IEC TR 62898-4

Edition 1.0 2023-04

TECHNICAL REPORT

colour inside

Microgrids –
Part 4: Use cases

IEC TR 62898-4:2023-04(en)

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

ICS 29.240.01 ISBN 978-2-8322-6645-8

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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MICROGRIDS –

Part 4: Use cases

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IEC TR 62898-4 has been prepared by subcommittee SC 8B: Decentralized electrical energy systems, of IEC technical committee 8: System aspects of electrical energy supply. It is a Technical Report.

The text of this Technical Report is based on the following documents:

Draft	Report on voting
8B/120/DTR	8B/142/RVDTR

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this Technical Report is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/standardsdev/publications.

A list of all parts in the IEC 62898 series, published under the general title *Microgrids*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under "http://webstore.iec.ch" in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

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INTRODUCTION

This document provides a set of use cases related to microgrids, as a form of "decentralized energy system". Decentralized energy systems are small energy systems containing loads and distributed energy resources (generation, storage) with decentralized management for energy supply. This document completes the SC 8B roadmap for decentralized electrical energy systems. The goal is to explain the methodology retained on the microgrid sub-domain, which is a kind of decentralized system. This methodology, based on IEC 62913-1, describes high-level use cases (business use cases) covering the main typical usage of microgrids, and details some of them through system use cases. The proposed list of use cases is a first version, proposed for review; the goal is to cover all use cases with the same level of depth.

MICROGRIDS –

Part 4: Use cases

1 Scope

In line with the methodology specified in IEC SRD 62913-1, this document describes business use cases (high-level use cases covering the main typical usage of microgrids) and details some of them. System use cases linked to those business use cases are listed and briefly described for contextualizing the main functions to be performed for managing microgrids. Ultimately, the goal of this document is to provide a consistent level of detail for all business use cases. The document details the methodology retained to develop system use cases from the business use cases.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC SRD 62913-1, *Generic smart grid requirements – Part 1: Specific application of the Use case methodology for defining generic smart grid requirements according to the IEC systems approach*

3 Terms, definitions, and abbreviated terms

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC SRD 62913-1 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

3.1.1
black start
start-up of an electric power system from a blackout through internal energy resources

[SOURCE: IEC 60050-617:2017, 617-04-24]

3.1.2
distributed energy resources
DER
generators (with their auxiliaries, protection and connection equipment), including loads having a generating mode (such as electrical energy storage systems), connected to a low-voltage or a medium-voltage network

[SOURCE: IEC 60050-617:2017, 617-04-20]

3.1.3
distributed energy resource management system
DERMS
system which, on behalf of other interested systems, manages the communications and control of individual distributed energy resources (DER), and can do this with a variety of field message protocols, and aggregates this information and communicates with other utility systems, such as a distribution management system (DMS)

3.1.4
distributed generation
DG
generation of electric energy by multiple sources which are connected to the power distribution system

[SOURCE: IEC 60050-617:2009, 617-04-09, modified – The preferred terms "embedded generation" and "dispersed generation" have been omitted.]

3.1.5
distribution management system
DMS
integration of business processes, hardware, software, and telecommunications equipment that provide effective tools to manage the operational business processes related to network management, outage management, power quality and other supporting operational practices

[SOURCE: IEC TS 61968-2:2011, 2.88]

3.1.6
electrical energy management system
EEMS
system monitoring, operating, controlling and managing energy resources and loads of the installations

Note 1 to entry: This equipment can be stand-alone or integrated in other larger equipment such as a home and building electronic system.

[SOURCE: IEC 60364-8-1:2019, 3.2.1, modified – Note 1 to entry has been added.]

3.1.7
electrical energy storage
EES
installation able to absorb electrical energy, to store it for a certain amount of time and to release electrical energy during which energy conversion processes can be included

EXAMPLE A device that absorbs AC electrical energy to produce hydrogen by electrolysis, stores the hydrogen, and uses that gas to produce AC electrical energy is an electrical energy storage.

Note 1 to entry: The term "electrical energy storage" may also be used to indicate the activity that an apparatus, described in the definition, carries out when performing its own functionality.

Note 2 to entry: The term "electrical energy storage" should not be used to designate a grid-connected installation; *electrical energy storage system* (3.1.8) is the appropriate term.

3.1.8
electrical energy storage system
EES system
EESS
installation with defined electrical boundaries, comprising at least one electrical energy storage, which extracts electrical energy from an electric power system, stores this energy internally in some manner and injects electrical energy into an electric power system and which includes civil engineering works, energy conversion equipment and related ancillary equipment

Note 1 to entry: The EES system is controlled and coordinated to provide services to the electric power system operators or to the electric power system users.

Note 2 to entry: In some cases, an EES system may require an additional energy source (non-electrical) during its discharge, providing more energy to the electric power system than the energy it stored. Compressed air energy storage is a typical example where additional thermal energy is required.

3.1.9
electric power system
EPS
composite, comprised of one or more generating sources, and connecting transmission and distribution facilities, operated to supply electric energy

Note 1 to entry: A specific electric power system includes all installations and plant, within defined bounds, provided for the purpose of generating, transmitting and distributing electric energy.

[SOURCE: IEC 60050-692:2017, 692-01-02]

3.1.10
isolated microgrid
group of interconnected loads and distributed energy resources forming a local electric power system at distribution voltage levels not currently capable of being connected to a wider electric power system

Note 1 to entry: Isolated microgrids are usually designed for geographical islands or for rural electrification.

Note 2 to entry: The definition includes a modification with respect to the IEV 617-04-23 to consider the fact that in the future, an isolated microgrid may be connected to an electric power system thanks to grid extension (this feature is explored further in this document).

[SOURCE: IEC 60050-617:2017, 617-04-23:2017, modified – In the definition, "with defined electrical boundaries" has been deleted, and "that cannot be connected" has been replaced with "not currently capable of being connected".]

3.1.11
microgrid
group of interconnected loads and distributed energy resources with defined electrical boundaries forming a local electric power system at distribution voltage levels, that acts as a single controllable entity and is able to operate in either grid-connected or island mode

Note 1 to entry: This definition covers both (utility) distribution microgrids and (customer owned) facility microgrids.

[SOURCE: IEC 60050-617:2017, 617-04-22]

3.1.12
prosumer's electrical installation
PEI
electrical installation connected to a public distribution network or not able to operate with one or both of local power supplies and local storage units, and that monitors and controls the energy from the connected sources delivering it to one or more of loads, local storage units, and public distribution network

3.1.13
virtual power plant
VPP
group of distributed energy resources which combine to function as a dispatchable unit

Note 1 to entry: A virtual power plant can be used for the purpose of participating in the electricity market or aggregating ancillary services.

[SOURCE: IEC 60050-617:2017, 617-04-27]

3.2 Abbreviated terms

BUC	business use cases
CIM	common information model
DC	direct current
DER	distributed energy resource(s)
DERMS	distributed energy resources management system
DG	distributed generation
DMS	distribution management system
DSO	distribution system operator
EEMS	electrical energy management system
EES	energy storage system
EESS	electrical energy storage system
EMS	energy management system
EV	electric vehicle
EPS	electric power system
FACTS	flexible alternating current transmission system
HV	high voltage
HVDC	high voltage direct current
IEC	International Electrotechnical Commission
LV	low voltage
MV	medium voltage
POC	point of connection
PEI	prosumer’s electrical installation
PQ	power quality
REP	retail energy provider
SCADA	supervisory control and data acquisition
SMU	system management unit
SUC	system use cases
SyC	system committee
TSO	transmission system operator
UML®[1]	Unified Modeling Language™
VPP	virtual power plant

[1] UML® and Unified Modeling Language™ are trademarks of The Object Management Group. This information is given for the convenience of users of this document and does not constitute an endorsement by IEC of the product named.

4 Overview of the document

In line with the methodology specified in IEC SRD 62913-1, this document describes business use cases (high-level use cases covering the main typical usage of microgrids) and details some of them.

Like any business use cases, these use cases attempt to be agnostic from any solutions or systems used for supporting the implementation of these use cases.

System use cases linked to those business use cases are listed for contextualizing the main functions to be performed for managing microgrids. For each of these, a short description and the involved system roles are listed with the intent to lay out technical requirements for further analysis. In the current document, not all the business use cases are covered in detail. Ultimately, the goal of the document is to provide a consistent level of detail for all business use cases. The document details the methodology selected to develop system use cases from the business use cases.

This work feeds the setting up of the standardization roadmap for decentralized energy systems, in the specific case of microgrids.

This means that this work will be followed by three next steps.

- Derive from these use cases some high-level objects to be standardized to ensure the implementation of a standard based solution for microgrids.
- Identify standards or standardization initiatives relevant in the context of microgrids and engage in a collaboration for coordination.
- Conclude on possible standardization recommendations to SC 8B or other TCs/SCs in IEC. Standardization activities could proceed with cooperation of concerned TC/SCs and SyCs, including but not limited to IEC SyC Smart Energy, SyC LVDC, TC 22, TC 57, TC 64, TC 82, TC 88, TC 95, TC 120.

Some additional benefits are expected from the content of this document:

- harmonization of the vocabulary related to microgrids across IEC initiatives;
- harmonization of the roles and functions;
- harmonization of the context of standardization for features cross cutting the IEC organization.

By nature, such a document is expected to evolve in order to reflect in the closest way market needs related to microgrids usage.

The proposed list of system use cases is a first version, proposed for review; the ultimate goal is to cover all use cases with the same level of depth.

5 Role model associated to decentralized electrical energy systems

5.1 Role model based on SGAM

The grouping of roles and actors (systems, components, operators, etc.) is based on a commonly accepted breakdown model, the EU M490 smart grid conceptual model Smart Grid Architecture Model (SGAM) in order to apprehend its complexity and to help maintain a global vision. SGAM is described in detail in IEC TR 62357-1 and IEC SRD 63200. IEC established a link between the SGAM framework and the use case methodology through key concepts: roles, business processes, activities, systems and functions in IEC SRD 62913-1. The SGAM framework enables the design of new smart grid architecture components to be organized on a three-axis basis (see Figure 1).

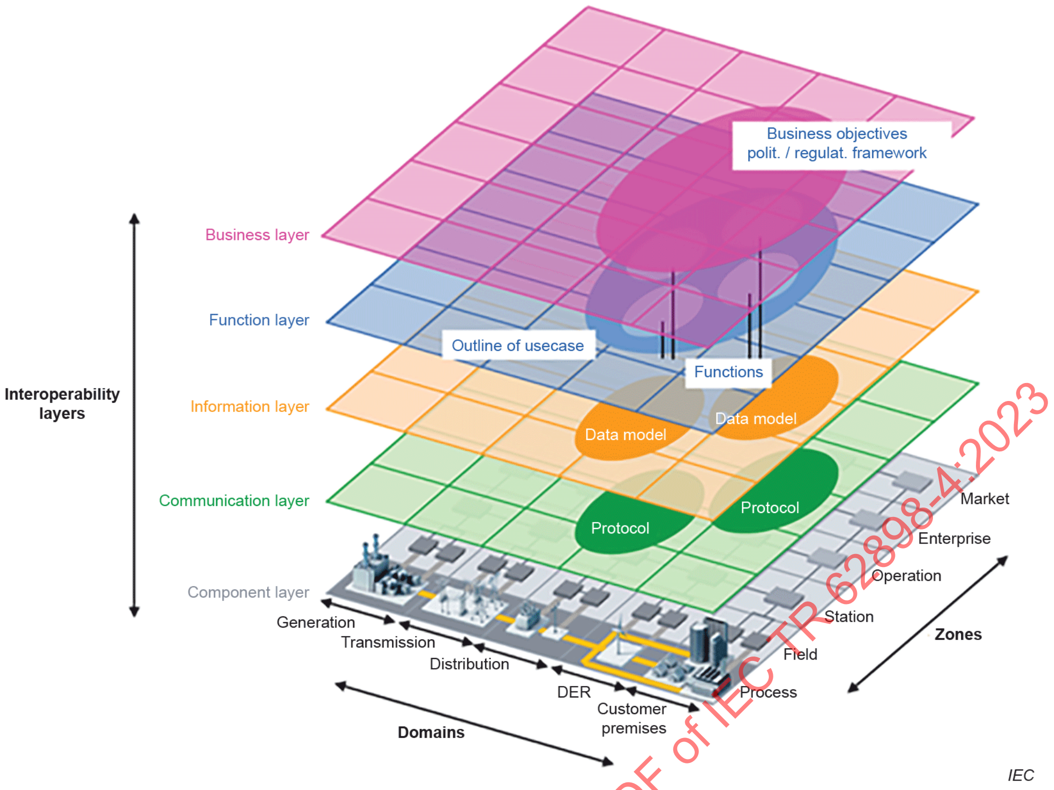


Figure 1 – The Smart Grid Architecture Model (CEN-CENELEC-ETSI, 2014)

5.2 Business roles

Table 1 lists the business roles that have been identified so far by IEC SyC Smart Energy following the guidelines for role modelling of IEC SRD 62913-1. This list is not exhaustive and will be updated as the use cases are drafted.

Table 1 – Business roles of the domain

Business roles	Definition
Generation and DER roles	
DER owner	Responsible party for overall market and financial decisions and contracts related to DER including microgrid design and operations
DER operator	Responsible party for operational aspects of the facilities and their DER systems including real time microgrid operations
Flexibility aggregator	A party which aggregates flexibilities for its customers. Can activate flexibility sites. Equivalent to retail energy provider (REP) in this document.
DER equipment manufacturer	Entity that produces, tests, sells, and implements DER systems
Producer	Party generating electric energy. Additional information: This is a type of grid user. [SOURCE: IEC 60050-617:2009, 617-02-01]
Prosumer	Network user that consumes and produces electrical energy [SOURCE: IEC 60050-617:2017, 617-02-16]
Decentralized electricity producer	Electricity producer with generator(s) connected to the distribution grid. Production can be dispatchable or non-dispatchable. This is a type of producer.
Power plant operator	Responsible party for operational aspects of a power plant

Business roles	Definition
Power plant owner	Responsible party for market and financial decisions and contracts related to a power plant
Client / customer / consumer (of electricity supplier)	A party connected to the EPS that contracts for the ability to consume electricity at a metering point.
Grid user	A party connected to the EPS and consuming or producing electricity or both. Grid users include consumers, producers, and prosumers. Equivalent to party connected to the grid.
Microgrid operator	Party responsible for the safe and reliable operation of a microgrid [SOURCE: IEC 60050-617:2017, 617-02-19]
Microgrid owner	Third party managing DER systems based on market information, financial decisions and contracts related to a microgrid
Transmission and distribution domain	
Microgrid manager	Entity responsible for the planning, operation, maintenance, and the development in given areas of the electricity network (LV, MV, and potentially HV), the quality of electricity supply (power delivery, voltage etc.), to arrange for grid connections to DERs and prosumers. The microgrid manager is responsible for the management of DER within the microgrid premises to match consumption.
Retail energy provider (REP)	Third party managing DER systems based on market information
System operator	Party responsible for safe and reliable operation of a part of the electric power system (EPS) in a certain area and for connection to other parts of the electric power system [SOURCE: IEC 60050-617:2009, 617-02-09]
Distribution system operator (DSO)	Party operating a distribution system [SOURCE: IEC 60050-617:2009, 617-02-10] The DSO is responsible for the planning, operation, maintenance, and the development in given areas of the electricity distribution network (LV, MV, and potentially HV), the quality of electricity supply (power delivery, voltage etc.), grid connection of DERs and prosumers for customer access to energy supply retail market through the DSO's system under regulated conditions. According to Article 2.6 of the Electricity Directive 2009/72/EC (Directive): "a natural or legal person responsible for operating, ensuring the maintenance of and, if necessary, developing the distribution system in a given area and, where applicable, its interconnections with other systems and for ensuring the long-term ability of the system to meet reasonable demands for the distribution of electricity"
Transmission system operator (TSO)	Party operating a transmission system [SOURCE: IEC 60050-617:2009, 617-02-11] The TSO is responsible for the planning, operation, maintenance, and the development in given areas of the electricity transmission network (HV), the quality of electricity supply (frequency and voltage), and access to the bulk market system for DER systems capable of participating. According to Article 2.4 of the Electricity Directive 2009/72/EC (Directive): "a natural or legal person responsible for operating, ensuring the maintenance of and, if necessary, developing the transmission system in a given area and, where applicable, its interconnections with other systems, and for ensuring the long-term ability of the system to meet reasonable demands for the transmission of electricity". Moreover, the TSO is responsible for connection of all grid users at the transmission level and connection of the DSOs within the TSO control area. [SOURCE: EU Commission Task Force for Smart Grids, EG3]
Balancing responsible arty	Party contractually responsible for the observed differences between electricity supplied and electricity consumed, within a defined area
Market services roles	
Service provider or energy service provider	Entity providing electricity-related services (such as energy efficiency or communication services)
Bulk power market or transmission market	Entity providing a market for buying and selling energy and ancillary services to the bulk power system

Business roles	Definition
Distribution market	Entity providing a market for buying and selling energy and ancillary services to the distribution power system In general, this entity does not exist as a "market", but many energy service providers can provide related capabilities.
Demand response market	Entity providing energy prices to consumers and prosumers so that they can change their energy demand based on those prices
Third party roles	
Meter operator	A party responsible for installing, maintaining, testing, certifying and decommissioning physical meters in compliance with the regulated conditions for contract between ESR and their customers [SOURCE: ENTSO-E, EFET, and ebIX, 2010]
Metering point administrator	A party responsible for registering the parties linked to the metering points in a Metering Grid Area. The metering point administrator is also responsible for maintaining the Metering Point technical specifications. The metering point administrator is responsible for creating and terminating metering points. [SOURCE: ENTSO-E, EFET, and ebIX, 2014]
Telecommunications operator	Entity that offers telecommunications services
Electricity installer	Entity that installs and maintains smart electric systems for industrial, commercial, and residential purposes
Equipment manufacturer	Entity that produces and sells electrical devices and electricity management devices

In addition, analysis has highlighted the need to extend business roles listed above with the following role:

Third party roles	
Weather service provider	A party responsible for providing weather forecast suitable for asset power forecast that can affect DER dispatchability

5.3 System roles

Table 2 lists the system roles identified by the IEC SyC Smart Energy and SC8B AhG2 relevant for this document along with some necessary additions.

To sort the system roles, the distinction was made between general and specific system roles. A specific system role is always attached to a general system role. A specific system role inherits the properties of the general system role and can also be referred to by the general system role. A system role can both be a general and a specific system role.

Note that this list is not intended to be exhaustive, nor does it intend to show all the relationships between different roles. Its intent is to serve the purpose of this document to provide details on the system roles to better describe the system use case.

Table 2 – System roles of the domain

System roles		Definition
General system role	**Specific system role**	
Level 0 Electric Power System		
Electric power system (EPS)		Composite, comprised of one or more generating sources, and connecting transmission and distribution facilities, operated to supply electric energy Note 1 to entry: A specific electric power system includes all installations and plant, within defined bounds, provided for the purpose of generating, transmitting and distributing electric energy. [SOURCE: IEC 60050-692:2017, 692-01-02]
	Local EPS	An EPS contained entirely within a single premises or group of premises
	Area EPS	An EPS that serves local EPSs
	Microgrid EPS	A local EPS that can operate as an island and can be operated as a virtual resource to the area EPS
	DC EPS	A local EPS that operates direct current
EPS measurement system		The overall measurement system of an EPS, consisting of all the sensors and relays that measure, record and deliver the electrical state variables of the EPS
	Frequency measurement system	A set of equipment that can measure frequency, record and provide the data for other systems to use.
	Voltages measurement system	A set of equipment that can measure voltage, record and provide the data for other systems to use.
Point of connection (POC)		Reference point on the electric power system where the user's electrical facility is connected. Note 1 to entry: In this document, point of connection indicates a point where an area EPS is connected to another local, DER or microgrid EPS. [[SOURCE: IEC 60050-617:2009, 617-04-01, modified – Note 1 to entry added.] NOTE For those POC between a utility EPS and a plant or site EPS, this point is identical to the point of common coupling (PCC) in IEEE Std 1547 "Standard for Interconnecting Distributed Resources with Electric Power Systems".
	POC switch	Switch plus its controller at the POC
	EPS switch	Switch plus its controller within an EPS
Synchronizing equipment		Equipment that synchronizes the frequency, voltage magnitude and angle between two EPSs
Weather system		Meteorological service providing weather system that can affect DER capabilities

System roles		Definition
General system role	**Specific system role**	
Level 1 Energy Resources		
Virtual resource (high level)		A set of one or more energy service resources, including generators, energy storage, controllable load, and ancillary services
Distributed energy resource (DER)		A distributed set of one or more energy service resources, including generators, energy storage, and ancillary services
	Renewable DER	DER system whose prime energy mover comes from renewable sources, including water, solar, wind, and biofuels
	Wind turbine	A rotating machinery in which the kinetic wind energy is transformed into another form of energy [SOURCE: IEC 60050-415:1999, 415-01-01]
	Hydroelectric power station	A power station in which the gravitational energy of water is converted into electricity [SOURCE: IEC 60050-602:1983, 602-01-04]
	Solar power station	A power station producing electrical energy from solar radiation directly by photovoltaic effect, or indirectly by thermal transformation [SOURCE: IEC 60050-602:1983, 602-01-29]
	Biomass power plant	A thermal power station in which the thermal energy is obtained by a combustion of biomass
	Geothermal power station	A thermal power station in which thermal energy is extracted from suitable parts of the Earth's crust [SOURCE: IEC 60050-602:1983, 602-01-28]
	Combined heat and power (CHP)	The production of heat which is used for non-electrical purposes and also for electricity. [SOURCE: IEC 60050-602:1983, 602-01-24] In some circumstances, electrical energy is the primary purpose with heat as a secondary purpose.
	Electric vehicle (EV) and electric vehicle supply equipment (EVSE)	Automobile which is powered completely or in part by electricity and whose battery can be charged from an EPS Combination of EV and EVSE is identified as a DER by IEC 63110-1.
	Fuel cell	A generator of electricity using chemical energy directly by ionisation and oxidation of the fuel [SOURCE: IEC 60050-602:1983, 602-01-33]
	Gas turbine set	A thermal generating set in which the prime mover consists of a gas turbine [SOURCE: IEC 60050-602:1983, 602-02-23]
	Heat pump	An electrical device that can heat a building (or part of a building) by transferring thermal energy from the outside using the refrigeration cycle
	Electrical energy storage system	A system that can store and deliver electrical energy by conversion into another form (chemical, potential, kinetic, thermal ...) Electrical energy storage system includes battery, flywheel, compressed air, and pumped hydro storage
DER unit		Prime mover and converter to or from electrical energy or both, including generators, energy storage, and controllable load
	DER storage unit	DER unit that includes energy storage that can be converted to electrical energy
	DER generating unit	DER unit that includes generation of electrical energy

System roles		Definition
General system role	**Specific system role**	
Load		Power demanded by a group of consumers
	Controllable load (high level)	Load allowed to be modified based on operating conditions, tariffs, contracts, or other criteria
	Non-controllable load	Load that is not allowed to be modified
	Critical load	Load within a local EPS having the highest priority of service These loads are served at the expense of all other loads.
	Non-critical load	Load within a local EPS having the lowest priority of service These loads can be left unserved in favour of critical loads.
DER controller		Controller of DER unit
DER system		Combined DER controller and DER unit, including generators, energy storage, and controllable load
	Regulating DER system	DER system responsible for frequency or voltage regulation or both The regulating DER system could be a generator, an energy storage system, or controllable load.
	Non-regulating DER system	DER system not participating in frequency or voltage regulation
Time synchronization source		Source of an accurate time signal
DER protection function		Safety-related function to prevent harm to personnel, the DER system and possibly other electrical equipment
	Protection	Provisions for detecting faults or other abnormal conditions in a power system, for enabling fault clearance, for terminating abnormal conditions, and for initiating signals or indications [SOURCE: IEC 60050-448:1995, 448-11-01]
	Firefighting	Function to prevent fire ignition
DER log		Log of significant events and alarms for use in market settlements, operational analysis, and other audit purposes
DER meter		Meter that records the energy produced within specified time periods, energy used within specified time periods for DER charging of storage, and demand curves of DER generation and storage over time Depending on the agreement between the system operator and the microgrid owner, the meter can perform recording of active and reactive power.
DER switch		Switch and its controller that connects a DER or a DER system to an upper-level EPS

System roles		Definition
General system role	**Specific system role**	
Level 2 Energy Management Systems		
DER management system (DER-MS)		System that manages the settings and dispatch of DER systems
	Facility DER EMS (FDEMS)	System that manages the settings and dispatch of DER systems within a facility. This facility could be a residence, a building, a commercial site, an industrial site, or any other high-level location.
	Microgrid DER EMS (MDEMS)	System that manages the settings and dispatch of DER systems within a microgrid, and that can cause the microgrid to become an island and to reconnect with the area EPS
	Power plant DER EMS (PDEMS)	System that manages the settings and dispatch of DER systems within a power plant
	Building DER EMS (BDEMS)	System that manages the settings and dispatch of DER systems within a building
	Virtual power plant (VPP) DER EMS (VDEMS)	System that manages the settings and dispatch of DER systems that are enrolled in a virtual power plant
	Electric vehicle EMS (EVEMS)	System that manages the settings for charging electric vehicles, including as DER systems
Electric vehicle supply equipment (EVSE)		Devices that supplies electric power to an EV to charge the vehicle's batteries
Level 3 Aggregators		
Aggregator / retail DER management system (ADEMS)		System that manages the settings and dispatch of DER systems that have been contracted to be operated by REPs or aggregators or both
Level 4 DSO and TSO		
TDEMS		TDEMS is part of the TSO EMS that manages large DER systems or large aggregations of smaller DER systems.
DSO DER EMS (DDEMS)		DDEMS is part of the DSO EMS that manages large DER systems or large aggregations of smaller DER systems.
Distribution management system (DMS)		High level term for all applications used for distribution management
	Distribution operations model and analysis (DOMA)	Topological model of distribution system, including the location and profile characteristics of all distribution equipment and DER systems (individually or in aggregate or both). This model is derived from the geographic model in the GIS, the facilities information (often included in the GIS or an asset management database), and the DER profiles (derived from the CIS and DER characteristics database)
	Distribution system power flow (DSPF)	Application that determines the power flows of the distribution system, using the DOMA model
	Transmission bus load model (TBLM)	
Geographic information system (GIS)		Geographic model of the distribution system, including the location and characteristics of all distribution equipment and DER systems (individually or in aggregate or both)
Customer information system (CIS)		System with customer information, including personal information, billing information, customer profile information, etc.
Distribution SCADA system (DSCADA)		A control system architecture comprising computers, networked data communications and graphical user interfaces for high-level supervision of an EPS

System roles		Definition
General system role	**Specific system role**	
Level 5 Market		
Retail market (high level)		Market in which transactions are made to provide energy to end-customers
	Demand response (DR) system	System providing demand response pricing information for different energy products during different time frames
Demand response (DR) pricing schedule		Schedule provided by REPs, DSOs, TSO, and others to indicate contractual and forecast prices for energy and ancillary services during specific time periods
	EV pricing program	Special pricing for charging EVs
	V2G DR program	Vehicle-to-grid demand response program

5.4 Clarifications on some roles and further detailing concepts

Moreover, it was found that several notions can target the same physical entity. In the frame of the work conducted in this document, it was found useful to clarify some roles, in particular, the typology of the electric power systems (EPS), the DER and the point of connection (POC).

a) Regarding EPS, DER and POC

Generally, an EPS consists of the infrastructure and systems that electrically connect several users together. Producers (DER), consumers (Load) and or prosumers (DER) compose these users.

– The area EPS consists of a group of EPS connected together. In the context of a use case, it can also stand for the external system(s) connected to the EPS(s) of interest. In that case, the required knowledge of the composition and the operation of the area EPS is limited to that of interest to the use case.

– The local EPS cannot operate on its own. It needs at least one (or several) external EPS to provide services that the local EPS lacks to operate. The external EPS can either be a microgrid EPS, an area EPS or both, depending on the nature of the services provided.

– The microgrid EPS can operate on its own and is not necessarily connected to an external EPS. The difference between the local and microgrid EPS is the ability of the microgrid EPS to be operated in both island mode and grid-connected mode.

A system can either or both be referenced as a DER and as an EPS, based on the type of service it provides, in the frame of each use case.

The physical separation between each EPS is the point of connection (POC). Figure 2 provides a visual explanation.

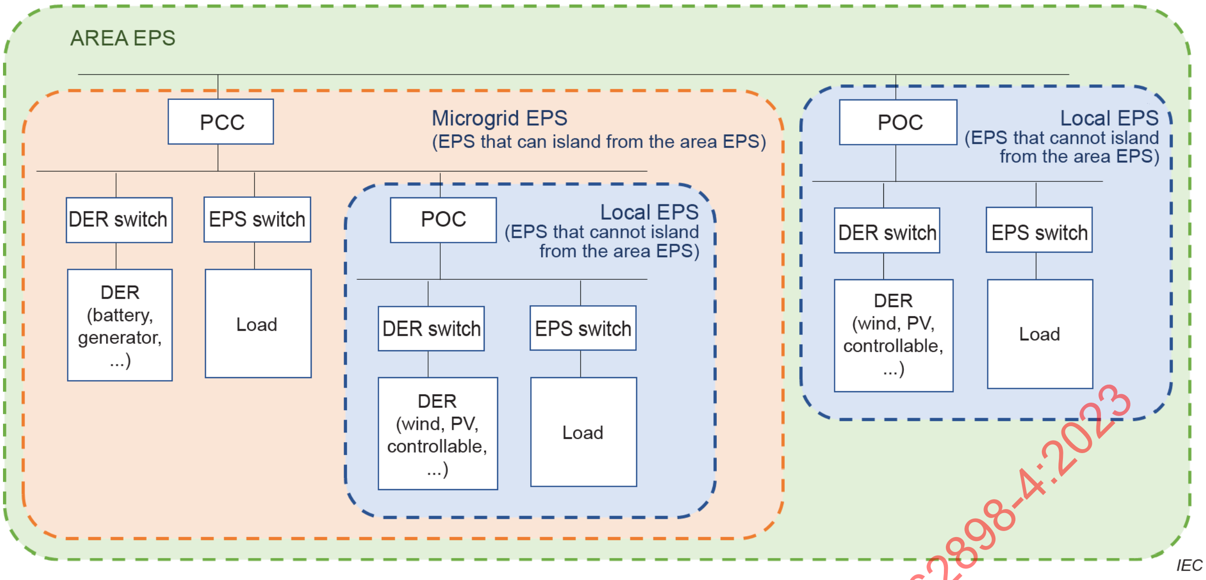


Figure 2 – Schematic view of the different types of electric power systems

b) The DER-MS as a generic DER management system

The DER-MS refers to the set of functions that are involved in the management of operations and settings of a set of DER. The functions related to DER management are included in each of the specific implementations of the DER-MS listed in Table 2 (FDEMS, MDMES, PDEMS, etc.), with variations based on the application case. The DER-MS consists then more in a set of functions than an actual system and can be hosted in many systems (Utilities systems, Service providers, and facility management systems). As such, the DER-MS is the generic role for DER management.

c) Regarding DER, DER unit (and its various subsystems) and DER system

The DER system roles proposed in Table 2 offer an array of useful concepts for describing functionalities carried out by DERs. Some clarifications are provided below on the use of these definitions:

– The DER is a distributed resource seen from the area EPS. It can be a heterogenous set of resources and includes all the facilities necessary for operation and feeding electrical energy to the area EPS. It is a general term and all the systems that have the capacity to feed energy and have the proper tools to perform so can be called DERs, regardless of their internal architecture and origin of power.

The word "unit", used in several terms, refers to an individual or a homogenous set of resources (with respect to the concepts developed).

Figure 3 provides an example of the use of system roles and highlights the key differences of scope between DER, DER unit and DER system.

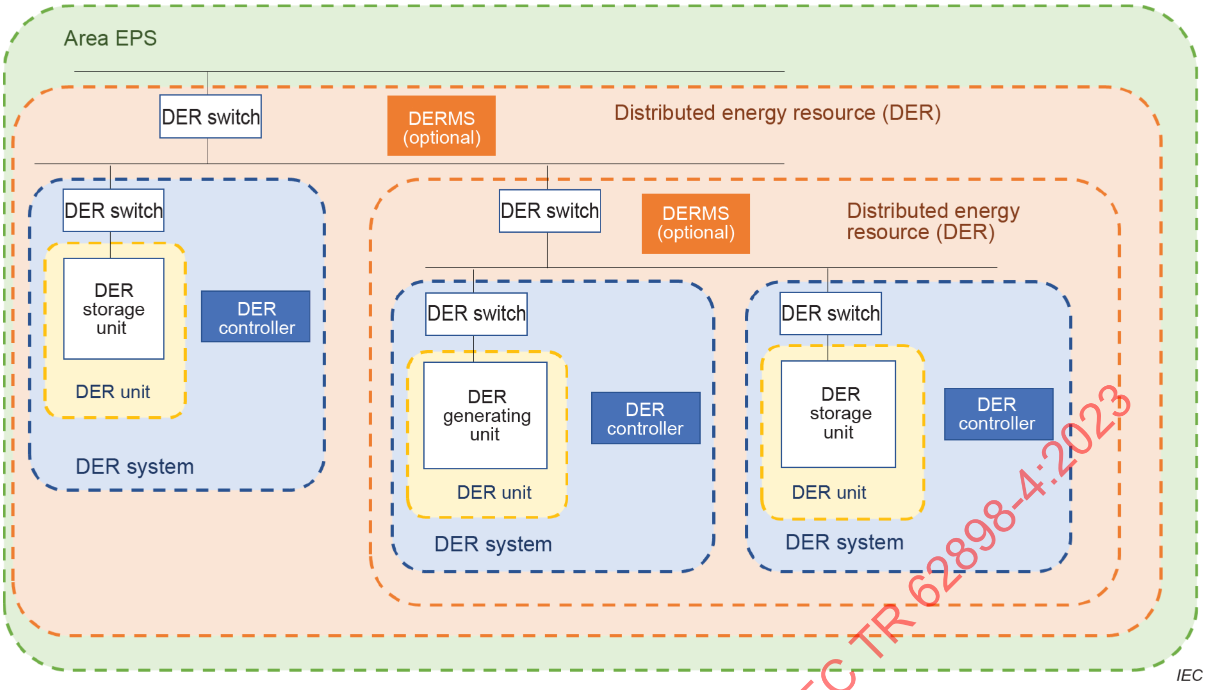


Figure 3 – Graphic user guide for DER related terms and concepts

6 Microgrids use cases

6.1 General

IEC SRD 62913-1 use case methodology has been followed as well as IEC SEG 6 results. IEC SEG 6 (System Evaluation Group on Non-conventional Distribution Networks / Microgrids) proposed a list of generic use cases which are listed in 6.2.

6.2 List of business use cases identified

The business use cases (BUC) have been classified based on their need and objectives as follows.

A Guarantee a continuity in load service by islanding.

B Electrify remote areas using renewable energy resources.

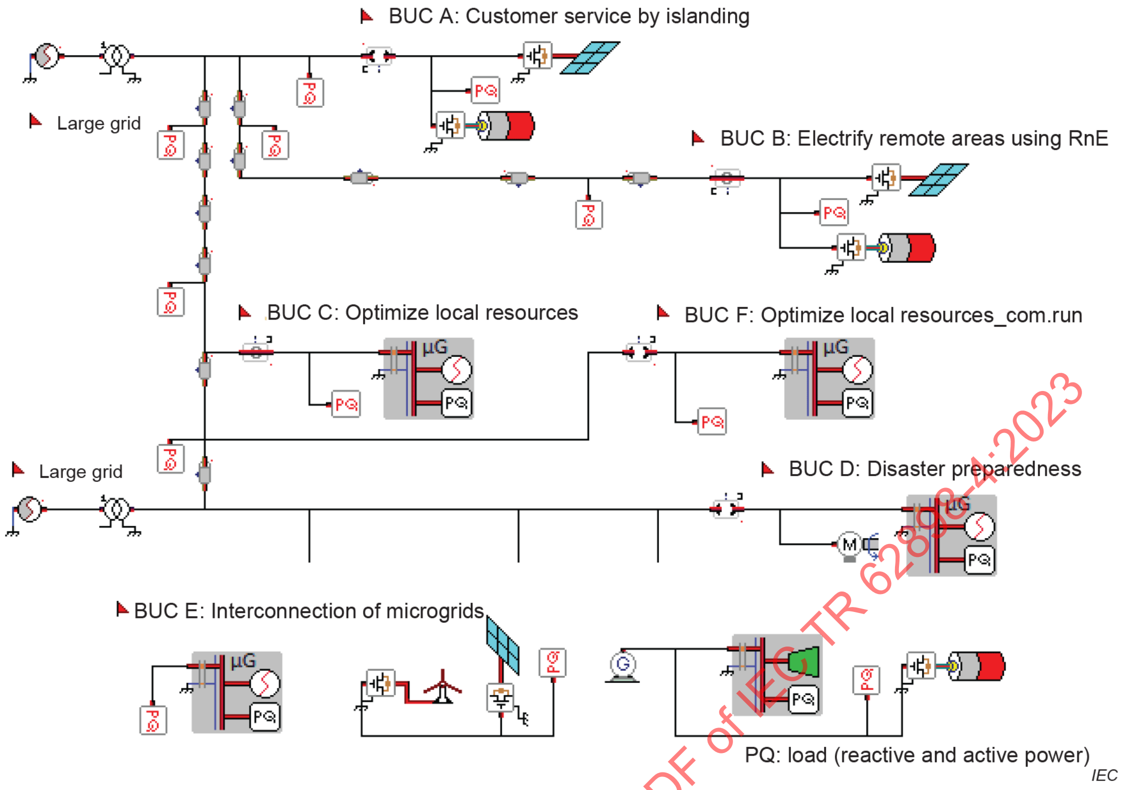
C Optimize local resources to provide service to customers inside microgrids.

D Optimize local resources to provide services to the area EPS / disaster preparedness.

E Develop larger energy system by interconnection of isolated microgrids.

F Optimize energy supply cost by proper use of local asset within a community-run distribution system.

These business use cases are illustrated in Figure 4.



Key

G generator

M meter

PQ load (reactive and active power)

RnE renewable energy resources

μG microgrid

Figure 4 – Schematic vision of the microgrids business use cases

A dedicated section for each of the BUCs identified above further describes them in detail.

6.3 Use case methodology applied to microgrid domain

BUC A (Guarantee a continuity in load service by islanding) and BUC C (Optimize local resources to provide service to customers inside microgrids) were analysed to determine their associated roles and system use cases. Around 25 SUCs for each BUC were identified, with commonalities between the two. Details were provided for each SUC to be understood and used by other working groups as a base for standardization work:

- short description;
- related business roles and system roles based on the list of roles provided in this document.

A methodology was developed to identify the system use cases, and was applied for BUC A and BUC C. The methodology is intended to fulfil the following goals.

– Ensure of the consistency with previous publications. Namely, a first set of system use cases is derived from the business use case itself, based on the details given by this document and IEC SRD 62913-2-1.

– Identify elementary system use cases and provide only essential details on each of them. This allows the use cases to be broadly understood and accessible. It also opens on a variety of implementations. Thus, the identified use cases will be stored in the IEC use case repository. Refer to Annex B for a succinct presentation of the IEC use case repository.

– Combine the system use cases so as to provide an exhaustive set of tools to achieve the related business use case.
– Build a shared vision throughout the working groups involved in activities related to the use cases to provide a reliable and representative set of use cases.

To meet these goals the group developed a step-by-step approach.

1) Derive a draft set of SUCs:

   Based on the business use case description and group member expertise, the coordination working group identifies a first set of elementary system use cases, with the aim of providing an exhaustive description of the systems involved to achieve the related BUC.

2) Propose UC based on specialized work:

   It is possible that use cases have been developed by other specialized working groups, based on their needs for standardization. These use cases need to fit into a coordinated set of use cases for microgrids and thus are integrated in the edition process.

3) Cross-check analysis:

   Then, the set of use cases is compared to work performed by other specialized working groups (either using UML methodology or other approaches). The comparison is intended

   a) to build further exhaustiveness by integrating the use cases that were found missing from the first step, and
   b) to validate the first list by finding links in between the reviewed works.

   This step was done for BUC A with the use cases provided by the relevant working group in TC 57, which later yielded the system use case identified in IEC 61850-90-23. In our approach a first list of use cases was used and in parallel reworked by the relevant working group in TC 57. Further work for alignment is planned in the near future.

4) Edit SUCs in a standardized format:

   To the consolidated list of SUCs were attributed business roles and system roles taken from Table 1 and Table 2. For each SUC, a first list of business and system roles were found. When required, the roles were then sorted with regards to their importance in carrying out the SUC in a set of primary and secondary business or system roles.

   Each SUC was completed with a short description featuring the elements of importance in the SUC and aiming at eliminating any ambiguity. The short description also provides preliminary details as to the actions attributed to each of the primary roles.

   The SUCs are developed following the guidelines of IEC SRD 62913-1 and IEC SRD 62913-2-1 and published in this document and stored in the IEC use case repository.

   The process is designed to loop between specialized working groups and the coordination group to derive consolidated use cases, but also to follow the evolving market and regulation frameworks. Roles can be part of the description process.

Figure 5 synthesizes the adopted process for each BUC.

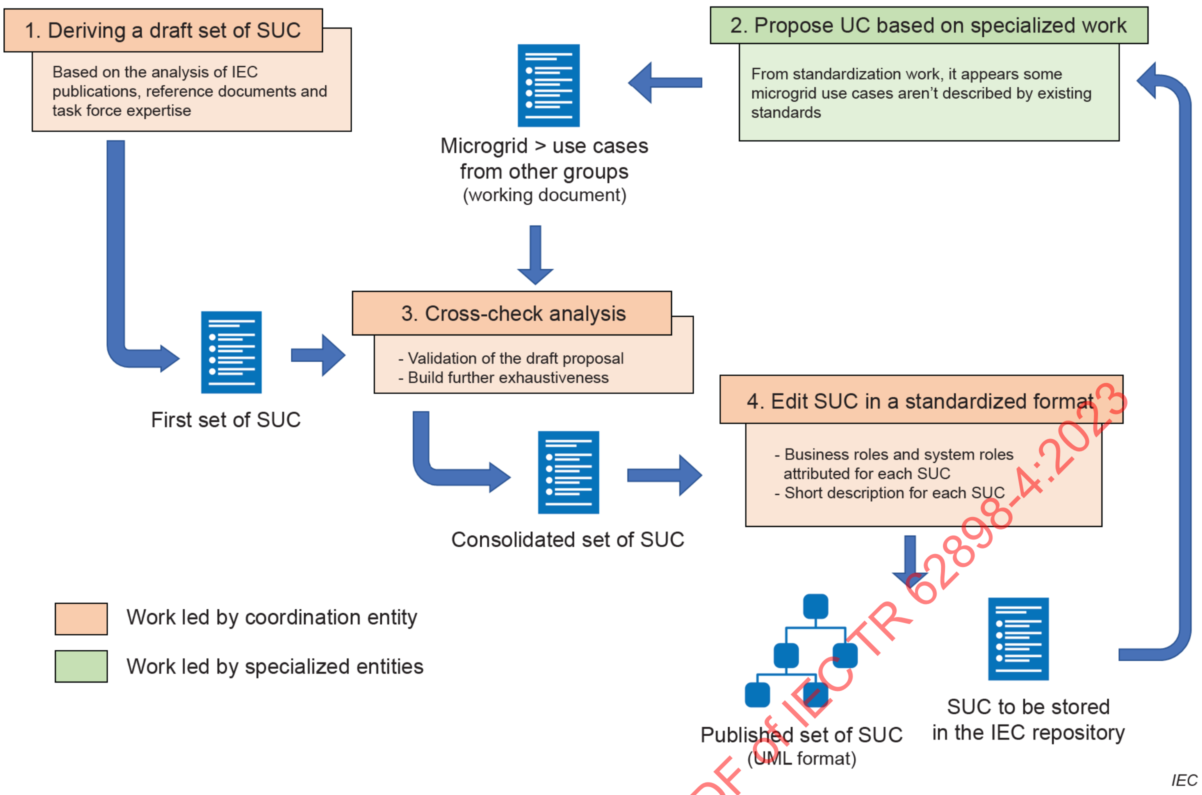


Figure 5 – Process for SUC edition for each BUC

6.4 Guarantee a continuity in load service by islanding (BUC A)

6.4.1 General

This BUC is based on IEC SRD 62913-2-1 and is intended to be consistent with it. BUC A was described using the IEC 62559-2 use case template. The description is provided in Annex A.

6.4.2 Scope

This BUC describes how a microgrid, which is generally operated in grid-connected mode, can guarantee continuity in load service by islanding, in other words by operating disconnected from the area EPS.

6.4.3 Objectives

This BUC has several objectives on the services to microgrid users:

- Improve reliability of power supply of customers by maintaining supply continuity or maintaining supply continuity for critical loads.
- Facilitate maintenance of network assets, by enabling supply continuity to customers during an interruption.
- Reduce the occurrence of outages and their duration for the customers within the microgrid.

Three kinds of islanding are possible:

- Preventive islanding in case a supply interruption is planned (for example, due to maintenance) or a grid outage is expected (storms that could damage overhead lines, damage by third parties, line congestion are non-exhaustive examples). Also, high price events are an abnormal situation to which islanding could be an appropriate answer.
- Unintentional islanding in case of unplanned grid failure; this islanding can be triggered automatically.

- Black start recovery to re-supply loads after grid failure, if the microgrid is technically not able to automatically and seamlessly island without any blackout.

After starting the islanding, the microgrid will continue to operate in island mode until the power is back to normal on the area EPS, as long as the local power sources are able to supply. Afterwards when the area EPS supply is back, the installation can reconnect to the area EPS and operate again in connected mode.

6.4.4 Operation of use case and technical issues

6.4.4.1 General

This use case can be broken down into four steps, including a total of six scenarios:

- Step 1: Before islanding (scenario 1)
- Step 2: Starting the islanding with one of the following scenarios:
  - Preventive islanding if a supply interruption is planned, or a grid outage is expected (scenario 2)
  - Automated islanding in case of unplanned grid failure (scenario 3)
  - Black start recovery to re-supply loads after grid failure (scenario 4)
- Step 3: Operating the islanded microgrid (scenario 5)
- Step 4: Reconnection to the area EPS (scenario 6)

Scenario 2 is only applicable for planned grid outages, which can be planned maintenance of upstream equipment or anticipation of possible upcoming failure or constraints on the network (storms that could damage overhead lines, line congestions are two examples).

Scenarios 3 and 4 are applicable when an unplanned outage of the area EPS occurs. The choice between both scenarios depends on the technical capabilities of the microgrid: automated islanding is better for the clients, as they do not sustain any outage, but is much more technically complicated to achieve, and thus needs more equipment and more investments.

The processes before and during the islanding, and for the re-connection to the area EPS are the same in every case.

6.4.4.2 Before islanding (scenario 1)

When the microgrid is connected to the area EPS, in normal operating conditions, the microgrid operator monitors the state of the area EPS and of the different generators, storage systems, controllable loads and other flexibilities inside the microgrid to enable islanding if an outage occurs and to assess the possible duration of islanding. Microgrid (storage) might operate only a limited time in island mode. This duration should be communicated with the DSO, especially for sensitive applications. The microgrid operator informs the DSO about the microgrid's possibility to island in real time. For utility microgrids, the DSO gives an authorization to island in case of outage (If possible, automatic action will be engaged).

The microgrid operator also prepares the different generators, storage systems, controllable loads and other flexibilities, so they are in the optimal state to start islanding if necessary, in coordination with the other use cases using them. For example, a certain percentage of a storage system's charge could be reserved to enable islanding, and not be used for other use cases. The microgrid operator can control either directly or through a system manager a generator, storage system or controllable loads (DER operator or EES operator) to prepare for islanding.

The preparation and the assessment of the islanding duration takes into account the forecasting of the consumption and production inside the microgrid. In case of critical loads such as hospitals, banks, etc., seamless switches are needed for islanding and the total islanding duration must be defined and guaranteed. Depending on the configuration of the microgrid EPS, operating DERs and causes for islanding, the islanding operation can temporarily degrade power quality. In this context, a seamless islanding refers to a level of disruption of power feed that stays within acceptable range of operation of the microgrid customers. The range of operation depends on the criticality of customer processes. It is possible that a microgrid is able to perform a seamless planned islanding but is unable to island seamlessly in response to an unplanned event.

6.4.4.3 Preventive islanding (scenario 2)

The preventive islanding can be triggered by one of the following events.

- For distribution microgrids, the MV/LV system operator informs the microgrid operator that it should perform a preventive islanding because of
  - an operation on the network that will cause a supply interruption in the microgrid area, or
  - an expected grid failure due to climatic events or constraints on the network.

    EXAMPLE Weather forecast alarm of imminent arrival of cumulonimbus clouds with possibility of lightning strike to the transmission or distribution line.

  The MV/LV system operator informs the microgrid operator about the starting time and the duration of this event.
- For facility microgrids, the private network operator can decide to operate a preventive islanding in one of the following cases.
  - The MV/LV system operator informs the private network operator about an operation on the network that will cause a supply interruption in the facility area.
  - The MV/LV system operator or a weather forecast provider informs the private network operator about an expected grid failure due to climatic events.
  - The MV/LV system operator informs the private network operator about an expected grid failure due to grid constraints.

In coordination with other use cases, the microgrid operator prepares the different generators, storage systems, controllable loads and other flexibilities, so that the system will be able to island during the entire event. For critical applications, periodic tests must be conducted to ensure the readiness of the system. The microgrid operator informs the MV/LV system operator about the microgrid possibility to island.

Before the event starting time (real or expected), the microgrid operator takes control of the operation mode of the different generators, storage systems, controllable loads and other flexibilities, and starts the islanding by commanding the resources to reduce transferred power to zero at the POC while switching the relevant resources to island mode then physically disconnecting the microgrid from the area EPS.

6.4.4.4 Unintentional islanding (scenario 3)

At a given time, an unplanned outage occurs on the area EPS, and is detected by the microgrid operator. If the conditions allow it, the microgrid operator takes control of the operation mode of the different generators, storage systems, controllable loads and other flexibilities, and starts the islanding by physically disconnecting the microgrid from the area EPS and simultaneously switching the relevant resources to island mode.

The microgrid operator informs the MV/LV system operator about the microgrid islanding state, and the possible duration of the islanding.

6.4.4.5 Black start recovery (scenario 4)

At a given time, an unplanned outage occurs on the area EPS, and the microgrid is unable to automatically island and is thus powered off. The microgrid operator evaluates the possibility to perform a black start recovery and informs the MV/LV system operator about it.

If a black start is possible, the microgrid operator takes control of the operation mode of the different generators, storage systems, controllable loads and other flexibilities, physically disconnects the microgrid from the area EPS and simultaneously switches the relevant resources to island mode, and performs a black start by managing the energy sources and the other flexibilities. The microgrid operator assesses the duration that it will be able to maintain islanding and informs the MV/LV system operator about it.

6.4.4.6 Maintaining the islanding (scenario 5)

Once the islanding has started, the microgrid operator has control over the different generators, storage systems, controllable loads, and other controllable devices in a microgrid. One of the goals of the microgrid operator is to maintain electricity supply within the quality limits defined for the area. Monitoring and controlling DERs of the microgrid in a coordinated manner by the microgrid operator serves this purpose. For AC systems, this notably implies to control voltage and frequency within the microgrid EPS. It can also imply modifying the protection functions for the new short-circuit levels and grounding situation as well as the ground connection to accommodate the new isolated grid.

The bus bars on LV level might be divided into non-interruptible (security lights, server, etc.), interruptible (heating, cooling, refrigeration, etc.) and interruptible with a time delay (dryer, washing machine). This usually ensures enough flexibility through a simple and reliable approach in order to manage them to maintain the islanding for the targeted duration. If it is impossible to maintain all the loads supplied for the total duration, the microgrid operator optimizes the supply time of the loads, taking into account priorities between the loads. As maintaining the islanding is not sufficient to maintain a stable operation, frequency and voltage control also need to be available. Depending on the use case, the selection of loads or generation power settings for continuous operation of islanding is realized by an automatic means or by service personnel of the microgrid operator.

The microgrid operator regularly assesses the possible duration of the islanding and informs the MV/LV system operator about it. This assessment takes into account the forecasting of the consumption and production inside the microgrid. Load priorities need to be considered when the microgrid is operated in island mode; for example, washing is not an important action during a blackout.

If, due to a lack of production, consumption or flexibility, islanding operation mode becomes impossible to maintain, the microgrid operator safely powers out the microgrid area, and reconnects the microgrid to the area EPS when it is possible.

6.4.4.7 Reconnection to the area EPS (scenario 6)

When the power on the area EPS has regained normal operating conditions, the MV/LV system operator informs the microgrid operator that it can reconnect the microgrid. The microgrid operator then manages the different generators, storage systems, controllable loads and other flexibilities to enable a reconnection without perturbation or interruption of the power supply, and physically performs the reconnection. The microgrid operator informs the MV/LV system operator about the reconnection, and continues to operate different generators, storage systems, controllable loads and other flexibilities based on the other use cases. The reconnection can follow different paths.

– Scenario 6.1: Seamless reconnection, if the microgrid EPS has the necessary facilities (synchronizer, frequency and voltage control of some DERs) to reconnect to the area EPS online.

– Scenario 6.2: Shutdown followed by an offline reconnection, if the DERs are unable to reduce the voltage or frequency difference at the POC. The startup procedure in this case follows the normal on-grid startup.

6.5 Electrify areas using renewable energy resources (BUC B)

6.5.1 General

This BUC implies that microgrid is one of the solutions to promote electrification in cases such as:

– far rural areas or islands;

– electrically congested areas with overloaded transmission or distribution feeders with integration of renewable energy resources (or distributed energy resources DERs).

This BUC can serve a community with weak transmission or distribution feeders.

6.5.2 Scope

The BUC concerns connected microgrids with weak transmission or distribution feeder and isolated microgrids used for purposes such as electrification in far rural areas or geographic islands.

6.5.3 Objectives

This BUC has several objectives:

– Local electrification in developing areas, before eventual construction of a main distribution network.

– Electricity supply on islands or areas where there is no possibility to connect to a main distribution network.

– Electricity supply on islands or areas where there is a main distribution network but it’s power reliability and power quality are very poor.

– Electricity supply on islands or areas where there is a main distribution network and low cost of electricity from local microgrids.

6.5.4 Operation of use case and technical issues

6.5.4.1 General requirements

In addition to local grid codes, IEC 62786 requirements apply to the user holding generation connected to the grid, with an assessment considering each feature’s impact on microgrids, one by one.

6.5.4.2 Basic functions

Basic essential functions include black-start as well as frequency and voltage regulation to guarantee necessary power reliability and quality.

6.5.4.3 Advanced functions

Advanced functions could include load shedding, load control, forecast of load and power generation.

Figure 6 shows an example of this kind of microgrid built in China with the following characteristics.

– The local area is far from local electric power distribution system.

– There is low power reliability and high maintenance cost of the area EPS.

– Some critical loads in this area need high power reliability.
– Local renewable energy resources are available.

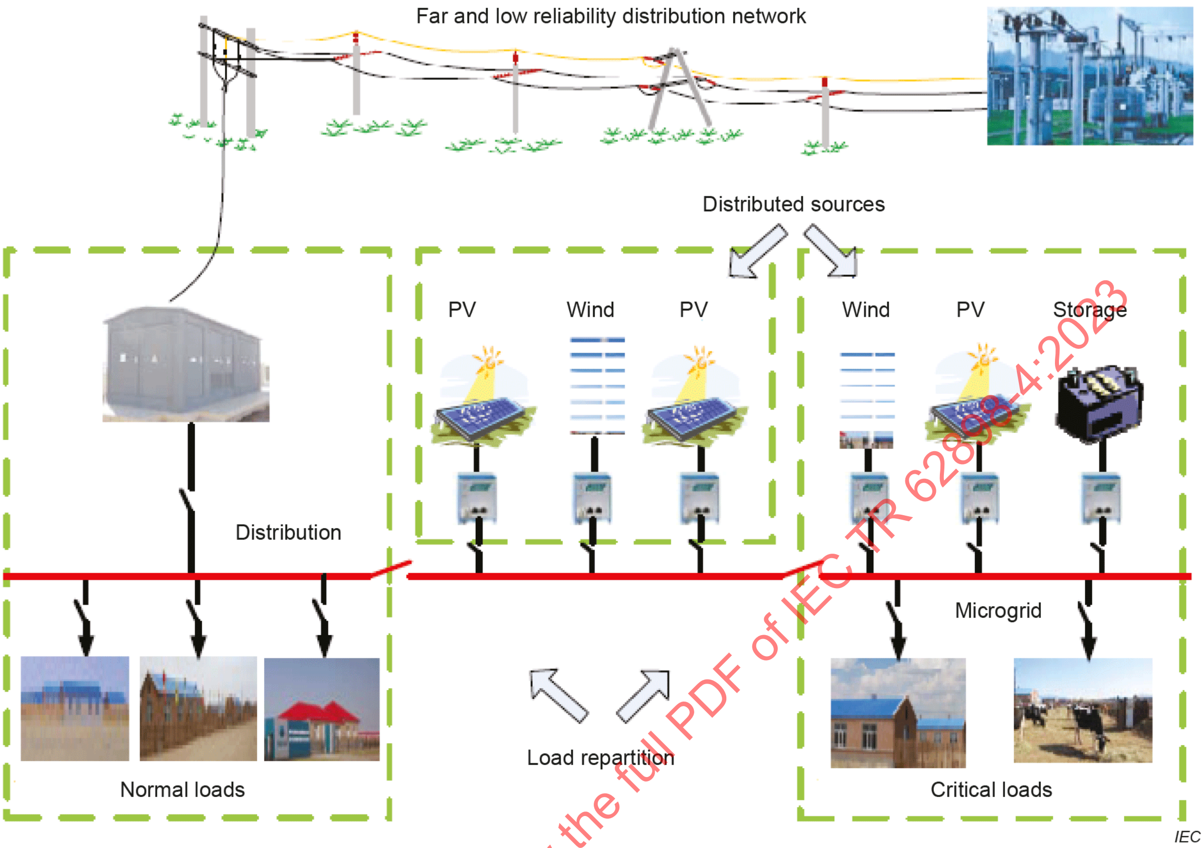


Figure 6 – Illustration of a microgrid for electrifying remote areas using renewable energy resources

6.6 Optimize local resources to provide services to customers inside the microgrid (BUC C)

6.6.1 Scope

This business use case concerns connected microgrids. It describes how microgrids can be used to provide services to their customers, by optimizing the assets such as energy storage, dispatchable loads, dispatchable generation, etc. The services provided can lead to reduction of the energy cost, increase of local energy consumption, decrease of greenhouse gas emissions, etc.

6.6.2 Objectives

This BUC has several objectives:

– Reduce the energy cost for microgrid users.
– Reduce installation costs (smaller cable sizes).
– Postpone further infrastructure investments.
– Promote local consumption.
– Facilitate renewable energy sources (RES) integration.
– Individual self-energy sufficient community connected for frequency or voltage stability or backup supply of critical loads (short-circuit protection and selectivity, more important for community connected case).

The services delivered to the area EPS could be:

– Manage power produced locally so that there is no injection (or limited injection) to the area EPS.
– Manage the reactive power consumed to avoid penalties. For example, in an installation comprising PV production, the PV system will produce an active power only by default. Thus, at the POC the consumed active energy will be reduced, but there will be the same reactive energy required, resulting in a degraded power factor.
– Manage loads so that their consumption matches with the local production.
– Optimize resource use (for example, PV, storage) depending on tariff condition or to optimize the self-consumption ratio.
– Facilitate peer-to-peer energy exchange (for example, by a trading platform) in order to increase self-consumption (within the microgrid), foster DER integration and utilize flexibilities.
– Other services to the area EPS can include voltage or frequency regulation or both and demand response, which are more in the scope of BUC D.

6.6.3 Operation and related technical issues

6.6.3.1 General requirements

This BUC concerns connected microgrids used in grid-connected mode.

In addition to local grid codes, IEC 62786 requirements apply to the user holding generation connected to the grid, with an assessment considering each feature's impact on microgrids, one by one.

Assuming compliance to grid code and agreement between network operator and the microgrid operator, the optimization of the microgrid assets can provide several services to its customers: reduction of the energy cost, increase of local energy consumption (self-consumption), decrease of greenhouse gases emissions, lower grid connection costs, etc.

The operational issues to achieve these goals are highly dependent on the regulatory framework, especially on the following points:

a) the possibility or not to have different levels of energy metering and billing: at the microgrid level, and at the customer level;
b) status of the microgrid as a consumer or as a producer or both (prosumer), and market structures for decentralized production.

Considering point b), several options can exist, which will impact the optimization strategies:

- Option 1a: Microgrid operator can sell the over-generated renewable energy to the area EPS with or without limitation in energy quantity according to the absorption capacity of the area EPS. In this case, the microgrid is considered temporarily as a power generator (cf. existing business model). In this case, the optimization is done considering the buying and selling costs of electricity.
- Option 1b: Microgrid operator can inject the over-generated renewable energy to the area EPS, with penalty for the quantity of energy injected (new business model taking into account the potential danger to the system operation).
- Option 2: Microgrid operator cannot sell over-generated renewable energy to the area EPS (new business model). The total customer load curve needs to be kept to positive or zero value, it never reaches permanently negative load power value, in other words maintaining the load profile as "consumer" rather than "generator". In this case, other control solutions could be studied further and put into place in order to avoid the injection of power into the area EPS:
  – system of penalty on customer billing for the injection of power to the area EPS (threshold, duration, price, etc.);

- real-time monitoring of customer load curve and sending an information or control signals for customer to regulate or limit its power generation on time;
- use of scheduling algorithms and peer-to-peer platforms to balance energy generation and demand as well as for capacity management;
- at customer side, a local control system, measuring the area EPS power consumption and controlling the local generators and storage system, so that the area EPS power consumption is always positive;
- last remedy to be studied further: circuit breaker (smart meter) in case of permanent power injection. Remark: there are technical risks if breaking off a power generation, further study needs to be carried out[2].

6.6.3.2 Requirements of area EPS for the above new business models

The requirements for the area EPS include the following, related to the options described in 6.6.3.1:

- Bidirectional meter for Options 1a, 1b and 2; or unidirectional meter for Option 2 but with negative power monitoring (for example, power fed to or received by the area EPS).
- Remote control of the circuit breaker tripping at the POC in case of grid event as the microgrid is considered as generator.
- The busbars of customers can be designed for load shedding of non-critical loads (electric vehicles, washing machine) to provide for additional flexibility. For this BUC, some controllable loads can be shifted (load shifting) for the period with local renewable energy production to optimize the self-consumption ratio.
- If a communication interruption occurs[3], the system must go to a safe mode. The communication is not allowed to be critical for a safe operation.

6.6.3.3 Requirements of microgrid side

Microgrid operator need to use power regulation, control and energy management systems within its own network to:

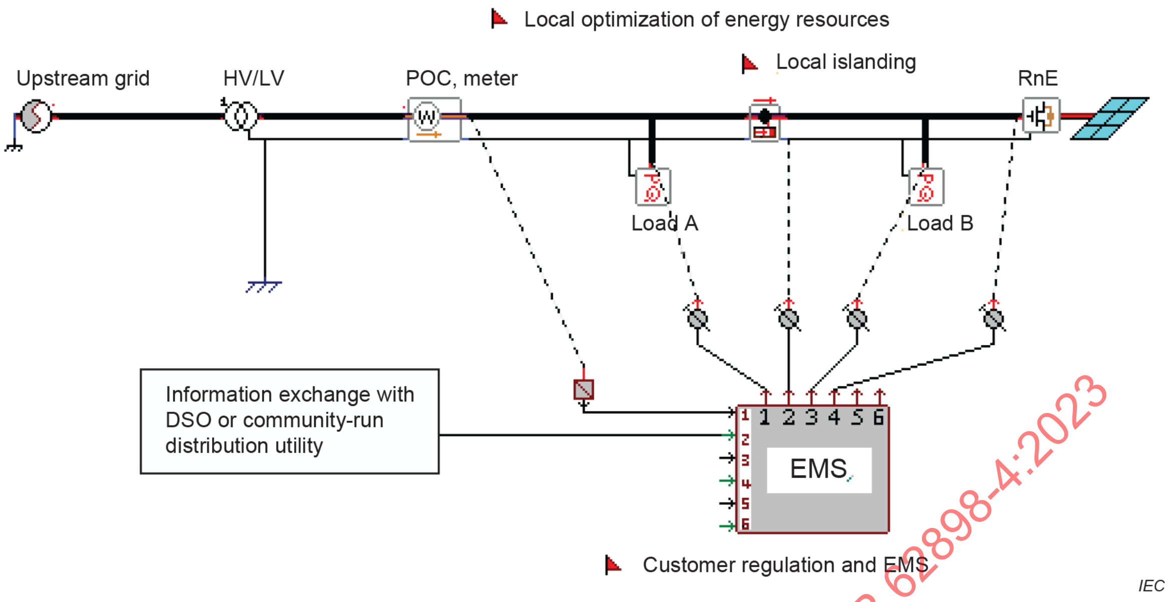
- regulate the total injection power at the POC under the given threshold for Options 1a and 1b;
- guarantee positive or zero load power at the POC for Option 2.

Microgrid power regulation and energy management system are considered as microgrid equipment and can be installed downstream of the meter under the microgrid operator's responsibility.

Figure 7 is a simplified representation of the options.

2 Regulatory framework could or could not allow breaking off a power generation depending on generator size.

3 This depends on the system design and control type: distributed controls with peer-to-peer communication are more resilient.



Key

W wattmeter

PQ load (reactive and active power)

RnE renewable energy resources

Figure 7 – Representation of the power regulation and control of a microgrid

In Figure 7, the customer power regulation and energy management system (EMS) is installed within the microgrid premises. The information link with DSO can be via internet or dedicated contract between microgrid operator and DSO.

6.7 Optimize local resources to provide services to the area EPS for disaster preparedness and power quality (BUC D)

6.7.1 Scope

Community microgrids serve critical facilities such as hospitals, grocery stores, pharmacies, emergency shelters, police and fire stations, banks and community cell-phone charging centres, and community communication assets. Such microgrids are also called "town centre" or "oasis" microgrids and connect to provide electricity to multiple customers in the face of an emergency (for example, storms, wind, fire, terrorism) and often cross public rights of way.

6.7.2 Objectives

The objectives of this use case include the following:

- Ancillary service for electric power system such as frequency regulation, area voltage control.
- Community safety and continuity.
- Limiting loss of property and life.
- Post-disasters of electric power system (enhance black-start capacity, help to start local wind turbine or HVDC link, etc.).
- Re-synchronization with area EPS.

This BUC implies that microgrids or distributed energy resource are one of the solutions to improve power quality, robustness and availability of power supply for customers of an EPS.

6.7.3 Operation of use case and technical issues

6.7.3.1 General requirements

In addition to local grid codes, IEC 62786 requirements apply to the user holding generation connected to the grid, with an assessment considering each feature's impact on microgrids, one by one.

6.7.3.2 Basic functions

Basic essential functions include black-start, reactive power control, frequency and voltage regulation and automatic transfer switching.

6.7.3.3 Advanced functions

Advanced functionalities could include management of priority of distribution and operation as a virtual power plant to respond to a grid event (for example, ancillary services, load curtailment).

6.7.3.4 References

– New Jersey Grant program: https://microgridknowledge.com/community-microgrids-3/

– A report on resiliency through microgrids in Maryland:

  http://energy.maryland.gov/documents/marylandresiliencythroughmicrogridstaskforcereport_000.pdf

– Borrego Springs (*whole community, not "town center") Demonstration Project:

  https://www.energy.ca.gov/publications/2019/borrego-springs-californias-first-renewable-energy-based-community-microgrid

– NEDO Microgrid at Sendai: http://www.nedo.go.jp/content/100516763.pdf

– Hoboken, New Jersey Microgrid Project: https://microgridknowledge.com/microgrids-made-easier-how-hoboken-is-creating-a-resilient-microgrid-and-how-your-city-can-too/

6.8 Develop larger energy systems by interconnection of isolated microgrids (BUC E)

6.8.1 Scope

This business use case concerns a type of non-conventional EPS in which the development of larger energy systems is accomplished by interconnection of isolated microgrids or distributed energy resources. This BUC implies that the development of large public power systems can be carried out in two steps: 1) building isolated microgrids, and 2) interconnection of existing microgrids by large transmission or distribution EPS.

6.8.2 Objectives

The objectives of this use case include the following:

– Optimize grid planning and investment phase by phase: it is possible to develop power systems by promoting local and isolated energy power systems as phase 1, and later interconnecting the existing local power system as phase 2 (see Figure 8 and Figure 9).

– Optimize energy exchanges among isolated microgrids, loads and local energy distribution zones.

– Enhance renewable energy integration into electric power grids.

– Improve power quality and power reliability.

– Ensure progressive settlement of new customers.

6.8.3 Operation of use case and technical issues

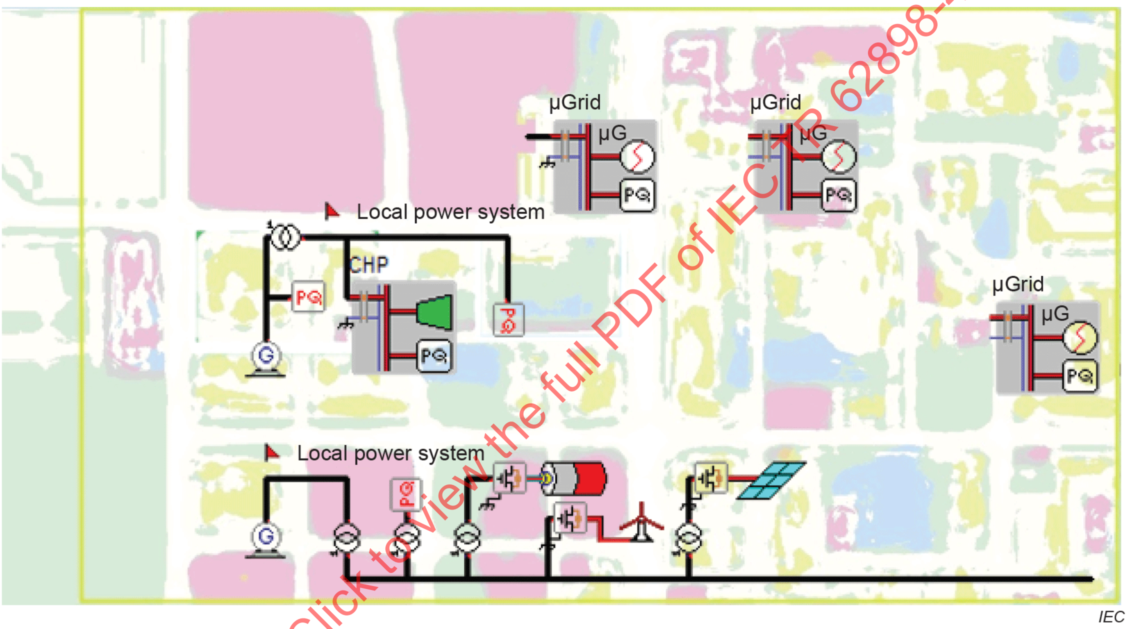
6.8.3.1 General requirements

In addition to local grid codes, IEC 62786 requirements apply to the user holding generation connected to the grid, with an assessment considering each feature's impact on microgrids, one by one.

This BUC case could generally be deployed in the following way.

– Phase 1: isolated microgrids and autonomous local power supply systems

  For example, in a developing zone where there is not yet large power supply system, the construction of isolated microgrids or local power supply areas will make it possible to develop local economies step by step. Figure 8 shows an area where there are three microgrids and two local energy supply systems without interconnection.



Key

G generator

PQ load (reactive and active power)

CHP combined heat and power

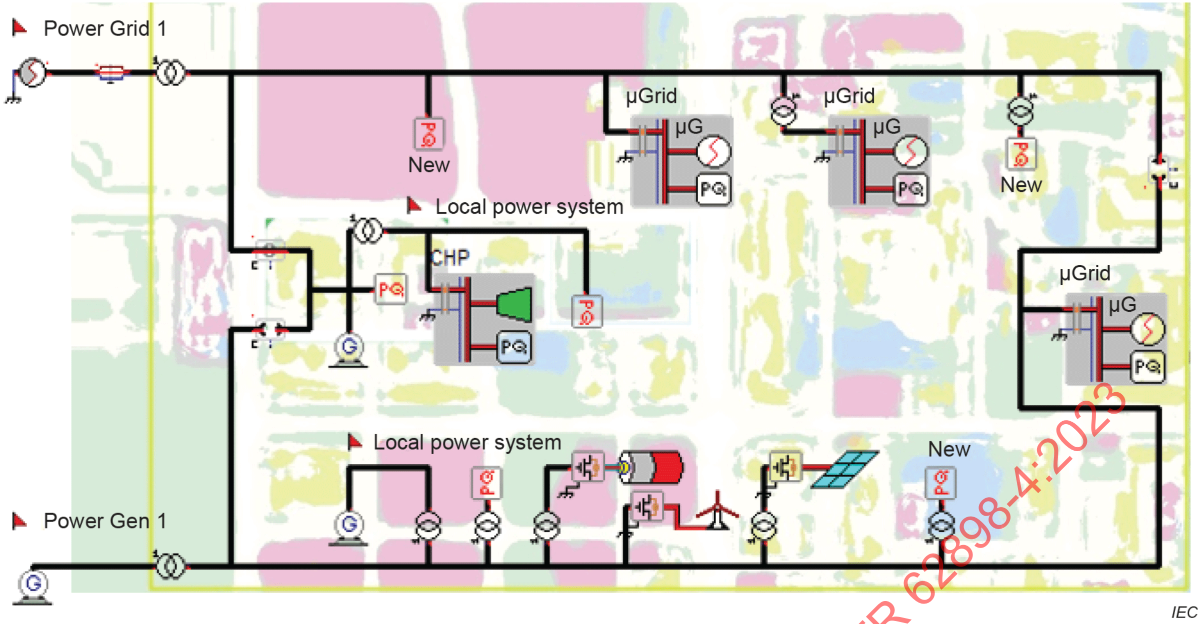
µG microgrid

Figure 8 – Illustration of an area with microgrids and local energy supply systems without interconnection

– Phase 2: interconnection of existing microgrids and settlement of more new customers

  Based on the existing local power supply systems and the economic evolution of the areas, it would be possible to plan the future power supply system in different ways:

  - arrival or extension of upstream large power supply system to the area (Power Grid 1 in Figure 9);
  - interconnection of existing microgrids and local power supply systems with or without centralized power generation (Power Gen 1 in Figure 9);
  - enhanced local power systems will be able to supply more customers (the two new loads in the Figure 9).



Key

G generator

PQ load (reactive and active power)

RnE renewable energy resources

μGrid microgrid

Figure 9 – Illustration of the connection between microgrids and local energy supply systems of an area

6.8.3.2 Basic functions

Basic essential functions include and are not limited to local energy balance, power flux control, frequency and voltage regulation, intermittence smoothing, power quality and reliability improvement.

6.9 Optimize energy supply cost and exploitation of local assets inside community-run distribution utility by managing local resources (BUC F)

6.9.1 Scope

This business use case concerns microgrids in grid-connected mode. It describes community-run or community-owned (also municipality-owned, neighbourhood-owned, cooperative-owned, etc.) distribution utilities that own or manage a complete part of the overall distribution network, downstream of the MV/LV, HV/MV or HV/LV transformer, aiming at two principal objectives.

1) To determine capital and operating expenses for the maintenance and the operation of the network infrastructure managed or owned. As a result, network use tariffs for the community members are also determined by owners.
2) To promote the use of local energy assets and resources accounting for the technical, economic and environmental impact of various energy production and transportation techniques.

The services provided to the community members can be the reduction of the network use tariff and of the energy supply cost, the increased consumption of energy locally produced (from renewable or conventional resources), the exploitation of local assets for self-sufficiency purposes, the creation of economies of scale in the community and in nearby areas, the decrease of greenhouse gas emissions, the active engagement of community members with innovative energy related technologies (metering, storage, etc.) and energy efficiency actions (demand side management), etc.

6.9.2 Objectives

The objectives of this BUC include the following:

- Protect community members against energy price volatility (concerning network use tariffs and energy supply cost).
- Promote the use of locally produced energy and the exploitation of local assets.
- Reduce network losses and optimize network operation and maintenance cost.
- Minimize energy transportation cost.
- Facilitate local RES integration (cooperative RES projects, ownership of local RES or storage installations).
- Create economies of scale in the community and in nearby communities (project management, project development, new technologies, etc.).
- Deliver services to the area EPS (if the existing legal framework allows such actions).
- Optimize operational expenses by eventually merging the service with other local utilities such as district heating, water utilities, sewage, waste management, desalination, etc.
- Increase community members' engagement in energy efficiency actions by offering tariff incentives (local re-profiling of network use tariff).
- Increase community participation in the current energy transition (for example, shared development and management of RES projects).
- Develop innovative (applied within the community) energy market models such as peer-to-peer systems.
- Customize energy trading and purchase to the specific needs, objectives and characteristics of the community.

6.9.3 Operation and related technical issues

6.9.3.1 General

This BUC concerns connected microgrids used in grid-connected mode. It is important to clarify that the BUC describes microgrids locally owned or run only by end-users to whom energy is supplied via the microgrid. This clarification is important in order to differentiate the BUC from general privatization, re-municipalization or re-nationalization models.

Assuming compliance with grid code and agreement between network operator and the microgrid operator, the previously mentioned objectives could be achieved. However, certain technical issues need to be addressed accounting for local conditions and the existing regulatory framework. The technical issues that need to be considered to achieve these goals are highly dependent on the regulatory framework, especially on the following points:

a) possibility of management or ownership or both of a part of the distribution network by the local community (cooperative business of end-users, local authorities);
b) possibility to have energy metering at different levels (at the point of common coupling of the microgrid with the area EPS, at the end-users' level, at some critical points within the microgrid, etc.);
c) possibility to have energy metering of different time resolutions (recordings of less than some hours, less than one hour, less than 10 minutes or 15 minutes, less than one minute);

d) possibility to apply a different energy billing model within the microgrid (for the network use tariff or for the energy supply tariff or both);

e) status of the microgrid as a consumer or as a producer, and market structures for decentralized production;

f) possibility of using the existing network wire or need to establish a private network wire;

g) possibility to establish a local (community-run) energy supplier or implement a franchising model that can be established by existing energy suppliers or energy service companies;

h) possibility to apply customized technologies for technical constraint management (inverters for renewable energy curtailment, three-phase four-wire inverters, customized voltage control strategies, etc.);

i) possibility to develop community-owned RES projects, storage projects.

Point a) depends on the legal framework of the country about the ownership and management of the power distribution network. Two general cases can exist:

- Case a.1: In countries where the distribution network is a public asset and cannot be privatized, a customized agreement could be established between the community and the state (or the respective municipality or the respective public distribution utility). Such an agreement could set the community as the microgrid operator that will be in charge of the system infrastructure, operation, energy supply, energy trading issues within the microgrid.
- Case a.2: In countries where the distribution network is privatized, the community can submit candidature for the ownership or the management of the local distribution network, by establishing an energy cooperative or another legal entity that could participate in the respective auction. In this case, the community can be the microgrid owner and operator.

Points b), c), d), f), g), h), i) would heavily depend on the terms of the customized agreement in Case a.1 or in the existing legal framework in Case a.2. Tariffs for the use of the public transmission and distribution network (upstream of the community-owned network) can be addressed in the agreement, considering the community as a single network user (metering at the POC with the area EPS is necessary).

The possibilities of implementing energy metering at the end-user level (point b)) and a local re-profiling of network use tariffs (point d)) are important for achieving the first principal objective of this BUC. If the local re-profiling of network use tariffs can be applied several options exist concerning the optimization of capital and operating expenses for the microgrid.

- Option d.1: Network use tariffs can be customized for microgrid users in order to reflect time-of-use and critical load, both depending on local energy resources, power and energy consumption patterns of community members. A well-studied tariff re-profiling can reduce network losses and slow down the degradation of network components.
- Network use tariffs can be customized for microgrid users but also points g) and h) can be implemented. If point g) can be implemented, the cost of energy supply can be reduced thanks to a customized energy trading or to the minimization of the energy transportation cost. If point h) can be implemented, customized constraint management (voltage control, etc.) and storage technologies can be used for optimizing the energy flow in the microgrid.

Concerning point f), duplicating the existing system is undoubtedly not cost-effective. Private wire networks are used in off-grid configurations or industrial parks; however, if the legal framework does not allow the use of the existing infrastructure in a community-run or community-owned microgrid, this option could be considered.

Regarding point g), the establishment of a local supplier could further support the second principal objective of this BUC. Local energy producers and community members could sell their energy to the local supplier and buy energy from it. Innovative market models, such as peer-to-peer models, could also be developed within the community. For implementing point g) two options could exist.

- Option g.1: Setting up a licensed supply company, such as a community-owned generation plant, a cooperative trading business or a local authority that can act on behalf of the community for negotiating power purchase agreements (PPAs) with the existing energy generation companies. However, setting up a licensed supply company requires a high initial capital and a flexible legal framework for integrating such businesses.
- Option g.2: Setting up a franchising model of existing licensed energy supply companies that can be implemented in the community microgrid by means of a community-run energy service business.

Concerning point e), several options can exist, which will impact the optimization strategies.

- Option e.1: Microgrid operator can sell the over-generated renewable energy to the area EPS with or without limitation in energy quantity according to the absorption capacity of the area EPS. In this case, the microgrid is considered temporarily as power generator (cf. existing business model). In this case, the optimization is done considering the buying and selling costs of electricity.
- Option e.2: Microgrid operator can inject the over-generated renewable energy to the area EPS, with penalty for the quantity of energy injected (new business model).
- Option e.3: Microgrid operator cannot sell over-generated renewable energy to the area EPS (new business model). The total customer load curve needs to be kept to positive or zero value; it never reaches permanently negative power value, in other words maintaining the load profile as "consumer" rather than "generator". In this case, technical and political solutions need to be studied further and put in force in order to avoid the injection of negative power into the area EPS:
  - system of penalty on customer billing for the injection of negative power to the area EPS (threshold, duration, price, etc.);
  - real-time monitoring of customer load curve and sending an information or control signal for customer to regulate or limit its power generation on time;
  - use scheduling algorithms and peer-to-peer platforms to balance energy generation and demand as well as for capacity management.
  - last remedy to be studied further: circuit breaker (smart meter) in case of permanent power injection. Remark: there are technical risks if breaking off a power generation, further study needs to be carried out.

6.9.3.2 General requirements

In addition to local grid codes, IEC 62786 requirements apply to the user holding generation connected to the grid, with an assessment considering each feature’s impact on microgrids, one by one.

6.9.3.3 Requirements of grid side for the above new business models

The requirements for the area EPS include:

- metering that allows bidirectional power measurement (either with two meters or with one meter that allows negative power measurement);
- remote control of the circuit breaker at the POC in case of grid event in the cases where the microgrid can feed power to the area EPS.

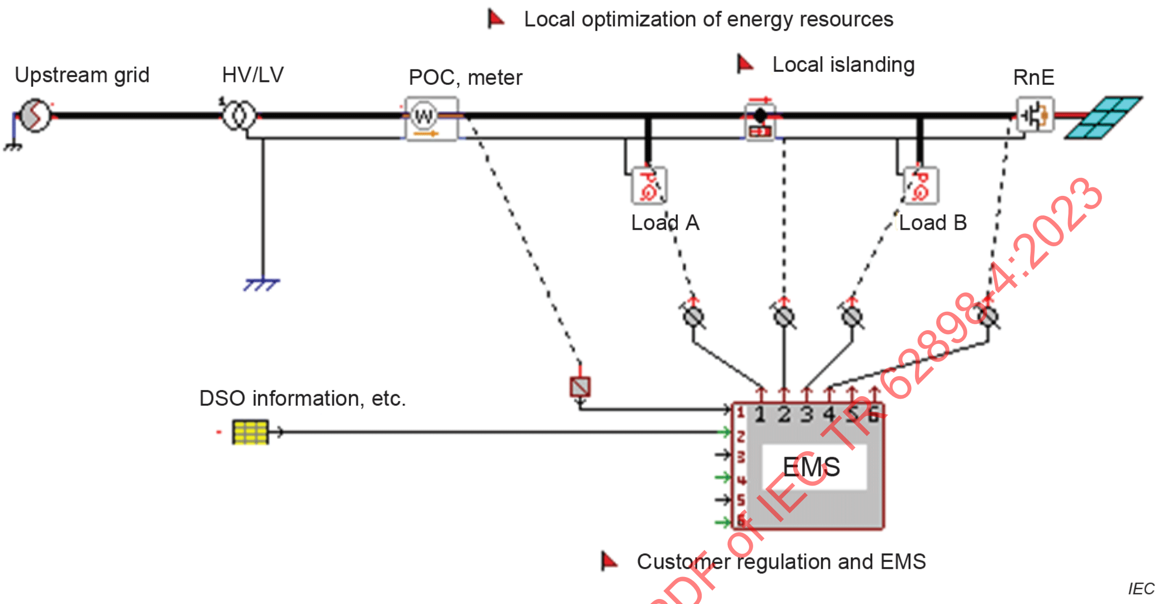
6.9.3.4 Requirements of microgrid side:

Microgrid operator needs to use power regulation, control and energy management systems within its own network to:

- regulate the total injection power at the POC under the given threshold for Option e.1;
- guarantee positive or zero load power at the POC for Option e.2.

Microgrid power regulation and energy management system are considered as microgrid equipment and can be installed downstream of the meter under the microgrid operator's responsibility.

Figure 10 provides a simplified representation of these options.



Key

W wattmeter

PQ load (reactive and active power)

RnE renewable energy resources

Figure 10 – Customer regulation and EMS connection options

In Figure 10, the symbol EMS refers to microgrid power regulation and energy management system. It is installed within the microgrid premises. The information link with DSO can be via internet or dedicated communication link between microgrid operator and DSO.

6.10 List of system use cases

Table 3 lists the system use cases identified for BUC A and BUC C.

Table 3 – List of microgrids system use cases

Name	BUC linked	Short description	Business roles involved	System roles involved
Monitor the state of the POC	A/C	The DERMS continuously monitors the state of the area EPS at the POC, whether the microgrid EPS is operated in islanded or grid-connected mode. The intent is to detect any unplanned outage from the area EPS as well as return to normal conditions, if the area EPS was previously out of service at the POC.	DER operator Microgrid operator DSO	DERMS POC Microgrid EPS Area EPS Local EPS Synchronizing equipment Time synchronization source DER protection function DERMS
Monitor the status of the DER in the microgrid EPS	A/C	The DERMS or the DER management system monitors in real time the status of DER (generators, storage units and controllable loads) within the premises of the microgrid EPS. Depending on the DER, status issued by the DER could include real time operating conditions and alarms.	Microgrid operator DER operator	DERMS DER DER controllable load Microgrid EPS Local EPS DER log DER meter DER system
Enable microgrid EPS islanding in case of an outage	A	In case an outage of the area EPS occurs, the POC switch disconnects the microgrid EPS from the area EPS. In addition, the relevant DER are switched to island mode. Requirements for switching from grid-connected mode to island mode, earthing and protection management are provided by IEC 60364.	Microgrid operator DER operator	DERMS DER DER controllable load Microgrid EPS POC switch
Assess the possible duration of islanding operation	A	The DERMS evaluates how long the microgrid EPS can be operated in island mode from the capabilities of each DER (generation, storage units and controllable loads) and forecasts the load within the upcoming time frame. In parallel, the DERMS and the DMS assess the time at which the microgrid EPS can be connected to the area EPS.	Microgrid operator DER operator DSO	DERMS DER DER controllable load Microgrid EPS DMS
Forecast of the consumption and production of the microgrid EPS	A	The DERMS forecasts the production with the capabilities of each DER (generation, storage units and controllable loads) and forecasts the load based on accurate algorithm for an upcoming time frame. The production forecast of intermittent DERs can be derived from predictions of a weather system.	Microgrid operator DER operator Weather provider	DERMS DER DER controllable load Microgrid EPS Weather system
Ensure that each relevant DER is in optimal state to enable islanding	A	The DERMS inquires on the capability of each relevant DER to be operated in island mode and requests the DERs to transition to optimal state to prepare for islanding (for instance, by charging the storage units).	Microgrid operator DER operator	DERMS DER

Name	BUC linked	Short description	Business roles involved	System roles involved
Manage DER storage units to enable islanding	A	The DERMS manages the storage units of the microgrid EPS to enable islanding. The intent is that the state of charge of DER storage units reaches a given percentage to facilitate islanded operations.	Microgrid operator DER operator	DERMS DER storage unit
Perform periodic tests for islanding readiness	A	The microgrid operator plans, manages and performs periodic tests, with the assistance of the DERMS, on the microgrid relevant premises (POC switch, relevant DER units and the communication network), to ensure the microgrid assets readiness for unplanned islanding.	Microgrid operator DER operator	DERMS DER Microgrid EPS POC switch Communication network
Monitor and provide microgrid islanding state	A	The DERMS monitors and provides the microgrid EPS islanding status directly to the requesting party or by broadcasting. Islanding status can cover islanding state and its possible duration, microgrid EPS readiness for islanding, microgrid EPS successfully tested to provide islanding service.	Microgrid operator DSO	DERMS Area EPS Microgrid EPS DMS
Evaluate and inform on the readiness of black start	A	The DERMS or a dedicated system verifies that the required conditions are met by the relevant actors (DERs, grid facilities and customers) to perform the black start up. The DERMS informs the operator on black start-up readiness.	DER operator Microgrid operator Client Flexibility aggregator	DERMS Microgrid EPS DER Grid facilities Customers
Manage the relevant DER and other flexibilities to perform black start	A	After the conditions are met and black start is available, the DERMS or a dedicated system manages the relevant actors (DER, grid facilities and customers) to perform the black start. During the black start, relevant DERs are connected to the area EPS and progressively ramped up to a stable operation state. Identified customers are energized in priority. The black start ends when some terminal conditions involving steady state operations are met.	DER operator Microgrid operator Client Flexibility aggregator	DERMS Microgrid EPS DER Grid facilities Customers
Manage DER to maintain islanding for the targeted duration	A	The DERMS manages the DER and controllable loads to maintain steady state operation of the microgrid EPS during a target duration. In parallel, it also regularly reassesses the possible duration of islanding based on evolving conditions (environment and load…) and updates the relevant systems about it.	Microgrid operator DER operator DSO	DERMS DER DER controllable load Microgrid EPS
Monitor and manage load types and priorities	A	The DERMS continuously monitors the type and priorities of the relevant loads of the microgrid EPS. Prioritizing helps the DERMS in targeting loads for shedding, feeding and so on. Priorities can be updated dynamically or by the microgrid operator.	Microgrid operator Client Flexibility aggregator	DERMS DER controllable load Microgrid EPS Client
Optimize supply time of loads in island mode	A	Based on the assessment of the possible duration of islanding operations, the DERMS attempts to maximize load feeding according to load priorities (if relevant) while matching target duration of islanding.	Microgrid operator Client Flexibility aggregator	DERMS DER controllable load Microgrid EPS Client

Name	BUC linked	Short description	Business roles involved	System roles involved
Safely power down the microgrid EPS in island mode	A	Upon request or when islanding becomes impossible to maintain, the DERMS or a dedicated system powers out the microgrid EPS while respecting a safety procedure. Step by step load shedding and DER ramp down are conducted in parallel to maintain power balance at all times. The DERMS also needs to ensure the capability of the microgrid EPS to be restarted by either relevant DER or the area EPS.	Microgrid operator DER operator Client	DERMS DER Microgrid EPS Client POC
Identify and update the relevant DERs for frequency and voltage regulation	A	Among the pool of relevant DER within the microgrid EPS premises, the DERMS identifies and informs the DER(s) that will perform frequency and voltage regulation. This process can be regularly repeated and can be triggered by islanding operation, preparation for islanding or based on unavailability of a grid forming DER.	Microgrid operator DER operator	DERMS DER
Regulate frequency in the microgrid EPS	A	For the complete duration of the islanding, DERMS performs real-time frequency regulation which involves continuous monitoring of the frequency, issuing frequency set points to relevant DERs, the identification of grid forming DERs to maintain frequency within acceptable limits for the system.	Microgrid operator DER operator	DERMS DER Frequency sensors DER
Regulate voltage in the microgrid EPS	A	For the complete duration of the islanding, DERMS performs real-time voltage regulation which involves a continuous monitoring of the microgrid EPS voltages, the identification, update and management of the contribution of each asset participating to voltage regulation (DERs, FACTS, on load tap changers, …).	Microgrid operator DER operator Voltage regulation asset operator	DERMS DER Voltage sensors Voltage regulation systems DER
Monitor POC facilities (microgrid EPS to area EPS)	A/C	The DERMS continuously monitors and issues the status of the POC between microgrid EPS to any DER systems within the microgrid EPS that can require it.	Microgrid operator DSO	DERMS POC Microgrid EPS Area EPS Synchronizing equipment Local EPS DER protection function DERMS
Perform a safe connection to the area EPS	A/C	Prior to performing safe reconnection, the DERMS verifies that all necessary conditions are met, on both microgrid EPS and area EPS. Then, it enables the synchronizing equipment to close the POC switch when opportune. Synchronizing requires some minor tweaks on DER production.	Microgrid operator DSO DER operator	DERMS POC Microgrid EPS Area EPS DER Synchronizing equipment Time synchronization source DER protection function

Name	BUC linked	Short description	Business roles involved	System roles involved
Perform a safe intentional islanding from the area EPS	A	Prior to islanding, the DERMS identifies DER for frequency and voltage regulation, ensures that the islanded operation time is feasible and that the authorization for islanding was given by the area EPS. Then, the DERMS performs a safe and planned islanding by opening the POC and in parallel, by notifying the relevant DER and the DMS.	Microgrid operator DSO DER operator	DERMS POC Microgrid EPS Area EPS DER DMS
Obtain permission for intentional islanding	A/C	The permission for islanding is requested by the DERMS of the microgrid EPS. After ensuring all conditions are met, the DERMS of the area EPS authorizes the microgrid EPS for a safe intentional islanding.	Microgrid operator DSO DER operator	Area EPS Microgrid EPS DERMS
Enable connection to area EPS after an outage occurs	C	Both EPS must first meet the necessary conditions for reconnection. The microgrid EPS will adapt its voltage to the voltage of the area EPS. The synchronizing equipment can be directly or indirectly interfaced with the DER involved in controlling voltage and frequency of the microgrid EPS. The synchronizing equipment performs synchronization of the voltage signals of both EPS and closes the POC switch. In addition, the relevant DER are switched to grid-connected mode by either the POC switch or the DER management system.	Microgrid operator	Area EP Microgrid EPS DERMS
Assess the possible duration under grid-connected operation	C	The DERMS evaluates how long the microgrid EPS can be operated in grid-connected mode by inquiring the capabilities of each DER (generation, storage units and controllable loads) and inquires the area EPS (grid) duration of availability.	Microgrid operator Energy service provider	Area EPS Microgrid EPS DERMS
Forecast of the consumption and production inside the microgrid in grid-connected mode	C	The DERMS forecasts the production by inquiring the capabilities of each DER (generation, storage units and controllable loads) and forecasts the load based on accurate algorithm for an upcoming time frame. The production forecast of intermittent DERs can be based on predictions from a weather system.	Microgrid operator Energy service provider	DER meter DERMS Aggregator Outage management system
Ensure that different generators are in the optimal state to start grid (re)connection	C	The DERMS inquires on the capability of each relevant DER to be operated in grid-connected mode and requests the DERs to transition to optimal state to start for grid connection operation (for instance, related to reserve management and grid forming sources).	Microgrid operator	Local EPS DERMS DER log DER meter DER system
Manage DER (sources / controllable loads) during the grid-connected mode for the targeted duration	C	The DERMS will manage the DERs of the microgrid EPS taking into consideration a targeted duration. At the end of the grid-connected time the microgrid EPS will be in island mode or grid-connected mode without any services received from the area EPS.	DER operator	Microgrid EPS Local EPS DERMS DER log DER meter DER system

Name	BUC linked	Short description	Business roles involved	System roles involved
Optimize the supply time of the loads in grid-connected mode, taking into account priorities between the loads (demand response)	C	Based on market prices and forecast within the demand response market, the flexibility aggregator optimizes the supply time of the loads under its supervision and with authorization of the DER operator to maximize profit and consumer utility according to load priorities (if relevant).	Flexibility aggregator Demand response market participant DER operator	Microgrid EPS Local EPS DERMS DER system Demand response (DR) system Demand response (DR) pricing schedule
Identify and update the DERs to perform frequency and voltage regulation in grid-connected mode	C	Among the pool of relevant DER, the DERMS identifies and informs the DER(s) to perform frequency and voltage regulation. This process can be regularly repeated and can be triggered by a request from the area EPS operator, preparation for islanding or based on unavailability of a grid forming DER.	Microgrid operator DER operator	Microgrid EPS Local EPS DERMS DER log DER meter DER system
Perform frequency and voltage regulation in real time for the duration in grid-connected mode	C	For the complete duration of the frequency/voltage regulation request, the DERMS performs real-time frequency regulation which involves continuous monitoring of the frequency, issuing frequency set points to relevant DERs.	Microgrid operator DER operator	Microgrid EPS Local EPS DERMS DER protection function DER system Area EPS Microgrid EPS
Monitor the level state of energy metering and billing: at the microgrid level, and at the customers level	C	The DER log, DER meter and customer information system send data to the DERMS in order to monitor the energy produced, measured and billed.	DER owner Producer Prosumer Microgrid owner	DER log DER meter DERMS Customer information system Demand response (DR) pricing schedule
Monitor the status of the microgrid as a consumer or as a producer or both (prosumer), and market structures for decentralized production	C	The DER owner, producer, prosumer or microgrid owner monitors the state of energy metering and billing at their POC. They send information to the DERMS about surplus or deficit then the DERMS decides on the status of the local EPS as consumer or a producer, based on the status of the DER within the facility.	DER owner Producer Prosumer Microgrid owner Energy service provider	DERMS
Monitor the absorption capacity of the area EPS	C	The position of the area EPS is requested by the DERMS. The position of the local EPS as a prosumer is made available to any systems that require it and would have the necessary authorizations. The area EPS absorption capacity provided depends on local and global constraints and can be limited for each system willing to export production.	Energy service provider Flexibility aggregator DSO DER operator Microgrid operator	Area EPS DERMS

Name	BUC linked	Short description	Business roles involved	System roles involved
Monitor the energy quantity accessible and dispatchable of the microgrid	C	The DSO provides the absorption capacity of the area EPS to any DER or microgrid EPS that request it, with the relevant authorizations.	DER operator Microgrid operator	DERMS
Monitor the buying and selling costs of electricity	C	The DERMS monitors the prices of the energy accessible and dispatchable within the microgrid EPS by requesting information from the retail market and from the demand response market.	Energy service provider Flexibility aggregator DSO DER operator Microgrid operator	DERMS Retail Market Demand response (DR) pricing schedule
Monitor and forecast the total customer load curve	C	The DERMS requests customer consumption information from the customer information system in order to collect real-time load data and forecast future short-term consumption.	Energy service provider Flexibility aggregator DSO DER operator Microgrid operator	DERMS Customer information system
Monitor the power flowing in (negative) and out (positive) to the area EPS	C	The DERMS monitors the power measurements from the POC power meters on both sides, local EPS and area EPS.	DER operator Microgrid operator	DERMS POC
Balance the total customer load curve to positive or zero value	C	In case of power flowing in the local EPS from the area EPS (negative power), the DERMS balances the negative power to zero by activating the controllable DERs or deactivating controllable loads. When the power flows from the local EPS to the area EPS (positive power), the DERMS will maintain the status of the DERs within the local EPS.	DER operator Microgrid operator	DERMS POC
Metering bidirectionally at grid side to sell the over generated renewable energy to the area EPS	C	When the power flows from the local EPS to the area EPS (positive power), the DERMS will detect if it is produced from renewable DER. In this case, the DERMS will meter bidirectionally to sell the level of positive power produced by renewables, with or without limitation in energy quantity according to the absorption capacity of the area EPS.	Energy service provider DSO Microgrid operator	DERMS DER meter DER log

7 Coordination with other IEC Standards

7.1 Links with IEC 61968-1

The IEC 61968 series is intended to facilitate inter-application integration, as opposed to intra-application integration of the various distributed software application systems supporting the management of utility electrical distribution networks. Intra-application integration is aimed at programs in the same application system, usually communicating with each other using middleware that is embedded in their underlying runtime environment. Additionally, the intra-application integration tends to be optimized for close, real-time, synchronous connections and interactive request-and-reply or conversation communication models. The IEC 61968 series, by contrast, is intended to support the inter-application integration of a utility enterprise that needs to connect disparate applications that are already built or new (legacy or purchased applications) each supported by dissimilar runtime environments. Therefore, the IEC 61968 series is relevant to loosely coupled applications with more heterogeneity in languages, operating systems, protocols, and management tools.

In the world of integrated systems, systems can also be a subset of a larger system, a system of systems or a set of federated systems. A system composed of coordinating subsystems can support activities more efficiently than the subsystems operating independently.

The standardization of data facilitates the reduction of errors, reduced time for data entry, and improved process control.

The IEC 61968 series recommends that the semantics (domain model) of system interfaces of a compliant utility inter-application infrastructure be defined using Unified Modeling Language (UML).

It is the intent of the IEC 61968 series to be leveraged by service-oriented architectures (SOAs) and to encourage the usage of enterprise service buses (ESBs). In the future, it is possible that payload formats other than XML could be officially adopted by the IEC 61968 series for specific parts or information exchanges

IEC 61968-1 is the first in a series that, taken as a whole, defines interfaces for the major elements of an interface architecture for distribution management.

IEC 61968-1 identifies and establishes recommendations for standard interfaces based on an Interface Reference Model (IRM). Each interface identified in the IRM is further detailed in a dedicated clause. They provide for interoperability among different computer systems, platforms, and languages. Methods and technologies used to implement functionality conforming to these interfaces are recommended in IEC 61968-100.

The Common Information Model (CIM) Interface Reference Model (IRM) describes the business functions, business objects and business roles involved in the different major business systems that build up the power utility business capabilities.

The IRM business functions are illustrated in Figure 11.

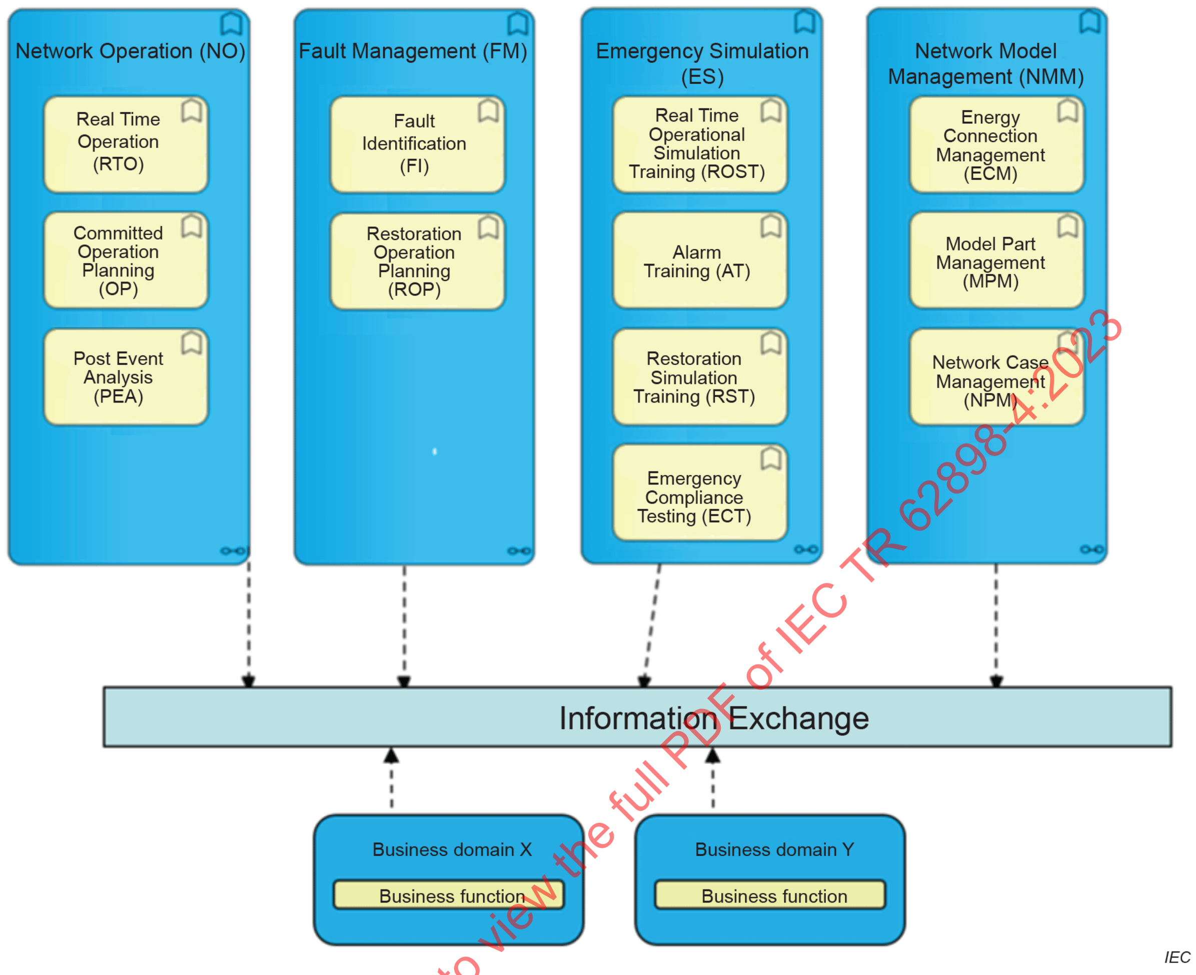


Figure 11 – Interface Reference Model (IEC 61968-1)

The goal of IEC 61968-1 is to create and maintain a common IRM for TC 57 working groups that cover domains like transmission, distribution, market, generation, consumer, and regional reliability operations. It also needs to be understood and used by IEC 61850 related working groups.

The modelling strategy for creating the IRM is to identify the relevant business objects that the Part teams (IEC 61968-3 to -9, -13) are releasing through one or more data objects, also called CIM profiles. The relevant business functions that consume or produce the business objects have been identified to create the relevant context for the business objects and to describe their purpose.

IEC 61968-1 lists several typical systems which are part of the network operation business domain: EMS, DMS, DERMS, for instance. These typical systems and their associated business objects are described in IEC 61968-3.

IEC 61968-1 provides a global architecture framework and helps to reduce complexity by providing a methodology used in the context of IT/OT enterprise architecture management. IEC 61968-1 includes DER related interface as described in IEC 61968-5.

7.2 Links with IEC 61968-5

The scope of IEC 61968-5 is the description of a set of functions that are needed for enterprise integration of DERMS functions. The scope of IEC 61968-5 specification does not include how the DERMS behaves, or how it manages communication to individual DER, but deals specifically with the communication between a DERMS and other enterprise systems or third parties in a business-to-business (B2B) mode of operation.

The DERMS works with groups of DER so that requests made to the DERMS for the behaviour of the power system can be handled in aggregates. This aggregation relieves the system operator from having to manage each DER individually, a situation that becomes more problematic as DER penetration in the power system continues to increase.

To that end, these use cases focus on the creation and maintenance of groups of DER, capability discovery, DER connect/disconnect, status monitoring and forecasting of these groups, and dispatching of power and voltage.

Figure 12 illustrates some DERMS deployment architectural options.

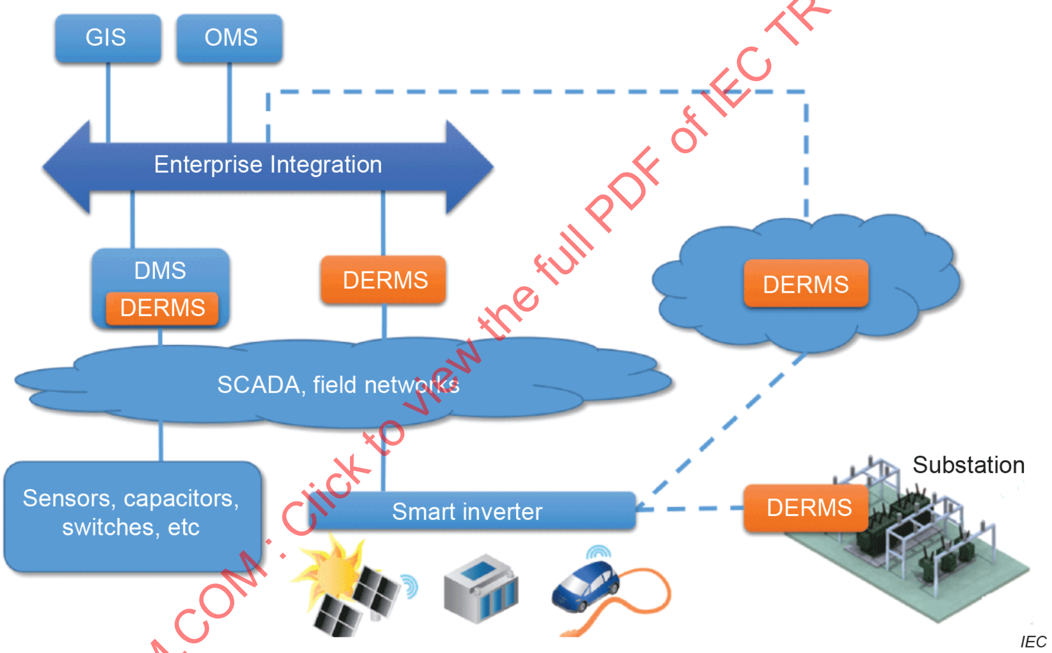


Figure 12 – Architectural options for DERMS deployment (from IEC 61968-5)

The use cases covered in IEC 61968-5 are

- DER group creation,
- DER group maintenance,
- DER group status and monitoring,
- DER group forecasting,
- DER group dispatch,
- DER group voltage ramp rate control,
- DER group connect and disconnect, and
- DER group capability discovery.

Three DER grouping functional requirements are proposed in IEC 61968-5 (group size, grouping by power system level, Grouping according to other attributes), and microgrid are associated to a "Grouping by power system level".

The creation of DER groups can be implemented using either of the approaches illustrated in Figure 13 and Figure 14.

Figure 13 involves a request-and-reply interaction in which a DER Group is defined by one entity (for example, the Group Forming entity such as a DMS) and provided to one or more Group Acknowledging entities (for example, one or more DERMS). The EMS/DMS is at the origin of the creation of the DER Groups.

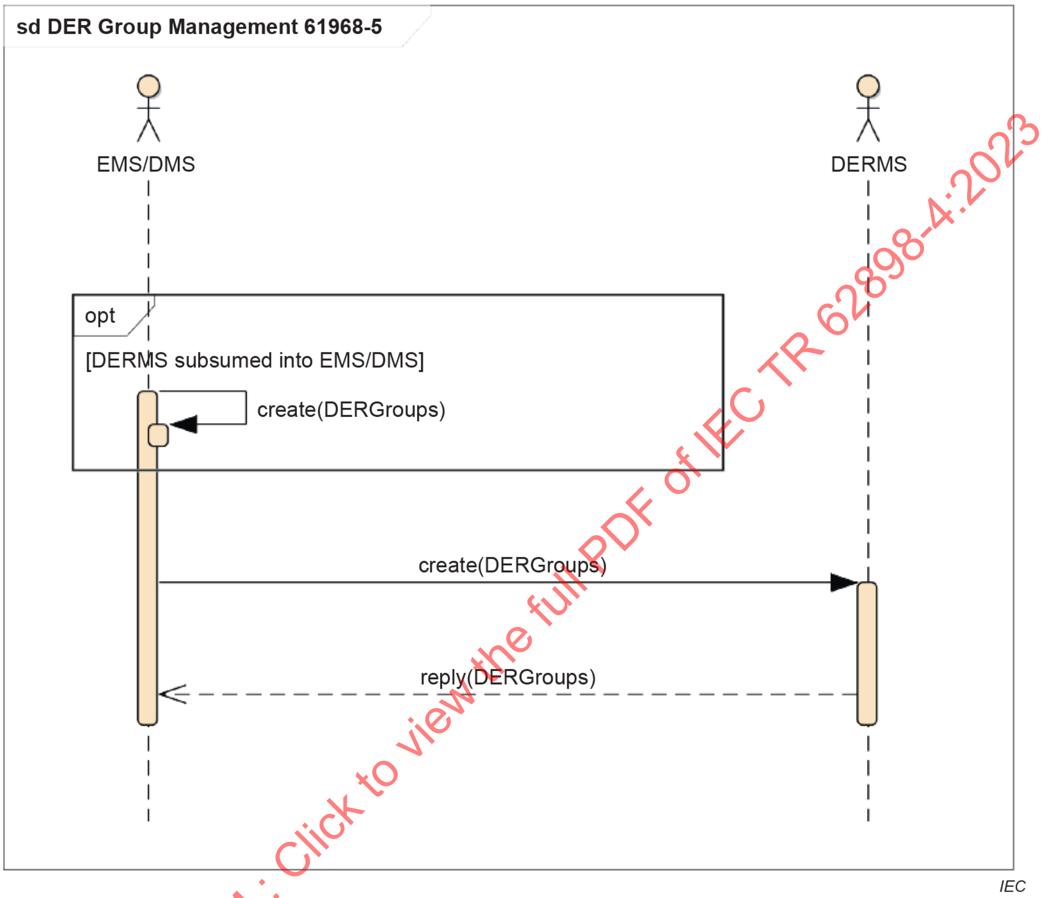


Figure 13 – Request-and-reply message exchange pattern for the creation of a DER Group (from IEC 61968-5)

Figure 14 depicts an alternate messaging approach for the same scenario. This example uses a notification message (referred to in IEC 61968-100 as an Event Stereotype message) rather than a request-and-reply message interaction. The DERMS is the starting point for the DER Group creation.

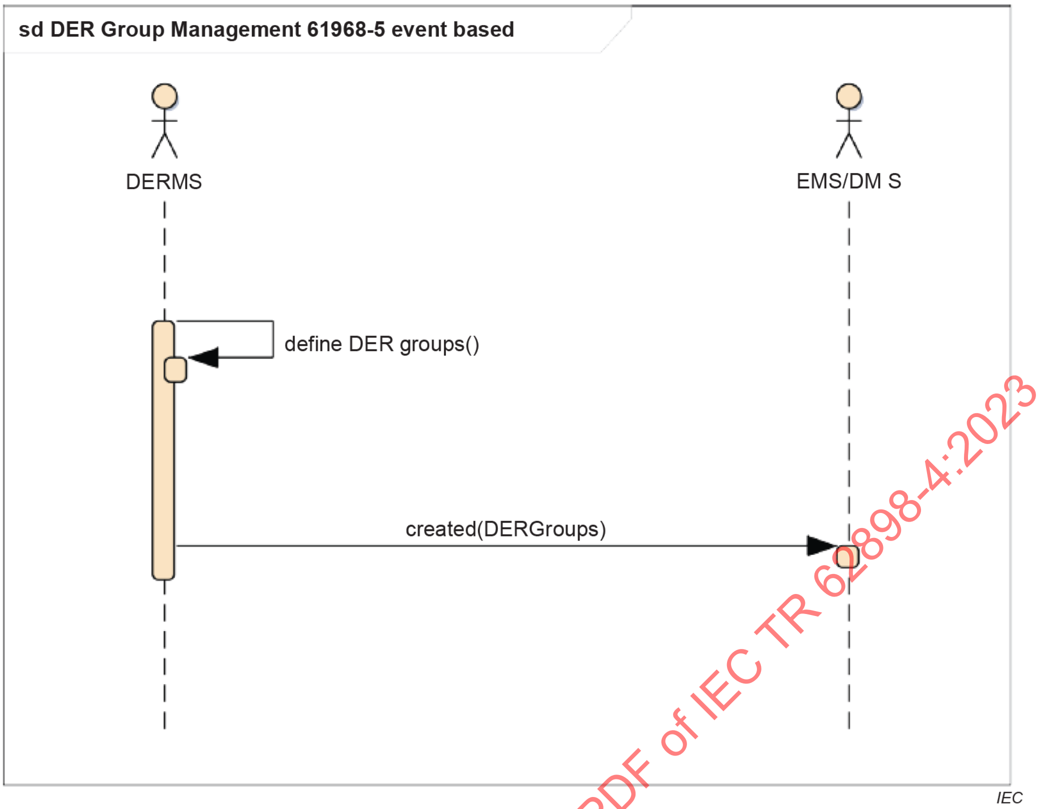


Figure 14 – Notification message exchange pattern for the creation of a DER Group (from IEC 61968-5)

IEC 61968-5 is focused on CIM related DER grouping and associated management. A relationship must also be established with IEC 61850 standards related to DER, microgrids, like IEC 61850-7-420 and IEC TR 61850-90-23.

7.3 Links with IEC TR 61850-90-23

IEC TR 61850-90-23[4], focusing on the Use of IEC 61850 for microgrids systems, is under development. It will provide necessary information within the IEC 61850 based object model in order to model functions of a microgrid as a DER. It will complement the generic DER data model exposed in IEC 61850-7-420:2021.

IEC TR 61850-90-23 will extend the IEC 61850 information model in order to support microgrids, including:

- operation and protection when grid-connected,
- operation and protection when islanded,
- planned transitioning from grid-connected to islanded,
- unplanned transitioning from grid-connected to islanded,
- reconnection from islanded to grid-connected, and
- black start as a microgrid.

From a configuration perspective, a microgrid could have a single point of connection to an electric power system (EPS), but it could also have multiple points of connection to the same or different voltage levels, or even for different electrically isolated EPSs.

4 Under development. Stage at the time of publication: IEC CD TR 61850-90-23:2022.

From a modelling perspective, a microgrid can be expressed as a DER. This means that all generic properties already defined for DERs can normally apply to a microgrid.

The purpose of the IEC TR 61850-90-23 consists in making a formal assessment of all these differences in order to identify the missing model elements and propose model complements accordingly.

A DER including microgrid is decomposed in sub-roles:

- The energy resource, which represents the "actuator", and whose mission is meeting the energy setpoints (mostly) provided by the DER power manager.
- The DER electrical point(s) of connection (ECP) to the area EPS, is there to feedback and loopback the DER power manager with the information related to the ECP of the DER. This is an equivalent to the point of connection used in this document.
- The DER power manager decides, by applying a strategy of usage to the resource, what are the expected setpoints the resource must follow and the states which must be reached by the resource to meet the different requests expressed by the users of the resources through the DER operational functions.
- The DER operational function(s) represents the interfaces through which the users of the resource will express their expectations, one of the resources possibly being the area EPS through mandatory requirements (grid codes functions), but possibly also facility or market requirements.

Figure 15 illustrates the first set of sub-roles attached to a DER (microgrid) deduced from IEC 61850-7-420.

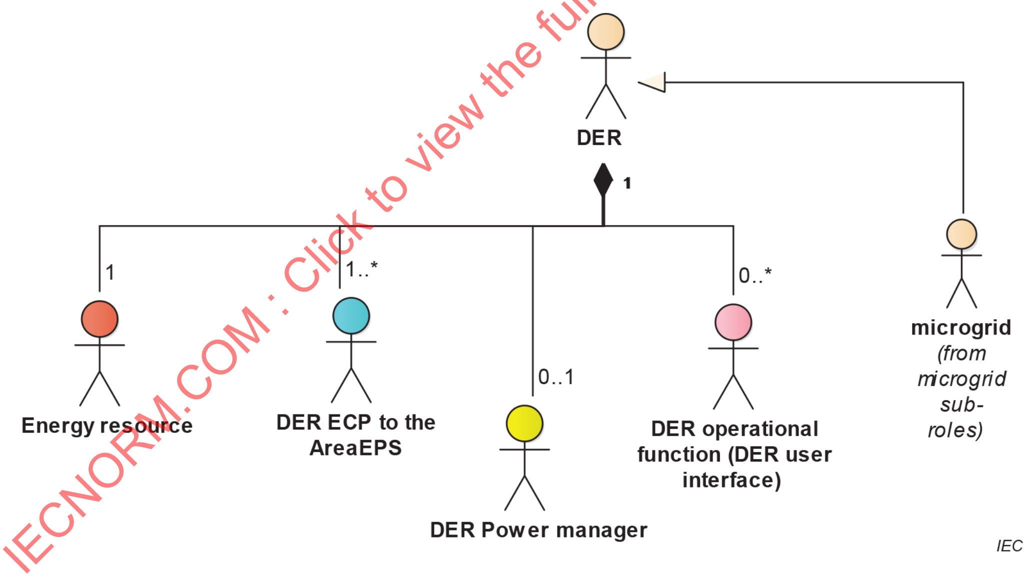


Figure 15 – First set of sub-roles attached to a DER (microgrid) deduced from IEC 61850-7-420

These roles are mapped into Logical Nodes (LNs), which are basic functions in IEC 61850. Figure 16 illustrates this mapping.

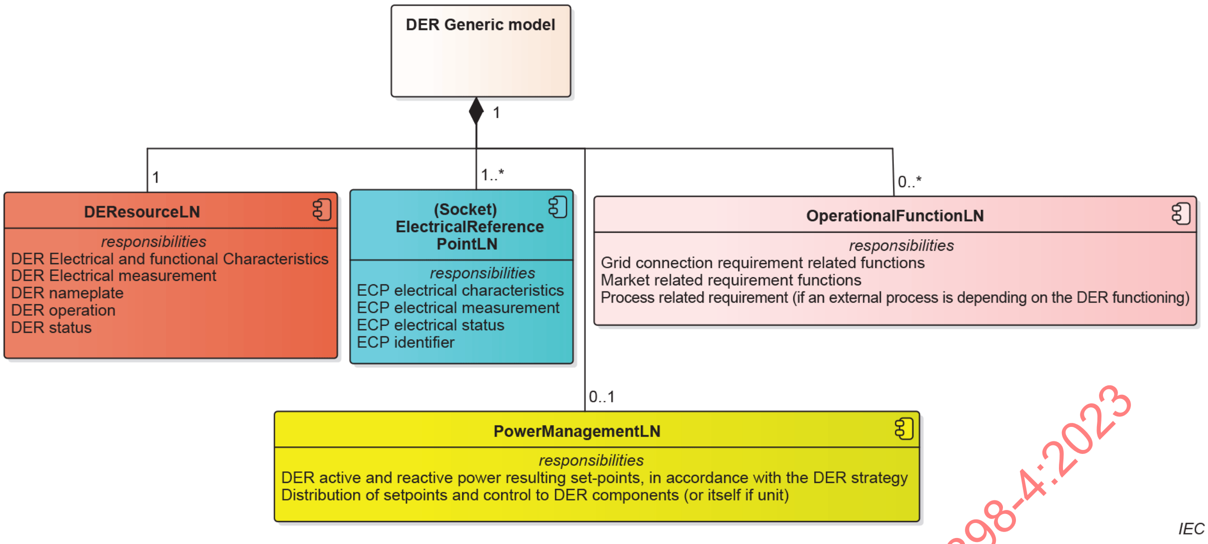


Figure 16 – Current role transpositions into LNs according to IEC 61850-7-420

For each of these roles, a corresponding microgrid related role is derived:

- the microgrid energy resource, possibly referring to energy resources internal to the microgrid;
- the microgrid ECP(s) to the area EPS;
- the microgrid (power) manager;
- the microgrid operational function(s).

7.4 Links with the IEC 62898 series

7.4.1 General

The IEC 62898 series is intended to provide comprehensive guidelines and requirements for microgrid projects. These requirements feed into this document to provide more insights on operation requirements and project management for microgrids.

7.4.2 Links with IEC TS 62898-1

IEC TS 62898-1 mainly covers the following issues:

- determination of microgrid purposes and application;
- preliminary study necessary for microgrid planning, including resource analysis, load forecast, DER planning and power system planning;
- principles of microgrid technical requirements that need be specified during planning stage;
- microgrid evaluation to select an optimal microgrid planning scheme.

7.4.3 Links with IEC TS 62898-2

IEC TS 62898-2 mainly covers the following issues:

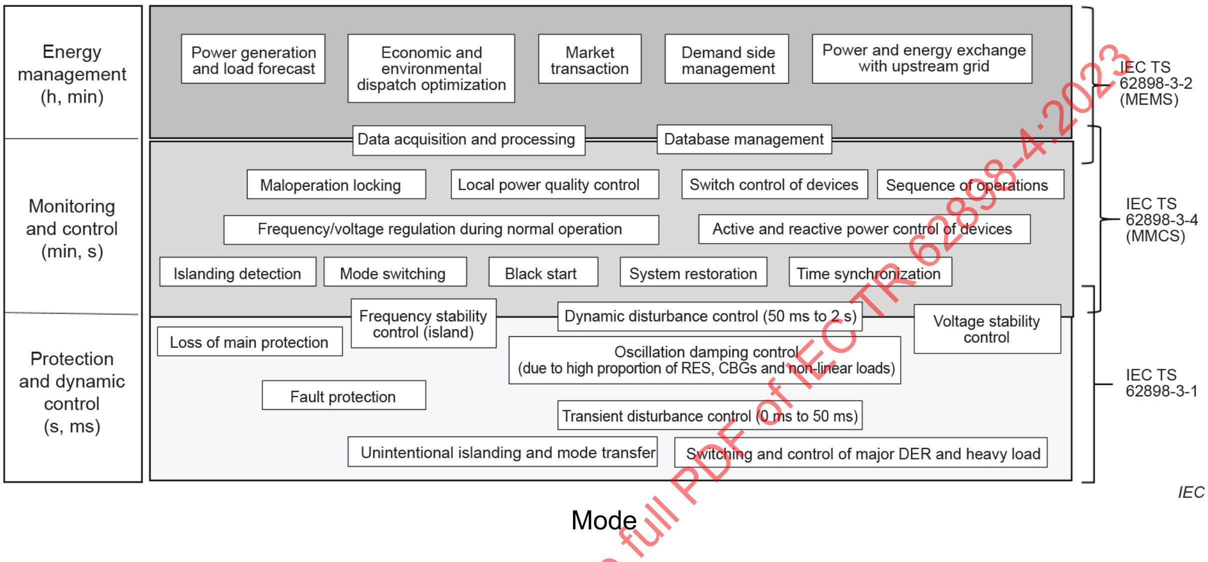
- response characteristic requirements of microgrids under different operation modes;
- the basic control strategies and methods under different operation modes;
- the requirements of electrical energy storage (EES), communication and monitoring under different operation modes;
- the principle of relay protection under different operation modes;
- basic requirements of synchronization and reclosing during mode transfer;

- principle for power quality, EMC, maintenance and test of microgrids.

7.4.4 Links with IEC TS 62898-3 series

7.4.4.1 General

The IEC TS 62898-3 series currently consists of four subparts. The series is focused on protection, stability and control (multilevel) of microgrids. IEC TS 62898-3-2[5] is slightly different as it focuses specifically on self-regulation of dispatchable loads in microgrids. The functions covered by the other three parts are presented in Figure 17.



Key

RES renewable energy sources

CBGs converter-based generators

Figure 17 – Function mapping among subparts in the IEC TS 62898-3 series

7.4.4.2 Links with IEC TS 62898-3-1

IEC TS 62898-3-1 is the first part of the IEC 62898-3 subseries which intends to provide guidelines for the specification of fault protection and dynamic control in microgrids. The document's scope is limited to single- or three-phase AC microgrids with a single point of connection (POC) to the upstream power network. Challenges and special requirements in protection, transient and dynamic disturbance control of microgrids are addressed. While general technical requirements and specific technical requirements of fault protection and dynamic control are provided, IEC TS 62898-3-1 does not specify stricter requirements and product requirements for measuring relays and protection equipment.

Microgrids with a higher proportion of converter-based-generators are given special attention in IEC TS 62898-3-1 due to the characteristics and requirements significantly different from conventional grids. Major points that need be considered in protection of microgrids from phase and earth faults are specified in IEC TS 62898-3-1.

The discussion on general requirements of protection systems that are mostly applicable to both conventional grids and microgrids is expanded by providing special considerations to be made in the microgrid perspective. The specific challenges and ways of addressing the challenges in protection of non-isolated microgrids which operate in island and grid-connected modes are also presented.

5 Under development. Stage at the time of publication: IEC DTS 62898-3-2:2022.