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DC Fast Charging Protocol for 48 V Systems

Contents

1. Introduction

1.1. Scope

This document specifies the fast-charging interface and communication protocol developed by Volvo Construction Equipment for construction equipment with 48 V DC electric driveline.
The DC charging system (DCCS) consists of the machine DC charging receptable, respective machine (Earth Moving Machinery, EMM) controls and the associated interfaces.

1.2. Glossary

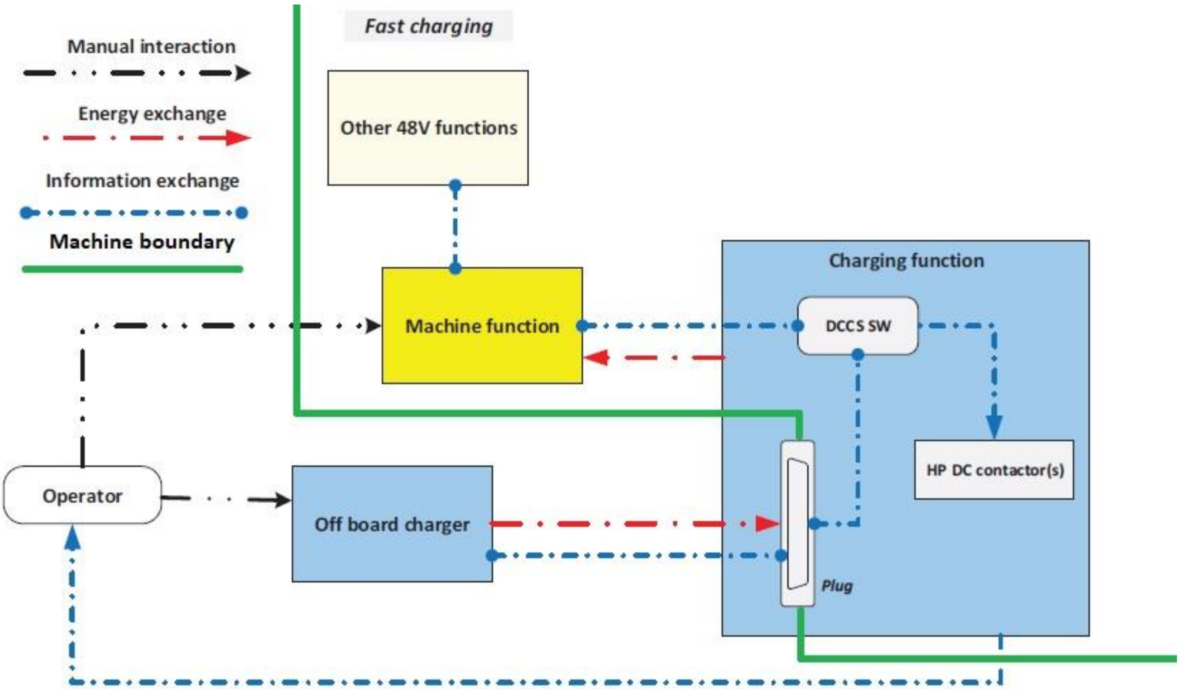
DCCS – DC charging system
EMM – Earth moving machinery
ESS – Energy Storage System

1.3. References

EN 1175	Safety of industrial trucks
ISO/DIS 23285	Agricultural machinery, tractors, and earthmoving machinery - safety of electrical and electronic components and systems operating at 32 to 75 DC and 21 to 50 VAC.

2. Boundary diagram and interfaces

2.1. Boundary diagram



2.2. Interfaces

2.2.1. Power interfaces

2.2.1.1. DC power interface

The DCCS charger shall include a separate DC power interface, as in the table.

Signal name	Description	Function
HP DC+	Positive pole to DC charger	48V DC supply (input)
	Positive pole to EMM	48V DC supply (output)
HP DC-	Negative pole to DC charger	48V DC supply (input)
	Negative pole to EMM	48V DC supply (output)

2.2.2. Communication interfaces

2.2.2.1. Charger to machine communication interface

The DC charger shall include a communication interface to the machine, as in the table

Signal name	Description	Function
EMM electric interlock out	Electric lock	+12/24 V supply*
EMM electric interlock in	Return connection	DI to Machine ECU
Interlock pilot out	Electric lock	Electrical safety
Interlock pilot in	Return connection	Electrical safety
CAN L	CAN connection	Data
CAN H	CAN connection	Data

*Depending on machine side supply.

2.2.2.2. Bus termination

The CAN bus shall be terminated with a 120Ω resistor in the DC charger. (See 2.2.3.2)

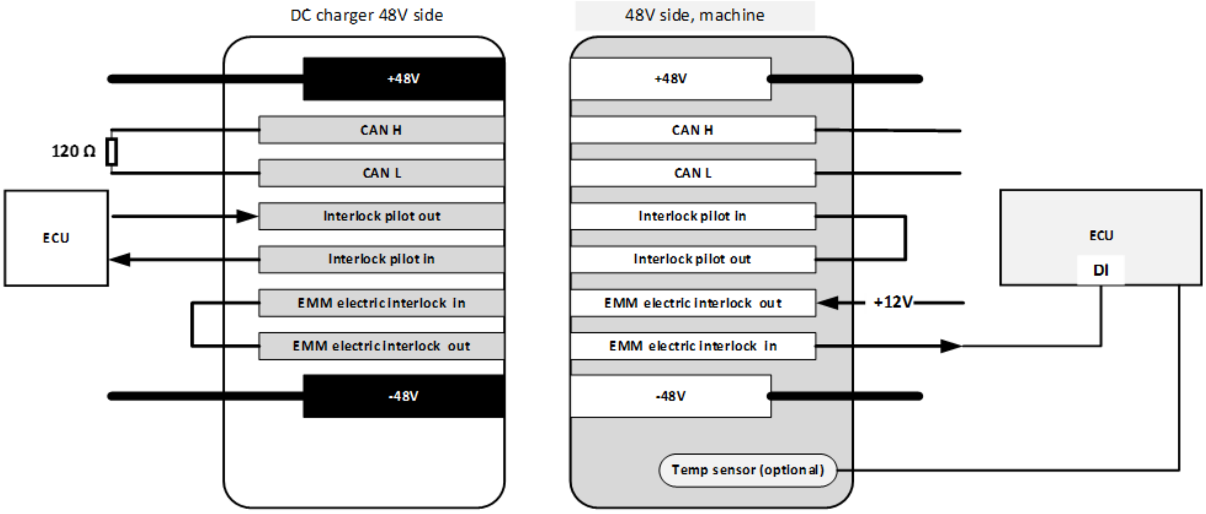
2.2.3. Connectors

2.2.3.1. DC charger connector

The 48V side connector on the DC charger shall be of the type “REMA MRC 400” or compatible.

2.2.3.2. DC charger power interface description

Comprehensive description of DC charger 48V interface.

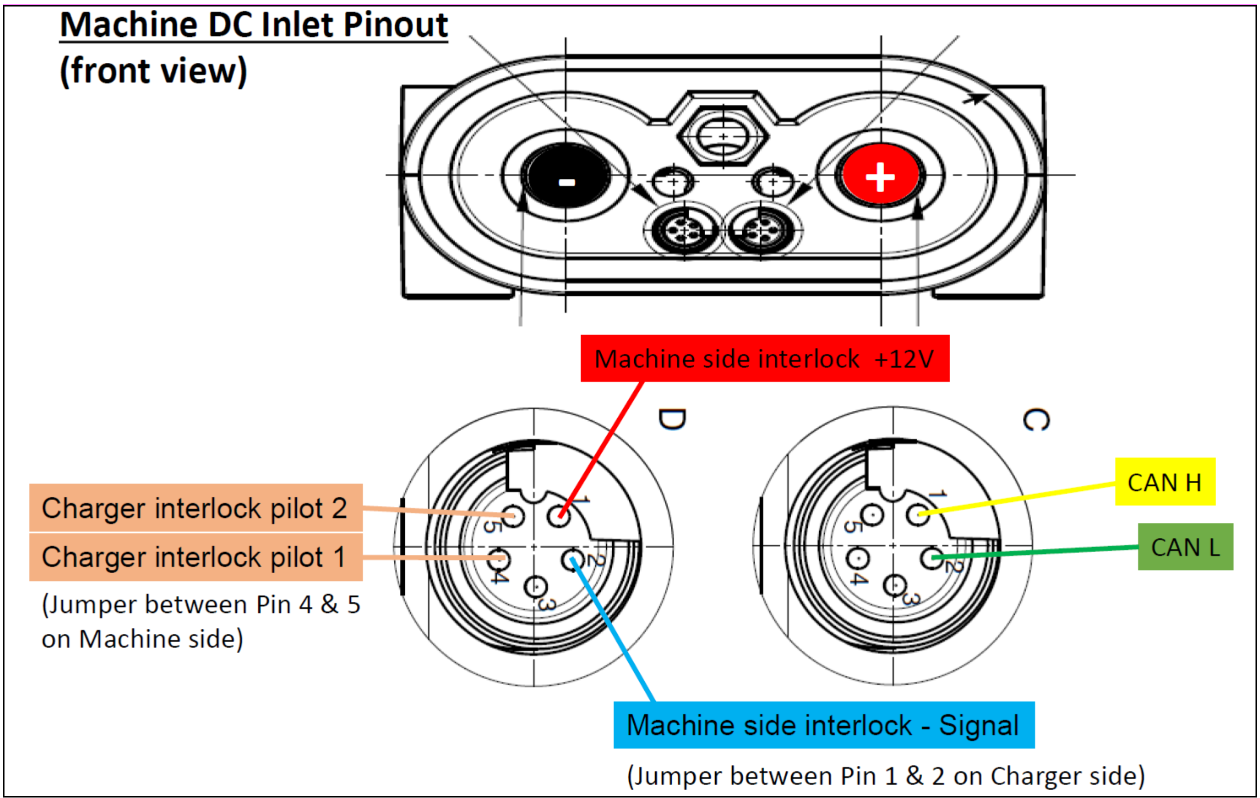


Note:

The implementation of temperature sensor is optional and each machine supplier should evaluate the need for temperature monitoring.

2.2.3.3. Communication pinout

The DC charger 48 V interface pinout shall match the machine interface as shown below:



Pin no	Signal name	Description
C1	CAN H	CAN connection
C2	CAN L	CAN connection
C3	-	*Not used*
C4	-	*Not used*
C5	-	*Not used*
D1	EMM electric interlock out	Electric lock
D2	EMM electric interlock in	Return connection
D3	-	*Not used*
D4	Interlock pilot out	Electric lock

D5	Interlock pilot in	Return connection

2.2.3.4. Disconnection protection

The 48V connector shall be secured against disconnection during charging.

Note:
A minimum necessary force of 15 N to separate the two half-connectors sets the threshold for secure connection (EN 1175 + A1:2010)

2.2.3.5. Power and communication separation

The 48V connector shall provide electrical separation between the DC traction power and communication interfaces.

Note:

The 48 VDC system is isolated from the machine chassis while the 12/24 VDC system and communaction are grounded in it.

2.2.3.6. Pilot interlock vs. power pins interruption precedence

The 48V side connector shall be designed so that the pilot interlock pins are interrupted before the power pins, early enough to prevent arcing.

2.2.4. Physical and signal limitations

2.2.4.1. Physical limitations

The DC charger shall have input and output physical limitations, as in the table.

Signal name	Value	Unit
DC nominal input voltage	48	V DC
DC max input voltage	≤60* (class A2 according to ISO/DIS 23285)	V DC
DC min input voltage	ISO/DIS 23285: >32**	V DC
Rated input power	20	kW
Rated input current	360	A

* It is recommended that the over voltage protection level is set below the upper limit of the standard, relative to the resolution and accuracy of the measurement method.
The machine (connector) shall **never** be exposed to voltages above 60 V DC.
** 36 V DC is implemented in current DCCS charging products and Volvo CE machines.

2.2.4.2. Overvoltage protection

2.2.4.2.1. Overvoltage protection threshold

The overvoltage protection threshold shall be set to 59.28 VDC

2.2.4.2.2. Overvoltage protection function

The EMM over voltage protection function aborts and opens the contactors if the voltage level exceeds the overvoltage protection threshold.
To avoid premature ageing or damage of the machine contactor, the DC charger **shall** abort charging (stop power output) within 10 ms after detecting a voltage level higher than the overvoltage protection threshold.

2.2.4.3. DCCS signal list

Signal exchange of the DCCS, as in the table.

Signal description	Description	Remark (CAN signal)
Required current	Limitation	TX to charger, CAN (DCCS_Command_ReqCurrent)
DCCS status	Bootup, operational, error	TX to charger, CAN (DCCS_Status_State)
DCCS charge command state	Charging OFF, Charging On, Charging Finished	TX to charger, CAN (DCCS_Command_ChargeState)
DC charger status	Bootup, Operational, Error	RX from charger, CAN (Charger_Status_State)
Nominal current	Limitation	RX from charger, CAN (Charger_Status_NominalCurrent)
Nominal voltage	Limitation	RX from charger, CAN (Charger_Status_NominalVoltage)
Output current	Actual value	RX from charger, CAN (Charger_Values_ActCurrent)
Output voltage	Actual value	RX from charger, CAN (Charger_Values_ActVoltage)
DC charger de-rate	Percentage (%)	RX from charger, CAN (Charger_Values_ActDerate)
DC charger STOP activation	OFF, ON	RX from charger, CAN (Charger_Status_StopActvn)
DC charger fault event	No error, Fuse blown, Grid error, Forced abort internal, Pilot contact error	RX from charger, CAN (Charger_Values_FaultType)
Charging-allowed enable	Yes, No	RX from EMM
Electric interlock hardwired signal	OFF, ON	DO from plug

2.2.4.4. Signal resolution

2.2.4.4.1. Voltage signal

The resolution for voltage signals transmitted on CAN shall be minimum 0.01V.

2.2.4.4.2. Current signal

The resolution for current signals transmitted on CAN shall be minimum 0.1A.

2.2.4.4.3. Derate signal

The resolution for derate signals transmitted on CAN shall be minimum 1%.

3. Component and procedure requirements

3.1. DCCS activation function

The DCCS activation function initializes and activates the component.

3.1.1. Activation function overview

Mission:

Get the DCCS to operational state.

Input:

A. DCCS electrical interlock secured (connector mated)

B. DC charger state received on CAN

C. DC charger fault event

D. EMM status

E. EMM charging allowed signal

Function:

1. When 12/24 V is enabled the DCCS shall go into state Boot-up.
2. When the DCCS electrical interlock circuit is closed the DCCS shall:
    a. Report its status on CAN, to the DC charger.
    b. Read the DC charger status received on CAN.
    c. Verify the EMM is in operational state.
3. When received signals, from DC charger and machine, satisfy preconditions and EMM Charging-allowed enable signal is set to high, the DCCS shall:
    a. Go into operational state.
    b. Close the HP DC contactor(s).
    c. Report its status on CAN, to the DC charger.
4. When the DC charger state is set to Boot up the DCCS shall:
    a. Read the DC charger nominal voltage received on CAN.
    b. Read the DC charger nominal current received on CAN.

5. When the DC charger state is set to operational the DCCS shall:
    a. Read the DC charger actual values (voltage, current, derate) received on CAN.
    b. Continuously convey the fault event CAN signal messages to the EMM.
6. If EMM is not in operational state, the DCCS shall remain in Boot-up state.
7. If the DC charger nominal voltage is different from EMM nominal voltage before DC charger goes to operational state, the DCCS shall:
    a. Go to error state.
    b. Report DC charger error.
8. If the DC charger nominal current is higher than rated before DC charger goes to operational state, the DCCS shall:
    a. Go to error state.
    b. Report DC charger error
9. If the DC charger fails to go into operational state within 5s from closure of HP DC contactors, the DCCS shall:
    a. Go to error state.
    b. Report DC charger error.

Output:

A. DCCS status.

B. DCCS output voltage.

C. DC charger fault event

3.1.2. Activation function requirements

3.1.2.1. Initiate activation sequence

When 12/24V is enabled the DCCS shall initiate the activation sequence.

3.1.2.2. Interlock circuit closed

3.1.2.2.1. Status report

When the electrical interlock circuit is closed the DCCS shall report its

status on CAN.

3.1.2.2.2. Clear SW alarms

When the electrical interlock circuit is closed the DCCS shall

remove all alarm SW messages present.

3.1.2.3. Operational state condition

The DCCS shall only go into operational state if it is verified that all preconditions are satisfied.

Note:

Preconditions are electrical interlock circuit closed, EMM in operational state, DC charger in Boot-up state and EMM charging allowed enable signal high.

3.1.2.4. Request EMM HP DC contactors

When the DCCS goes into operational state, it shall request the EMM to close the HP DC contactor(s).

3.1.2.5. DCCS Error state

3.1.2.5.1. Voltage deviation

If the DCCS activation cannot be performed due to a DC charger nominal voltage deviation and the DC charger is not in operational state, the DCCS shall go to error.

3.1.2.5.2. Over current

If the DCCS activation cannot be performed due to DC charger nominal current being higher than rated value and the DC charger is not in operational state, the DCCS shall go to error state.

3.1.2.5.3. Time out

If the DC charger fails to become operational within 5s from HP DC contactors closure, the DCCS shall go to error state.

3.1.2.6. Alarms

3.1.2.6.1. Voltage deviation

If the DCCS activation cannot be performed due to a DC charger nominal voltage deviation and the DC charger is not in operational state, the DCCS shall send an alarm SW message.

3.1.2.6.2. Over current

If the DCCS activation cannot be performed due to DC charger nominal current being higher than rated value and the DC charger is not in operational state, the DCCS shall send an alarm SW message.

3.1.2.6.3. Timeout

If the DC charger fails to become operational within 5s from HP DC contactors closure, the DCCS shall send an alarm SW message.

3.1.2.7. Fault event signal

The DCCS shall continuously convey the fault event CAN signal messages to the EMM.

3.1.2.8. EMC performance

DCCS Activation Function shall not deviate from normal function in any unsafe manner, in the perceived EMC environment.

3.2. DCCS charging function

The DC charging function delivers DC power to the ESS until the required SOC is achieved.

3.2.1. Charging function overview

Mission:

To deliver DC power to the ESS in a controlled manner until the required

SOC is achieved.

Input:

A. EMM status

B. EMM charging current

C. DC-charger status CAN signal

D. Fault event CAN signal

E. EMM charging-allowed enable signal

F. DC-charger actual current, voltage and de-rate CAN signals

Function:

1. When the EMM charging current is above threshold level the DCCS shall:
    a. Calculate current request.
    b. Send the “Charging” command charge state on CAN.
    c. Send the required current on CAN.
2. When the EMM charging current is below threshold level the DCCS shall:
    a. Send the “Charging finished” command charge state on CAN.

   b. Calculate current request.

3. If actual current is not reduced below threshold limit within 5s after EMM charging finished request is set, the DCCS shall:
   a. Go to error state.
   b. Report DC charger error.
4. If the Charging-allowed enable signal is set to low before DC charger goes to operational state, the DCCS shall go to Boot-up state.
5. If the Charging-allowed enable signal is set to low during charging the DCCS shall:
   a. Set current request to zero.
   b. While current remains stay in operational state.
   c. When current drops below threshold level go to Bootup state.
   d. Report its status on CAN.
6. If the "Stop activation" message is received in the charger status CAN signal the DCCS shall:
   a. Set current request to zero.
   b. While current remains stay in operational state.
   c. When current drops below threshold level go to Bootup state.
7. If CAN communication is lost for longer than [CAN recovery timeout] the DCCS shall go into error state.
8. If the EMM state goes to state other than {operational, charging} the DCCS shall:
   a. Go to error state.
   b. Report its status on CAN, to the DC charger.
9. If the DCCS detects an internal error it shall:
   a. Go to error state.
   b. Report its status on CAN, to the DC charger.

Output:

A. DCCS status

B. DCCS command state

C. DCCS current request

D. DCCS fault value

3.2.2. Charging function requirements

3.2.2.1. Contactor type

The HP DC charger contactor(s) shall be of type “normally open”.

3.2.2.2. EMC performance

DCCS charging Function shall not deviate from normal function in any unsafe manner, in the perceived EMC environment.

3.2.2.3. EMM charging current rising

3.2.2.3.1. EMM charging current above threshold

When the charging current, as measured in the machine, is above 1A, the DCCS shall read the DC charger status received on CAN.

Note:

The current value stated is subject to calibration and may differ in different machines.

3.2.2.3.2. Send charging command

If the DC charger is in operational state, the DCCS shall send the ‘charging ON’ command on CAN.

3.2.2.3.3. Calculate charging current

The DCCS current request shall be equal to the min {EMM charging current, nominal DC charger current}.

3.2.2.3.4. Send charging current request

If the DC charger is in operational state, the DCCS shall send the current request on CAN.

3.2.2.4. EMM charging current decreasing

3.2.2.4.1. Set current request to zero

When the charging current, as measured in the machine, is below 0.5A, the DCCS shall send zero current request on CAN.

Note:

The current value stated is subject to calibration and may differ in different machines.

3.2.2.4.2. Send charging finished command

When the charging current, as measured in the machine, is below 0.5A, the DCCS shall send the 'charging finished' command on CAN.

Note:

The current value stated is subject to calibration and may differ in different machines.

3.2.2.5. Current reduction performance

3.2.2.5.1. Current reduction response time

When the 'charging finished' command is set on CAN, the DCCS shall reduce current exchange to less than 5A within 5s.

3.2.2.5.2. Timeout

If the actual current is not reduced below threshold limit within 5s after the 'charging finished' command is set on CAN, the DCCS shall go to error state.

3.2.2.5.3. Report charger error

If the actual current is not reduced below threshold limit within 5s after the

'charging finished' command is set on CAN, the DCCS shall report DC

charger error.

3.2.2.6. Charging aborted before operational

If the Charging-allowed enable signal goes low and the DC charger is not in operational state, the DCCS shall go to Boot-up state.

3.2.2.7. Charging aborted during charging

3.2.2.7.1. Set current request to zero

If the Charging-allowed enable signal goes low during charging the DCCS shall request zero current.

3.2.2.7.2. Go to Boot-up state

If the Charging-allowed enable signal goes low and actual current is below 5A the DCCS shall go to Boot-up state.

3.2.2.8. Lost communication

If CAN communication is lost for more than 500ms the DCCS shall go to error state.

3.2.2.9. Charging aborted by EMM

If the EMM state goes to a state other than {operational, charging} the DCCS shall go to error state.

3.2.2.10. Charging aborted by internal error

If an internal error is detected the DCCS shall go to error state.

3.2.2.11. Error messages

3.2.2.11.1. Charging current not decreasing

If the actual current is not reduced below threshold limit within 5s after the 'charging finished' command is set on CAN, the DCCS shall send an alarm SW message.

3.2.2.11.2. Communication lost

If CAN communication is lost for more than 500ms the DCCS shall send an alarm SW message.

3.3. DCCS deactivation function

To protect the ESS during a fault the DCCS shall always be able to disconnect.

Mission:

Abort charging and disconnect the DCCS from the 48V system.

Input:

A. DCCS status (internal)

B. DCCS command state (internal)

C. DC-charger actual current, voltage and de-rate signals received on CAN

D. DC charger status signal received on CAN

E. Electrical interlock detection signal (internal)

Function:

1. If the DCCS status moves from "Operational" to "Boot-up" the DCCS shall:
    a. Set current request to zero.
    b. When current drops below threshold level open the HP DC contactor(s).
2. If the DCCS status is set to "Error" the DCCS shall:

   a. Set current request to zero.
   b. Open the HP DC contactor(s).
3. If the DC charger status signal received on CAN is “Error” the DCCS shall go to error state.
4. If the electrical interlock circuit is interrupted the DCCS shall go to error state.
5. If the actual current delivered exceeds the requested current, during charging, the DCCS shall shall go to error state.
6. If the actual voltage of the DC charger deviates from voltage range allowed, during charging, the DCCS shall shall go to error state.

Output:

A. DCCS HP DC contactor(s)

B. DCCS status

3.3.1. Deactivation function requirements

3.3.1.1. Contactors load breaking performance

3.3.1.1.1. Peak load

The DCCS shall withstand to open at a load current of no less than 400A, at least once.

3.3.1.1.2. Nominal load

The DCCS shall withstand to open at a load current of at least 5A without reduced lifetime.

3.3.1.2. Transition from Operational state to Boot-up state

3.3.1.2.1. Set current request to zero

When a DCCS goes to Boot-up state the DCCS shall send zero current request.

3.3.1.2.2. Open contactors

When the DCCS goes to Boot-up state the DCCS shall open all contactors (interrupt galvanic coupling).

3.3.1.3. Transition to Error state

3.3.1.3.1. Set current request to zero

When the DCCS goes to error state the DCCS shall send zero current request.

3.3.1.3.2. Open contactors

When the DCCS goes to error state the DCCS shall open all contactors (interrupt galvanic coupling).

3.3.1.4. Charger error signal

3.3.1.4.1. Set current request to zero

When an error signal from the DC charger is received on CAN the DCCS shall send zero current request.

3.3.1.4.2. Open contactors

When an error signal from the DC charger is received on CAN the DCCS shall open all contactors (interrupt galvanic coupling).

3.3.1.5. Electrical interlock interrupted

3.3.1.5.1. Set current request to zero

If the electrical interlock circuit is interrupted the DCCS shall request zero current.

3.3.1.5.2. Open contactors

If the electrical interlock circuit is interrupted the DCCS shall open all contactors (interrupt galvanic coupling).

3.3.1.6. Over voltage

If actual voltage exceeds maximum allowed voltage the DCCS shall go to error state.

3.3.1.7. EMC performance

DCCS Deactivation Function shall not deviate from normal function in any unsafe manner, in the perceived EMC environment.

3.4. Logging behaviour (EMM)

The Logging function shall log a multitude of signals, when DCCS is operational.

Mission:

Log specified signals.

Input:

A. All signals applicable for logging

Function:

1. Log values for fault tracing and function evaluation purposes.

Output:

A. Logs

3.4.1. Log descriptions

3.4.1.1. De-rating log

The purpose of this log is to collect information of how much the charging current is de-rated during operation in the field. The time spent with de-rating active is sorted into different buckets depending on the amount of de-rating set.
Each bucket corresponds to a 5 % interval, i.e. 0<d<5, 5≤d<10 etc., except the last bucket that covers the interval ≥ 45%.

This log data will allow for better knowledge on how the charging de-rating system is working in the field. With this data table we can also calculate the average de-rating and % of time with high-derate for the machine. The log data can also be used to investigate a machine with low charging performance.

3.4.1.2. Charging current and duration log

The purpose of this log is to collect information on the distribution of charging current and charging time in the field. The log will record the total amount of ampere hours, the time spent charging with different current levels, and the distribution of time between charging start and stop. The charging time is stored in different cells based on the charging current. After a charging cycle is finished then the appropriate cell is incremented based on the duration of the charging cycle.
The average charging current can be calculated with the total amount of ampere hours divided by the total charging time in hours. By using this method the error will be lower than if the distribution table would be used.

3.4.1.3. Charging Voltage Log

The purpose of this log is to collect information of how the voltage varies during charging. The log will divide the time spent charging into different classes based on the current charging voltage. The voltage range is set to include a narrow band around 48v were the system is expected to operate with over/underflow cells on each end for any unexpected voltages.
This log data will allow for better knowledge on how the charging voltage varies during operation and help with error tracing of the system.

3.4.1.4. Charging Error Log

The purpose of this log is to collect information on how many times the different DCCS error types are triggered during charging. When a DCCS error is triggered, the log increments the cell corresponding to the type of error. The number of charging cycles and time is also logged to be able to normalize the number of errors for comparison between machines.

This log data can be used in fault tracing of the charging system and potentially to predict faults with the error frequency.

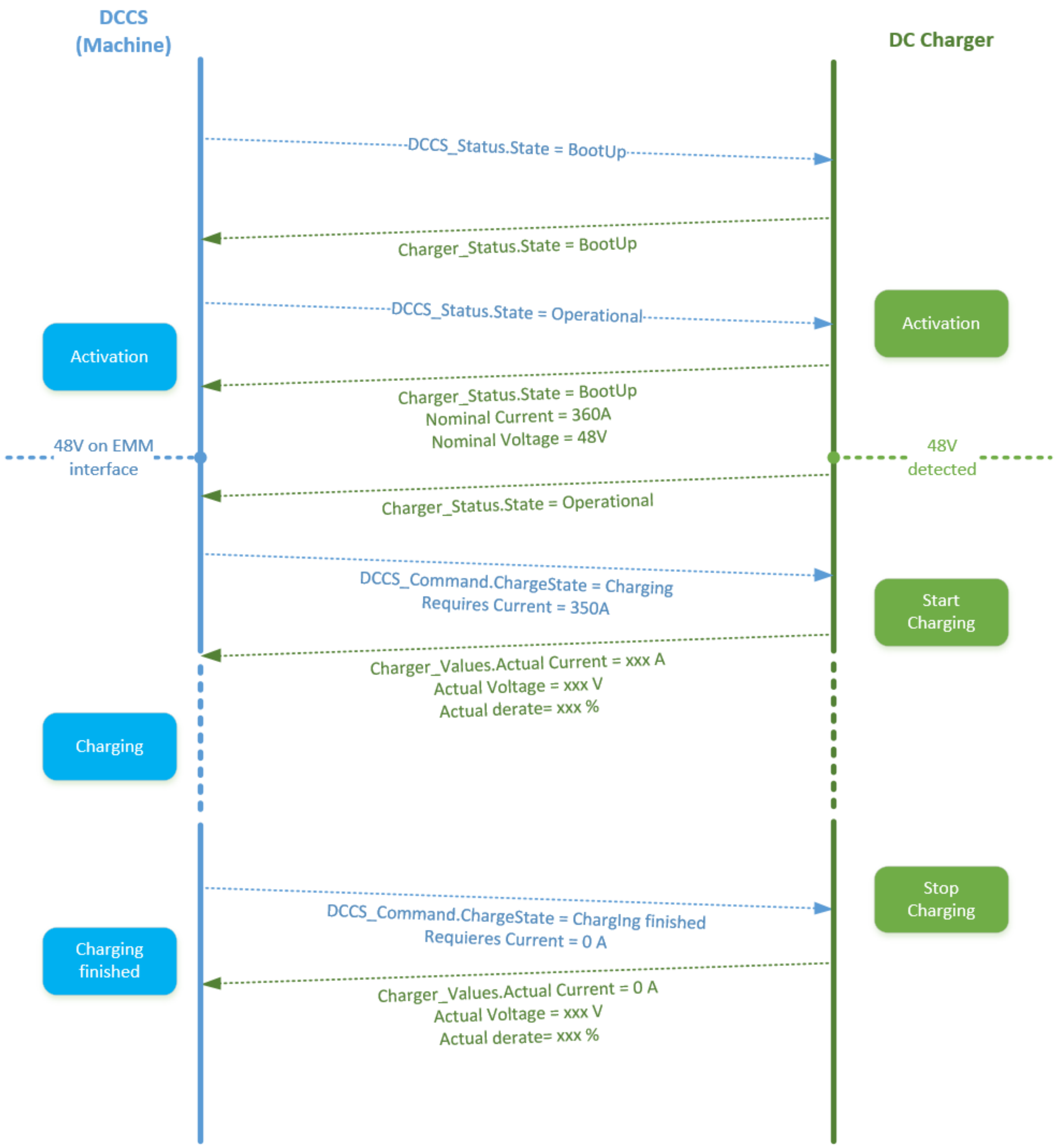
Signals logged are *Charging State*, *Error State* and *Error Type*.

4. CAN

4.1. CAN bus baud rate

The CAN bus baud rate shall be 250kbaud/s.

4.2. Communication flow



4.3. Signal and message definitions

Message	Signal	Range	Resolution	Offset	Factor	Value definition		Remark
DCCS_Status	**DCCS_Status_State**					0x03	Bootup	
						0x0C	Operational	
						0xFF	ERROR	
Message	Signal	Range	Resolution	Offset	Factor	Value definition		Remark
DCCS_Command	**DCCS_Command_ChargeState**					0x03	Charging OFF	
						0x0C	Charging ON	
						0x30	Charging Finished	
	DCCS_Command_ReqCurrent	0-1000	0.1	0	0.1	0x0000-0x2710	Valid	[A]
						0x2711-0xFFFA	Unused	Reserved
						0xFFFB-0xFFFE	Error 1 - Error 4	Reserved
						0xFFFF	Not Available	

Message	Signal	Range	Resolution	Offset	Factor	Value definition		Remark
Charger_Status	**Charger_Status_State**					0x03	Bootup	
						0x0C	Operational	
						0xFF	Error	
	Charger_Status_NominalCurrent	0-1000	0.1	0	0.1	0x0000-0x2710	Valid	[A]
						0x2711-0xFFFA	Unused	Reserved
						0xFFFB-0xFFFE	Error 1 - Error 4	Reserved
						0xFFFF	Not Available	
	Charger_Status_NominalVoltage	0-120	0.1	0	0.1	0x0000-0x04B0	Valid	[V]
						0x04B1-0xFFFA	Unused	Reserved
						0xFFFB-0xFFFE	Error 1 - Error 4	Reserved
						0xFFFF	Not Available	
	Charger_Status_Reserved_1	0-255	1	0	1	0xD8	27	Reserved, mandatory
	Charger_Status_Reserved_2	0-255	1	0	1	0x00	0	Reserved, mandatory
	Charger_Status_STOPActvn					0x03	OFF	
						0x0C	ON	

Message	Signal	Range	Resolution	Offset	Factor	Value definition		Remark
Charger_Values	Charger_Values_ActCurrent	0-1000	0.1	0	0.1	0x0000-0x2710	Valid	[A]
						0x2711-0xFFFA	Unused	Reserved
						0xFFFB-0xFFFE	Error 1 - Error 4	Reserved
						0xFFFF	Not Available	
	Charger_Values_ActVoltage	0-1000	0.01	0	0.1	0x0000-0x2710	Valid	[V]
						0x2711-0xFFFA	Unused	Reserved
						0xFFFB-0xFFFE	Error 1 - Error 4	Reserved
						0xFFFF	Not Available	
	Charger_Values_ActDerate	0-100	1	0	1	0x00-0x64	Valid	[%]
						0x65-0xFA	Unused	Reserved
						0xFB-0xFE	Error 1 - Error 4	Reserved
						0xFF	Not Available	
	Charger_Values_FaultType					0x00	No error	
						0x03	Fuse blown	
						0x0C	Grid error	
						0x30	Forced abort internal	
						0xFF	Pilot contact error	

ID	Cycle time	TX	RX	Byte0	Byte1	Byte2	Byte3	Byte4	Byte5	Byte6	Byte7
0x701x (DCCS_Status)	100 ms	DCCS	Charger	_State							
0x702x (DCCS_Command)	100 ms	DCCS	Charger		_ChargeState	_ReqCurrent L-Byte	_ReqCurrent H-Byte				
0x801x (Charger_Status)	100 ms	Charger	DCCS	_State	_Nominal-Current L-Byte	_Nominal-Current H-Byte	_Nominal-Voltage L-Byte	_Nominal-Voltage H-Byte	_Reserved_1	_Reserved_2	_STOP-Actvn
0x802x (Charger_Values)	100 ms	Charger	DCCS	...ActCurrent L-Byte	_ActCurrent H-Byte	_ActVoltage L-Byte	_ActVoltage H-Byte	_ActDerate			_Fault-Type

5. Annex: Extended voltage range

5.1. Baseline voltage

The protocol was designed with the intention to be used with a nominal traction voltage of 48 VDC.

5.2. Extended voltage range

The protocol itself is agnostic to the nominal voltage of the traction voltage system, meaning there is no reason it cannot be used with other voltages.

5.3. Constraints

5.3.1. Connector voltage rating

The REMA 400 connector is rated to a maximum voltage of 150 VDC.

5.3.2. Max voltage limit

The max voltage range shall be limited to 120 VDC, enabling the use of 96 VDC traction voltage systems.

5.3.3. Coding pins

The REMA 400 connector enables voltage classes differentiation by the use of coding pins. The coding pins physically inhibit connection of unmatching voltage classes by the means of “poka-yoke”.

The coding pins support 96 VDC through a dedicated coding pin.

5.3.4. Voltage class intermingling not allowed

Voltage class intermingling shall be prohibited!

That voltage classes shall use dedicated connectors exclusively, i.e. the voltage shall be considered as a level and not a ceiling.

Each charging connector shall be for single purpose use.

5.3.5. Electrical safety

Since this protocol was developed to support sub 60 VDC traction voltage machines, no consideration was taken to fulfill electrical safety demands of higher voltages.

Any equipment supplier intending to use a higher voltage needs to assess the safety requirements for that particular application and voltage level.