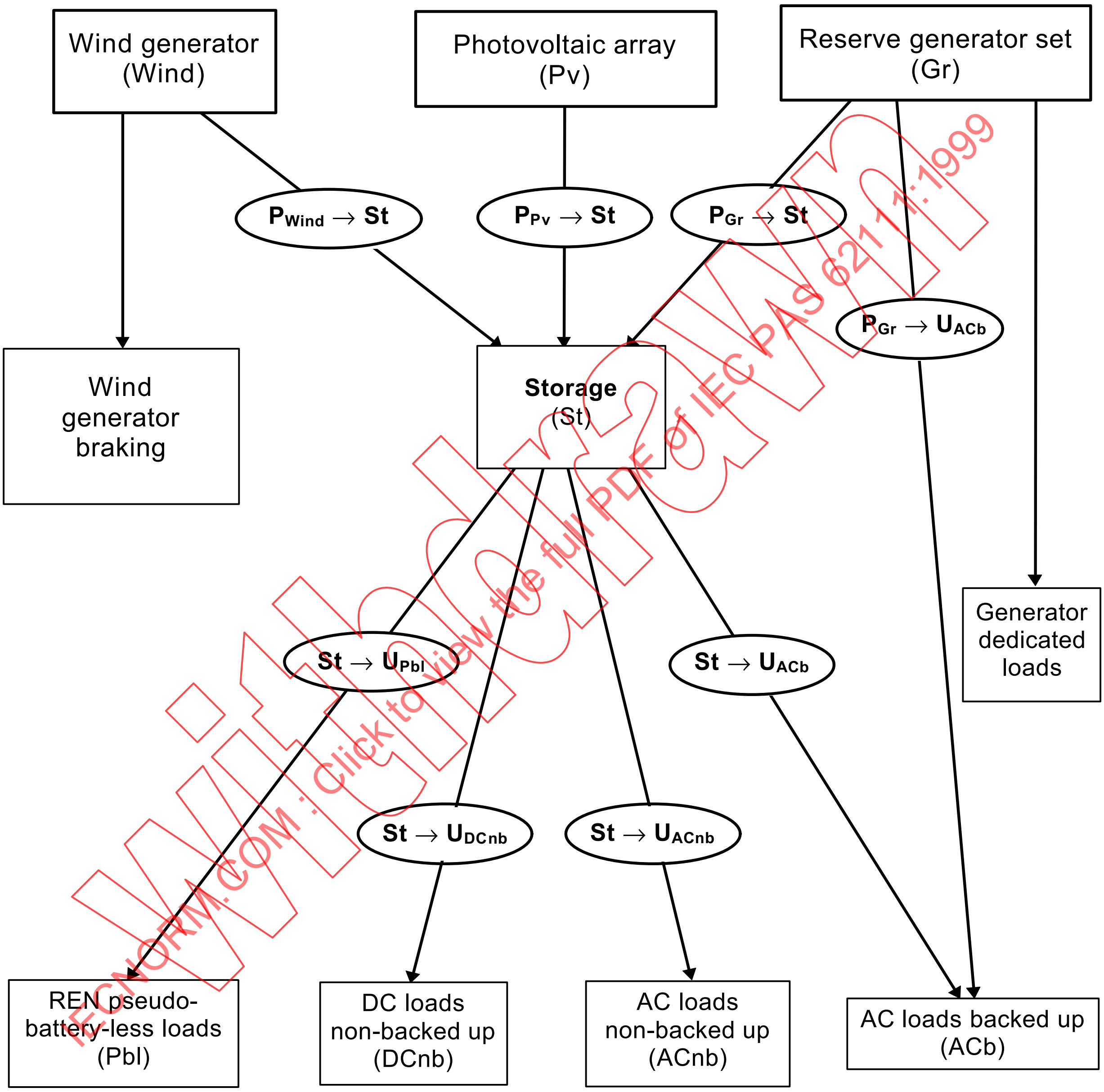

Figure 2 : Energy fluxes taken into account by the energy controller

3.2 Functional range of energy controllers

There are three main categories of energy controllers for the electrification system for isolated sites comprising production sources using renewable energy (that is types 1 to 7 of the system typology)[1] :

- **G_1** intended for "direct REN" systems ;
- **G_2** intended for single and multi-user systems (types 2 and 4) without generator set but with storage which subdivides into :
  - ◊ **G_{2a} :** basic controller ;
  - ◊ **G_{2b} :** controller similar to G_{2b} with an additional function to protect loads from voltage surges or voltage drops, with the option of controlling priority loads ;
- **G_3** intended for single and multi-user systems, with storage :
  - ◊ **G_{3a} :** controller for systems integrating REN sources and a generator set whose only purpose is to provide power to recharge the batteries, if the RENs are inadequate ;
  - ◊ **G_{3b} :** controller similar to G_{3a} with an additional function to protect loads from voltage surges or voltage drops ;
  - ◊ **G_{3c} :** controller for systems integrating REN sources and a generator set designed to recharge the battery and power some or all of the loads. (Backed-up loads) ;
  - ◊ **G_{3d} :** controller meeting the widest range of needs.
- **G_4** used for small diesel power stations with storage, powering a small grid :
  - ◊ **G_{4a} :** basic controller ;
  - ◊ **G_{4b} :** controller meeting the widest range of needs.

Table 1 shows the list of functions which energy controllers must observe.

Table 1 : Functional range of energy controllers

			Type of controller								
Function N°	Description of function	File	G_1	G_{2a}	G_{2b}	G_{3a}	G_{3b}	G_{3c}	G_{3d}	G_{4a}	G_{4b}
1 : Management of energy fluxes in Production - Storage links											
1.1	Battery charging by PV generators	A-1		●	●	●	●	●	●		
1.2	Non battery overload	A-2		●	●	●	●	●	●		
1.3	Optimisation of the power of the PV generators as a function of irradiance	A-3							●		
1.4	Equalisation load (programmed day)	A-4		●	●	●	●	●	●		
1.5	Control of direction of circulation of the current in the PV generator - battery link	A-5		●	●	●	●	●	●		
1.6	Battery charging from wind generator	A-6		●	●	●	●	●	●		
1.7	Non battery overload			●	●	●	●	●	●		

[1] the energy management devices for type 6 systems (hybrid small power station, with synchronous coupling) and type 8 (small diesel power station) are not defined in this document

Table 1 (end) : Functional range of energy controllers

Function N°	Description of function	File	Type of controller G_1	G_{2a}	G_{2b}	G_{3a}	G_{3b}	G_{3c}	G_{3d}	G_{4a}	G_{4b}
1.8	Equalisation load (programmed day)			●	●	●	●	●	●		
1.9	Control of the direction of circulation of the current in the wind generator - battery link			●	●	●	●	●	●		
1.10	Battery charging by the generator set (any day)	A-7				●	●	●	●	●	●
1.11	Non battery overload by the generator set	A-8				●	●	●	●	●	●
1.12	Equalisation load by the generator set (programmed day)	A-9				●	●	●	●	●	●
2 : Management of energy fluxes in the Storage - Loads links											
2.1	Power supply for backed-up AC/DC loads	A-10			●			●	●	●	●
2.2	Jettisoning of backed-up AC/DC loads	A-11			●			●	●	●	●
2.3	Maximum voltage limit at terminals of backed-up AC/DC loads	A-12			●				●		●
2.4	Holding minimum voltage at terminals of backed-up AC/DC loads	A-13			●				●		●
2.5	Power supply to non-backed up AC/DC loads	A-14		●	●	●	●	●	●	●	●
2.6	Jettisoning of non-backed up AC/DC loads	A-15		●	●	●	●	●	●	●	●
2.7	Maximum voltage limit at terminals of non-backed up AC/DC loads	A-16	●		●		●		●		●
2.8	Holding minimum voltage at terminals of non-backed up AC/DC loads	A-17	●		●		●		●		●
2.9	Power supply to pseudo-battery-less loads	A-18			●				●		
2.10	Jettisoning pseudo-battery-less loads	A-19			●				●		
3 : Management of energy fluxes in the Production - Loads links											
3.1	Power supply to backed-up AC loads from the generator set	A-20						●	●		
3.2	Break in power supply to backed-up AC loads by the generator set	A-21						●	●		
4 : Management of on/off commands to the generator set											
4.1	Starting generator set	A-22				●	●	●	●	●	●
4.2	Stopping generator set	A-23				●	●	●	●	●	●
5 : Management of information											
5.1	Supplied by the instrumentation	A-24	●	●	●	●	●	●	●	●	●
5.2	Supplied by the operator	A-25		(●)	(●)	●	●	●	●	●	●
5.3	Supplied by the user	A-26				(●)	(●)	●	●	●	●
5.4	Return information relating to management decisions to actuators	A-27	●	●	●	●	●	●	●	●	●
5.5	Return information relating to management decisions to the operator	A-28		●	●	●	●	●	●	●	●
5.6	Return information relating to management decisions to the user	A-29		●	●	●	●	●	●	●	●

Note. - Files A-1 to A-29, describing the various functions of the energy controllers, are in annex A.

3.3 Correspondence between types of electrification systems and energy controllers

Table 2 indicates the link existing between the type of electrification system based on REN (see document DRE - B 1 : "Architecture of Electrification Systems") and the energy controllers defined above.

Table 2 : Correspondence between functional range of energy controllers and the typology of electrification systems

	Typology of electrification systems					
Range	T_1	T_2	T_3	T_4	T_5	T_7
G_1	✸					
G_{2a}		✸		✸		
G_{2b}		✸		✸		
G_{3a}			✸			
G_{3b}			✸			
G_{3c}			✸		✸	
G_{3d}			✸		✸	
G_{4a}						✸
G_{4b}						✸

3.4 Management of battery state of charge

Electrochemical batteries are normally used for storage, the charge level of which is characterised by the indications in figure 3.

Overload condition

Equalized : forced charging state, in order to reconfigure the battery to nominal performance

Full : nominal state of charge

full-h

h = detectable energy quantity to discriminate between states of charge

low 1+h

low 1 : state of charge requiring jettisons to ensure continuity of power supply for priority users

low 2+h

low 2 : state of charge below which power supply is no longer ensured by the battery to priority users

empty : state of charge below which the battery would risk damage

Figure 3 : Battery State of charge

Using the state of charge shown in figure 3, management modes for the loads are illustrated in figure 4.

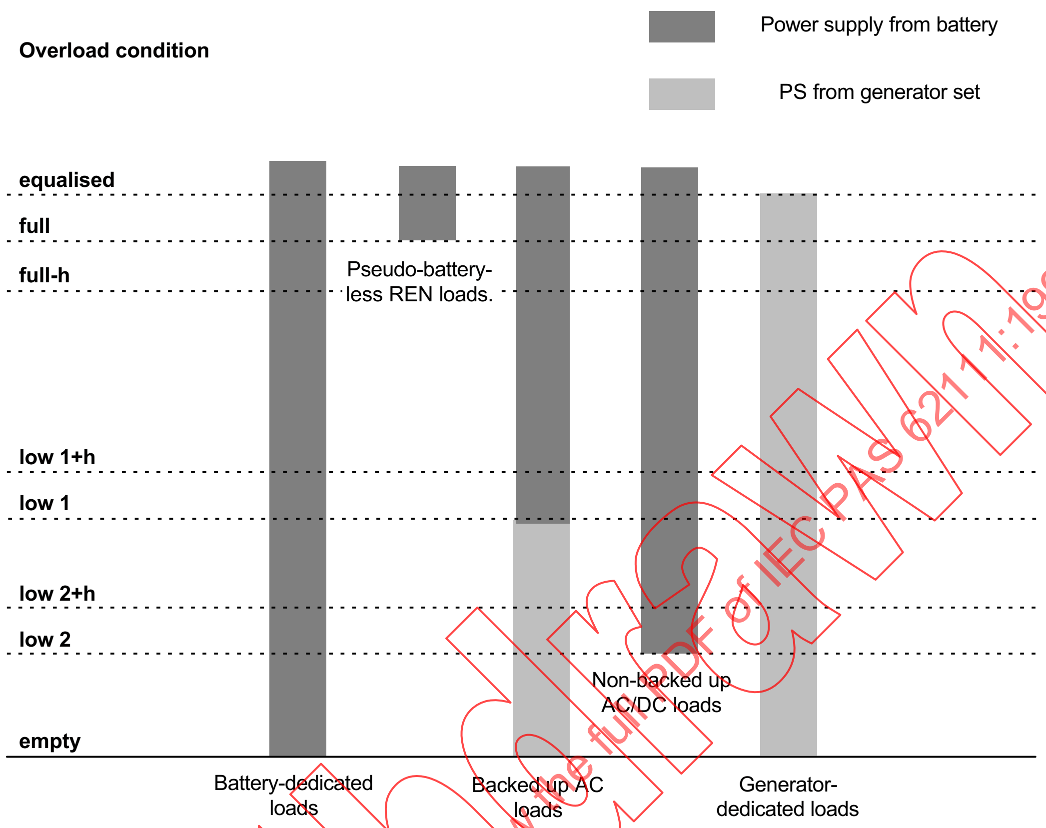

Figure 4 : Management modes for loads

NOTES :

1 - Depending on the rules established for control of the generator set, it is possible to assign the thresholds "low 1" or "low 2" to jettisoning of backed- up or non-backed up loads.

2 - For type G2a, G3a, G3b controllers, a single "low" battery threshold is sufficient.

3 - The technological solution used to evaluate the various charge levels is not chosen in advance. The state of charge of the battery may be evaluated by association of measurements relating to :

	Base	Option
Battery voltage	●	
Temperature		●
Energy budget		●

4 - If other storage methods are used instead of batteries, the energy storage level definition should be reviewed.

4. Conditions of service

Under study.

4.1 Conditions of storage

Under study.

5. Electrical characteristics

Under study.

6. Constructional characteristics

Under study.