Ballard Power Systems Europe A/S
Majsmarken 1
9500 Hobro
Denmark

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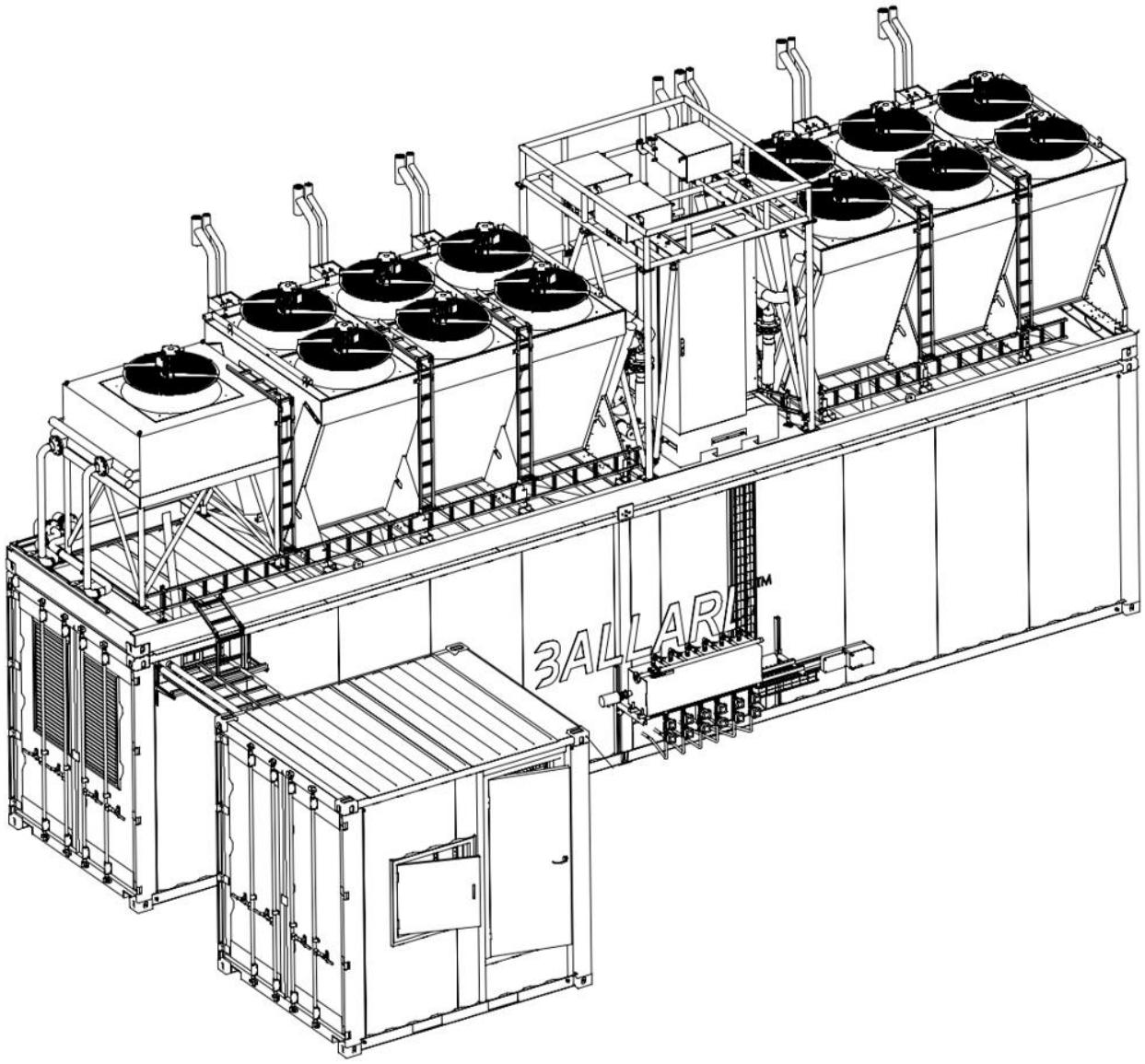
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FC PowerGen 1000kW

Part no.: 601456B-7002362

Configuration: 40ft Fuel Cell Container w. 6 FCwave™
10ft Converter Container, 6,6 kVAC

Integration Manual



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1.0 Disclaimer

NOTE: READ THIS BEFORE ATTEMPTING ANY PROCEDURES DESCRIBED IN THIS MANUAL

There are inherent risks in the operation of a fuel cell module that can result in death or bodily injury or loss or damage to property. It is therefore necessary for the customer to take all prudent safety precautions in the installation, use, and maintenance of this device. Persons who install, operate, and service the device are required to be technically qualified and experienced in working with electrical equipment, compressed gases, and H2.

This manual includes certain safety guidelines and recommendations; however, this manual is not intended to cover all situations. The customer is responsible for determining the suitability of the customer's particular design or application, and for ensuring the safe operation, maintenance, and storage of the device and any systems into which it is integrated. Ballard Power Systems Europe A/S ("BPSE") cannot be responsible for the use of the device in ways, or as part of systems, that deviate from the operating recommendations in the manual. The customer is responsible for being aware of, and complying with, all applicable laws and regulations. BPSE has limited its liability for damages incurred by the customer or its personnel in the contract documents pursuant to which the device is provided to the customer. Please refer to those documents for additional information.

Procedures described in any part of the manual can only be attempted once the customer has read this entire manual. Failure to follow any instruction or recommendation could result in death or bodily injury or loss or damage to property.

BPSE intends for the device to be installed, operated, and serviced only by approved technically qualified and experienced people who understand the principles of fuel cell technology, are aware of the safe operating limits of fuel cells, and are familiar with the risks posed by operating a fuel cell module. BPSE relies on customers to use their own knowledge and experience when installing, operating, and servicing the device. BPSE also relies on the people using this manual to be familiar with common terms and abbreviations used in the manual.

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2.0 General Information

2.1 System introduction

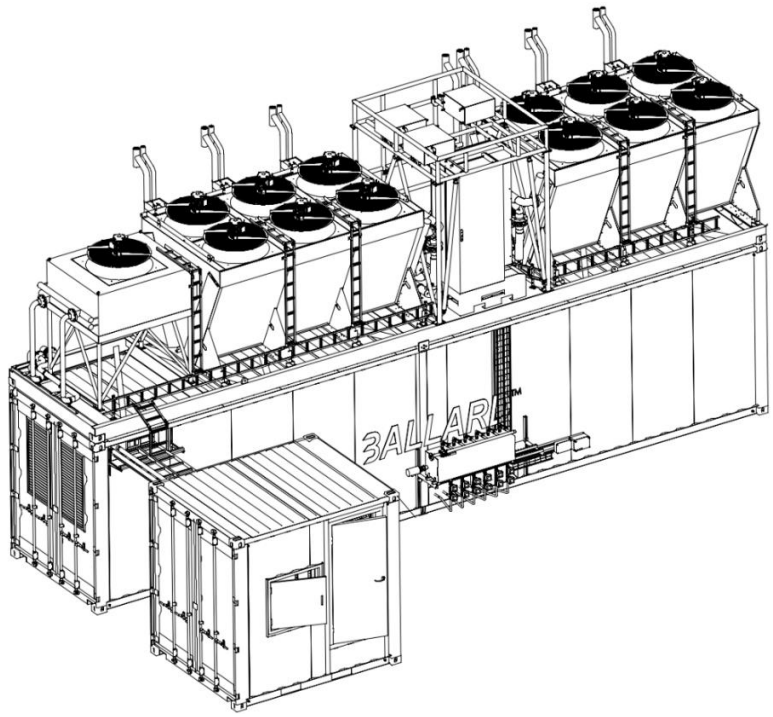
The Ballard FC PowerGen is a modularized power generator, comparable to a diesel-generator. It is a stationary, megawatt-scale hydrogen PEM fuel cell solution, utilizing the FCwave™ from Ballard.

The solution contains all needed elements to produce 1MW AC from hydrogen, when supplied with an auxiliary power supply, a local hydrogen supply, and an electrical grid that is controlled by a Power Management System (PMS), communicating with the use of Modbus.

Integration between the FC PowerGen and the local PMS enables the integrator to create a coherent and automatic system that reacts on the power-demand on the grid, within the given dynamic and capability limits of the solution.

The FCwave and the internals of the containers are designed in such a way that no explosive hazard zones are created inside the solution.

Figure 1: System overview



Indicative illustration layout of system.

2.2 Manual purpose and scope

This Integration Manual offers instructions, procedures, technical information, and best practice to assist integrators in designing a compatible designated site and subsystems that integrate seamlessly with it, in preparation for installation of the system.

It covers topics such as:

- Integration safety
- System descriptions
- Mechanical/electrical interfaces and control details.
- Required In- and Outputs

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Before commencing integration and installation of the system, personnel must read and understand the Operator Manual and this Integration Manual.

2.3 Intended audience

The intended user of this manual is qualified Integrators partaking in designing the designated site and subsystems for the FC PowerGen, within the intended use and limits of the system.

Aspects of this manual require the integrator to have read and understood the Transport and Handling Manual, Operator Manual and Service and Maintenance Manual. Furthermore, a general knowledge of the fuel cell processes, and how to set up control and communications using Modbus TCP/IP are required.

2.4 Manual series

The Manual Series provides manuals covering different life-phases of the system, as defined in Table 2-1:

Table 2-1: Manual series contents

Document no.	Title	Brief purpose description	Intended user(s)
Ballard: 7003672 CW: K559-2254-CWIWP4202202-R01-002	Transportation and Handling Manual	Enables safe, land-based, transport and handling from manufacturer to designated site.	Personnel qualified in preparation of, handling, and transport of freight.
Ballard: 7003718 CW: K559-2254-CWIWP4202202-N01-001	Integration Manual	As described in section 2.2	As described in section 2.3
Ballard: 7003717 CW: K559-2254-CWIWP4202202-N01-002	Operator Manual	Provides information to personnel for safe operation of the solution, instructions for operator-based maintenance, safety rules and recommendations	Operators, Integrators, Installers, Service and Maintenance personnel, personnel working in or near the system, and persons instructing visitors.
Ballard: 7003719 CW: K559-2254-CWIWP4202202-N01-003	Service and Maintenance Manual	Provide information regarding Service and Maintenance schedules and related safety.	Service and Maintenance personnel.

Ballard Power Systems Europe may update the provided manuals on an ongoing basis.

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2.5 Hazard Symbols

Hazard symbols throughout the manual indicate objectives or potentially dangerous situations.

Table 2-2: Hazard symbols

	**MANDATORY ACTIONS**: are marked with blue action-points. This indicates actions that must be performed. Ignoring may result in an accident, which could cause damage to equipment or other property, and could cause bodily injury if not promptly detected and remedied.
	**PROHIBITIONS**: are marked with red prohibition-signs. This indicates a forbidden action. Ignoring may result in immediate bodily injury or loss of life or could cause damage to equipment or other property
	**WARNINGS**: are marked with yellow triangles and/or square warning. Indicates hazards that may result in an accident, which could cause immediate bodily injury or loss of life or could cause damage to equipment or other property.
	**CAUTION:** indicates actions that may result in an accident, which could cause damage to equipment or other property, and which could cause bodily injury if not promptly detected and remedied.
	**ELECRICAL HAZARD** Obey ALL warnings, cautions, and safety instruction related to electricity. Failure to do so may result in electrical shock leading to personal injury or death.

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2.6 References

Throughout the manual are referrals to separate documents. These references documents are available on the BPSE after sales Service Portal.

Should a document not be available, contact BPSE.

Table 2-3: Reference documents

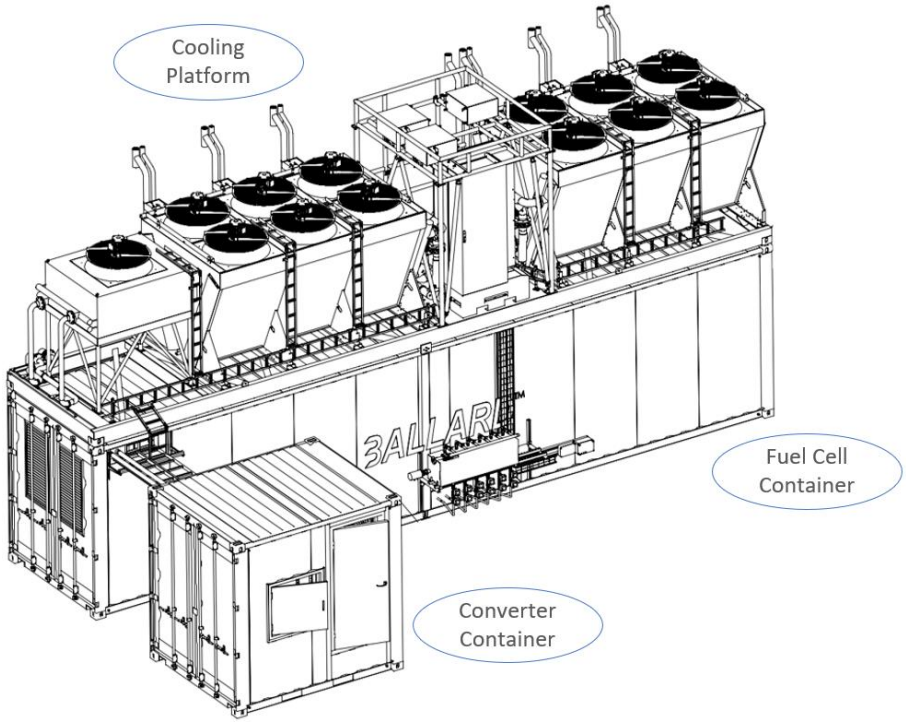
Document no.:	Document name:
K559-2254-CWIWP4202202-D03-001Rev002	Technical Datasheet
K559-2254-CWIWP4202202-C08-001Rev004	Control philosophy and Logic block diagrams
K559-2254-CWIWP4202202-D05-001Rev001	Material Safety Data Sheets
K559-2254-CWIWP4202202-C99-001Rev002	Hydrogen Safety Concept
K559-2254-CWIWP4202202-K02-001Rev002	Equipment hazardous area certificate and schedule
K559-2254-CWIWP4202202-B01-001Rev010	General Arrangement
K559-2254-CWIWP4202202-E99-004Rev002	Grounding Layout
K559-2254-CWIWP4202202-E01-001Rev001	Interconnection Diagram
K559-2254-CWIWP4202202-E99-003Rev001	Cable Transit Schedule
K559-2254-CWIWP4202202-E03-008Rev001	Electrical Interface Documentation
K559-2254-CWIWP4202202-E99-005Rev001	Secure Remote Access
K559-2254-CWIWP4202202-C03-001Rev006	P&IDs
K559-2254-CWIWP4202202-J08-001Rev003	Factory Acceptance Test
K559-2254-CWIWP4202202-C08-002Rev005	FC package Modbus Map
K559-2254-CWIWP4202202-C08-003Rev003	Alarm list
K559-2254-CWIWP4202202-N01-005Rev001	Lockout Tagout
K559-2254-CWIWP4202202-N01-006Rev002	Fuel Cell Module Integration Manual

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3.0 System Description

The system is a modularized power generator based on a number of FCwave™ Fuel cell units.
The FC PowerGen consists of the following main components:

Figure 2: Major components overview



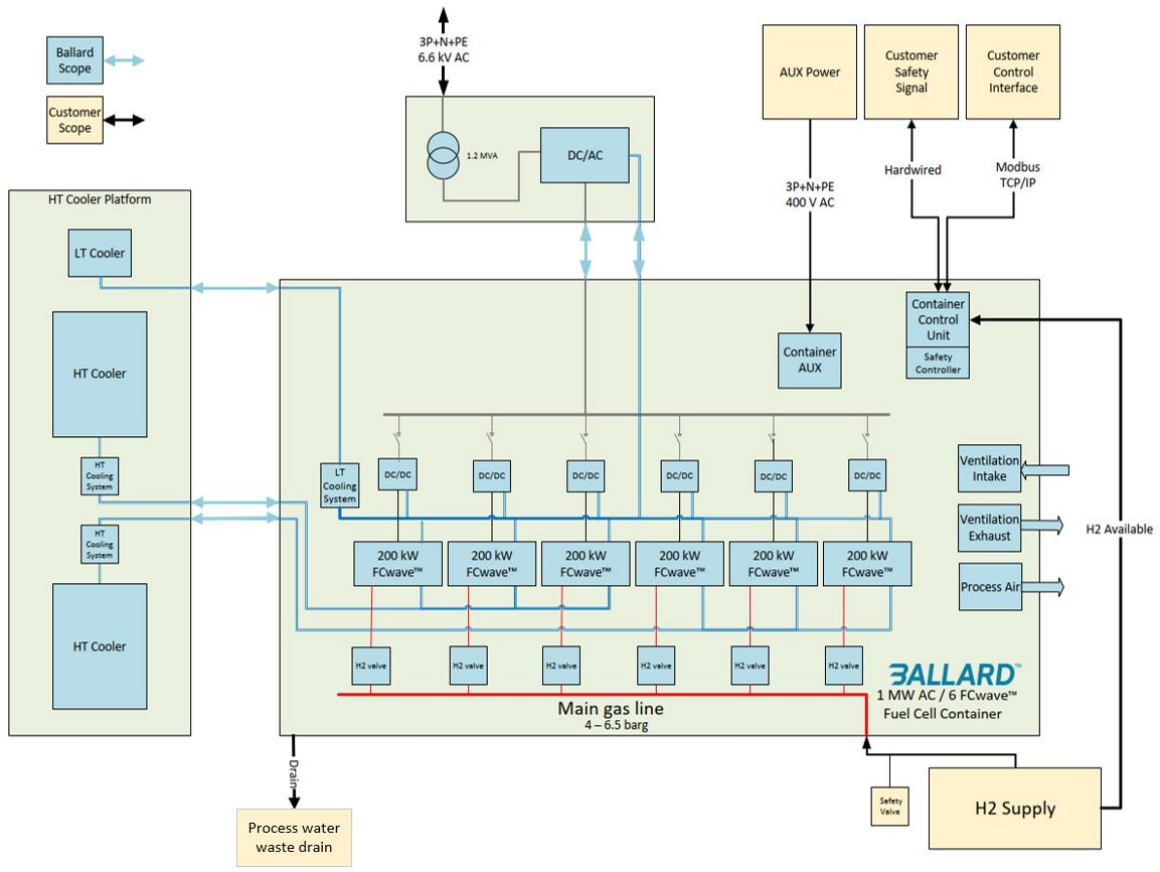
Short descriptions of major components can be found in Table 3-1

Table 3-1: Major components of the machine (See Figure 2)

Component	Short Description
Fuel Cell Container	Based on a 40ft HC container, modified to a machine housing with access, ventilation, light safety etc. The container holds 6 FCwave modules with installation, internal 400VAC power supply for complete Balance of Plant components, main controller, LT pump system and DC/DC converters.
Cooling Platform	40ft Cooling Platform with service platform. 2 individual HT radiators dimensioned to the specific solution 2 individual HT pump-systems 1 LT radiator
Converter Container	Based on a 10ft HC container, modified to a machine housing with access, ventilation, light, safety etc. Holds DC to AC grid-forming power electronics, Isolation transformer, and Grid Main Breaker.

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Figure 3: Scope block diagram



Block Diagram showing the scope of main components and connections of the system.

3.1 Intended use

The system acts as a grid following power generator, providing up to 1MW electrical power from H2 at 6.6kVAC 50Hz. This system is designed and is intended to be used for offshore stationery application (fixed installed system). Hydrogen supply to the system is in the customer scope and the details about the hydrogen standards, quality etc. are mentioned in the integration and other manuals that will be provided to the customers. The customer local Power Management System (PMS) requests the amount of power to be generated within the given dynamic and capacity limits of the system, which are communicated in real-time on the Modbus TCP/IP. The Modbus data is transported between the system and the PMS.

The system has multiple operating data available on the same Modbus, including alarms.

The system is placed in operation by request from PMS via Modbus, and similarly can be stopped, if necessary, which will stop power supplying the to the grid. The system can be stopped remotely on request. During normal operation, a power request of 0 is accepted by the system.

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3.2 General Operating states

Table 3-2: General Operating mode descriptions

Operating Mode	Brief description
Off	Container fully depowered.
Sleep	Container minimum operational level. Control and safety system are operating, but no high-power systems (>20kW) are operating. Hydrogen supply and fuel cells are inactive.
Standby	Waiting state for "Run" command from high level control system. Hydrogen supply and MV link disabled.
Running	Operational state for the container, where the fuel cell modules are consuming hydrogen to produce electrical energy. Cooling and ventilation systems are operating to support fuel cell modules.
Shutdown	The cooling and ventilation systems shuts down. Container returns to standby.
Fault	Internal fault state. Hydrogen supply and fuel cells are inactive.

For more details, refer to section 7.1

3.3 General System description

3.3.1 Fuel Cell Container

The Fuel Cell Container houses 4-6 FCwave™ units. Each FCwave™ is a separate unit with full hydrogen safety and a double wall barrier to ventilate any possible hydrogen leakages, internal to the FCwave™, directly to the outside.

The fuel cell container is equipped with a ventilation system, which will ensure that filtered process air is available for the FCwave™. The ventilation system will also create an air flow through the container, for cooling and ventilation the room.

Process piping installation is generally below the raised floor. Access to this area below the floor is for service only and requires tools. For moving heavy service components inside the container, it is equipped with a crane rail for a manual trolley.

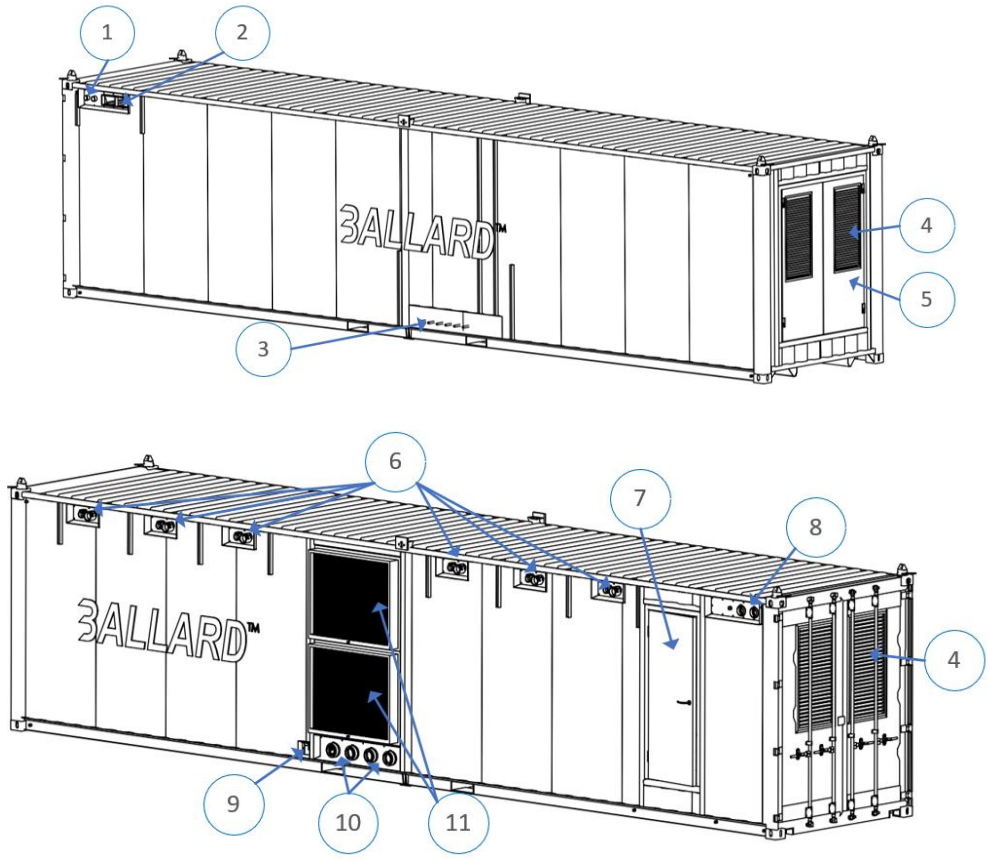
The DCDC panels for fuel cell power output connects each FCwave™ to a common DC link busbar, which feeds the outgoing connection of the Fuel Cell Container. Each DCDC panel for fuel cell output can be isolated electrically, to allow for maintenance on the specific cabinet or related FC wave.

The system controller is a centralized unit that monitors and operates the entire system and includes a separate safety controller to prevent any critical failure or emergency situations to escalate.

The power for auxiliary units such as water pumps, container ventilation and basic power is fed from a 400V AUX power panel which again is supplied from the DC link or from an external power supply, in case of shutdown of the solution.

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Figure 4: Fuel Cell Container overview



Indicative overview of Fuel Cell Container with numbered ballons (see Table 3-3)

Table 3-3: Fuel cell Container overview descriptions (See Figure 4)

1	LT Cooling interface (Converter Container)
2	Wall passthrough for Control Signals, auxiliary power, and DC power cables to Converter Container
3	Gaseous hydrogen piping wall passthrough
4	Ventilation exhaust
5	Service doors
6	Process air and hydrogen enclosure ventilation exhausts
7	Main access door
8	LT Cooling interface (Heat dissipation and Header tank)
9	Process water drain
10	HT Cooling system interface
11	Ambient air intake: Container ventilations and process air

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3.3.2 Cooling Platform

The Cooling platform is a steel structure with the footprint of a 40ft container. The purpose of the cooling platform is to dissipate the heat generated by the High Temperature (HT) cooling system that cools the Fuel Cell Modules, and heat generated by the Low Temperature (LT) cooling system that cools the power electronics of the solution. The standard installation method of the platform is to mount it on top of the fuel cell container, using standard container locks.

The sizing of the coolant fans and radiators are dependent on the ambient temperatures of the designated site and operating conditions of the system.

If utilization of the generated heat produced by the fuel cells during operating for heating of building etc., a heat exchanger can be fitted to allow heat recovery.

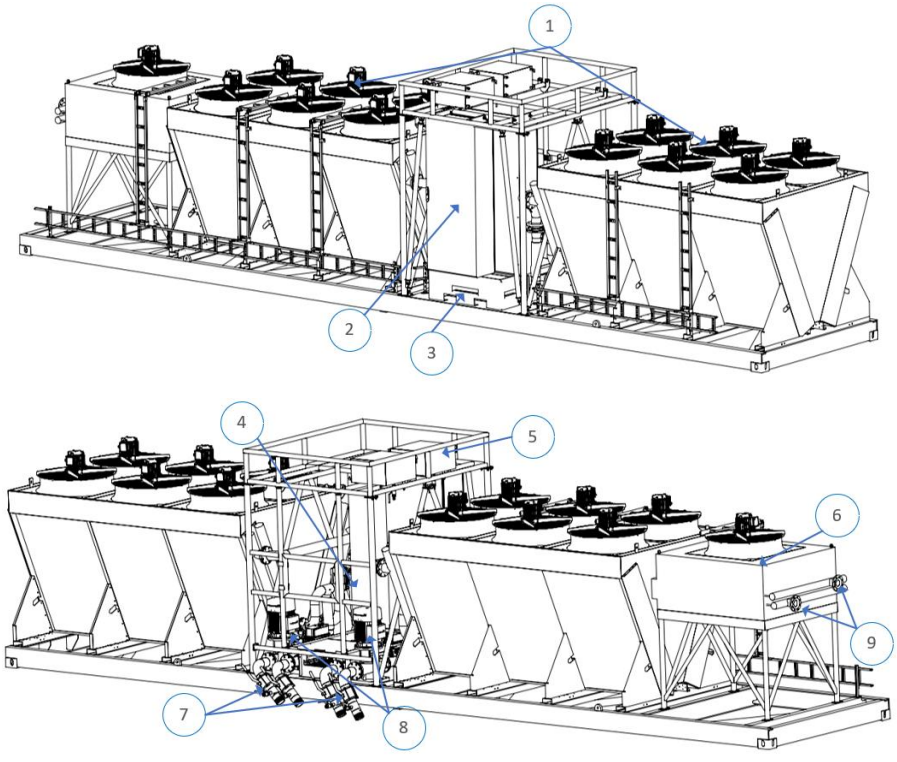
The cooling systems are open unpressurized circuits, cooling with the media Ethylene glycol. Each system has an open header tank for volume changes due to temperature.

The highest temperature of the HT and LT cooling systems are approximately 60 and 48 °C.

The pumps and pump control for the HT Cooling system is placed between the two big radiators (HT Coolers) on the cooling platform. Access is to this area is for service only and requires a ladder.

The pump for the LT Cooling system is located inside the Fuel Cell Container. The control is located in the same cabinet as the HT cooling.

Figure 5: HT cooling platform overview



Indicative overview of HT Cooling Platform with numbered ballons (see Table 3-4)

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Table 3-4: HT Cooling platform overview descriptions (See Figure 5)	
1	HT Cooler with fans
2	Controller panel (backside)
3	Control signals in- and out
4	Service platform
5	Header tank
6	LT Cooler with fan
7	HT Coolant in- and outlet
8	HT Coolant pump
9	LT Coolant in- and outlet

3.3.3 Converter Container

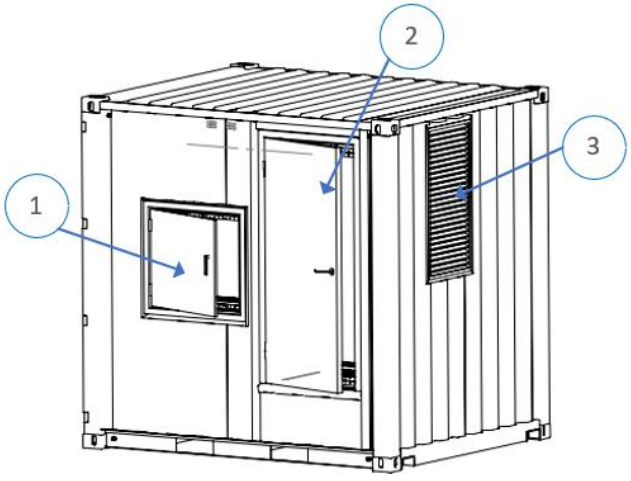
The Converter Container is structurally a 10ft high-cube double-door container, modified to the specific need. It is designed as an electrical cabinet, housing DC/AC converters and a transformer that converts the energy to the desired voltage (6,6kV). Access to the inside is through the normal container doors which are, because of electrical safety, mechanically prevented from opening during operation. These are also equipped with safety sensors, which will immediately bring the entire solution to "Failure state" if opened.

Access is restricted to instructed and trained personnel, and only after a safety procedure is followed, which will deenergize the container to a safe mode.

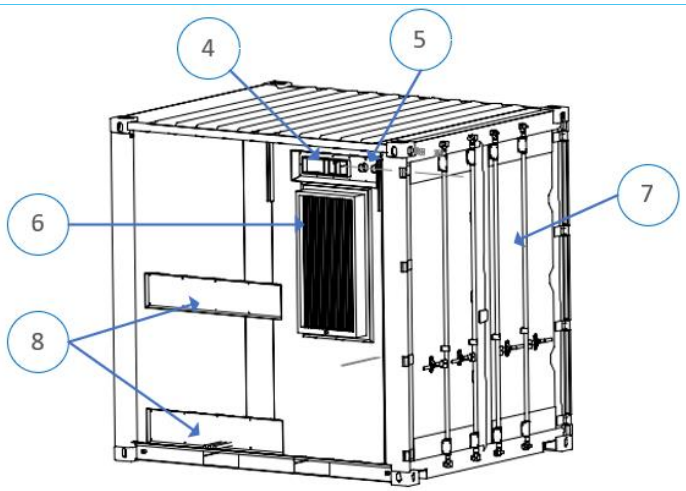
The control panel and grid breaker front of the Converter Container is accessible from the outside, behind an additional locked door which will not shut down the solution if opened.

Customers connection of the grid is through the container side.

Figure 6: Converter Container overview



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Indicative overview of Converter Container with numbered ballons (see Table 3-5)

Table 3-5: Converter Container overview descriptions (See Figure 6)	
1	Control panel access door
2	Main output breaker access door
3	Ventilation exhaust
4	Wall passthrough for Control Signals and DC power cables from Fuel Cell Container
5	LT Cooling interface
6	Ventilation air intake
7	Service doors
8	Output interface (1MW AC)

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4.0 Safety

The system is to be installed in cooperation with Ballard personnel. While working on the system there should always be more than one person present.



The reader of this manual must read the operator manual mentioned in section 2.4 as a complement to this integration manual regarding general function and safety.

4.1 Designated site Access and Security

It is recommended that the designated site is fenced off to prevent unauthorized access, and access within the fenced area should be limited.

The site responsible shall ensure that access to the site is limited to qualified personnel who are familiar with the site safety requirements. Appropriate Personal Protection Equipment (PPE) must be worn per site guidelines and warning signage must be adhered to.

4.2 Machine Access

At no time is unauthorized personnel permitted inside the containers or on the Cooling Platform of the solution.

To access the containers and the Cooling Platform through the designated doors, it may be required by local legislation that permanent stairs and use of temporary scaffolding or lifts are installed/available. Stairs could be as indicated in Figure 7.

Ballard can assist in creating such additional component to the system if agreed upon.

Figure 7: Example access stairs



Indicative example of solution to access the Main Access Door on the Fuel Cell Container

The exterior container doors must always remain locked except during active installation, integration, service, or maintenance. The locks should be inspected regularly by site personnel to ensure that only authorized personnel have access to the insides.

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It is recommended to keep a communications device on your person when being inside.

During operation, it is not recommended to be inside the Fuel Cell Container and access the Cooling Platforms.

The Converter Container is designed with safety-interlock on the access door, preventing access during operation. Opening the container doors of the Converter Container triggers a safety-switch which acts as an emergency stop, immediately shutting down the system.

4.3 Site safety for Personnel

As soon as practical the site responsible shall provide Ballard with a written set of site safety requirements and safety protocols that will conform with local regulations and industry norms.

The site responsible may amend the site safety requirements to conform to local regulations and such industry norms, by providing written notice of changes to Ballard reasonably in advance of their effective date.

The site responsible must require that all contractors and visitors comply with these site safety requirements. Ballard will comply with site safety requirements provided and be allowed access to the site to perform necessary tasks throughout the life of the system.

Site safety requirements given by Ballard are minimum requirements, as they may be a result of a mitigation measure from the risk assessment.

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4.4 Hazardous materials

The complete list of coolants and lubricants used in the 1MW Fuel Cell Container is shown below.

Table 4-1: Hazardous materials

Type	Name	Description / Use	Sub-assembly
Coolant	Glysantin® FC G20®	Used in the internal cooling loop of the fuel cell modules, where a low electrical conductivity is required. Pre-mixed 50/50 ethylene glycol-based coolant specifically developed to support the requirements in fuel cell technologies. It maintains a low and stable electrical conductivity, while at the same time providing protection against corrosion, frost and overheating.	Fuel Cell Modules
Coolant	Proviflow® Neo	Used in both HT and LT cooling loops. Pre-mixed 50/50 ethylene glycol-based coolant with OAT (Organic Acid Technology) inhibitors and designed to offer freeze point suppression as well as protection against corrosion, hard water scaling and bacterial growth.	Container Solution
Lubricant	Ceramic Grease PV.20.01	High-grade assembly paste and high temperature lubricant grease without metal particles used for lubrication of bolts.	Container Solution
Lubricant	Krytox™ GPL 205	Chemically inert, PTFE thickened grease based on perfluoropolyether (PFPE) oils that is safe for use around hazardous chemicals, these lubricants are non-flammable and safe for use in oxygen service. They can be used in extreme conditions, such as continuous high temperatures of up to 204 °C (400 °F) and will survive short-term peak temperatures of up to 220 °C (429 °F).	Fuel Cell Modules
Lubricant	Krytox™ GPL 206	Chemically inert, PTFE thickened grease based on perfluoropolyether (PFPE) oils that is safe for use around hazardous chemicals, these lubricants are non-flammable and safe for use in oxygen service. They can be used in extreme conditions, such as continuous high temperatures of up to 260 °C (500 °F) and will survive short-term peak temperatures of up to 270 °C (518 °F).	

More details can be found in the document Material Safety Data Sheets.

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4.5 Energy Lock-out-tag-out (LOTO)

Energy sources provided to the system, as well as the Grid connection, must be provided with means for lockout (de-energization), and a written procedure detailing the equipment, and steps required.

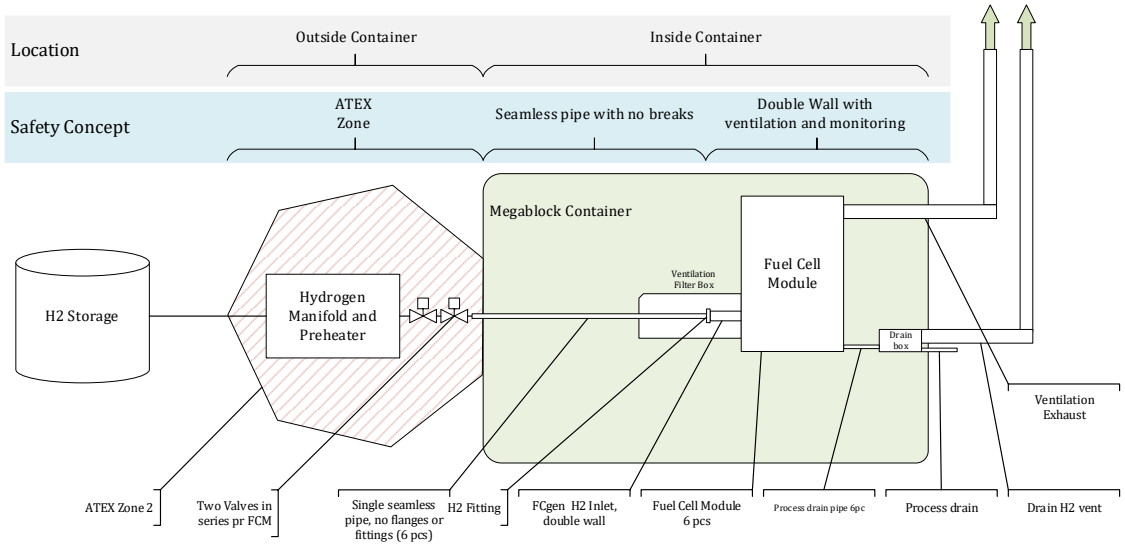
Use proper work-etiquette regarding LOTO when working on energy-suppling components.

Refer to Lockout Tagout document for details.

4.6 Explosion safety

The hydrogen safety philosophy has several safety concepts, as indicated in Figure 8.

Figure 8: Hydrogen flow overview



Illustrative overview of hydrogen flow. See Hydrogen Safety Concept for more details.

Hydrogen is delivered to the hydrogen interface from a local hydrogen storage (refer to section 6.3 for specifications).

The area in which the interface, the hydrogen-manifold and -preheater, and hydrogen safety valves resides, is classified as an ATEX Zone 2. A hazardous mixture will not likely be present in normal operating conditions, and if so, only for a short period at a time. Electrical equipment in this zone is and shall conform to regulations and have the "EX" marking or similar. Detailed drawing of the hazard zone can be found in the General Arrangement. For more information regarding equipment installed in the zone, refer to the Equipment hazardous area certificate and schedule

Respect the zone indicated, do not introduce any source of ignition.

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There is no risk of hydrogen leakages inside the general space of the FC PowerGen Fuel Cell Container that can create an explosive atmosphere, due to the design of the feed pipes being seamless, one-piece-bends from outside of the container, routed through the container space, and connected the applicable Fuel Cell module.

The connection to a Fuel Cell Module (The H2 Fitting) is encapsulated within an extension of the Fuel Cell Modules Hydrogen Enclosure called the "Ventilation filter box", thus utilizing dilution and removal of any potential hydrogen with mechanical ventilation. Should leakages from this connection occur, the hydrogen detectors within the Fuel Cell Module will detect it and trigger a safe shutdown of that module and hydrogen supply.

The Ventilation system of the Fuel Cell Container creates a slight over-pressure to counteract ingress from particles and gas. As an additional precaution in case of hydrogen entering, the general space inside is equipped with hydrogen sensors. The position of these will detect any hydrogen entering or exiting the container through the ventilation system.

All safety-related triggers of the solution will shut off the hydrogen supply of either the affected system or the entire system.

4.6.1 Trace amount of H2

The process exhaust contains all biproducts from the fuel-cell stacks within the Fuel Cell Modules. The exhaust is a mixture of high-humidity, low-oxygen process air with trace amounts of hydrogen. The concentration of hydrogen will always be below 1%v, i.e. 25% of Lower Explosive Level (LEL), leading to a non-hazardous zone according to Fuel Cell Module Integration Manual.

The source of the media in the Process Water Drain stems from the process exhaust. Thereby are also here found trace amount hydrogen which also are under 25% of LEL, leading to a non-hazardous zone. A hydrogen separator is fitted upstream to the process water drain and the trace amount of hydrogen are led through an exhaust to above the containers.

4.7 Fire safety

The Fuel Cell Modules have internal fire detection in the form om smoke detectors and linear heat detectors. If a Fuel Cell module detects to high temperature, it will automatically perform a safe shutdown of itself and indicate an alarm.

If Smoke is detected inside the general space of the Fuel Cell Container, the entire system will perform a safe shutdown and indicate an alarm.

Should a fire occur, exit through the provided emergency exits.

The system is not delivered with fire-extinguishers.

4.8 Craneage and lifts

During installation onto the designated site, and installation of general hardware i.e. exhausts and interconnections between the major components of the solution, tools such as cranes and lifts are to be used. These tasks can only be done by instructed personnel.

Scaffolding, lifts, and cranes must be made available, unless otherwise agreed upon with Ballard.

A lifting study for craneage is recommended to be conducted by the site responsible, referring to the respective transport and handling manual of the solution's major components and description of positioning and assembly in section 5.1.

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4.9 Electrical safety

Installation of electrical connections between the major components of the solution is the responsibility of Ballard if not agreed upon otherwise. Electrical connections to the Interfaces described in section 6.0 is the responsibility of the interface-connecting party.



The electrical system of the solution is designed in accordance with electrical and fuel cell codes to minimize electrical hazards. Electrical hazards will occur when the design is significantly compromised, typically through alteration, improper maintenance, or wear.

Dimensioning of cables and safety-equipment on the supplying and receiving end of electrical connections outside the solution must be done according to local legislation.

Select cabling and safety-equipment to the system that appropriately suits the application. Ensure to meet specifications of voltage, current, environmental temperature limits, chemical and mechanical resistance, and flexure requirements of the application. Avoid hazardous and unsafe situations that could result from condition such as, but not limited to:

- Improper grounding
- Handling electrical leads or devices with wet hands or on wet ground
- Frayed electrical leads
- Incorrect or improper connection of the terminal leads
- Short circuits
- Back-feed from energized normal and emergency power sources

Shutting down the solution during active installation and integration may be necessary. Voltages may remain in the solution for a length of time. No activities are to be performed during this time as it presents a shock hazard.

Certain circumstances can lead to voltage persisting on the electrical systems. Always check for residual voltage before any activities. In some cases, it may require removal of hydrogen in the FCwave.

4.9.1 High DC Voltage Isolation Failures

Under normal circumstances, all high DC voltages are isolated from ground and the resistance is monitored. If isolation is lost on one high-voltage pole, a person working on the electrical system can sustain a fatal current-flow by touching the other voltage-pole and ground.

If two simultaneous faults occur and isolation is lost on both voltage-poles, a high voltage short circuit can occur resulting in extremely high currents/flash arcs. High currents can generate a large amount of heat which can subsequently damage electrical equipment and cause bodily harm.

Components inside the solution affects the resistance to ground, resulting in lower resistance over time.

Above-mentioned hazards are mitigated by the safety system of the solution. It actively monitors the resistance, warning if anything is to be reacted on, or shutting down the entire system in case of sustained resistance-drop or fault.

⚠ ELECTRICAL HAZARD	
	**If an isolation failure is detected and located in the MODULE, do not operate the fuel cell module until the root cause is determined and remedied.**

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4.9.2 Batteries



Inside the solution reside several Lead-acid batteries for UPS systems. Prior to transportation of the solution, the State of Charge (SoC) have been lowered to >30% and connections have been disconnected.

Ballard personnel will re-connect these according to respective manuals and the SoC is raised to normal operation conditions during commissioning.

4.9.3 Converter Container access



The internals of the Converter Container are designed as an electrical cabinet (IP00), meaning that current-carrying conductors and terminals are exposed.

⚠ ELECTRICAL HAZARD	
	**HIGH VOLTAGE – 6.6 kV** **Danger of electrocution** **Authorized personnel only** **Keep clear and follow safety protocols** **Proper PPE required** **Failure to comply may result in serious injury or death**

Access is prohibited during operation. Opening the doors, except the control panel door on the side, activates the safety system, triggering emergency stop of the entire system. Residual voltages remain in certain components.

Entering this container requires prober de-energization and lockout tagout. Wait at least 10 minutes after de-energization before entering, and measure for residual voltages (<20VDC is safe)



Disconnection of the 6.6 kV connection must be done by trained personnel.

The disconnection must have lock-out-tag-out performed (Keyed interlock system) by the work-responsible. Please referee to Lockout Tagout procedure



4.9.4 Earthing

Provided Earthing-connection by the site is crucial for electrical safety. Refer to Grounding Layout for details.

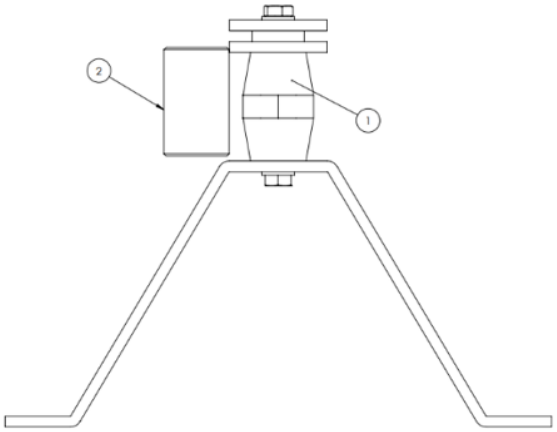
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4.9.5 Transportation Spacer

Prior to Transportation of the solution, an electrical isolator has been swapped with a transportation tube made of steel, ensuring stability of the MV transformer, located in the Converter Container.

This must be swapped back to the isolator prior to any commissioning activities.

Figure 9: Transportation Spacer



Indicative illustration of the Isolator (1) that are swapped with the transportation tube (2)

4.10 Personal Protective Equipment (PPE)

Personnel must bring and use appropriate PPE.

In general:

- Safety shoes are mandatory.
- Hearing protection must be available and used when the system is operational.
- Fire inhibited clothes must be used when working on the electrical system.
- Helmets must be used when working with internal crane.
- Helmets and Fall arrest equipment must be used when working in heights.
- Suitable gloves and eye protection must be used for working with coolant.
- Suitable gloves must be used for where risk of cuts is present.
- Suitable tools for working on live voltages – marked with double triangle as per EN 60900.

During installation is it further recommended that personnel around the activities wear fluorescent jackets for visibility.

Working atop the containers (outside of the service platform) creates a risk of falling from almost 3m - Harnesses are required.

Do not work in these areas during extreme raining, windy, or snowy conditions.

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4.11 Environmental conditions

Activities during rainy/snowy conditions should be avoided. If activities are performed during these conditions, the technician is responsible for ensuring that rain etc. does not enter the containers and electrical cabinets.



Process exhaust contains water. During freezing conditions, snow and icicles may form.

Wear safety helmets under these conditions.

4.12 Installation planning



It is recommended to create a realistic timeline for an installation-plan, mitigating the risk of stressful situations, potentially leading to injuries.

4.13 Control safety

The solution provides several control signals and information through the Modbus TCP/IP Connection. Follow the instructions in section 7.0 to ensure safe operation.

4.14 Testing safety

The solution is tested at the manufactures site according to the Factory Acceptance Test (FAT).

During commissioning of the solution, a similar Site Acceptance Test (SAT) will be conducted.

Only authorized personnel are allowed in the vicinity of the solution during testing.

During full-load testing (all FCwave™ running), no personnel are allowed on the Cooling platform.

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5.0 Positioning and Assembly

Activities during positioning and assembly of the solution at the designated site is according to agreements with Ballard. Customer must provide the specified requirements in section 5.2 as well as a cranage plan on site, prior to Ballard engagement in these activities.

NOTE: Some interface connections described in section 6.0 could be beneficial to have ready prior to Positioning and Assembly.

5.1 General Positioning and Assembly process

The following procedure describes the general process of positioning and assembly onto the designated site, not necessarily in chronological order. Refer to General Arrangement for details on site-specific details.

The major units of the system are to be handled as described in the respective Transport and Handling Manual (See section 2.4).

- The Fuel Cell Container is positioned onto the designated site for permanent installation, anchored to the ground.
- Twist-locks are placed in the upper ISO corners of the Fuel Cell Container, as well as middle-support for Cooling Platform.
- The Cooling platform is lifted and placed on top of the twist-locks and the middle-support, ensuring that it is properly supported.
- Twist-locks are locked, permanently fixating the Cooling platform to Fuel Cell Container.
- The Converter Container is positioned onto the designated site for permanent installation, anchored to the ground.
- Electrical and mechanical assembly between the units are carried out by Ballard personnel.
- Electrical and mechanical connection to the system is carried out by suppliers.
- Applicable tests after assembly are performed.

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5.2 Designated site Requirements

The following sections describe requirements for Positioning and Assembly of the system.

5.2.1 Environmental Operation Conditions

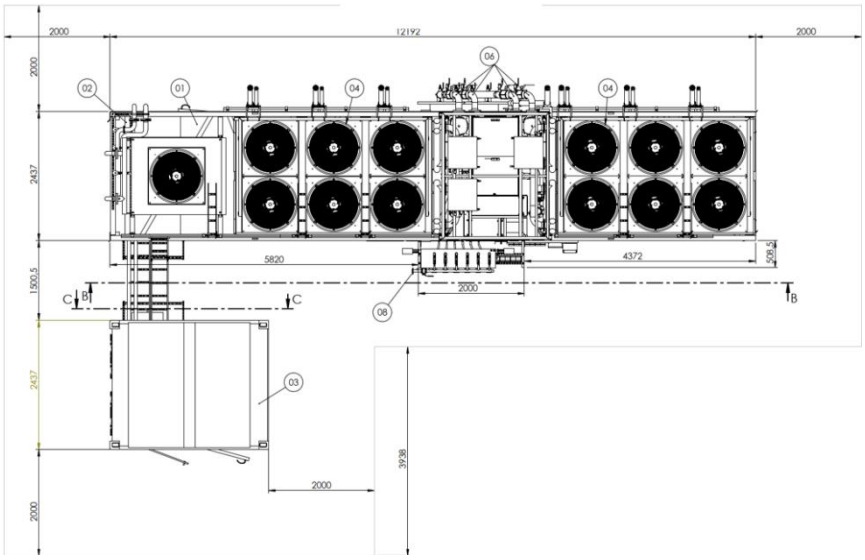
The system is intended to be installed outside, exposed to weather conditions.

Table 5-1: Operating conditions	
Altitude	< 100 m
Minimum ambient temperature, operating	-8,4 °C
Maximum ambient temperature, operating	+25 °C
Humidity	5-95% RH
Wind velocity	31 m/s
Extreme wind velocity for 1-Year recurrence	33,1 m/s
Extreme wind velocity	41 m/s
Weather	Designed for all year operation in temperate offshore areas, including wind driven rain and snow
Salt mist and Sea salt protection	Yes
Flooding	Approx 10cm above ground level
Earthquake	Not earthquake safe but designed to withstand customer-defined accelerations.

5.2.2 Space claim

The system has a space claim that enables access to the system required for future service and maintenance. To ensure proper function of the coolers, any buildings taller than 6.6 meters should be located at least 5 meters away.

Figure 10: Indicative illustration of space claim



Actual space claim can be found in General Arrangement

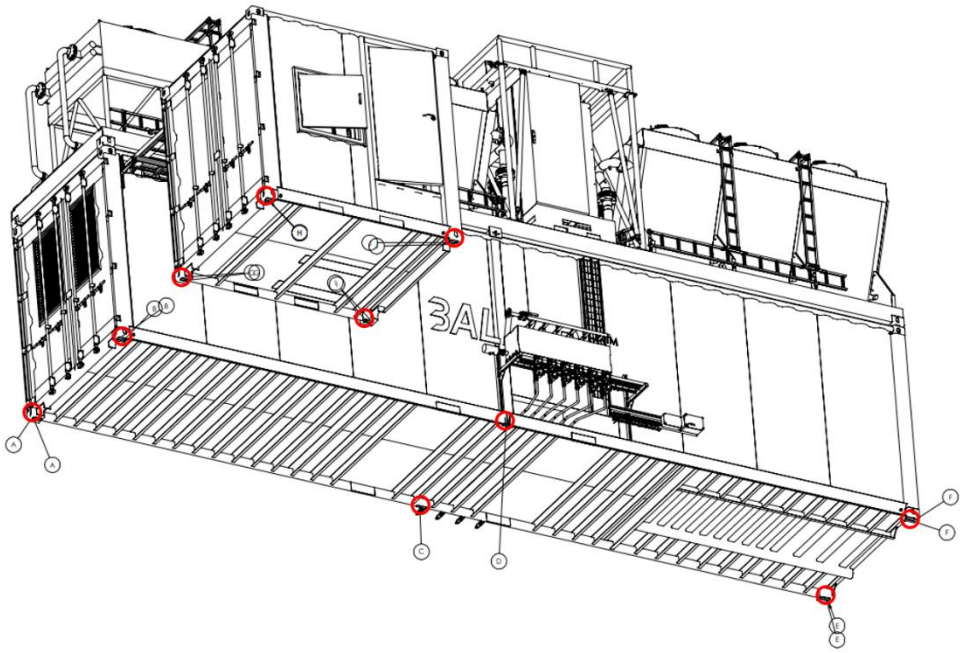
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5.2.3 Floor/foundation characteristics

Requirements of the foundation is a level surface, and it need to be able to carry the final weight of the assembled system on the designated load-points.

Refer to General Arrangement for details.

Figure 11: Indicative illustration of load-points



Specific Loads can be found in General Arrangement

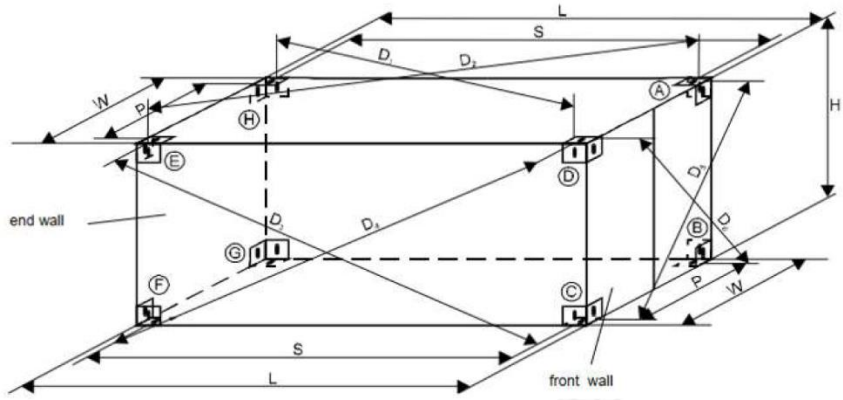
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5.2.4 Anchoring

The containers must be anchored to the ground using container tie-downs or ground-plate twist-locks. Ensure physical support of designated load-points as described in section 5.2.3.

If anchoring is done using the bottom-side of the ISO corners (B, C, F, G in Figure 12), e.g. ground-plate twist-locks, verify the corner-distances of the containers prior to design of site.

Figure 12: ISO Container corners distances (see Table 5-2)



Source: Polski Rejestr Statków – Rules for the construction of containers – July 2014

Table 5-2: Distance between container corners for anchoring (See Figure 12)

Item	P	S
Fuel Cell Container	2260 (+3) (-5) mm.	11989 (+3) (-10) mm.
Converter Container		2787 (+3) (-10) mm.

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5.3 Temporary requirements

For commissioning of the system, the following temporary requirements are applicable, depending on the agreements with Ballard.

5.3.1 Trucking and crane workspace

The designated site for the system shall provide space for the trucks delivering the major system components, as well as for crane lifting and handling as defined in the respective Transportation and Handling Manual (see section 2.4).

5.3.2 Load bank

If the designated grid for the system is not ready to provide the needed load for testing procedures defined in the SAT, an electrical load bank may be necessary during commissioning. The load bank can be provided by Ballard if agreed upon.

A load bank needs to be installed temporarily, and the site must provide space and power for this unit.

Space claim and power requirements for the Load bank provided by Ballard may vary.

Ballard-provided load bank will be removed after functional testing of the system.

5.3.3 Hydrogen Battery and manifold

For testing purposes during commissioning, a Hydrogen Battery and manifold may be needed if the local supply is not ready. For guidance on the hydrogen battery and manifold please contact your Ballard representative.

The hydrogen battery needs to be installed temporarily, and the site must provide space and power for the unit, keeping in mind safety precautions.

Space claim for the Hydrogen Battery and manifold may vary. Contact your Ballard representative for more information.

Ballard-provided Hydrogen and manifold battery will be removed after functional testing of the system.

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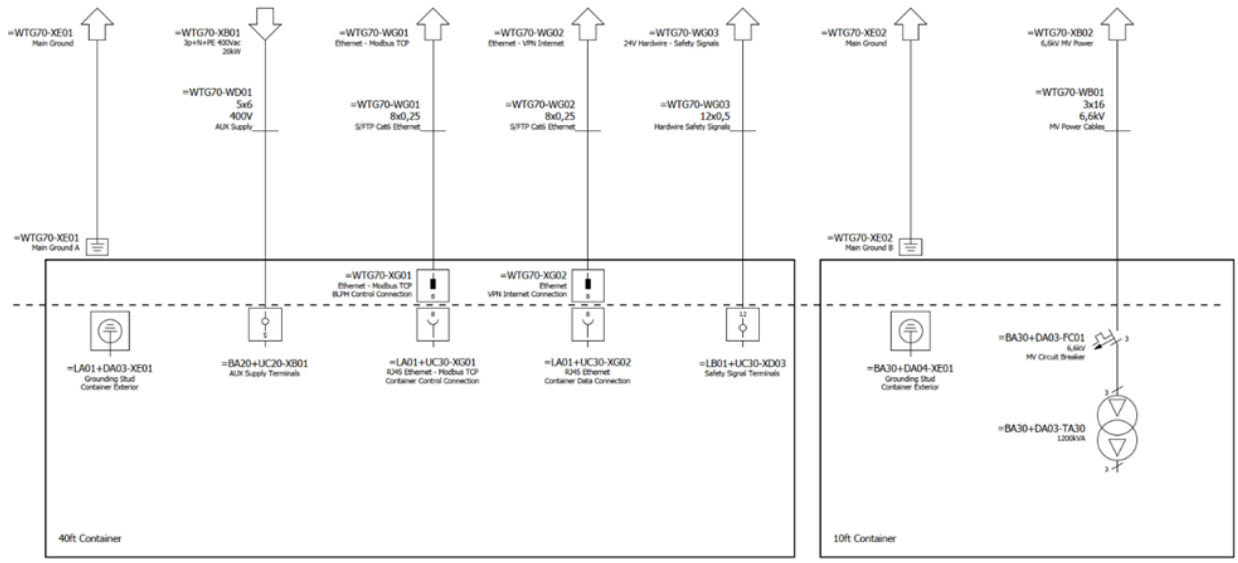
6.0 Interface descriptions and requirements

All delivered energy sources to the interfaces must have an applicable LOTO-procedure for Ballard personnel to use when installing. All interfacing flanges/connections must be fully supported and compensated for loads and moments.

6.1 Cable connections

Drawing of cable connections can be seen below in Figure 13.

Figure 13: Cable Interconnection Diagram



See Interconnection Diagram for detailed version.

Table 6-1: Electrical, network and safety-signals connections

Connection	Description	Physical connection
MV Interface	Main power delivery interface – 3 phase 6,6kV AC 50Hz 100A connection	3 pcs single Conductor Cables
Auxiliary supply	Container auxiliary supply – 3p+N+PE 400V 50Hz 32A supply	5G6 Cable (optionally 5G10)
Network Connection	Network cable carrying Modbus TCP control signals and SCADA data to local Power Management System.	Copper ethernet ($4x2x0,5mm^2$) OR Fiber optic cable (addon, depends on agreed upon solution)
Service Connection	Network cable carrying service and troubleshooting information to Ballard. Encrypted. See section 6.2 for details.	
Safety Signals	Multiconductor signal cable carrying hardwired safety signals between FC package and local PMS.	Multiconductor cable ($6x2x0,75mm^2$)

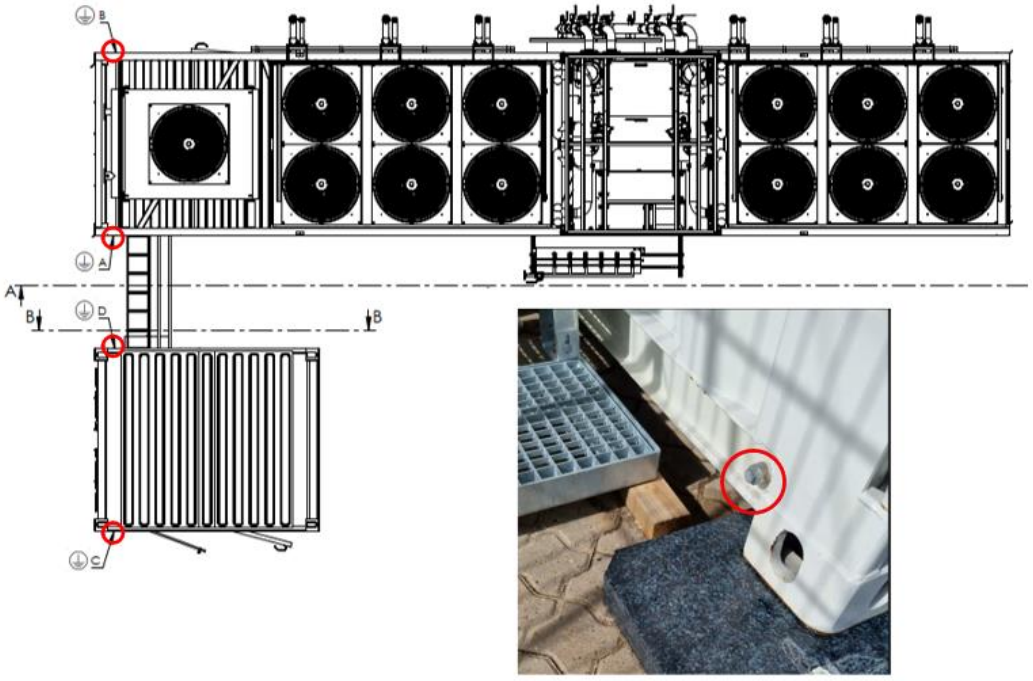
Details of connections in Table 6-1 can be found in the Cable Transit Schedule and the Electrical Interface Documentation.

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6.1.1 Earthing

The solution provides 2 earthing studs on each container. Each stud needs an earthing connection with low enough resistance to ground as defined by local legislation.

Figure 14: Location of interfaces for Earthing



The earthing points are located at each corner of each container – refer to Grounding Layout

Table 6-2: Earthing point specifications

Point	Bolt size
A	M12x1.5
B	M12x1.5
C	M12x1.5
D	M12x1.5

6.2 Service connection

The service connection enables Ballard service technicians to use a secure and encrypted VPN connection to gain remote access to the control system for monitoring and service. During installation, it is Ballard preference to deliver with a Secure Remote Access gateway installed including a 4G wireless antenna, which allows the service connection, data collection and remote access.

This wireless function will be removed if the final architecture enables a wired secure access tunnel through the local infrastructure to the internet. This access tunnel should be completely separated from the local PMS in order to maintain the best possible separation between the Operational Technology and data going to the internet.

Refer to Secure Remote Access document for more details.

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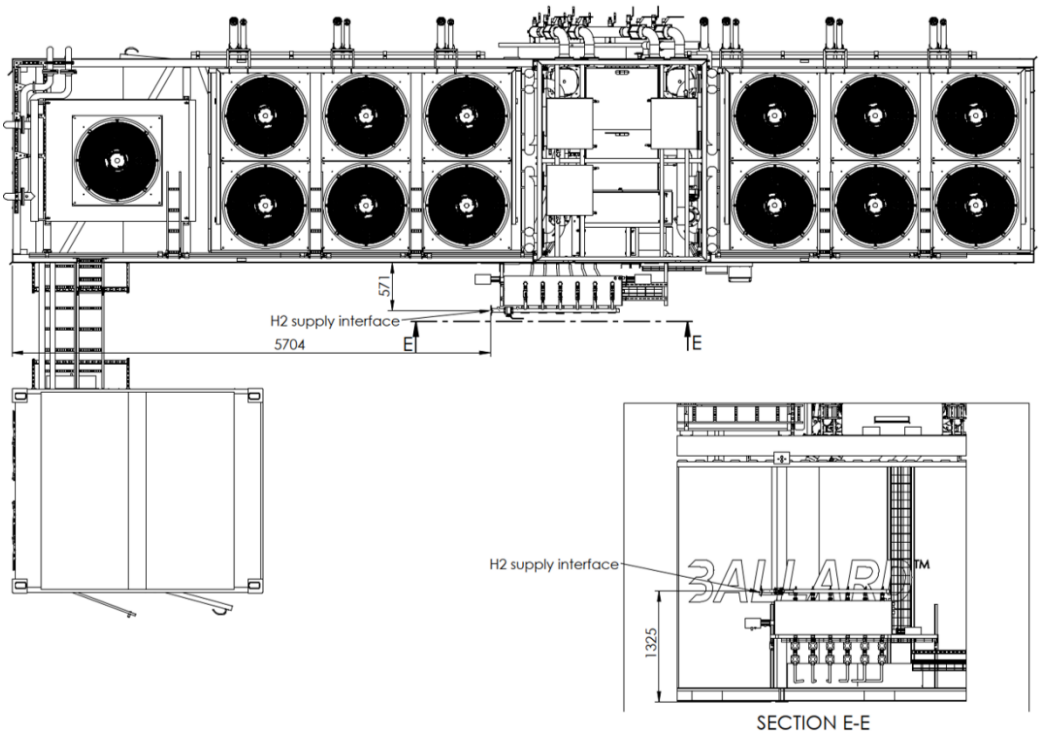
6.3 Upstream Hydrogen supply

For each FCwave™ installed in the Fuel Cell Container, a hydrogen supply pipe is routed inside the Fuel Cell Container to the outside. Each pipe it is connected to an outlet on the Hydrogen heater, that increases the temperature of the supplied hydrogen if needed.

The upstream hydrogen supply is to be connected to the interfaces on the hydrogen heater, located as indicated in Figure 15.

The upstream hydrogen supply provided may be compressed gas storage, vaporization of liquid hydrogen or reforming of other fuels, if requirements listed in Table 6-3 are met.

Figure 15: Location of Upstream hydrogen supply interface



Indicative figure of Upstream hydrogen supply interface. Refer to General Arrangement for specific location.

Table 6-3: Upstream hydrogen supply requirements

Item	Requirements
Fuel type	Gaseous hydrogen
Hydrogen grade	As per SAE spec. J2719 OR ISO 14687:2019 Type I, Type II – Grade D
Hydrogen supply Pressure	4 – 6.5 bar(g)
Hydrogen temperature	-8,4 - 80 °C
Hydrogen Consumption Rate, BOL	0,9-29,4 g/s

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Table 6-3: Upstream hydrogen supply requirements	
Physical interface	Standard flange DN32 (EN1759-1) Flange face RF Allowable nozzle load: 50 N*
Upstream particulate filter	40µm
Upstream isolation valve	Manual and lockable isolation valve as close interface as possible (Access for service personnel)

Refer to P&IDs for more details.

* All interfacing flanges/connections must be fully supported and compensated for loads and moments.



The pipe connection must be protected against accidental damage.



Purging the internal H2 system through the hydrogen supply is prohibited. Special procedures apply for purging of the FCwave, and training is required.

6.3.1 Pressure relief valve

With the required pressure of the system stated in Table 6-3, the integrator must install a pressure relief valve for the hydrogen supply set for 10 bar(g). The solution closes the hydrogen supply safety valve(s) applicable if pressure exceeds the maximum.

Handling of released hydrogen must be done in a safe manner, not creating a potential explosion zone near the equipment.

6.4 Process Water drainage

The fuel cell process produces DI water, which are routed from each FCwave™ to a common drainpipe using gravity. The common drainpipe has a hydrogen separation box to make sure no traces of hydrogen will be in the process drain. The potential H2 is routed in a pressure loose chimney to a safe area. Due to this separation box, only pure process water will exit at the drain connection.

The process water drain piping downstream must be constructed of materials resistant to corrosion since DI water is present. Contact Ballard with questions regarding material selection.

The solution provides a heat-trace cable that is pushed into the drainpipe downstream from the interface so that it does not freeze and/or block the flow of liquid. If the process water is unable to flow, the system will indicate with an error.

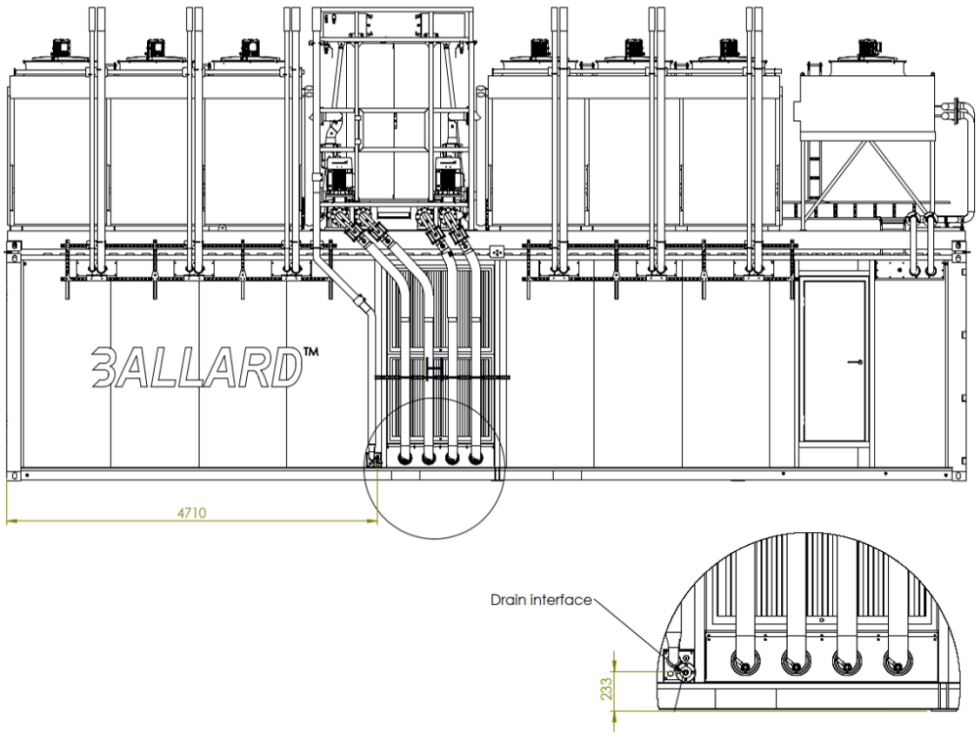
Disposal of the media should be done according to local legislation.

Table 6-4: Process Water Drainage connection requirements	
Item	**Value**
Media	De-Ionized Water
Temperature	10-50 °C
Volume	0 – 13,2 L/min

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Table 6-4: Process Water Drainage connection requirements	
Drinking water	no
Physical connection	1’’ ASME B 16.5 flange

Figure 16: Location of Process Water Drain interface



Refer to General Arrangement – Drain Interface

6.5 Lightning protection

The site responsible must follow EN62305 or other applicable local legislation regarding lightning protection.

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7.0 Control of the system

The solution is designed for the Integrators local PMS to control the system through a wired Ethernet Modbus TCP/IP Connection.

The solution is made as simple as possible for the Integrator, with few control signals, and a high amount of system information signals available.

7.1 Operating States

The solution operates in the modes described in Table 7-1 and illustrated in Figure 17.

Table 7-1: Operating mode descriptions

Operating Mode	Brief description	Preconditions
Off	Container fully depowered.	No power supplied to container; UPS batteries depleted
Initialization	Functions to establish baseline container status, with connections to external power and communications.	After bootup. 400Vac Auxiliary power supplied to Container.
Sleep	Container minimum operational level. Control and safety system are operating, but no high-power systems (>20kW) are operating. Hydrogen supply and fuel cells are inactive.	400Vac Supplied to Container. Communications heartbeat from PMS
Wakeup	Container enables 24V supply to fuel cell modules and starts container ventilation system.	400Vac Supplied to Container. Signal from PMS (Standby).
Standby	Waiting state for "Run" command from high level control system. Hydrogen supply and MV link disabled.	400Vac Supplied to Container Signal from PMS (Standby)
Startup	Transitional phase when PMS signals container to initiate operation. The significant part of this phase is that the container will draw a significant amount of power during startup, to energize fuel cell modules and cooling fans/pumps. After startup is complete on the fuel cells, the container transitions to "Running". All systems operational. Hydrogen system active.	400Vac from internal microgrid. Signal from PMS (Run). MV link active (10-150kW power draw, depending on # of FCwave starts concurrent). Hydrogen-supply active.
Running	Operational state for the container, where the fuel cell modules are consuming hydrogen to produce electrical energy. Cooling and ventilation systems are operating to support fuel cell modules.	Signal from PMS (Run). Signal from PMS (Power request). MV link active (up to 1050kW power produced) Hydrogen-supply active.

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Table 7-1: Operating mode descriptions		
Rampdown	When signaled from PMS that operation is done, the container stops power production and performs fuel cell module shutdown procedures. Fuel cell modules shutting down. Hydrogen system transitions from active to inactive. After shutdown is complete, container proceeds to aftercooling.	Signal from PMS (Standby) MV link active (~10kW power draw) Hydrogen-supply active.
Aftercooling	After fuel cell system has shut down, container performs aftercooling from the cooling system and ventilation from the container ventilation	400Vac Supplied to Container MV link active (~5kW power draw)
Shutdown	The cooling and ventilation systems shuts down. Container returns to standby.	400Vac Supplied to Container. MV link transitions from active to Inactive.
Fault	Internal fault state. Hydrogen supply and fuel cells are inactive.	400Vac Supplied to Container. Fault indication to PMS.

For more details, refer to Control philosophy and Logic block diagrams.

The primary state machine is shown below in Figure 17.

For states with a fixed duration, the current best estimate is shown.

For states with no duration listed, the transition depends on external signals.

In all states, the solution can transition to a fault state and the corresponding alarm will appear on the HMI and Modbus, where measures must be remedied prior to re-engagement/reset.

Figure 17: State machine diagram

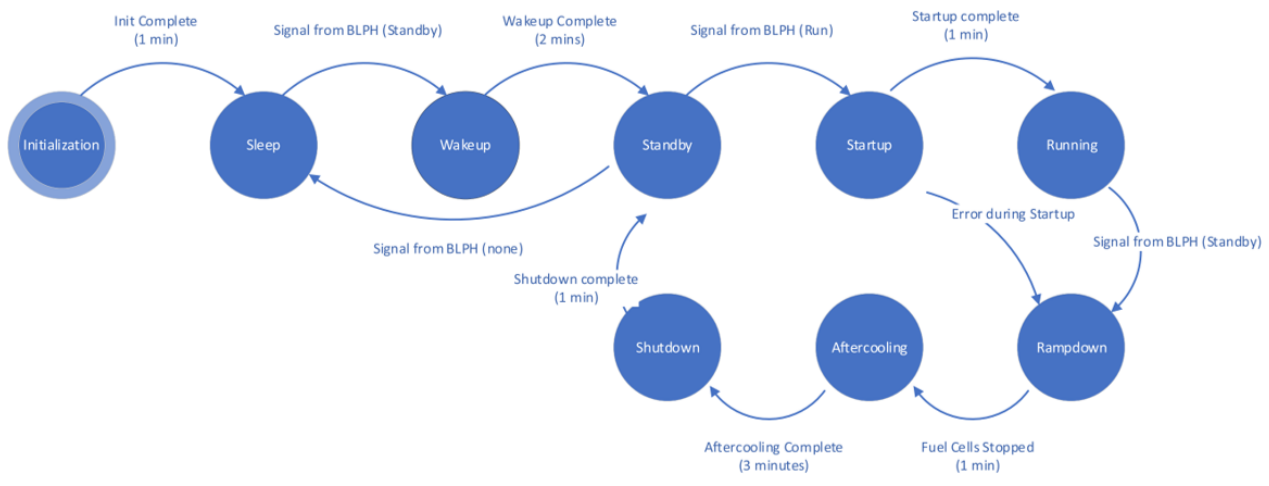


Diagram for the main state machine for the FC PowerGen.

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7.2 Control

This section outlines guidelines for the Power Request from the BLPH, which should be known by the integrator.

- The startup duration for a fuel cell module is approx. 30 seconds.
- A running fuel cell module can ramp from minimum power to rated power in 10 seconds.
- Start-up and significant step-up in power request will be limited by the startup duration, followed by the ramp-up time.
- Ramp-down is not limited by startup duration.
- The power request should be set to the desired value, instead of incrementally increased as fuel cells come online.
    - If the power request is incrementally increased, the FC package controller may not start all required fuel cell modules, and the power output will be limited by multiple sequential startup delays.
- Ballard expects that a Battery Energy Storage System (BESS) or similar power-spike capable system is used for short term spikes and dips in load and the FC package is responsible for long term power delivery with minimum short-term changes in requested power.
- The fuel cell package restart limits are as follows:
    - Restart less than 6 times in an hour.
    - Restart less than 20 times in a 24-hour period.

7.3 Disconnecting the MV bus

This section describes the consequences of disconnecting the MV bus from the FC package.

7.3.1 Disconnecting when not in operation

When the package is not in operation (State "Sleep" or "Cold Standby"), the MV bus can freely be disconnected.

7.3.2 Disconnecting while operating

The MV bus cannot be disconnected while the FC package is operating.

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7.4 Modbus TCP/IP

Control of the system is through the use of ethernet Modbus TCP/IP.

Provided Modbus table can be found in the FC package Modbus Map.

The Modbus Map presents the available read and write signals, using the function codes in Table 7-2.

The following descriptions presents the main signals that are available for the Integrator.

Table 7-2: Allowable Function Codes	
Discrete coils	
Function code 01	Read single coil
Function code 05	Write single coil
Function code 15	Write multiple coils
Discrete inputs	
Function code 02	Read single discrete input
Holding register	
Function code 03	Read single Holding register
Function code 06	Write single Holding register
Function code 16	Write multiple Holding register
Input register	
Function code 04	Read single Input register

7.4.1 Discrete coils

Read and write access.

A limited amount, if any at all, of discrete coils may be available.

7.4.2 Discrete Inputs

Read only access.

Here the status of components such as the Main Low Voltage Breaker, Local/remote control status, and statuses of internal subsystem are available.

7.4.3 Holding register

Read and write access.

7.4.3.1 Export Power Setpoint

The purpose of this signal is for the integrators PMS to signal the amount of delivered power desired at any given time.

Function: Export Power Setpoint

Tag: POWER_SP

Address 1000

Datatype: INT16

Scaling: 0.1 [kW]

Range: 55.0 to 1000.0 kW *(.0 is necessary)*

If 0<POWER_SP<55.0, the delivered power is 55.0 kW.

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The nature of Fuel Cell technology limits the speed of which it can rise and lower the delivered power. With this, the integrator can expect a defined maximum ramp-up and Ramp-down. The system will automatically follow these ramps, regardless of the export power setpoint.

7.4.3.2 Control word

The control word is the signal that enables the external signal to initiate the state changes described in section 7.1.

Function: Control word

Address 1001

Datatype: BOOL

Bit 0: wakeup/go to standby

Bit 1: go to sleep

Bit 2: Start/run

(In running mode, exported power is controlled as defined in section 7.4.1)

Bit 3: Stop

Bit 4: <Spare>

Bit 5: Reset

7.5 Input Register

Read only access.

An extensive list of live information, such as statuses and error codes. Refer to the FC package Modbus Map.

7.6 Alarm list

Refer to Alarm list for details.

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8.0 Testing

During installation and integration of the system, subsystems and interface connections, test procedures are conducted. These procedures verify the functionality and safety of specific parts of the system and integrated subsystems.

The tests are performed by/in collaboration with Ballard personnel and sub-suppliers.

The Site Acceptance Test (SAT) is similar to the Factory Acceptance Test document.

Tests could include, but are not limited to:

- Functionality tests
  - Visual inspection
  - Coolant circuit leakage tests
  - Electrical interconnection test
  - Electrical safety test
  - Initial Power up
  - Safety system
  - Auxiliary power and Balance of Plant (BOP) validation
  - UPS
  - Internal Load test
  - Hydrogen leakage test
- Pre-operations tests
  - Fuel Cell Commissioning
  - Emergency stop, no load, low load, full load
  - Hydrogen storage interface
  - Cooling circuits
  - Ventilation
  - Noise level
  - Thermographic
- Operations test
  - System start/stop – normal low load
  - Error simulation
  - Change FCwave to "service state"
  - Steady state operation
  - Power quality tests
  - Load test
    - ramp up, ramp down
    - step response
    - Load test – full load
    - Load test – no load
  - Full operation test cycle

8.1 Testing of hydrogen supply

For initial testing of the system itself, a temporary hydrogen supply in the form of a Hydrogen Battery and manifold (See requirements of this in section 5.3.3) may be used. This is to verify the functionality of the delivered system, prior to integration of the hydrogen supply delivery system of the designated site.

Integration and testing of the hydrogen supply on the designated site is a collaborative test.

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8.2 Load testing

Initial load-testing of the solution may be performed with the use of a temporary load bank that is mounted to the grid interface.

Testing with the designated grid and signals to/from the integrators PMS is done in collaboration with the responsible.

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