IEC TS 61851-3-4

Edition 1.0 2023-07

TECHNICAL SPECIFICATION

colour inside

Electric vehicles conductive charging system – Part 3-4: DC EV supply equipment where protection relies on double or reinforced insulation – General definitions and requirements for CANopen communication

IEC TS 61851-3-4:2023-07(en)

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CONTENTS

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ELECTRIC VEHICLES CONDUCTIVE CHARGING SYSTEM –

Part 3-4: DC EV supply equipment where protection relies on double or reinforced insulation – General definitions and requirements for CANopen communication

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IEC TS 61851-3-4 has been prepared by IEC technical committee 69: Electrical power/energy transfer systems for electrically propelled road vehicles and industrial trucks. It is a Technical Specification.

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

Draft	Report on voting
69/650/DTS	69/671/RVDTS 69/671A/RVDTS

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 Specification 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/publications.

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– requirements: in roman type;
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- withdrawn,
- replaced by a revised edition, or
- amended.

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INTRODUCTION

This document is published in separate parts according to the following structure:

IEC TS 61851-3-1, *Electric vehicles conductive charging system – Part 3-1: DC EV supply equipment where protection relies on double or reinforced insulation – General rules and requirements for stationary equipment*

IEC TS 61851-3-2, *Electric vehicles conductive charging system – Part 3-2: r DC EV supply equipment where protection relies on double or reinforced insulation – Portable and mobile DRI EV supply equipment*

IEC TS 61851-3-4, *Electric vehicles conductive charging system – Part 3-4:DC EV supply equipment where protection relies on double or reinforced insulation – General definitions and requirements for CANopen communication*

IEC TS 61851-3-5, *Electric vehicles conductive charging system – Part 3-5:DC EV supply equipment where protection relies on double or reinforced insulation – Pre-defined communication parameters and general application objects*

IEC TS 61851-3-6, *Electric vehicles conductive charging system – Part 3-6:DC EV supply equipment where protection relies on double or reinforced insulation – Voltage converter unit communication*

IEC TS 61851-3-7, *Electric vehicles conductive charging system – Part 3-7:DC EV supply equipment where protection relies on double or reinforced insulation – Battery system communication*

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ELECTRIC VEHICLES CONDUCTIVE CHARGING SYSTEM –

Part 3-4: DC EV supply equipment where protection relies on double or reinforced insulation – General definitions and requirements for CANopen communication

1 Scope

This part of IEC 61851, which is a Technical Specification, applies to CANopen communication for the conductive transfer of electric power between the supply network and an electric road vehicle or a removable rechargeable energy storage system (RESS) or on-board rechargeable energy storage systems (RESS) of an electric road vehicle.

The energy management system (EMS) for control of power transfer between battery systems and voltage converter units (VCU) provides the communication for all devices that can take part in energy management control.

The basic application profile for energy management systems (EMS) consists of IEC TS 61851-3-4, IEC TS 61851-3-5, IEC TS 61851-3-6, IEC TS 61851-3-7.

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 60309 (all parts), *Plugs, socket-outlets and couplers for industrial purposes*

IEC 60364 (all parts), *Low-voltage electrical installations*

IEC 60884 (all parts), *Plugs and socket-outlets for household and similar purposes*

IEC 61850 (all parts), *Communication networks and systems for power utility automation*

IEC TS 61851-3-1:2023, *Electric vehicles conductive charging system – Part 3-1 DC EV supply equipment where protection relies on double or reinforced insulation – AC and DC conductive power supply systems*

IEC TS 61851-3-5:2023, *Electric vehicles conductive charging system – Part 3-5: DC EV supply equipment where protection relies on double or reinforced insulation – Pre-defined communication parameters and general application objects*

IEC TS 61851-3-6:2023, *Electric vehicles conductive charging system – Part 3-6: DC EV supply equipment where protection relies on double or reinforced insulation – Voltage converter unit communication*

IEC TS 61851-3-7:2023, *Electric vehicles conductive charging system – Part 3-7: DC EV supply equipment where protection relies on double or reinforced insulation – Battery system communication*

IEC TS 62196-4: *Plugs, socket-outlets, vehicle connectors and vehicles inlet – Conductive charging of electric vehicles – Part 4: Dimensional compatibility and interchangeability requirements for DC pin and contact-tube accessories for class II or class III applications*[1]

ISO/IEC 646:1991, *Information technology – ISO 7-bit coded character set for information interchange*

ISO/IEC 14443 (all parts), *Identification cards — Contactless integrated circuit(s) cards — Proximity cards*

ISO/IEC 18092:2013, *Information technology – Telecommunications and information exchange between systems – Near Field Communication – Interface and Protocol (NFCIP-1)*

ISO 11898-2:2016, *Road vehicles – Controller area network (CAN) – Part 2: High speed medium access unit*

ISO 11898-5:2007, *Road vehicles – Controller area network (CAN) – Part 5: High speed medium access unit with low-power mode*

ISO 11898-6:2013, *Road vehicles – Controller area network (CAN) – Part 6: High speed medium access unit with selective wake-up functionality*

CiA 302-1:2009, *CANopen additional application layer functions – Part 1: General definitions (available at www.can-cia.org)*

CiA 302-2:2009, CANopen *additional application layer functions – Part 2: Network management* (available at www.can-cia.org)

CiA 302-3:2010, *CANopen additional application layer functions – Part 3: Configuration and program download (available at www.can-cia.org)*

CiA 305:2013, *CANopen layer setting services (LSS) and protocols* (available at www.can-cia.org)

EN 50325-4:2002, *Industrial communications subsystem based on ISO 11898 (CAN) for controller- device interfaces – Part 4: CANopen*

EN 50604-1:2016, *Secondary lithium batteries for light EV (electric vehicle) applications – Part 1: General safety requirements and test methods*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC TS 61851-3-1, EN 50325-4:2002, ISO 11898-2:2016, ISO 11898-5:2007, ISO 11898-6:2013 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

[1] Under preparation. Stage at the time of publication: DTS.

3.1
active device
device connected to DC power circuit, AUX supply circuit and CAN circuit

3.2
voltage converter
set of equipment, to convert one type of electric current to another type different in nature, voltage and/or frequency

[SOURCE: IEC 60050-811:2017, 811-19-01, modified – The word "voltage" has been added to the term, and the words "static or rotating" deleted from the definition.]

3.3
voltage converter unit
VCU
voltage converter with local EMS and communication interface

[SOURCE: IEC TS 61851-3-1:2023, 3.1.8]

3.4
rechargeable energy storage system
RESS
system that stores energy for delivery of electric energy and which is rechargeable

EXAMPLE Battery systems, capacitors.

Note 1 to entry: A battery system can be named in general within the context of IEC 61851-3 (all parts) as an RESS.

[SOURCE: ISO/IEC 17409:2015, 3.36, modified – In the example, the word "batteries" has been replaced by "battery systems", and the note to entry has been added.]

3.5
battery system
energy storage device that includes cells or cell assemblies or battery pack(s) as well as electrical circuits and electronics

Note 1 to entry: For further explanation, see ISO 12405-1:2011, 5.5.2, 5.5.3, A.3.1 and A.3.2. Battery system components can also be distributed in different devices (battery packs) within the vehicle.

Note 2 to entry: Examples of electronics are the BCU and contactors.

Note 3 to entry: For all applications according to IEC 61851-3 (all parts), the battery control unit (BCU) is replaced by a battery management system (BMS).

[SOURCE: ISO 12405-1:2011, 3.3, modified – The parentheses "(battery packs)" have been added to Note 1 to entry, and Note 3 to entry has been added.]

3.6
battery pack
energy storage device that includes cells or cell assemblies normally connected with cell electronics, voltage class A or B circuit and overcurrent shut-off device, including electrical interconnections, interfaces for external systems

Note 1 to entry: For further explanation, see 5.4 and Clause A.2 of ISO 12405-1:2011.

Note 2 to entry: Examples of external systems are cooling, voltage class B, auxiliary voltage class A and communication.

[SOURCE: ISO 12405-1:2011, 3.2, modified – The words "A or" have been added to the definition.]

3.7
battery management system
BMS
local energy management system for the battery system, protecting the battery system from damage, monitoring and increasing the lifetime, and maintaining the functional state

Note 1 to entry: BMS and BCU (according to the ISO 12405 series) do not have the same functions.

3.8
energy management system
EMS
system consisting of active and passive devices for controlling the power transfer

Note 1 to entry: Active and passive devices are connected to the AUX supply circuit and the CAN circuit. Additionally, active devices are also connected to the DC power circuit.

3.9
energy management system controller
EMSC
device or virtual device that manages the communication as well as the energy exchange

3.10
local energy management system
local EMS
active device's internal system that protects the energy buffer, source or load from damage, monitors and increases the lifetime of the buffer, source or load, maintains the buffer, and source or load in a functional state

3.11
remote energy management system
remote EMS
further independent EMS coupled to EMS via a VCU

3.12
energy management system input
EMS input
current flow which occurs from source into the energy management system power lines

3.13
energy management system output
EMS output
current flow which occurs from energy management system power lines into load

3.14
human machine interface
HMI
passive device that allows user interaction, interface between operating staff or end-user and the instrumentation and computer systems connected to the EMS

EXAMPLE Display or user communication system.

3.15
node-ID check
monitoring unique node-ID usage in EV by EMSC

3.16
passive device
device connected to AUX supply circuit and CAN circuit

3.17
safe state
device state in which the device is protected against influences of overcurrent or overvoltage

3.18
silent master
CANopen device that hosts NMT master capability, but acts as NMT slave in the network and issues neither NMT master services, LSS master services, SYNC messages nor any other NMT/LSS master-related service

Note 1 to entry: Examples of NMT/LSS master-related service are Configuration manager and EMSC.

3.19
state of charge
SOC
available capacity in a battery pack or system

Note 1 to entry: The state of charge is expressed as a percentage, Ah or Wh of rated capacity.

3.20
state of health
SOH
actual performance of the battery pack or system compared to the performance of a fresh battery pack or system

3.21
finite-state automaton
FSA
model of computation consisting of a set of states, a start state, an input alphabet, and a transition function that maps input symbols and current states to a next state

Note 1 to entry: Computation begins in the start state with an input string; it changes to new states depending on the transition function.

Note 2 to entry: Finite-state automaton (FSA) (plural: automata) or finite-state machine (FSM) or simply a state machine.

3.22
local layer settings
LLS
settings of a CANopen device's CANopen node-ID and CANopen bit timing

3.23
flying master
ability of an NMT master capable CANopen device to become dynamically the active NMT master in case the absence of a higher-prior NMT master is detected

3.24
logical device
logical entity of a CANopen device providing to the CANopen device status, control and diagnostic information in a pre-defined format

3.25
virtual device
entity of software capable of accomplishing a functional element of a field/physical device

4 Symbols and abbreviated terms

For the purposes of this document, the following symbols and abbreviated terms, and those given in ISO 11898-2:2016, ISO 11898-5:2007 and ISO 11898-6:2013 apply.

AC	alternating current
BMS	battery management system
C. param.	communication parameter
Const	constant
DC	direct current
EEC	emergency error code
EMCY	emergency
EMS	energy management system
EMSC	energy management system controller
EV-EMSC	EV-Energy management system controller
EV	electric vehicle
FSA	finite-state automaton
GAO	general application objects
HMI	human machine interface
LSS	layer setting services
M_param.	mapping parameter
MCU	motor control unit
MSN	message number
MPPT	maximum power point tracker
NMT	network management
PDO	process data object
RPDO	receive PDOs
ro	read only
rw	read write
SDO	service data object
SOC	state of charge
SOH	state of health
TPDO	transmit PDOs
VCU	voltage converter unit
VD	virtual device
VDN	virtual device number
WLAN	wireless local area network

5 General conditions for the tests

It is recommended that implementers of devices obtain proof that a suitable conformance test has been performed.

The conformance test shall include:

– testing of all implemented CANopen communication services;

– testing of all implemented parameters specified in this document and IEC TS 61851-3-5, IEC TS 61851-3-6 and IEC TS 61851-3-7;

– testing of all implemented state automata specified in this document and IEC TS 61851-3-5, IEC TS 61851-3-6 and IEC TS 61851-3-7.

NOTE For testing:

– CiA 310-1 covers the general conformance test plan for CANopen communication;
– CiA 312-7 covers the specific conformance test plan for CANopen communication according to IEC 61851-3 (all parts).

6 Physical layer specification

6.1 General

The general physical layer definitions for CANopen-related communication are provided in EN 50325-4:2002 and apply to CANopen devices compliant to this application profile.

6.2 Medium access unit

Any type of ISO 11898-2:2016 compliant transceiver may be used. With regard to energy saving, the medium access units with low power mode, compliant to ISO 11898-5:2007 or ISO 11898-6:2013 are recommended.

6.3 Transmission rates

Devices compliant to this profile shall support a bit rate of 250 kbit/s; other bit rates may be supported. The LSS shall be used, in case it is required to switch during runtime dynamically from the current bit rate to another bit rate. For initial adjustment of the bit rate during start-up, an automatic bit rate detection mechanism is recommended. Transmission rates of NFC are described in Annex F.

6.4 Node-ID assignment

The CANopen device hosting the virtual device EMSC in EV applications shall have the node-ID 1. The node-IDs for the other CANopen devices are assigned by LSS. The LSS master shall reside in the same device where EMSC resides. Scanning for non-configured devices shall be done via the LSS-fastscan services as defined in CiA 305. The LSS slaves shall be connected to the EMS application with the invalid node-ID FF_h and shall lose their node-ID settings as soon as they are disconnected from the bus.

The DRI EV supply equipment shall claim a fixed node-ID in the range 120 to 127 as specified in Table 1. Within an EV application, the node-IDs 120 to 127 shall be reserved (not used).

NOTE 1 Preferred location of the EV-EMSC can be in the same CANopen device as the MCU.

The diagnostic tool shall not support LSS slave functionality as well and shall claim the fixed node-ID 125.

A CANopen device in bootloader mode shall claim the fixed node-ID 126. Therefore, in an EV application, only one CANopen device is allowed to stay in bootloader mode. See also 10.4.

NOTE 2 The limitation of assigning a CANopen device in bootloader mode a fixed node-ID 126 was introduced to allow implementing bootloader applications for EVs, without the need of supporting LSS.

The DRI EV supply equipment shall not support LSS slave functionality and shall claim the node-ID 127. The fixed node-ID of the DRI EV supply equipment shall remain, if the device acts as master in case the EMSC of the EV is not available.

Table 1 – DRI EV supply equipment and external device node-ID assignment

Node-ID	External device
120	Reserved
121	Reserved
122	Reserved
123	Reserved
124	Load monitoring device for charging/locking cable
125	Diagnostic tool
126	Bootloader
127	External power supply implementing VCU with integrated (EMSC)

6.5 Network topology

The network topology shall be as specified in EN 50325-4:2002. See also Figure 9 and Figure A.1.

NOTE Recommended bit-timing and estimated bus lengths can be specified according to EN 50325-4:2002.

6.6 Gateway

The use of a gateway is recommended to separate the CANopen EMS communication from external influences. For further information, see 8.4.3 and Annex A.

7 Error handling

7.1 General

Clause 7 specifies the handling of errors. Emergency messages shall be supported and triggered by internal errors in the device (see EN 50325-4:2002 for a description of emergency message handling).

7.2 Enhancement of the emergency message handling

In addition to the specifications provided in EN 50325-4:2002, the range for manufacturer-specific error information shall be shortened by 1 byte. This byte shall be used for indicating that a specific virtual device is the source of the device internal error.

In addition, a general addressing mask for the device profile specific emergency error code (EEC) is specified. The first digit of the 4 digit hexadecimal address indicates with "F" the application profile specific error. For a multiple logical device, the second digit indicates that logical device, in which the error occurred. The last two digits provide the profile specific error information.

The protocol EMCY write is specified in Figure 1. Table 2 provides the value definition.

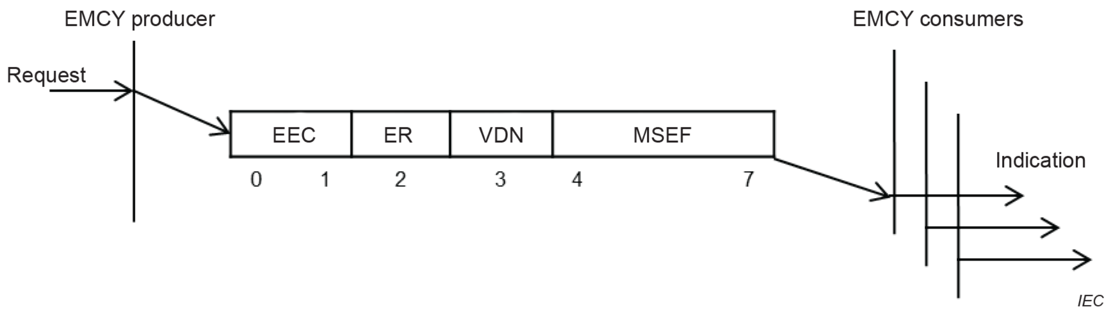


Figure 1 – Protocol emergency write for energy management applications

Table 2 – Value definition for EMCY message

Bit field	Value [hex]	Description
EEC (emergency error code)	0000 to EFFF	See EN 50325-4:2002
	F000	Generic device error (see EN 50325-4:2002)
	F001 to F0FF	The error refers to the entire CANopen device.
	F100 to F1FF	The error refers to the logical device 1; a detailed error description is provided in the related part this application profile.
	F100	Logical device 1; generic error
	F200 to F2FF	The error refers to the logical device 2; a detailed error description is provided in the related part of this application profile.
	F200	Logical device 2; generic error
	F300 to F3FF	The error refers to the logical device 3; a detailed error description is provided in the related part of this application profile.
	F300	Logical device 3; generic error
	F400 to F4FF	The error refers to the logical device 4; a detailed error description is provided in the related part of this application profile.
	F400	Logical device 4; generic error
	F500 to F5FF	The error refers to the logical device 5; a detailed error description is provided in the related part of this application profile.
	F500	Logical device 5; generic error
	F600 to F6FF	The error refers to the logical device 6; a detailed error description is provided in the related part of this application profile.
	F600	Logical device 6; generic error
	F700 to F7FF	The error refers to the logical device 7; a detailed error description is provided in the related part of this application profile.
	F700	Logical device 7; generic error
	F800 to F8FF	The error refers to the logical device 8; a detailed error description is provided in the related part of this application profile.
	F800	Logical device 8; generic error
	F900 to FEFF	Reserved
	FF00 to FFFF	See EN 50325-4:2002
ER (error register)	See EN 50325-4:2002	
VDN (virtual device number)	00	Multiple virtual devices, which are listed in object 6000_h are responsible for the occurred error and/or distinguishing between the different error sources is not possible
	01 to FE	Value refers to that sub-index of object 6000_h which provides the description of that virtual device, which is source of the error
	FF	Reserved, shall not be used.
MSEF (manufacturer specific error field)	Manufacturer specific error information	

7.3 Pre-defined error field

The pre-defined error field (object 1003_h) is specified in EN 50325-4:2002 and shall be supported by all CANopen devices used in EMSs.

7.4 Error behaviour

If a severe device failure is detected in NMT operational state, the CANopen device shall enter by default the NMT pre-operational state (see EN 50325-4:2002 CANopen NMT state machine).

If object 1029_h is implemented, the CANopen device may be alternatively configured in case of a device failure to enter the stopped state or remain in the current state.

Device failures shall include the following communication errors:

– bus-off conditions on the CAN interface;
– heartbeat event with state "occurred".

Severe device errors may also be caused by device internal failures.

7.5 Additional error codes

In addition to the error codes defined in EN 50325-4:2002, the additional error codes given in Table 3 shall be used if appropriate.

Table 3 – Additional error codes

EEC [hex]	Description
0n80	Warning; important device parameter was changed
0n81	Warning; at least one prefix of process data was changed
0n82	Warning; prefix of process data given in Ampere was changed
0n83	Warning; prefix of process data given in Volt was changed
0n84	Warning; prefix of process data given in Watt was changed
Fn01	Invalid control word (6001_h); generic error/unknown command
Fn02	Invalid control word (6001_h); target FSA state not supported
Fn03	Invalid FSA status
Fn04	Reserved
Fn10	Virtual device over-voltage at local EMS or "side B"
Fn11	Virtual device under-voltage at local EMS or "side B"
Fn12	Virtual device EMS input or " side B" over-current
Fn13	Virtual device EMS output or "side B" over-current
Fn14	Virtual device control components temperature limit (high) exceeded
Fn15	Virtual device temperature limit (low) exceeded control components
Fn16	Virtual device temperature limit (high) exceeded power components
Fn17	Virtual device temperature limit (low) exceeded power components
Fn18	Virtual device communication error
Fn19	Virtual device compatibility error
Fn1A	Virtual device non-authorized access
Fn1B	Virtual device over-voltage at remote EMS including "side A"
Fn1C	Virtual device under-voltage at remote EMS including "side A"
Fn1D	Virtual device over-current at remote EMS input including "side A"
Fn1E	Virtual device over-current at remote EMS output including "side A"
The character "n" shall indicate a number in the range of [0;8], depending on the logical device that was source of the error (see Table 2). NOTE The terms "side A", "side B" allow to distinguish between both sides of a voltage converter, for example in a setup where two power lines are controlled via one CANopen network.	

8 Operating principles

8.1 General

Clause 8 provides a description of the operating principles, device modelling and an application FSA.

8.2 Functional description

8.2.1 General

The energy management system (EMS) consists of devices, for example:

– energy management system controller (EMSC);
– voltage converter unit (VCU);
– battery system.

It also consists of optional devices, for example:

– security unit;
– manufacturer device.

Battery systems are charged or discharged by a VCU, while located inside or outside of the EMS. The switching from one battery system to another is handled by the EMSC. See also 8.3.3.5 and Annex E.

Each device connected to the EMS shall be able to limit its voltage, current and power consumption to avoid overload of the system and to adjust the power consumption to the power available in the system. The voltage, current and power limits of every device connected to the EMS shall be known and controlled by the EMSC.

NOTE Active devices, for example solar panels, hydrogen fuel cells, or battery systems, deliver power to the public infrastructure via DC to AC VCU.

8.2.2 Voltages, currents, loads

8.2.2.1 General

The voltage ranges are specified in 7.2 of IEC TS 61851-3-1:2023 and the voltage ranges definitions for EMS are provided in 6.2.2 of IEC TS 61851-3-5:2023.

8.2.2.2 Current counting direction

This subclause specifies the current counting direction for applying the Kirchhoff's circuit laws. In this profile, the source counting current direction shall apply. Any current flow from a device to the EMS is counted positive. Any current flow from the EMS to a device is counted negative.

NOTE According to the counting direction specification, the current flow to a consumer for example motor is counted in a negative way. The current flow from a producer for example solar cells to the EMS is counted in a positive way.

8.2.2.3 General specifications for energy management systems (EMS) in EVs

The recommended system voltage for active devices shall be in the range as defined in 7.2.1 of IEC TS 61851-3-1:2023. The nominal voltage at AUX supply circuit shall be according to 7.2.3 of IEC TS 61851-3-1:2023.

Protection for maximum system current shall be checked and managed by the EMSC. Each device shall be self-protected against over- and under voltage as well as against over-current in both directions. See also Clause 13 of IEC TS 61851-3-1:2023.

The maximum sum of all directly connected capacities shall not exceed 1 000 µF. The active devices shall be protected against high currents (peak-currents) resulting from switch-on the big capacitive loads. See also 12.1.6 of IEC TS 61851-3-1:2023.

8.2.3 Activating of the energy management system (EMS)

8.2.3.1 General

The EMS is activated and switched off by the EMSC only. For activating the EMS, the EMSC shall handle the following tasks:

– initiate power up the AUX supply circuit;

– remote wake-up of the network participants;

– compatibility check according to 8.2.3.4;

– limiting and operating.

NOTE In addition the EMSC checks cyclically, whether further un-configured LSS slaves have accessed the EMS.

8.2.3.2 Initiate power up of the AUX circuit

When coupling the EV or the battery system to the DRI EV supply equipment, the DRI EV supply equipment can power on the AUX supply circuit according to 7.2.3 of IEC TS 61851-3-1:2023. Also by using the battery system voltage, the EMS shall be able to communicate with all devices.

In case no battery system is available but other power sources are available (e.g. VCU, solar cells), these power sources may be used to power the AUX supply circuit. These other power sources supply the AUX supply circuit so that all connected devices are enabled to start communication.

8.2.3.3 Remote wakeup of the network participants

The EMSC shall initiate the wake-up service as specified in D.3.4.

8.2.3.4 Compatibility check with regard to identity and electrical parameters

Prior to the activation of power sources in the system a compatibility check between all connected devices shall be done by the EMSC. The EMSC shall check the following CANopen device attributes:

– device type;

– supported functionality;

– device vendor;

– serial number;

– software and hardware version;

– physical limits (e.g. minimum/maximum voltage, maximum current);

– node-ID.

Within the CANopen object dictionary of the device, which hosts the EMSC, the object dictionary index range from $1F80_h$ to $1F88_h$ shall be supported. Beside the CANopen slave assignment list these objects provide a database indicating the data required for device compatibility check. After the compatibility check the EMSC allows activation of power sources, see also Annex B.

Prior to switch on an active device, the EMSC shall compare the maximum voltage of all active devices to the voltages of the active devices with fixed (pre-defined/rated) voltage (e.g. battery systems).

8.2.3.5 Limiting and operating

Prior to switch on an active device with controllable voltage (e.g. voltage converter unit) the voltage limits of that active device shall be set to the voltage of the already connected active device with the lowest voltage maximum.

Prior to switch on an active device with controllable current (e.g. voltage converter unit) the current limit in both directions shall be set to the maximum current of the device with fixed (pre-defined/rated) voltage (e.g. battery system).

NOTE Example of implementation of compatibility check is given in Annex C.

8.2.4 Connection and disconnection of devices

It shall be possible to add or remove devices (e.g. battery systems, voltage converter) to or from the EMS. The connecting and disconnecting of devices to or from the EMS shall be detected by the EMSC. The EMSC shall switch off the power in the EMS, see also 8.4.4.

After connecting an either active or passive device, the EMSC shall execute a compatibility check as specified in 8.2.3.4. Handling of multiple sources is described in Annex E.

8.2.5 "Sleep"

All devices in the system shall support the "sleep".

NOTE 1 For implementation according to Annex D, "sleep” maintains at least for a certain time (0,1 ms).

The maximum current consumption of all EMS-connected devices shall be chosen in a way that the battery systems are not deeply discharged (see also 7.2.3 of IEC TS 61851-3-1:2023).

NOTE 2 Transition from "sleep" is possible to "controller switched on" according to Annex D.

The "sleep" is considered as an energy saving mode; the vehicle is still capable to power up with the remaining energy buffered in the battery system. All devices consume only the power that is required for holding the microcontrollers (EV-EMSC, EMSC, local EMS) in "sleep" and to wait for further communication on CAN.

8.3 Use case specific definitions for EMSs in EVs

8.3.1 General

This subclause provides examples of several use case specific definitions for EMS.

The DRI EV supply equipment is classified according to the EV supply system configuration of IEC TS 61851-3-1:2023 as follows:

– EV supply system configuration type A;
– EV supply system configuration type B;
– EV supply system configuration type C;
– EV supply system configuration type D;
– EV supply system configuration type E;
– EV supply system configuration type F.

8.3.2 EMS in operation

In case the EMS is in operation, the EMS is controlled via the EMSC. In case there is no active EMSC, the EMS shall transit into the safe state, see also 8.4.4.

8.3.3 Design and implementation for EV supply system configurations Types "A-F"

8.3.3.1 General

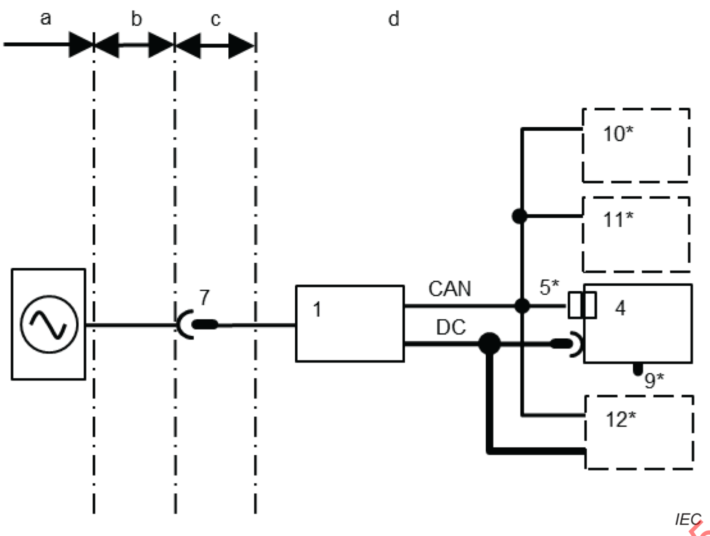
This subclause covers the concept for power transfer between a battery system (in the EV) and a DRI EV supply equipment. But this does not exclude other applications using the DRI EV supply equipment for further energy consumers/generators.

See also Annex A for use cases.

8.3.3.2 EV supply system configuration Type "A"

EV supply system configuration Type "A", a removable or non-removable RESS and the EV is supplied with energy using a portable or mobile DRI EV supply equipment connected to the supply network over a fixed cable on vehicle side (case "A"). See Figure 2.

In EV supply system configuration Type A the VCU, the battery system and the EMSC are placed inside the EV. The use of EMS is optional as long the battery system is not removable. If the battery system is removable, at least the battery system has to comply with the relevant standards for example EN 50604-1:2016 for removable battery systems.



Key	Description	Abbreviation
a	supply network (AC or DC), and fixed installation (according to IEC 60364)	
b	stationary equipment (see 6.7 of IEC TS 61851-3-1:2023)	
c	portable or mobile equipment (see 6.7 of IEC TS 61851-3-1:2023)	
d	EV (located inside of the electric vehicle)	EV
1	portable or mobile DRI EV supply equipment (not permanently fixed to the EV)	
2	pPortable or mobile DRI EV supply equipment	
3	stationary DRI EV supply equipment	
4	removable or non-removable RESS (battery system)	
5	vehicle coupler (DC) (according to IEC TS 62196-4)	
7	standard plug and socket-outlet (AC) (according to IEC 60884 or IEC 60309)	
8	dedicated plug and socket-outlet (DC) (according to IEC TS 62196-4)	
9	A/B coupler (manufacturer specific)	
10	EMS controller in the EV (according IEC TS 61851-3-4)	EV-EMSC
11	human machine interface, passive device, optional (according to CiA 454)	HMI
12	motor control unit, optional (according to CiA 454)	MCU
13	EMS controller in the VCU (according IEC 61851-3 series)	EMSC
14	security unit in the VC optional (according to CiA 454)	
15	security unit in the EV (according to CiA 454)	
16	manufacturer specific battery system	
17	ateway according CiA 454	
18	conversion device	
19	voltage converter	VC
20	load unit	
*	optional	

Key list is valid for Figure 3 to Figure 8.

Figure 2 – EV supply system cConfiguration type A

8.3.3.3 EV supply system configuration type B and C

In configuration type B and C, the EV is in operation (not in motion) while connected to DRI EV supply equipment. Plug present (proximity function) according to 7.3.1 of IEC TS 61851-3-1:2023 shall be activated in the EV.

NOTE For EVs using accessories according to IEC TS 62196-4 over 60 V or over 5 A, under configuration type B and C while connected to the supply network, plug present (proximity function) is provided according to 10.3 of IEC TS 62196-4. For communication purpose, object 6311_h can be used according to IEC TS 61851-3-5:2023.

This use case is considered as a lengthening of the EV energy management system (EMS). The EV-EMSC functionality as well as the NMT master functionality remains in the EV. The EMSC functionality as well as the NMT master functionality in the DRI EV supply equipment shall be disabled.

In order to assure that only a single active EMSC is in the system, the EMSC hosted by the VCU scans for the heartbeat of the EV-EMSC (node-ID 01h). In case VCU detects an active NMT master/EMSC, the EMSC master functionality in the DRI EV supply equipment shall act as a silent master. Neither NMT/LSS master, nor EMSC-related tasks shall be executed. In this case, the EV-EMSC transfers all relevant data between battery systems and the VCU, so that the DRI EV supply equipment is enabled to execute the power transfer process.

In case the DRI EV supply equipment is supplying an EV battery system while the EV is switched off, the DRI EV supply equipment acts as EMSC and NMT master. In case someone is activating the EV respectively the EV-EMSC during the power transfer process, that EV-EMSC will become the active NMT master and will take over the energy management. The DRI EV supply equipment will act as silent master. In this case, the EV-EMSC transfers all relevant data between battery systems and the VCU, so that the DRI EV supply equipment is enabled to execute the power transfer process.

See, for portable device, Figure 3 and for fixed installation, Figure 4.

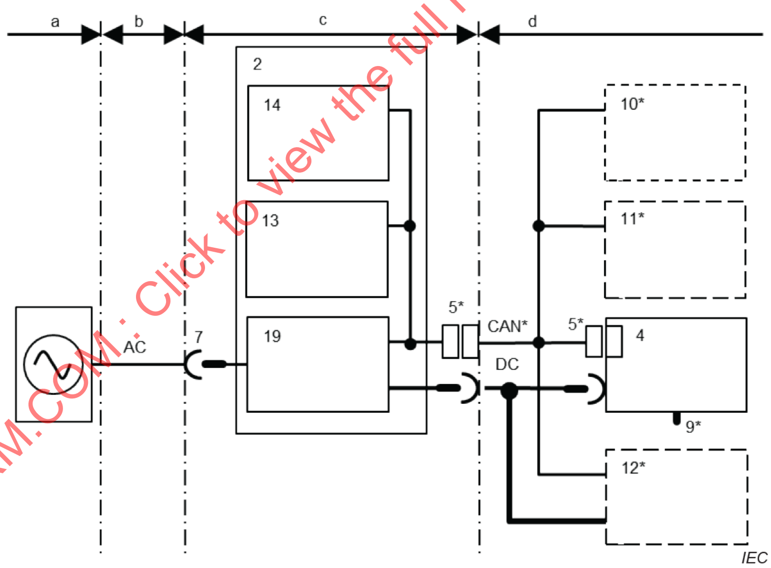


Figure 3 – EV supply system configuration type B

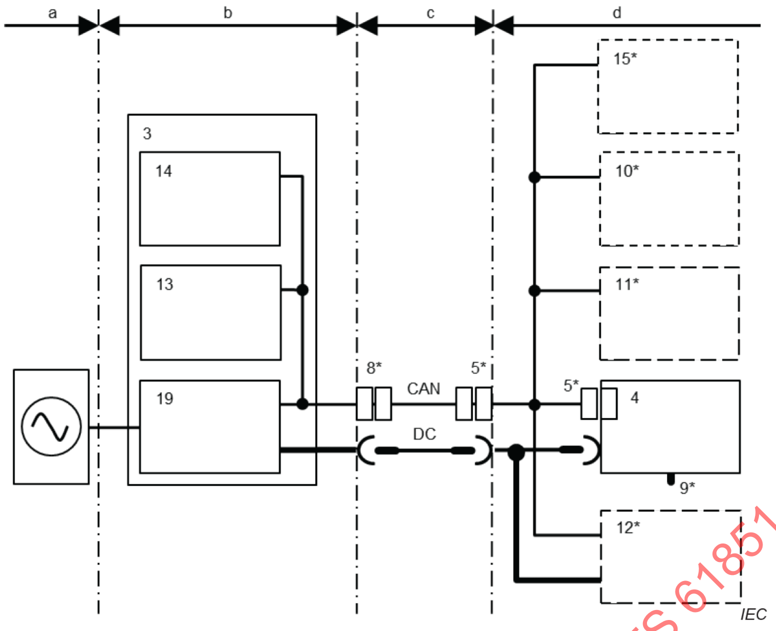


Figure 4 – EV supply system c~~C~~onfiguration type C

8.3.3.4 EV supply system configuration type D and E

In case a battery system is removed from the EV and connected to a DRI EV supply equipment, the active EMSC resides within the DRI EV supply equipment. In such a use case, the typical EMS consists of a connection between one battery system, a voltage converter with AC-to-DC converter functionality and the EMSC. The EMSC resides in the same CANopen device as the AC-to-DC converter functionality. See, for portable device, Figure 5 and for fixed installation, Figure 6.

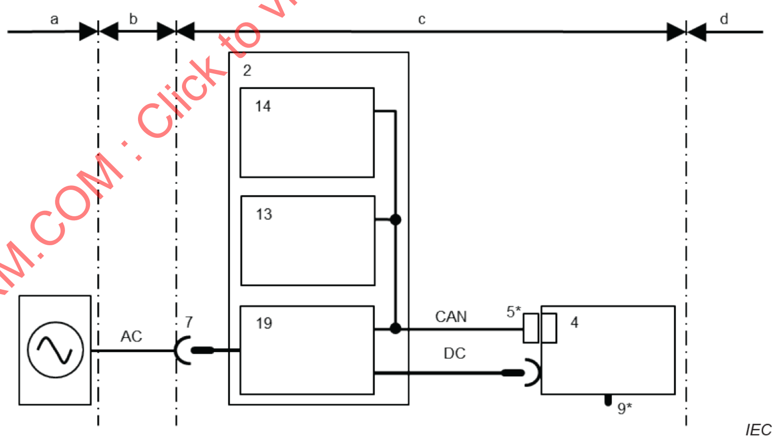


Figure 5 – EV supply system configuration type D

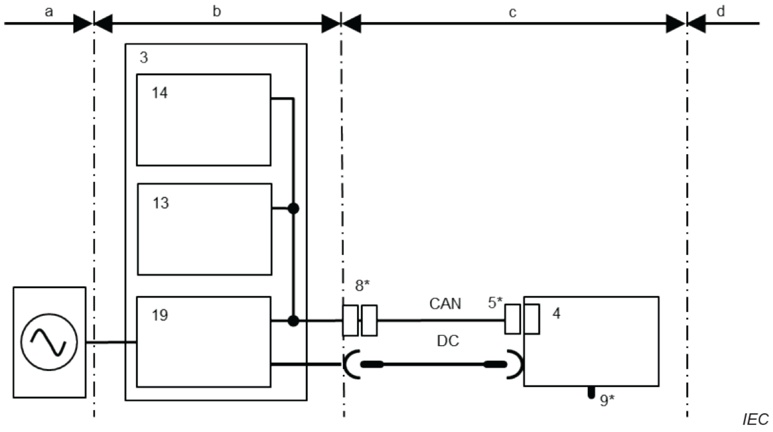


Figure 6 – EV supply sytem configuration type E

8.3.3.5 EV supply system configuration type F

This use case is typical for battery swapping station. One VCU can handle up to 16 instances of battery systems. See also Figure 7.

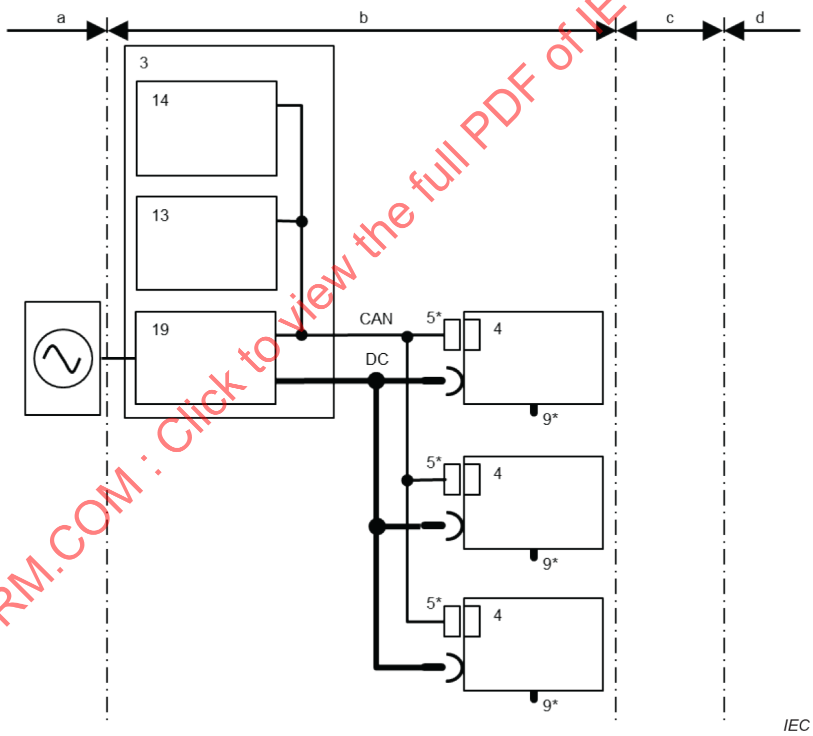


Figure 7 – EV supply system configuration type F

8.3.3.6 Conversion device

With the conversion device it is possible to connect a proprietary EV to supply network according to 7.1.8 of IEC TS 61851-3-1:2023. See Figure 8.

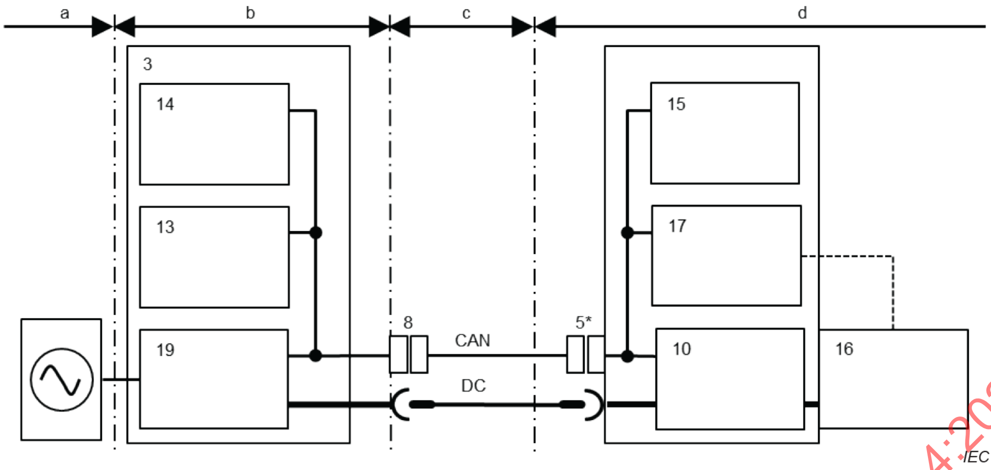


Figure 8 – Conversion device for configuration type C

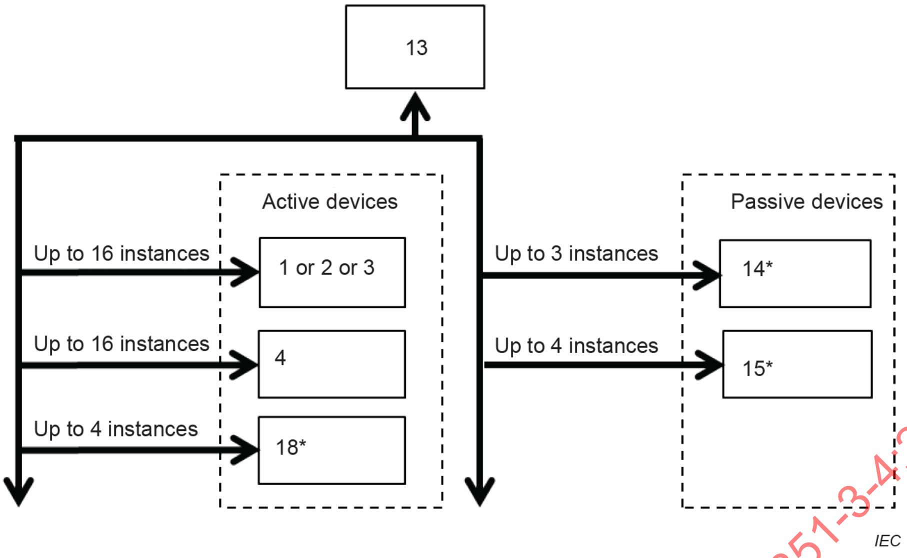
8.4 Virtual architecture of the EMS

8.4.1 General

This application profile for EMS defines several virtual devices. They share the CANopen object dictionary entries from 6000_h to $67FF_h$. A logical CANopen device consists of one or more virtual devices. A virtual device shall not be distributed to several CANopen devices. Physical devices are not defined. In case several virtual devices are implemented on the very same CANopen device, the communication between these virtual devices may be handled locally, via the application.

8.4.2 Standard virtual EMS control network

The standard virtual control network is illustrated in Figure 9. The numbers indicate the maximum amount of instances in the context of the IEC 61851-3 series that may be integrated in one EMS implementation. For maximum virtual control network, see Figure A.1.



Key	Description	Abbreviation
1	portable or mobile DRI EV supply equipment (not permanently fixed to the EV)	
2	portable or mobile DRI EV supply equipment	
3	stationary DRI EV supply equipment	
4	removable or non-removable RESS (battery system) (according IEC 61851-3 series)	
13	microcontroller (with local EMS in the VCU (according IEC 61851-3-4)	EMSC
14	security unit in the VCU optional (according to CiA 454)	
15	security unit in the EV (according to CiA 454)	
18	conversion device	
*	optional	

Figure 9 – Virtual standard architecture of the EMS

8.4.3 General application object (GAO)

Any CANopen device used in an EMS application, for example for EVs, shall support all mandatory general application objects (GAOs) and may additionally support any amount of the optional general application objects. The GAOs provide on the one hand general information on a CANopen device. On the other hand, GAO provides information about locally measured EMS conditions, for example actual voltage or current. Those parameters are mandatory for active devices and may be supported by passive devices.

Instances that may be integrated in one EMS implementation (normative):

– energy management system controller (EMSC), see 8.4.4;
– voltage converter unit (VCU), see 8.4.5;
– battery system, see 8.4.6;

Additional instances that may be integrated in one EMS implementation (informative):

– security unit, see 8.4.7;
– manufacturer-specific virtual devices, see 8.4.8;
– motor control unit, see A.3.2;
– load monitoring unit, see A.3.3;
– generator unit, see A.3.4;
– load unit, see A.3.5;
– HMI unit, see A.3.6;

– sensor unit, see A.3.7;
– gateway, see A.3.8;
– IEC 61850 gateway, see A.3.9.

8.4.4 Energy management system controller (EMSC)

There is only one energy management system controller (EMSC) – see Annex B – located in the EMS even in a lengthened EMS application. The virtual device EMSC may reside in CANopen devices that support further virtual devices as well, for example a motor controller, an HMI or VCU. The EMSC shall not reside in an exchangeable device, for example a battery system. Two EMSs shall not be connected (e.g. bridged via a DRI EV supply equipment). These networks may interchange data, for example via a gateway application that keeps the single EMS applications separated. The EMSC handles and limits all power provided to respectively taken from the power lines. The EMSC handles the on/off switching of the EMS and of all connected devices. The EMSC shall recognize the limits of all vehicle couplers and cables that are installed in the EMS and shall protect them by limiting voltages and currents for each device. The EMSC maintains security and safety of the entire EMS. The EMSC may control the ignition key.

The device hosting the EMSC shall provide the CANopen NMT master functionality, LSS master functionality as well as the energy management in the EMS. The EMSC provides the SDO clients to the default SDO servers of all connected devices.

In case a new device with EMSC functionality is added to the EMS, this new device shall evaluate whether an EMSC is already available in the network. This shall be done using the service "active NMT master detection" as defined in CiA 302-2. Therefore the EMSC that hosts the active NMT master functionality shall be capable to act in the "active NMT master detection protocol" according to CiA 302-2. If a CANopen device with the EMSC functionality is already available in the EV, the newly connected device shall switch off its NMT master functionality and shall act as an NMT slave in the network. In addition, this device shall set its SDO client COB-ID parameters invalid.

In EV applications, the scanning for a vehicle-internal active EMSC (EV-EMSC) is done by scanning for the heartbeat of that EV-EMSC (CAN message CAN-ID 701h). Therefore no flying NMT master services are required. In case there are additional master-capable devices available in the system, those devices set their master activity only active, in case the primary master (node-ID 1) is lost. Those "secondary" masters keep their original node-ID value. Other device that have to monitor the "new" active NMT master have to be preconfigured in a way so that they receive the heartbeat of all NMT master capable devices or that they understand the master negotiation protocol.

In case a faulty configuration is detected (e.g. several devices claim the same node-ID or there are several active NMT masters in the system), the entire EMS shall switch to a safe state.

8.4.5 Voltage converter unit (VCU)

This virtual device shall specify any type of voltage converter, for example:

– DC/DC converters (uni- or bidirectional);
– AC/DC converters (uni- or bidirectional);
– frequency converters (uni- or bidirectional).

NOTE This virtual device handles power transfer/discharging management, for example EV supply equipment.

8.4.6 Battery system

The battery system includes a BMS which provides the local EMS function of the battery system.

8.4.7 Security unit (optional)

This virtual device allows connecting security-related devices to the EMS. This virtual device may be implemented in devices hosting functionality, for example security device, latching/unlatching vehicle coupler or plug, ignition key, main switch, etc.

NOTE The security unit is not specified in this document but is specified in CiA 454-10.

8.4.8 Manufacturer-specific virtual devices (optional)

Manufacturer-specific virtual devices allow integrating manufacturer-specific functionality; in maximum there may reside up to 8 manufacturer-specific virtual devices in a EV. In maximum 4 active and passive manufacturer-specific virtual devices shall be installed.

9 Finite state automaton (device modelling)

9.1 General

The device modelling described in Clause 9 applies for all CANopen devices implemented according to this profile and operated in an EMS. The operation of an EMS-connected device is provided in form of a finite state automaton (FSA) that defines the behaviour of the EMS-connected device as seen by the EMSC. This application profile introduces a FSA, which enables the EMSC to control the EMS-connected devices. The FSA consists of mandatory and optional FSA states and sub-states. Any EMS-connected device supports the mandatory FSA states.

Optional FSA states are only supported in case the related functionality is supported respectively required, by the devices connected to the EMS. State transitions within the FSA are based on device internal events (e.g. occurrence of device errors, value change, etc.) or on the reception of the control word (see object 6001_h). All devices connected to the EMS shall support the FSA specified in Figure 11.

The FSA is controlled by the EMSC via the Device control object 6001_h and Device status object 6002_h. The NMT FSA as defined in 5.3.2 of EN 50325-4:2002 and the EMS FSA are coupled in the following way: a state change in the EMS FSA may trigger state changes in the NMT FSA.

The logical operation function unit of the device connected to the EMS implements an arbitration mechanism between commands either received from local input or remotely by means of the control word. The logical operation of the EMS-connected device may initiate the transmission of emergency messages, in addition to, but independent of emergency messages triggered by the operation of the EMS-connected device according to the specifications in EN 50325-4:2002. The detailed specification of the logical operation is not in the scope of this document, nor is the local control mode. Returning to remote control mode may require device re-initialization.

The current status of the EMS-connected device is reported as status word. The EMS FSA is also controlled by error detection signals. Figure 10 shows the structure of the remote and local control function.

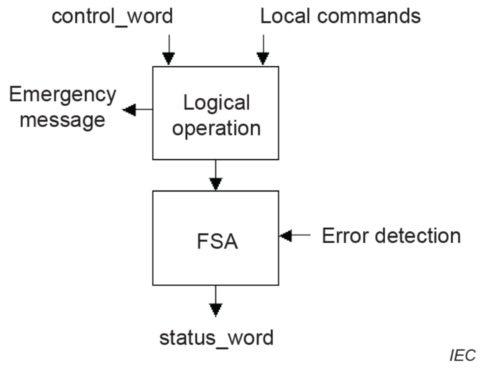


Figure 10 – Remote and local control

9.2 EMS finite state automaton (FSA)

9.2.1 State definition

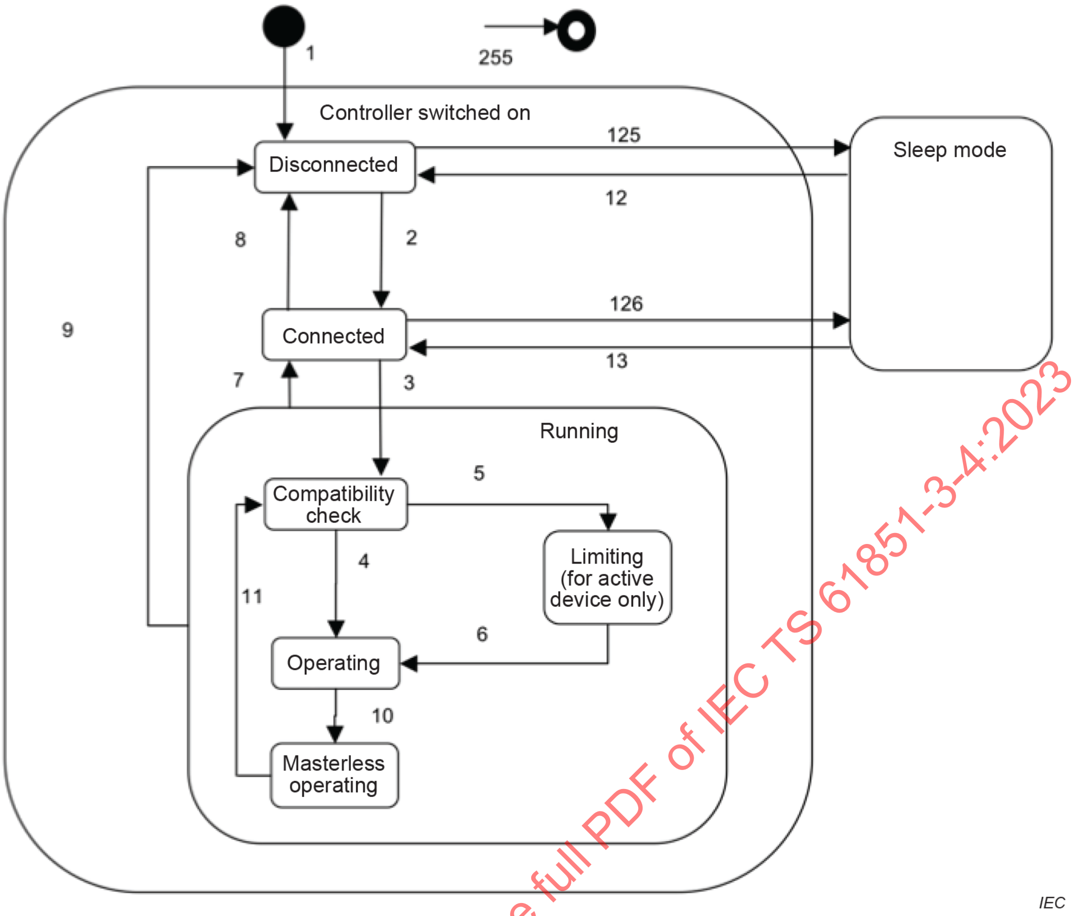
The EMS finite state automaton (FSA) as specified in Figure 11 shall provide the following states with the described behaviour in Table 4.

Table 4 – State description

Name	Description
Initial	This shall be a pseudo state indicating the start when the FSA is activated during the start-up sequence of the active or passive device.
Disconnected	The active or passive device shall transit to this state after power-on or NMT application reset. The active or passive device shall be not connected to the power lines and the CAN interface shall be disabled. However, in case the device supports an own external power supply, the device's application may already be running.
Connected	In this state, the active or passive device shall be configurable via the network or from a local terminal. When the active or passive device enters this state, a limited energy is provided via the power lines in order to power the CAN communication and applies its local layer settings, for example bit rate and node-ID. The power lines are not fed with full power respectively current.
Compatibility_Check	The active or passive device awaits that it is checked by EMSC and waits for further commands. In addition, the active or passive device may be configured by the EMSC. In this state, the EMSC executes the node-ID check. In case the device fails the compatibility check, the device may either remain in Compatibility Check or may transit to Connected or Disconnected.
Limiting[a]	This is a state for active devices only. In this state, the electrical parameters shall be limited to the operating limits of the EMS. [a]
Operating	In this state, the active or passive device shall operate according to its application-specific FSA, for example power transfer, discharging, etc.
Final	This shall be a pseudo state indicating the end when the FSA is destroyed due to the active or passive device is powered off.
Controller_Switched_On	Status indicating that the device application is powered-on.
Running	Status indicating that device is ready to operate in the EMS in principle.
Masterless_Operating	The device manages the electrical interface to the EMS locally, so that the device is operating within its operational limits. The device in this state is no longer controlled via the EMSC. This is an optional state but mandatory for stationary EMSs.
"Sleep"	Energy saving mode (see 8.2.5).

NOTE For error description, see Clause 7.

[a] This state was introduced for assuring a safe power up. Dynamic limitation takes place in Operating.



NOTE Numbers shown in Figure 11 are the number of transition in Table 5.

Figure 11 – EMS FSA

9.2.2 Transitions of the EMS FSA

The FSA shall support the state transitions as given in Table 5.

Table 5 – Events and actions

Transition	Event(s)	Action(s)
1	Automatic transition after power-on or in NMT sub-state reset application	Update status word (see IEC TS 61851-3-5)
2	Automatic transition after connection of the device to the EMS	Update status word (see IEC TS 61851-3-5)
3	Automatic transition after successful setting of the CANopen device's local layer settings	Update status word (see IEC TS 61851-3-5)
4	Enter Operating state in control word; for passive devices only	Update status word (see IEC TS 61851-3-5)
5	Enter Limiting state in control word; for active device only	Update status word (see IEC TS 61851-3-5)
6	Enter Operating state in control word for active device	Update status word (see IEC TS 61851-3-5)
7	Enter Connected state in control word; NMT service reset communication; In case EMS FSA is in Operating state, any NMT state change causing leaving of NMT operational;	Update status word (see IEC TS 61851-3-5)
8	Automatic transition after disconnecting the device from the EMS	Update status word (see IEC TS 61851-3-5)
9	Enter Disconnected state in control word; automatic transition for passive devices in case they are disconnected from the EMS but have still their own external power supply; NMT service reset node	Update status word (see IEC TS 61851-3-5)
10	Detection of the absence of the EMSC	Update status word. Local control of the device's EMS inputs and outputs.
11	Enter Compatibility check state in control word.	Update status word
12	Detection of Wake up event and node-ID equal FF_h	Update status word
13	Detection of Wake up event and node-ID unequal FF_h	Update status word
125	Transition to Prepare "sleep" in power management FSA (see Figure D.1)	Enter energy saving mode
126	Transition to Prepare "sleep" in power management FSA (see Figure D.1)	Enter energy saving mode
255	Power off	Leave state machine.
NOTE The status word is updated, even if it is not visible at the CAN-interface in certain FSA states.		

10 General CANopen communication capabilities in EMSs

10.1 Network management

The boot-up procedure defined in CiA 302-2:2009 shall be used. The heartbeat protocol shall be supported as specified in EN 50325-4:2002.

The EMSC monitors the CANopen devices via the heartbeat mechanism. In addition, all active devices shall support a TPDO that is triggered by the reception on any SYNC message. EMSC shall host the SYNC producer functionality. EMSC shall support the heartbeat consumer functionality, so that the heartbeat messages of all network participants are received and evaluated.

The device, which is determined as highest prior host controller in the EMS, provides the EMSC functionality (node-ID 1), and acts as the NMT master, LSS master and energy management master.

Other master-capable devices may be available in the system. The specification of handing over from one EMSC to another is not in the scope of this document.

NMT flying master capability as specified in CiA 302-2:2009 is recommended.

In case firmware updates for active – or passive – devices through EMS interface are required, the firmware update is handled via CANopen according to the bootloader functionality, as specified in 10.4.

10.2 SDO communication

Each active or passive CANopen device supports only the first SDO server channel as defined in EN 50325-4:2002. In addition, the EMSC provides SDO client channels to all devices that are connected to that EMS.

10.3 PDO communication

The general PDO specification is given in EN 50325-4:2002, which specifies TPDOs for all considered virtual devices. Depending on the provided functionality, a CANopen device shall implement RPDOs that allow reception of the required data to be enabled to provide the implemented device functionality to the EMS.

10.4 Bootloader

10.4.1 General

The bootloader mode is required to update the firmware of CANopen device directly via the CANopen interface. A CANopen device staying in bootloader mode is a fully CANopen device, which has no running application program. Just the bootloader program is running, capable to manage the reception and handling of application program. The handling of the bootloader mode in this profile is based on the mechanisms for software download and control, provided in CiA 302-3:2010.

10.4.2 Bootloader mode

A CANopen device supporting this profile shall enter the bootloader mode in case it hosts and executes no valid, running firmware. In addition, the EMSC is able to switch a CANopen device implemented according to this profile to bootloader mode, by writing the right signature to object $605A_h$ sub-index 05_h and disabling the firmware program by means of write access to object $1F51_h$. Figure 12 illustrates the relationship between bootloader mode and operating a valid firmware.

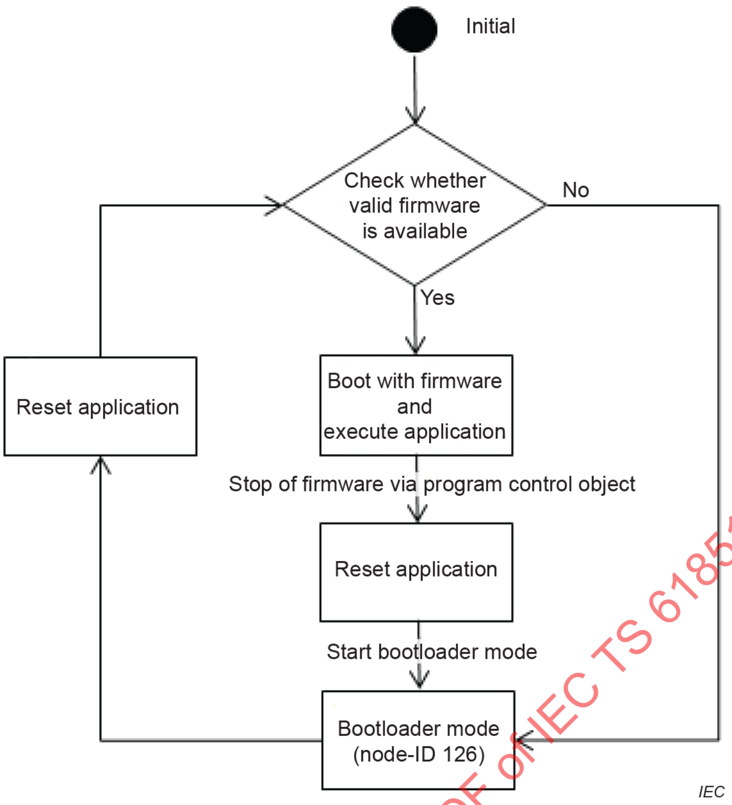


Figure 12 – Flow chart for switching between bootloader mode and application

A CANopen device staying in bootloader mode shall be indicated in the device type object 1000_h, by means of Bit 30 in the bit field "additional information".

In bootloader mode, at least the following objects shall be implemented and accessible by means of the default SDO server: device type (1000_h), error register (1001_h), producer heartbeat time (1017_h), identity (1018_h), program download ($1F50_h$), program control ($1F51_h$), application software identification ($1F56_h$), and flash status identification ($1F57_h$). Optionally, further objects may be implemented.

The new firmware is transferred to the CANopen device via SDO segmented transfer or SDO block transfer to object $1F50_h$.

10.4.3 Starting and stopping the application program

Accessing the bootloader mode shall only be possible in case the CANopen device is in FSA state Compatibility check. To start the bootloader mode, the CANopen device's application program shall be stopped. After the successful stop of the application program, the CANopen device shall be forced to enter the NMT reset application sub-state.

Prior to force the CANopen device to enter NMT reset application sub-state, the "old" application program should be deleted or the "Stop value (00_h)" in object $1F51_h$ should be set to power on value. This handling avoids restarting the "old" application program unintended after NMT reset application.

NOTE In EV applications; a CANopen device in bootloader mode claims the fixed node-ID 126.

In bootloader mode, the new application program/firmware shall not start automatically. The CANopen device shall wait for a start program command by means of the program control object $1F51_h$.

As soon as the application program/firmware is started, primarily the CANopen device shall enter NMT application reset sub-state. This shall reset the application and communication parameter including the device type object 1000_h.

10.4.4 Application program file format

The application program file format is manufacturer-specific. To keep the CANopen devices in electric vehicle applications simple, the validity of the downloaded application software is directly checked either by the provider of the application program file or by the EMSC.

In case the CANopen devices supporting bootloader mode have enough processing power and memory resources, it is recommended to follow with the application program file format specified in 10.4.4. The application program illustrated in Figure 13 is described by several program identifiers, specified in Figure 14, Figure 15, Figure 16, Figure 17 and Figure 18. Program identifiers start with keywords, followed by the related parameter value, for example:

– $CANopenSoftware-ID;
– $CANopenVendor-ID;
– $CANopenProductCode;
– $CANopenSoftwareVersion;
– and $CANopenVendorName.

Within a program identifier, the parameter value is encapsulated by means of the value 00_h. Parameter values, providing a numerical value, shall provide this value as hexadecimal value and shall start with 0x. Parameter values that provide a literal value shall start with a $ sign. The program identifiers may be located anywhere in the application program. Location and order of the program identifiers within the application program is manufacturer-specific.

NOTE 1 However, the location of the program identifiers is not defined, grouping the keywords as a program header or trailer eases the program handling.

Table 6 provides the value definition. The 32-bit hash value (**<Hashvalue32-bit>**) is calculated in a manufacturer-specific way.

Byte 0	Byte 1	…	Byte x
0			x

IEC

Figure 13 – Application program

$CANopenSoftware-ID	00h	<Hashvalue32-bit>	00h
0 20	21	22 29	30

IEC

Figure 14 – Program identifier 1

$CANopenVendor-ID	00h	Vendor-ID	00h
0 17	18	19 26	27

IEC

Figure 15 – Program identifier 2

$CANopenProductCode	00h	Product code	00h
0 19	20	21 28	29

IEC

Figure 16 – Program identifier 3

$CANopenSoftwareVersion	00h	Software version	00h
0 23	24	25 y	y+1

IEC

Figure 17 – Program identifier 4

$CANopenVendorName	00h	Vendor name	00h
0 18	19	20 z	z+1

IEC

Figure 18 – Program identifier 5

NOTE 2 The example provided in Figure 19 illustrates an example for transmitting the Program identifier 2 CANopen Vendor-ID with the parameter value $CAFEAFFE_h$. In this example, the first column indicates the string to be transferred. The second column indicates the hexadecimal values according to ISO/IEC 646.

Table X – xxx

String	Coding according to ISO/IEC 646
$	24_h
C	43_h
A	41_h
N	$4E_h$
o	$6F_h$
p	70_h
e	65_h
n	$6E_h$
V	56_h
e	65_h
n	$6E_h$
d	64_h
o	$6F_h$
r	72_h
-	$2D_h$
I	49_h
D	44_h
\	00_h
0	30_h
x	78_h
C	43_h
A	41_h
F	46_h
E	45_h
A	41_h
F	46_h
F	46_h
E	45_h
\	00_h

IEC

Figure 19 – Example for program identifier handling

Table 6 – Value definition

Name	Description	Entry category
$CANopen_Software-ID	Keyword indicating that this program identifier provides the **CANopen_Software-ID**. The keyword shall be coded as **VISIBLE_STRING** and shall start with a **$** sign.	Mandatory
<Hashvalue32-bit>	**CANopen_Software-ID** parameter value, coded as a VISIBLE_STRING. The CANopen software ID shall correspond to the entry given in object $1F56_h$. The most significant byte shall be transmitted first; the least significant byte shall be transmitted as last byte. The value shall start with 0x.	Mandatory
$CANopenVendor-ID	Keyword indicating that this program identifier provides the CANopen Vendor-ID. The keyword shall be coded as VISIBLE_STRING and shall start with a $ sign.	Mandatory
Vendor-ID	**CANopen_Vendor-ID** parameter value, coded as a **VISIBLE_STRING**. The **CANopen_Vendor ID** shall correspond to the entry given in object 1018_h sub-index 01_h. The most significant byte shall be transmitted first, the least significant byte shall be transmitted as last byte of the **CANopen_vendor-ID**. The value shall start with 0x.	Mandatory
$CANopen_Software_Version	Keyword indicating that this program identifier provides the **CANopen_Software_Version**. The keyword shall be coded as **VISIBLE_STRING** and shall start with a **$** sign.	Optional
Software version	**CANopen_Software_Version** parameter value, coded as a **VISIBLE_STRING**. The **CANopen_Software_Version** shall correspond to the entry given in object $100A_h$ sub-index 00_h. The most significant byte shall be transmitted first; the least significant byte shall be transmitted as last byte of the software version. The value shall start with 0x.	Optional
$CANopen_Product_Code	Keyword indicating that this program identifier provides the **CANopen_Product_Code**. The keyword shall be coded as **VISIBLE_STRING** and shall start with a **$** sign.	Optional
Product_Code	**CANopen_Product_Code** parameter value, coded as a **VISIBLE_STRING**. The **CANopen_Product_Code** shall correspond to the entry given in object 1018_h sub-index 02_h. The most significant byte shall be transmitted first; the least significant byte shall be transmitted as last byte of the product code. The value shall start with 0x.	Optional
$CANopen_Vendor_Name	Keyword indicating that this program identifier provides the **CANopen_Vendor_Name**. The keyword shall be coded as **VISIBLE_STRING** and shall start with a **$** sign.	Optional
Vendor_Name	**CANopen_Vendor_Name** parameter value, coded as a **VISIBLE_STRING**. The initial letter of the vendor shall be transmitted first. The parameter value of **CANopen_Vendor_Name** shall start with a **$** sign.	Optional

NOTE 1 The entry category applies only in case the recommended structure for the application program is supported.

NOTE 2 Mandatory is indicated if the option is used.

10.4.5 Error management

10.4.5.1 General

Subclause 10.4.5 provides a pre-defined behaviour for specific error conditions

10.4.5.2 Interrupted firmware update process

In case the firmware update process fails, the CANopen device shall remain in the bootloader mode, as there is no valid application program running. The firmware download needs to be started again.

10.4.5.3 Reception of erroneous firmware

If the CANopen device is capable of detecting that it has received erroneous firmware, the CANopen device shall reject execution of this program. Starting this firmware via object $1F51_h$ shall generate an SDO abort code.

11 Representation of analogue values

11.1 General

The analogue values of the same SI-unit, defined in this document, are represented in the same data type as well as the same resolution. If not specified in a different way in the related index' value definition, analogue values shall be given as specified in 11.2, 11.3, 11.4 and 11.5. Optionally, manufacturers may represent additional information in the manufacturer-specific object dictionary index range in a manufacturer-specific format. Clause 11 specifies data type and resolution of analogue values, used in EMS.

11.2 Representation of generic analogue values

11.2.1 Percent

The data type shall be **UNSIGNED16**. The value shall be given in multiples of 0,01 %.

11.2.2 Temperature

The data type shall be **INTEGER16**. The value shall be given in multiples of 0,1 °C.

11.2.3 Temperature rate (ΔT)

The data type shall be **UNSIGNED16**. The value shall be given in multiples of 0,001 °C/min.

11.2.4 Time (days)

The data type shall be **UNSIGNED32**. The value shall be given in multiples of 1 day.

11.2.5 Time (minutes)

The data type shall be **UNSIGNED32**. The value shall be given in multiples of 1 min.

11.2.6 Time (milliseconds)

The data type shall be **UNSIGNED32**. The value shall be given in multiples of 1 ms.

11.3 Electrical-related analogue value representation

11.3.1 Current

The data type shall be **INTEGER32**. The value shall be given in multiples of 1 mA. A positive value shall indicate a current flow from the active device to the EMS (e.g. when discharging the battery system). A negative value shall indicate a current flow from the EMS to the active device (e.g. when charging the battery system).

NOTE The terms "charging" and "discharging" are used in IEC 61851-3 (all parts) very carefully, and only if the situation is absolutely related to this issue. The term "power transfer" is used because the direction and purpose of the power transfer is not known and not relevant for the requirement or considerations.

11.3.2 Electric charge

The data type shall be **UNSIGNED32**. The value shall be given in multiples of 1 mAh.

11.3.3 Electric charge (for statistical purposes)

The data type shall be **UNSIGNED32**. The value shall be given in multiples of 1 Ah.

11.3.4 Electric charge rate

The data type shall be **UNSIGNED32**. The value shall be given in multiples of 1 mAh/day.

11.3.5 Energy power (for statistical purposes)

The data type shall be **UNSIGNED32**. The value shall be given in multiples of 1 Wh.

11.3.6 Energy power

The data type shall be **UNSIGNED32**. The value shall be given in multiples of 1 mWh.

11.3.7 Frequency

The data type shall be **UNSIGNED16**. The value shall be given in multiples of 0,01 Hz.

11.3.8 Power

The data type shall be **INTEGER32**. The value shall be given in multiples of 1 mW.

11.3.9 Power factor

The data type shall be **UNSIGNED16** and the value shall be given in multiples of 0,001.

11.3.10 Resistor

The data type shall be **UNSIGNED32**. The value shall be given in multiples of 0,1 mΩ.

11.3.11 Voltage

The data type shall be **INTEGER32**. The value shall be given in multiples of 1 mV.

11.4 Mechanical-related analogue value representation (optional)

11.4.1 Angle/circular position

The data type shall be **UNSIGNED16**. The value shall be given in multiples of 0,0055°.

11.4.2 Distance (long)

The data type shall be **UNSIGNED32**. The value shall be given in multiples of 1 m.

11.4.3 Distance (short)

The data type shall be **UNSIGNED32**. The value shall be given in multiples of 1 mm.

11.4.4 Force

The data type shall be **INTEGER32**. The value shall be given in multiples of 0,01 N.

11.4.5 Rotational speed

The data type shall be **INTEGER16**. The value shall be given in multiples of 1 rpm.

11.4.6 Revolutions

The data type shall be **INTEGER32**. The value shall be given in multiples of 1 revolution

11.4.7 Torque

The data type shall be **INTEGER16**. The value shall be given in multiples of 0,01 Nm.

11.4.8 Velocity

The data type shall be **INTEGER16**. The value shall be given in multiples of 0,01 km/h.

11.5 Optical-related analogue value representation – Colour/brightness

The data type shall be **UNSIGNED32**. The object structure is specified in Figure 20.

31 … 24	23 … 16	15 … 8	7 … 0
Reserved	Blue	Green	Red
MSB			LSB

IEC

Figure 20 – Object structure

Bit 0 to 7 provide the proportion of red, given in multiples of 0,4 %.

Bit 8 to 15 provide the proportion of green, given in multiples of 0,4 %.

Bit 16 to 23 provide the proportion of blue, given in multiples of 0,4 %.

Bit 24 to 31 shall be always 0.

Annex A
(informative)

System architecture and use cases

A.1 General

Annex A provides application profiles for EMS and some use case for stationary as well as mobile applications.

A.2 Application profile for EMS

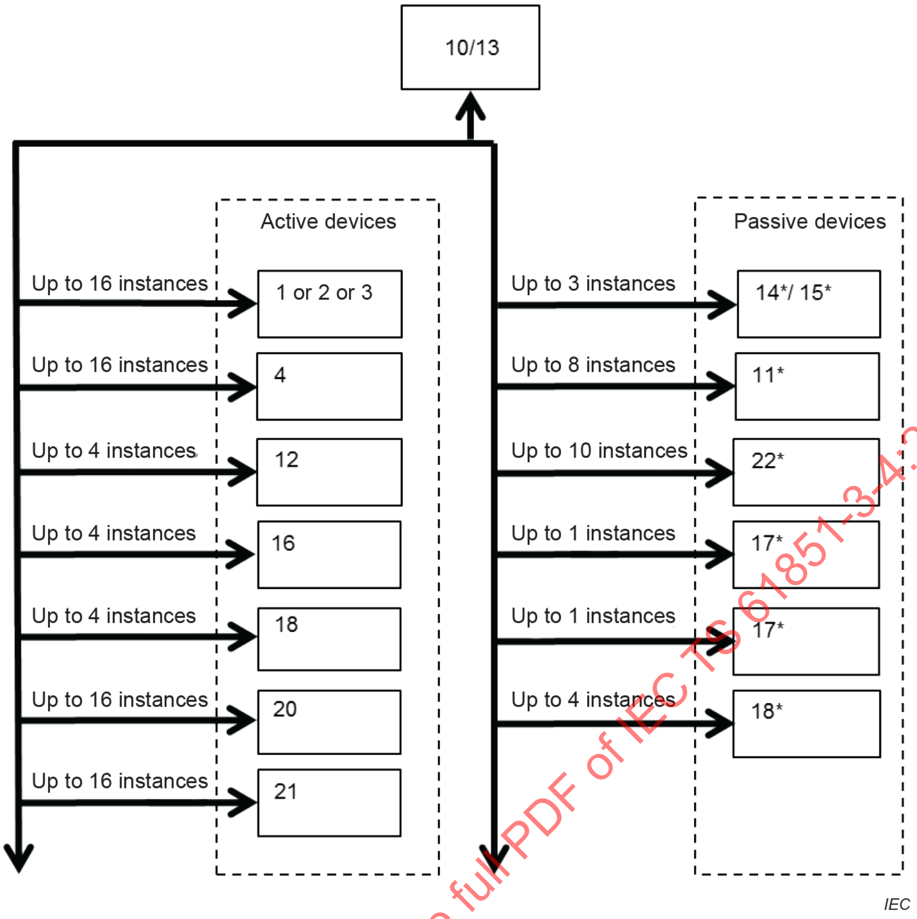
A.2.1 General

Application profile for EMS, see also 8.4.

The maximum possible devices on a virtual EMS control network are given in A.2.2. The minimum possible devices on a virtual EMS control network are given in A.2.3.

A.2.2 Maximum possible devices on a virtual EMS control network

The maximum virtual control network is illustrated in Figure A.1. The numbers indicate the maximum possible amount of instances that may be integrated in one EMS implementation.



Key	Description	Abbreviation
1	portable or mobile DRI EV supply equipment (not permanently fixed to the EV)	
2	portable or mobile DRI EV supply equipment	
3	stationary DRI EV supply equipment	
4	removable or non-removable RESS (battery system)	Figure A.2
10	EMS controller in the EV (according IEC TS 61851-3-4)	EV-EMSC
11	human machine interface, passive device, optional (according to CiA 454)	HMI
12	motor control unit, optional (according to CiA 454)	MCU
13	microcontroller (with local EMS in the VCU (according IEC 61851-3-4)	EMSC
14	security unit in the VC optional (according to CiA 454)	
15	security unit in the EV (according to CiA 454)	
16	manufacturer specific battery system	
17	gateway according CiA 454	
18	conversion device	
20	load unit	
21	active device	
22	passive device	
*	optional	

Figure A.1 – Virtual maximum architecture of the EMS

A.2.3 Minimum virtual EMS control network

The minimum virtual control network is illustrated in Figure A.2. The numbers indicate the minimum needed amount of instances that has to be integrated in one EMS implementation.

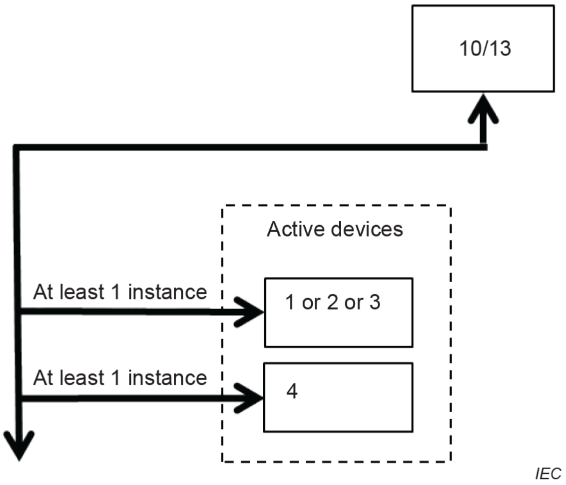


Figure A.2 – Virtual minimum architecture of the EMS

A.3 General application object

A.3.1 General

According to 8.4.3, any CANopen device used in an EMS application, for example for EVs, shall support all mandatory general application objects (GAOs) and may additionally support any amount of the optional general application objects. The GAOs provide on the one hand general information on a CANopen device. On the other hand, GAO provides information about locally measured EMS conditions, for example actual voltage or current. Those parameters are mandatory for active devices and may be supported by passive devices.

Instances that may be integrated in one EMS implementation:

- energy management system controller (EMSC), see 8.4.4;
- voltage converter unit (VCU), see 8.4.5;
- battery system, see 8.4.6;
- security unit, see 8.4.7;
- manufacturer-specific virtual devices, see 8.4.8;
- motor control unit;
- load monitoring unit;
- generator unit;
- load unit;
- HMI unit;
- sensor unit;
- gateway;
- IEC 61850 gateway .

A.3.2 Motor control unit

This virtual device handles the motor management and provides all objects required for remote motor control.

NOTE The load monitoring unit is not specified in this document, but in CiA 454-7.

A.3.3 Load monitoring unit

This virtual device monitors the state of health of active devices.

NOTE The load monitoring unit is not specified in this document but in CiA 454-8. According to the security concept provided in the CiA 454 series, the load monitoring unit acts as counterpart for the security unit in public power transfer infrastructure.

A.3.4 Generator unit

This virtual device provides energy to the EMS.

NOTE The generic generator unit is not specified in this document but in CiA 454-13.

A.3.5 Load unit

This virtual device consumes energy from the EMS.

NOTE The generic load unit is not specified in this document but in CiA 454-14.

A.3.6 HMI unit

This virtual device handles HMI device management and provides all objects required for the remote control of the HMI control unit, for example to display the current settings of an active device to the end user, the HMI control unit may be implemented in any CANopen device.

NOTE The HMI is not specified in this document but in CiA 454-9.

A.3.7 Sensor unit

The sensor unit is implemented in any kind of sensors, for example velocity- acceleration-, biometric-, or GPS sensor, in order to allow remote control of the sensor via CANopen.

NOTE The sensor unit is not specified in this document but in CiA 454-11.

A.3.8 Gateway

The gateway provides any kind of gateway functionality in order to allow communication links via, for example, CANopen to Bluetooth, CANopen to Wireless Local Area Network (WLAN), etc.

NOTE The virtual device Gateway is not specified in this document but is specified in CiA 454-12. In addition, CiA 315 provides communication techniques to run CANopen on a wireless transmission media and to allow access from a wireless transmission media to CANopen networks.

A.3.9 IEC 61850 gateway

The IEC 61850 gateway allows the data exchange between an EMS application and the control system for public electric power systems.

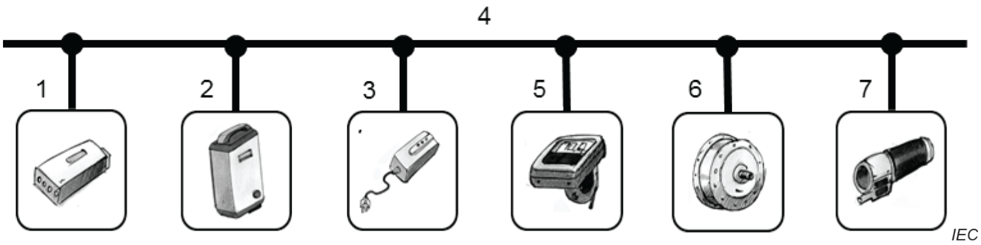
NOTE 1 The IEC 61850 gateway is not specified in this document but in CiA 454-12.

A.4 Use cases (informative)

A.4.1 EV use case

In these applications, the availability of several energy sources (e.g. battery systems, generators, etc.) as well as several energy loads (motors, sensors, lights, displays, battery systems, etc.) requires a comprehensive energy management. This document introduces therefore a DC power circuit that is controlled via a CANopen network.

Figure A.3 illustrates such a typical EMS application. The battery system provides the energy to the motor. The EMSC provides not only valid set points to the motor but is also responsible for the energy management; for example in case of lengthening the application by plugging a VCU to the EV. Displays and biometric sensors may be powered via the EMS as well, and offer the driver of the EV enhanced functionality.



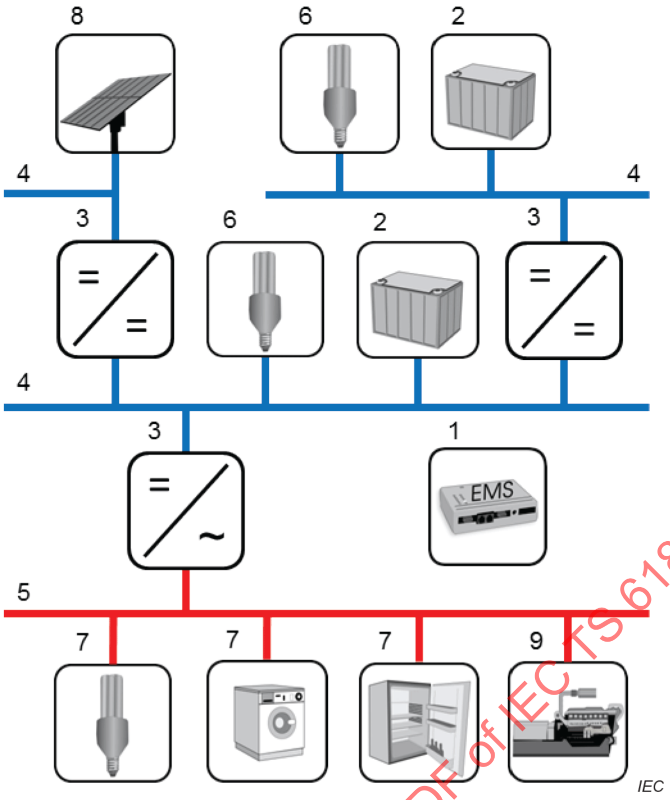
Key

1 energy management system controller
2 battery system
3 voltage converter unit
4 DC power circuit
5 human machine interface
6 motor control unit
7 sensor

Figure A.3 – EMS application in EV

A.4.2 Stationary use case

Subclause A.4.2 provides typical use cases for stationary EMSs, see Figure A.4.



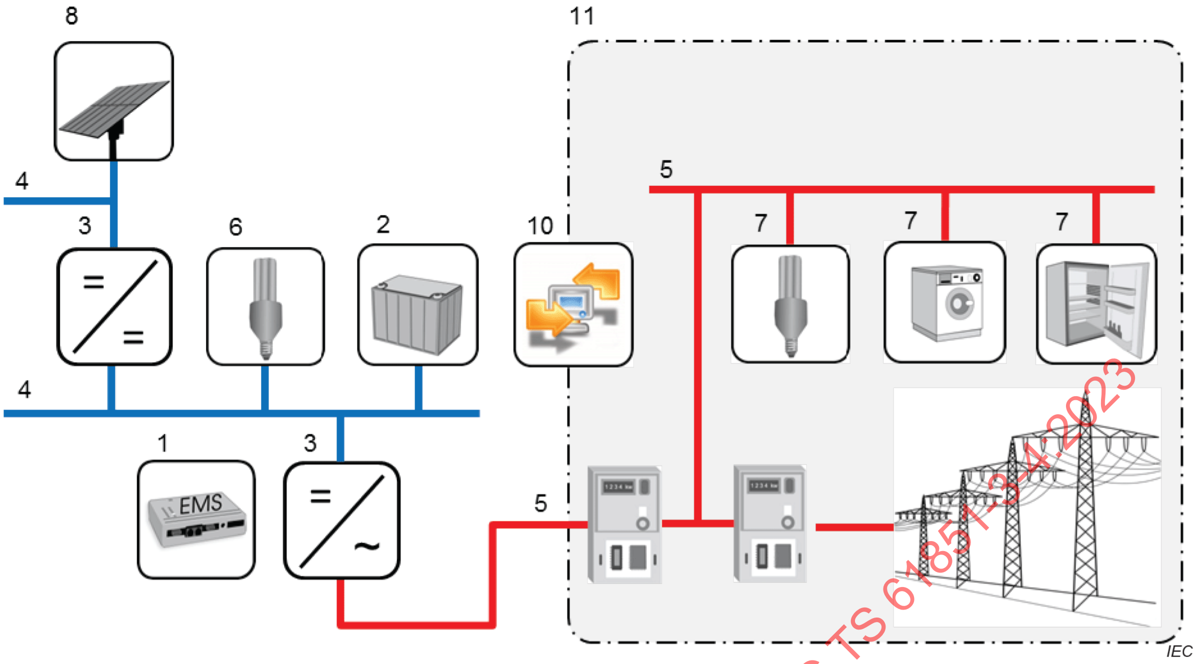
Key

1	energy management system controller
2	battery system
3	voltage converter unit
4	DC power circuit
5	AC power circuit
6	DC load unit
7	AC load unit
8	DC generator
9	AC generator
10	Gateway

Figure A.4 – Typically stationary photovoltaic hybrid off-grid application

One use case may be a stationary photovoltaic off-grid application as illustrated in Figure A.4. The solar cells produce power, which is provided to the DC or AC coupled consumers via the voltage converters. In case the solar cells are not able to produce sufficient power, a generator can support the infrastructure with additional powers. Surpluses of power may be buffered in the battery systems. As the devices are interconnected via CANopen, one host controller is able to optimize the energy management (e.g. which energy source or load shall be activated or disabled).

Another use case for stationary EMS application is the self-consumption regulation as illustrated in Figure A.5.



Key

1	energy management system controller
2	battery system
3	voltage converter unit
4	DC power circuit
5	AC power circuit
6	DC load unit
7	AC load unit
8	DC generator
10	Gateway
11	not part of this document

Figure A.5 – Use case according to self-consumption regulation

In this use case, the EMS is used to regulate the submission of self-produced energy to the public infrastructure. The solar cells produce the energy, and the produced energy may be buffered in a battery system, until the best moment (e.g. with regard to making profit) of submitting the energy to public infrastructure is reached. The accompanying CANopen-based control network of the EMS approach realizes this management.

Annex B
(normative)

Energy management system controller (EMSC)

B.1 General

Annex B specifies tasks and application objects of the virtual device energy management system controller (EMSC).

B.2 Object dictionary

B.2.1 General

The CANopen device hosting the virtual device EMSC shall provide network management master functionality as specified in CiA 302-1:2009.

B.2.2 NMT communication objects

B.2.2.1 General

The objects shall be used to identify CANopen devices connected to the EMS.

B.2.2.2 Object 1F80$_h$: NMT startup

The EMSC shall implement this object. Among others, this object indicates the device's NMT master capability. For details, see CiA 302-2:2009.

B.2.2.3 Object 1F81$_h$: NMT slave assignment

This object shall be implemented. It assigns CANopen devices to the NMT master, the device that shall implement this object. For details, see CiA302-2:2009.

B.2.2.4 Object 1F82$_h$: Request NMT

This object shall be implemented. It allows requesting a specific NMT service for a unique CANopen device in the network or for all CANopen devices in the network. For details, see CiA302-2:2009.

B.2.2.5 Object 1F84$_h$: Device type identification

This object shall be implemented. It is used for verification of the other network participants in the EMS application. For details, see CiA302-2:2009.

B.2.2.6 Object 1F85$_h$: Vendor identification

This object shall be implemented. It is used for verification of the other network participants in the EMS application. For details, see CiA302-2:2009.

B.2.2.7 Object 1F86$_h$: Product code

This object shall be implemented. It is used for verification of the other network participants in the EMS application. For details, see CiA302-2:2009.

B.2.2.8 Object 1F87$_h$: Revision number

This object shall be implemented. It is used for verification of the other network participants in the EMS application. For details, see CiA302-2:2009.

B.2.2.9 Object 1F88$_h$: Serial number

This object shall be implemented. It is used for verification of the other network participants in the EMS application. For details, see CiA302-2:2009.

B.2.3 Produced application objects

B.2.3.1 General

Subclause B.2.3 defines the application objects produced by EMSC.

B.2.3.2 Object 6080$_h$: EMS status

This object shall provide the status of EMS.

Figure B.1 illustrates the value structure. Table B.1 shall provide the value definition. Table B.2 specifies the object description and Table B.3 specifies the entry description.

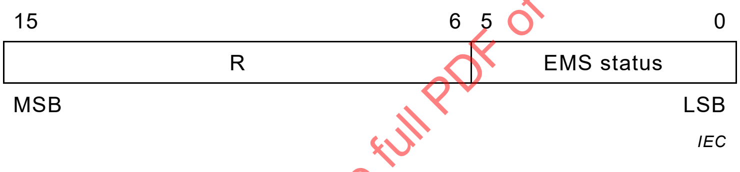


Figure B.1 – Value structure

Table B.1 – Value definition

Name	Bit	Value	Description
EMS status	0	0_b	Power circuit off
		1_b	Power circuit on
	1	0_b	EMS is sleeping or on transition to "sleep"
		1_b	EMS is not sleeping, ready to work
	2	0_b	CAN communication is not working properly
		1_b	CAN communication is working properly
	3	0_b	Reserved (always 0)
	4	0_b	EMS no warning
		1_b	EMS warning; reason shall be given in manufacturer specific object
	5	0_b	EMS no error
		1_b	EMS error; reason shall be given in manufacturer specific object
r	6 to 15	0_b	Reserved (always 0)

Table B.2 – Object description

Attribute	Value
Index	6080_h
Name	EMS status
Object code	VAR
Data type	UNSIGNED16
Category	Mandatory

Table B.3 – Entry description

Attribute	Value
Sub-Index	00_h
Access	Ro
PDO mapping	Optional
Value range	See value definition
Default value	No

B.2.3.3 Object 6081_h: Type of EV (optional)

Figure B.2 illustrates the object structure. This object applies for mobile energy management only and shall provide information about the type of EV. Table B.4 and Table B.5 specifies the value definitions. Table B.6 specifies the object description and Table B.7 specifies the entry description.

NOTE Vehicle classification is subject to local or national regulation.

15	14 … 8	7 … 0
Reserve	Speed	EV type
MSB		LSB

IEC

Figure B.2 – Object structure

Table B.4 – Value definition EV type

Value [hex]	Description
00_h	Not applicable
01_h	EV
02_h	Electrical bicycle
03_h	Motor-bike
04_h	Scooter
05_h	Wheelchair
06_h	Robot
07_h to FF_h	Reserved

Table B.5 – Value definition speed

Value [hex]	Description
00_h	Not applicable
01_h to FE_h	Designed speed given in multiples of 1 km/h
FF_h	Designed speed equal or higher than 255 km/h

Table B.6 – Object description

Attribute	Value
Index	6081_h
Name	Type of EV
Object code	VAR
Data type	UNSIGNED16
Category	Mandatory

Table B.7 – Entry description

Attribute	Value
Sub-Index	00_h
Access	ro
PDO mapping	Optional
Value range	See value definition
Default value	No

B.2.3.4 Object 6093_h: EMSC status

This object shall provide the current status of the EMSC.

NOTE This parameter is primary intended to evaluate the EMSC functionality by, for example, diagnostic tools.

Figure B.3 illustrates the value structure. Table B.8 shall provide the value definition. Table B.9 specifies the object description and Table B.10 specifies the entry description.

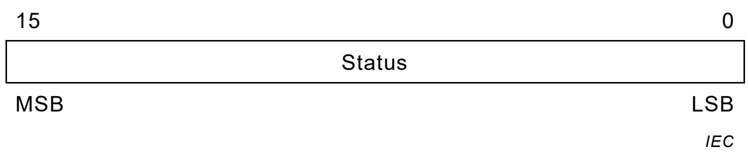


Figure B.3 – Value structure

Table B.8 – Value definition

Name	Bit	Value	Description
Status	0	0_b	Silent master mode not active
		1_b	Silent master mode active
	1	0_b	EMSC is not controlling the energy management
		1_b	EMSC is controlling the energy management
	2 to 15	0_b	Reserved; always 0

Table B.9 – Object description

Attribute	Value
Index	6093_h
Name	EMSC status
Object code	VAR
Data type	UNSIGNED16
Category	Mandatory

Table B.10 – Entry description

Attribute	Value
Sub-Index	00_h
Access	ro
PDO mapping	Optional
Value range	See value definition
Default value	No

B.2.4 Consumed application objects

B.2.4.1 General

Subclause B.2.4 defines the consumed application objects. The CANopen device hosting the virtual device EMSC shall consume these objects.

B.2.4.2 Object 6090_h: Priority source (optional)

This object shall provide information about EMS sources and shall indicate switching on/off priority of the sources. The sources, available in the EMS application, are listed in object $1F84_h$. Sources with high priority provide more energy to the EMS than the sources with low priority. Sources with high priority shall be switched on before and switched off after sources with low priority, to maintain stable power distribution on the EMS. In case a source with high priority does not provide enough energy to the EMS, additionally, sources with lower priority shall be used. The values shall be given in multiples of 0,01 %. The value definition is provided in Table B.11. Table B.12 specifies the object description and Table B.13 specifies the entry description.

Table B.11 – Value definition

Value	Description	Function
0000_h	0% Priority	Device with lowest priority
To		
2710_h	100% Priority	Device with highest priority
2711_h to $FFFF_h$	-	Reserved

Table B.12 – Object description

Attribute	Value
Index	6090_h
Name	Priority source
Object code	ARRAY
Data type	UNSIGNED16
Category	Optional

Table B.13 – Entry description

Attribute	Value
Sub-index	00_h
Description	Highest sub-index supported
Entry category	Mandatory
Access	ro
PDO mapping	No
Value range	01_h to FE_h
Default value	No
Sub-index	01_h
Description	Priority source node-ID 1
Entry category	Mandatory
Access	rw
PDO mapping	Optional
Value range	See value definition
Default value	Manufacturer-specific
Sub-index	02_h
Description	Priority source 2
Entry category	Optional
Access	rw
PDO mapping	Optional
Value range	See value definition
Default value	Manufacturer-specific
To	
Sub-index	FE_h
Description	Priority source 254
Entry category	Optional
Access	rw
PDO mapping	Optional
Value range	See value definition
Default value	Manufacturer-specific

B.2.4.3 Object 6091_h: Priority load (optional)

This object shall provide information about EMS loads and shall indicate switching on/off priority of the sinks. Loads, available in the EMS application, are listed in object $1F84_h$. The load with low priority may consume more energy from the EMS than the load with high priority. The load with high priority shall be switched on before and switched off after the load with low priority to maintain stable power distribution on the EMS. The values shall be given in multiples of 0,01 %. The value definition is provided in the Table B.14. Table B.15 specifies the object description and Table B.16 specifies the entry description.

Table B.14 – Value definition

Value	Description	Function
0000_h	0% Priority	Device with lowest priority
To		
2710_h	100% Priority	Device with highest priority
2711_h to $FFFF_h$	-	Reserved

Table B.15 – Object description

Attribute	Value
Index	6091_h
Name	Priority load
Object code	ARRAY
Data type	UNSIGNED16
Category	Optional

Table B.16 – Entry description

Attribute	Value
Sub-index	00_h
Description	Highest sub-index supported
Entry category	Mandatory
Access	ro
PDO mapping	No
Value range	01_h to FE_h
Default value	No
Sub-index	01_h
Description	Priority load 1
Entry category	Mandatory
Access	rw
PDO mapping	Optional
Value range	See value definition
Default value	Manufacturer-specific
Sub-index	02_h
Description	Priority load 2
Entry category	Optional
Access	rw
PDO mapping	Optional
Value range	See value definition
Default value	Manufacturer-specific
to	
Sub-index	FE_h
Description	Priority load 254
Entry category	Optional
Access	rw
PDO mapping	Optional
Value range	See value definition
Default value	Manufacturer-specific

B.2.4.4 Object 6092_h: EMSC request

This object shall indicate commands and requests to the EMSC.

NOTE This parameter is primary intended to influence the EMSC functionality by, for example, diagnostic tools.

Figure B.4 illustrates the value structure. Table B.17 shall provide the value definition. Table B.18 specifies the object description and Table B.19 specifies the entry description.

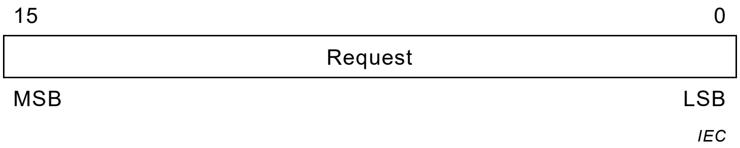


Figure B.4 – Value structure

Table B.17 – Value definition

Name	Bit	Value	Description
Request	0	0_b	No action
		1_b	Request silent master mode
	1	0_b	Request EMSC shall start or continue controlling the energy management
		1_b	Request EMSC shall stop controlling the energy management
	2 to 15	0_b	Reserved; always 0

Table B.18 – Object description

Attribute	Value
Index	6092_h
Name	EMSC request
Object code	VAR
Data type	UNSIGNED16
Category	Mandatory

Table B.19 – Entry description

Attribute	Value
Sub-Index	00_h
Access	rw
PDO mapping	Optional
Value range	See value definition
Default value	0000_h

B.3 Tasks of an EMSC

B.3.1 General

Clause B.3 clarifies the tasks of an EMSC, for example network management and compatibility check. The recommended practice for these tasks of the EMSC is based on the system topology as illustrated in Figure 9.

The EMSC manages all registered devices in a list within its object dictionary ($1F84_h$ to $1F88_h$, 6000_h). In this listing, all devices are managed that were detected by the EMSC by means of the layer setting services (LSS). Therefore, all LSS addresses are available for the EMSC to check, for example after a power loss, whether still the same devices are available.

It is task of the EMSC to register, manage and release all devices, participating in the EMS.

B.3.2 Start-up

The EMSC, hosting the LSS master, scans permanently the entire network for unconfigured devices (CANopen node-ID equal to FF_h) by means of the LSS identify non-configured remote slave service (see CiA 305). The LSS master finds and distinguishes between the unconfigured devices by means of the LSS fastscan service. The EMSC assigns unique node-IDs to the unconfigured devices in the range 2 to 119. It is recommended that the EMSC administers all LSS addresses of the detected devices in its object dictionary in the objects $1F84_h$ to $1F88_h$ (see CiA 302). The detected devices respectively the node-ID management is handled via the object $1F81_h$.

The EMSC configures SDO client channels to all detected devices and configures the RPDOs, which are complementary to the TPDOs of the detected device.

The EMSC executes a SDO read access to object 1000_h (Device type), 1018_h (Identity) and 6000_h (Supported virtual devices) for device identification. In addition the EMSC adjusts the heartbeat consumer for all detected devices.

B.3.3 Compatibility check

During the compatibility check, the EMSC evaluates, whether the detected devices are allowed to operate in the EMS. During compatibility check, the EMSC fulfils the tasks defined in Table B.20.

Table B.20 – Compatibility check

Requirements	Condition
The EMSC verifies the origin of the detected device (device's identity, device hard- and software version).	Only if the device's origin fits, the compatibility check is going on; otherwise failed.[a]
The EMSC evaluates the supported virtual devices.	If required the EMSC attempts adjusting the global instance number by means of SDO write access to object 6000h "instance offset" bit field. Only if the maximum number of instances of that type of virtual device is not exceeded and if the adjustment of the instance offset was successful, the compatibility check is continued; otherwise failed.
For active devices, the EMSC checks the parameters that are relevant for operating at the power lines (device class, max. voltage, max. current, etc.).	In case these parameters fit, the device has passed the compatibility test; otherwise compatibility check fails.
[a] If applicable, the EMSC may execute a firmware update.	

After passing the compatibility check successfully, the EMSC switches passive devices to FSA Operating state directly. For active devices, the EMSC may limit the operating parameters at the power lines by switching the device to FSA Limiting.

B.3.4 Releasing devices

In case a device is released from the EMS, the EMSC fulfils the following tasks:

- the EMSC disables the power lines of the device to be released in a safe way;
- the EMSC triggers a state transition to FSA Disconnected;
- the related entries in object $1F81_h$, $1F84_h$ to $1F88_h$ are deleted;

In order to allow a fast recognition of devices that had already been attached to that EMS, It is recommended to store the LSS addresses of all detected devices permanently in an EMSC-internal memory.

– the related RPDOs are set to invalid;
– the related heartbeat consumer is set to invalid in object 1016_h;
– the number of global instances of that virtual device is decreased.

In order to avoid gaps in the instance number management it can be helpful to reduce the instance offset of the remaining virtual devices of that class. In case this is done, the PDO configuration shall be reconfigured as well.

In case a device detects an unintended absence of a device (e.g. by missing heartbeat), the EMSC transfers the system into the safe state.

B.3.5 "Sleep"- mode

The EMSC is responsible for the "sleep" management. At the EMSC the final decision is taken, whether either the entire EMS or parts of it are turned to "sleep" or kept awake. The "sleep" management is done as defined in Annex D.

Annex C
(informative)

Implementation guidelines

C.1 General

This informative annex provides implementation guidelines for IEC 61851-3 (all parts).

C.2 Timings

C.2.1 General

Clause C.2 provides timing definitions for EV.

C.2.2 Start up

All devices shall be capable to communicate within 125 ms after power on.

C.3 Master handling

C.3.1 General

The IEC 61851-3 series demands that in any case the master-functionality residing in the EV-internal EMSC is the highest prior master-functionality in EMSs. In case there is no EV-internal master-capable device available, another device, for example the DRI EV supply equipment, may overtake the master functionality.

C.3.2 Detecting master availability

The DRI EV supply equipment is able to detect the availability of an EV-master by means of scanning for the heartbeat message with node-ID 1 (CAN message 701_h). In case this message is available, an EV-internal EMSC/master is active. The DRI EV supply equipment acts as "silent master" and does not issue any NMT or LSS master services, does not use the first SDO server channels of other devices in the network and does not transmit the SYNC message. In such a case, the EV-EMSC is going to transfer all relevant data between DRI EV supply equipment and other active devices.

In case an EV-master is starting up, this device is scanning for the heartbeats of the DRI EV supply equipment (VCU; node-ID 127; CAN message $77F_h$) and the diagnostic tool (node-ID 125; CAN message $77D_h$).

C.3.3 EMSC SDO handling

The EV-internal master claims the SDO default server channels of all other devices in the network. Therefore the EMSC is responsible for transferring data that needs to be interchanged between other devices in the network (e.g. a VCU requires the battery chemistry as well as maximum and minimum voltage for managing the power transfer process).

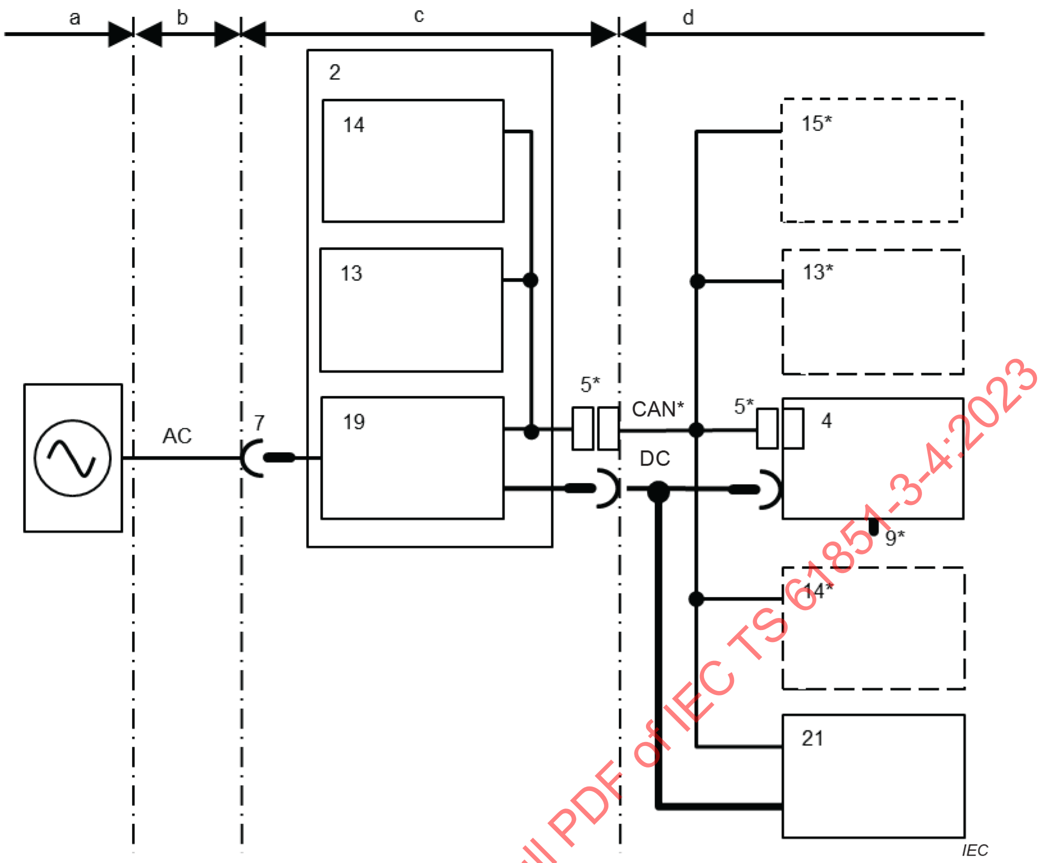
C.4 Design of voltage converter unit communication for EVs

C.4.1 Use cases

A (public) power transfer infrastructure is not only be used for serving power transfer requests. It is possible as well that the power transfer infrastructure is used as generic power supply for the EV.

In such a scenario, for example, the heating can be enabled/disabled suddenly during the power transfer process. This may cause a fast increase/decrease of the current and the measured current at the VCU will differ from the "charge current" at the battery.

Such a scenario, as illustrated in Figure C.1, is not in the scope of Annex C.



Key	Description	Abbreviation
a	supply network (AC or DC), and fixed installation (according to IEC 60364)	
b	stationary equipment (see 6.6 of IEC TS 61851-3-1:2023)	
c	portable or mobile equipment (see 6.6 of IEC TS 61851-3-1:2023)	
d	EV (located inside of the electric vehicle)	EV
2	portable or mobile DRI EV supply equipment	
4	removable or non-removable RESS (battery system)	
7	standard plug and socket-outlet (AC) (according to IEC 60884 or IEC 60309)	
8	dedicated plug and socket-outlet (DC) (according to IEC TS 62196-4)	
10	EMS controller in the EV (according IEC 61851-3 series)	EV-EMSC
11	human machine interface, passive device, optional (according to CiA 454)	HMI
12	motor control unit, optional (according to CiA 454)	MCU
13	microcontroller (with local EMS in the VCU (according IEC 61851-3-4)	EMSC
21	load unit	
*	optional	

Figure C.1 – Voltage converter unit used as power supply for EV

C.4.2 Recommended power transfer protocol

C.4.2.1 General

In case a battery system is connected directly to the VCU, the VCU EMSC has full access to the battery system by means of the CANopen communication link between the VCU and exactly one battery system. Therefore the VCU-manufacturer can implement any manufacturer-specific type of power transfer to the battery system, as full control of the battery system via the CANopen communication link is guaranteed.

The power transfer protocol described in C.4.2 is intended for power transfer with an EV in the public. As there is only one master-application allowed, the master-application (EMSC) that is available in the VCU is "silent" (refer to silent master, 3.18). As the EV-EMSC claims all Default SDO server channels of all devices in the EV, the EV- EMSC moderates the power transfer process. The VCU is not able to access EV-internal devices (e.g. the battery system) via SDO. It is the task of the EV- EMSC to transfer all relevant data between the VCU and the battery system.

C.4.2.2 Startup

After connecting the EV to the VCU, the VCU-EMSC detects the EV-EMSC's heartbeat (node-ID 1). The sequence diagram in Figure C.2 illustrates the start-up. As EV-application, an EV is used.

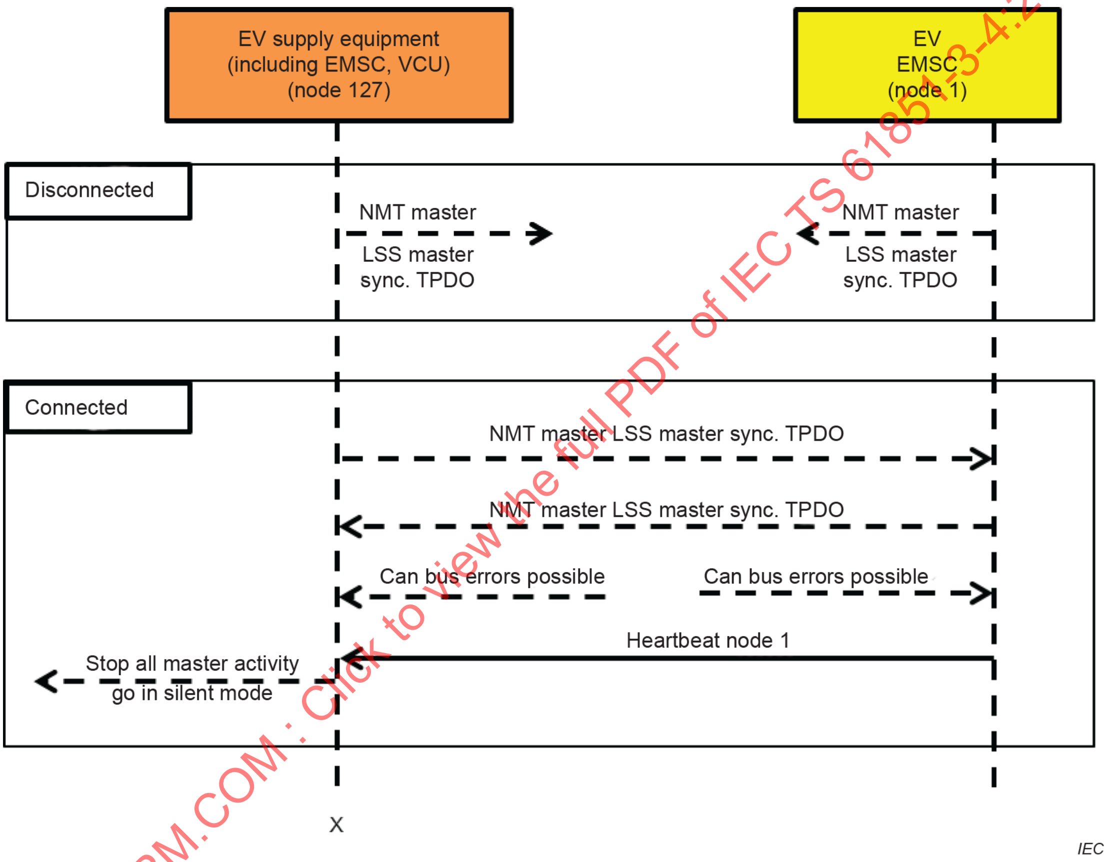


Figure C.2 – Sequence diagram for startup of the connection

On detecting this heartbeat, the EMSC in the VCU (VCU-EMSC) is not allowed to fulfil the following tasks:

– sending of NMT protocols;
– sending of EMSC-related TPDOs;
– sending of LSS protocols;
– device handling in general.

In addition, the VCU-EMSC:

– switches from SYNC producer to consumer;
– shall remain or switch to NMT operational;
– shall switch EMS FSA to "Compatibility check".

C.4.2.3 Compatibility check

Figure C.3 illustrates the scenario, when a new device is connected. The EV-EMSC reads the configuration of the CANopen device "VCU" and executes among others the compatibility check for the supported virtual devices. A major criterion for compatibility is that the maximum voltage (index 6026_h) of the battery system is located between minimum (index 6027_h) and maximum voltage (index 6026_h) of the voltage converter.

In addition it is required that the battery system is able to indicate the voltage limitations as well as the input current limitations. The voltage converter is also able to limit the voltage as well as the current input to the EMS.

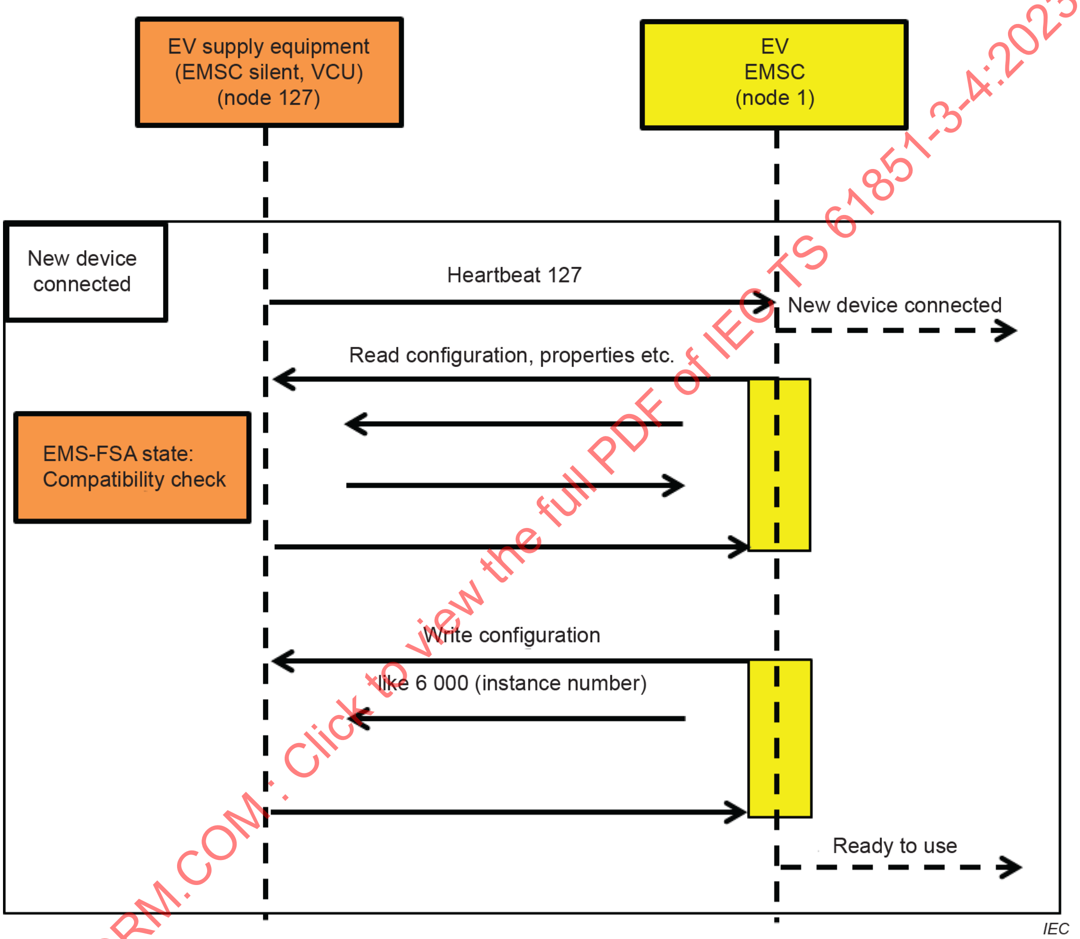


Figure C.3 – Sequence diagram "New device connected"

C.4.2.4 Configuration

At this point, the battery system is in EMS FSA Operating and the virtual devices supported by the CANopen device "VCU" have successfully passed the compatibility check. During the configuration, some information for the power transfer process is transferred between VCU and battery (Sub-index = VDN by default). Figure C.4 illustrates this procedure.

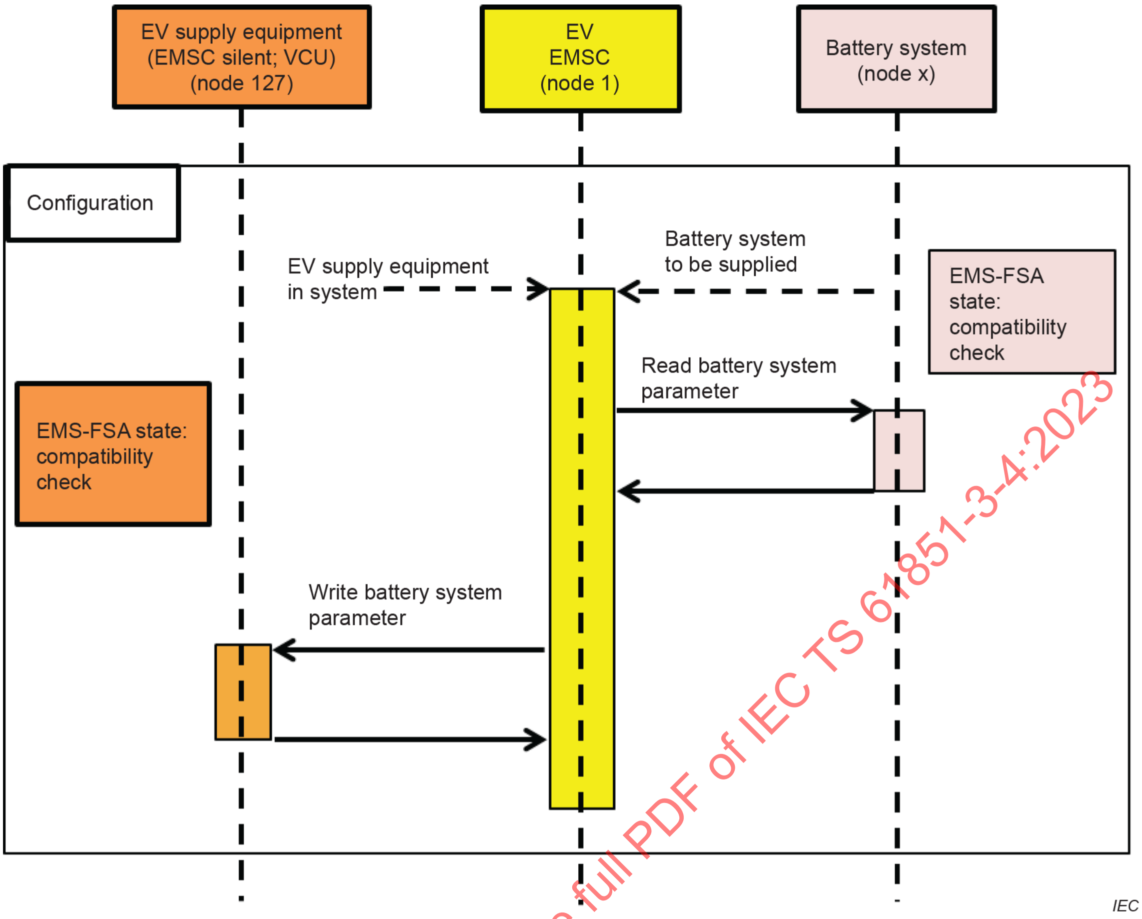


Figure C.4 – Preparation of the power transfer procedure

Table C.1 provides all data that is transferred by the EV-EMSC to the CANopen device "VCU". The table applies with the restriction that all potentially available, EV-internal voltage converters, start with a global instance number of at least two.

Table C.1 – Data transfer from battery system to VCU's

Index OD battery system	Index OD VCU	Description
6000_h sub 01_h	$60F0_h$ sub 01_h	The (calculated) global instance number of the battery system is required for RPDO configuration in the voltage converter. In addition the VDN is required to check the Emergencies.
$600A_h$ sub 01_h	$60F2_h$ sub 01_h	This parameter provides the device alarm capability. If the battery system does not support this parameter, 0x0000 is written to the voltage converter.
6100_h sub 01_h	$60F3_h$ sub 01_h	This parameter provides the type of battery system.
6102_h sub 01_h	$60F4_h$ sub 01_h	For example for error evaluations and timeout calculations, the rated battery Wh capacity is required.
6072_h sub 01_h	6072_h sub 81_h	Device available output voltage
6073_h sub 01_h	6073_h sub 81_h	Device available output current
6026_h sub 01_h	$60F5_h$ sub 01_h	The battery system's device maximum voltage (constant) is required for limiting voltage.
6027_h sub 01_h	$60F6_h$ sub 01_h	The battery system's device minimal voltage (constant) is required for testing under voltage conditions.
6024_h sub 01_h	$60F7_h$ sub 01_h	The battery system's maximum input current during charge (constant) is required for limiting the input current (device maximum continuous input current).
Battery system VDN 1 is assumed. In case VDN differs, the battery systems indices sub-index shall be adapted accordingly.		

The transfer, from the battery system to the voltage converter, of the additional parameters provided in Table C.2 allow a better error handling.

Table C.2 – Additional parameters relevant for power transfer process

Index OD battery	Index OD voltage converter	Description
6120_h sub 01_h	$60F9_h$ sub 01_h	The parameter provides the maximum battery system temperature during power transfer.
6121_h sub 01_h	$60FA_h$ sub 01_h	The parameter provides the minimum battery system temperature during power transfer.
Battery system VDN 1 is assumed. In case VDN differs, the battery systems indices sub-index shall be adapted accordingly.		

Furthermore, the EMSC provides the parameters as given in Table C.3 to the CANopen device "VCU".

Table C.3 – Additional parameters relevant for power transfer process

Index OD Voltage converter	Description
$60F1_h$ sub 01_h	The node-ID of the battery system to allow the reception of battery system's heartbeat and emergency messages.
$60F8_h$ sub 01_h	The intended power transfer limit is later in the power transfer process compared to the relative Wh capacity 6164h and is required for stopping charge in case this limit is reached.
Battery system VDN 1 is assumed. In case VDN differs, the battery systems indices sub-index shall be adapted accordingly.	

C.4.2.5 Limiting

The EV-EMSC shall configure the limits at the VCU's. The EV-internal EMSC sets the optional objects 6046_h (Device set maximum voltage) and $604B_h$ (Device set maximum continuous output current) in the voltage converter. Table C.4 summarizes the most important parameters for limiting.

Table C.4 – Most important parameters for limiting

Index OD battery	Index OD voltage converter	Description
6192_h sub 01_h	6192_h sub 81_h	Battery system estimated charging time
6193_h sub 01_h	6193_h sub 81_h	Battery system maximum charging time
6026_h sub 01_h	6046_h sub 01_h	Device set maximum voltage
6024_h sub 01_h	$604B_h$ sub 01_h	Device set maximum continuous output current (optional)
Battery system VDN 1 is assumed. In case VDN differs, the battery systems indices sub-index shall adapted accordingly. NOTE The battery system input current is considered equal to the voltage converter output current.		

The EV-EMSC shall check the correct configuration. The configuration of the limiting is illustrated in Figure C.5.

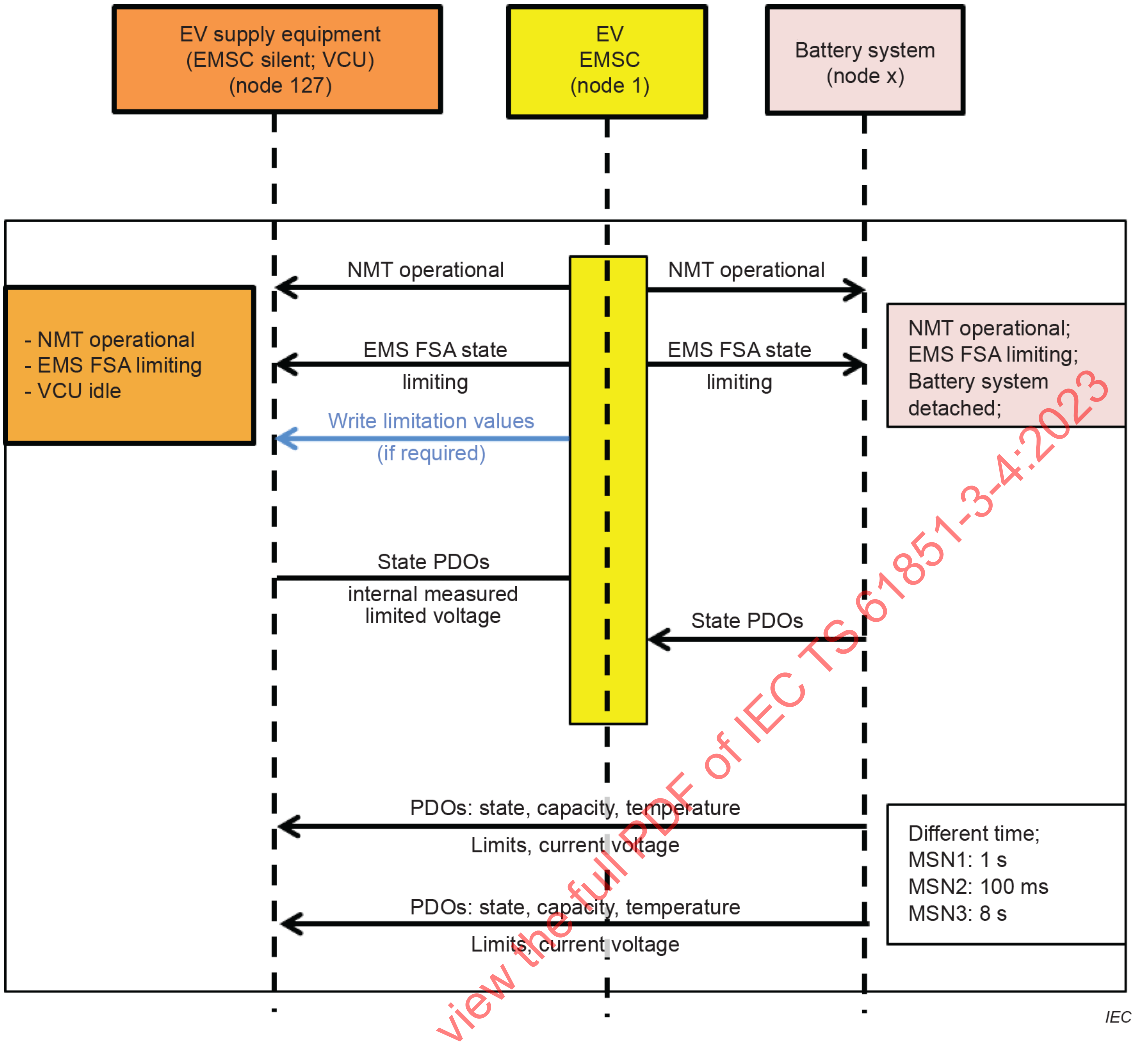


Figure C.5 – Configuration of limitations

The limits are given depending on the maximum current and voltage values as provided in Table C.5.

Table C.5 – Limit calculation for battery systems

Parameter	Name	Required for	Description
6020_h	Device dynamic voltage limitation	power transfer	The value is given in X % of the device maximum voltage (6026_h).
6022_h	Device dynamic current input limitation	power transfer	The value is given in X % of the maximum input current during charge (6024_h).
6023_h	Device dynamic current output limitation	continuous output current	The value is given in X % of the maximum continuous output current (6025_h).

C.4.2.6 Start power transfer and power transfer in progress

The way the power transfer procedure is initiated is illustrated in Figure C.6.

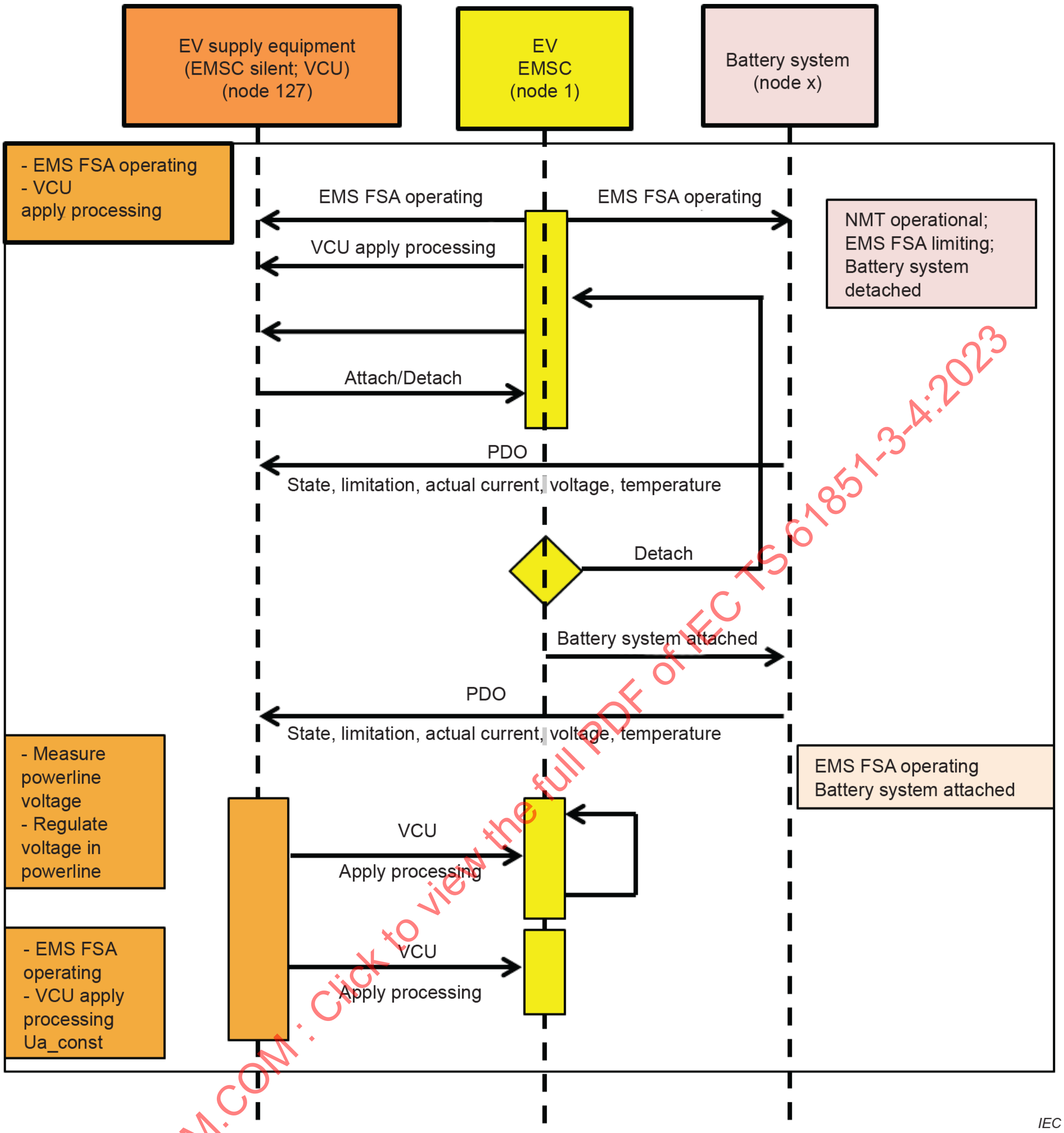


Figure C.6 – Start up procedure for initiate power transfer

The VCU requires an attached battery system to measure the voltage for starting the power transfer process. Starting the power transfer process covers the following steps.

a) The EV-EMSC initiates at the VCU "Apply processing" via the control word.

b) The EV-EMSC reads the battery system command at the VCU and commands "attach battery system to the power line" via control word. The input FETs for power transfer are activated

NOTE If supported, input FETs are commanded separately.

c) The VCU measures battery system voltage in attached state.

d) The VCU configures itself to the measured voltage.

e) The VCU provides power to the power line in the adjusted way of processing, for example U_b_const.

Table C.6 summarizes the parameters that have to be transferred from the battery system to the voltage converter so that the voltage converter is able to execute a safe and secure power transfer procedure. Some parameters are available on the CANopen network via PDO. Others have to be transferred cyclically by the EV-EMSC by SDO.

Table C.6 – Data transfer from battery to VCUs

Index OD battery	Index OD voltage converter	Description
6009_h sub 01_h	$60FB_h$ sub 01_h	Battery system alarm status to be transferred via SDO cyclically
6002_h sub 01_h	6002_h sub 01_h	Device status transferred via PDO MSN1
$603E_h$ sub 01_h	$603E_h$ sub 01_h	Actual current transferred via PDO MSN2, to detect a difference between VCU and battery system actual current, for example in case of other consumers
6040_h sub 01_h	6040_h sub 01_h	Actual voltage transferred via PDO MSN2, to detect errors
6020_h sub 01_h	6020_h sub 01_h	Device request for dynamic voltage limitation transferred via PDO MSN1 (x % of maximum voltage of the battery system).
6022_h sub 01_h	6022_h sub 01_h	Device request for dynamic current input limitation transferred via PDO MSN1 (x % of continuous input current). [a]
6160_h sub 01_h	6160_h sub 01_h	Absolut Wh capacity transferred in PDO MSN3
6164_h sub 01_h	6164_h sub 01_h	Relative Wh capacity transferred in PDO MSN3
6105_h sub 01_h	6105_h sub 01_h	Highest temperature of the battery system temperature transferred in PDO MSN3
6192_h sub 01_h	6192_h sub 81_h	Battery system estimated charging time

Battery VDN 1 is assumed. In case VDN differs, the battery systems indices sub-index shall be adapted accordingly.

[a] The battery system itself is not able to limit its input current but it is able to ask for the limitation (at the voltage converter).

In order to allow the voltage converter to send commands to the battery, the EV-EMSC transfers cyclically the parameters listed in Table C.7 from the voltage converter to the battery system.

Table C.7 – Data transfer from VCUs to the battery

Index OD voltage converter	Index OD battery	Description
$60FC_h$ sub 01_h	6001_h sub 01_h	Command from the VCU to attach/detach the battery system to/from the power line.

Battery system VDN 1 is assumed. In case VDN differs, the battery systems indices sub-index shall be adapted accordingly.

The control of the power transfer process is illustrated in Figure C.7.

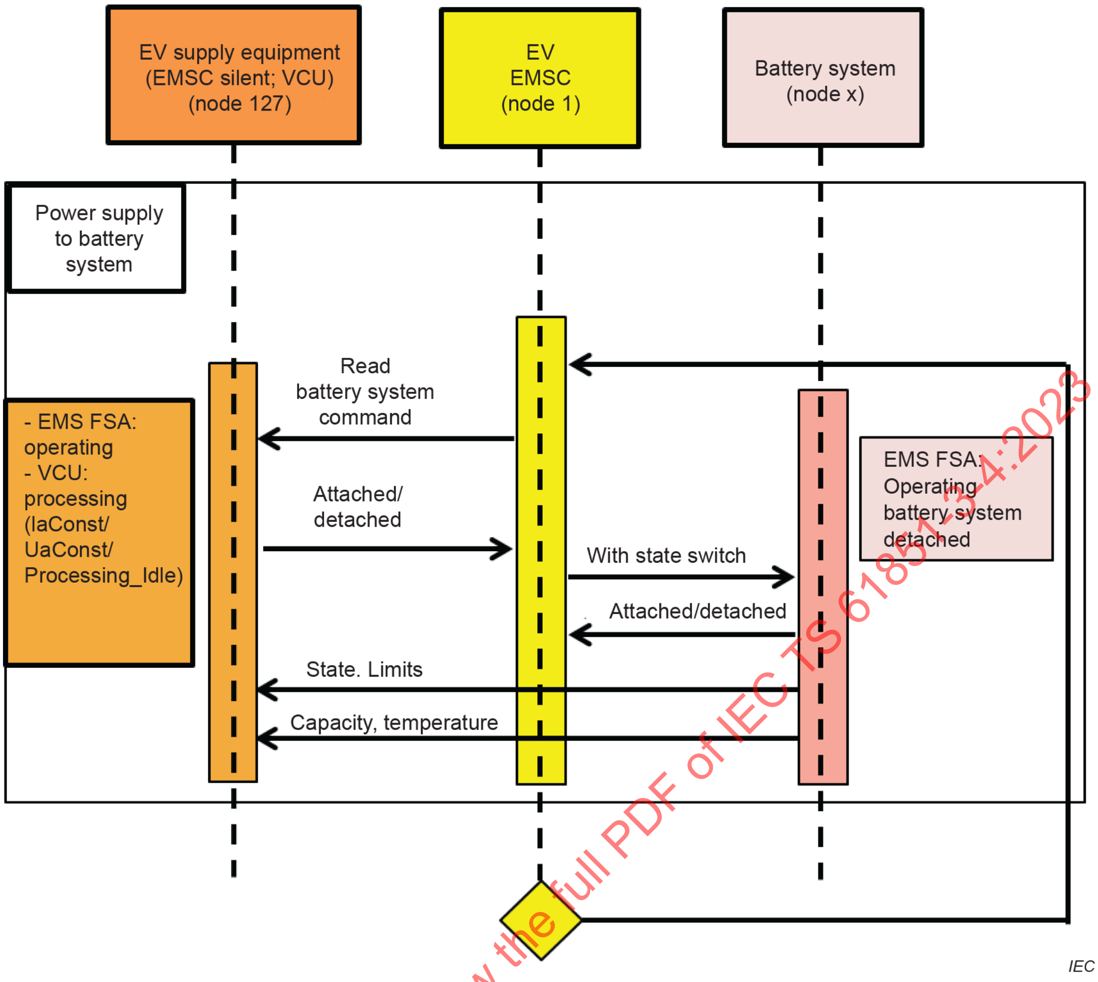


Figure C.7 – Power transfer in progress

C.4.2.7 End of power transfer

There are two possibilities for the end of power transfer:

– abrupt, for example in case the battery system detaches itself or the VCU stops the power supply in case the power transfer limit is reached;

– a smooth transition to stop the power supply. The VCU may request a "Detach" at the battery system. The VCU may switch to stop processing either on command of the EV-EMSC or by trigger of the local application.

Leaving the processing state sets the data of the battery system to be supplied invalid at the VCU. Also "set max. voltage" and "set max. output current" become invalid on this state transition.

Annex D
(normative)

Power management via "sleep"

D.1 General

Annex D specifies services and protocols for power management, for example "sleep" and wake-up mechanisms. It considers CAN transceivers, which support power management and are wake-up capable. A transceiver is wake-up capable if it is capable of waking up via the CAN bus, for example CAN transceivers compliant to ISO 11898-5:2007 or ISO 11898-6:2013.

NOTE Awaking the EMS in a EV application can be triggered either by CAN traffic, via a local input signal or further application-specific events.

D.2 Operation principles

D.2.1 General

The power management provides services and protocols to either set all or none of the CANopen devices, which support power management, to a mode of reduced power consumption.

D.2.2 Pre-conditions

As defined in D.2.2, the power management during "sleep" demands pre-conditions that are prerequisite for the proper handling of switching to "sleep" and back to "Controller switched on". The following pre-conditions shall be fulfilled in the EMS.

- Unconfigured LSS slaves that enter NMT Initialisation state, shall not transmit any CAN message. In case there has been no LSS master request detected for at least 10 s, the LSS slave shall prepare "sleep".
- The LSS master shall cyclically ask, whether there is an unconfigured LSS slave in the network (for details see CiA 305). The cycle time for this request shall be in maximum 1 s.
- In case the NMT master intends to switch the system to "sleep", the NMT master shall not just stop transmitting the request for unconfigured LSS slaves but shall use the services specified in Clause D.2 (see D.3.2 and D.3.3). In case no "sleep" objection has been received, the LSS master shall stop the cyclically transmission of the request for unconfigured LSS slaves.

The detection of the absence of the NMT master/LSS master/EMSC causes a different behaviour in stationary EMS applications in comparison to mobile applications according to EV profile 1. In EVs according to EV profile 1, the absence or the NMT master/LSS master/EMSC is considered as error condition and the CANopen device shall transit to "Prepare "sleep". In stationary EMSs, this condition triggers the EMS FSA state transition to "Masterless operation" state. For detecting the absence of the master application, the heartbeat service is used.

D.2.3 Finite state automaton for power management

The power management state machine as shown in Figure D.1 shall be implemented. This state machine specifies the descent from "normal operation" to "sleep". The "sleep" may be entered in any NMT state. The "sleep" is only accessible from FSA Connected and Disconnected state as specified in Figure 11.

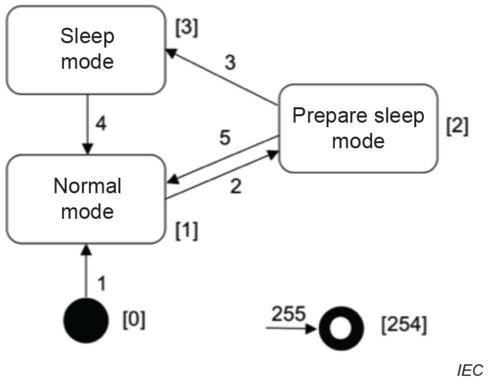


Figure D.1 – Power management FSA

The power management FSA shall provide the following states according to Table D.1.

Table D.1 – State description

Name	Description
Initial	Pseudo state, indicating the activation of the FSA.
Normal mode	In this state, the CANopen device may operate with the maximum power consumption.
Prepare "sleep"	On entering this mode, the CANopen device shall stop communication activities. The transmission of messages is stopped. This state is left based on time condition (t_{swt} = "sleep" wait time). [a]
"Sleep"	In this state, the power consumption of the CANopen device is reduced. The CANopen device applies the actual "sleep" policy. The state is immediately left, if it was entered with an active wake-up reason. A wake-up reason may be activated by a local event (detected via local inputs) or caused by activity on the network, detected by the CAN transceiver's remote wake-up detection capability. A wake-up reason needs to be handled by the local application and therefore requires leaving the "sleep".
Final	Pseudo state, indicating the deactivation of the FSA.
[a] In this state, the transmission and reception of heartbeat messages is disabled as well. Requests from the local SDO client, emergency messages and transmission of PDOs are inhibited. However, a CANopen device in Prepare "sleep" state is still capable to react on wake-up conditions.	

The FSA shall support the state transitions as given in Table D.2.

Table D.2 – Events and actions

Transition	Event(s)	Action(s)
1	Power on	
2	Reception of service "set "sleep" is indicated. [a, b]	Switch to FSA "sleep"
3	"sleep" wait time t_{swt} expired	
4	CAN transceiver has detected wake up event on the CAN bus. The CANopen device's application software has generated a wake up event.	Switch to either FSA Disconnected or FSA Connected state depending on the local settings
5	CAN transceiver has detected wake up event on the CAN bus. The CANopen device's application software has generated a wake up event.	Switch to either FSA Disconnected or FSA Donnected state depending on the local settings
254	Power off	

[a] Usually, the service "query sleep objection" is requested prior.

[b] In EV applications, unconfigured LSS slaves that do not receive an LSS master's request for a period of 10s, trigger this transition as well.

D.3 Services

D.3.1 General

The handling of the "sleep" requires further services. These additional services are specified in Clause D.3.

D.3.2 Service "query sleep objection" and "sleep objection"

By means of the "query sleep objection" service, the NMT master queries all CANopen devices in the network if a transition to "sleep" is possible. All CANopen device that are not able to switch to "sleep" because of application-specific reasons shall request the service "sleep objection". If the service "wake-up" is indicated during the objection time-out t_{oto}, the service "query sleep objection" is requested for a second time. Figure D.2 illustrates a rejected transition to "sleep". The "sleep" is rejected by CANopen device by means of the service "sleep objection".

If the service "sleep objection" is not indicated within the objection time-out t_{oto} at the NMT master, the NMT master may initiate the service "set "sleep".

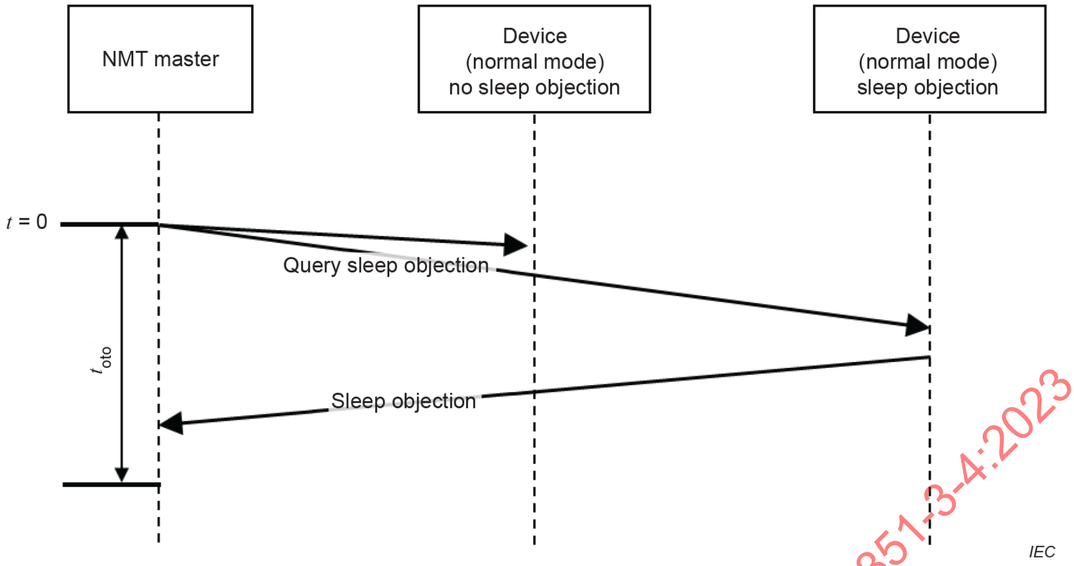


Figure D.2 – "Sleep" inhibited by objection

D.3.3 Service Set "sleep"

On the indication of the service Set "sleep", all CANopen devices shall enter the state Prepare "sleep". In the state Prepare "sleep" the CANopen device shall not transmit any CAN messages. After the "sleep" wait time t_{swt}, the CANopen device shall enter the state "sleep". Figure D.3 illustrates the transition to the state "sleep" without indication of the service "LSS sleep objection". Figure D.4 illustrates the use case of the request of the service "query sleep objection" for a CANopen device in "sleep".

In addition, an NMT master may request the service at any time in case the service "NMT sleep objection" is indicated.

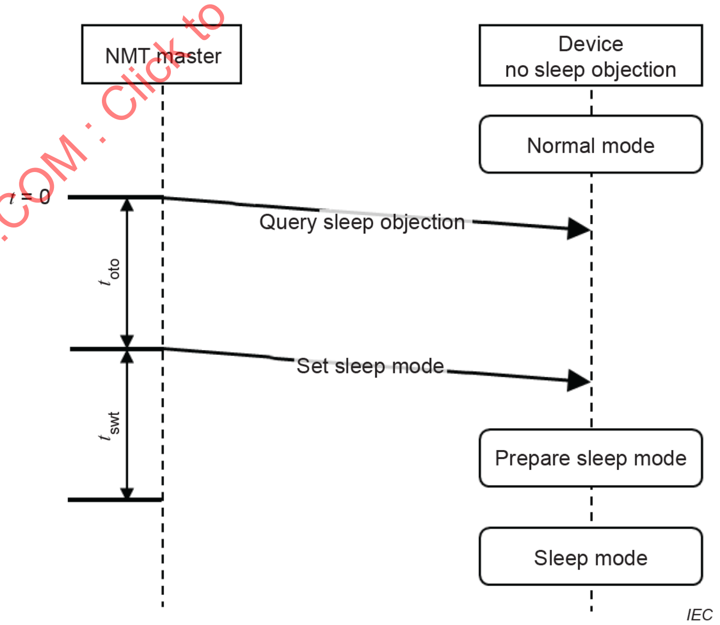


Figure D.3 – Transition into "sleep" without objection