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Final design of Proton Motor FCM

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Abstract: This deliverable contains the supplier specific design of the FCM according to the WP3 Standard

Revision History

Date	Description	Author
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1 Introduction

Proton Motor as a core participant in the StasHH project, is being responsible for the design, development, manufacture and delivery of a fully tested fuel cell system (FCS) incorporating a fuel cell module (FCM) tailored to the project-defined AA standard size.

This hydrogen-powered PEM fuel cell system is designed for heavy-duty applications and provides a reliable and efficient power source for demanding transport requirements. It has been developed for multi-unit validation trials in small fleets and for rigorous real-world testing. With a net peak power output of about 43 kW, the system is designed to extend the operating range or serve as a hybrid energy solution for large commercial vehicles such as trucks and buses.

Proton Motor's fuel cell system consists of a main module with the fuel cell module, an air supply unit, a hydrogen circuit and an internal cooling circuit/heat management system. Other units are also required for operation, which can be integrated into the system at a more suitable location during subsequent vehicle integration. These essentially include the air filter unit, hydrogen supply and parts of the cooling circuit that can be connected to the vehicle cooling system. These peripheral components can be combined into one unit, which brings additional advantages. In a modular design with multiple systems, these components work in unison to ensure optimal performance and seamless integration into the overall system. To meet the standardisation efforts of StasHH, the fuel cell module has been developed in accordance with the AA standard size category to ensure compatibility with modular applications.

As part of its contribution to StasHH, Proton Motor was provided with the complete fuel cell system for extensive testing and evaluation. By participating in this initiative, Proton Motor is supporting the development of standardised, scalable hydrogen fuel cell solutions, thus promoting sustainable and emission-free mobility for the heavy-duty transport sector.

2 WP3 standard overview

The following sub-sections provide an overview of the WP3 standard definition, which is necessary to verify the compliance of the FCM design according to the StasHH definitions. The exact and binding requirements are listed in the official documents. A minimum power output of 30 kW (Beginning of life, BOL) of the FCM is mandatory for the StasHH standard.

2.1 Standard size definition

Three series of FC boxes were defined within the standard: A, B, and C series. For the A-series a doubling in the height direction is possible, which will be denoted with the subscript AA. The B-series allows for doubling or tripling in height direction denoted with the subscript BB and BBB respectively. The dimensions of the boxes can be found in Table 1 and the following tolerances in all directions are tolerated: +0/-100 mm.

Table 1: Dimensions FC module A, B and C

StasHH	Length / mm	Width / mm	Height / mm	Expected PEM kW
A	1.020	700	340	50
AA	1.020	700	680	110
AAA	1.020	700	1020	160

B	1.360	700	340	70
BB	1.360	700	680	145
BBB	1.360	700	1.020	220
C	1.700	700	340	90

The respective volumes of the different sizes are as follows:

- A external volume is max. 0.243 m^3
  AA external volume is max. 0.486 m^3
  AAA external volume is max. 0.729 m^3
- B external volume is max. 0.324 m^3
  BB external volume is max. 0.647 m^3
  BBB external volume is max. 0.971 m^3
- C external volume is max. 0.405 m^3

A visual representation of the A to C series boxes including the multiple sizes is shown in Figure 1.

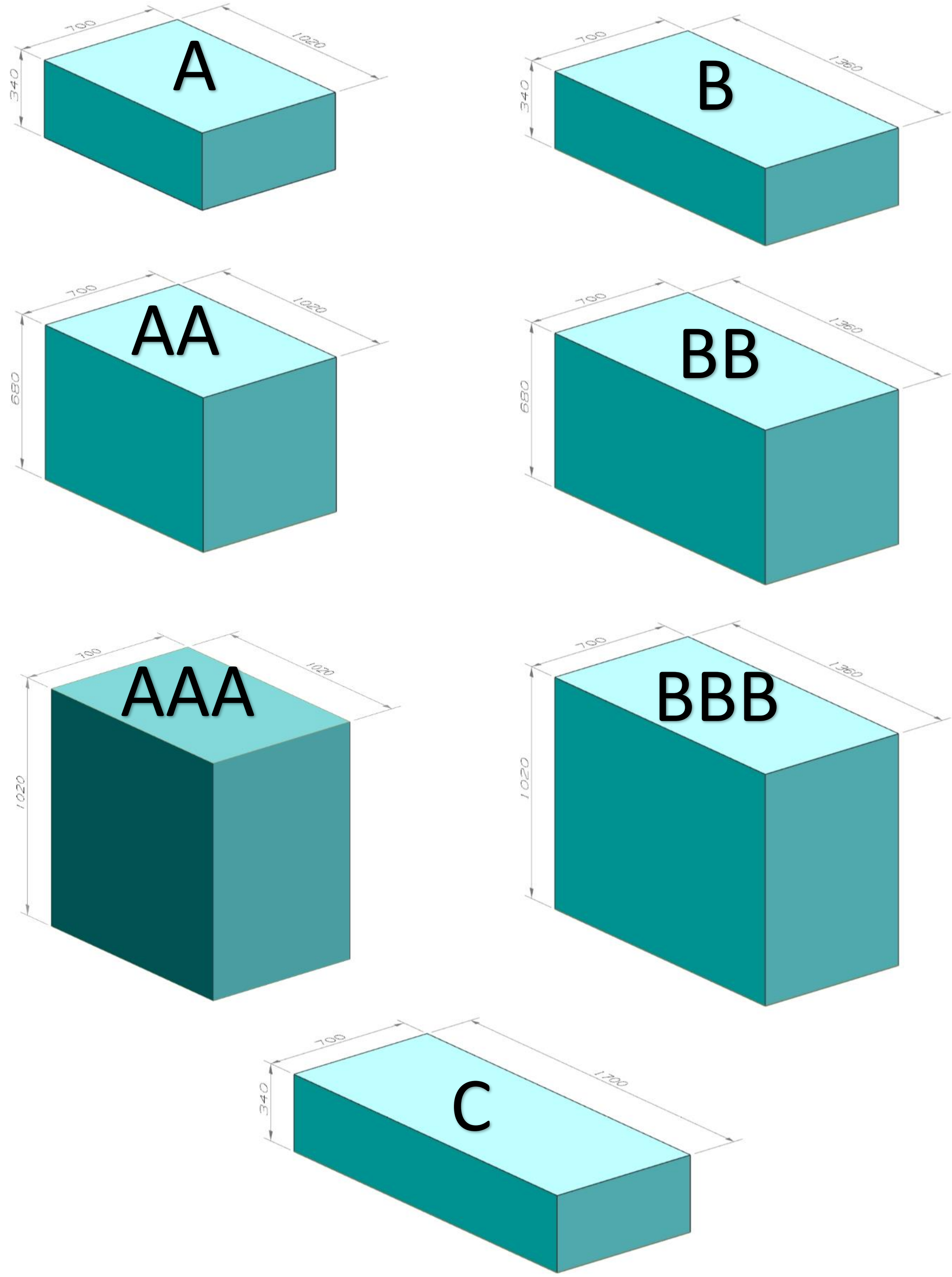

Figure 1: FC modules A, B and C

The orientation of all FC boxes is fixed according to the LengthxWidthxHeight definition except for the A(A) boxes which can be orientated optionally on its side. This is not a StasHH requirement. The optional orientation on the side is shown in Figure 2

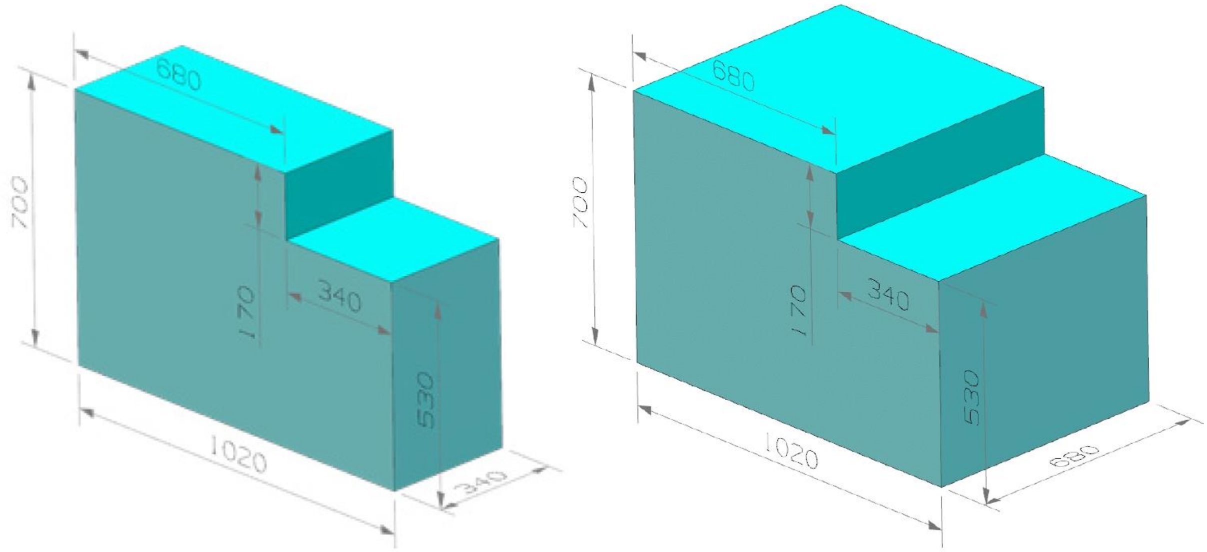

Figure 2: A and AA on their side

2.2 Standard interface definition

The interface areas and requirements for the pneumatic, hydraulic, and electronic connections are defined in the following.

2.2.1 Interface area

The interface area can be on two different sides. At least all pneumatic and hydraulic connections are within this interface area (except eventually the drain or (box) ventilation). Sides are defined with FC module in horizontal position:

1. In corner 3, on the LxH side FC module. See Figure 3. The dimensions of the interface area will be max. 340mm x $Depth_{main}$ x Module Height
2. In corner 4, on the WxH side FC module. See Figure 3. The dimensions of the interface area will be max. 700mm x $Depth_{main}$ x Module Height

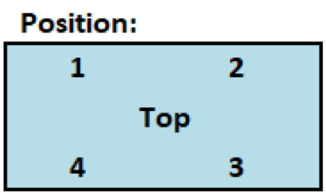

Figure 3: Top view of FCM for interface area definition

"$Depth_{main}$" or "D_{main}" is defined as the minimum depth needed to stay within the overall FC module volume (defined in D3.2), with connected male and female connectors.

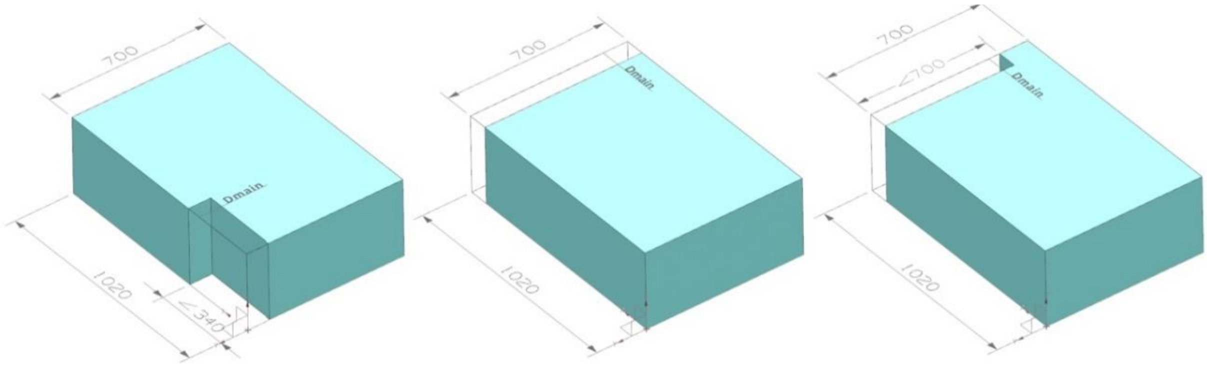

Figure 4: FCM interface areas possibility (1st side)

The size definitions of the interfacial areas can also be found in a tabulated manner in Table 2

Table 2: Dimensions FC module interface areas (1st side)

Interface 1st side	Length / mm	Depth / mm	Height / mm
A	Max. 340	$\geq D_{main}^{x}$	340
AA			680
AAA			1.020
B			340
BB			680
BBB			1.020
C			340

Interface 1st side	Length / mm	Depth / mm	Height / mm
A	Max. 700	$\geq D_{main}^{x}$	340
AA			680
AAA			1.020
B			340
BB			680
BBB			1.020
C			340

*Depth is min. Depth needed to stay within overall FC module volume with connected interfaces

Optionally, a second interface area can be utilized under the following conditions:

3. The main side complies with 1. with depth “Dmain”, and the second side complies with 2. with depth “Dsub”

OR

4. The main side complies with 2. with depth “Dmain”, and the second side complies with 1. with depth “Dsub”
5. Both connections areas are mechanically redundant, i.e., all pneumatic and hydraulic connections are on both sides (except eventually the drain or (box) ventilation)

“$Depth_{sub}$” or “D_{sub}” is defined as the minimum depth needed to stay within the overall FC module volume, with not connected male or female connectors.

Table 3: Dimensions of FC module interface areas (optional 2nd side)

Interface 2nd side	Length or width / mm	Depth / mm	Height / mm
A	Max. 340 or 700	$\geq D_{sub}^{x}$	340
AA			680
AAA			1.020
B			340
BB			680
BBB			1.020
C			340

An exemplary image of the optional second interface area is depicted in

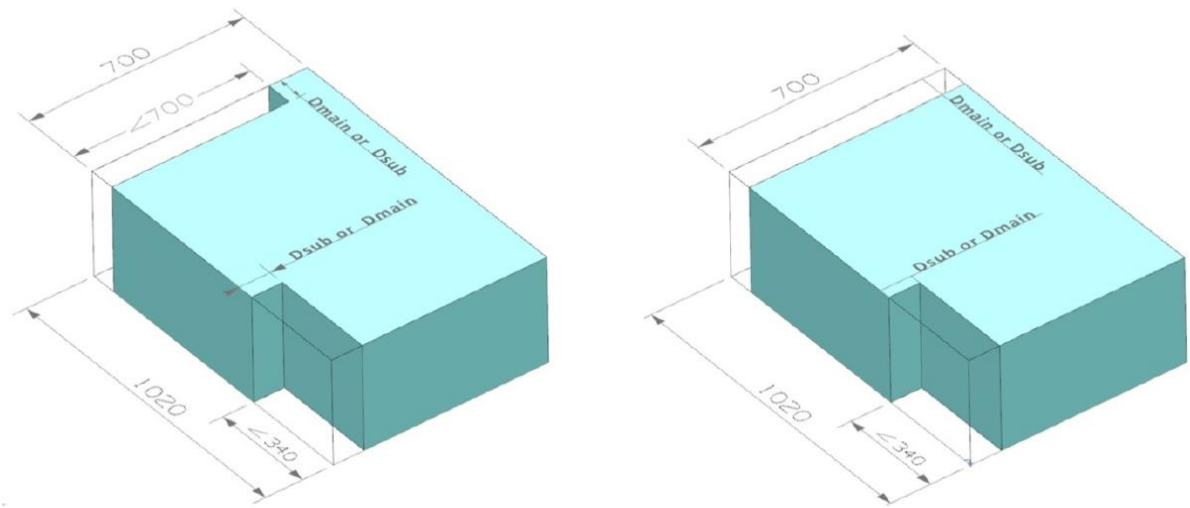

Figure 5: Example of FC module interface area with 1st side and optional 2nd side

2.2.2 Hydraulic, pneumatic, and electrical interfaces

All hydraulic and pneumatic interfaces must comply with the following conditions:

- All the pneumatic and hydraulic connections, excluding the optional drain or (box) ventilation, are positioned in the defined interfaces areas
- The connections' principle will be fixed for all FCMs, but can be different depending on usage. For example, for air this can be a hose, for hydrogen a pipe. See Table 4
- The connection size ranges (in mm) are defined, but will vary with the power range of the FC module Table 4.
- The electrical and I/O communication can be positioned anywhere within the chosen overall dimensions of A, B and C.

Table 4: Hydraulic and pneumatic interfaces of FC modules

	Interfaces	Inner diameter / mm Nominal power				Remark
		≤ 70 kW	71 - ≤ 100 kW	101 - ≤ 130 kW	131 - ≤ 160 kW	
Hydrogen	Pipe fitting	6-8	8-12	12-16	16-20	6-22 bar
Air	Nozzle + Hose	30-60	45-75	60-90	75-105	
Steam	Nozzle + Hose	30-60	45-75	60-90	75-105	
Drain	Nozzle + Hose	6-8	8-12	12-16	16-20	optional
Cooling FC	Nozzle + Hose	20-40	30-50	40-60	50-70	In/Out
Cooling -E	Nozzle + Hose	15-35	20-40	25-45	30-50	Optional
Breather	Banjo	M14x1.5	M14x1.5	M14x1.5	Tbd	Optional
Ventilation	Nozzle + Hose	20-40	20-40	20-40	20-40	Optional

An additional condition for the main hydraulic and pneumatic connections is that they may not interfere in the horizontal and vertical directions, see Figure 6.

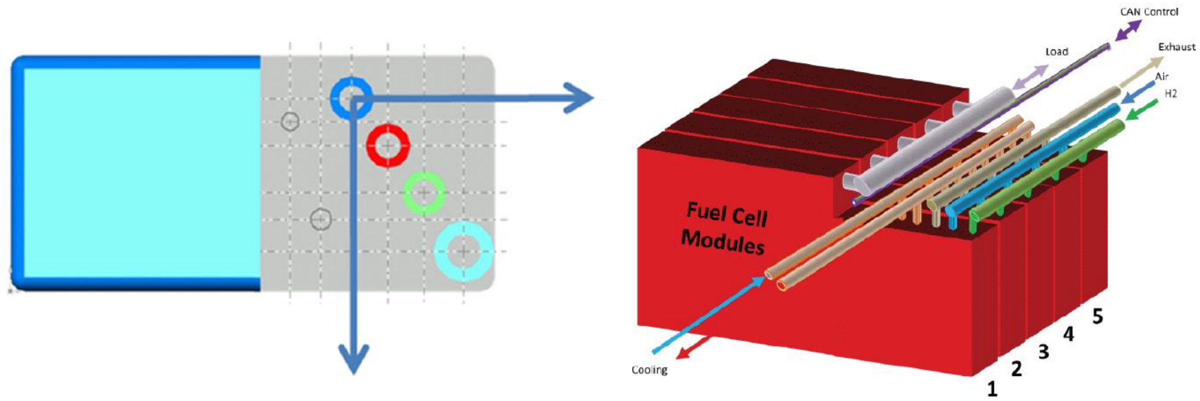

Figure 6: Non-interfering hydraulic and pneumatic connections

2.2.3 Low and high voltage connectors

Within StasHH the pins for the LV and HV connection are specified but not the specific connector.

High voltage connector:

The connector must have two pins, plus and minus. Additionally, it must withstand the maximum FCM voltage and current. Connectors, already utilized in heavy-duty applications are preferred.

Low voltage connector:

The LV connector must withstand up to 100 A and cable lugs are suggested.

2.3 Standard API definition

2.3.1 Physical connector

For the physical connector for the communication with the FCM only the pins are specified and not the connector itself. It is proposed to use an 18 pin connector to include additional functions of needed. The connector shall at least have an ingress protection level of IP54 with a proposed pinout, depicted in Figure 7.

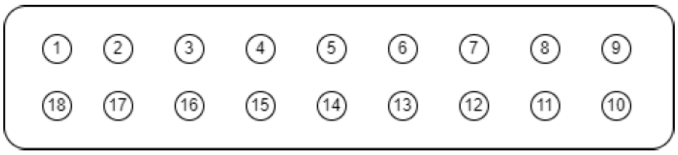

Figure 7: Pinout

The physical connector shall have enough pins to transfer all electrical signals needed and must fulfil the requirements resulting from the working environment or use case of the application.

The following pins must be included in the connector:

1. CAN ground
2. CAN high
3. CAN low
4. OPTIONAL shield
5. Wakeup signal
6. Emergency stop

The following optional pins are also specified:

7. OPTIONAL HVIL in
8. OPTIONAL HVIL out
9. OPTIONAL 24V
10. OPTIONAL ground for LV power
11. OPTIONAL CAN high for DC/DC or secondary FCM
12. OPTIONAL CAN low for DC/DC or secondary FCM
13. OPTIONAL CAN high manufacturer specific diagnostic bus
14. OPTIONAL CAN low manufacturer specific diagnostic bus

The remaining pins 15 to 18 are intended for future use and additionally deployments

2.3.2 State machine

The state machine shall at least contain the following states:

- Idle:
  In this state the FCM has LV power sufficient to activate the FCCU. This state corresponds to "Power on" in J1939. Periodic counter messages are transmitted
- Standby:
  No HV output power but necessary subsystems are powered and ready such that it can start producing output within a short time. Error and diagnostic messages can be sent
- Starting:
  FCM is transitioning from standby to running state. Power is ramping up and HV bus is enabled – Module can consume and provide energy
- Running:

FCM is active and delivering power. Power may be limited due to derating which will be indicated by FCM

- Stopping:
  FCM is ramping down and returning to standby state. HV bus must be enabled during shut-down procedures.
- Error:
  Error state must be enabled from any other state. FCM shall be brought in a safe state

Proprietary substates can be defined by the FCM manufacturers.

For further information see D3.4 document.

2.3.3 Messages

In the following the messages that are used in the communication between the application ECU and FCCU are listed:

- State machine control
- State machine feedback
- Emergency stop request
- Reference power value
- FCM actual current and voltage
- Power limits
- Voltage limits
- High voltage bus information
- FCM temperature
- Time and date
- Ambient conditions
- Vehicle speed
- FCM gas leakage
- Alarm messages

For a generic description of the messages including a mapping to a J1939 message, please refer to the official D3.4 document.

3 Design of the Proton Motor Fuel Cell GmbH HyRange® AA

The Proton Motor StasHH AA fuel cell system consists of the actual HyRange® AA fuel cell module and other peripheral components that are not included in the HyRange® AA module but are necessary for operation and are part of the system. In a typical heavy-duty vehicle application, these are usually provided by the higher-level system, as they depend on the respective application. This separation provides a certain degree of freedom in the design. Furthermore, it is possible to combine these peripheral components in a meaningful way in multi-module systems. This reduces mass, space requirements and uses synergy effects during operation.

The HyRange® AA was developed for mobile applications, mainly for heavy-duty applications. The following application areas are mainly seen here. Other applications are possible in principle, but must be clarified and agreed with PM in advance.

The *HyRange® AA* benchtop structure consists of several functional units, which are described in more detail below.

Main modules in the *HyRange® AA*:

- PM 400 stack module
    - Fuel cell stack
    - Media adapter plate
    - Contactor assembly
    - Enclosure
- Peripheral components
    - Compressor
    - Intercooler
    - Cooling circuits Fuel cell and peripheral components,
    - Mixing valve cooling circuit
    - Main pump fuel cell cooling
- Fuel Cell Control Unit (FCCU)
- Enclosure with IP protection

Additional components in the benchtop structure:

- Hydrogen supply
    - Valve for H_2 supply: 3/2-way safety valve (pressure relief)
- Air supply
    - Air filter
- Cooling circuit
    - Heat exchanger for dissipating the waste reaction heat
    - Coolant expansion tank
    - Ion exchange cartridge
    - Coolant pump peripheral circuit
- Media discharge
    - Condensate separator Product water
- Other peripheral components:
    - Data acquisition unit (not shown in the R&I scheme)

The system is completely connected, piped and internally wired as delivered.

3.1 Key technical specifications

The mandatory key technical specifications are listed in Table 5.

Table 5: Mandatory technical specifications of FCM according to StasHH

Requirement	**StasHH requirement**	**FCM**
Service life / h	> 15.000	> 15.000 [a)]
Geographical heights / m	< 3.000 with derating	< 2.000 without derating 3.000 with derating
IP class	> IP54	IP55 (*HyRange® AA* without periphery components)
Low voltage / V	24DC	20 – 26 / 0 – 50 A
High voltage output / V	160 – 850 DC	85 – 165 DC
Operational ambient temperature / °C	-25 to 45	-25 to +45
Conductivity glycol / µS/cm	< 6 (ASTM D 1125	max. allowed < 10
H_2 input pressure / bar	6 - 22	6-8
Hydrogen quality	ISO 14687 or SAE J2719	ISO 14687:2019 (Type I, Grade D) / SAE J2719 / Linde 5.0

a) *Extrapolated value, experimental proof ongoing*

Additional technical specifications of FCM are listed in

Table 6: Additional key technical specifications of FCM

Requirement	**FCM**
Net continuous system power output P_{net} BOL / kW	42,6
Net continuous system power output P_{net} EOL / kW	34 [b)]
Weight / kg	325
DC/DC included in FCM / -	HV DCDC not included in the FCM
Peak system efficiency / %	Not disclosed
System efficiency at P_{net} BOL	Not disclosed
System efficiency at P_{net} EOL	Not disclosed
Gravimetric system power density @ BOL / kW/ton	Not disclosed
Volumetric system power density @ BOL / kW/m³	Not disclosed

b) *Calculated according EoL defined as 80 % of BoL*

3.2 Exterior design

The exterior design of the FCM with all main dimensions is shown in Figure 8.

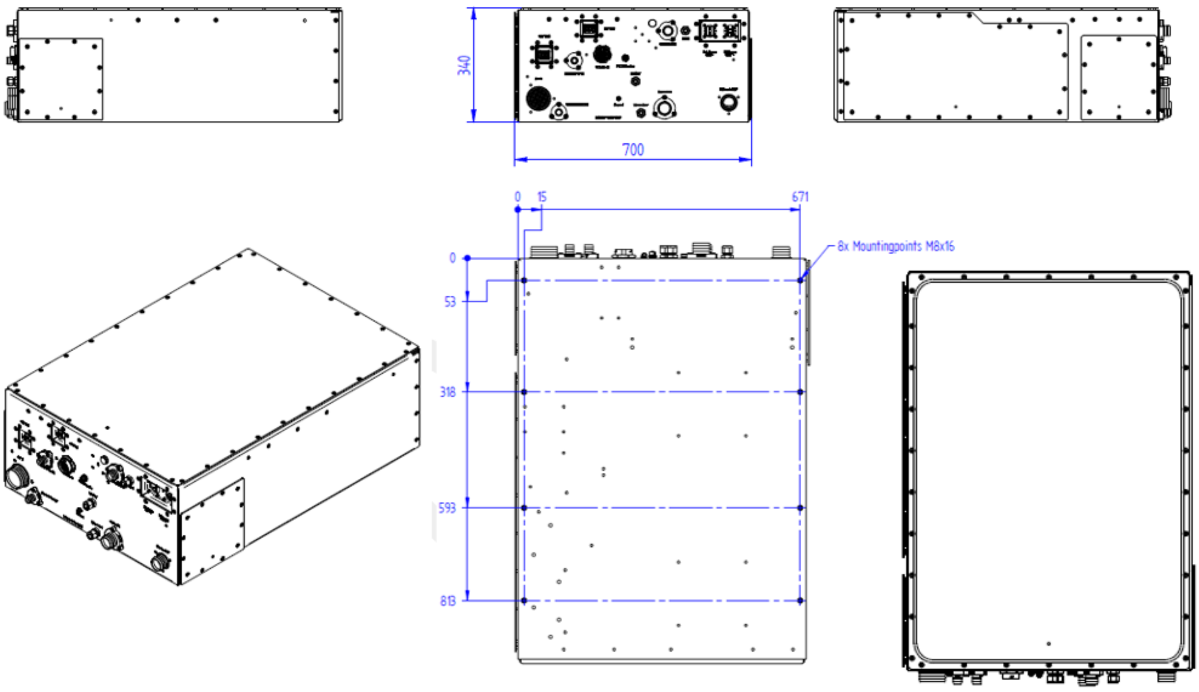

Figure 8: Exterior design with main dimensions of FCM [please add CAD images of all sides to verify compliancy to StasHH]

3.3 Module Pictures

Pictures of the module built for testing shown in Figure 10.

Figure 9: Benchtop system at testing in the FEV test laboratories

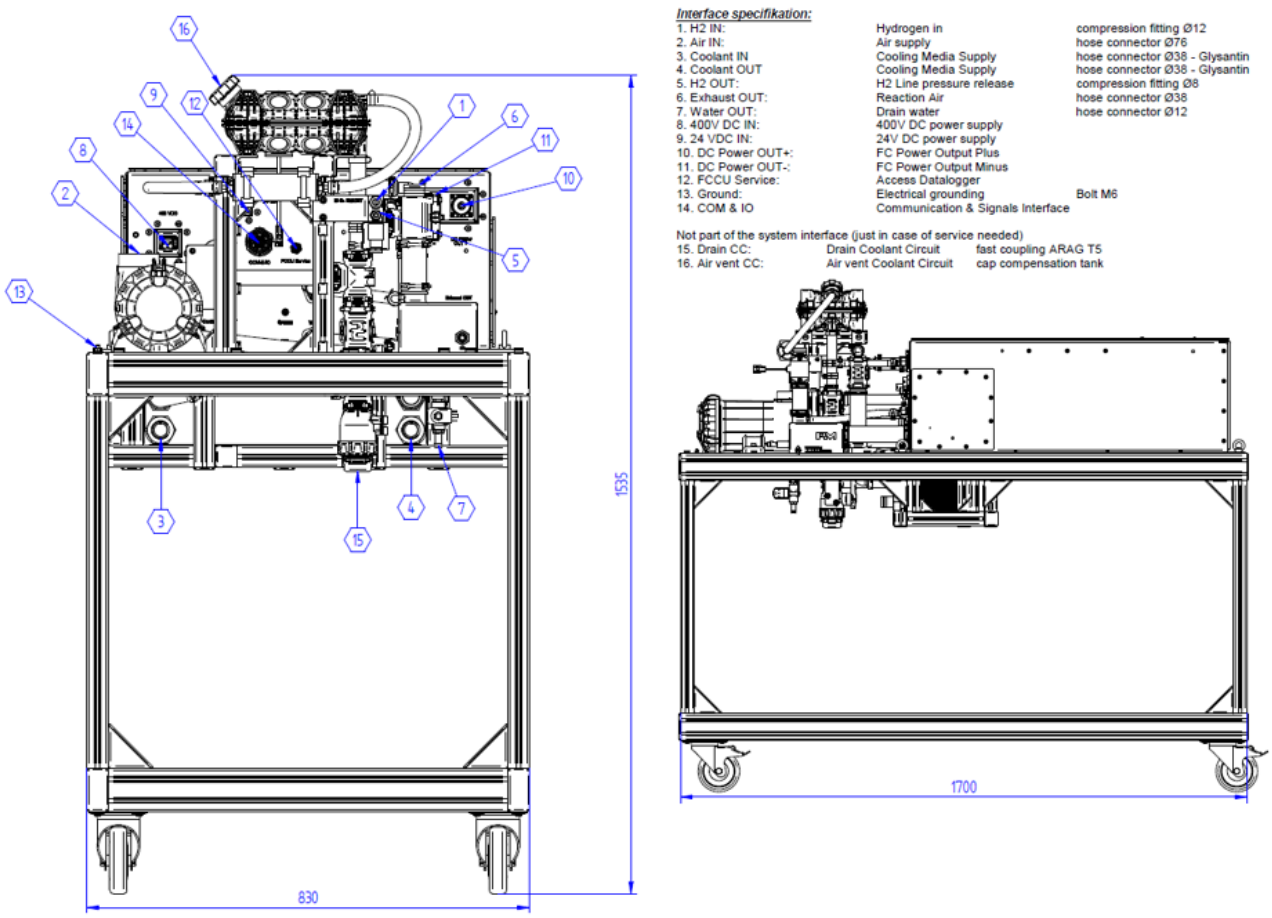

Figure 10: Drawings of the complete benchtop system with the FCM Module built for testing

3.4 Interface specification and area

The Proton Motor HyRange® AA System provides the following interfaces:

Gas interfaces

- Air outlet (also called reaction exhaust air)
- Hydrogen input (H_2 input)
- Air inlet (also called reaction air). Is drawn in from the ambient air
- H_2 Pressure relief on 3/2 way valve

Hydraulic interfaces

- Water output (also called H_2 O, condensate or reaction waste water)
- Coolant inlet
- Coolant outlet

Electrical interfaces

- Power inputs/supply of peripherals (compressor, pumps etc.) 400 VDC[1]
- Power inputs/supply of peripherals (compressor, pumps etc.) 24 VDC
- Power output (gross power of the stack module after DC/DC converter)
- Communication interfaces to the BZA
- PM Service Interface

3.4.1 Interface area including hydraulic and pneumatic interfaces

The design and dimensions of the interface area is depicted in Figure 11

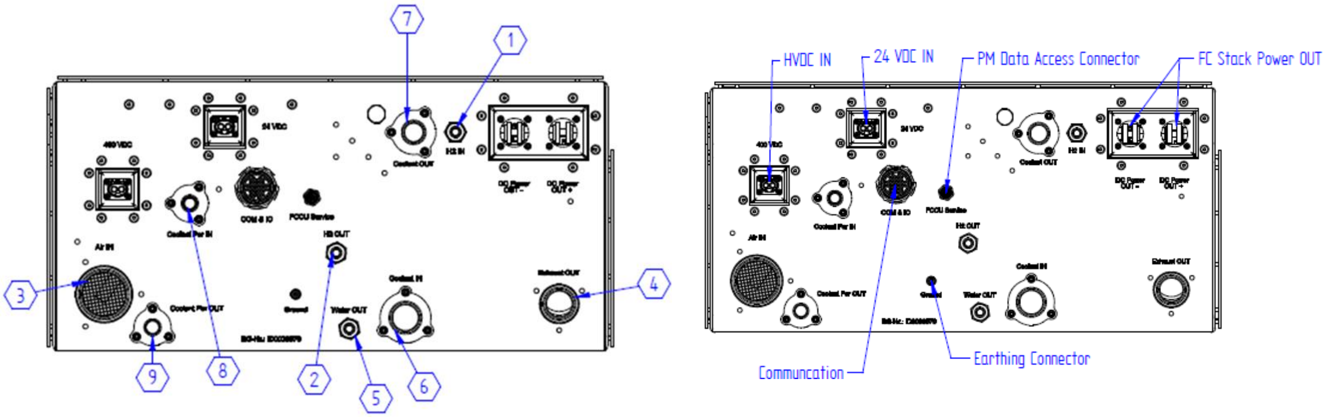

Figure 11: Main interface area of FCM (see description in the following table 7)

The positioning of the electrical and communication interfaces of the FCM within the interface area are shown in Figure 12. The specifications of the interfaces are summarized in Table 7.

[1] Permitted range of high-voltage supply: 450 VDC - 750 VDC

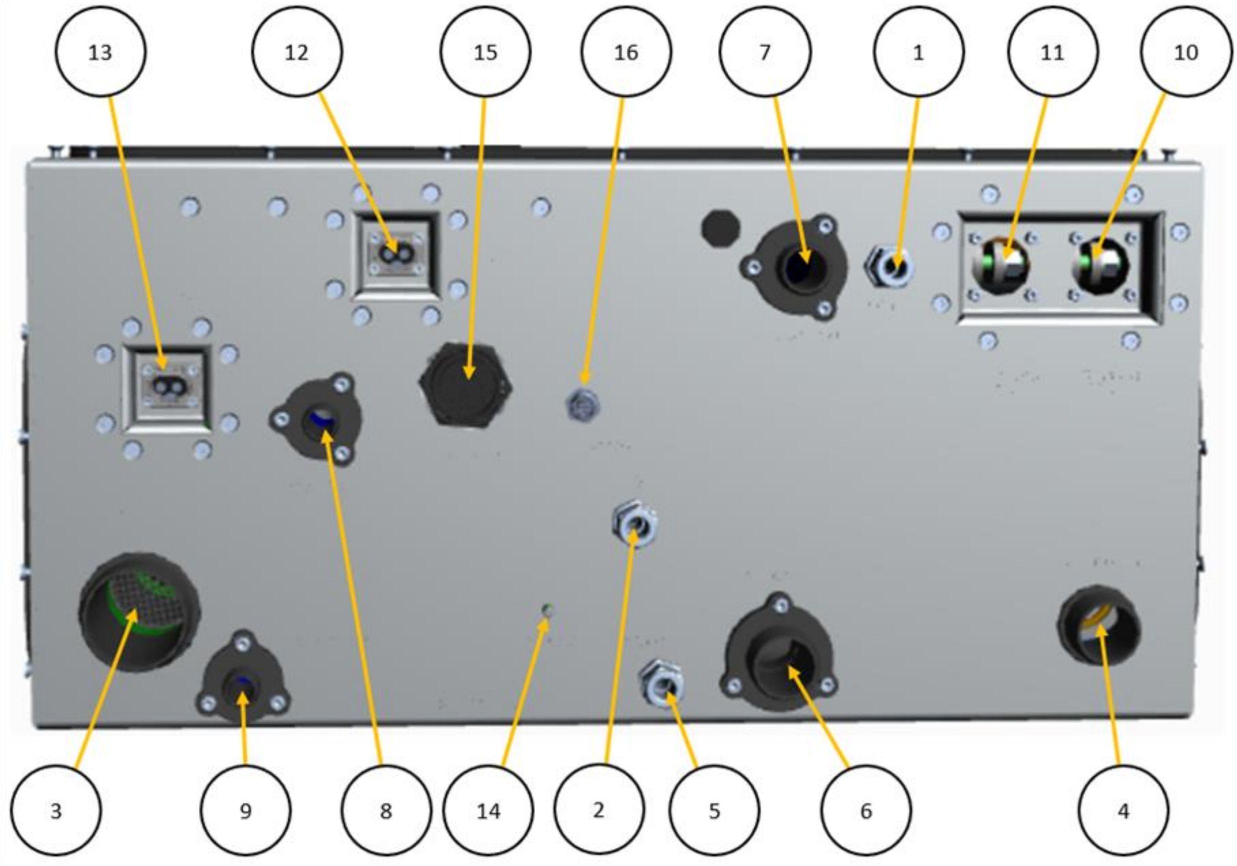

Figure 12: Position of hydraulic and pneumatic connections of FCM

Table 7: Specifications of interfaces of the FC module

Pos.	Interface	Designation
1	Hydrogen input	H2 IN
2	Hydrogen outlet (Purge)	H2 OUT
3	Reaction air inlet	Air IN
4	Reaction air outlet	Exhaust OUT
5	Reaction water outlet (drain)	Water OUT
6	Cooling Fuel cell Input	Coolant IN
7	Cooling fuel cell output	Coolant OUT
8	Cooling Periphery Input	Coolant Per IN
9	Cooling Periphery Output	Coolant Per OUT
10	Load output PLUS	DC Power OUT +
11	Load output MINUS	DC Power OUT -
12	Low-voltage power supply	24 VDC IN
13	High-voltage power supply	400 VDC IN
14	Earthing bolt/potential equalisation M6	Ground
15	Communication and signal interface	COM & IO
16	PM service interface and access to data logger	FCCU Service

No.		Interface type	Inner diameter / mm
1	Hydrogen IN (Supply)	Compression Fitting, Swagelok SS-12M0-61	9 mm
2	Hydrogen OUT (Purge)	Compression Fitting, Swagelok SS-12M0-61	9 mm
3	Air IN	Hose Connector Ø60 mm, 3-D printed part, made of PA 12 (MJF)	54 mm (hose connector), 60 mm (air supply hose)
4	Air/Steam OUT	Hose Connector Ø38 mm, 3-D printed part, made of PA 12 (MJF)	32 mm (hose connector), 38 mm (exhaust outlet hose)
5	Reaction Water OUT (Drain)	Compression Fitting, Swagelok SS-12M0-61	9 mm
6	Cooling FC IN (FC Stack IN)	Hose Connector Ø38 mm, 3-D printed part, made of PA 12 (MJF)	32 mm (hose connector), 38 mm (coolant supply hose)
7	Cooling FC OUT (FC Stack OUT)	Hose Connector Ø28 mm, 3-D printed part, made of PA 12 (MJF)	22 mm (hose connector), 28 mm (coolant outlet hose)
8	Cooling -E IN (Peripheral BoP IN)	Hose Connector Ø19 mm, 3-D printed part, made of PA 12 (MJF)	13 mm (hose connector), 19 mm (coolant supply hose)
9	Cooling -E OUT (Peripheral BoP OUT)	Hose Connector Ø19 mm, 3-D printed part, made of PA 12 (MJF)	13 mm (hose connector), 19 mm (coolant outlet hose)

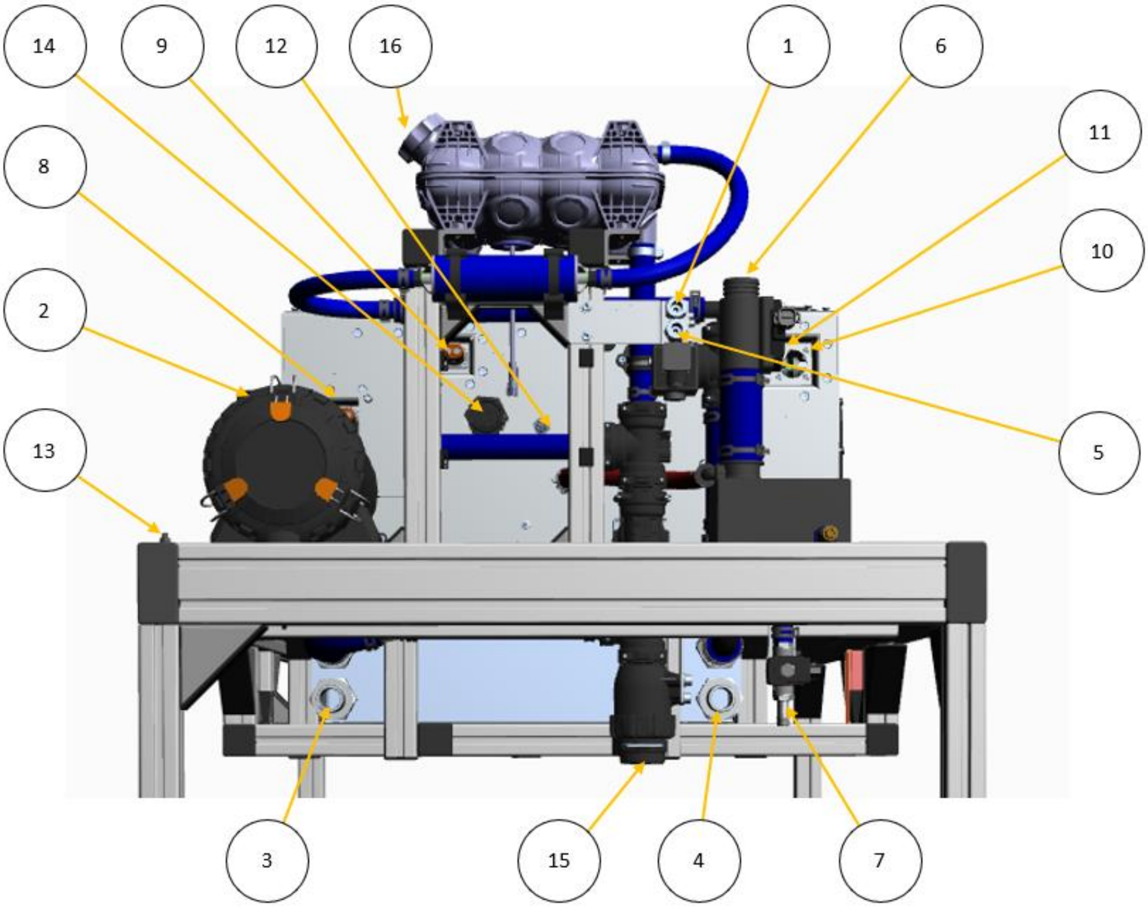

Figure 13: Interfaces of the benchtop system with peripheral components

Table 8: Specifications of the benchtop system with peripheral components

Pos.	Interface	Designation
1	Hydrogen input	H2 IN
2	Reaction air inlet	Air IN
3	Cooling input	Coolant IN
4	Cooling output	Coolant OUT
5	Hydrogen outlet, Purge	H2 OUT
6	Reaction air outlet	Exhaust OUT
7	Product water outlet	Water OUT
8	High-voltage power supply 400 VDC (*HyRange® AA*)	400 VDC IN
9	Low voltage power supply 24 VDC (*HyRange® AA*)	24 VDC IN
10	Load output PLUS (*HyRange® AA*)	DC Power OUT +
11	Load output MINUS (*HyRange® AA*)	DC Power OUT -

12	PM service interface and access to data logger (*HyRange® AA*)	FCCU service
13	Earthing bolt/potential equalisation M6	Ground
14	Communication and signal interface (*HyRange® AA*)	COM & IO
15	Coolant drain	Drain CC
16	Filler neck Coolant expansion tank with pressure compensation	Air vent CC

3.4.2 Electrical and communication interfaces

The electrical and electrotechnical connection of the HyRange® AA is essentially made via the load cables for discharging the generated electrical energy, the supply lines and the signal cables for connection to the higher-level control system.

The load cables themselves required for this are not part of the standard product scope described here due to the application-specific design. Details of the electrical and communication interfaces are given in **Fehler! Verweisquelle konnte nicht gefunden werden.**. See also Figure 11.

Table 9: Technical details on electrical and communication interfaces

Interface	**Interface/Connector**	**Parameter**	**Comment**
High-voltage supply	X_HV.A (Amphenol)	450 - 750 VDC / 0-55 A	Mating connector with cable (open cable ends) included in scope of delivery
24 V supply	X_24V.A (Amphenol)	450 - 750 VDC / 0-55 A	
DC power output + / -	X_HVpl.A (PLUS) X_HVmin.A (MINUS) (Amphenol)	46 kW (max, BoL) 85 - 165 VDC / 50 - 500A	
Service connection FCCU		M12 connection (cable with RJ45 plug)	Service Ethernet Interface for PM Customer Service
Potential equalisation		M6 screw bolt	Several places on the girder frame
COM & IO	X_CUS3		Mating connector with cable (open cable ends)

3.5 API definition

The used communication protocol is based on the CANopen standard CiA 301 (for more information please refer to: https://www.can-cia.org/can-knowledge/canopen).

A detailed description of the used CAN protocol will be provided in section **Fehler! Verweisquelle konnte nicht gefunden werden.**.

3.5.1 State machine

A state machine for the main states of the FCM is shown in Figure 14. The properties of the different states are described in this section.

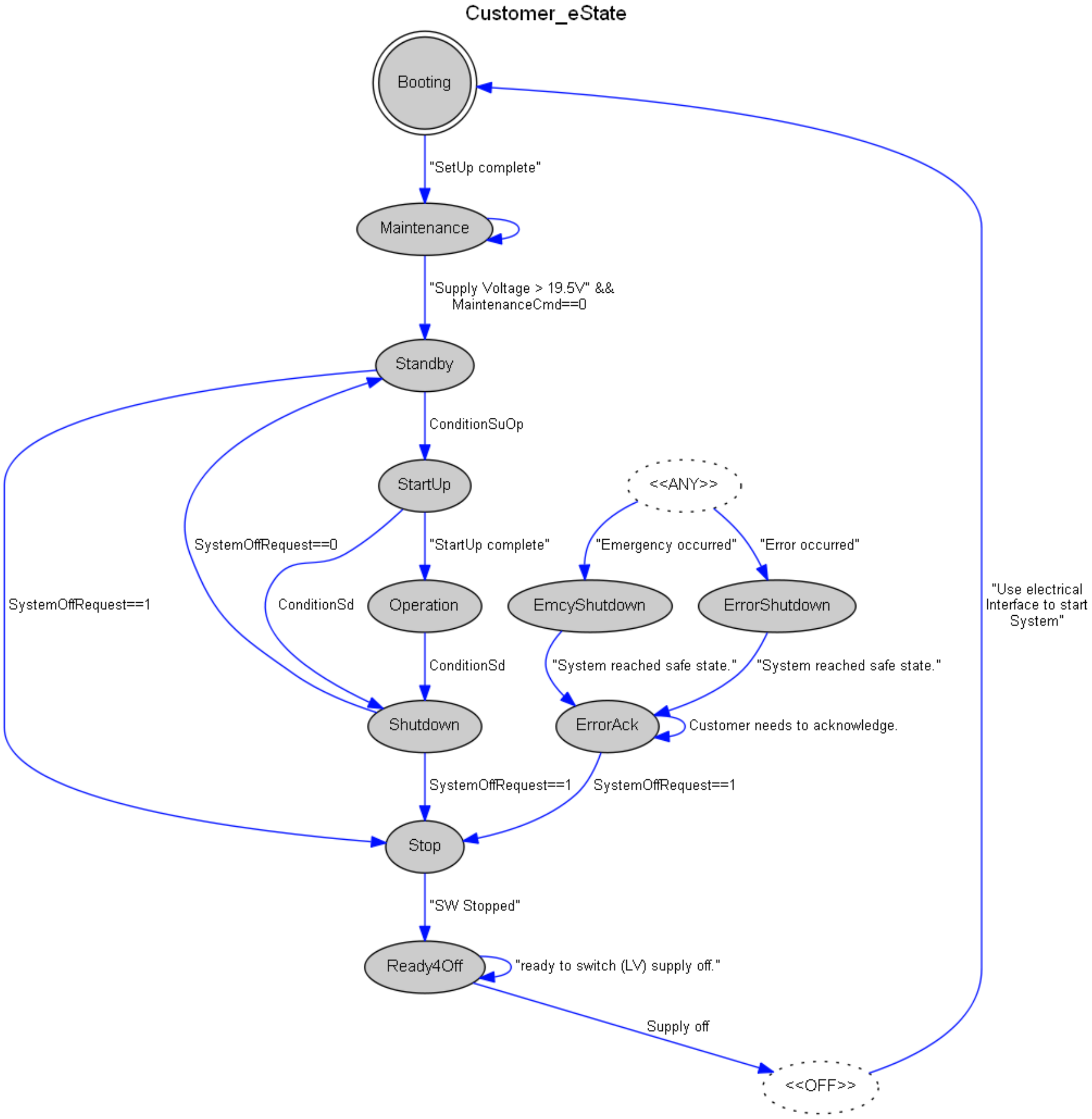

Figure 14: State machine of the HyRange® AA Fuel cell module

The individual operating states are described in more detail in the following section. During the entire operating phase, the system passes through various states, which can be roughly divided into the following points:

- Put into operation: Booting, Standby, Starting
- Operating phase: Operation

- Switch off: Switch off (normal, safety, emergency switch off), stop

Booting

This state is used for the pre-testing or initialisation of various sensors, components and control units up to process engineering subsystems. Furthermore, the prerequisite for interrogating and closing the internal safety chain is to be created in this operating state.

Stand-by

In this state, the control unit waits for a start command via CAN communication.

Start-up

In this state, the fuel cell system is started and the individual subsystems (cooling, air supply, anode gas supply, etc.) are gradually put into operation. Before this, all valves for the hydrogen supply must be open so that the mean hydrogen pressure is available, and the anode compartment of the fuel cell can be charged with hydrogen. The condition is completed by closing the main contactors and ramping up to minimum power.

Operation

In this state, the fuel cell system is in the regular operating phase in which it remains. All control functions of the circuits are fully active here. The internal power management regulates the FC setpoint current in a superordinate manner depending on the power requirement within the framework of the currently permissible operating conditions.

In dynamic control of the load current, the dynamics of the air supply result in current ramps that prevent the load current from increasing too quickly. In this state, if the power demand is set to "0" or to a value less than a limit in the corresponding configuration, the system slowly reduces the current to zero and enters the shutdown state.

Switch off

If this condition is triggered, the FC main contactors open. The power output to the load or to the DC/DC converter is thus disconnected. The system is then prepared for disconnection.

Stop

The system goes through this operating state before it is completely shut down. After this state is completed, the system must be restarted. The hydrogen supply can be closed and the pressure can be relieved.

Error

If a fault is detected in the system, the system is switched off in a shortened/adjusted manner depending on which component has a fault or whether the safety circuit is still closed. The system remains in this state and displays the error that has occurred until it is switched off by a command.

3.5.2 CAN protocol

On the CAN client interface, a protocol is implemented as standard through which the HyRange® AA can be given a power specification via a higher-level controller (client). Furthermore, information about the status of the HyRange® AA is communicated via this CAN bus.

The baud rate of the CAN interface is 500 kBits. The customised CAN interface of the HyRange® AA is activated by default in the configuration. The HyRange® AA starts sending the Transmit Process Data Objects (TxPDOs) defined in the protocol in the appendix immediately after the power supply is switched on. This protocol contains all the necessary information for the operation of the HyRange® AA. To control the HyRange® AA via the CAN interface, the customer must send the receive process data object 1 (RxPDO 1) with a cycle time of 1000 ms. A setpoint greater than 0 is required for a system start, and the FC_On bit must also be set to 1. The byte order is Big Endian.

The following Table 10 shows an overview of the pin assignment on the CAN interface (connector Y_CUS3).

Table 10: Technical details of the Communication & Signal Interface

<table>
<tr><th>Pin</th><th>Signal designation</th><th>Function</th><th>Comment</th></tr>
<tr><td>1</td><td>Start_24V</td><td>Start signal for the system (24 VDC are permanently required to operate the system)</td><td>5 A fuse required</td></tr>
<tr><td>2</td><td>SSD_Signal</td><td>ESD (Emergency Shut Down) signal</td><td></td></tr>
<tr><td>3</td><td>SSD_NC1</td><td>ESD (Emergency Shut Down) Response</td><td></td></tr>
<tr><td>4</td><td>Start_GND</td><td>Mass</td><td></td></tr>
<tr><td>5</td><td>CAN_H</td><td>CAN High</td><td rowspan="3">CAN-interface must be terminated with a 120 Ω resistor</td></tr>
<tr><td>6</td><td>CAN_L</td><td>CAN Low</td></tr>
<tr><td>7</td><td>CAN_GND</td><td>CAN Ground</td></tr>
<tr><td>8</td><td>FFC_niO</td><td>Status Notification Controller</td><td></td></tr>
</table>

4 Scope of delivery and accessories

Table 11: Standard scope of delivery HyRange® AA

No.	Article	Quantity	Description / Comment
1	*HyRange®* AA	1 pc.	Hydrogen fuel cell system (BZS)
2	Connection cable	1 set	(supply HV, supply 24V, communication, HV output stack)
3	Original operating manual	1 pc.	digital and/or in paper form

Further peripheral components are necessary for the operation of a HyRange® AA. However, these depend on the respective application and the system environment (e.g. already existing infrastructure). The process engineering systems of the hydrogen gas supply, the recooler to be connected to the cooling section, etc. are not part of the standard product scope and are optionally available.

However, in the Benchtop system within the StaSHH project, these are partially included:

Table 12: Scope of delivery StaSHH Benchtop structure

No.	Article	Quantity	Description / Comment
1	*Standard HyRange®* AA	1 pc.	As described above
2	Table construction	1 pc.	On rollers
3	3/2-way valve	1 pc.	Safety valve hydrogen inlet with pressure relief
4	Heat exchanger	1 pc.	For decoupling the reaction waste heat (cooling circuit)
5	Coolant expansion tank	1 pc.	

Table 13: Optional components and parts available for the StaSHH system

No.	Article	Order number	Description / Comment
1	Cooling medium	8022261	BASF Glysantin® FC G 20-00/50 (5 litre container)
2	Modem (optional)	-	Extension module for data logger. This enables remote access via the mobile phone network.

5 Figures

6 Tables