Horizon
Fuel Cell Spain

MW-Scale Containerized "DC output" Stationary Fuel Cell System Introduction

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Who we are

Horizon Fuel Cell Technologies

Horizon background and description

Based in Singapore, Horizon Fuel Cell Group is a company that possesses extensive expertise in electrochemistry, including fuel cells, MEA, core materials, and electrolyser systems. Horizon has a unique existing capability in manufacturing such equipment on a large scale, making them a leading producer of fuel cell systems and PEM electrolysers. Their strong presence in the competitive Chinese market is a testament to their vertical integration.

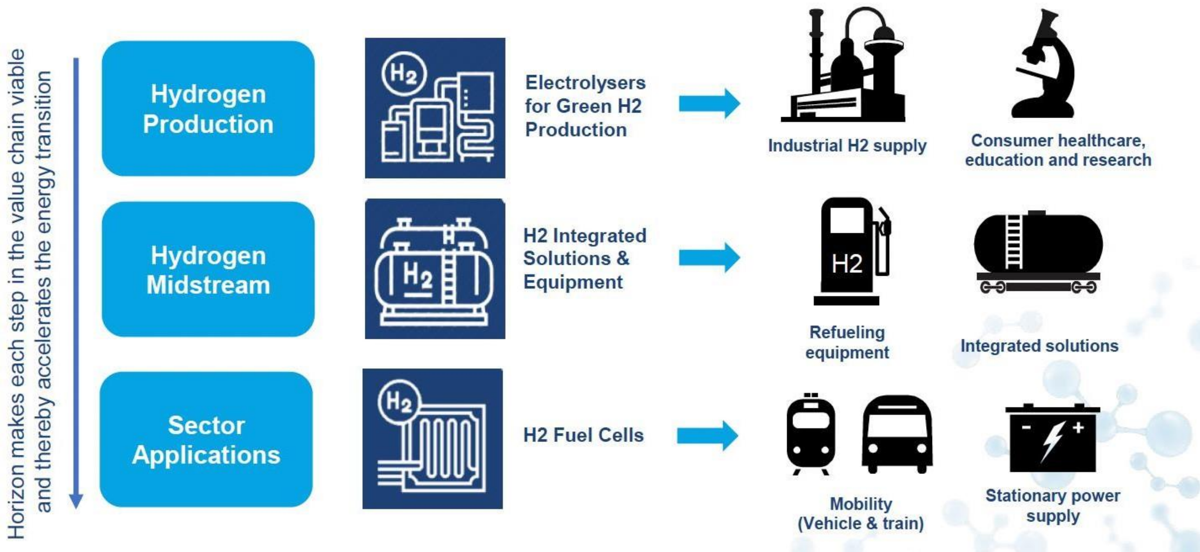


Fig 1. Horizon core technologies enable participation across the hydrogen value chain

Horizon has successfully implemented zero-emission stationary power systems with a capacity of up to 2MW, which can operate solely for power or combined heat and power production, achieving an impressive efficiency of over 90%. Horizon's new 1MW electrolyser stacks can be utilized as building blocks for large-scale production of "green hydrogen" from renewable energy sources.

PEM fuel cells use a catalyst-coated solid polymer electrolyte and require only oxygen from the air and hydrogen to produce electricity. The advantages of a PEM fuel cell are that they have a high-power density, so they can be small and light compared to other fuel cell technologies. Horizon's patented technology on hybrid bi-polar plate material, membrane construction, metal coating, graphite embossing, and impregnation and assembly process help to optimize performance, power density, durability, and cost for commercialization.
As the world increasingly turns to hydrogen as a key role in achieving decarbonization of industrial and commercial activities to mitigate climate change, PEM and other fuel cell technologies are expected to play an important role.

Horizon PEMFC Systems – globally competitive

The Horizon Fuel Cell Group possesses extensive expertise in electrochemistry, specifically in MEA and fuel cells. Unlike other companies, Horizon does not primarily rely on external suppliers for fuel cell components and sub-systems. Instead, they prioritize producing these necessary subsystems internally. This includes manufacturing their own patented bipolar plates, creating catalyst blends, producing the MEA and fuel cell stack, as well as certain key "balance of plant" components. This strategy allows for continuous innovation, adaptability to customer demands and minimizes potential supply chain risks.

Horizon Hybrid Bipolar Plate – providing meaningful differentiation.

Horizon's hybrid bipolar plates consist of two uniquely tailored layers reflecting the different characteristics of the hydrogen and air environments within PEM fuel cells. Due to the low oxygen concentration in air, the channels which guide the air flow should have a very fine structure. Such fine structures are better delivered using graphite material, compared with metal. Horizon uses a moldable graphite precursor, which can be processed on a continuous line to form such structures. A subsequent impregnation process closes all pores and makes the plate gastight. Graphite is an ideal material for the air compartment because it is chemically extremely stable towards oxidation.

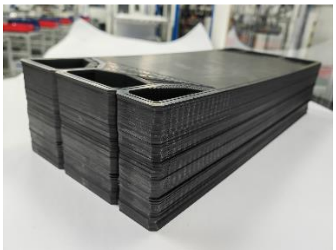


Fig.2 Air side of the bipolar plate

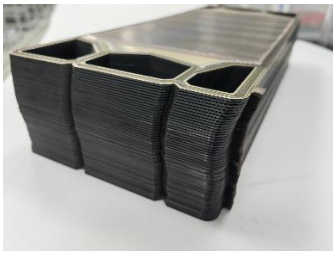


Fig. 3 Hydrogen side of the bipolar plate

For the hydrogen side of the plate fine structures are not necessary. We are using a lightweight, molded titanium foil for this. Protected with an in-house developed coating, this thin, lightweight layer provides extreme durability on the hydrogen side. Horizon's hybrid bipolar plates are lightweight and produced cost-effectively and are a key factor in achieving industry-leading power density with strong economics.

Fig. 4 Finished single cells, bipolar plate including MEA.

MEA - where the magic happens inside a PEM Fuel Cell

The acronym MEA stands for Membrane Electrode Assembly, which contains an ion-conductive polymer film which is coated with a catalyst on both sides. In conjunction with the bipolar plate, it is the heart of a fuel cell system. Horizon has developed its own high-volume, printing-style process to apply the proprietary catalyst compound which contains additives to extend the operational life of the MEA. Horizon has optimized the production procedure to apply the catalyst blend to the polymer membrane in a continuous process by means of a large in-house slot die coating machine.

Fig: 5 Roll of MEA

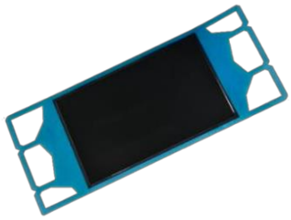


Fig. 6: Framed MEA

After coating, a plastic frame and two gas diffusion layers must be fixed to pieces of cut MEA that are cut to the size of single cells. This assembly is called 7-layer MEA and is produced by an almost fully automated process in-house. The MEA is combined with Horizon's patented hybrid bipolar plates to create "single cells" that are ready to be combined into a fuel cell stack. Up to 500 bipolar plates and MEA's are layered on top of each other to form a fuel cell stack.

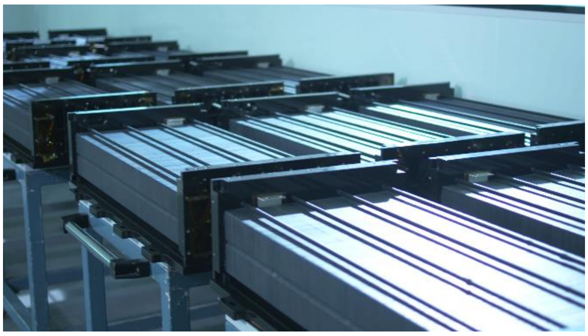


Fig. 7 Completed fuel cell stack without housing.

Balance of Plant (BOP) – helping to make things work.

To make a fuel cell work, several peripheral components and subsystems are necessary, such as hydrogen recirculation module, air compressor, humidifier, pumps, valves (all part of the BOP), and finally control software. Horizon combines the BOP to the fuel cell stack in a production line. Some critical components, such as the hydrogen recirculation module, are made in-house to ensure optimal integration and performance for the fuel cell system being assembled, and also to control quality and mitigate supply chain risks.

Fig.8: BOP component. Hydrogen recirculation module

A key aspect to the working fuel cell system is the control software which manages the stack and BOP components in the optimum way to provide the highest operating efficiency possible under the operating scenario, and also to provide the longest possible life in service, which is partially achieved by the careful control of individual cells in the stack. Many years of experience from durability testing and failure mode analysis has contributed to this capability within Horizon.

System Description

The Horizon VLIII 200kW fuel cell system was originally designed primarily for commercial vehicles, with high reliability and durability. Such fuel cells are very suitable for stationary power generation in prime power, backup, or occasional demand power modes. Combining these modules in container type configurations enables power delivery at MW scale.

Fig.9: Modular Cabinet Power Plant

Horizon can provide a containerized system capable of providing a Maximum of 2.8 MW as peak power, depending on the quantity of the 200kW fuel cell system used. To meet a client's requirements for future large-scale power systems, 'containerized' systems can be supplied as follows, with the objective of delivering maximum efficiency and optimized footprint.

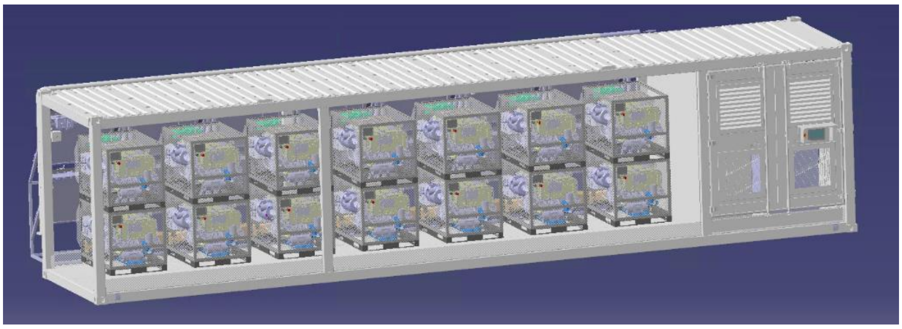


Fig.10: MW-scale Fuel Cell Power Plant

Particular	***Description***
Fuel cell Technology	*PEM (Proton Exchange Membrane)*
Installation	*Outdoor Containerized System*
Equipment Footprint	*20/30/40 Feet Partially Enclosed Customized Container (as per the Qty. of 200kW system)*
Expected life of the Fuel cell Stacks	*Max. 16,000h*
H_2 Purity Required	*>99.97% , in accordance with SAE J2719 / ISO 14687-2*
Rated Output Voltage	*500~750vdc*
Rated Output Power	*MW-scale, shall be requested by the client*
System net efficiency(LHV, hydrogen in dc out)	*Maximum efficiency >53% , can be adjusted on request*
Hydrogen Inlet Pressure	*8~14barg*
Control protocol	*CAN 2.0b/Modbus TCP/Modbus RTU*
Power input for start-up	*10kW@380VAC/480VAC or others on request*
Zoning Recommended	*Non-Hazardous Area (Horizon's containerized system is designed with special considerations for maintaining adequate ventilation at all times)*

Note:

- Specifications are subject to change.
- The power consumption of the radiator depends on the ambient temperature. To maintain rated power net output, the efficiency may be reduced, and the hydrogen consumption may be slightly increased when the radiator is operating. However, the efficiency and hydrogen consumption we indicate is based on the radiator operating under maximum load.
- The efficiency of the fuel cell is higher when output power demand is lower during the operation.
- If heat exchange equipment is added, the power consumption of the radiator will reduce, which means

the efficiency will be higher than using a standard solution.

System Diagram

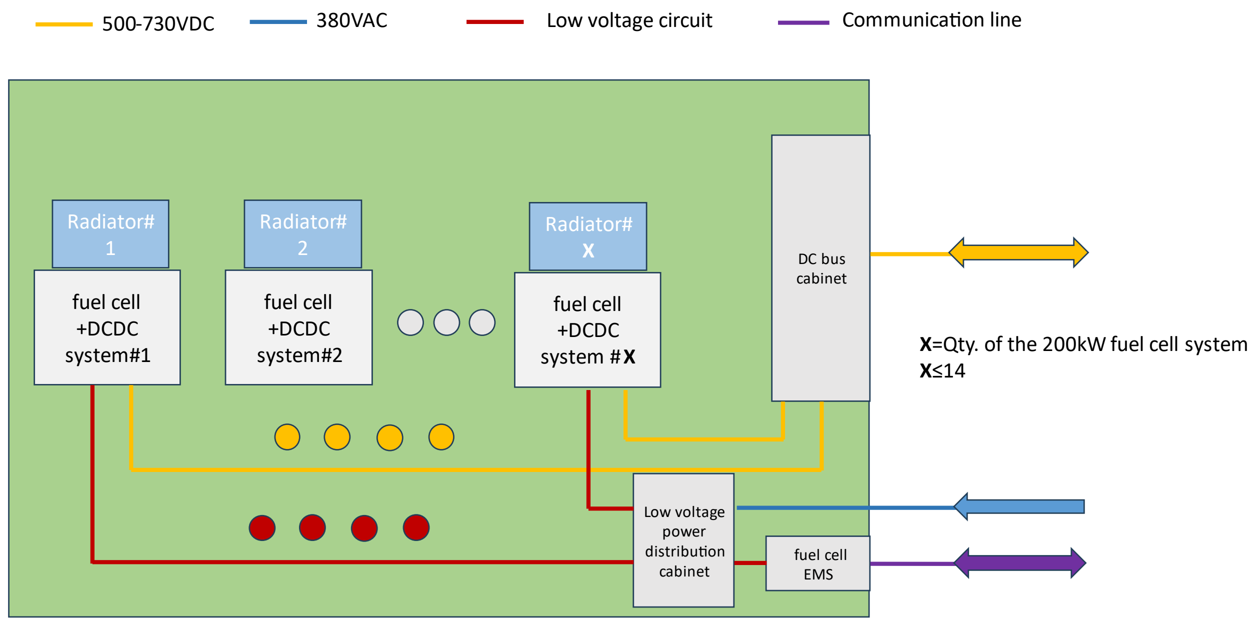


Fig.11: System diagram #1 (recommended)

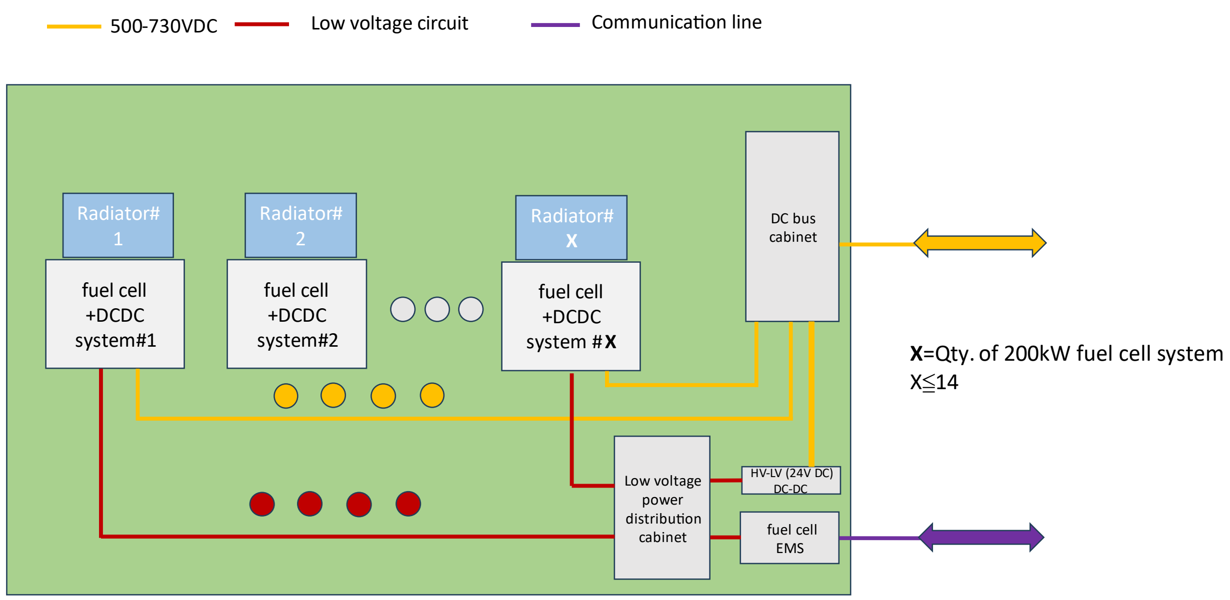


Fig.12: System diagram #2

The efficiency of a containerized system can be increased by adding an additional 200kW fuel cell Modules once the rated output power is determined by the client.

To meet the client's requirements for a containerized system with a specific output power & efficiency AND with the smallest possible footprint, propose:

- *20ft containerized system with maximum 6 * 200kW fuel cell modules.*
- *30ft containerized system with maximum 10 * 200kW fuel cell modules.*
- *40ft containerized system with maximum 14 * 200kW fuel cell modules.*

Scope of Supply

As per the above system diagram, the standard scope of supply of Horizon's MW scale containerized Stationary Fuel cell System covers:

- ✓ X units of VLIII 200 fuel cell system with DC-DC converter
- ✓ low voltage power distribution cabinet
- ✓ DC bus Cabinet
- ✓ EMS of fuel cell systems
- ✓ hydrogen pipeline system +cabling
- ✓ hydrogen sensors +forced ventilation
- ✓ radiators
- ✓ 1 * 20/30/40ft Partially Enclosed Container

Specific exclusions from Scope

- ✓ Project management and engineering support
- ✓ Installation
- ✓ Independent Third-Party Calibrated Measurements (SAT)
- ✓ Certification & Compliance
- ✓ Travel, Transportation, Crane, and Logistics

Kindly Note: Above services can be included in the offering after the customer's request and commercial acceptance of each service.

On-Site Requirements / Preparation Work.

- Area for installation should be level and even, suggest concrete slab at least 150 mm higher than surrounding ground level.
- Maintain sufficient distance from surrounding buildings to ensure good ventilation conditions.
- Embedded equipment grounding and lightning protection grounding will be required.
- When the Fuel cell system is running, there will be drinkable condensed water flowing out of the exhaust port which will need to be collected or drained, depending on the outdoor ambient temperature conditions.
- A hydrogen supply of ≥ 99.97+ % dry hydrogen, with a proper inlet pressure indicated in "System Description".
- The containerized system has embedded monitoring and control systems which communicate with each module in the system and control the power generation of the entire system based on the load conditions or by pre-set controls. Also included is a communication interface which can be used to monitor and set the system parameters. The system can communicate to the client's electrical systems by CAN 2.0b/ Modbus TCP/Modbus RTU.
- External power system and/or battery energy storage system to be configured to provide any required external power input for system startup and/or standby power.

Heat Recovery Potential.

Horizon's containerized system can have an outlet port that can be used for heat capture purposes if needed. This may be of benefit in contributing to the client's requirement for heating water and /or cooling purposes. Potential heat generation is very dependent on the installation location, elevation, and outside ambient temperature. Each 200kW Fuel cell module produces heat in operation according to the indicated rated output power and efficiency.

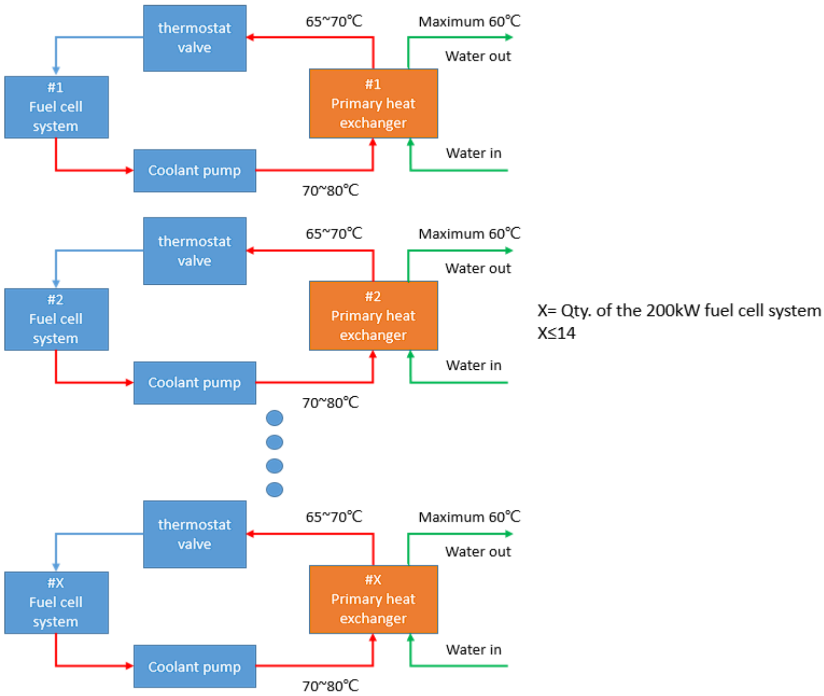


Fig.13: Heat recovery potential per 200kW module

Code and Regulation

The design, and manufacturing of Horizon MW scale containerized stationary fuel cell system comply with the following standards and regulations :

- ✓ Low Voltage Directive 2014/35/EU
- ✓ Electromagnetic Compatibility Directive 2014/30/EU
- ✓ IEC 62282-3-100:2019

Kindly Note: Additional standards and regulations may be available on request.

F.A.Q.

What is the price of a MW containerized stationary fuel cell system?

The price of a containerized system is determined by the quantity of 200kW single systems inside. For example, if a customer requests a 1MW containerized system, we can use either 6 units of 200kW ~ 12 units of 200kW systems, or even more. A 6*200kW containerized system to output 1MW would have lower system efficiency, whereas using a 12*200kW system for the output would result in much higher efficiency. For fuel cell systems, higher efficiency means lower hydrogen consumption and a longer lifespan, but it also comes with a higher cost. Therefore, the customer needs to make a comprehensive assessment based on the operating environment, condition, time, and available hydrogen. For systems that will be running for long periods, we recommend using a configuration with higher efficiency to enhance the system's durability and reliability.

Can 5 units of 200kW systems achieve a net output of 1MW?

When a 200kW system outputs 200kW, it does not take the losses from DC-DC conversion and the power consumption of the radiator into account. Additionally, there is electricity consumption by the control system, exhaust fans, lighting, and other equipment. Therefore, at least six units of 200kW systems would be required to achieve a net output of 1MW. We understand that many manufacturers in the market may blur these distinctions, but all parameters and efficiencies provided by Horizon are based only on net output.

What kind of application scenarios is the system suitable for?

The system is suitable for off-grid backup power, on-grid power generation, microgrids, etc.

How to make the system operate appropriately in different application scenarios?

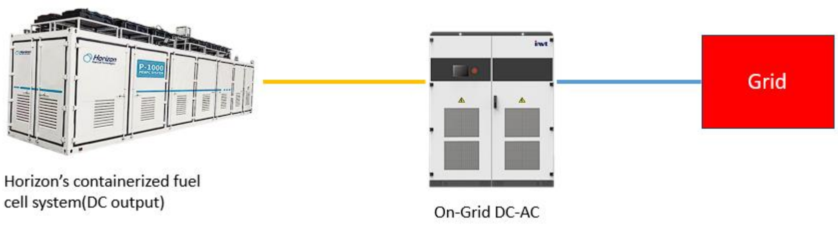
The customer may need batteries or control systems to ensure the stable operation of the fuel cell system.

	Battery	EMS/SCADA/DCS	DC-AC
On-grid power generation	N	TBD	On-grid DC-AC
Off-grid backup power	Y	Y	Off-grid DC-AC
PV/Hydrogen DC micro-grid	micro-grid battery	Y	Micro-grid DC-AC
PV/Hydrogen AC micro-grid	micro-grid battery	Y	On-grid DC-AC

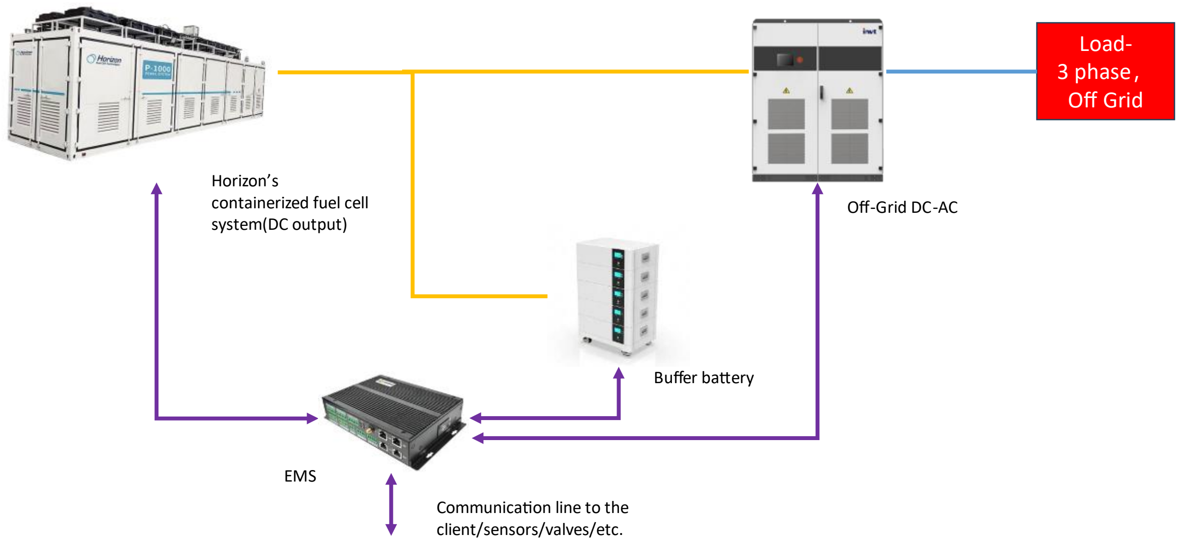
Why is it necessary to have batteries in off-grid or microgrid applications?
In dynamic load scenarios, since the dynamic response capability of fuel cell systems cannot follow rapid load changes, batteries are needed to buffer the fluctuation of the load. Additionally, starting up a fuel cell system also requires high voltage input, making the battery an essential component.
For on-grid applications, fuel cells usually maintain a steady power output, so there is no need for batteries to buffer, only a bi-directional on-grid DC-AC is needed for operation.

Typical diagram for each scenario:

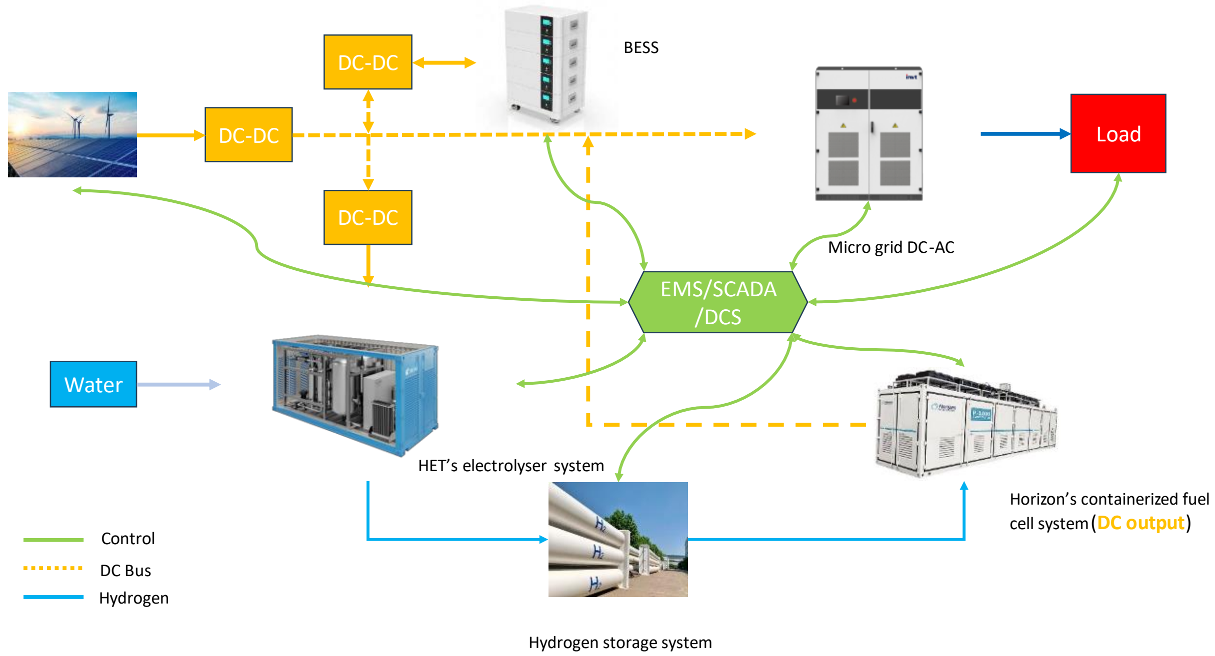
-On-grid power generation



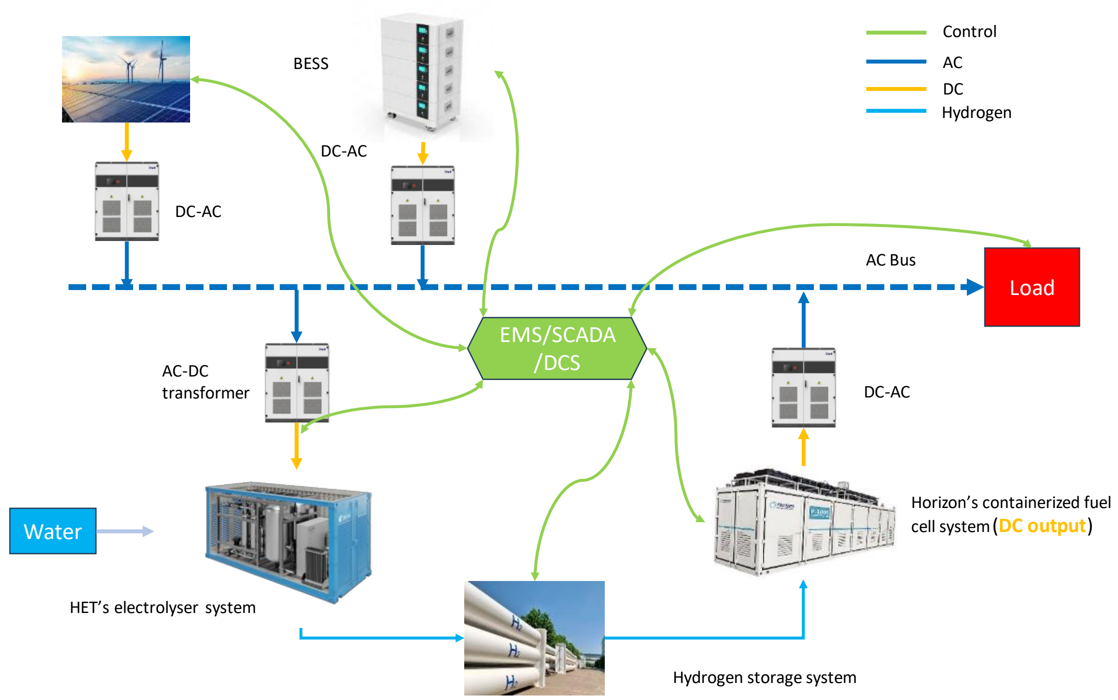
-Off-grid backup power:



-PV/Hydrogen DC micro-grid:



-PV/Hydrogen AC micro-grid:



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