



**International  
Standard**

**ISO 23316-6**

**Tractors and machinery for  
agriculture and forestry —  
Electrical high-power interface 700  
V DC / 480 V AC —**

**Part 6:  
Communication signals**

*Tracteurs et matériels agricoles et forestiers — Interface  
électrique haute puissance 700VDC/480VAC —*

*Partie 6: Signaux de communication*

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## Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO document should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see [www.iso.org/directives](http://www.iso.org/directives)).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see [www.iso.org/iso/foreword.html](http://www.iso.org/iso/foreword.html).

This document was prepared by Technical Committee ISO/TC 23, *Tractors and machinery for agriculture and forestry*, Subcommittee SC 19, *Agricultural electronics*.

The document is intended to be used in conjunction with the ISO 11783 series and the other parts of ISO 23316.

A list of all parts in the ISO 23316 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at [www.iso.org/members.html](http://www.iso.org/members.html).

## Introduction

Due to the requirements of modern agriculture, the precise control of implement functions is a key issue in agricultural technology. The required precision is difficult to achieve with mechanical or hydraulic devices; it is more efficient to provide control with electric and electronic means, i.e. electric power and ISOBUS. The use of electric power allows implement manufacturers to offer farmers improved implements that provide a higher degree of automation and navigation, resulting in greater precision, better power distribution, and better controllability.

The purpose of the ISO 23316 series is to provide a design and application standard covering implementation of electrical high-power interfaces operating with a nominal voltage of 700 V DC/480 V AC for manufacturers of agricultural machinery.

The ISO 23316 series specifies the physical and logical interface requirements that provide interoperability and cross compatibility for systems and equipment.

Conformance to the ISO 23316 series means all applicable requirements from ISO 23316-1 to ISO 23316-7 are met.

It is permitted for partial systems or components to conform to the ISO 23316 series by applying all applicable requirements, for example, for the plug, receptacle, or inverters, on a tractor or an implement.

NOTE 1 If a DC-mode only HPI is provided, it is not necessary to conform with ISO 23316-4 which describes AC-mode, as it is not applicable. If an AC-mode only HPI is provided, it is not necessary to conform with ISO 23316-5 which describes DC-mode, as it is not applicable.

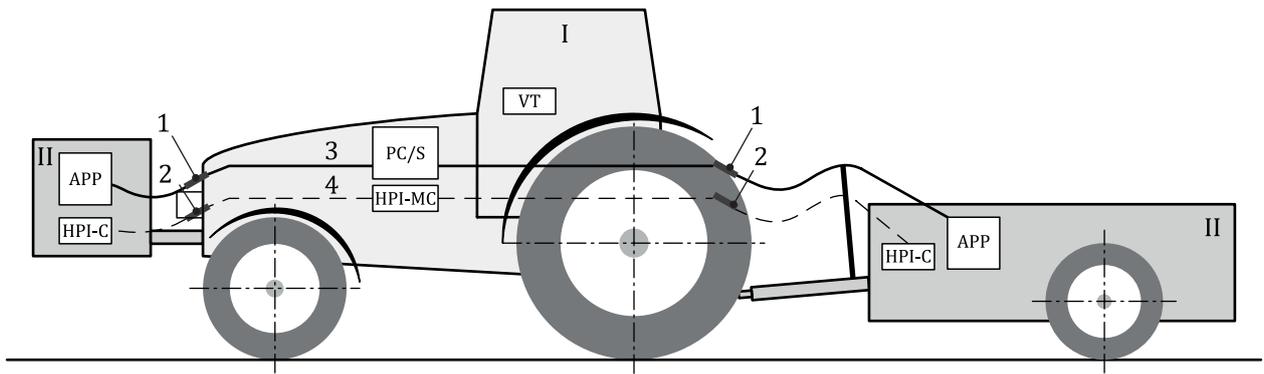
The ISO 23316 series defines an interface between a power providing device (supply system) and a power consuming device (consumer system), used within an automated electrified system in the agricultural industry. This series deals with electrical, mechanical and bus communication objectives and is used in conjunction with ISO 11783, which defines the ISOBUS. [Figure 1](#) portrays the elements of typical equipment that involve the high-power interface.

The following aspects are not within the scope of ISO 23316:

- service, maintenance, and related diagnostics;
- functional safety;
- control strategies for high-power supplies and loads;
- application-specific strategies and operational modes;
- component design;
- energy storage systems, e. g. supercapacitors or batteries;
- multiple electrical power supplies to a common DC link.

NOTE 2 [Annex D](#) lists some basic diagnostics by DTCs.

NOTE 3 For example, AEF guideline 007 handles some aspects of functional safety already.



**Key**

Symbol	Description	Symbol	Description
APP	application	1	high-power interface
PC/S	power converter/switch	2	ISOBUS connector
HPI-C	high-power interface - control	3	power lines
HPI-MC	high-power interface - master control	4	ISOBUS
VT	virtual terminal (user interface)	————	power connection
I	supply system	-----	signal connection
II	consumer system		

**Figure 1 — Typical elements of system incorporating a high-power interface**

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# Tractors and machinery for agriculture and forestry — Electrical high-power interface 700 V DC / 480 V AC —

## Part 6: Communication signals

### 1 Scope

This document specifies the communication interface, so that the transmitted parameters, signals and objects between a supply system (SS), with power converter/switch (PC/S) and high power interface – master control (HPI-MC) including the tractor implement management (TIM) server, and a consumer system (CS), with application (APP) and high power interface – control (HPI-C) including the TIM client and the task controller, can be used in the agricultural industry. The mentioned signals are used during identification, initialization, operation, and shutdown modes of operation.

This document does not cover the definitions of suspect parameter numbers (SPNs) for the signals, within the parameter group numbers (PGNs) for messages and the message setup. These definitions are given in ISO 11783 and SAE J1939.

NOTE For information on messages (PGNs) see also [Annex B](#).

### 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.

ISO 16230-1:2015, *Agricultural machinery and tractors — Safety of higher voltage electrical and electronic components and systems — Part 1: General requirements*

ISO 23316-1, *Tractors and machinery for agriculture and forestry — Electrical high-power interface 700 V DC / 480 V AC — Part 1: General description*

ISO 23316-2, *Tractors and machinery for agriculture and forestry — Electrical high-power interface 700 V DC / 480 V AC — Part 2: Physical layer*

ISO 23316-4:2023, *Tractors and machinery for agriculture and forestry — Electrical high-power interface 700 V DC / 480 V AC — Part 4: AC operation mode*

ISO 23316-5:2023, *Tractors and machinery for agriculture and forestry — Electrical high-power interface 700 V DC / 480 V AC — Part 5: DC operation mode*

ISO 23316-7, *Tractors and machinery for agriculture and forestry — Electrical high-power interface 700 V DC / 480 V AC — Part 7: Mechanical integration*

ISO 11783 (all parts), *Tractors and machinery for agriculture and forestry — Serial control and communications data network*

IEC 60204:2016, *Safety of machinery — Electrical equipment of machines*

SAE J1939DA, *Serial Control and Communications Heavy Duty Vehicle Network — Digital Annex*

### 3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 23316-1, ISO 23316-2, ISO 23316-4, ISO 23316-5, ISO 23316-7 and the following apply.

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

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

#### 3.1

##### **direction of rotation**

positive values for frequency or speed related to powering the power converter phases in the sequence U V W positive torque means torque in the direction of positive speed

Note 1 to entry: If not stated otherwise (e.g. ground speed), the term 'speed' within this document refers always to rotational movement.

#### 3.2

##### **fieldbus maindevice**

device integrated within inverter onboard supply system, controls actively the communication within the fieldbus network and requests/receives data to/from the *fieldbus subdevice* (3.3), subordinated controller) in a cyclically and time-wise deterministic manner

#### 3.3

##### **fieldbus subdevice**

device integrated within LLB on-board consumer system receives data (e.g. requests) from and provides data (e.g. feedback) to the *fieldbus maindevice* (3.2) passively

#### 3.4

##### **insulation monitor**

**IM**  
device monitoring the ungrounded system between an active phase conductor and the equipotential bonding

#### 3.5

##### **power converter/switch control**

**PC/S-C**  
control for AC mode, a power converter; for DC mode, a switch such as a contactor or solid-state switch, typically an integral part of the PC/S-C

#### 3.6

##### **minimum isolation resistance**

**MIR**  
value in failure free condition but at worst case ambient conditions (considering humidity, fluids, cooling type, etc. in operation)

#### 3.7

##### **multi consumer system**

**MCS**  
system of more than one consumer systems or consumer system trains, connected to the HPI in any combination of a series or parallel configuration

#### 3.8

##### **online insulation monitor**

**OIM**  
system to measure the overall system isolation resistance onboard of the initial supply system

**3.9**  
**parameter group number**  
**PGN**

3-byte CAN Message, 24 bit, representation of the extended data page, data page, protocol data unit (PDU) format, and group extension (GE) fields

[SOURCE: ISO 11783-1:2017, 3.44]

Note 1 to entry: The parameter group number uniquely identifies a particular parameter group.

**3.10**  
**pre-charge procedure**

capacitor charging procedure to balance different DC link voltage levels

**3.11**  
**pre- and discharge unit**

unit to pre- or discharge the DC link connected via HPI, typically an integral part of the PC/S-C

**3.12**  
**supply system master**  
**SS-M**

supply system that includes the initial power source, such as generator/rectifier unit or fuel cell, commonly the tractor, typically the HPI-MC also resides there.

**3.13**  
**suspect parameter number**  
**SPN**

19-bit number used to identify a particular element, component, or parameter associated with a control function

[SOURCE: ISO 11783-1:2017, 3.58]

Note 1 to entry: Suspect parameter numbers are assigned to each individual parameter in a parameter group, and to items that are relevant to diagnostics but are not presently a parameter in a parameter group.

Note 2 to entry: See SAE J1939 definitions for more details.

**4 Voltage classes**

[Table 1](#) indicates the range of voltages (as defined in ISO 23285).

**Table 1 — Voltage classes**

Voltage class	Maximum working voltage	
	V DC	V AC RMS
VC-A	$0 < U \leq 60$	$0 < U \leq 30$
VC-A1	$0 < U \leq 32$	$0 < U \leq 21$
VC-A2	$32 < U \leq 60$	$21 < U \leq 30$
VC-B	$60 < U \leq 1\,500$	$30 < U \leq 1\,000$
VC-B1	$60 < U \leq 75$	$30 < U \leq 50$
VC-B2	$75 < U \leq 1\,500$	$50 < U \leq 1\,000$
U = nominal voltage		

NOTE 1 The definition of RMS values in [Table 1](#) is related to a pure sine wave form or the fundamental frequency of a modulated signal. The RMS value of a modulated signal may differ from them.

NOTE 2 Unipolar PWM is DC. Bipolar PWM is AC.

## 5 General system overview

### 5.1 General

Initially, the basis for the communication between supply system (SS) and consumer systems (CSs), high power interface (HPI) controllers (shown in [Figure 2](#) and [Figure 3](#)) shall use the ISOBUS as specified in the ISO 11783 series.

NOTE 1 High speed ISOBUS and other alternative communication media such as Automotive Ethernet and EtherCAT™<sup>1)</sup> based technologies can be used but likely need an update to this document. For information, ISO technical committees TC 82, TC 23 and TC 127 are collaboratively working on high-speed secure communication interfaces.

NOTE 2 Topologies showed in this clause are only examples, implementations can differ from them (e.g. in number of interfaces).

If applicable, as basis for the communication between Power Converter/Switch Controller (PC/S-C) and application (APP)/load (shown in [Figure 2](#)), the fieldbus as defined in [Clause 7](#) may be used.

The communication shall follow the TIM approach on ISOBUS.

NOTE 3 Advantage of this approach is using already defined measures like secure communication, usage of an existing automation state machine, etc. Refer to AEF guidelines 023 on automation and 040 on security for details.

NOTE 4 As diagnostics is not in scope, [Annex D](#) gives an informative overview of feasible DTCs.

### 5.2 Basic AC-system topology

Typically, an electric AC drive system consists of one Power Converter (PC, e.g. a three-phase inverter) within the SS which is connected to at least one Application (APP), in particular an AC-load (ACL), on the side of a CS via one HPI. A SS provides at least one HPI.

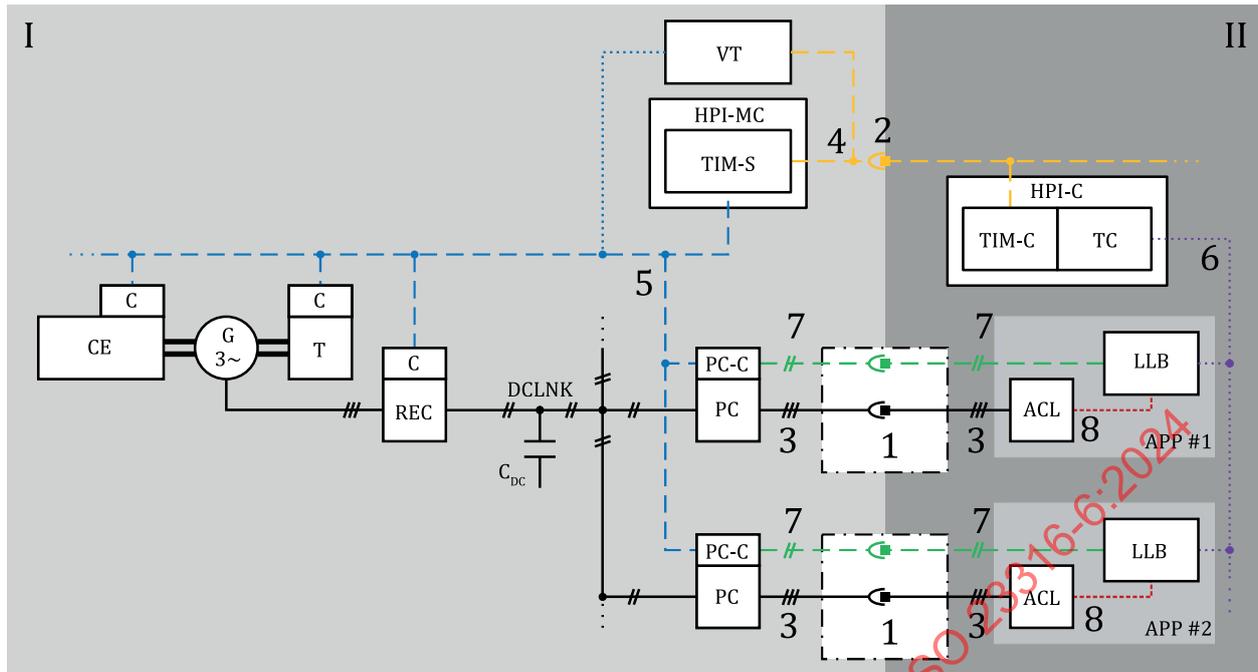
Application specific communication shall use ISOBUS, e.g. for transmission of working process data from implement (as CS) to tractor (as SS).

Load specific communication shall use the fieldbus for ACL identification and transmission of feedback. The fieldbus shall be a 1:1 connection, enabling reliable and unambiguous communication between Power Converter (PC) and load logical box (LLB).

NOTE The load specific communication between SS and CS is functionally necessary since there is a split in the electric drive between Power Converter PC and ACL.

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1) EtherCAT™ is a Tradename of Beckhoff, used as an example of a suitable product available commercially. This information is given for the convenience of users of this document and does not constitute an endorsement by ISO of this product.



**Key**

Symbol	Description	Symbol	Description
—————	power connection	.....	optional signal connection
- - - - -	signal/bus connection	II	consumer system
I	supply system	5 — — —	supply system communication bus (e.g. tractor bus)
1	high-power interface	6 .....	consumer system communication bus (e.g. implement bus)
2	ISOBUS connector	7 - - - -	fieldbus (used also for interlock function)
3 ———	power lines	8 .....	feedback signal (e.g. sensor signal)
4 - - - -	ISOBUS	PC	(DC/AC) power converter
ACL	AC-load (e.g. electric motor)	PC-C	power converter controller
APP	application	REC	rectifier (AC/DC power converter)
C	controller of a device	T	transmission
C <sub>DC</sub>	DC link capacitor	TC	task controller
CE	combustion engine	TIM-C	tractor implement management - Client
DCLNK	DC link	TIM-S	TIM - server
HPI-C	HPI - control	VT	virtual terminal (user interface, e.g. display)
HPI-MC	HPI - master control		
LLB	load logical box		

**Figure 2 — AC-system topology example with two loads**

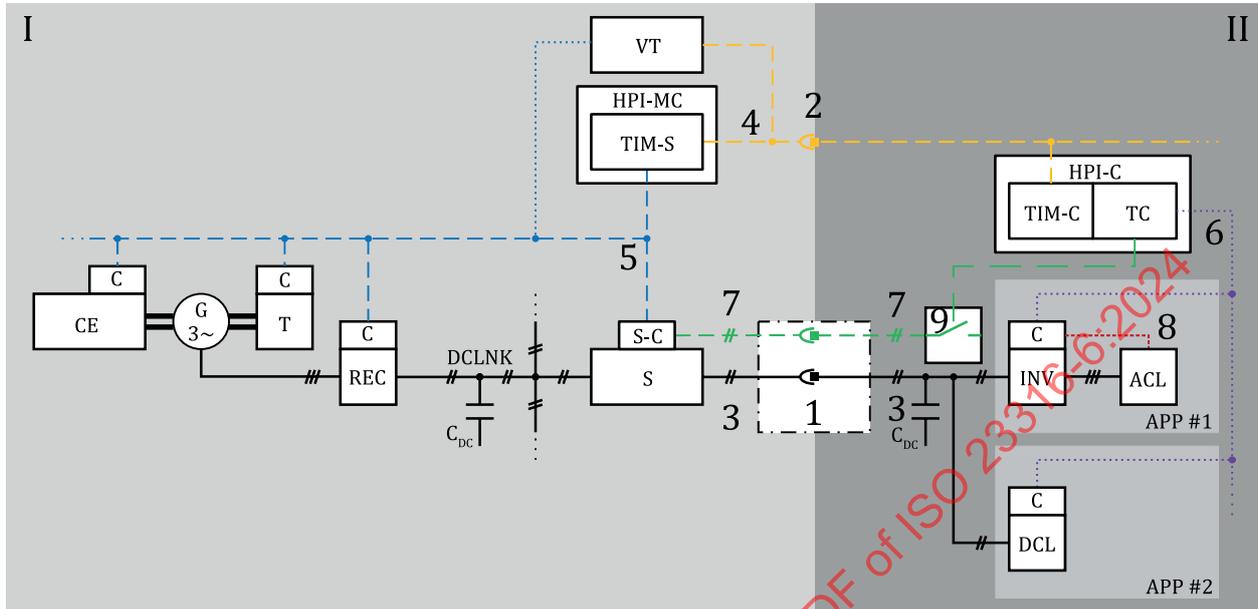
The SS and CSs may include additional communication bus systems (as shown in [Figure 2](#)), these are not within the scope of this document.

The interaction (sequences for identification, initialization, operation and shutdown) between SS [including the Tractor Implement Management (TIM) server <sup>2)</sup> on-board, e.g. a tractor] and CS [including TIM client and Task Controller (TC) on-board e.g. an implement] is described in [Clauses 6, 7](#) and [9](#) for fieldbus-based systems.

2) Depending on specific topologies, an implement can also be a server.

The total number of TCs of a CS is not specified by the example in Figure 2, it is permitted to use a dedicated TC per APP.

5.3 Basic DC-system topology



Key

Symbol	Description	Symbol	Description
—————	power connection	.....	optional signal connection
- - - - -	signal/bus connection	H	consumer system
I	supply system	6	consumer system communication bus (e.g. implement bus)
1	high-power interface (HPI)	7	interlock loop
2	ISOBUS connector	8	feedback signal (e.g. sensor signal)
3	power lines	9	interlock signal line breaker
4	ISOBUS		
5	supply system communication bus (e.g. tractor bus)		
ACL	AC-load (e.g. electric motor)		
APP	application		
C	controller of a device		
CDC	DC link capacitor		
CE	combustion Engine		
DCLNK	DC link		
HPI-C	high-power interface-control		
HPI-MC	high-power interface-master control		
INV	inverter (DC/AC power converter)		
		REC	rectifier (AC/DC power converter)
		S	switch (contactor or solid-state switch, including pre- and discharge unit)
		S-C	switch controller
		T	transmission
		TC	task controller
		TIM-C	tractor implement management-client
		TIM-S	tractor implement management-server
		VT	virtual terminal (user interface, e.g. display)

Figure 3 — DC-system topology example with two loads

Typically, an electric DC drive consists of a switch (this includes a contactor or a solid-state switch and as well as a pre-/discharge device) that is connected with at least one APP (e.g. a three-phase inverter for

a three-phase electrical machine) on the CS side via one HPI. A SS provides at least one HPI. A CS usually includes a DC-load (DCL). A CS may act as SS for a subsequent CS.

Application specific communication shall use ISOBUS, e.g. for transmission of working process data from implement (as CS) to tractor (as SS).

NOTE Load specific communication between SS and CS is not needed since there is no split in the electric drive (as shown in [Figure 3](#): Split between INV and ACL in APP #1).

SS and CSs may include additional communication bus systems (as shown in [Figure 3](#)). These communication systems are not covered by this document.

The interaction (sequences for identification, initialization, operation and shutdown) between a SS (including the TIM server<sup>3)</sup> on-board e.g. a tractor) and a CS (including TIM client and TC on-board e.g. an implement) is described in [Clauses 6, 8](#) and [10](#) for Interlock Loop (IL)-based systems.

The total number of TCs of a CS is not specified by the example in [Figure 3](#), it is permitted to use a dedicated TC per APP.

## 6 Communication process and system handshake

### 6.1 System handshake phases

The system handshake determines the communication between the LLB, PC/S, HPI-MC, and HPI-C (see [Clause 5](#) for details of the topologies and abbreviations). The system handshake consists of the following phases (see also [Figure 4](#) and [5](#)) after connecting the ISOBUS interface and the HPI:

- a) identification;
- b) initialization;
- c) operation; and
- d) shutdown.

NOTE 1 The “identification phase” is known in other industries (e.g. construction) as “discovery phase”.

NOTE 2 LLB is only used mandatorily in an AC-system per [5.2](#). In DC-systems, it is an option. Hence, the corresponding process steps are only needed if an LLB is applied.

The system handshake shall use the existing TIM function state machine. This will be defined in [6.4](#).

NOTE 3 For details on the TIM function state machine, see AEF 023 RIG3 (2023).

After address claiming on ISOBUS as common, the start-up sequence is split into the above mentioned two phases (more details see [6.4](#)):

- The identification phase (see [Figure 8](#)), where the PC/S shall be assigned to the corresponding HPI-C:
  - For fieldbus-based systems, the sequence per [Clause 9](#) shall be used, or
  - For IL-based systems, the sequence per [Clause 10](#) shall be used.
- The initialization phase, where the PC/S shall receive:
  - Load-specific data from the LLB to initialize the PC/S subordinated controls (e.g. torque control), and
  - Application-specific data from the application ECU (specific HPI-C / TC or specific SS ECU) to initialize the higher-level controls (e.g. speed control).

3) Depending on specific topologies, an implement can also be a server.

As a fallback if the identification processes per [Clauses 9](#) and [10](#) are not supported or not successful, each SS HPI-C and CS HPI-C shall support a manual configuration page as it is defined by TIM for other applications as hydraulic interfaces.

NOTE 4 The manual configuration will be performed by the operator.

Generally, a system may have both, a fieldbus and an IL connection. If this applies, the fieldbus has a higher priority since it enables a higher number of functions and is used for operating the system. For details see ISO 23316-4:2023, 4.8.

NOTE 5 Inherently, a PC/S or an APP can have both, a fieldbus and an IL. It depends on the completed system which one is active finally.

## 6.2 Conditions for system handshake

It is a precondition that signals that are sent by the HPI-C to the PC/S and vice versa shall be routed via the ISOBUS through the HPI-MC and the SS communication bus.

Objects that are sent by the LLB to the PC/S and vice versa shall be always routed directly via the fieldbus (so this is a mandatory precondition for the clauses on fieldbus-based systems).

The whole 'electric drive' (consisting of PC/S and APP) shall be controlled by the HPI-C or in specific cases the HPI-MC via the TIM function state machine (at least for enabling/disabling, consider the different control modes per ISO 23316-4 and ISO 23316-5).

NOTE 1 The controlling instance - HPI-C or HPI-MC - will be chosen by the application control type per [Table A.2](#). It defines two modes: "Implement-controlled" and "tractor-controlled". In the "implement-controlled" mode - as common - the CS's HPI-C requests as a TIM client a function of the TIM server at the SS. Whereas in the "tractor-controlled" mode - which is not common - the SS's HPI-MC requests the control of a function at the CS.

NOTE 2 The status of the TIM function state machine is reflected in the VT by the TIM automation states [see AEF 023 RIG3 (2023) Annex E.1 also].

CAN messages between PC/S-C and HPI-C shall include a command byte which is the (TIM) Function ID as representation of the PC/S address. This shall differentiate the PC/Ss onboard of a certain SS against each other.

NOTE 3 A similar approach is made within TIM for, e.g., tractor's hydraulic valves.

NOTE 4 The command byte can be understood as a multiplexer for this message. Within the message structure for the AC and DC modes, this and additional multiplexers are used for several purposes. For information on messages (PGNs), see [Annex B](#).

The definitions of the CAN messages and the corresponding message sets shall be compliant to and documented in ISO 11783 and SAE J1939. Using transport protocol is an option for these messages.

The connection status of each HPI shall be monitored (see details in [6.3](#)).

For each sent signal, the receiver shall send an acknowledgement as confirmation to the sender.

NOTE 5 Similar requirement exists in AEF 023.

## 6.3 HPI connection status monitoring

Each dedicated electrical HPI shall be monitored in respect of its dedicated connection status (connection via connector and cable between SS and CS) frequently, this is mentioned by interlock function. This check shall be performed while the connection status is "disconnected" also for determining an already inserted connector.

At least one of these two options of connection status monitoring shall be supported:

— IL-based monitoring, and

— Fieldbus-based monitoring.

In fieldbus-based systems, the interlock function shall be provided by monitoring the fieldbus (for details, see [Clauses 7](#) and [9](#)).

In IL-based systems, the interlock function shall be provided by monitoring a dedicated physical interlock loop (for details, see [Clauses 8](#) and [10](#)).

If both, IL and fieldbus are available for monitoring the HPI connection status, a decision shall be made by the PC/S based on ISO 23316-4:2023, 4.8.3. This decision shall be valid from beginning of the identification phase.

NOTE 1 The physical interface as specified in ISO 23316-2 includes both, fieldbus and dedicated IL pins.

Consequently, a separate interlock function handling and handshake for each interface shall be applied.

NOTE 2 SS or CS internal interlock loops are not the focus of ISO 23316 series. So, the term interlock is used otherwise as common in automotive industry.

## 6.4 Interaction with TIM function state machine

This subclause defines the handshake sequence in general. It points out how the phases mentioned in [6.1](#) are interacting with the TIM function state machine.

- a) As the TIM function state machine is in the state “(0) automation unavailable”, the transition into the state “(1) automation not ready” shall require in addition to the already defined conditions the connected status per HPI.
- b) As the TIM function state machine is in the state “(1) automation not ready”, the transition into the state “(2) automation ready to enable” shall require in addition to the already defined conditions the identification of the APP (load) connected per HPI using fieldbus (LLB addressing) and IL (determination per [Annex C](#)) functionality. Consequently, a logical check is performed which kind of interlock is implemented and thus which operational modes are generally available.
- c) As the TIM function state machine is in the state “(2) automation ready to enable”, the transition into the state “(3) automation enabled” shall require all the following in this specific sequence:
  - For each connected HPI as result and reflection of the successful APP (load) identification, the HPI-MC assigns a TIM function ID per HPI and sends this assignment information by a destination specific message ‘TIM server to TIM client’ to the one specific CS HPI-C,
 

NOTE 1 Generally, an SS HPI-C can be combined with a PC/S-C and a CS HPI-C with a TC.

NOTE 2 One CS HPI-C can control several HPI. A CS (an implement) can contain several HPI-Cs.
  - For each connected HPI, the CS HPI-C assigns control type and application control type (see [Table A.2](#) in [Annex A](#)) to the corresponding SS HPI-C<sup>4)</sup> by sending a message ‘TIM client to TIM server’, this includes a logical check of possible and allowed modes by the SS HPI-C,
 

NOTE 3 As defined in [Table A.2](#), the control type and the application control type are only set once, they will not change during operation.
  - Optionally, the HPI-MC and the other HPI-Cs are communicating the needed parameters (see [Table A.4](#)) on the insulation resistance and monitoring per [Clause 11](#),
  - For each connected HPI which is using the fieldbus, the LLB sends the load specific initialization parameters (see [Table A.11](#)) to the PC/S-C, if needed the PC/S-C forwards initialization parameters to the corresponding SS HPI-C and the CS HPI-C,

4) In most cases, the SS HPI-C will be the HPI-MC. In topologies with implements connected in series, this statement is not valid.

- For each connected HPI, the PC/S-C sends the needed reference values (see [Table A.1](#)) as required per chosen control type via SS HPI-C to the CS HPI-C,

It is recommended to set a quantity reference to '0' if not needed per chosen control type.

- For each connected HPI, the CS HPI-C sends the required initialization values (limits, thresholds etc. in [Table A.2](#), [Table A.5](#) - [Table A.10](#), [Table A.18](#) to [Table A.20](#)) per chosen control type to the corresponding SS HPI-C and vice versa this SS HPI-C forwards the needed initialization values per chosen control type to the corresponding CS HPI-C, if needed the SS HPI-C forwards initialization parameters to the PC/S-C,
  - For each connected HPI, the specific controlling HPI-C of CS (TIM client) and SS (TIM server) provide the information on finished successful initialization.
- d) As the TIM function state machine is in the state "(4) automation pending", the transition into the state to "(5) automation active" shall require no additional action as already defined.
- e) As the TIM function state machine is in the state "(5) automation active", for each HPI, the CS HPI-C shall start sending the target values to the corresponding SS HPI-C for starting operation and vice versa the SS HPI-C (PC/S-C) shall start sending actual values as feedback to the CS HPI-C.

Changing the control type and the application control type shall require the deactivation of the HPI and a complete reinitialization process including stepping back the TIM function state machine.

[Figure 4](#) shows the sequence diagram for a fieldbus-based system. This can also be adapted to an IL-based system while ignoring the fieldbus specific and adding IL-specific tasks (see [Figure 5](#)). These figures are not including the insulation resistance initializing and monitoring related communication.

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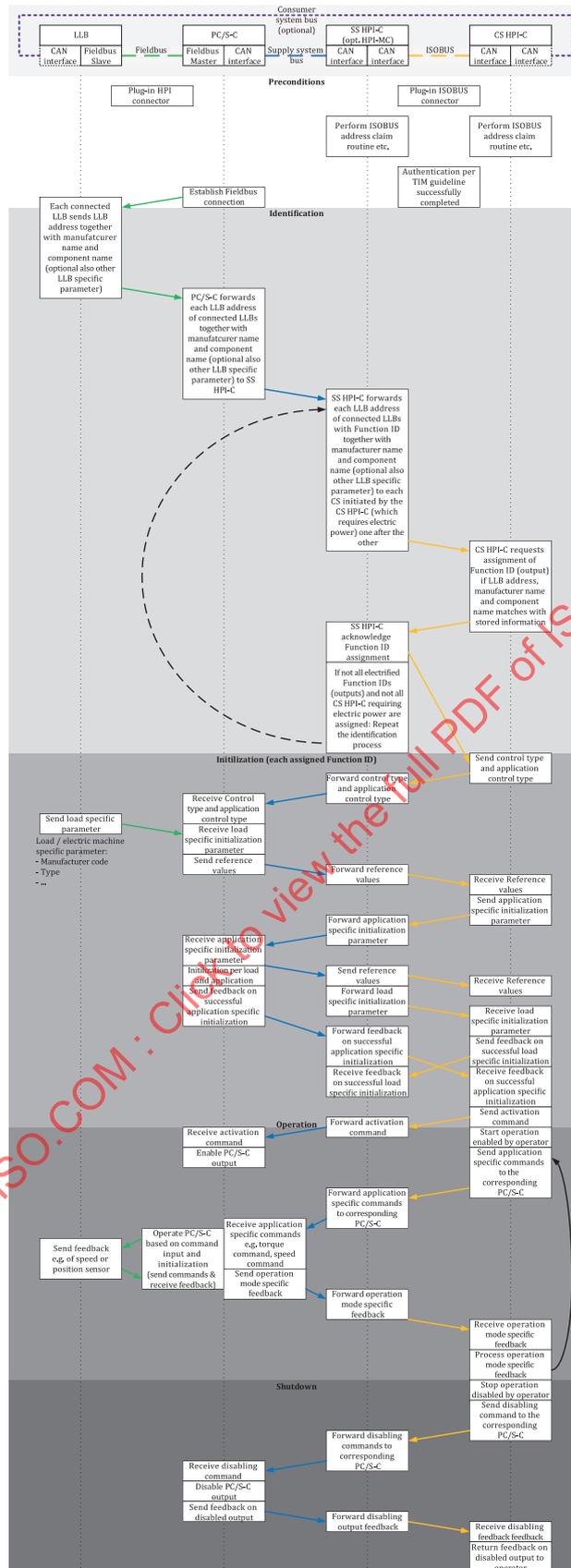
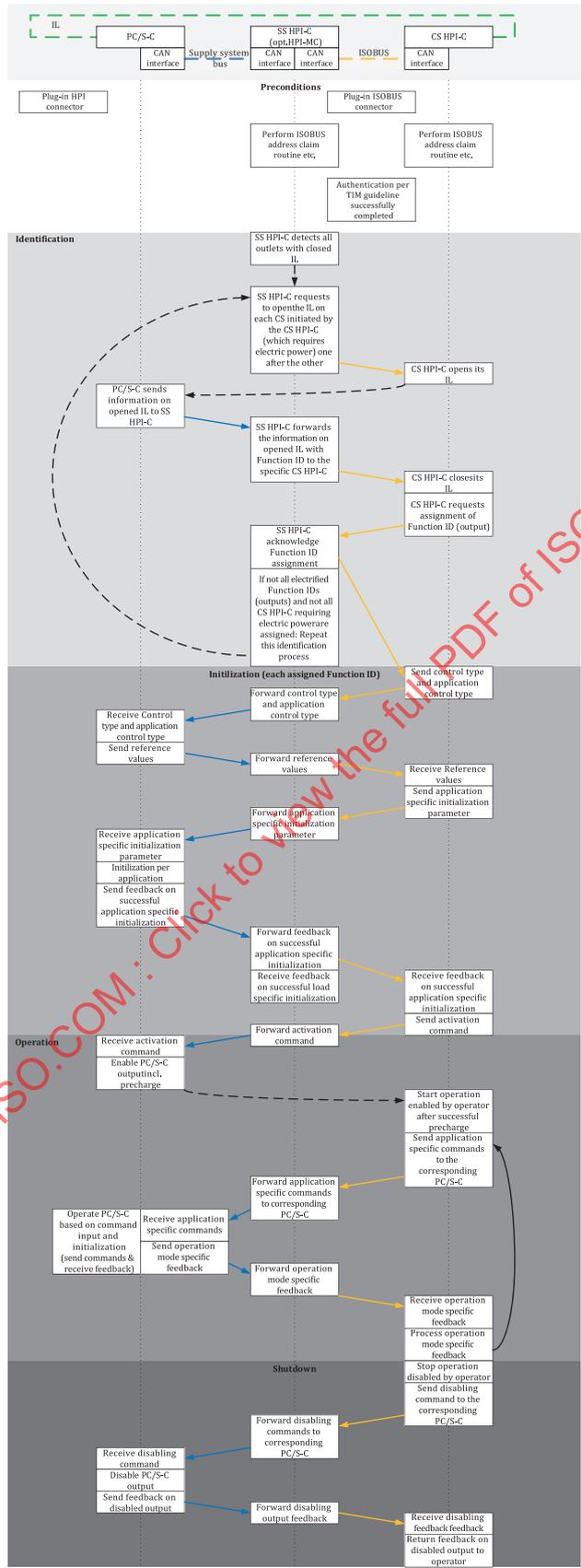


Figure 4 — Sequence diagram for a fieldbus-based system without insulation monitoring (see ISO 23316-6DA)

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NOTE 4 For details on fieldbus-based systems, see [Clauses 7](#) and [9](#). For the handshake specifically, see [Clause 9](#). For detailed sequence diagrams, see [Figures 8](#) to [11](#). For insulation monitoring, see [Clause 11](#).



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**Figure 5 — Sequence diagram for an IL-based system without insulation monitoring (see ISO 23316-6DA)**

NOTE 5 For details on IL-based systems, see [Clauses 8](#) and [10](#). For the handshake specifically, see [Clause 10](#). For detailed sequence diagrams, see [Figures 17](#) to [20](#). For insulation monitoring, see [Clause 11](#).

## 7 Fieldbus

The fieldbus shall use EtherCAT as described in ISO 23316-4:2023, Clause 5 for the high-speed communication between SS and CS: The PC/S-C acts as the fieldbus maindevice and the LLB acts as a fieldbus subdevice.

NOTE The necessary data definitions (feedback values such as rotor position, rotor speed, winding temperature, and initialization values) are listed in A.2.2.

## 8 HPI interlock function

### 8.1 Functional requirements

The dedicated interlock signal shall only be used for the following functions:

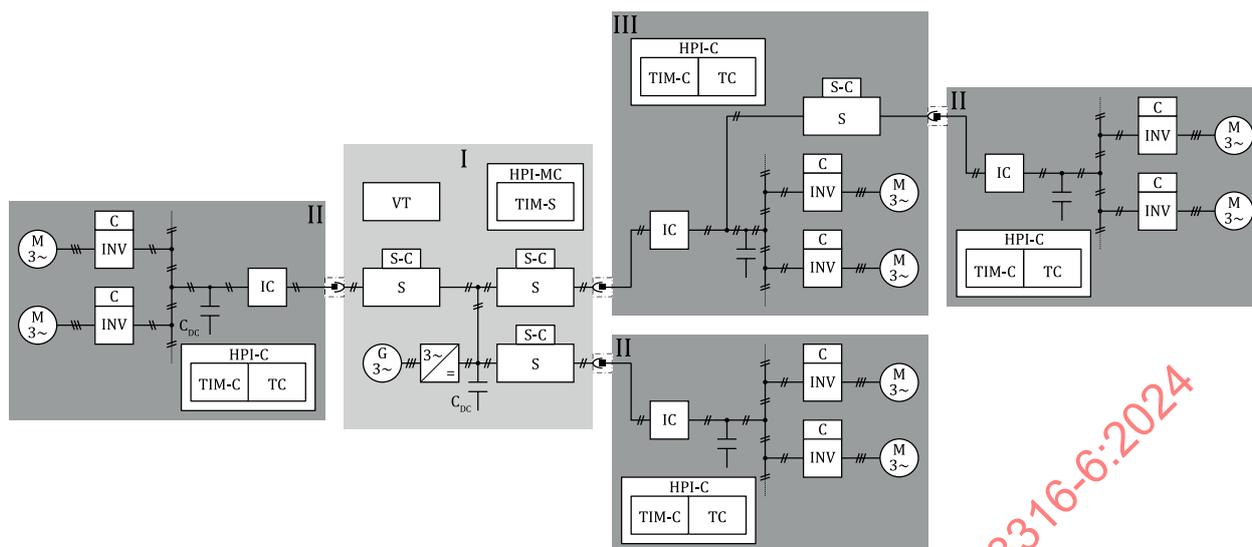
- determination of AC system topology using open-loop control modes per ISO 23316-4 and a DC system topology per ISO 23316-5, and
- monitoring the HPI connection status by the SS (e.g. fault detection caused by an unintended disconnect) for the mentioned topologies.

AC systems topology using open-loop control modes may use one of the following options:

- Field-bus based system, or
- IL-based system.

In case of any interruption of the interlock signal, the VC B2 power shall be turned off by the SS in accordance with the guidance given by ISO 16230-1:2015, 6.2.

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**Key**

Symbol	Description	Symbol	Description
I	supply system	II	consumer system
III	consumer and supply system	S	switch (contactor or solid-state switch, including pre- and discharge unit)
C	controller of a device	S-C	switch controller
HPI-C	high-power interface - control	TC	task controller
HPI-MC	high-power interface - master control	TIM-C	tractor implement management - client
IC	input circuit	TIM-S	tractor implement management - server
INV	inverter (DC/AC power converter)	VT	virtual terminal (user interface, e.g. display)

**Figure 6 — Simplified topology example for a SS with multiple CSs and multiple HPIs**

If IL interruption is monitored before pre-charge is started, the pre-charge shall not be performed.

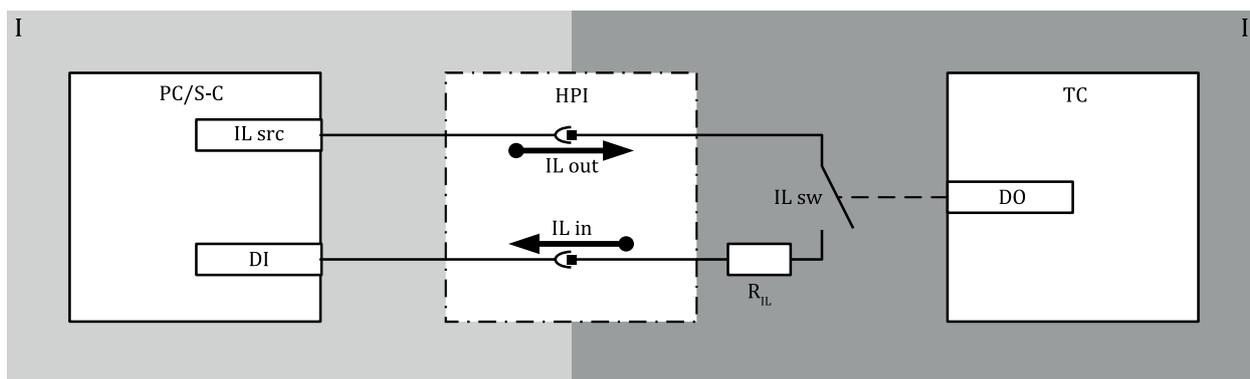
NOTE 2 Electric units on the SS and CS are part of their own machine interlock loops if applied; they do not include or interfere with the HPI interlock loop.

In cases of multiple implements, the interlock handling and hardware handshake shall be performed between each HPI (first implement with second implement, second implement with third implement, and so on). See topology example in [Figure 6](#).

**8.2 Functional principle**

[Figure 7](#) shows the functional principle. The illustrated IL-switch on the SS side has following functions:

- When the internal check on the CS side is faultless, the IL-switch shall be closed.
- If more than one HPI is used on the tractor-implement-combination and more than one CS is connected, each SS shall identify the CS, which is connected to the relevant physical HPI via demanding the toggling of IL-switch (identification procedure is described in [Clause 10](#)).
- In series to the IL-switch a resistance  $R_{IL} = 1 \text{ k}\Omega \pm 10 \%$  shall be connected.



**Key**

Symbol	Description	Symbol	Description
I	supply system	II	consumer system
DI	digital input	IL in	interlock input
DO	digital output	IL out	interlock output
HPI	high power interface	IL src	interlock source
PC/S-C	power converter/switch controller	IL sw	interlock switch
TC	task controller	$R_{IL}$	IL circuit resistance

**Figure 7 — Example of an IL circuit (simplified)**

NOTE The physical location of the PC/S-C or TC can differ, it could be included in the HPI-MC for the S-C, HPI-C for the TC or in another separate controller.

## 9 Fieldbus-based system

### 9.1 Identification sequence using fieldbus

See [Figure 8](#) for this specific part of the sequence (as excerpt from [Figure 4](#)).

The following kind of identification and use of a command byte is required while potentially several loads/application ECUs with a certain number of drives are attached at the power supply.

As preconditions:

- A specific fieldbus address is required per LLB within a CS (see [Annex A](#)).
- A specific unique fieldbus address is required per PC/S<sup>5)</sup>.

The PC/S is connected to the HPI-C via source bus, HPI-MC, and ISOBUS.

NOTE 1 The inverter, as fieldbus maindevice, sends out data packages cyclically while activated (kind of data request), independently of whether a fieldbus subdevice is connected or not. If a fieldbus subdevice is connected, it responds by sending its data.

While the fieldbus connection is established between LLB and PC/S, the identification sequence shall be started. Hence, the fieldbus maindevice (PC/S onboard of SS) shall check the load/electric machine manufacturer code, the load/electric machine code and the LLB address (fieldbus subdevice onboard CS) in the standard data package (see [Table 2](#)).

5) The generic system, without designation as AC or DC system, uses PC/S. An AC system uses a PC. The DC uses an S. From a basic function perspective this is equivalent.

Table 2 — Fieldbus data package

Data package	Fieldbus index	Content	Reference
Standard	0	Identification Feedback	<a href="#">Table A.11</a> <a href="#">Table A.12</a>
	1	General	<a href="#">Table A.13</a>
Enhanced	2 or 3 or 4	Electric machine characteristics: IM PM RM	<a href="#">Table A.14</a> <a href="#">Table A.15</a> <a href="#">Table A.16</a>

The PC/S shall request at the LLB the content of data of ‘Fieldbus index 1’ (see [Annex A](#)).

The PC/S shall send the load/electric machine manufacturer code (shortly: manufacturer name in [Figure 8](#)), the load/electric machine code (shortly: component name in [Figure 8](#)) and the LLB address on ISOBUS as a broadcast message (includes the (TIM) function ID).

The HPI-C / TC<sup>6)</sup> shall know the architecture of the CS (using an internal data storage) and shall compare the LLB-specific data received from the PC/S against each other. Consequently, on a successful comparison, the HPI-C shall assign its APP (for example in an AC topology: ACL with LLB per [Figure 2](#)) with the (TIM) function ID.

NOTE 2 (TIM) Function ID is the representation of the corresponding inverter within ISOBUS messages.

NOTE 3 Spreadsheets with the required parameters are given in [Annex A](#).

NOTE 4 All sequence diagrams in this clause indicate sequential behaviour mostly indicated by the arrows in between. If blocks are positioned horizontally together without arrows, parallel processing is assumed. If blocks are positioned vertically together without arrows, serial processing from top-down is assumed.

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6) The HPI-C/TC of the CS knows its own architecture and setup, as well as the related information of electric load(s) onboard of its own to compare this with the “feedback” received via ISOBUS. These data may be sent via the CS bus directly from the LLB to the HPI-C / TC, or it is stored in the HPI-C / TC non-volatile memory.

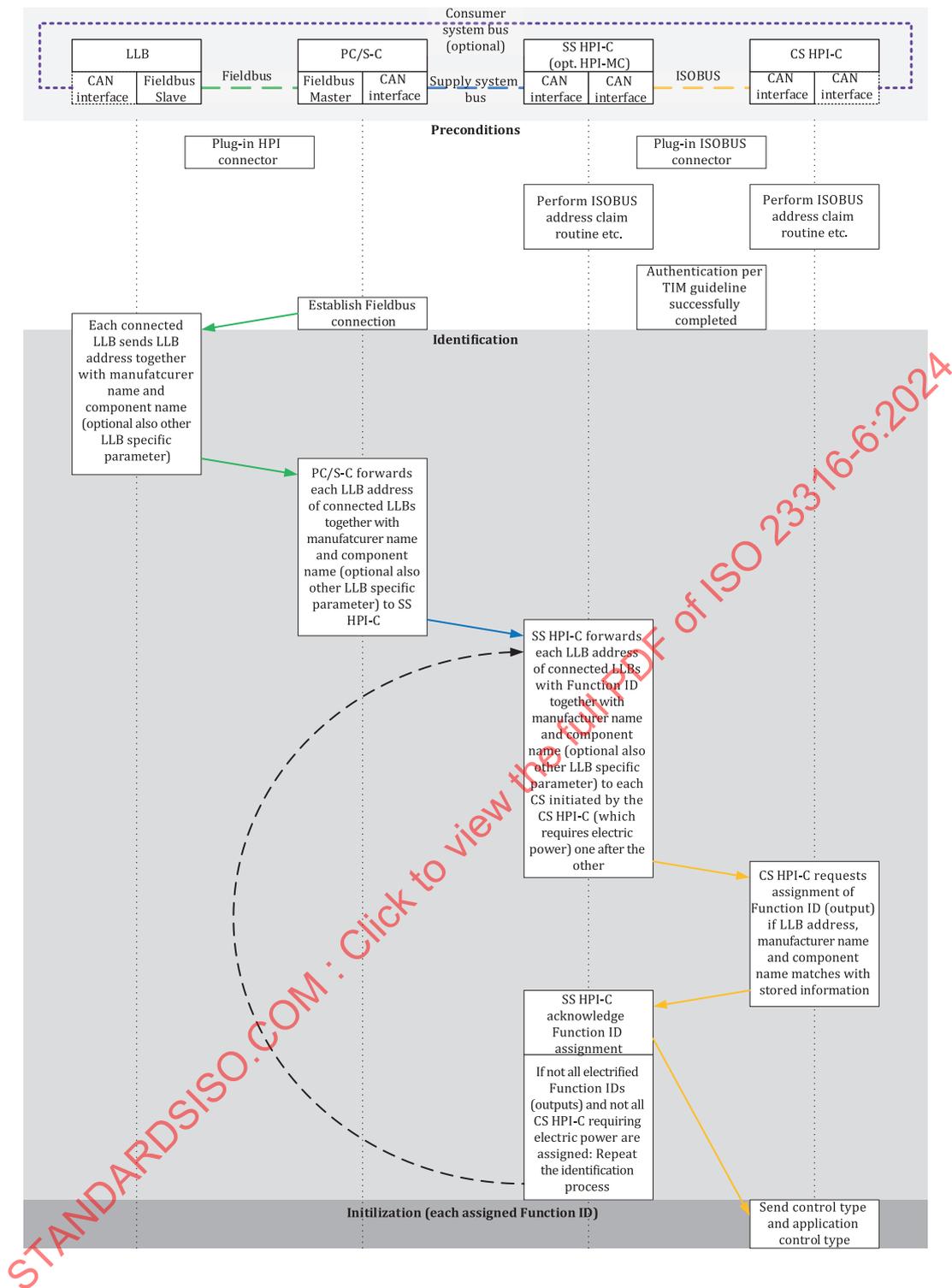


Figure 8 — Identification phase of a fieldbus-based system

## 9.2 Initialization sequence using fieldbus

See [Figure 9](#) for this specific part of the sequence (as excerpt from [Figure 4](#)).

In response to the assignment in the identification sequence, the LLB-corresponding HPI-C shall start to send the application specific objects for PC/S initialization (incl. application type):

- The application type shall be processed.
- Then the control type shall be processed.

For both see [Table A.2](#).

Based on the application type set by the HPI-C/TC and the control mode set by the HPI-C/TC, the PC/S shall perform its initialization.

**Table 3 — Allowed control modes per ISO 23316-4**

Load type	Open-loop control (see ISO 23316-4:2023, 4.4.2 and 4.7.3)			Closed-loop control (see ISO 23316-4:2023, 4.4.1 and 4.7.2)	
	V/f characteristic (see ISO 23316- 4:2023, 4.7.3.2)	Independent AC supply (see ISO 23316- 4:2023, 4.7.3.3)	Variable DC sup- ply (see ISO 23316- 4:2023, 4.7.3.4)	Torque (see ISO 23316- 4:2023, 4.7.2.1)	Speed (see ISO 23316- 4:2023, 4.7.2.2)
<b>General load</b>	x	x	x	—	—
<b>Electric machine</b>	x	x	—	x	x

NOTE 1 A general load could be a motor, solenoid, heater, or light.

In the standard data package, the PC/S shall check the following (see [Annex A](#)):

- Load/electric machine manufacturer code,
- Load/electric machine code, and
- Load/electric machine type.

If a closed-loop control mode is chosen, the PC/S shall be initialized by the electric machine characteristic parameters first. Therefore, the inverter shall use

- internally saved data (load / electric machine manufacturer code and load / electric machine code can enable a search in a data pool for predefined closed-loop control parameters), or
- request the needed parameters at the LLB dependent on the electric machine type (see [Table A.9](#), [Table A.10](#) and [Table A.11](#)).

The initialization of open-loop control modes shall only be based on parameters received from the HPI-C / TC.

NOTE 2 Spreadsheets with the initialization parameters vs. the operational/control mode are given in [Annex A](#).

NOTE 3 The signal ‘Control type’ in [Table A.2](#) allows customized modes too. The needed signals and message sets need collaboration between the partnering manufacturers of CS and SS. It enables flexibility for non-standard use cases of the HPI.

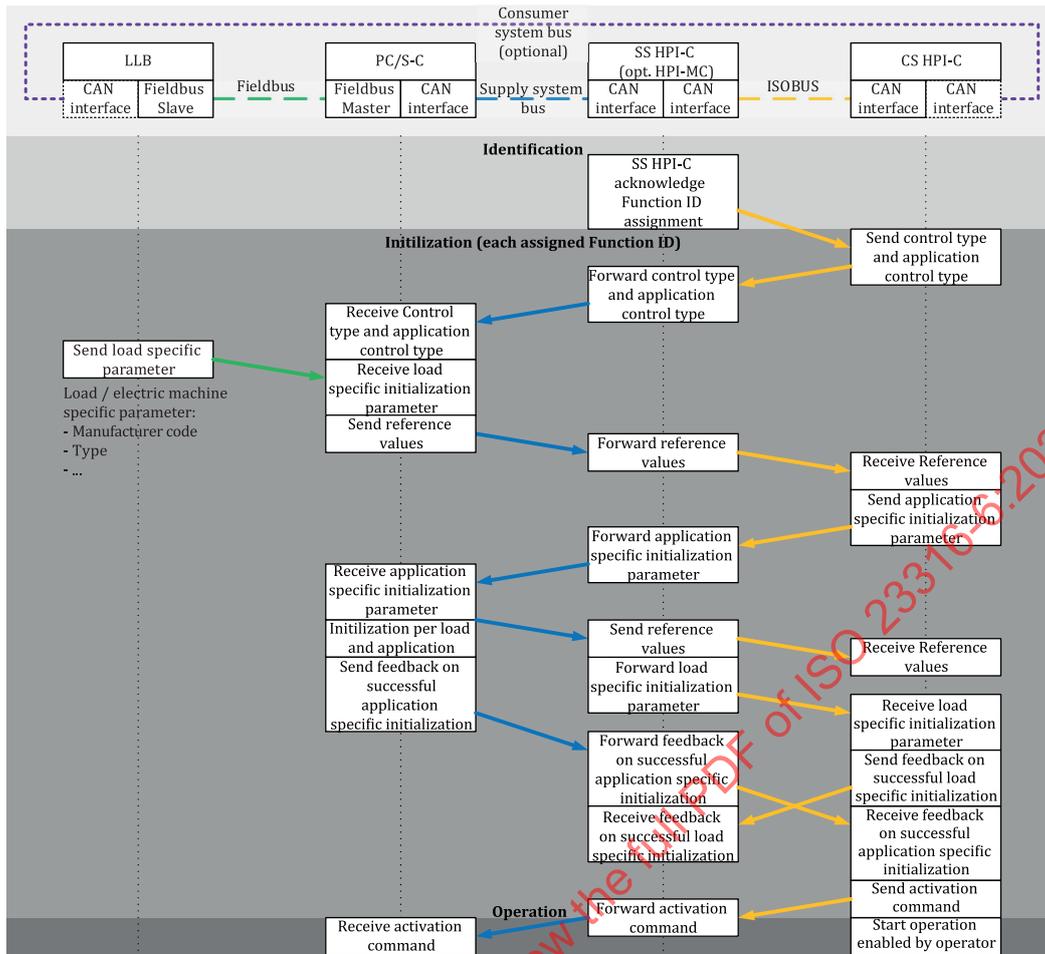


Figure 9 — Initialization phase of a fieldbus-based system

The reference values shall be set at the beginning of the initialization phase by the PC/S in coordination with the values transmitted via fieldbus from the LLB.

A change of the application type, the control mode, or the reference values while in operation ("on the fly") shall not be possible. Whereas a change of other process-specific limits or characteristics (e.g. maximum speed or torque slope) shall be possible.

### 9.3 Normal operation sequence using fieldbus

See Figure 10 for this specific part of the sequence (as excerpt from Figure 4).

After successful initialization of the controls, the drive shall be ready to be enabled by the operator. The enabling process of an electric drive shall generally follow the common ISOBUS process (per ISO 11783) as defined for hydraulic drives.

The HPI-C/TC shall send control parameters and cyclical commands (e.g. speed target value) to the inverter (per operational mode Table A.2 in of Annex A). Thus, the PC/S shall start to operate in the desired mode.

NOTE 1 Basically, the HPI-C/TC is assumed as the automation process controller, which is the source of commands to the actuator, in particular the inverter.

During normal operation, the HPI-C/TC shall repeat the commands per mode periodically as defined per operational mode in Annex A. The PC/S shall send periodically feedback as defined per operational mode in Annex A to the HPI-C/TC.

The PC/S shall request periodically via fieldbus the required feedback signals as defined per operational mode in Annex A from the LLB. The LLB shall send them as answer periodically back to the PC/S.

NOTE 2 The repetition rates on ISOBUS and on fieldbus are independent. Usually the feedback loops are asynchronous, and the repetition rate on fieldbus is much higher than that of ISOBUS.

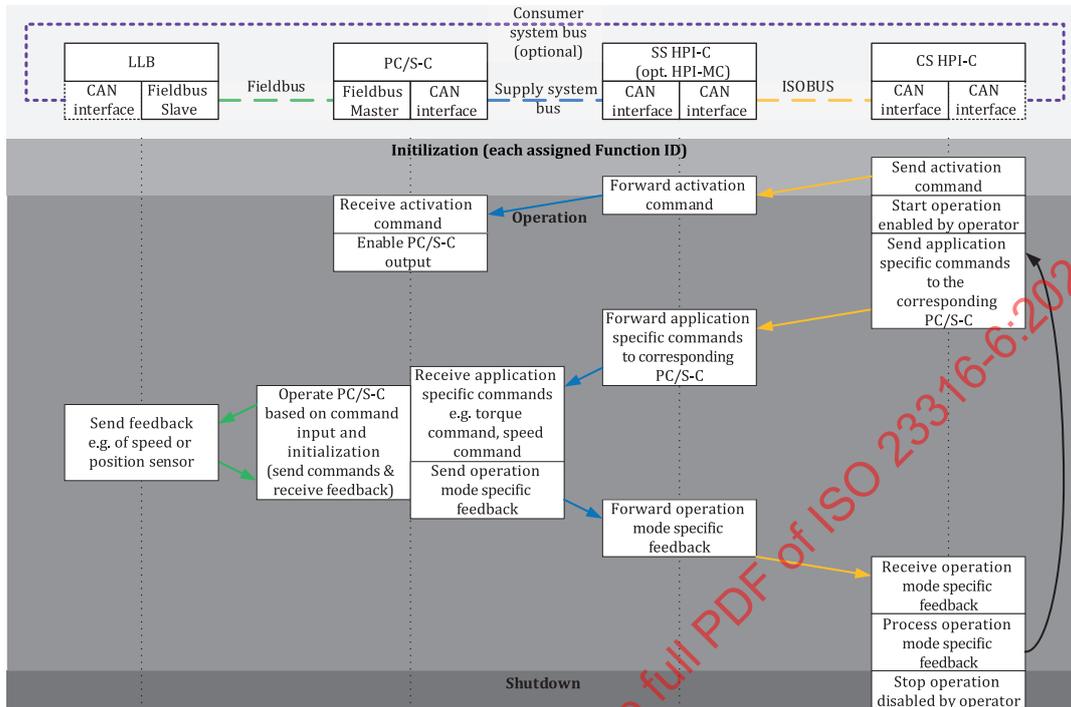


Figure 10 — Normal operation phase of a fieldbus-based system

### 9.4 Sequence definition for normal system shutdown using fieldbus

Figure 11 describes the normal system shutdown part of the sequence (as excerpt from Figure 4).

When the operator wants to disable the application, the HPI-C/TC shall bring the application into a convenient shutdown condition (dependent on the application this can be, e.g. speed = 0 or torque = 0). After achieving the shutdown state, it shall send the disabling command to the PC/S which the PC/S shall then disable its output. On successfully disabling its output, the PC/S shall send a feedback signal to the HPI-C/TC indicating the disabled state.

While receiving this PC/S feedback signal, the HPI-C/TC shall acknowledge the disabled output to the operator, e.g. by a status signal in the VT.

NOTE Independent of the controlled shutdown as defined above in this clause, is a potential “hard” shutdown caused by, e.g., an application or by an inverter fault/error. For resetting, an interaction with the operator is necessary.

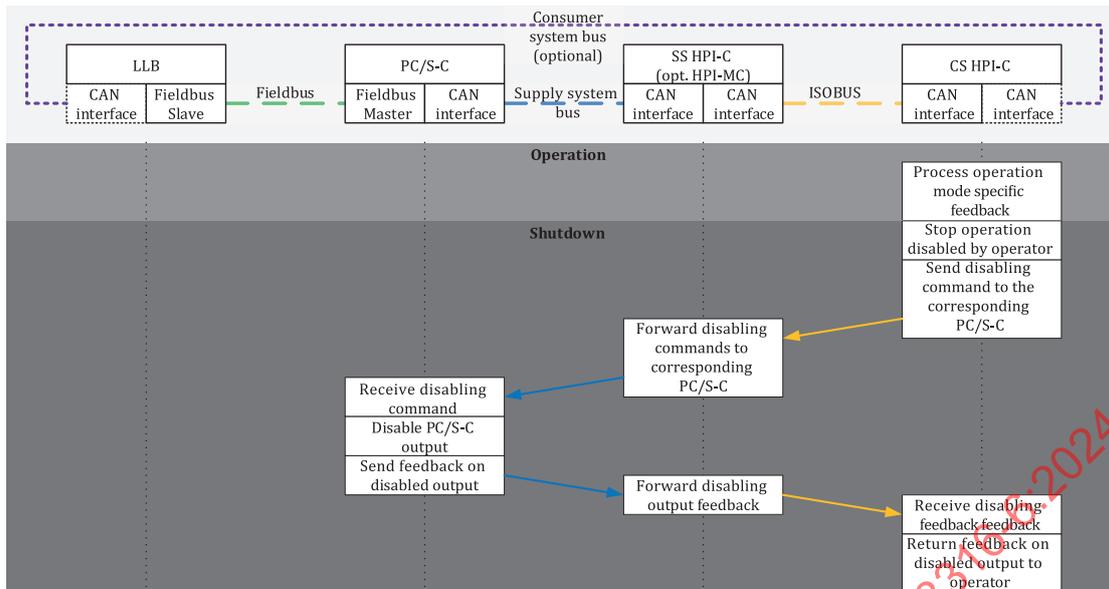


Figure 11 — Shutdown phase of a fieldbus-based system

## 10 IL-based system

### 10.1 Identification and initialization of an IL-based system

#### 10.1.1 General

VC-B2 systems shall use special identification and initialization procedures, which are described in this clause.

The (TIM) Function ID shall represent the address of each HPI-C.

The knowledge of the overall topology of the VC-B2 network is necessary to initiate initialization and pre-charge operations in the right sequence. The identification of the topology consists of two steps:

- 1) CS identification (see [10.1.2](#))
- 2) Determine the topology of VC-B2 network (see [Annex C](#))

The maximum number of topology levels (determined by [Annex C](#)) shall be 4.

When topology is determined, every HPI-MC/HPI-C shall get knowledge of its position in the VC-B2 network. Additionally, the CS shall get the information, if it acts as CS only or if it acts also as SS for one or more connected CSs (see also example in [Figure 6](#)).

After the identified combinations of SS and CS exchange their electrical capabilities during initialization procedure (see [10.3](#)), the power connection between SS and CS shall be activated. After successful pre-charge procedure, the APP shall be ready to be activated.

If a CS is acting as the SS for a succeeding CSs, the above defined sequence of activation and pre-charge shall be repeated for each of such HPI.

**NOTE** All flow charts in this clause indicate sequential behaviour. Timing is indicated by arrows connecting the elements. Vertical position does not reflect timing due to limited space in the document.

### 10.1.2 CS identification of an IL-based system

The procedure as described below is used to determine the unambiguous assignment of connected HPI (receptacle and plug).

The procedure shall identify the CS based on toggling of the IL-switch (which is located on the side of CS). Based on the toggling of the IL-switch, the procedure shall identify the connected CS:

- Starting point is the unknown topology of the VC-B2 network.
- The following preconditions are considered:
  - HPI-MC and HPI-C shall have addresses according to address claiming procedure on the ISOBUS in accordance with ISO11783-5. Thereby all nodes of the built-up network shall be known.
  - The IL through the HPI shall be closed by default (does not include open states due to e.g. identified failures).

### 10.1.3 Identification procedure

All the following operations shall be done for all VC-B2 related nodes of the ISOBUS network:

- a) The HPI-MC shall address the first CS and initiate opening the IL-switch of this CS via the signal "PC/S Operational Status - IL-switch demand" (set the 2-bit parameter as follows: [0,1] → [0,0]).
  - All other SSs shall listen to this demand, to be able to assign a reaction of the IL.
- b) To confirm the switch demand of the SS, the addressed CS shall open its IL-switch and indicate the opened state via the ISOBUS signal "Load Operational Status - IL-switch state".
- c) The related SS shall detect the interrupted IL-signal within 250 ms.
- d) The HPI-MC shall initiate re-closing the IL-switch of the first CS via the signal "PC/S Operational Status - IL-switch demand" (set the 2-bit parameter as follows: [0,0] → [0,1]).
- e) To confirm the switch demand of the SS, the addressed CS shall close its IL-switch and indicate the closed state via the signal "Load Operational Status IL-switch state".
- f) The related SS shall detect the re-closed IL within 250 ms.
- g) If the same SS detects opening and closing of its IL in the allowed time frame related to the IL-switch demand, SS and CS shall be clearly assigned.
- h) The information of identified HPI shall be transferred to the HPI-MC.
- i) The procedure shall be repeated until all CS(s) will be addressed and clearly assigned to SSs.
- j) When all CS are assigned, the HPI-MC shall be able to build up the topology of the VC-B2 network.

See flowchart in [Figure 12](#).

### 10.1.4 Additional conditions

- The status message "PC/S Operational Status - IL-switch demand" is intended for identification of the CS only. To avoid unintended IL opening and therefore VC-B2 power shutdown, the CS(s) shall not react on HPI-MC IL-switch demand" until the state "Ready for operation" is reached.
- If PWM-signal is used for IL-observation, the PWM-period shall be significantly smaller than the allowed response time (250 ms).

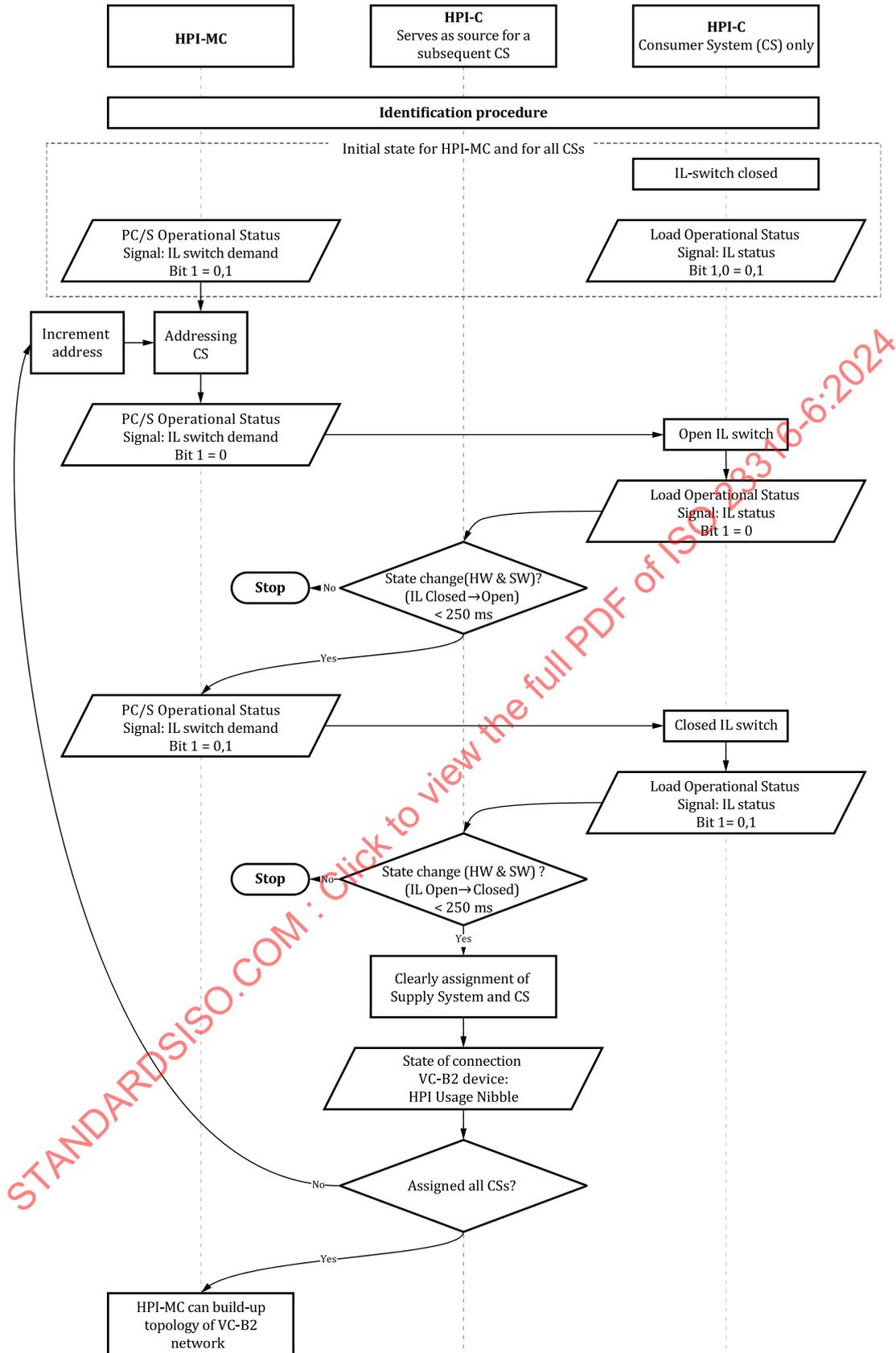


Figure 12 — CS identification flowchart

## 10.2 Determining the topology of the VC-B2 network of an IL-based system

With the described procedure in [10.1.2](#) and following subclauses, and the flowchart in [Figure 12](#), the assignment of SSs and CS(s) connected together is clearly defined. This information is used to determine the overall topology of the VC-B2 network.

The procedure is based on a two-byte status word which implies the following limitations for the topology:

- Every SS can have up to fourteen HPI (to connect up to 14 CSs);
- Every CS has only one HPI to connect to SS;
- A series connection of CS(s) (multiple implements) is limited to four levels (e.g. tractor and four series connected implements as maximum).

The procedure below describes additional information of the HPI used for each CS. This information is transmitted in the form of a nibble (half byte = 4 bits) to the HPI-MC. With this information, the HPI-MC can create a two-byte status word “HPI master control network topology”, which describes for each HPI the connected topology of the SS.

The signals “HPI usage nibble” and “HPI master control network topology” contain the information about the used HPI(s). Each HPI-C, which is responsible for a following CS, notes the state of its own HPI(s) (used/not used) in the status nibble. This status nibble describes the number of used HPIs (binary coded; 0 = no CS connected).

The sender of the nibble is the HPI-C, which detects the toggle of the IL (according to [10.1.2](#)). It transmits the nibble to the HPI-MC, when the assignment to the related CS was successful (see [Figure 13](#)). Hence the HPI-MC can create step by step the whole topology of the VC-B2 network (an example is described in [Annex C](#)).

The toggling frequency of the IL shall  $15 \text{ Hz} \pm 2 \text{ Hz}$ . The toggling sequence shall last for 500 ms to 2 s. Recommended toggling sequence time is 1 s.

## 10.3 System Initialization of an IL-based system

### 10.3.1 General

The system initialization procedure is based upon a three-step query for current specification to ensure best performance. The procedure shall follow [Figure 13](#).

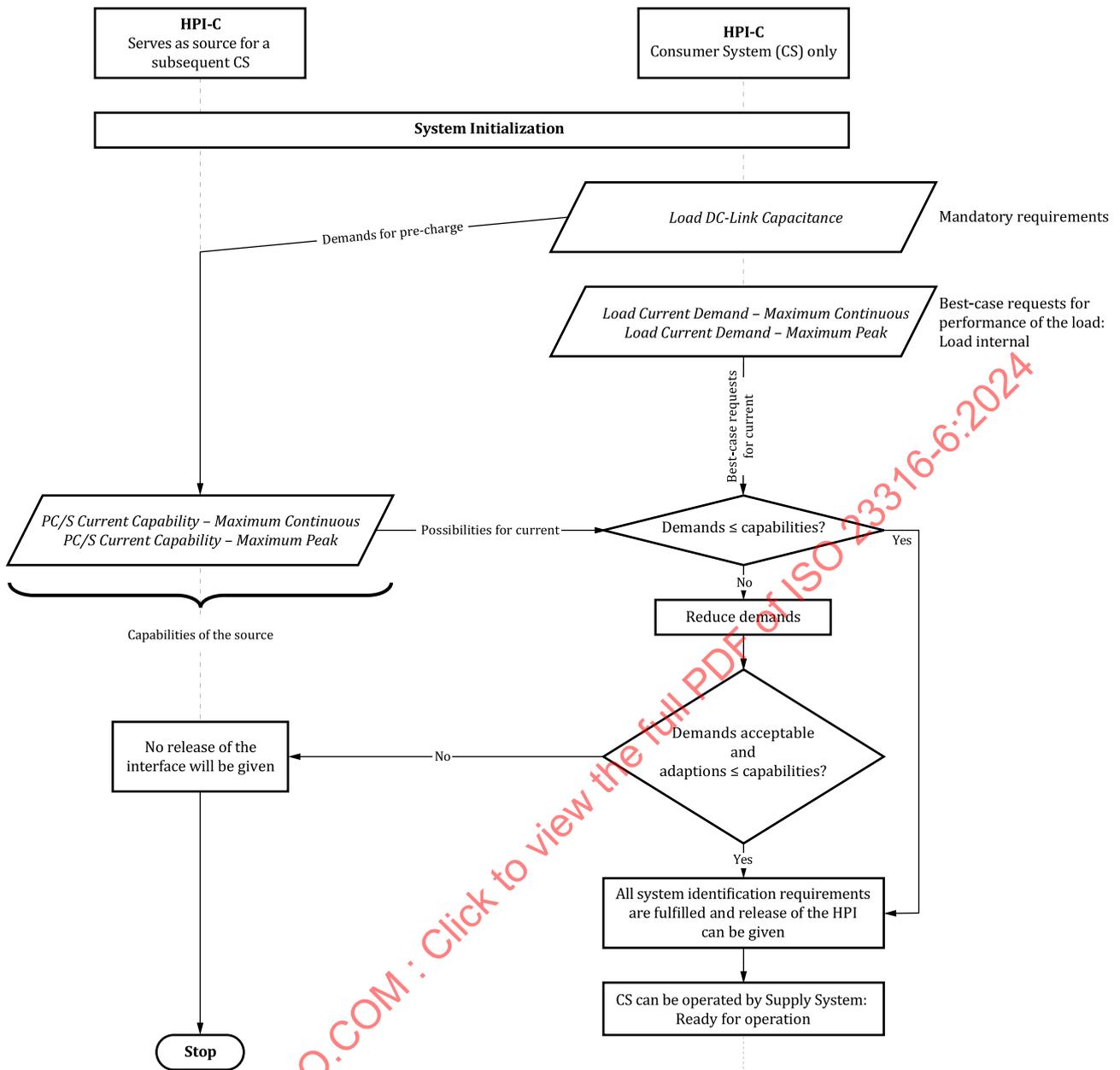


Figure 13 — System identification flow chart

After communication is established, the CS shall send its requirements with respect to DC link capacitance, operation voltage and currents to the SS.

The SS shall send back its capabilities and adapt the CS accordingly. This adaption should be completed automatically or may achieved by operator input via VT.

If the power/current requirements are still above the capabilities of the HPI, it shall not be activated and the operator shall be informed including a description, what caused the rejection of this CS.

If all system identification requirements are satisfied, the HPI shall become active, and the CS shall be ready for operation by the SS.

The reference values shall be set at the beginning of the initialization phase by the PC/S.

### 10.3.2 System handshake of an IL-based system

Important states for system handshake and other operation states shall be noted in a set of status signals of HPI-MC and HPI-C. The status signals shall be transmitted cyclically.

NOTE [Figure 14](#) shows the required content, more detailed information about interpretation of the signal states is listed in [A.3.1](#).

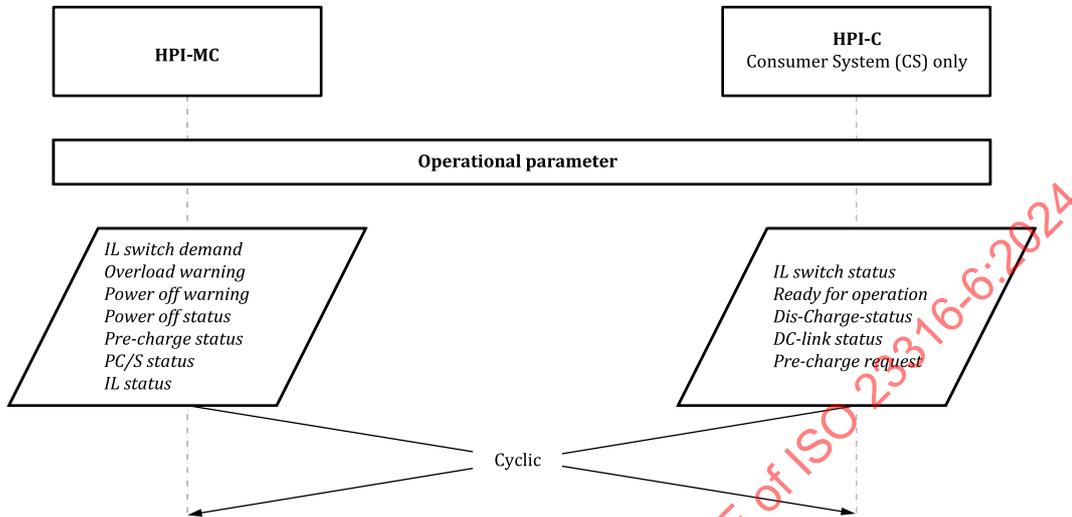


Figure 14 — Status summary chart

### 10.4 Sequence definition for normal start-up of an IL-based system

The start-up sequence under normal conditions (maintenance is out of scope) shall follow the procedure in [Figure 15](#).

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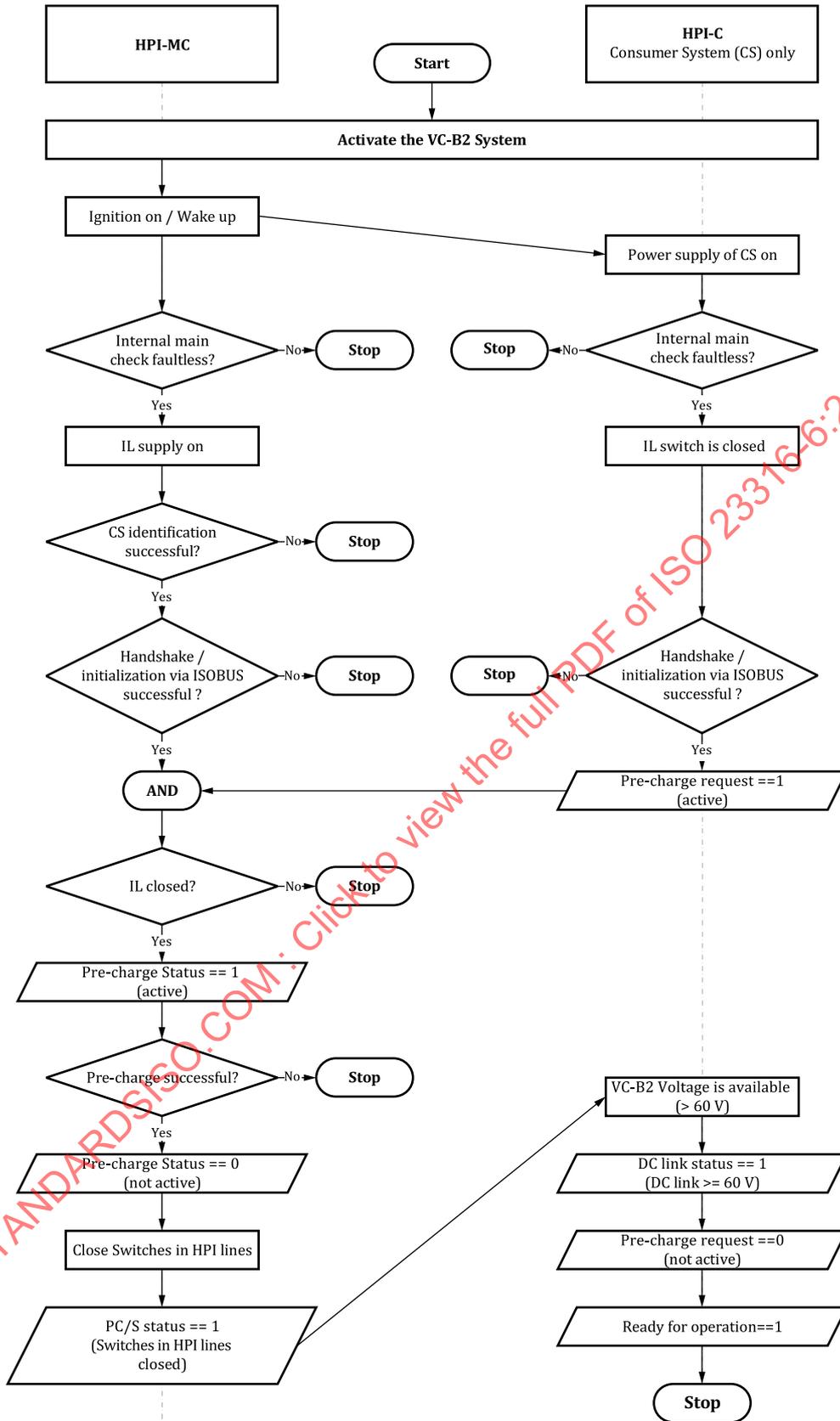


Figure 15 — IL and pre-charge flow chart

## 10.5 Sequence definition for normal system shutdown of an IL-based system

The normal system shutdown shall include the steps in [Table 4](#) to prevent deactivating the PC/S under load.

It is important that the PC/S in the VC-B2 lines are switched without electric current normally. For clarification, a certain amount of “leakage current” (up to 0,5 A) is still allowed per ISO 23316-5:2023, 5.1.12 as shown in [Figure 16](#) (leakage current check). When focusing on this “leakage current”, the condition during dis- and pre-charge is similar. Reasons for this “leakage current” are for example auxiliary devices powered via the DC link or passive dis-charge devices continuously connected to the DC link at the CS.

**Table 4 — Shutdown steps**

No.	Priority	Name	Description
1	Mandatory	Shut off the CS(s)	Regular shut-off of all electric drives and loads of the application.
2	Mandatory	Disable the release <sup>a</sup> of the CS(s)	Invoke the inverter release of all electric drives and loads to ensure a load current of approximately zero.
3	Optional	Monitoring of the actual current flow over the HPI on SS side	Give some information about the current flow (value, or state, if lower than or equal to allowed leakage current) to the operator, so that they can recognize the state.
4	Optional	Disable the release of the SS (path to the HPI)	If an inverter supplies the HPI, it is responsible for switching off VC-B2 DC power during shutdown procedure.
5	Mandatory, if disconnecting of the plug is requested	Open the PC/S on SS and, if available, on CS	Interrupt the VC-B2-lines (open the PC/S) to ensure de-energized state, before disconnecting SS and CS.

<sup>a</sup> Herein, “release” is used in analogy of the hydraulic domain, so releasing a hydraulic flow by a valve.

NOTE The flow-chart in [Figure 16](#) shows a non-binding example for a semi-automated system shutdown:

- The status messages of supply system and CS provide some information for a controlled shut down triggered by the system states in HPI-MC and HPI-C.
- Switching of main switching devices in the VC-B2 lines under current greater than the allowed idle current is used only during emergency shutdowns.

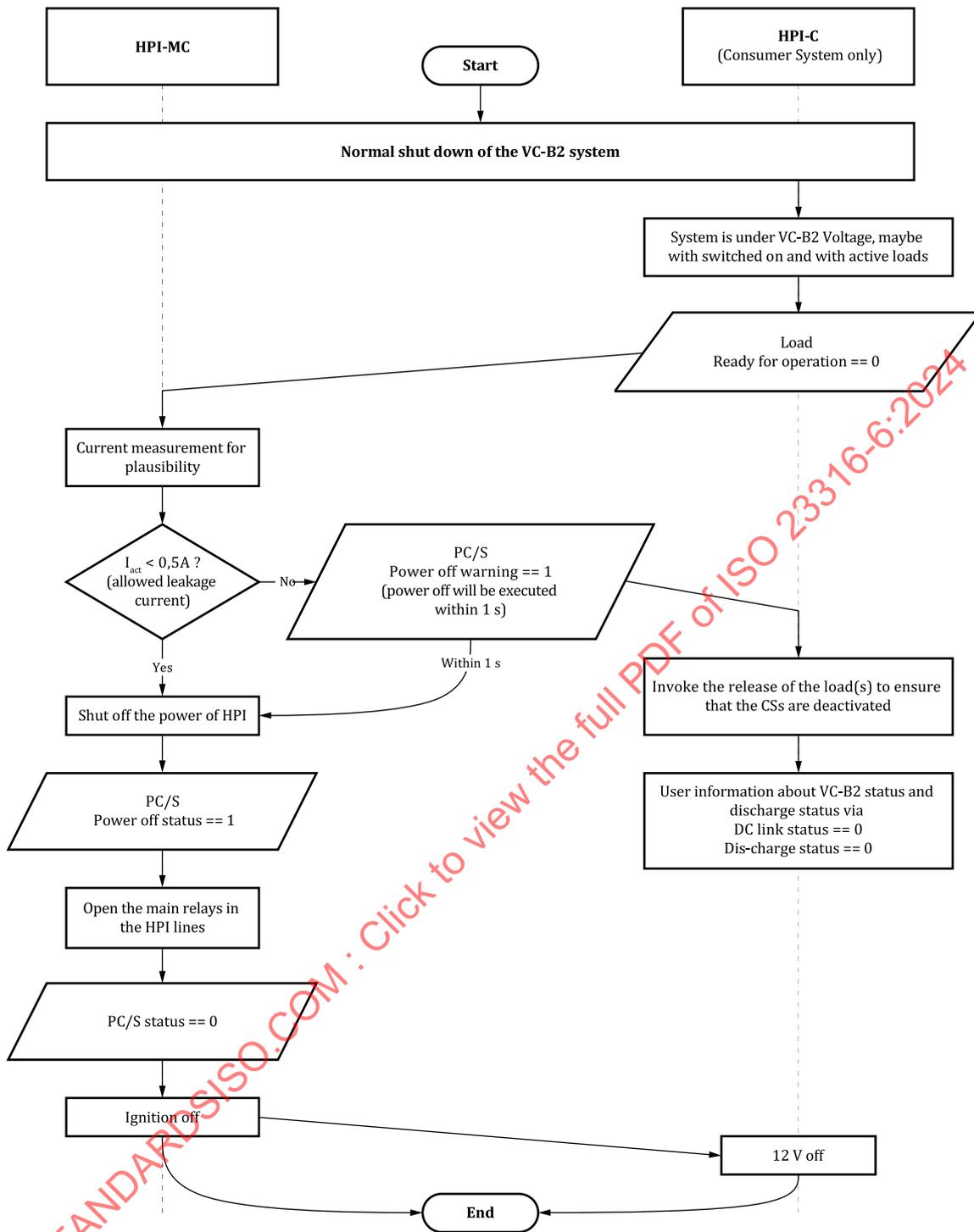


Figure 16 — Example of the sequence for a normal system shutdown

### 10.6 Sequence diagrams for system handshake of an IL-based system

The sequence diagrams (see [Figures 17 to 20](#)) for IL-based systems in this subclause shall complement the flow charts (see [Figures 12 to 16](#)) in the other subclauses of [Clause 10](#). These sequence diagrams align the system handshake for IL-based and fieldbus-based systems.

The SS HPI-C shall process the identification sequence per CS HPI-C in maximum 3 times as it is not successful.

The starting condition for each IL circuit shall be closed while connected.

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The SS HPI-C should start the identification process with the CS HPI-C having the lowest ISOBUS address.  
 The SS HPI-C should perform the identification process only for CS having an HPI-C.

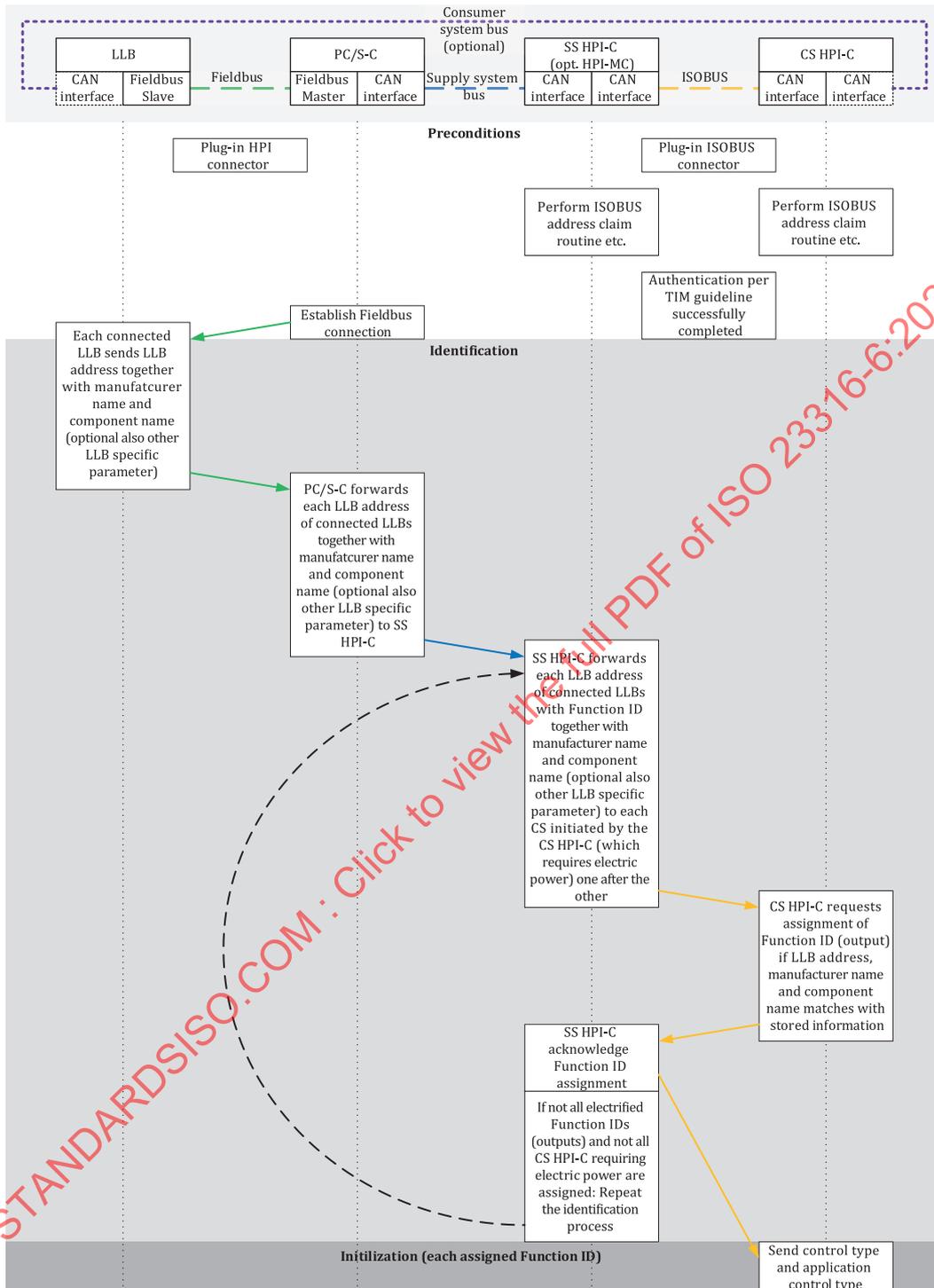


Figure 17 — Identification phase of an IL-based system

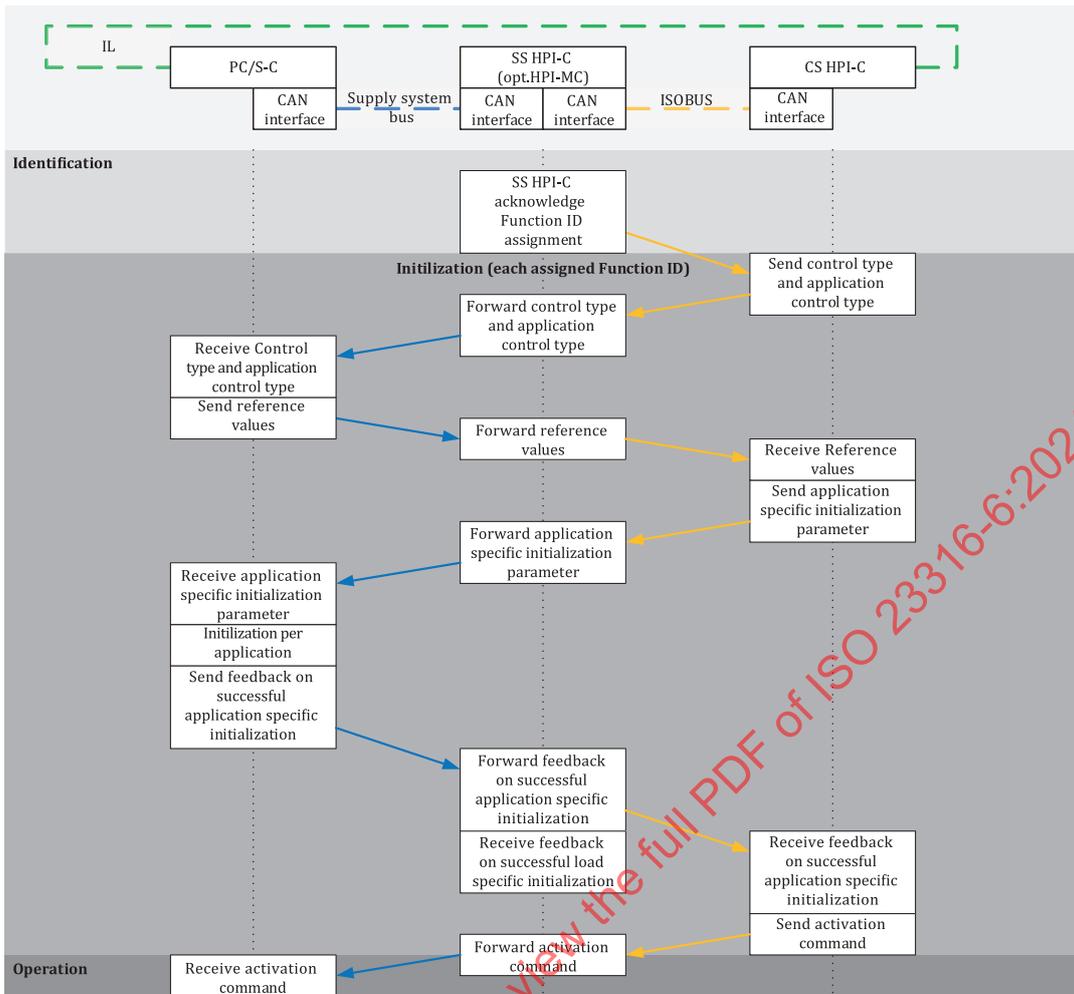


Figure 18 — Initialization phase of an IL-based system

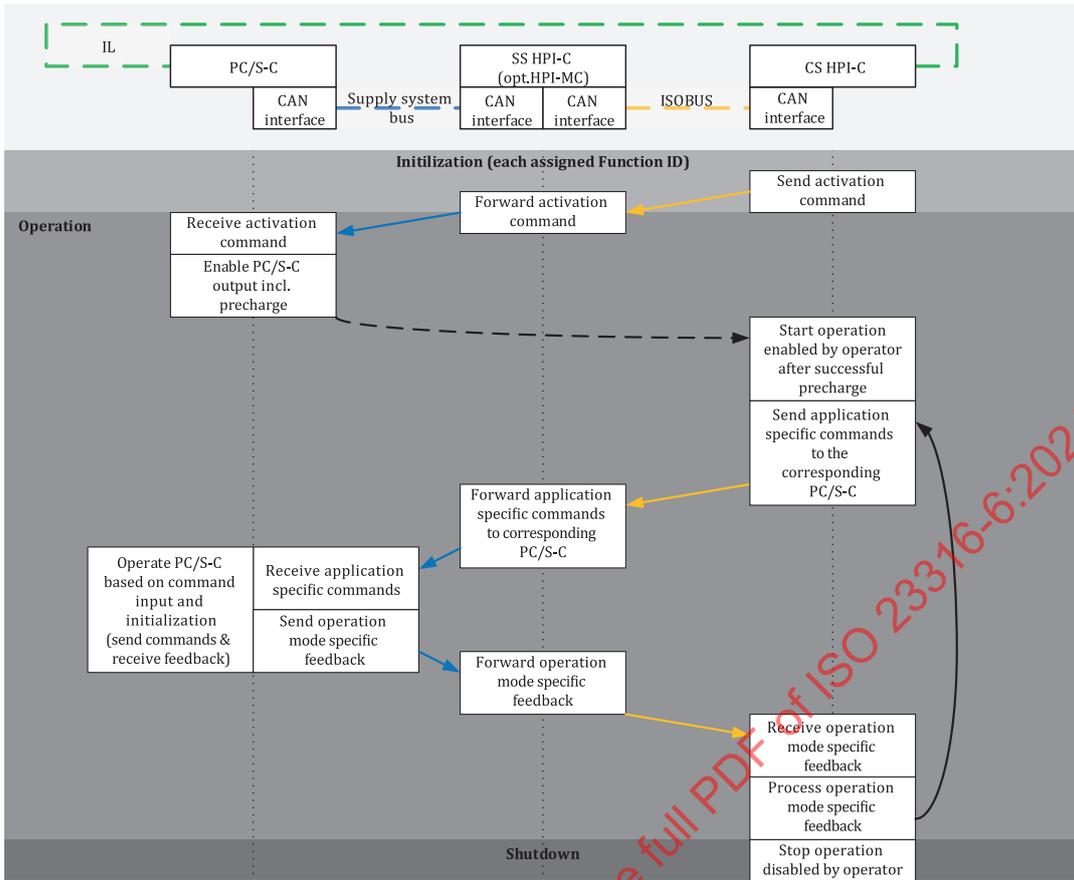


Figure 19 — Normal operation phase of an IL-based system

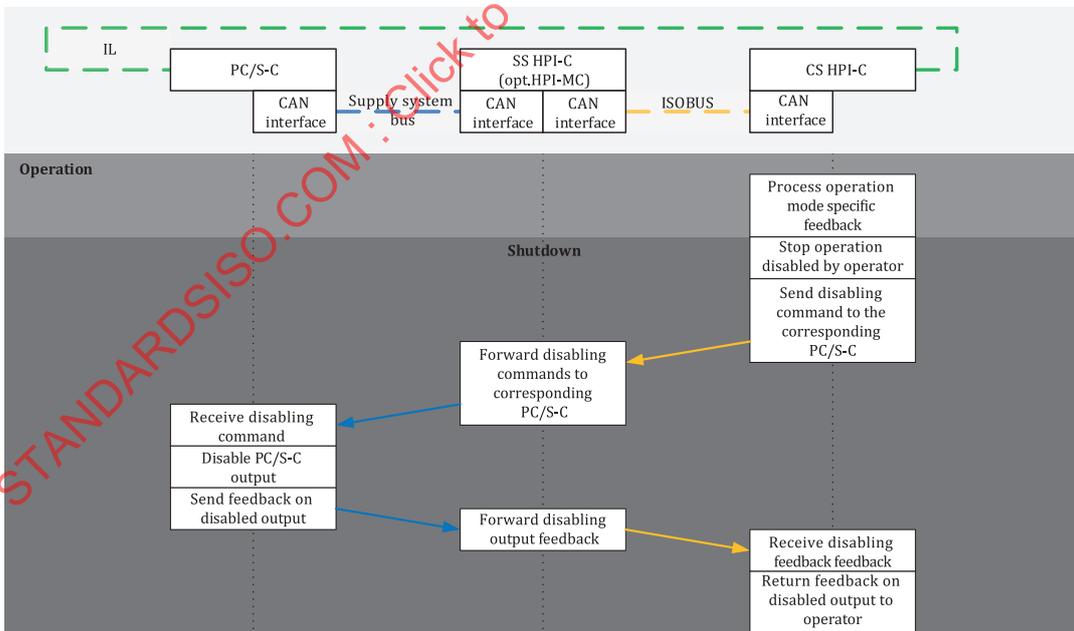


Figure 20 — Shutdown phase of an IL-based system

## 11 Isolation resistance and insulation monitoring

### 11.1 General

Any measuring method shall be agreed upon between the HPI-C and HPI-MC. Therefore, for tractor and implement combinations, the SS-M (usually at the tractor) monitors the combination as a whole, and the CS (usually an implement) is not additionally monitoring.

NOTE 1 Generally, only one insulation monitor can make measurements at a time on a VC-B2 circuit at a time. Multiple simultaneous measurements will generally interfere and cause erroneous measured values, which can result in inappropriate reaction of the HPI system.

Coordination of insulation monitoring shall be provided as a function of the HPI-MC, even if the system is not relying on it being continuously monitored by an Online Insulation Monitor (OIM)<sup>7)</sup>.

ISO 6469-3:2018, 6.3.2 may be used as guidance for different monitoring solutions, including multi consumer system (MCS).

As a maximum, only one OIM shall be active in the completed system located at the SS-M.

When an OIM is used:

- the HPI-MC shall coordinate the OIM operation;
- the HPI-Cs and HPI-MC shall agree on the coordination of any obtained isolation resistance (IR) values (e.g. SS at the tractor and CS at the implement need to be compatible). There may be EMC suppression devices including capacitance and high valued resistors (e.g. several M $\Omega$ ).

Alternatively, the HPI-C and HPI-MC may be pre-approved between the manufacturers (e.g. at an industry alignment event), with respect to insulation coordination and troubleshooting functionality.

- The manufacturer should provide a list of known verified comparable HPI-C and HPI-MC systems. Additionally, there should be other information such as literature or online guidance readily available, to increase the likelihood of compatibility.
- The HPI-MC shall be able to obtain the combined resultant resistance of SS and all the connected CSs of VC-B2 circuits in all operating modes.
- It is each manufacturers' decision about how to warn, or possibly disable the VC-B2 circuits. However, for any SS/CS combinations, the SS-M determines the relevant resistance values for any warning or other appropriate response.
- If the HPI-MC determines that the connected systems have an insulation resistance less than a value determined acceptable by the manufacturer, then the insulation monitoring system shall initiate an appropriate response, which may take the form of:
  - diagnostic trouble codes (DTCs),
  - de-rating,
  - disabling engine re-start or
  - de-energizing.
- If there is no functioning OIM connected to VC-B2 conductors, and a lack of measuring is determined, this information shall be brought to the attention of the operator. Allowing continued operation with a non-functioning OIM should be risk assessed and actioned accordingly.

7) An OIM is a device which continuously monitors the isolation resistance of a complete VC-B2 system during operation. It is an inherent part of the overall VC-B2 system.

- If the HPI-MC determines the connected SS and CSs have had a severe insulation fault, then the operator shall, as a minimum, be warned. A low resistance value can be an indication of a risk of fire. Allowing continued operation with a low resistance should be risk assessed and actioned accordingly.
- If a manufacturer chooses the method of automatically de-energizing the HPI, then a risk assessment shall be performed to determine if any harm can occur to the machinery systems or persons when it is invoked. The principles of IEC 60204-1:2016, 9.2 shall be used to address any potential harm identified. Any other reactions should be made based on a risk assessment of the combined systems.
- Prior to initiating any protective response, the HPI-MC may take into consideration erroneous data arising from cold start-up, temporary condensation, and the number of connected CSs.

NOTE 2 It can be possible to selectively disconnect/disable devices and determine more precisely where any system fault could reside, or to provide reduced/limited functionality in the event of a lower-than-expected resistance detection.

## 11.2 Communication

### 11.2.1 General

The following process steps in [11.2.2](#), [11.2.3](#) and [11.2.4](#) shall be performed during the initialization routine after the authentication and identification routines have successfully concluded and thus, the overall system topology is identified.

NOTE 1 Generally, an OIM is not mandatorily needed in system, it is only an option per ISO 23316-3.

NOTE 2 See [Table A.4](#) for the signal definitions.

### 11.2.2 OIM initialization

The manufacturer should risk assess if operation without an OIM is allowed, considering that an OIM is only an option.

NOTE Otherwise, different OIMs interfere with each other, and which can lead to inconsistent IR values.

The OIM initialization shall include the following steps:

- 1) The HPI-MC onboard of the SS-M broadcasts to each HPI-C whether an OIM is on-board of the corresponding CS or SS<sup>8)</sup>.
- 2) Each CS and SS send by its HPI-C an acknowledge to the HPI-MC.
- 3) If CS operation is not allowed, the operator shall be informed accordingly by the HPI-C of the specific CS or SS.

### 11.2.3 Minimum isolation resistance initialization

The manufacturers shall define a Minimum Isolation Resistance (MIR)<sup>9)</sup> value for each SS and CS considering the worst-case ambient conditions (e.g. high humidity for systems including air cooled components).

The MIR initialization process shall include all steps in the following order.

- 1) Each SS's HPI-C shall prohibit the activation of its output until the MIR process was successful.

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8) Considering that a CS can act as a SS for subsequent CS.

9) The wording "minimum isolation resistance" is chosen instead of "rated isolation resistance" or "nominal isolation resistance" since it represents the minimum isolation resistance in "normal" ambient conditions and without any insulation fault.

- 2) Each assigned CS HPI-C sends its MIR to its SS HPI-C as reaction of the assignment. If a CS acts as SS for subsequent CS (see example in [Figure 12](#) or [Annex C](#)), the HPI-C of the higher-level CS transmit the total MIR of itself and all subsequent CSs.
- 3) The HPI-MC onboard SS-M processes the received MIR data from all HPI-C.

NOTE 1 Consider that all IR values of SS and CSs are connected in parallel, this includes all potential IM impedances connected with the EPC.

- 4) The HPI-MC decides depending on the MIR result about its MIR-based operational status.
- 5) The HPI-MC broadcasts the MIR result and its MIR-based operational status to all HPI-C.
- 6) Each HPI-C decides on the MIR result about its MIR-based operational status.
- 7) Each CS's HPI-C responds by sending the MIR-based operational status to the HPI-C of its specific SS.

Normally, the MIR initialization process stops while reaching step 7. Because of a delayed connection of an HPI-C or other conditions, the HPI-MC may recognize an HPI-C which was not assigned at the beginning of the MIR initialization process or even after finalizing it. In such a case, the delayed HPI-C shall start with step 2 and the following process steps shall be repeated.

NOTE 2 The repetition of the process leads to a revised MIR and therefore to potentially revised MIR-based operational statuses.

HPI-MC and each HPI-C shall inform the operator on its own if its operation is not possible.

NOTE 3 For transfer of IR values, a specific signal definition is needed to handle the huge range of such resistance values, also considering usage in other applications. See definition in [A.1](#) and [Table A.4](#).

NOTE 4 For examples, see [Annex E](#).

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- Each SS or CS shall broadcast feedback on decision if needed (e.g. by sending a corresponding command or DTC).

Missing acknowledgement should be risk assessed and actioned accordingly.

NOTE 4 For examples, see [Annex E](#).

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## Annex A (normative)

### Communication signals

#### A.1 General

If not stated otherwise in the specific tables 'description, reference and comments' field, each parameter/signal may be changed in operation.

Relative parameter/signal quantities (usually percentages) shall reference to the values listed within [Table A.1](#); examples are actual and target values.

'Actual values'<sup>10)</sup> which are sent on a repeatable base shall be filtered with a filter constant equivalent to the repetition time, thus the average per transmission cycle is sent.

'Actual values' which are sent 'on request' shall be filtered with a useful time constant per quantity (e.g. temperatures will be usually filtered with a time constant of several seconds).

NOTE 1 According to ISO 11783-7:2020, Table 2 and Table 3 single-bit values for discrete parameters or control commands are not allowed. At minimum, two bits for describing are necessary, where the higher priority states are reserved for indicating error (bit-pattern: 1 0) and indicating not available/not installed (bit-pattern: 1 1).

NOTE 2 Depending on the kind of signal, common Scaling, Limit, Offset and Transfer function (SLOTs) from SAE J1939DA or specific value definitions are used. If applicable, therefore the corresponding SLOT name/identifier is referenced in "Description, reference and comments"; otherwise "- / -" is filled in.

NOTE 3 If same parameters with the same name are used in different operational modes, the same SLOT is usually applied.

NOTE 4 Only the necessary repetition rates are listed. However, if there is the requirement to transfer the parameter only during initialization phase, then this value is only transmitted automatically 'on change' once. Nevertheless, this parameter can be transmitted 'on request' again (e.g. during operation). It can be useful to transfer such parameters also frequently for other reasons (e.g. for a consistency check), as common practice this is permitted but not mentioned in the 'repetition rate' column.

The Suspect Parameter Number (SPN) per signal shall be defined in SAE J1939.

NOTE 6 Target and actual values will change during operation by intend. Therefore, no further hint is given that they can be changed during operation in the 'description, reference, and comments' column.

NOTE 7 Some modes will not use only a single target and / or actual value. This will be considered and reflected in the message sets finally.

#### A.2 General communication signals for AC mode according to ISO 23316-4 and DC mode according to ISO 23316-5

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10) 'Actual values' are feedback values as (e.g. measured current). It is the counterpart of the 'target value' (also known as set point, set value or desired value) in control technology.

Table A.1 — Application specific signals — Quantity references<sup>b</sup>

Signal	Source	Size/ length in bit	Values	Resolution/ scaling (per bit)	Signal range allowed		Repetition rate (allowed range <sup>a</sup> )	Description, reference and comments
					Minimum (signal offset)	Maximum (theoretical)		
Speed (rotational velocity) reference	PC/S (see description, reference and comments also)	16	—	4 rpm	0 rpm	250 000 rpm (257 020 rpm)	On change (during initialization) and on request	This parameter shall be set during initialization. The parameter shall not be changeable during the subsequent workflow and in operation. Recommendation: — Use the maximum operational speed set by LLB. — Per default set a value of 10 000 rpm. For further details see ISO 23316-4:2023, 4.7.2. SLOT: SAEvr03 / 77
Torque reference	PC/S (see description, reference and comments also)	16	—	1 Nm	0 Nm	64 000 Nm (64 255 Nm)	On change (during initialization) and on request	This parameter shall be set during initialization. The parameter shall not be changeable during the subsequent workflow and in operation. Recommendation: — Use the maximum operational peak torque set by LLB. — Per default set a value of 1 000 Nm. For further details see ISO 23316-4:2023, 4.7.2. SLOT: SAEtq02 / 70
Voltage reference	PC/S (see description, reference and comments also)	16	—	1 V	0 V	1 500 V (64 255 V)	On change (during initialization) and on request	This parameter shall be set during initialization. The parameter shall not be changeable during the subsequent workflow and in operation. Recommendation: — Use the voltage reference set by PC/S. — Per default set a value of 1 000 V. SLOT: SAEev02 / 145

<sup>a</sup> If applicable.

<sup>b</sup> for both ISO 23316-4 and ISO 23316-5.

Table A.1 (continued)

Signal	Source	Size/ length in bit	Values	Resolution/ scaling (per bit)	Signal range allowed		Repetition rate (allowed range <sup>a</sup> )	Description, reference and comments
					Minimum (signal offset)	Maximum (theoretical)		
Current reference	PC/S (see description, reference and comments also)	16	—	1 A	0 A	4 000 A (64 255 A)	On change (during initialization) and on request	This parameter shall be set during initialization. The parameter shall not be changeable during the subsequent workflow and in operation. Recommendation: — For DC mode per ISO 23316-5 use a reference value of 300 A. — For modes according ISO 23316-4 use the maximum operational peak current set by LLB. — Per default set a value of 1 000 A. SLOT: SAEEc04 / 146
Power reference	PC/S (see description, reference and comments also)	16	—	0,05 kW	0 kW	3 000 kW (3 212,75 kW)	On change (during initialization) and on request	This parameter shall be set during initialization. The parameter shall not be changeable during the subsequent workflow and in operation. Recommendation: — For DC mode per ISO 23316-5 use the product of voltage reference · current reference. — For modes according ISO 23316-4 use the maximum operational peak power set by LLB. — Per default set a value of 1 000 kW. SLOT: SAEPw05 / 346
Frequency reference	PC/S (see description, reference and comments also)	16	—	1 Hz	0 Hz	4 000 Hz (64 255 Hz)	On change (during initialization) and on request	This parameter shall be set during initialization. The parameter shall not be changeable during the subsequent workflow and in operation. Recommendation: — Use the maximum operational frequency set by LLB. — Per default set a value of 1 000 Hz. SLOT: - / -

<sup>a</sup> If applicable.

<sup>b</sup> for both ISO 23316-4 and ISO 23316-5.

Table A.2 — Application specific signals — General parameter<sup>b</sup>

Signal	Source	Size/ length in bit	Values	Resolution/ scaling (per bit)	Signal range allowed		Repetition rate (allowed range <sup>a</sup> )	Description, reference and comments
					Minimum (signal offset)	Maximum (theoretical)		
Control type		4	No type DC mode (per ISO 23316-5) Torque control (per ISO 23316-4) Speed control (per ISO 23316-4) Voltage-frequency characteristic control (per ISO 23316-4) Independent voltage and frequency supply (per ISO 23316-4) Variable DC chopper supply (per ISO 23316-4)	—	—	On change and on request	This parameter shall be set at beginning of the initialization process. The parameter shall not be changeable during the subsequent workflow and in operation. For further details, see ISO 23316- 4:2023, subclauses 4.4 and 4.7. SLOT: - / - No type is used during initializa- tion of the quantity references and as feedback value while no mode is set. The definition of custom modes shall be a collaborating effort between the manufacturers of CS and SS. These modes are intended for non-standardized usage of the HPI (e.g. for implementing a testing mode). These modes may use proprietary signals in addition to standardized signals, but for sure will need proprietary message sets (with an unknown content) which are based upon the standardized frame given for the standardized modes.	

<sup>a</sup> If applicable.

<sup>b</sup> For both ISO 23316-4 and ISO 23316-5.

Table A.2 (continued)

Signal	Source	Size/ length in bit	Values	Resolution/ scaling (per bit)	Signal range allowed		Repetition rate (allowed range <sup>a</sup> )	Description, reference and comments
					Minimum (signal offset)	Maximum (theoretical)		
			<p>7<sub>hex</sub> Custom mode 1</p> <p>8<sub>hex</sub> Custom mode 2</p> <p>9<sub>hex</sub> - C<sub>hex</sub> Reserved (not for use)</p> <p>D<sub>hex</sub> Tractor-controlled mode (per ISO 23316-4, as feedback only)</p> <p>E<sub>hex</sub> Not allowed (used for diagnostic purposes)</p> <p>F<sub>hex</sub> Not available</p>					<p>Remark: Reserved for specific purposes are the values D<sub>hex</sub> and E<sub>hex</sub>. These values are only used as a multiplexer in the message setup or for diagnostics.</p> <p>D<sub>hex</sub> = Not allowed for setting, it is intended to indicate the tractor-controlled mode per ISO 23316-4:2023, 4.7.1.2.3 as feedback. Setting the happens by application control type.</p> <p>E<sub>hex</sub> = 'Diagnostics' mode is intended to enable the reading of the server / client communication for diagnostic purposes. It enables also to request signals which are not transmitted on certain repetition rates, e.g. initialization parameters.</p> <p>While this as a multiplexer in the "message header", it will not change the control mode.</p>
Application control type		4	<p>0<sub>hex</sub> No type / no change</p> <p>1<sub>hex</sub> Implement-controlled</p> <p>2<sub>hex</sub> Tractor-controlled</p> <p>3<sub>hex</sub> - E<sub>hex</sub> Reserved</p> <p>F<sub>hex</sub> Not available</p>				On change and on request	<p>This parameter shall be set at beginning of the initialization process.</p> <p>The parameter shall not be changeable during the subsequent workflow and in operation.</p> <p>For further details see ISO 23316-4:2023, 4.7.1.2.</p> <p>SLOT: - / -</p> <p>Remark: In the implement-controlled mode - as common - the CS requests as a TIM client a function of the TIM server at the SS. Whereas in the tractor-controlled mode - which is not common - the SS requests the control of a function at the CS.</p>

<sup>a</sup> If applicable.

<sup>b</sup> For both ISO 23316-4 and ISO 23316-5.

Table A.2 (continued)

Signal	Source	Size/ length in bit	Values	Resolution/ scaling (per bit)	Signal range allowed		Repetition rate (allowed range <sup>a</sup> )	Description, reference and comments
					Minimum (signal offset)	Maximum (theoretical)		
PC/S maximum supply power capability		8	—	0,5 %	0 %	125 % (125 %)	On change and on request	Power capability of the PC/S, re- fers to motoring mode of a load. If the source can provide ≥125 %, set this value to 125 %. This parameter shall be set during the initialization process. The parameter shall not be changeable during the subsequent workflow and in operation. Percentage of power reference SLOT: SAEPc18 / 299
PC/S maximum braking power capability		8	—	0,5 %	0 %	125 % (125 %)	On change and on request	Power capability of the PC/S, re- fers to generating (recuperating) mode of a load. If the PC/S can consume ≥125 %, set this value to 125 %. This parameter shall be set during the initialization process. The parameter shall not be changeable during the subsequent workflow and in operation. Percentage of power reference SLOT: SAEPc18 / 299
PC/S maximum current capability		8	—	0,5 %	0 %	125 % (125 %)	On change and on request	Current capability of the PC/S. If the PC/S can provide ≥125 %, set this value to 125 %. This parameter shall be set during the initialization process. The parameter shall not be changeable during the subsequent workflow and in operation. For further details see ISO 23316- 4:2023, 4.5.2.1. Percentage of power reference SLOT: SAEPc18 / 299

<sup>a</sup> If applicable.

<sup>b</sup> For both ISO 23316-4 and ISO 23316-5.

Table A.2 (continued)

Signal	Source	Size/ length in bit	Values	Resolution/ scaling (per bit)	Signal range allowed		Repetition rate (allowed range <sup>a</sup> )	Description, reference and comments
					Minimum (signal offset)	Maximum (theoretical)		
Limitation of maximum load current		8	—	0,5 %	0 %	125 % (125 %)	On change and on request	Limit of load current based on im- plement self-protection measures (e.g. i <sup>2</sup> t monitor): — RMS for AC, — Average for DC. This parameter shall be set during the initialization process. The parameter shall not be changeable during the subsequent workflow and in operation. For further details see ISO 23316- 4: 4.5.2.2.2. Percentage of current reference. SLOT: SAEpc18 / 299
Actual electrical active PC/S output power		16	—	0,01 %	-250 % (-327,27 %)	250 % (321,28 %)	On request	Feedback of PC/S output power. This is an operational parameter which is changed during opera- tion. Percentage of power reference. SLOT: SAEpc22 / 387
Actual current		16	—	0,01 %	-250 % (-327,27 %)	250 % (321,28 %)	On request	Feedback of inverter (PWM) current: — Signed RMS for AC, — Signed average for DC. For further details see ISO 23316- 4:2023, 4.5.2.2.2. Percentage of current reference. SLOT: SAEpc22 / 387
Actual voltage		16	—	0,01 %	-250 % (-327,27 %)	250 % (321,28 %)	On request	Feedback of inverter PWM voltage (RMS): — Fundamental component for AC, — Signed average for DC. Percentage of voltage reference. SLOT: SAEpc22 / 387

<sup>a</sup> If applicable.

<sup>b</sup> For both ISO 23316-4 and ISO 23316-5.

Table A.2 (continued)

Signal	Source	Size/ length in bit	Values	Resolution/ scaling (per bit)	Signal range allowed		Repetition rate (allowed range <sup>a</sup> )	Description, reference and comments
					Minimum (signal offset)	Maximum (theoretical)		
Fieldbus presence		2	0 Fieldbus not present 1 Fieldbus present 2 Error 3 Not available	—	—	On change and on request	This parameter shall be set during the initialization process. The parameter shall not be changeable during the subsequent workflow and in operation. This flag indicates the presence of a fieldbus in all modes, to enable the IL function via fieldbus in both AC- and DC-mode. SLOT: - / -	
Actual value request		2	0 No request 1 Request 2 Error 3 Not available	—	—	On request	This parameter indicates the request of actual values e.g. of voltage, current, power or tem- perature. SLOT: - / -	
<sup>a</sup> If applicable. <sup>b</sup> For both ISO 23316-4 and ISO 23316-5.								

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The isolation resistance (IR) value requires a new SLOT definition, and the following definition shall be introduced:

— 3-digit number multiplied with the power of 10 exponent.

This results in 3 x 4 bit + 4 bit for defining the value. It enables the following value range:  $000 \cdot 10^3 \Omega \dots 999 \cdot 10^{10} \Omega$ . Hence, 3 nibbles (4 bits) are used for the numerals NNN (4 bit) and one nibble for the exponent E:  $NNN \cdot 10^E$  with each N in a range 0...9 and E with a range of -3...+10.

NOTE 1 The IR value varies in a wide range. No common linear scaling useful.

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Table A.3 — Signal definition for IR values

Hex	Dec	Digit (N)	Exponent (E)
0	0	0	-3
1	1	1	-2
2	2	2	-1
3	3	3	0
4	4	4	1
5	5	5	2
6	6	6	3
7	7	7	4
8	8	8	5
9	9	9	6
A	10	-	7
B	11	-	8
C	12	-	9
D	13	-	10
E	14	Diagnostics	Diagnostics
F	15	Not allowed	Not allowed

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The signals of online insulation monitoring (OIM) and IR in [Table A.4](#) shall be shared between the HPI-MC and each HPI-C in both ways (broadcasted).

NOTE 2 Broadcasting of these signals is necessary while there can be relations or dependencies between different HPI-Cs onboard of the same or different CSs.

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Table A.4 — Application specific signals – insulation monitor and isolation resistance coordination<sup>b</sup>

Signal	Source	Size / length in bit	Values	Resolution/ scaling (per bit)	Signal range allowed		Repetition rate (allowed range <sup>a</sup> )	Description, reference and comments
					Minimum (signal offset)	Maximum (theoretical)		
Online insulation monitor (OIM) presence			0 OIM not present at SS 1 OIM present at SS-M 2 Error 3 Not available	—	—	On change (during initialization) and on request	This parameter shall be set by the HPI-MC during initialization phase. No further changes during operation shall be allowed. It defines whether an OIM is present at the SS-M. SLOT: - / -	
Minimum isolation resistance (MIR)		4x4 = 16	3-digit number NNN (decimal system): 0...9 represent the numeral, A...D unused, E Diagnostics, F Not allowed Exponent E (power of 10): 0...D represent -3...+10, E Diagnostics, F Not allowed	—	—	On change (during initialization) and on request	This parameter shall be set by HPI-MC and each HPI-C during the initialization phase. No further changes during operation shall be allowed. It defines the MIR per design of the SS and each CS. SLOT: - / - NOTE: The signal example NNNE = 1 234 defines a MIR of 123e1 Ω = 123·10 <sup>1</sup> Ω = 1 230 Ω.	
MIR based operation		2	0 Disable 1 Enable 2 Error 3 Not available	—	—	On change (during initialization) and on request	This parameter shall be set by HPI-MC and each HPI-C after receiving MIR values from all other SS and CSs by SS and each CS during initialization phase. No further changes during operation shall be allowed. SLOT: - / -	
Actual isolation resistance (IR)		4x4 = 16	3-digit number NNN (decimal system): 0...9 represent the numeral, A...D unused, E Diagnostics, F Not allowed Exponent E (power of 10): 0...D represent -3...+10, E Diagnostics, F Not allowed	—	—	1 Hz (0,1 Hz...1 Hz), on change and on request	This parameter shall be set by the HPI-MC periodically. It defines the online measured actual IR if an OIM is present at the SS-M. SLOT: - / - NOTE: The signal example NNNE = 1 234 defines a MIR of 123e1 Ω = 123·10 <sup>1</sup> Ω = 1 230 Ω.	
Actual IR based operation		2	0 Disable 1 Enable 2 Error 3 Not available	—	—	1 Hz (0,1 Hz...1 Hz), on change and on request	This parameter shall be set by HPI-MC and each HPI-C after receiving the actual IR by SS and each CS also periodically. SLOT: - / -	

<sup>a</sup> If applicable.

<sup>b</sup> For both ISO 23316-4 and ISO 23316-5.

### A.3 Communication signals for AC mode according to ISO 23316-4

#### A.3.1 ISOBUS signals

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Table A.5 — Application specific signals — General AC mode specific parameter<sup>b</sup>

Signal	Source	Size/ length in bit	Values	Resolution/ scaling (per bit)	Signal range allowed		Repetition rate (allowed range <sup>a</sup> )	Description, reference and comments
					Minimum (signal offset)	Maximum (theoretical)		
Load initialization parameter			8+8+32 = 48-0 - 7 Index 8 - 15 Sub-index -6 - 47 Value	—	—	—	On request	Parameter transmitted by LLB, this is intended to read out values provided via fieldbus to the PC/S e.g. during initialization. SLOT: - / -
Load max. allowed voltage slope (dU/dt)		8	—	1 kV/µs	5 kV/µs (0 kV/µs)	100 kV/µs (250 kV/µs)	On change and on request	Load threshold of maximum allowed PWM voltage slope (dU/dt). This parameter shall be set during initialization. The parameter shall not be changeable during the subsequent workflow and in operation. See <a href="#">Table A.13</a> and ISO 23316-4:2023, 4.5.1.3. SLOT: - / -
Inverter voltage slope (dU/dt)		8	—	1 kV/µs	5 kV/µs (0 kV/µs)	100 kV/µs (250 kV/µs)	On change and on request	Inverter threshold of maximum allowed PWM voltage slope (dU/dt). This parameter shall be set during initialization. The parameter shall not be changeable during the subsequent workflow and in operation. See <a href="#">Table A.13</a> and ISO 23316-4:2023, 4.5.1.3. SLOT: - / -
Actual load temperature 1 <sup>a</sup>		16	—	0,031 25 K	-50 °C (-273 °C)	300 °C (~1 735 °C)	On request	E.g. motor winding temperature; enables OOR (out of range) indication low and high. This is intended to forward the actual temperatures of <a href="#">Table A.12</a> . SLOT: SAETp02 / 68
Actual load temperature 2 <sup>a</sup>		16	—	0,031 25 K	-50 °C (-273 °C)	300 °C (~1 735 °C)	On request	E.g. motor winding temperature; enables OOR (out of range) indication low and high. This is intended to forward the actual temperatures of <a href="#">Table A.12</a> . SLOT: SAETp02 / 68

<sup>a</sup> If applicable.

<sup>b</sup> See ISO 23316-4.

Table A.6 — Application specific signals — Torque control parameter<sup>b</sup>

Signal	Source	Size/ length in bit	Values	Resolution/ scaling (per bit)	Signal range allowed		Repetition rate (allowed range <sup>a</sup> )	Description, reference and comments
					Minimum (signal offset)	Maximum (theoretical)		
Target torque		16	—	0,01 %	-100 % (-327,27 %)	100 % (321,28 %)	10 Hz, on change and on request	Percentage of torque reference SLOT: SAEpc22 / 387
Actual torque		16	—	0,01 %	-250 % (-327,27 %)	250 % (321,28 %)	10 Hz, on change and on request	Percentage of torque reference SLOT: SAEpc22 / 387
Actual speed		16	—	0,01 %	-250 % (-327,27 %)	250 % (321,28 %)	10 Hz, on change and on request	Percentage of speed reference. SLOT: SAEpc22 / 387
Torque slew rate for increasing target value		16	—	1 %/s	0 % / s	60 000 %/s (64 255 %/s)	On change and on request	This parameter shall be set during initialization. The parameter shall changeable during operation. Percentage of torque reference per second SLOT: - / -
Torque slew rate for decreasing target value		16	—	1 %/s	0 %/s	60 000 %/s (64 255 %/s)	On change and on request	This parameter shall be set during initialization. The parameter shall changeable during operation. Percentage of torque reference per second SLOT: - / -
Speed limitation - positive direction of rotation		8	—	0,5 %	0 %	125 % (125 %)	On change and on request	This parameter shall be set during initialization. The parameter shall changeable during operation. See ISO 23316-4:2023, 4.7.2.1.2. Percentage of speed reference SLOT: SAEpc18 / 299

<sup>a</sup> If applicable.

<sup>b</sup> See ISO 23316-4:2023, 4.7.2.1 and following subclauses.

Table A.6 (continued)

Signal	Source	Size/ length in bit	Values	Resolution/ scaling (per bit)	Signal range allowed		Repetition rate (allowed range <sup>a</sup> )	Description, reference and comments
					Minimum (signal offset)	Maximum (theoretical)		
Speed limitation - negative direction of rotation		8	—	0,5 %	0 %	125 % (125 %)	On change and on request	This parameter shall be set during initialization. The parameter shall changeable during operation. See ISO 23316-4:2023, 4.7.2.1.2. Percentage of speed reference SLOT: SAepc18 / 299
Torque ramp down speed - posi- tive direction of rotation		8	—	0,5 %	0,5 % (0 %)	125 % (125 %)	On change and on request	This parameter shall be set during initialization. The parameter shall changeable during operation. See ISO 23316-4:2023, 4.7.2.1.2. Percentage of speed reference SLOT: SAepc18 / 299
Torque ramp down speed - nega- tive direction of rotation		8	—	0,5 %	0,5 % (0 %)	125 % (125 %)	On change and on request	This parameter shall be set during initialization. The parameter shall changeable during operation. See ISO 23316-4:2023, 4.7.2.1.2. Percentage of speed reference SLOT: SAepc18 / 299

<sup>a</sup> If applicable.

<sup>b</sup> See ISO 23316-4:2023, 4.7.2.1 and following subclauses.

Table A.7 — Application specific signals — Speed control parameter<sup>b</sup>

Signal	Source	Size/ length in bit	Values	Resolution/ scaling (per bit)	Signal range allowed		Repetition rate (allowed range <sup>a</sup> )	Description, reference and comments
					Minimum (signal offset)	Maximum (theoretical)		
Target speed		16	—	0,01 %	-100 % (-327,27 %)	100 % (321,28 %)	10 Hz, on change and on request	Percentage of speed reference. SLOT: SAEpc22 / 387
Actual torque		16	—	0,01 %	-250 % (-327,27 %)	250 % (321,28 %)	10 Hz, on change and on request	Percentage of torque reference SLOT: SAEpc22 / 387
Actual speed		16	—	0,01 %	-250 % (-327,27 %)	250 % (321,28 %)	10 Hz, on change and on request	Percentage of speed reference. SLOT: SAEpc22 / 387
Slew rate for increasing target value		16	—	1 %/s	0 %/s	60 000 %/s (64 255 %/s)	On change and on request	This parameter shall be set during initialization. The parameter shall changeable during operation. Percentage of speed reference per second. SLOT: - / -
Slew rate for decreasing target value		16	—	1 %/s	0 % / s	60 000 %/s (64 255 % / s)	On change and on request	This parameter shall be set during initialization. The parameter shall changeable during operation. Percentage of speed reference per second. SLOT: - / -
Limitation for positive values of controller output variable		8	—	0,5 %	0 %	100 % (125 %)	On change and on request	This parameter shall be set during initialization. The parameter shall changeable during operation. Percentage of torque reference SLOT: SAEpc18 / 299

<sup>a</sup> If applicable.

<sup>b</sup> See ISO 23316-4:2023 subclause 4.7.2.2 and following subclauses.

Table A.7 (continued)

Signal	Source	Size/ length in bit	Values	Resolution/ scaling (per bit)	Signal range allowed		Repetition rate (allowed range <sup>a</sup> )	Description, reference and comments
					Minimum (signal offset)	Maximum (theoretical)		
Limitation for negative values of controller output variable		8	—	0,5 %	0 %	100 % (125 %)	On change and on request	This parameter shall be set during initialization. The parameter shall be changeable during operation. Percentage of torque reference SLOT: SAEPc18 / 299
Proportional gain ( $k_p$ )		16	—	0,01 = 0,01 % <sub>Nm</sub> / % rpm	0	100 (642,55)	On change and on request	A value of 0 disables this portion of the speed controller. This parameter shall be set during initialization. The parameter shall be changeable during operation. See ISO 23316-4:2023, 4.7.2.3. Percentage of torque reference (default: 1). SLOT: SAEr05 / 362
Integration gain ( $k_i$ )		16	—	0,001/s = 1/ms = 1/ms-%N- m/%rpm	0/s	10/s (64,255/s)	On change and on request	A value of 0/s disables this portion of the speed controller. This parameter shall be set during initialization. The parameter shall be changeable during operation. See ISO 23316-4:2023, 4.7.2.3. Percentage of torque reference (default: 0). SLOT: - / -

<sup>a</sup> If applicable.

<sup>b</sup> See ISO 23316-4:2023 subclause 4.7.2.2 and following subclauses.

Table A.8 — Application specific signals — Voltage / frequency (U/f) characteristics control parameter<sup>b</sup>

Signal	Source	Size/ length in bit	Values	Resolution/ scaling (per bit)	Signal range allowed		Repetition rate (allowed range <sup>a</sup> )	Description, reference and comments
					Minimum (signal offset)	Maximum (theoretical)		
Target frequency		16	—	0,01 %	-100 % (-327,27 %)	100 % (321,28 %)	10 Hz, on change and on request	Output frequency (frequency of fundamental component) before ramp generator. Percentage of frequency reference. SLOT: SAEPc22 / 387
Actual voltage		16	—	0,01 %	-250 % (-327,27 %)	250 % (321,28 %)	10 Hz, on change and on request	Output voltage (amplitude of fun- damental component) after ramp generator. Percentage of voltage reference. SLOT: SAEPc22 / 387
Actual frequency		16	—	0,01 %	-250 % (-327,27 %)	250 % (321,28 %)	10 Hz, on change and on request	Output frequency (frequency of fundamental component) after ramp generator. Percentage of frequency reference. SLOT: SAEPc22 / 387
Slew rate for increasing target value		16	—	1 %/s	0 %/s	60 000 %/s (64 255 %/s)	On change and on request	This parameter shall be set during initialization. The parameter shall be change- able during operation. Percentage of frequency reference per second. SLOT: - / -
Slew rate for decreasing target value		16	—	1 %/s	0 % / s	60 000 %/s (64 255 % / s)	On change and on request	This parameter shall be set during initialization. The parameter shall be change- able during operation. Percentage of frequency reference per second. SLOT: - / -
U0		8	—	0,5 %	0 %	100 % (125 %)	On change and on request	Output voltage at 0Hz (DC volt- age). See <a href="#">Figure 9</a> . This parameter shall be set during initialization. The parameter shall not be changeable during the subsequent workflow and in operation. Percentage of voltage reference. SLOT: SAEPc18 / 299

<sup>a</sup> If applicable.

<sup>b</sup> See ISO 23316-4:2023, 4.7.3.2.

Table A.8 (continued)

Signal	Source	Size/ length in bit	Values	Resolution/ scaling (per bit)	Signal range allowed		Repetition rate (allowed range <sup>a</sup> )	Description, reference and comments
					Minimum (signal offset)	Maximum (theoretical)		
U1		8	—	0,5 %	0 %	100 % (125 %)	On change and on request	Output voltage (amplitude of fundamental component) $U1 \geq U0$ at frequency $f1$ . See <a href="#">Figure 9</a> . This parameter shall be set during initialization. The parameter shall not be changeable during the subsequent workflow and in operation. Percentage of voltage reference. SLOT: SAepc18 / 299
U2		8	—	0,5 %	0 %	100 % (125 %)	On change and on request	Output voltage (amplitude of fundamental component) $U2 \geq U1$ for $f \geq f2$ . See <a href="#">Figure 9</a> . This parameter shall be set during initialization. The parameter shall not be changeable during the subsequent workflow and in operation. Percentage of voltage reference. SLOT: SAepc18 / 299

<sup>a</sup> If applicable.

<sup>b</sup> See ISO 23316-4:2023, 4.7.3.2.

Table A.8 (continued)

Signal	Source	Size/ length in bit	Values	Resolution/ scaling (per bit)	Signal range allowed		Repetition rate (allowed range <sup>a</sup> )	Description, reference and comments
					Minimum (signal offset)	Maximum (theoretical)		
f1		8	—	0,5 %	0 %	100 % (125 %)	On change and on request	Frequency of fundamental component at definition point 1 ( $f_1 \geq 0\text{Hz}$ ). See <a href="#">Figure 9</a> . This parameter shall be set during initialization. The parameter shall not be changeable during the subsequent workflow and in operation. Percentage of frequency reference. SLOT: SAepc18 / 299
f2		8	—	0,5 %	0 %	100 % (125 %)	On change and on request	Frequency of fundamental component at definition point 2 ( $f_2 \geq f_1$ ). See <a href="#">Figure 9</a> . This parameter shall be set during initialization. The parameter shall not be changeable during the subsequent workflow and in operation. Percentage of frequency reference. SLOT: SAepc18 / 299
f3		8	—	0,5 %	0 %	100 % (125 %)	On change and on request	Maximum output frequency of fundamental component ( $f_3 \geq f_2$ ). See <a href="#">Figure 9</a> . This parameter shall be set during initialization. The parameter shall not be changeable during the subsequent workflow and in operation. Percentage of frequency reference. SLOT: SAepc18 / 299

<sup>a</sup> If applicable.

<sup>b</sup> See ISO 23316-4:2023, 4.7.3.2.

Table A.9 — Application specific signals — Independent voltage and frequency (U&f) supply parameter<sup>b</sup>

Signal	Source	Size/ length in bit	Values	Resolution/ scaling (per bit)	Signal range allowed		Repetition rate (allowed range <sup>a</sup> )	Description, reference and comments
					Minimum (signal offset)	Maximum (theoretical)		
Target frequency		16	—	0,01 %	-100 % (-327,27 %)	100 % (321,28 %)	10 Hz, on change and on request	Output frequency (frequency of fundamental component) before ramp generator. Percentage of frequency refer- ence. SLOT: SAEpc22 / 387
Actual frequency		16	—	0,01 %	-250 % (-327,27 %)	250 % (321,28 %)	10 Hz, on change and on request	Output frequency (frequency of fundamental component) after ramp generator. Percentage of frequency refer- ence. SLOT: SAEpc22 / 387
Slew rate for increasing frequen- cy target value		16	—	1 %/s	0 %/s	60 000 %/s (64 255 %/s)	On change and on request	This parameter shall be set dur- ing initialization. The parameter shall be changea- ble during operation. Percentage of frequency refer- ence per second. SLOT: - / -
Slew rate for decreasing frequen- cy target value		16	—	1 %/s	0 % / s	60 000 %/s (64 255 % / s)	On change and on request	This parameter shall be set dur- ing initialization. The parameter shall be changea- ble during operation. Percentage of frequency refer- ence per second. SLOT: - / -
Target voltage		16	—	0,01 %	0 % (-327,27 %)	100 % (321,28 %)	10 Hz, on change and on request	Output voltage (amplitude of fundamental component) before ramp generator. Percentage of voltage reference. SLOT: SAEpc22 / 387

<sup>a</sup> If applicable.

<sup>b</sup> See ISO 23316-4:2023, 4.7.3.3.

Table A.9 (continued)

Signal	Source	Size/ length in bit	Values	Resolution/ scaling (per bit)	Signal range allowed		Repetition rate (allowed range <sup>a</sup> )	Description, reference and comments
					Minimum (signal offset)	Maximum (theoretical)		
Actual voltage		16	—	0,01 %	-250 % (-327,27 %)	250 % (321,28 %)	10 Hz, on change and on request	Output voltage (amplitude of fundamental component) after ramp generator. Percentage of voltage reference. SLOT: SAEpc22 / 387
Slew rate for increasing voltage target value		16	—	1 %/s	0 %/s	60 000 %/s (64 255 %/s)	On change and on request	This parameter shall be set dur- ing initialization. The parameter shall be changea- ble during operation. Percentage of frequency refer- ence per second. SLOT: - / -
Slew rate for decreasing frequen- cy target value		16	—	1 %/s	0 % / s	60 000 %/s (64 255 % / s)	On change and on request	This parameter shall be set dur- ing initialization. The parameter shall be changea- ble during operation. Percentage of frequency refer- ence per second. SLOT: - / -

<sup>a</sup> If applicable.

<sup>b</sup> See ISO 23316-4:2023, 4.7.3.3.

Table A.10 — Application specific signals — Variable DC chopper supply parameter<sup>b</sup>

Signal	Source	Size/ length in bit	Values	Resolution/ scaling (per bit)	Signal range allowed		Repetition rate (allowed range <sup>a</sup> )	Description, reference and comments
					Minimum (signal offset)	Maximum (theoretical)		
Target voltage		16	—	0,01 %	0 % (-327,27 %)	100 % (321,28 %)	10 Hz, on change and on request	Output voltage (DC voltage). Percentage of voltage reference (before ramp generator) SLOT: SAepc22 / 387
Actual voltage		16	—	0,01 %	-250 % (-327,27 %)	250 % (321,28 %)	10 Hz, on change and on request	Output voltage (DC voltage). Percentage of voltage reference (after ramp generator). SLOT: SAepc22 / 387
Slew rate for increasing voltage target value		16	—	1 %/s	0 %/s	60 000 %/s (64 255 %/s)	On change and on request	This parameter shall be set during initialization. The parameter shall be changea- ble during operation. Percentage of frequency reference per second. SLOT: - / -
Slew rate for decreasing voltage target value		16	—	1 %/s	0 % / s	60 000 %/s (64 255 % / s)	On change and on request	This parameter shall be set during initialization. The parameter shall be changea- ble during operation. Percentage of frequency reference per second. SLOT: - / -

<sup>a</sup> If applicable.

<sup>b</sup> See ISO 23316-4:2023, 4.7.3.4.

## A.3.2 Load specific signals

### A.3.2.1 Datatype definition

The datatype “string” shall represent a combination (an array) of characters (interpreted as enhanced ASCII code: characters/letters and numerals). Each character shall have the length of 8 bit. The string length shall be 50 characters.

Each load specific signal sent on the fieldbus shall be accessible on ISOBUS as a response while sending the corresponding index and sub-index as request.

NOTE 1 The datatype’s intended use is the ‘manufacturer code’, ‘type code’, etc. Such a datatype is already defined e.g. for C++. If the datatype will be transferred via CAN, the use of the so called “transport protocol” is necessary.

NOTE 2 See [Clause 7](#) for the physical layer of the fieldbus.

NOTE 3 Fieldbus index 5 – 13 not used yet. For compatibility with CAN bus restrictions, fieldbus index and sub-index  $F_{\text{hex}}$  (=15) is not available.

NOTE 4 IEC 61800-7-202 is used as reference for load/electric machine parameters in [Table A.11](#).

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Table A.11 — Load specific signals — Load parameter for identification<sup>c</sup>

Fieldbus object Index (4 bit)	Fieldbus object Sub- index (4 bit)	Signal	Source	Size/ length in bit	Values	Resolution/ scaling (per bit)	Signal range allowed		Repetition rate <sup>a</sup> (allowed range <sup>b</sup> )	Description, reference and comments
							Minimum (signal offset)	Maximum (theoretical)		
0	0	—	—	—	—	—	—	—	On change and on request	Refer to PGN 6700 per SAE J1939DA (2023, May), details are listed in ISO 11783-12. This parameter shall be set dur- ing identification. The parameter shall not be changeable during the subse- quent workflow and in operation. Used for identification per <a href="#">subclause 9.1</a> . String, in analogy to the manu- facturer code on ISOBUS. SLOT: - / -
0	1	Load/electric machine manufacturer code	—	String	—	—	—	—	On change and on request	Refer to PGN 6701 per SAE J1939DA (2023, May), details are listed in ISO 11783-12. This parameter shall be set dur- ing identification. The parameter shall not be changeable during the subse- quent workflow and in operation. Used for identification per <a href="#">subclause 9.1</a> . String, in analogy to the type code on ISOBUS. SLOT: - / -
0	2	Load/electric machine code	—	String	—	—	—	—	On change and on request	Refer to PGN 6701 per SAE J1939DA (2023, May), details are listed in ISO 11783-12. This parameter shall be set dur- ing identification. The parameter shall not be changeable during the subse- quent workflow and in operation. Used for identification per <a href="#">subclause 9.1</a> . String, in analogy to the type code on ISOBUS. SLOT: - / -
0	3	Load/electric machine serial number	—	String	—	—	—	—	On change and on request	This parameter shall be set dur- ing identification. The parameter shall not be changeable during the subse- quent workflow and in operation. Optional, for future use (e.g. diagnostics). SLOT: - / -

<sup>a</sup> If not otherwise specified, the repetition rate is valid for ISOBUS transmission and fieldbus transmission.

<sup>b</sup> If applicable

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Table A.11 (continued)

Fieldbus object Index (4 bit)	Sub-index (4 bit)	Signal	Source	Size/ length in bit	Values	Resolution/ scaling (per bit)	Signal range allowed		Repetition rate <sup>a</sup> (allowed range <sup>b</sup> )	Description, reference and comments
							Minimum (signal offset)	Maximum (theoretical)		
0	4	Load/electric machine type		4	0 <sub>hex</sub> No type 1 <sub>hex</sub> General load 2 <sub>hex</sub> IM 3 <sub>hex</sub> PM 4 <sub>hex</sub> RM 5 <sub>hex</sub> - E <sub>hex</sub> Reserved F <sub>hex</sub> Not available	—	—	On change and on request	This parameter shall be set during initialization. The parameter shall not be changeable during the subsequent workflow and in operation. Used for initialization according to ISO 23316-4:2023, 4.4.1.2. This parameter defines the type of the load. The general load (e.g. resistive loads) is used for open-loop controls. The electric machine types used for closed-loop controls, leading to the required parameters per machine type in <a href="#">Table A.14</a> , <a href="#">Table A.15</a> or <a href="#">Table A.16</a> . SLOT: - / -	
0	5	LLB manufacturer code		String	—	—	—	On change and on request	This parameter shall be set during identification. The parameter shall not be changeable during the subsequent workflow and in operation. Optional, for future use (e.g. diagnostics). SLOT: - / -	
0	6	LLB type code		String	—	—	—	On change and on request	This parameter shall be set during identification. The parameter shall not be changeable during the subsequent workflow and in operation. Optional, for future use (e.g. diagnostics). SLOT: - / -	
0	7	LLB serial number		String	—	—	—	On change and on request	This parameter shall be set during identification. The parameter shall not be changeable during the subsequent workflow and in operation. Optional, for future use (e.g. diagnostics). SLOT: - / -	

<sup>a</sup> If not otherwise specified, the repetition rate is valid for ISOBUS transmission and fieldbus transmission.

<sup>b</sup> If applicable

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The signals 'actual rotor position' and 'actual rotor speed' are used for control purposes by the PC/S. Hence, the LLB shall transmit them with the repetition rate required by the PC/S.

NOTE 5 The signals 'actual temperature 1' and 'actual temperature 2' in [Table A.12](#) are intended as input for over-temperature protection features of the corresponding HPI-C.

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Table A.12 — Load specific signals — Sensor feedback values

Fieldbus object Index (4 bit)	Fieldbus object Sub- index (4 bit)	Signal	Source	Size/ length in bit	Values	Resolution/ scaling (per bit)	Signal range allowed		Repetition rate <sup>a</sup> (allowed range <sup>b</sup> )	Description, reference and comments
							Minimum (signal offset)	Maximum (theoretical)		
0	9	LLB feedback repetition rate		16	—	1 Hz	0 Hz	64 000 Hz (64 255 Hz)	On change and on request	LLB repetition rate for 'actual rotor position' and 'actual rotor speed'. This parameter shall be set during initialization. The parameter shall not be changeable during the subsequent workflow and in operation. SLOT: - / -
0	10	Actual rotor position		16	—	0,005 49° (360°/FFFFh)	0	FFFFh	LLB feedback repetition rate	Absolute mechanical position of the electric machine shaft. SLOT: SAEct14 / 340
0	11	Rotor position offset		16	—	0,005 49° (360°/FFFFh)	0	FFFFh	On request	Absolute mechanical offset position of the electric machine shaft. Offset between mechanical and electrical reference. SLOT: SAEct14 / 340
0	12	Actual rotor speed		16	—	0,01 %	-250 % (-327,27 %)	250 % (321,28 %)	LLB feedback repetition rate	Actual speed of electric machine shaft. SLOT: SAEpc22 / 387
0	13	Actual load temperature 1		16	—	0,031 25 K	-50 °C (-273 °C)	300 °C (~1 735 °C)	On request	Temperature e.g. electric machine winding. See also <a href="#">Table A.2</a> for signal transmission to HPI-C. SLOT: SAEtp02 / 68
0	14	Actual load temperature 2		16	—	0,031 25 K	-50 °C (-273 °C)	300 °C (~1 735 °C)	On request	Temperature e.g. electric machine winding. See also <a href="#">Table A.2</a> for signal transmission to HPI-C. SLOT: SAEtp02 / 68

<sup>a</sup> If not otherwise specified, the repetition rate is valid for ISOBUS transmission and fieldbus transmission.

<sup>b</sup> If applicable.

<sup>c</sup> See ISO 23316-4:2023, 4.10.

Table A.13 — Load specific signals — General load parameter

Fieldbus Index (4 bit)	Fieldbus Sub-index (4 bit)	Signal	Source	Size/length in bit	Values	Resolution/scaling (per bit)	Signal range allowed		Repetition rate <sup>a</sup> (allowed range <sup>b</sup> )	Description, reference and comments
							Minimum (signal offset)	Maximum (theoretical)		
1	0	—	—	—	—	—	—	—	—	—
1	1	(Rotational) Speed reference See definition in <a href="#">Table A.1</a> .	—	16	—	See definition in <a href="#">Table A.1</a> .	See definition in <a href="#">Table A.1</a> .	—	On change and on request	This parameter shall be set during initialization. The parameter shall not be changeable during the subsequent workflow and in operation.
1	2	Torque reference See definition in <a href="#">Table A.1</a> .	—	16	—	See definition in <a href="#">Table A.1</a> .	See definition in <a href="#">Table A.1</a> .	—	On change and on request	This parameter shall be set during initialization. The parameter shall not be changeable during the subsequent workflow and in operation.
1	3	Voltage reference See definition in <a href="#">Table A.1</a> .	—	16	—	See definition in <a href="#">Table A.1</a> .	See definition in <a href="#">Table A.1</a> .	—	On change and on request	This parameter shall be set during initialization. The parameter shall not be changeable during the subsequent workflow and in operation.
1	4	Current reference See definition in <a href="#">Table A.1</a> .	—	16	—	See definition in <a href="#">Table A.1</a> .	See definition in <a href="#">Table A.1</a> .	—	On change and on request	This parameter shall be set during initialization. The parameter shall not be changeable during the subsequent workflow and in operation.
1	5	Power reference See definition in <a href="#">Table A.1</a> .	—	16	—	See definition in <a href="#">Table A.1</a> .	See definition in <a href="#">Table A.1</a> .	—	On change and on request	This parameter shall be set during initialization. The parameter shall not be changeable during the subsequent workflow and in operation.
1	6	Frequency reference See definition in <a href="#">Table A.1</a> .	—	16	—	See definition in <a href="#">Table A.1</a> .	See definition in <a href="#">Table A.1</a> .	—	On change and on request	This parameter shall be set during initialization. The parameter shall not be changeable during the subsequent workflow and in operation.

<sup>a</sup> if not otherwise specified, the repetition rate is valid for ISOBUS transmission and fieldbus transmission.

<sup>b</sup> If applicable.

<sup>c</sup> See ISO 23316-4:2023, 4.4 and following subclauses.

Table A.13 (continued)

Fieldbus Index (4 bit)	Sub-index (4 bit)	Signal	Source	Size/length in bit	Values	Resolution/scaling (per bit)	Signal range allowed		Repetition rate <sup>a</sup> (allowed range <sup>b</sup> )	Description, reference and comments
							Minimum (signal offset)	Maximum (theoretical)		
1	7	Rated voltage		8	—	0,5 %	0 %	100 % (125 %)	On change and on request	Rating of (electronic) nameplate. Refer to IEC 61800-7-202:2015, 7.3.5.2, attribute ID 1318. This parameter shall be set during initialization. The parameter shall not be changeable during the subsequent workflow and in operation. Percentage of reference. SLOT: SAEpc18 / 299
1	8	Continuous current limitation		8	—	0,5 %	0 %	100 % (125 %)	On change and on request	Rating of (electronic) nameplate. Refer to IEC 61800-7-202:2015, 7.3.5.2, attribute ID 1319. Load current threshold for continuous duty cycle (S1 acc. to IEC 60034-1). See ISO 23316-4:2023, 4.5.2.2. This parameter shall be set during initialization. The parameter shall not be changeable during the subsequent workflow and in operation. Percentage of reference. SLOT: SAEpc18 / 299
1	9	Peak current limitation		8	—	0,5 %	0 %	100 % (125 %)	On change and on request	Rating of (electronic) nameplate. See IEC 61800-7-202:2015, 7.3.5.2, attribute ID 1320. Load current threshold for transients. See ISO 23316-4:2023, 4.5.2.2. This parameter shall be set during initialization. The parameter shall not be changeable during the subsequent workflow and in operation. Percentage of reference. SLOT: SAEpc18 / 299

<sup>a</sup> if not otherwise specified, the repetition rate is valid for ISOBUS transmission and fieldbus transmission.

<sup>b</sup> If applicable.

<sup>c</sup> See ISO 23316-4:2023, 4.4 and following subclauses.

Table A.13 (continued)

Fieldbus Index (4 bit)	Signal	Source	Size/length in bit	Values	Resolution/scaling (per bit)	Signal range allowed		Repetition rate <sup>a</sup> (allowed range <sup>b</sup> )	Description, reference and comments
						Minimum (signal offset)	Maximum (theoretical)		
1	Rated continuous power		8	—	0,5 %	0 %	100 % (125 %)	On change and on request	Rating for (electronic) nameplate in continuous duty cycle (S1 acc. to IEC 60034-1). See IEC 61800-7-202:2015, 7.3.5.2, attribute ID 1321. This parameter shall be set during initialization. The parameter shall not be changeable during the subsequent workflow and in operation. Percentage of reference. SLOT: SAEpc18 / 299
1	Rated continuous torque		8	—	0,5 %	0 %	100 % (125 %)	On change and on request	Rating for (electronic) nameplate in continuous duty cycle (S1 acc. to IEC 60034-1). See e.g. IEC 61800-7-202:2015, 7.3.5.6, attribute ID 1339. This parameter shall be set during initialization. The parameter shall not be changeable during the subsequent workflow and in operation. Percentage of reference. SLOT: SAEpc18 / 299
1	Operational speed limitation		8	—	0,5 %	0 %	100 % (125 %)	On change and on request	Threshold for maximum allowed speed of electric machine in operation. This parameter shall be set during initialization. The parameter shall not be changeable during the subsequent workflow and in operation. Percentage of reference. SLOT: SAEpc18 / 299

<sup>a</sup> if not otherwise specified, the repetition rate is valid for ISOBUS transmission and fieldbus transmission.

<sup>b</sup> If applicable.

<sup>c</sup> See ISO 23316-4:2023, 4.4 and following subclauses.

Table A.13 (continued)

Fieldbus Index (4 bit)	Sub-index (4 bit)	Signal	Source	Size/length in bit	Values	Resolution/scaling (per bit)	Signal range allowed		Repetition rate <sup>a</sup> (allowed range <sup>b</sup> )	Description, reference and comments
							Minimum (signal offset)	Maximum (theoretical)		
1	13	Rated frequency		8	—	0,5 %	0 %	100 % (125 %)	On change and on request	Rated (stator) frequency. See IEC 61800-7-202:2015, 7.3.5.8, attribute ID 1345. This parameter shall be set during initialization. The parameter shall not be changeable during the subsequent workflow and in operation. Percentage of reference. SLOT: SAEpc18 / 299
1	14	Min. inverter switching frequency		8	—	100 Hz =0,1 kHz	1 kHz (0 Hz)	5 kHz	On change and on request	Defines min. switching frequency for open-loop control. See Table A.5 and ISO 23316-4:2023, 4.5.1.2. This parameter shall be set during initialization. The parameter shall not be changeable during the subsequent workflow and in operation. SLOT: - / -
1	15	Max. voltage slope		8	—	1 kV/μs	5 kV/μs (0 kV/μs)	100 kV/μs (250 kV/μs)	On change and on request	Threshold of maximum allowed PWM voltage slope. See Table A.5 and ISO 23316-4:2023, 4.5.1.3. This parameter shall be set during initialization. The parameter shall not be changeable during the subsequent workflow and in operation. SLOT: - / -

<sup>a</sup> if not otherwise specified, the repetition rate is valid for ISOBUS transmission and fieldbus transmission.

<sup>b</sup> If applicable.

<sup>c</sup> See ISO 23316-4:2023, 4.4 and following subclauses.

Table A.14 — Load specific signals — Induction machine (IM) parameter<sup>a</sup>

Fieldbus object Index (4 bit)	Fieldbus object Sub- index (4 bit)	Signal	Source	Size/ length in bit	Values	Resolution/ scaling (per bit)	Signal range allowed		Repetition rate <sup>a</sup> (allowed range <sup>b</sup> )	Description, reference and comments
							Minimum (signal offset)	Maximum (theoretical)		
2	0	—	—	—	—	—	—	—	—	—
2	1	IM number of poles	—	8	—	1	0	250	On change and on request	Refer to IEC 61800-7-202:2015, 7.3.5.4, attribute ID 1329. This number is always an even num- ber as poles always exist in pairs This parameter shall be set dur- ing initialization. The parameter shall not be changeable during the subse- quent workflow and in operation. SLOT: SAEct02 / 129
2	2	IM stator resistance	—	16	—	0,1 mΩ =0,000 1 Ω	0 mΩ	6 425,5 mΩ	On change and on request	Stator resistance in cold condi- tions (20 °C). Refer to IEC 61800-7-202: 2015, 7.3.5.8, attribute ID 1347. This parameter shall be set dur- ing initialization. The parameter shall not be changeable during the subse- quent workflow and in operation. This parameter shall be set dur- ing initialization. The parameter shall not be changeable during the subse- quent workflow and in operation. SLOT: - / -
2	3	IM stator leakage inductance	—	16	—	10 μH =0,000 01 H =0,01 mH	10 μH (0 μH)	642 550 μH	On change and on request	Refer to IEC 61800-7-202:2015, 7.3.5.8, attribute ID 1348. Use inductance instead of reac- tance for being independent of frequency. This parameter shall be set dur- ing initialization. The parameter shall not be changeable during the subse- quent workflow and in operation. SLOT: - / -

<sup>a</sup> See also IM parameter in Table 29 of IEC 61800-7-202:2015.

<sup>b</sup> If not otherwise specified, the repetition rate is valid for ISOBUS transmission and fieldbus transmission.

<sup>c</sup> If applicable.

Table A.14 (continued)

Fieldbus object Index (4 bit)	Sub- index (4 bit)	Signal	Source	Size/ length in bit	Values	Resolution/ scaling (per bit)	Signal range allowed		Repetition rate <sup>a</sup> (allowed range <sup>b</sup> )	Description, reference and comments
							Minimum (signal offset)	Maximum (theoretical)		
2	4	IM magnetization inductance		16	—	10 µH =0,000 01 H =0,01 mH	10 µH (0 µH)	642 550 µH	On change and on request	Magnetization inductance (RMS) at rated load conditions. Refer to IEC 61800-7-202:2015, 7.3.5.8, attribute ID 1349. Use inductance instead of reactance for being independent of frequency. This parameter shall be set during initialization. The parameter shall not be changeable during the subsequent workflow and in operation. SLOT: - / -
2	5	IM rotor resistance		16	—	0,1 mΩ =0,000 1 Ω	0 mΩ	6 425,5 mΩ	On change and on request	Rotor resistance in cold conditions (20 °C). See IEC 61800-7-202:2015, 7.3.5.8, attribute ID 1350. This parameter shall be set during initialization. The parameter shall not be changeable during the subsequent workflow and in operation. SLOT: - / -

<sup>a</sup> See also IM parameter in Table 29 of IEC 61800-7-202:2015.

<sup>b</sup> If not otherwise specified, the repetition rate is valid for ISOBUS transmission and fieldbus transmission.

<sup>c</sup> If applicable.

Table A.14 (continued)

Fieldbus object Index (4 bit)	Sub- index (4 bit)	Signal	Source	Size/ length in bit	Values	Resolution/ scaling (per bit)	Signal range allowed		Repetition rate <sup>a</sup> (allowed range <sup>b</sup> )	Description, reference and comments
							Minimum (signal offset)	Maximum (theoretical)		
2	6	IM rotor leakage inductance		16	—	10 µH =0,000 01 H =0,01 mH	10 µH (0 µH)	642 550 µH	On change and on request	Stator leakage inductance. Refer to IEC 61800-7-202:2015, subclause 7.3.5.8, attribute ID 1351. Use inductance instead of reactance for being independent of frequency. This parameter shall be set during initialization. The parameter shall not be changeable during the subsequent workflow and in operation. SLOT: - / -
2	7	IM rated flux current		8	—	0,5 %	0 %	125 % (125 %)	On change and on request	Magnetizing current (RMS) at rated load conditions. Refer to IEC 61800-7-202:2015, 7.3.5.8, attribute ID 1346. This parameter shall be set during initialization. The parameter shall not be changeable during the subsequent workflow and in operation. Percentage of current reference. SLOT: SAEpc18 / 299
2	8	IM rated slip		16	—	0,01 %	-100 % (-327,27 %)	100 % (321,28 %)	On change and on request	Slip at rated load conditions. Refer to IEC 61800-7-202:2015, 7.3.5.8, Attribute ID 1352. This parameter shall be set during initialization. The parameter shall not be changeable during the subsequent workflow and in operation. SLOT: SAEpc22 / 387

<sup>a</sup> See also IM parameter in Table 29 of IEC 61800-7-202:2015.

<sup>b</sup> If not otherwise specified, the repetition rate is valid for ISOBUS transmission and fieldbus transmission.

<sup>c</sup> If applicable.

Table A.15 — Load specific signals — Permanent-magnet synchronous machine (PM) parameter<sup>a</sup>

Fieldbus Index (4 bit)	Sub-index (4 bit)	Signal	Source	Size/length in bit	Values	Resolution/scaling (per bit)	Signal range allowed		Repetition rate <sup>a</sup> (allowed range <sup>b</sup> )	Description, reference and comments
							Minimum (signal offset)	Maximum (theoretical)		
3	0	—	—	—	—	—	—	—	—	—
3	1	PM number of poles	—	8	—	1	0	250	On change and on request	Refer to IEC 61800-7-202:2015, 7.3.5.4, Attribute ID 1329. This number is always an even number as poles always exist in pairs. This parameter shall be set during initialization. The parameter shall not be changeable during the subsequent workflow and in operation. SLOT: SAEct02 / 129
3	2	PM stator resistance	—	16	—	0,1 mΩ =0,000 1 Ω	0 mΩ	6 425,5 mΩ	On change and on request	Stator resistance in cold conditions (20 °C). Refer to IEC 61800-7-202:2015, 7.3.5.3, attribute ID 1327. This parameter shall be set during initialization. The parameter shall not be changeable during the subsequent workflow and in operation. SLOT: - / -
3	3	PM d-axis inductance	—	16	—	10 μH =0,000 01 H =0,01 mH	10 μH (0 μH)	642 550 μH	On change and on request	d-axis inductance at rated load conditions. Refer to IEC 61800-7-202:2015, 7.3.5.3, attribute ID 1354. This parameter shall be set during initialization. The parameter shall not be changeable during the subsequent workflow and in operation. SLOT: - / -

<sup>a</sup> See also PM parameter in Table 29 of IEC 61800-7-202:2015.

<sup>b</sup> If not otherwise specified, the repetition rate is valid for ISOBUS transmission and fieldbus transmission.

<sup>c</sup> If applicable.

Table A.15 (continued)

Fieldbus Index (4 bit)	Sub-index (4 bit)	Signal	Source	Size/length in bit	Values	Resolution/scaling (per bit)	Signal range allowed		Repetition rate <sup>a</sup> (allowed range <sup>b</sup> )	Description, reference and comments
							Minimum (signal offset)	Maximum (theoretical)		
3	4	PM q-axis inductance		16	—	10 µH =0,000 01 H =0,01 mH	10 µH (0 µH)	642 550 µH	On change and on request	q-axis inductance at rated load conditions. NOTE: For surface PM the inductances in d- and q-axis are assumed approximately same, whereas for interior PM they are assumed not negligible different. Refer to IEC 61800-7-202:2015, 7.3.5.3, attribute ID 1353. This parameter shall be set during initialization. The parameter shall not be changeable during the subsequent workflow and in operation. SLOT: - / -
3	5	PM torque constant		16	—	0,001 Nm/A <sub>RMS</sub>	0,001 Nm/A <sub>RMS</sub> (0 Nm/A <sub>RMS</sub> )	64,255 Nm/A <sub>RMS</sub>	On change and on request	Torque constant at rated conditions. Refer to IEC 61800-7-202:2015, 7.3.5.6, attribute ID 1340. This parameter shall be set during initialization. The parameter shall not be changeable during the subsequent workflow and in operation. SLOT: - / -

<sup>a</sup> See also PM parameter in Table 29 of IEC 61800-7-202:2015.

<sup>b</sup> If not otherwise specified, the repetition rate is valid for ISOBUS transmission and fieldbus transmission.

<sup>c</sup> If applicable.