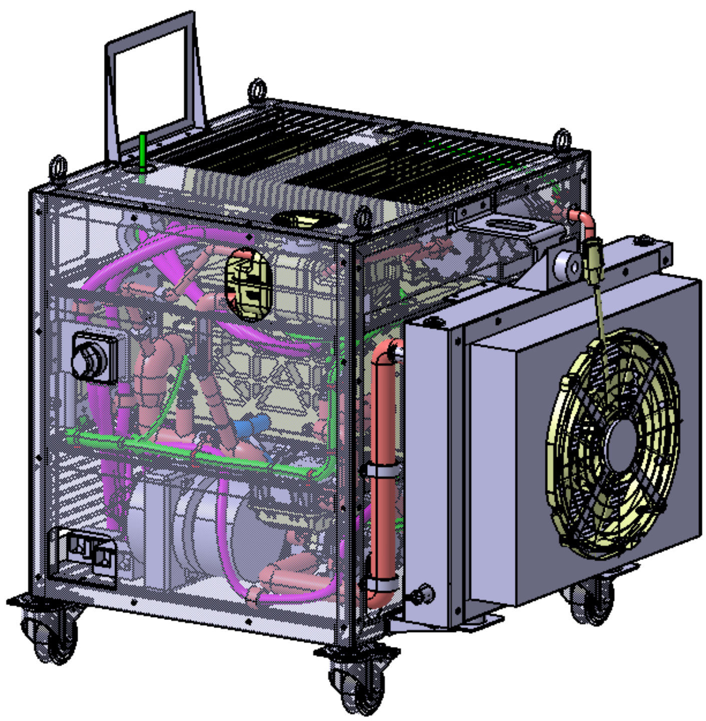
10kW fuel cell system manual



Updated 20 March, 2022

VL-10 fuel cell system_manual_V2.0

Disclaimer

This manual incorporates safety guidelines and recommendations. However, it is not intended to requirements and to ensure safety during operation, maintenance and storage of the stack.

Although all efforts have been made to ensure the accuracy and completeness of the information contained in this document, Horizon reserves the right to change the information at any time and assumes no liability for its accuracy.

Actions that will void the fuel cell stack warranty:

- Attempt, under any circumstance, to disassemble the fuel cell stack.
- Operate fuel cell stack in a specified manner not in system settings or in specific product user manuals.
- Failure of fuel cell system caused by accidents, misuse, human injury or negligence.
- Use impure or incorrect fuel.
- Operate the fuel cell stack with a controller not designed and built by Horizon for the specific fuel cell.
- Operate the fuel cell with no controller, or the controller used is not produced by Horizon Company.
- Supply hydrogen to fuel cell system using hydrogen source which does not meet the requirements of Horizon Company.
- Supply hydrogen to fuel cell system with hydrogen pressure which does not meet the requirements of Horizon Company.

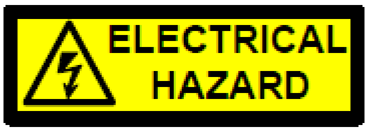
Do not attempt, under any circumstance, to disassemble or inappropriately tamper with the fuel cell. There will be no returns, refunds or exchanges should disassembly or tampering occur. If you have questions or need help with regards to the fuel cell and its technology contact: support@horizonfuelcell.com

Contents

Revision history

Revision history			
Rev.#	**Description**	**Author**	**Datea**
1.0	Initial	Kevin	2022/3/20

1. Safety



ELECTRICAL HAZARD: Fuel cell stacks generate high voltage. Obey all warnings, cautions, and safety instructions. Failure to do so may result in electrical shock leading to personal injury or death.

1.1 General Safety

(1) The fuel cell stack may contain residual voltage when not operating.

(2) Keep all guards, screens, and electrical enclosures in place when the system is operating.

(3) The fuel cell stack should not be used or stored in wet or damp conditions.

(4) Remove jewelry, watches, rings, and metal objects on clothing that can cause short circuits when working with the fuel cell stack or system.

1.2 High Temperature and High Pressure Safety

(1) The fuel cell stack can reach a temperature of 70 °C or higher if operated outside the specification. Avoid touching exposed components during or shortly after operation.

(2) The fuel cell stack and associated system use pressurized gases, which can be hazardous. Use caution and ensure circuits are de-pressurized before opening any lines or fittings.

(3) The fuel cell stack is assembled under high compression. Do not attempt to disassemble the stack.

1.3 High Voltage Safety

(1) Always ensure that the Stack Power HV+ and HV-terminals are connected to an appropriate load prior to operation.

(2) Current leakage from the stack can also occur if there is inadequate isolation elsewhere in the electrical system and the stack is not fully isolated from that portion of the electrical system. The inadequate isolation could occur elsewhere in the fuel cell module or external to the fuel cell module. This leak path can be minimized by ensuring all electrical equipment and wiring in the fuel cell module is adequately isolated and by ensuring that the fuel cell module electrical buses are isolated from the application electrical system.

(3) Stack Power connection cables must be appropriately sized to suit the application for voltage, current and insulation temperature limits. Cables must have suitable voltage rating, current carrying capacity, and insulation temperature rating, depending on the end-users' specific application and operating environment.

(4) Exercise caution when routing the Stack Power Cables. In particular, ensure that no other electrical cables are routed in between the physical loop formed by the Fuel Cell Stack power terminals, the HV+ and HV- and the load power terminals.

(5) Exercise caution when working with the stack. Residual reactants within the stack can rapidly develop a charge, even when there is no fuel flow and the stack has been short-circuited. A reading of zero volts across the entire stack does not guarantee that all cells are uncharged.

(6) Never, under any circumstances, touch live electrical parts such as bus bars or connections.

(7) Be sure that all electrical connections and connectors are properly installed and connected with proper torque. Do not over-torque,

as this can damage the stack.

(8) Avoid hazardous voltage situations that could result from unsafe conditions such as, but not limited to, the following:

- Improper grounding;
- Accumulation of foreign material or debris between live stack parts and hardware that could lead to loss of isolation or reduction in creep age/clearance；
- Handling electrical leads or devices with wet hands or on wet ground；
- Frayed electrical leads；
- Improper connection or re-connection of the terminal Leads；
- Short circuits；
- Back-feed from energized normal and emergency power sources.

1.4 Hydrogen Safety

(1) Hydrogen is a colorless, odorless, highly flammable gas.

(2) Hydrogen must be sited and handled in accordance with applicable regulations and the gas supplier’s recommendations.

(3) Hydrogen is non-toxic but can cause asphyxiation by displacing the oxygen in the air. There are no warning symptoms before unconsciousness results.

Hydrogen molecules are smaller than any other gas, making hydrogen more difficult to contain. It can diffuse through many materials considered airtight. Fuel lines, non-welded connections, and non-metal seals such as gaskets, O-rings, pipe thread compounds and packing present potential leakage or permeation sites. Furthermore, hydrogen’s small molecule size results in high buoyancy and diffusivity, so leaked hydrogen will diffuse and become diluted quickly. Stack hydrogen leak rates will generally increase with stack lifetime.

The responsibility for leak detection and the mitigation of combustible leaks rests with the customer. Hydrogen leaks emanating from the fuel cell stack can be readily detected by means of a hydrogen detector, which can trigger warnings well before the hydrogen/air mixture reaches a flammable concentration.

1.5 Stack Fire Safety

Operation of the fuel cell stack in a manner that is significantly outside specification may result in open flame at the stack. Specifically, the following conditions may result in fire:

- Operation with significant fuel starvation (insufficient purge, long periods of over-cooled operation)
- Operation above maximum stack temperature rating;

1.6 Asphyxiation Safety

The fuel cell stack consumes O_2 while operating. If operating the stack in poorly ventilated, small enclosures, care must be taken that O_2 concentrations do not drop below safe levels.

2. System Introduction

This section mainly describes the working principle and the electrical properties of the fuel cell stack. The fuel cell stack is an electrochemical device that directly outputs a stable DC high voltage, so it can be directly connected to a transformer or inverter to convert the DC voltage to the DC or AC voltage.

Fuel cell stacks are considered a clean, non-polluting green technology by electrochemical reactions of pure hydrogen and oxygen, generating electricity and water which makes fuel cell solutions more attractive for places where emissions limits are required.

Fuel cells are similar to generators and it can operate uninterrupted if the fuel cell has appropriate fuel source, which means that while the fuel cell is used in conjunction with appropriate fuel storage solution it can be efficiently stored as a standby power source in a customer application.

The fuel cell stack is an electrochemical conversion device with high power density and high conversion efficiency by using proton exchange membrane as electrolyte, which converts the chemical energy produced by pure hydrogen and oxygen in the air directly into electrical energy. Hydrogen in the anode loses electrons to form hydrogen protons by the catalyst, hydrogen protons reach to the cathode through the proton exchange membrane and react with oxygen to produce pure water. The electrochemical reaction of the stack is shown as follows:

Anodic reaction： $H_2-2e^- \rightarrow 2H^+$

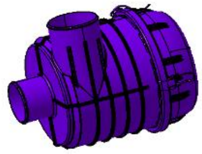
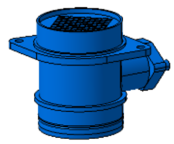
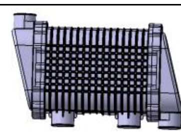
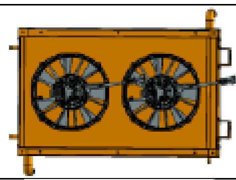
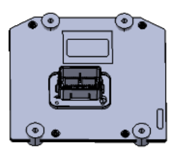
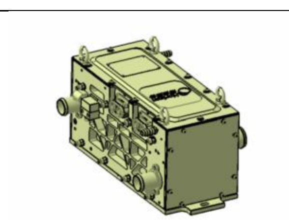
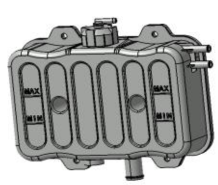
Cathode reaction： $4H^+ + O_2 + 4e^- \rightarrow 2H_2O$

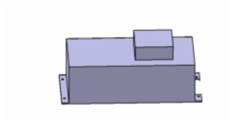
Total reaction： $2H_2 + O_2 \rightarrow 2H_2O$

2.1 System composition

In terms of function, the fuel cell system is mainly composed of five subsystems: oxygen supply system, hydrogen supply system, heat dissipation system, control system and fuel cell stack, The core components are shown in the table below .

Table 2-1 Flow chart of fuel cell system structure

No.	Item	Drawing	Function
1	Air filter		Prevents damaging size particles from entering fuel cell
2	Air flow meter		Monitoring feedback of air flow
3	Humidifier		Adds humidity to the air entering the stack
4	Radiator		Removes excess heat from the system
5	Ion Exchange		Absorbs ions in the coolant and reduce the conductivity of the coolant
6	Controller		Control system, system and vehicle communication
7	Fuel cell stack		Oxygen and hydrogen react to produce power
8	Fill water tank		Filling water and purge air for the fuel cell system

9	Fuel cell 24V water pump		Powers the cooling cycle of the fuel cell
10	Constant voltage DC		Charge the 48V power battery
11	Blower		Provide air for the system

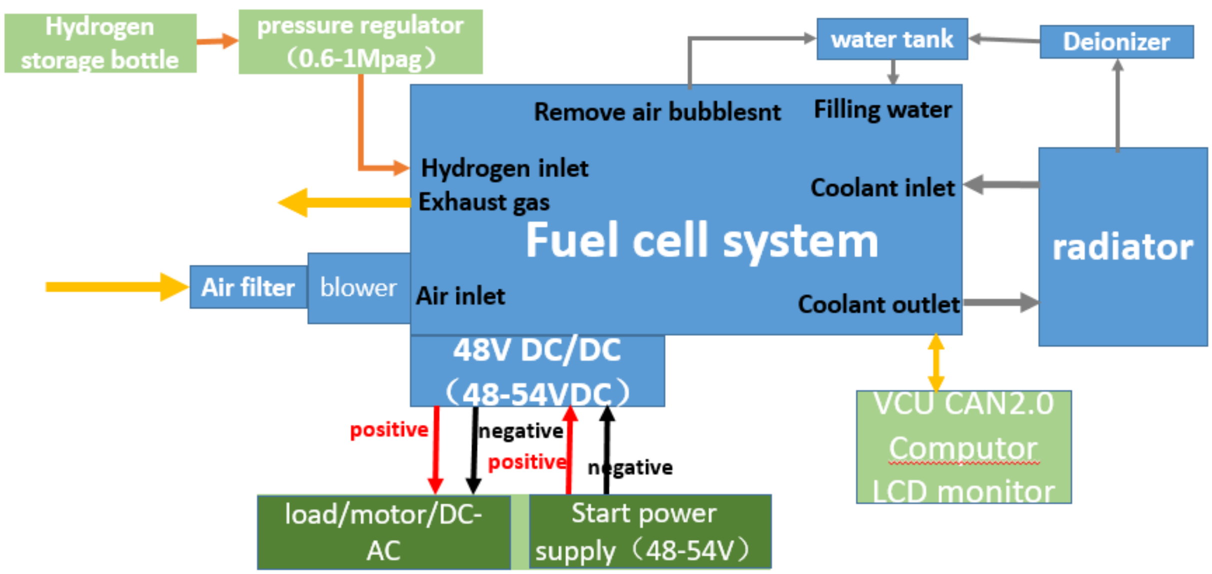
In addition to the above components, the fuel cell system is also equipped with some sensors to feed back the temperature, pressure and humidity signals of the controller system during operation.

The internal oxygen supply system and cooling system components of the system also need to be connected with silicone tubes and multi-way joints to ensure the flow of fluids in the system.

The fixing of the various parts of the system requires the support of a bracket, and the whole system needs a fixed frame, which is connected and fixed together by the frame. Finally, many electrical parts in the system need to be connected with high-voltage wiring harness or low-voltage wiring harness.

The working principle diagram of the fuel cell system is shown in Figure 2-1 below.

Figure 2-1 Working principle diagram of the gas power system



The blue module is the material delivered with the fuel cell system, while the others need to be prepared by customers.

Start power and load description:

1. Fuel cell system is a power generation unit, which does not store energy, so it requires an external power source to start;

2. It is recommended to use 48V battery as the starting power supply, 48V/60AH. The larger the capacity, the better.

3. Bidirectional electronic load can also be preferred;

4. It is not recommended to use resistive load alone, because when the power changes, the system voltage range fluctuation is relatively large, triggering failure, debugging is more difficult, if it is resistive load, it must be able to set constant voltage mode;

5. No matter what kind of load, the simplest is to add a group of 48V power battery at the back end of the fuel cell system, which can debug the workload.

2.2 System Operating Conditions

2.2.1 Gas and Liquid Requirements

The fuel cell stack is used to generate electricity by converting the chemical energy produced by hydrogen and oxygen in the air into electricity, using coolant to circulate in the stack to dissipate heat, So the stack is strictly required to use qualified fuel gas, oxidizing gas and coolant. Detailed requirements are shown in table 2-2 below.

Table 2-2 Gas and liquid specification sheets

Description	**Specification**
Fuel gas（> 99.97% H_2）	
Other components	< 300ppm
	＜2ppm CO_2
	＜0.1ppm CO
	＜5ppm H_2O
	＜2ppm Hydrocarbons
	＜5ppm O_2
	＜300ppm He
	＜200ppm N_2、Ar
	＜0.004ppm Total sulfur compounds
	＜0.01ppm Formaldehyde
	＜0.2ppm Formic acid
	＜0.1ppm NH_3
	＜0.05ppm Total halogenated compounds
Oxidizing gases (air)	
O_2	＞20.95%
N_2	＜78.08%
Other gas components	
	＜0.1ppm CO
	＜1% CO_2
	＜1ppm O_3
	＜0.01ppm SO_2
	＜0.04ppm Hydrogen sulfide
	＜0.025ppm NO
	＜0.05ppm NO_2
	＜0.008ppm Volatile Organic Compound
	＜0.01ppm NH_3
Atmospheric particulate components	
	＜90µg/m^3 PM10
	＜15µg/m^3 PM2.5
Coolant	
	Deionized water
	Particle diameter＜100µm
	Conductivity＜5µs/cm

Warning:

➢ If the working environment has a lot of dust, air filter should be installed to filter the air; if there is too much Nitrogen and oxygen compounds, Oxygen and sulfur compounds and other contaminants in the working environment, the air should be chemically filtered.

➢ Choice of coolant should be prudent, the widespread use of coolant in the market may not applicable, it may contain additives to lead to high conductivity, insulation resistance is too low, and therefore need to be coupled with the device which can monitor electrical conductivity.

2.2.2 System Working Condition

The operating point of the system also affects the normal operation of the system as shown in table 2-3.

Table 2-3 Working condition table

Environmental requirements	Specific parameters
Start-up temperature of stack	≥- 10℃(< 5℃ Auxiliary heating is required)
Storage temperature	-20℃~60℃
Altitude Range	0~1000m（>1000m performance drops 3.5% for every 500m increase）
Humidity Range	0%~100%RH
Air pressure	0 to 0.2barg
H_2 pressure（Inside the stack）	0.3 to 0.6barg

2.2.3 System performance

The performance parameters of the 10kW system are as follows: Table 2-5：

Table 2-5：10kWFuel cell system parameters

NO.	performance parameters	Specific parameters
1	System rated power output（kW)	10（DC efficiency loss is not included)
2	Stack rated power（kW)	12

3	System idle Power（kW）	≤2
4	Cell Number（cells）	90
5	Efficiency of the system（%）	＞40（DC efficiency loss is not included）
6	Operating ambient temperature	-10-40℃
7	Storage ambient temperature	-20-60℃
8	Response time (start-up to idle)	＜30S（Ambient temperature＞5℃）
9	-10℃ low temperature start time	＜15min
10	Operating ambient humidity	0-95%
11	Operating pressure	≤50kPa
12	IP rating	IP54
13	Vibration noise	≤80dB
14	Voltage current output	222A@54V
15	System size (mm,Contains the DC/DC)	940*700*770
16	System weight(kg)(Includes DC and radiator)	180
17	DC output voltage(V)	54
18	Stack operating temperature(℃)	60-70
19	H2 purity	＞99.97% hydrogen
20	Hydrogen inlet pressure（Mpag）	0.6-1
21	Hydrogen reserved interface model	1/2 inches Card sleeve joint
22	hydrogen flow rate(l/min)	≤150
23	Insulation resistance (Ω/V)	≥500Ω/V
24	Coolant	≤5us/cm

Figure 2-2 U-I curve of fuel cell system

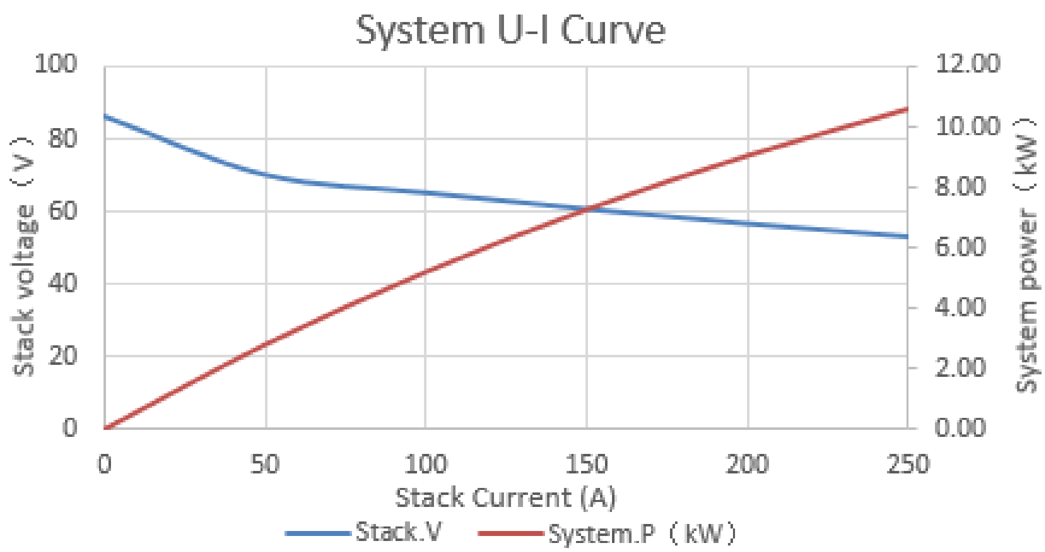
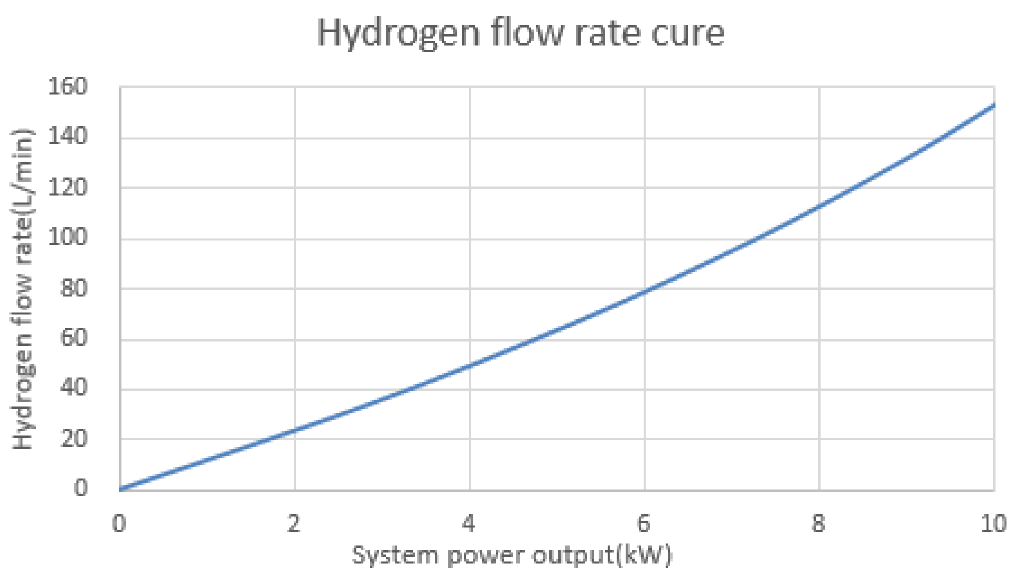


Figure 2-3 Curve of hydrogen flow rate

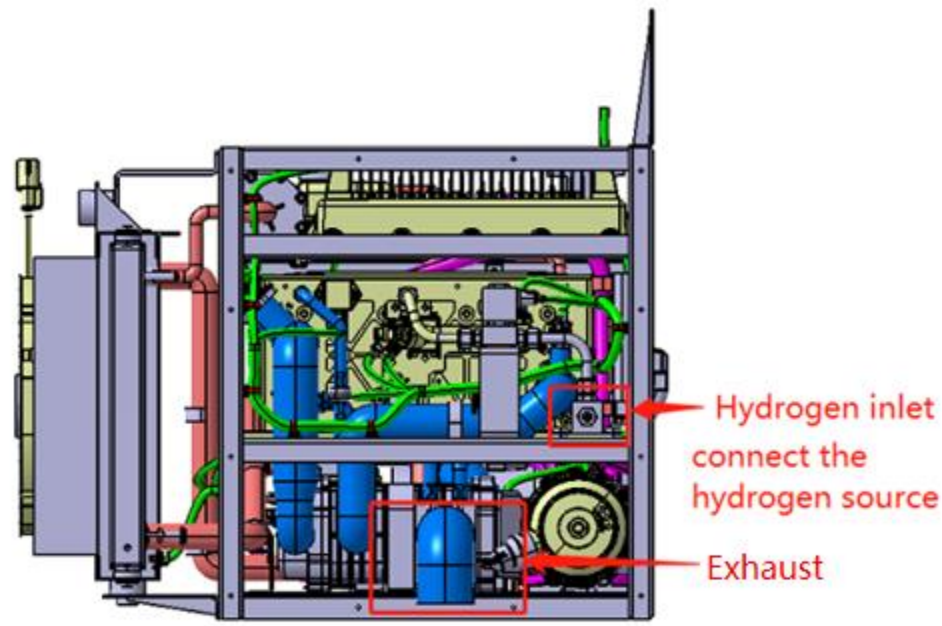


3. System operation

The fuel cell system is mainly composed of a fuel cell stack module, a hydrogen supply module, an oxygen supply module, a cooling module and an electrical control module. The hydrogen supply module provides the hydrogen required for the reaction of the fuel cell system. The oxygen supply module provides the air required for the reaction of the fuel cell system. The cooling module is mainly used for the heat dissipation of the fuel cell system, and heat dissipation is performed through the circulation of the coolant. The electrical control module controls the components in the entire system.

3.1 System connection instructions

Need to connect the tailpipe of the system, the hydrogen inlet (connected to the hydrogen source), and the high-pressure end of the DCDC (need to be connected to the load). After all the pipelines are connected, manually add a certain amount of deionized water to the system kettle.



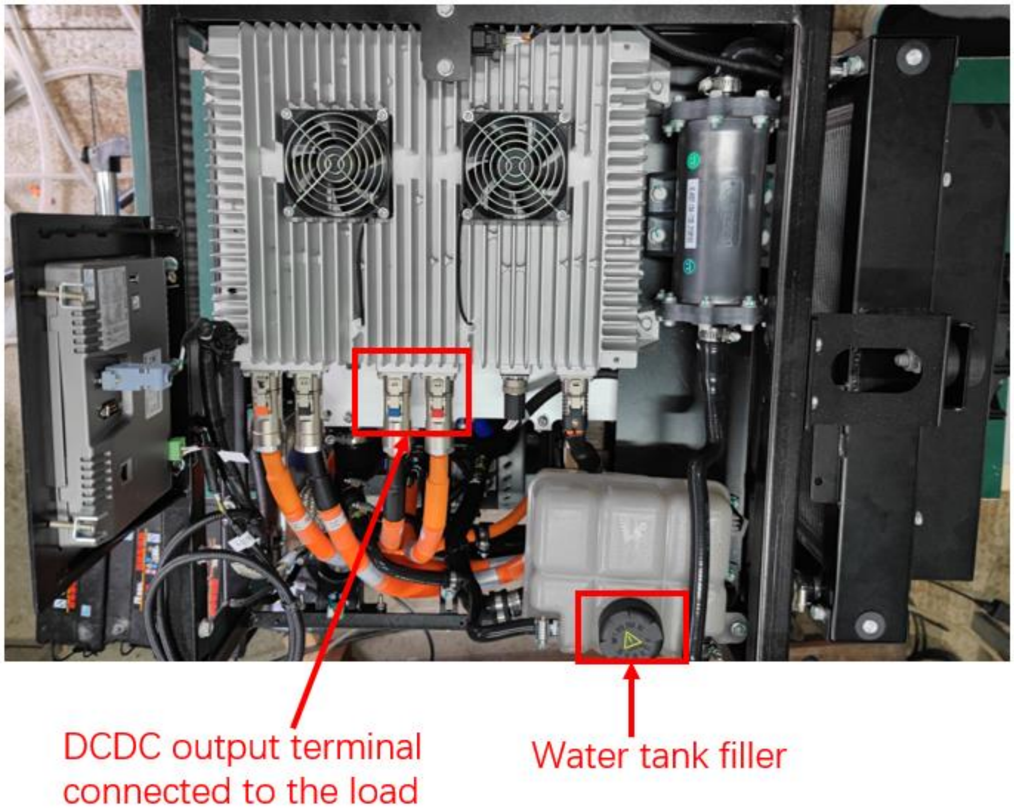


Figure 3-1 System connection diagram

3.2 System communication line connection

As shown in Figure 3-2, it is the connection method of the communication line between the system and the computer. Connect the communication line we configured with KVASER, one end of the communication line is connected to the CAN2 interface of the system ECU, and the other end of the KVASER is connected to the computer.

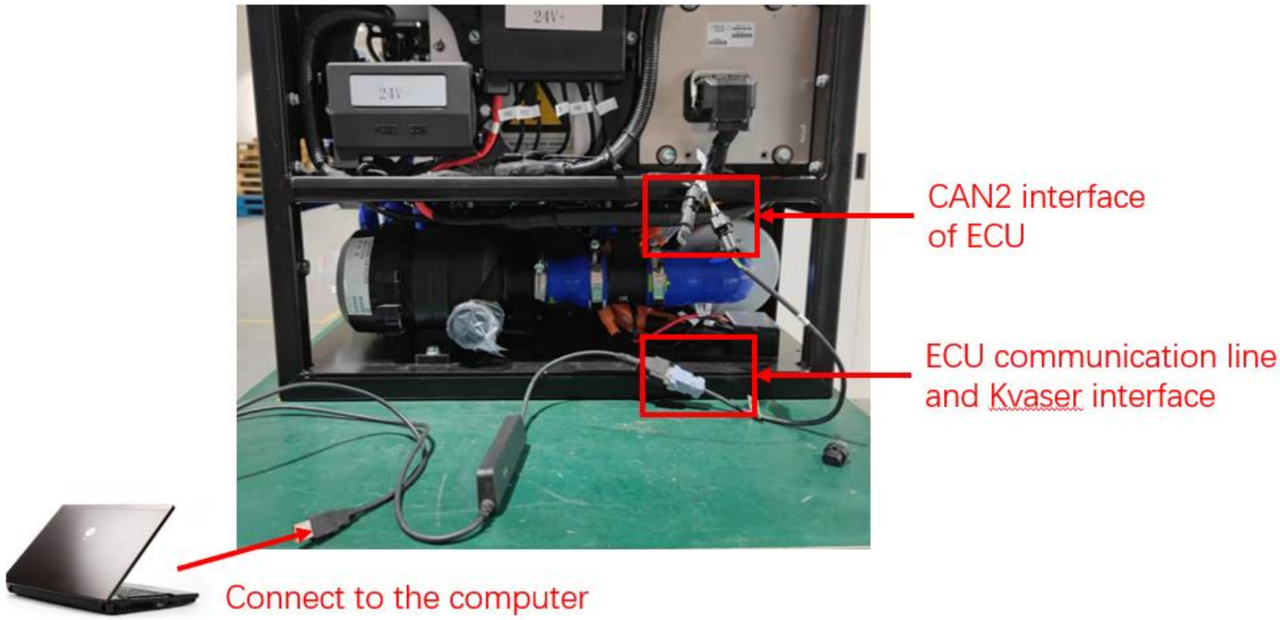


Figure 3-2 Communication line connection

3.3 Screen display control instructions

As shown in Figure 3-3, it is the control interface of our system, which can start and shut down the system and modify the power through the control of the screen.

Operation 1： When you click this button , it will become Set Remote Control , At this time, it can be operated on the display screen, Otherwise, Ethernet operation will be performed.

Operation 2： This button is the lock key of the screen, Clicking this button will become Set Control Lock , before power setting and other operations can be performed . Otherwise, the screen will not operate.

Operation 3： This is the system emergency stop button. When the button becomes Reset Normal Mode , the system will be in emergency stop state.

Operation 4： After the power setting is completed, click this button to change to STOP to start the system. Clicking again will stop the system.

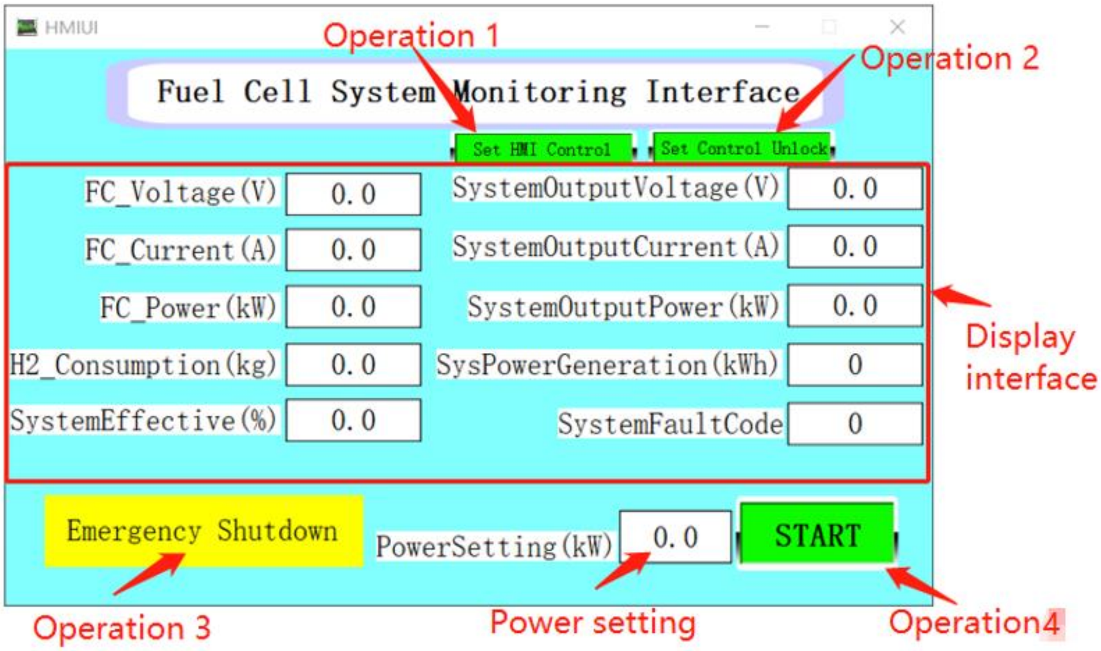


Figure 3-3 Screen control interface

4. Software operation instructions

4.1 Open the Software

Unzip the application package, run Horizon VL series monitor.exe. Note: if the package decompressed to the C drive, please right click the computer mouse to allow Horizon VL series monitor.exe operation in administrator mode. Otherwise, the software can't write to Excel and blf file, thus failed to recording.

4.2 Getting Started

First, make sure the fuel cell system is properly wired. Second, supply the 24V power. Third, click the Run button, as long as the CAN connection indicator shows ONLINE, it means the system communication is run correctly, Forth, wait the system to complete self-check, then it runs into standby status, after that the fuel cell system is ready to operate.

Note: It is necessary to add enough deionized water and expelling all the air in the coolant circuit to start the fuel cell system for the first time.

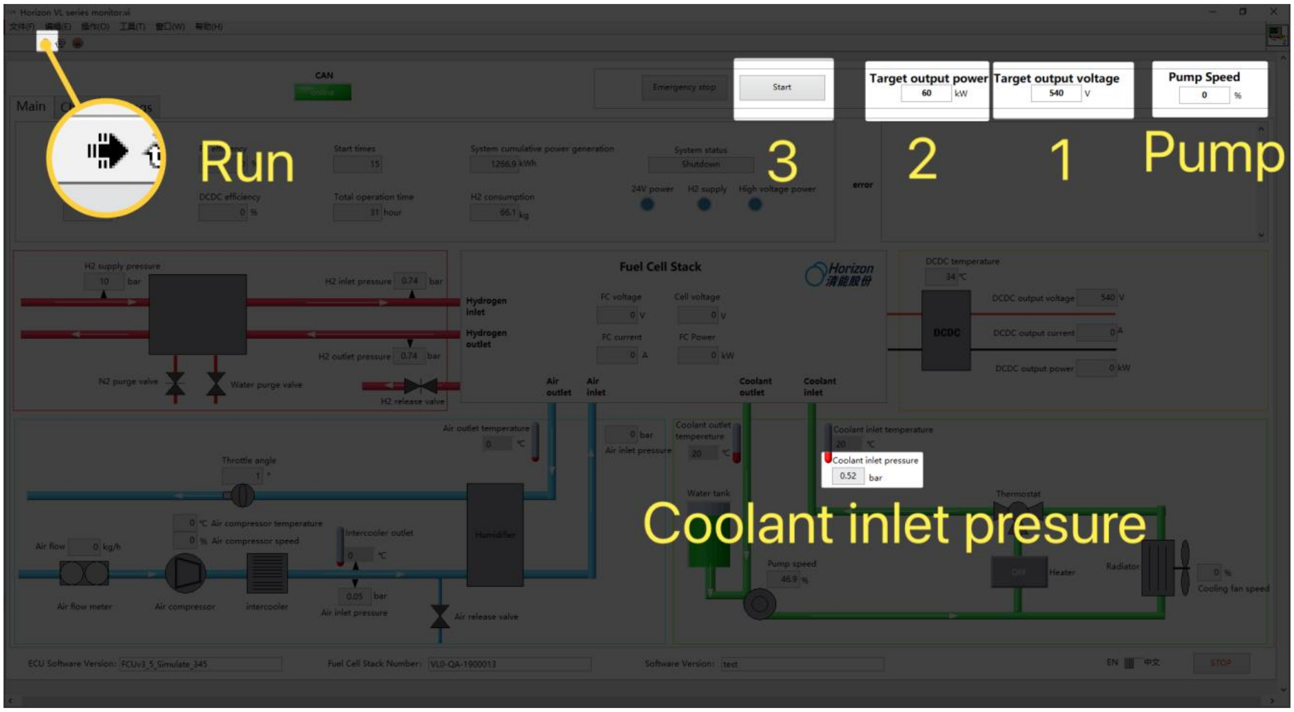


Fig4-1 Software operation interface

Start steps

(1) . Set the output voltage which is marked in 1；

(2) . Set the target power which is marked in 2；

(3) . Click the button which is marked in 3 to start the fuel cell system. If the system need to be stop, please click the button marked in 3 again.

Before run the fuel cell system, the water pump need to be turn on to expelling the air in the coolant line. When the coolant inlet pressure stabilizes between ±0.01 bar, it can be considered that the air in the coolant circuit has been emptied. The specific steps to set the pump speed and waiting time can refer to the following table. Make sure that the pump speed is 0 before start the Fuel Cell System.

Pump speed	10%	20%	30%	40%	50%	40%	30%	20%	10%	0%	50%
Waiting Time	2min	2min	2min	2min	2min	2min	2min	2min	2min	2min	2min

4.3 Monitoring system status

4.3.1 Main

On the main page, you can see various real-time observation values from the fuel cell system.

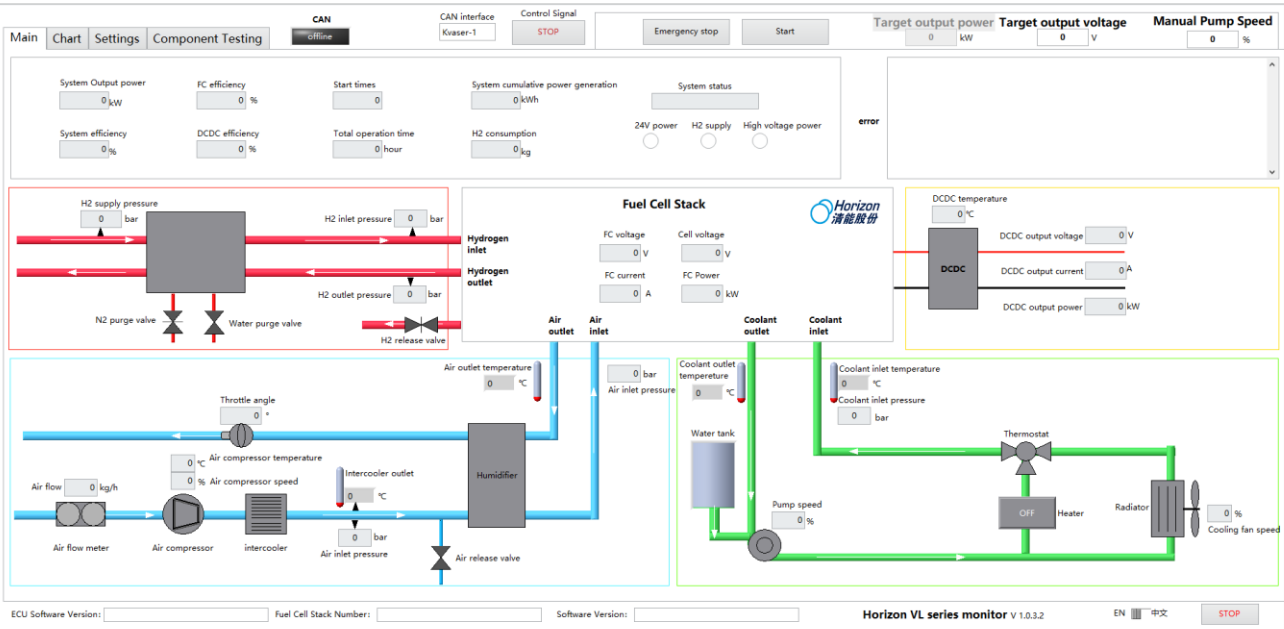


Fig4-2 Main interface

4.3.2 Chart

On the chart page, you can see the Historical data curve of some observed values. Both X axis and Y axis can change the axis range by modifying the numbers on both sides of the axis, Y axis supports mouse operation. When the mouse moves into the corresponding Y-axis range, the Y-axis can be zoomed in and out by the mouse wheel.

4: The option on the left side of the chart can be checked to show/hide the curve.

5: The box on the right is the curve setting option, you can change setting items

such as curve color

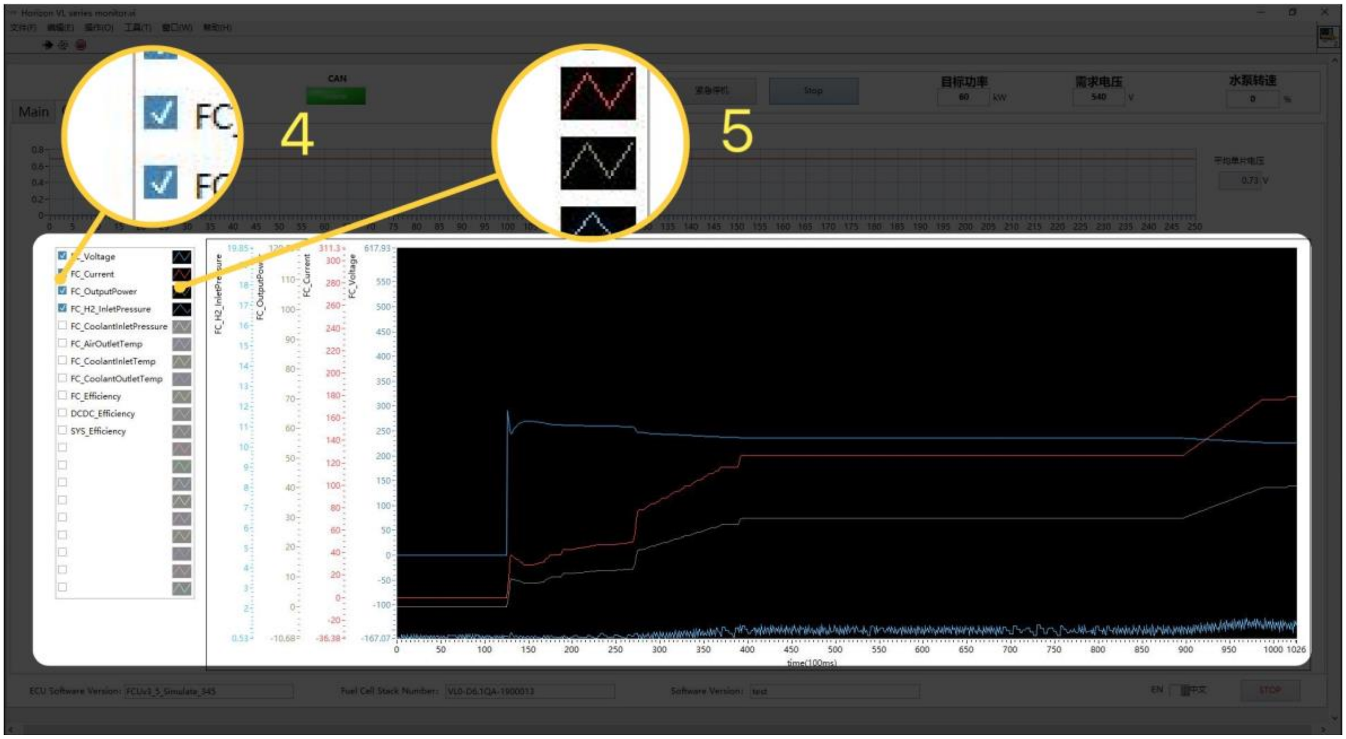


Fig4-3 Chart interface

4.4 Calibration parameters

This operation has a high risk and must be carried out under the guidance of Horizon Fuel Cell Technologies.

(I): Click the path selection icon to select the file. The calibration interface will appear when the correct file is selected.

(II): Click to select the parameter you want to modify, The selected row will be highlighted. Click the value again, and the value can be modified when it becomes the input state.

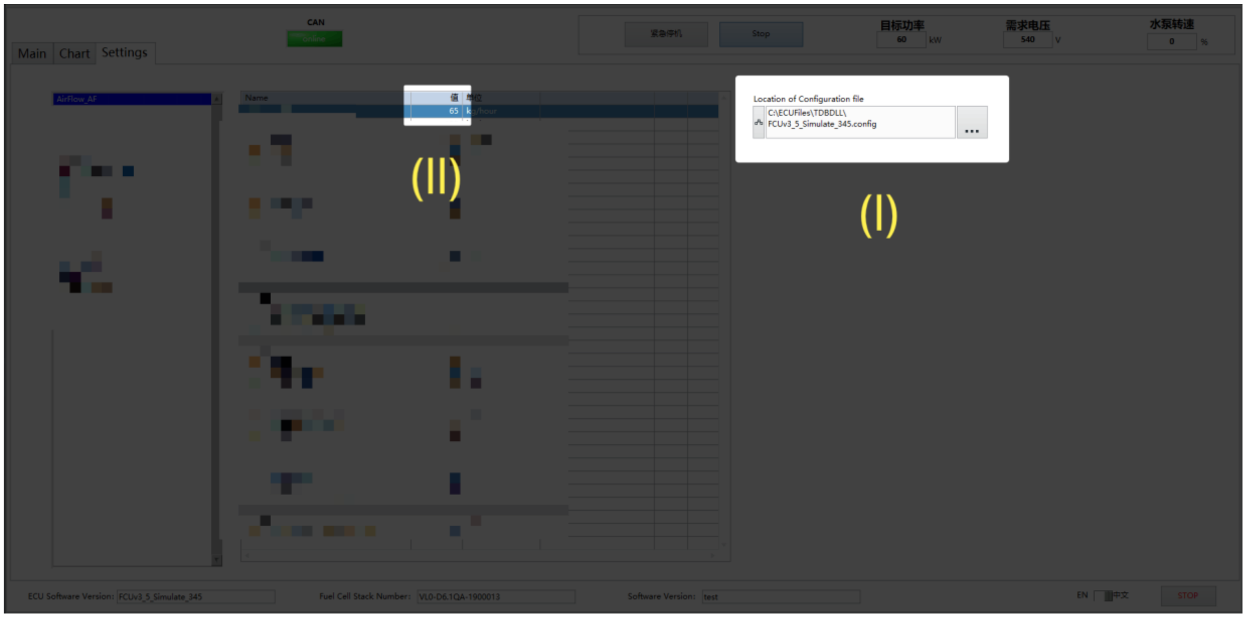
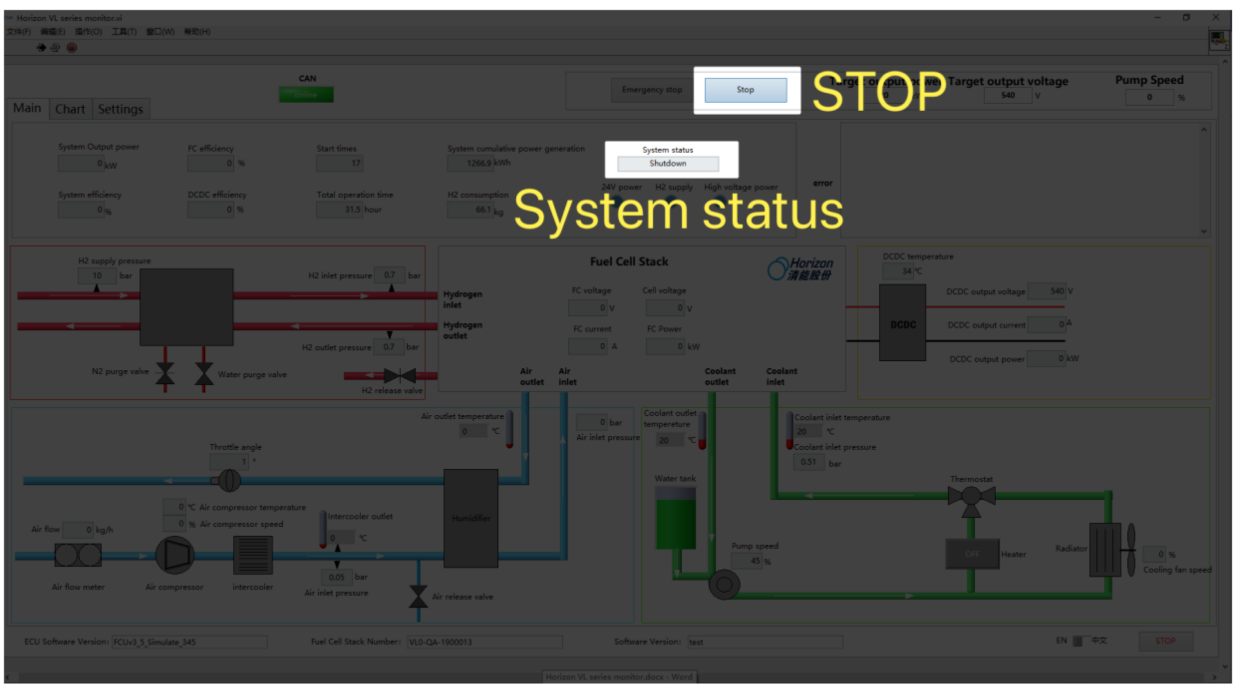


Fig4-4 Calibration parameters interface

4.5 System shutdown

Click the Stop button and wait for the system to execute the shutdown command. When the system status turn into standby, it means the shutdown command is over.



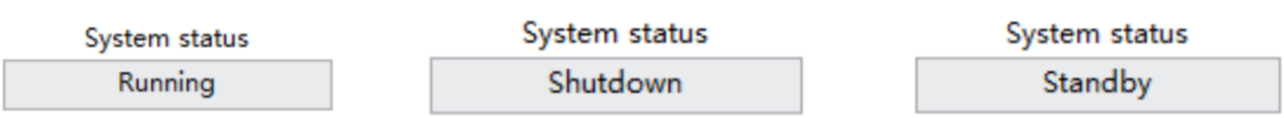


Fig4-5 Shutdown steps

4.6 Firmware update

When the stack is in self-check, standby and fault state, you can click the update ECU firmare button to update the program. Select the .srz file required by the update program and click start to start the update. After the program is updated, click update ECU firmare again to shrink the window before starting the operation.

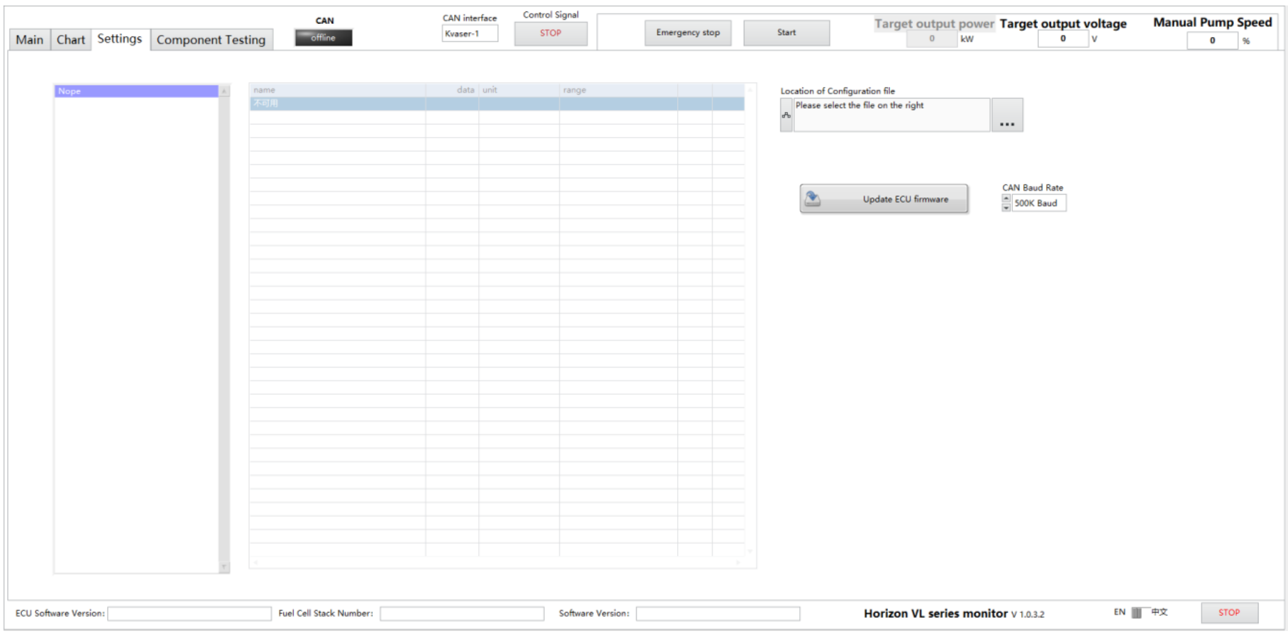
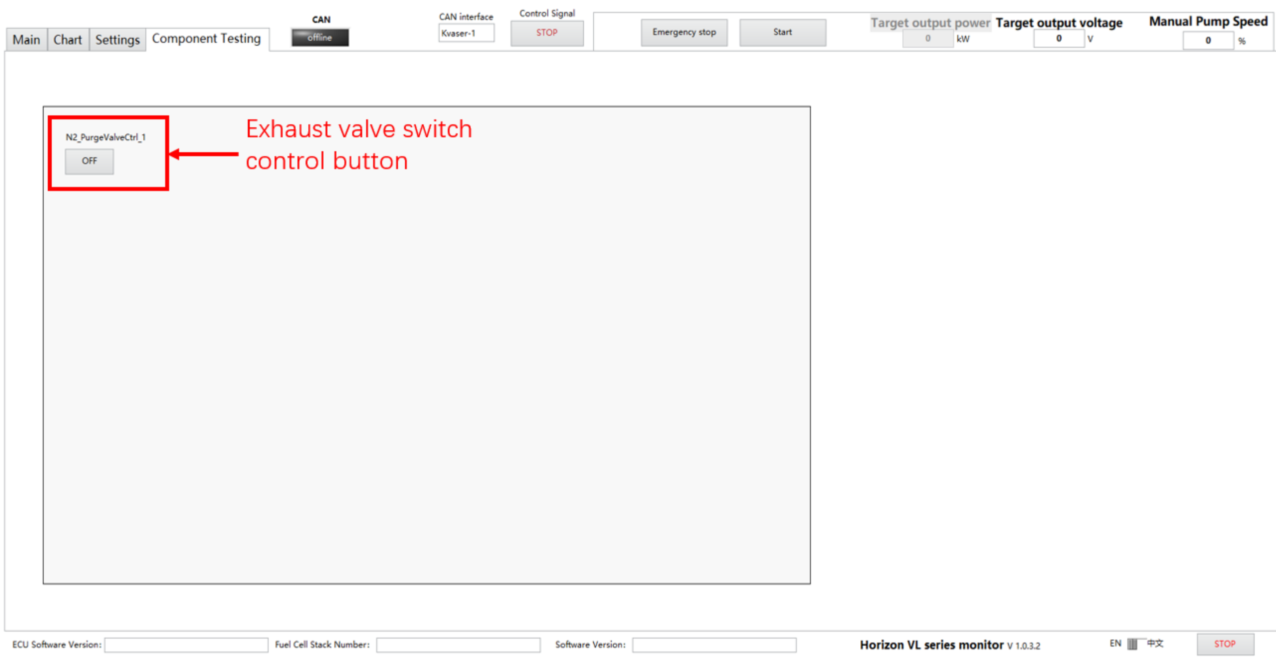


Fig4-6 Firmware update

4.7 Manually open the exhaust valve

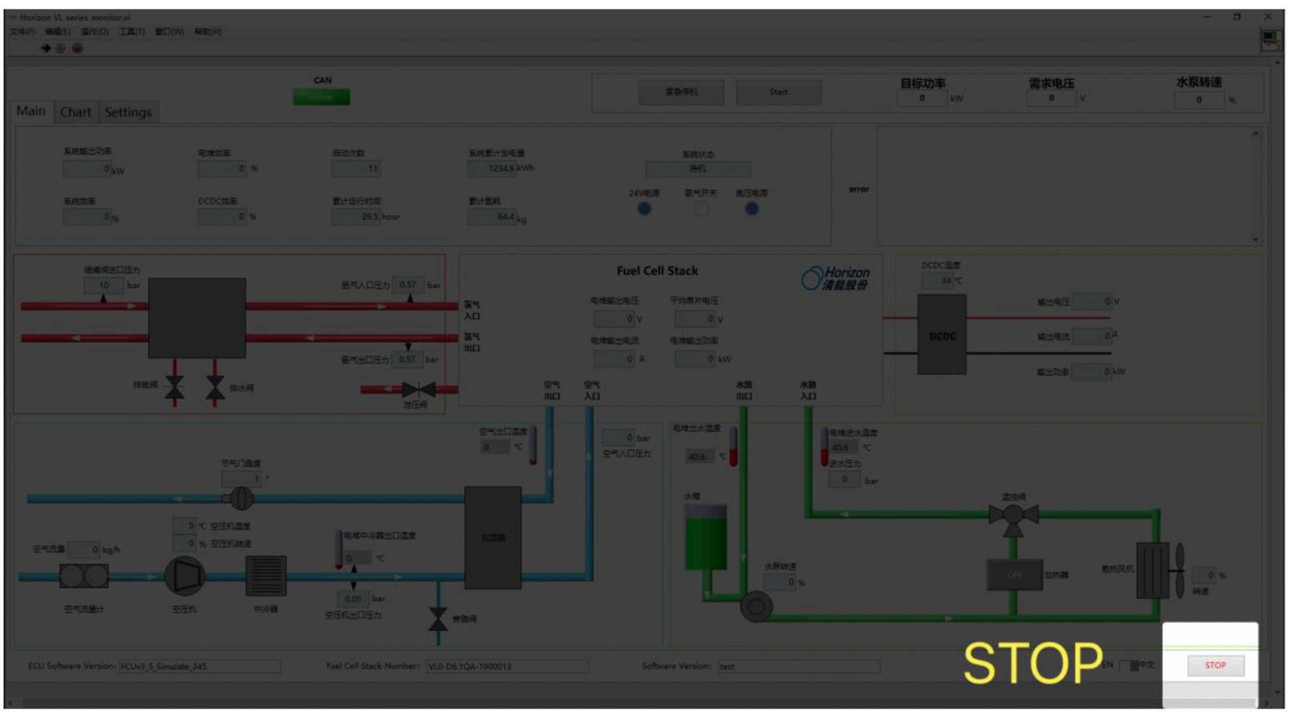
Before the pure hydrogen test, you need to manually open the exhaust valve, and then open the intake switch to ensure that the exhaust time exceeds 5s, and then close the exhaust valve (at this time the intake switch is normally open), then the system can be operated.

Component Testing is the control interface of the exhaust valve switch.



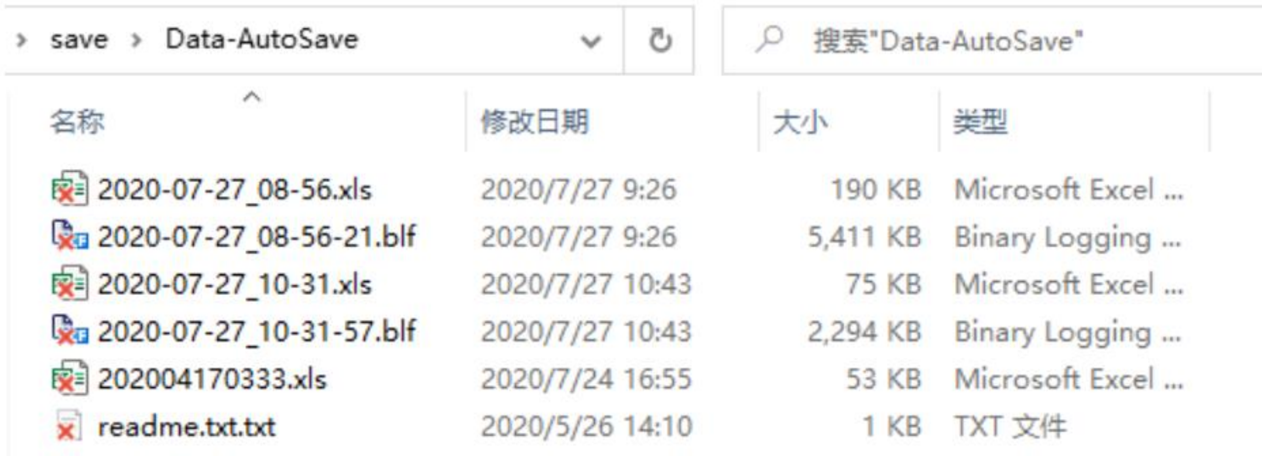
4.8 Stop Horizon VL series monitor

Click the STOP button to stop the Horizon VL series monitor software running.



4.9 Data record

After the program runs correctly, Labview will automatically save the datas to the folder named Save which belongs to the same foder where the application programmes located.



5. Precautions for system operation

5.1.1 Routine inspection before startup

The fuel cell engine system needs to be checked as follows before starting, but it is not limited to the following points:

1. Visual inspection of the stack module. Check whether the fuel cell stack module is damaged, deformed, etc., and whether there are scratches on the surface.

2. Check at the interface. There is no water leakage or looseness at the interface of the fuel cell system; the hydrogen pipeline joints are free of debris, and the fixing is firm and reliable; the stack cooling water inlet and outlet pipe interfaces are not loose or leaking; the air pipeline clamps are not loose, and the fixing is firm; the can line The external plug-in connection is normal and there is no looseness; the controller 24V low-voltage wiring harness is connected normally; the weak current connection line has no empty plug hanging in the air, and it is firmly fixed.

3. Check the water level of the water tank. The water level of the water tank needs to be within the normal water level. If it is not enough, add the specified coolant. Radiator check. Check whether the radiator is damaged or deformed, and whether there is leakage.

5.1.2 System operation process

During system operation, real-time monitoring of relevant parameters and status is required. The items that need to be monitored are: whether the communication is normal (with or without interference, delay or acceleration), output voltage and current, water inlet pressure, etc. You can view the real-time status of relevant data during system operation on the chart interface.

During the test, use the operating gap to check regularly whether the fuel cell system has any abnormal phenomena such as water leakage, gas leakage, hydrogen tail discharge or other abnormal noises, and report and deal with it in time, and check whether the water tank water level is normal every day; the user collects timely system operation data, download and record system data regularly; avoid running the system in areas with serious air pollution (such as black smoke, burning whip, heavy dust, etc.); no open flames are allowed around the system.

5.1.3 System fault reset operation

If the system reports related fault information during operation, to restore the system state to the standby state, you can do as follows:

1. Turn off the 24V power supply;
2. Turn on the computer according to the normal startup process again, and the system status on the display screen will be displayed as standby.

6. Maintenance and Repair

6.1 Maintenance of Fuel Cell System

The daily maintenance of the fuel cell system is divided into: daily inspection and maintenance, monthly inspection and maintenance and long-term parking inspection and maintenance. The following is a brief description in the form of a table.

Table 6-1： Daily Inspection and Maintenance Record of Fuel Cell System

No.	Maintenance item	Specific operation method	Estimated time	Note
1	After starting, observe whether the	start the vehicle after it is electrified, observe the	5min	Follow the system instructions

	parameters are normal	parameters through the display screen as well as visual inspection		

Table 6-2 Monthly Inspection and Maintenance Record of Fuel Cell System

No.	Maintenance item	Specific operation method	Estimated time	Note
1	High and low voltage electrical components	Check whether the high and low voltage plug-in is loose, whether the wiring harness is firmly fixed, and whether there is wear	5min	Timely feedback if any abnormality is found
2	System component fixation inspection	Check all parts for fastness and bolts for looseness	5min	
3	Radiator and air filter inspection	Check the radiator and air filter for any blockage	5min	
4	Check the level of coolant	Visually check tank level	1min	When it is below the level, fill the antifreeze timely to the level no higher than the line

Table 6-3 Fuel Cell System Long-term Parking (more than 30 days) Maintenance Record Sheet

No.	Maintenance project	Specific operation method	Estimated time	Note
1	Long downtime before storage	Make sure the fuel cell is normally shut down and purged, and the 24V power supply is closed. If deionized water or purified water is added, please drain the coolant in the	10min	(special antifreeze for fuel cell must be used when the lowest ambient temperature is

		pipeline		below 5°C)
2	Check fuel regularly	Open the 24V handle switch, start the fuel cell to work for more than 20 minutes, and then shut down the vehicle normally	30min	The fuel cell starts and stops once a month

7. Transport and storage

7.1 System transport

➢ Products in the transport process should not be violent vibration, impact and inverted.

➢ The transport temperature is within the -40°C to 65°C range.

➢ Products should be able to adapt to sea and air transport conditions.

➢ Products should be sealed packaging and other protective measures to avoid unnecessary damage while it is in sea and air transport conditions.

7.2 System storage

➢ Safe and reliable storage sites or warehouses should be provided to prevent damage. The product should have proper method of receiving and distributing the goods in the storehouse.

➢ Products placed in a ventilated and dry environment, storage temperature in the -40 ℃ to 65 ℃ range. In the case of normal storage, since the factory date within six months, if it is rust or damaged, the factory should be responsible for the products.

7.2.1 Short time Storage

➢ When the store environment temperature is < 30 ℃, the performance attenuation is slow, we recommend to operate the stack with 80% load for 1 hour to maintain performance monthly.

➢ When the store environment temperature is > 30 ℃, it should be sealed storage and we recommend to operate the stack with 80% load for 1 to 2 hours to maintain performance every two weeks.

7.2.2 Long time Storage

For the long time storage, the performance degradation is inevitable but it can be recoverable and the recovery time is longer than the normally used stacks. There are two ways to recovery for the stacks stored for a long time.

- First, make sure the hydrogen supply is enough. Second, connect load to let the system output 20% total power for 3 minutes. Then shut down the system and restart after few minutes. Operating at 40% total power for 3 minutes. Shut down again and repeat the steps until the power is up to 80% total power, operate the system for 1 to 2 hours.
- Make sure the hydrogen supply is enough and let the stack in the process of gradual load to restore its performance slowly by exhaust and short-circuit control.