



HETS-AEM-S SERIES ELECTROLYZER TEST SYSTEM

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1. Product Overview

The HETS-AEM-S series is aimed at providing an accurate, reliable and convenient test platform for hydrogen production with AEM electrolyzers. The system features back pressure up to 3.2Mpa. The system consists of electrolyte circulation system, nitrogen purging unit, pressure regulating unit, gas-water separation unit, flow monitoring unit, PLC sampling and control unit, HMI, safety monitoring unit, etc. It adopts the test software independently developed by our company, and it meets AEM electrolyzer performance, durability, reliability and safety test requirements.

The HETS-AEM-S series products have indoor bench-type, outdoor skid-mounted type and outdoor containerized type available based on customer requirements.



Bench type



Containerized

2. Product Features

- Automatic back pressure control for H₂ and O₂.
- Rapid and accurate regulation of circulant temperature and flow.
- Precise control over a wide range of power conditions of 10%~150%.
- A variety of safety protection measures for: load shedding, sudden unloading, rapid cutting off, temperature reduction, voltage reduction.
- Efficient gas-water separator design.
- Nitrogen purging, online monitoring of gas concentration, automatic DI water replenishment, gas cooling/ drying/ filtering, etc.
- Cell voltage monitoring.
- Data acquisition and analysis capabilities.
- Automatic operation mode, supporting long periods of unattended work.

3. System Composition

The test system applies to performance test, durability test, reliability test, safety test and other R&D and EOL tests for AEM electrolyzers.

The following page is the diagram of the system design (for reference only).

The test system mainly consists of the following parts.

1. Circulation System

Driven by the circulating pump, the electrolyte inside the system first enters the inlet of the anode and then flows out from the outlet of the anode of the electrolyzer, passes through the gas-water separator, accumulates at the bottom of the gas-water separator, and finally returns to the inlet of the circulating pump. The reaction inside the electrolyzer and the hydrogen consume the DI-water, which is replenished by the make-up pump under the control of the separator liquid-level switch at the anode outlet.

2. Coolant Temperature Control System

The anode outlet temperature of the electrolyzer is controlled by a heat exchanger at the anode inlet. The coolant temperature control system mainly consists of the heat exchanger and control valves. Coolant from the coolant system takes away the heat in the system through the heat exchanger, and the flow of coolant is regulated by the control valve, thus regulating heat exchange capacity and therefore coolant temperature.

3. N₂ Purging Unit

Nitrogen is used as a system protection gas for purging and replacement in the hydrogen and oxygen pipelines of the electrolyzer test bench. The external nitrogen gas is connected to the cathode and anode pipelines respectively, and the air-controlled solenoid valve is switched on and off under specific conditions. Before starting the system, nitrogen purging is carried out to replace the residual air as well as condensate inside the pipelines, preventing the presence of excess air in the hydrogen pipeline. At the end of hydrogen production, the solenoid valves at the cathode and anode are opened to purge the pipeline and displace the residual hydrogen of high temperature and high moisture, preventing the accumulation of excess hydrogen as well as condensate after gas cooling. Upon system status exceptions, a shutdown process will be activated based on the status level, in which cases the pressure relief valve will open, the nitrogen inlet valve open, and pipelines be purged to protect the system.

4. Pressure Regulation Unit

The pressure at the cathode and anode is controlled separately with control valves so that the pressure is within a certain safety range of pressure difference, on which basis the hydrogen production efficiency of the electrolyzer is tested under different pressure conditions.

5. Gas Analysis Unit

Hydrogen flow from the electrolyzer can be measured online. In the meantime, the cathode and anode of the electrolyzer feature online monitoring of H₂ in O₂ and O₂ in H₂.

6. PLC Acquisition and Control Unit

This unit supports acquisition of monitoring information and control of the functional operation of the system, including the control program module, digital/signal acquisition module, digital/signal output control module, and communication data exchange module.

7. HMI

The system adopts our self-developed upper computer software with functions such as parameter display and setting, data storage, graphic display, data tagging, process scripting and interface customization. Employing the communication mode of Ethernet + switch, the system is able to support remote operation in the background; moreover, Ethernet communication boasts excellent anti-interference properties.

8. Safety Monitoring Unit

The test system is equipped with functions such as hydrogen leakage alarm, real-time monitoring of H_2 in O_2 and O_2 in H_2 , emergency stop switch, over-limit alarm for system operation parameters, and safety interlock.

4. System Functions

4.1 Test Functions

Test Item		Functional Conditions
Performance Test	Polarization curve	Current-voltage control, temperature/pressure/flow rate control
	Cell voltage and consistency	Cell voltage monitoring, current-voltage control, temperature/pressure/ flow rate control
Life Test	Constant current/ constant voltage test	Constant current, constant voltage control, temperature/pressure/ flow rate control
	Variable power test	Editable power settings, temperature/pressure/flow rate control
Gas Producing Efficiency and Quality	Hydrogen production (measured without water)	Gas flow/temperature/pressure monitoring, indoor hydrogen monitoring and alarming
	H2 in O2/ O2 in H2	Safety sampling at room temperature
	Energy consumption for hydrogen production	Voltage detection, temperature/pressure/flow rate control, power supply voltage and current measuring
Auxiliary function	Electrolyzer cleaning	Reduce the conductivity of the circulating water flowing through the electrolyzer before the test

4.2 Technical Parameters

The technical parameters are as follows:

Model		HETS-AEM-S-5K	HETS-AEM-S-10K	HETS-AEM-S-100K	HETS-AEM-S-1000K
Power (150%)		7.5 kW	15 kW	150 kW	1.5 MW
H2/O2 system module	Max. H2 flow	25 NLPM	50 NLPM	30 Nm ³ /h	300 Nm ³ /h
	H2 flow meter range ratio	100:1			
	H2 pressure range	0.1~3.2 MPa			
	Max. O2 flow	12.5 NLPM	25 NLPM	15 Nm ³ /h	150 Nm ³ /h
	O2 pressure range	0.1~3.2 MPa			
	Steady state pressure control accuracy	≤±0.5%F.S.			
	Differential pressure control range	Equal and differential pressure control for gas on both sides; differential pressure control ≤±50kPa in cases of equal pressure operation, and ≤3MPa in cases of differential pressure operation			
Circulation module	Flow range	0.5~5 NLPM	1.5~30 NLPM	0.5~9.3 m ³ /h	2~40 m ³ /h
	Flow control accuracy	≤±1%F.S.			
	Medium	Alkaline solution			
	Temperature control range	RT+5℃~95℃, control accuracy ≤±1℃(steady state)/±2℃(dynamic state)			

	Pre-heating rate	$\geq 3^{\circ}\text{C}/\text{min}$
	Automatic water make-up	Yes
Detection module	O2 in H2 sensor	0~5%vol, $\leq \pm 2\%$ F.S.
	H2 in O2 sensor	0~5%vol, $\leq \pm 2\%$ F.S.
Cell voltage monitoring	Detection channel	Up to 1024 channels, -5~5V@1mV
Complete system	Controller	PLC
	Communication protocols	Modbus, Ethernet, etc.
	Remote operation interface	LAN
	Power source	AC380V, three-phase five-wire
	Ambient temperature	5~45 $^{\circ}\text{C}$
Optional configuration	Online monitoring of lye concentration	Make up the lye when the concentration is too low
	Online monitoring of O2 in N2/H2 in N2	Detect O2 and H2 content in pipeline during N2 purging
	Online monitoring of O2 flow	Measured with water removed
	Customization of power supply for hydrogen production	Configure a power supply that meets the test requirements

Note: For products of 50kW and above, a full explosion-proof design is adopted.

4.3 Data Acquisition

In the test process, the test bench mainly records parameters as follows:

No.	Test Point	No.	Test Point
1	O2 in H2 content	7	Electrolyte temperature (into the electrolyzer)
2	H2 flow	8	Electrolyte flow (into the electrolyzer)
3	H2 in O2 content	9	H2-water separator level
4	Inlet and outlet pressure at the cathode/anode of the electrolyzer	10	H2-water separator pressure
5	Inlet and outlet temperature at the cathode/anode of the electrolyzer	11	O2-water separator pressure
6	Water tank level	12	O2-water separator level

4.4 Design Accuracy

No.	Name	Accuracy
1	Temperature sensor	$\leq \pm 0.5^{\circ}\text{C}$
2	Pressure sensor	$\leq \pm 0.5\%$ F.S.*
3	Lye flow meter	$\leq \pm 1\%$ F.S.
4	H2 flowmeter	$\leq \pm 1\%$ F.S.

5	O2 sensor	$\leq \pm 2\% \text{F.S.}$	
6	H2 sensor	$\leq \pm 2\% \text{F.S.}$	

*: Reference temperature: 25°C

4.5 System Safety and Emergency Handling

1) In cases of emergency, such as cell status exceptions, the monitoring parameters may change later than the operator perceives. In such cases, the operator may push the emergency stop button, and the system will control some key valves immediately and directly through the circuitry, cut off the power and gas source, and at the same time send the emergency switch status signal to the controller. Upon receiving the signal, the controller will run fault handling process immediately to ensure the safety of the cell, equipment and personnel.

2) The test system detects system operating status and displays fault information on the software interface.

4.6 Brands of Core Components

Name	Description	Brand
Separator, heat exchanger, water tank and other containers	Gas-water separation, heat exchange, electrolyte storage, etc.	Kewell
Back pressure valve	Back pressure control of hydrogen and oxygen discharge outlets, respectively	Equilibar, ASCO, Burkert or equivalent imported brands
Circulation pump	Drive electrolyte circulation and control its flow	CNP, Shinhoo, Suofu or equivalent brands
Solenoid or pneumatic valve	Control the output of hydrogen and oxygen systems	ASCO, CKD or equivalent brands
Filter	Filter impurities from hydrogen and nitrogen	FITOK, Modentic or equivalent brands
Check valve	Control the unilateral output of hydrogen and oxygen	FITOK, Modentic or equivalent brands
Hand valve	Flow on/off control	FITOK, Modentic or equivalent brands
Ferrule	Connections for small-sized pipes, valves, instruments, gas supply pipes, etc.	FITOK or equivalent brands
Hydrogen flow meter	Measure hydrogen output flow	Alicat/Bronkhorst/Emerson or equivalent brands
Liquid flow meter	Measure water circuit flow rate	ZHYQ/Xindongxing or equivalent brands
Pressure sensor	Detect pressure in the H2, O2 and water circuits	WIKA/ASHCROFT/Siemens or equivalent brands
Temperature sensor	Detect temperature in the H2, O2 and water circuits	ZHYQ, ISO/ASHCROFT or equivalent brands
Hydrogen sensor	Detect H2 content in O2	MICHELL or equivalent brands
Oxygen sensor	Detect O2 content in H2	All or equivalent brands

PLC	Data acquisition and control	Mitsubishi/Siemens
IPC	HMI	Ennoconn or equivalent brands
Cell voltage monitor (CVM)	Cell voltage monitoring, detection of input voltage/ current of the electrolyzer	Kewell
Test power supply	Supply power to the electrolyzer	Kewell or equivalent brands
Note: If affected by uncontrollable factors, an equivalent brand may be selected with the consent of the customer.		

5. Software Interface

5.1 Introduction to Software

1) Operating system

The upper computer software of the test system is applicable to running on various platforms (such as Microsoft Windows), including Windows7, Windows8, and Windows10. The standard equipment comes with I5 processor, 8G RAM, 1T hard disk drive, WIN10 system, screen display, the keyboard and mouse set, and office software.

2) Registration

The software initialization requires registration, which will be completed before leaving factory. Moreover, if the customer needs to install the software on other computer(s), the machine code(s) of the computer(s) shall be sent to Kewell, who will then return the serial number(s).

3) User permissions

The user permissions fall into three categories:

Admin: Users who have all software operation privileges and can add or delete other users;

Tester: Users who have battery test step editing and other operation permissions in the software but cannot modify software parameter settings;

Guest: Users who have basic test operation permissions in the software (such as importing step file) but cannot modify the step test content.

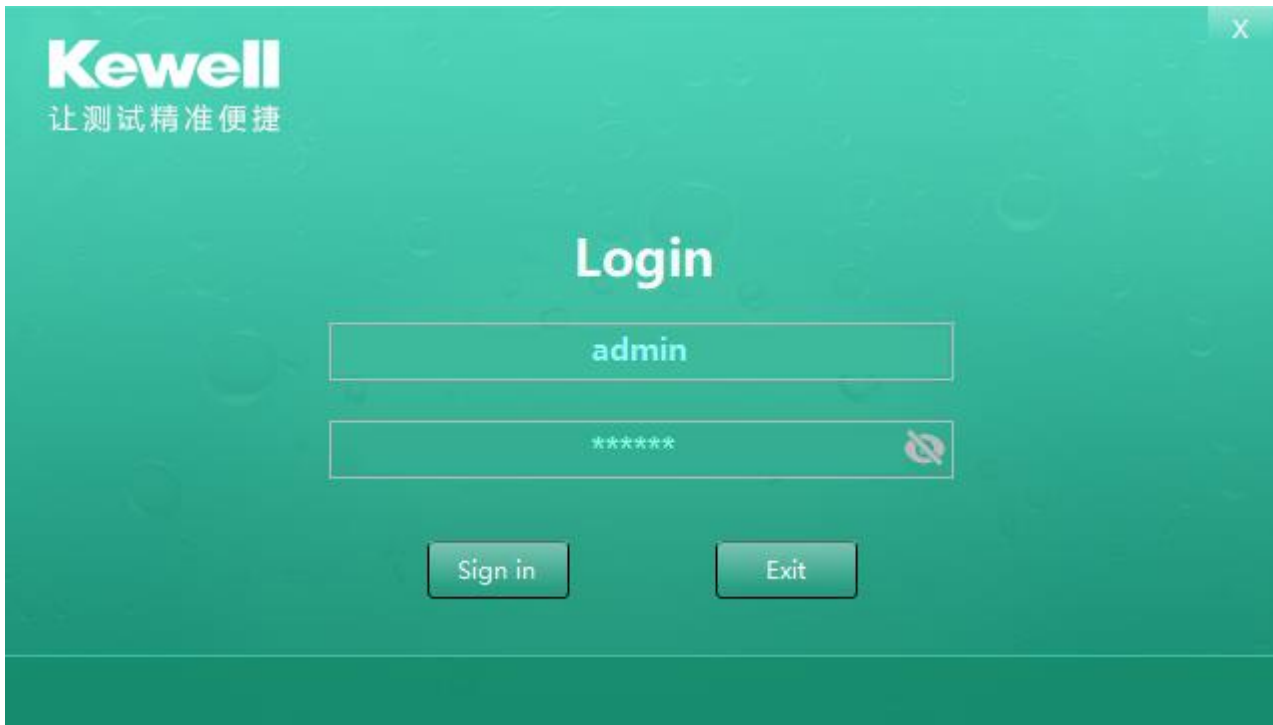
5.2 Software Functions

Function	Description
User management	Three levels of user permissions. Defined as: 1-admin, 2-tester, 3-guest. Users of each permission level can configure functions subject to their own level of permissions, and the upper limit of their configured permissions will not exceed the current user permission level.
Tag system	TestWell uses a "tag" system that manages all parameters in the system, including measurements, controls, calculations, and user inputs. Each parameter is assigned a unique tag name and all tags are managed in a tag database. The tag system integrates all the functional modules, and one module can be empowered to control another module. (For example, when running a script, you can enable equipment connection and pop up a certain user-defined interface)
Script compiler and runner	The script compiler and runner are applied to several modules (including: real-time formula module, safety alarm module, test script module, test status module). They support the use of user-defined control process and respond to changes in the system in real time and at high speed. The other modules implement real-time formula calculations,

	safety alarms, and other functions through different call-to-run mechanisms.
User-defined Interface	The user-defined interface module gives TestWell the freedom to read and write tags to control the entire test process and to present the process.
Data graphics	User-defined graphs support user-defined curve content and curve form, and can display real-time bar charts, sequence diagrams, X-Y charts, etc. When it is combined with "real-time formula", it can flexibly define the data representation of each scenario.
Alarm	According to the alarm judgement of the process control system, alarm prompts and alarm contents are given in the relevant position of the process display.
Storage module	The storage module contains a variety of test solutions, to which users can also add their own storage solutions, providing flexible support for variable data requirements.
Real-time formula	Real-Time formula provides a real-time calculation of tags, which can be triggered by a change in the tag that is an independent variable of the formula. It supports a wide range of computational symbols for high-speed and accurate calculations.
Safety alarm module	Corresponding safety configuration file has been included in the system. Users may also refer to the existing safety profiles and make secondary edits as needed for more detailed safety protection of the test system. "Admin" can set three levels of alarm thresholds on the upper computer to monitor the hardware and take action/warn the operator.
Component module	The component module provides PID control capability and can create multiple PID groups for a single controlled quantity, with each PID differentiated by condition for more flexible PID control.
Auto step module	It supports user-defined script as work steps for testing, supporting cycles, branches and feedback during execution.

5.3 Software Interfaces

5.3.1 Login



The main functions of the software are as follows:

- 1) Tag system: Tags are the core of using this software. The I/O tag library contains all the

available input/output tags in the system. It also includes system tags representing the start and stop of various operational modules. Users can control the start and stop of these modules using scripts (such as starting a device driver to establish a connection with the device). In the tag management interface, the tag sets visible with the current permission level of the user will be displayed (as shown in the following figure "full set of tags").

Tag name	Tag description	Current value	Unit	Change time	I/O type
equation_system_basic	For equation state control	false			Read/Write
safety_system_CVM Alarm	For safety state control	false			Read/Write
safety_system_DC Power Alarm	For safety state control	false			Read/Write
safety_system_PLC Alarm1	For safety state control	false			Read/Write
safety_system_PLC Alarm2	For safety state control	false			Read/Write
safety_system_PLC Alarm3	For safety state control	false			Read/Write
script_system_Activation_Single	tag=(stop,run,pause)				Read/Write
script_system_Dropload	tag=(stop,run,pause)				Read/Write
script_system_Dropload_Direct	tag=(stop,run,pause)				Read/Write
script_system_Power_trans	tag=(stop,run,pause)				Read/Write
script_system_Test_All	tag=(stop,run,pause)				Read/Write
script_system_Test_Durability	tag=(stop,run,pause)				Read/Write
script_system_Test_Polarization	tag=(stop,run,pause)				Read/Write
Activation_Max	Upper limit of activation	0			Read/Write
Activation_Min	Lower limit of activation	0			Read/Write
Activation_Mode	Activation power supply mode	0			Read/Write
Activation_Rise	Gradient value	0			Read/Write
Activation_Stay	Duration	0			Read/Write
Activation_Stay2	Duration of peak in load ramp-up	0			Read/Write
Area	Active area	0	cm2		Read/Write

2) Customizable charts, allowing users to define numerous graphical combinations, where each combination can utilize multiple tags at the same time. The divisible graphics can be split into multiple graphs, and users can customize their position on the screen.

Express name	Edit privilege	Express description	Value
1 <input type="checkbox"/> Cur calculate	guest		Line 1: The s
2 <input type="checkbox"/> Current method flow rate	guest		Line 1: The a
3 <input checked="" type="checkbox"/> Density	guest		Grammar rec
4 <input checked="" type="checkbox"/> dewpoint calculate	guest		Grammar rec
5 <input checked="" type="checkbox"/> Power calculation value	guest		Grammar rec
6 <input checked="" type="checkbox"/> Unit energy consumption	guest	Unit energy consumption	Grammar rec
7 <input type="checkbox"/> Vol calculate	guest		The result ta

3) Script customization using a mature logic control language. The equipment comes with dedicated script editing software with complete programming capabilities.

Script editor

Script content

```

1  Test_State=1;
2  bool booltemp=true;
3  double timetemp=systemtime();
4
5  if(Polarization_Mode==0)//Mode selection, 0: constant current
6  {
7      if(DC_iPowerModeSet_CC==false)//Power mode setting: constant current off
8      {
9          DC_iPowerModeSet_CC=true;//constant current on
10         wait(500);
11         DC_CurSet=DC_iCur;
12         DC_VolSet=10;
13     }
14     if(DC_iPowerStuSetOn==false)//Power on: false
15     {
16         DC_iPowerStuSetOn=true;//Power on
17         wait(2000);
18     }
19     DC_CurSet=Polarization_Min;
20
21     timetemp=systemtime();
22     while(systemtime()-timetemp<Polarization_Stay*1000)
23     {
24         wait(10);
25     }
26     /*Wait for the current to reach the set value*/
27     if(DC_iCur<0.05)
    
```

Script name
Polarization_Test

Script description
Polarization curve

Group
Test

Edit privilege
admin

Access privilege
guest

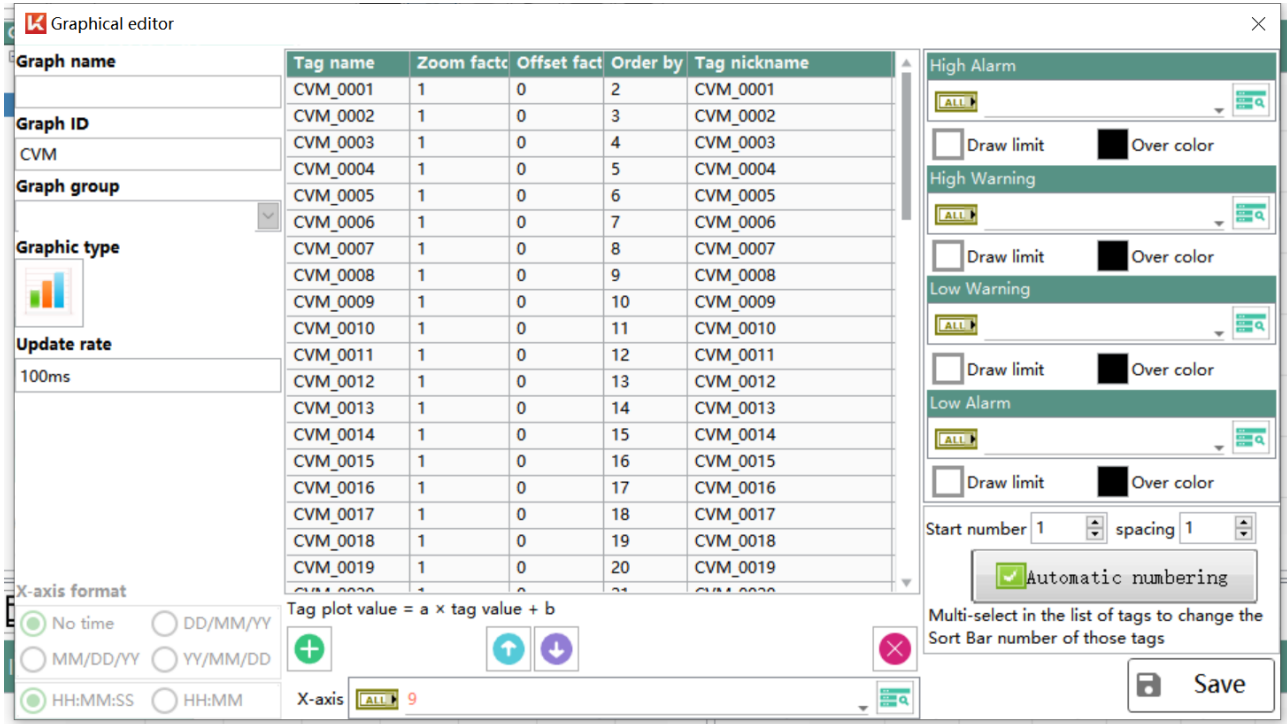
Interface
GUI_system_Polarization_Test

Cache
Initialize custom variables each time it runs

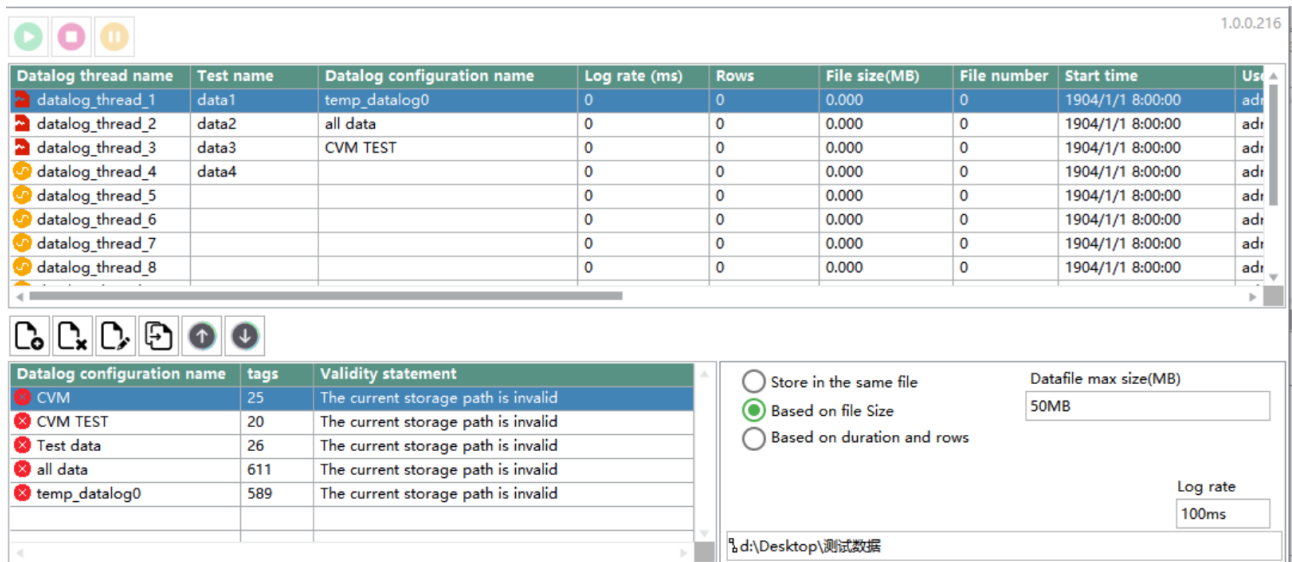
Grammatical information

Numeric oper	
+	Addition: a+b
-	Subtraction: a-b
*	Multiplication: a*b
/	Division: a/b
%	Modulo operation: a%b
pow()	Exponential operation: a^b
sqrt()	Square root: sqrt(a)
sin()	Sine, the parameter is the angle
cos()	Cosine, the parameter is the angle
tan()	Tangent, the parameter is the angle
cot()	Cotangent, the parameter is the angle
ln()	Natural logarithm: ln(a)
log()	Logarithm with the base 10: log(a)
abs()	Absolute value: abs(a)
ceiling	Ceiling: ceiling(a)
floor	Floor: floor(b)
sizeof()	Get Size: sizeof(a)
Logical oper	
=	Assignment expressions
	Or logic: a b
&&	And logic: a&&b
==	Equal: a==b
!=	Not equal: a!=b
<	Smaller than: a	Larger than: a>b

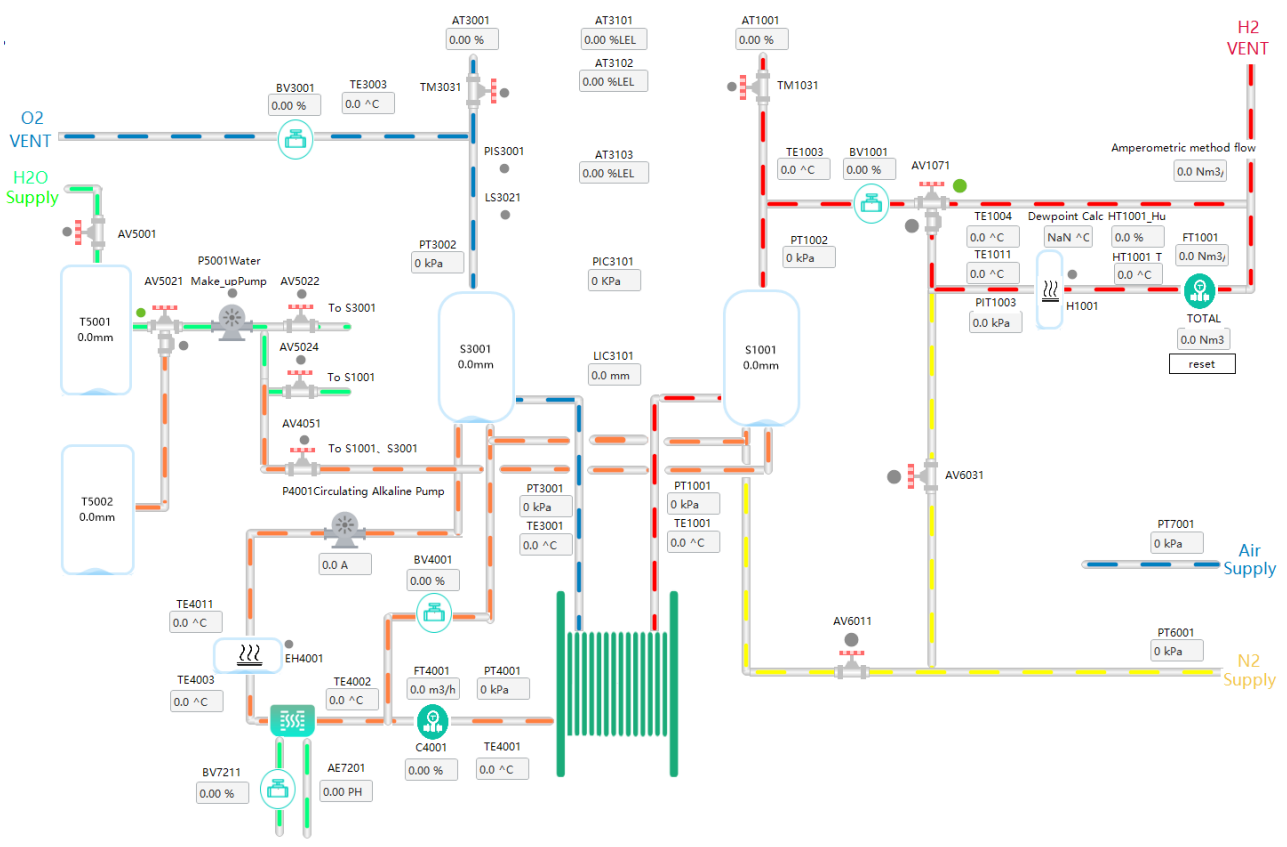
4) Function allows users to create mathematical equations and perform basic function operations. It supports user-defined equations and statistical calculations. Through customizable equations and automated scripts users can monitor the defined calculation variables in real-time and set alarm conditions based on these variables.



5) Independent data loggers, up to 8 separate sets of data logging can be executed simultaneously. Each data logger can log an unlimited amount of data and can be automatically turned ON/OFF through automated script files.



6) Custom interface, users can add and edit interface content, including but not limited to display content, position, size, and color.



7) Curve editing, users can add curves to be displayed through tags, and set the curve format, such as point type, line type and width, and so on.

Graph name	Tag name	Zoom factor	Offset factor	Order by	Tag nickname
	CVM_0001	1	0	2	CVM_0001
	CVM_0002	1	0	3	CVM_0002
	CVM_0003	1	0	4	CVM_0003
	CVM_0004	1	0	5	CVM_0004
	CVM_0005	1	0	6	CVM_0005
	CVM_0006	1	0	7	CVM_0006
	CVM_0007	1	0	8	CVM_0007
	CVM_0008	1	0	9	CVM_0008
	CVM_0009	1	0	10	CVM_0009
	CVM_0010	1	0	11	CVM_0010
	CVM_0011	1	0	12	CVM_0011
	CVM_0012	1	0	13	CVM_0012
	CVM_0013	1	0	14	CVM_0013
	CVM_0014	1	0	15	CVM_0014
	CVM_0015	1	0	16	CVM_0015
	CVM_0016	1	0	17	CVM_0016
	CVM_0017	1	0	18	CVM_0017
	CVM_0018	1	0	19	CVM_0018
	CVM_0019	1	0	20	CVM_0019
	CVM_0020	1	0	21	CVM_0020

High Alarm: Draw limit Over color

High Warning: Draw limit Over color

Low Warning: Draw limit Over color

Low Alarm: Draw limit Over color

Start number 1 spacing 1

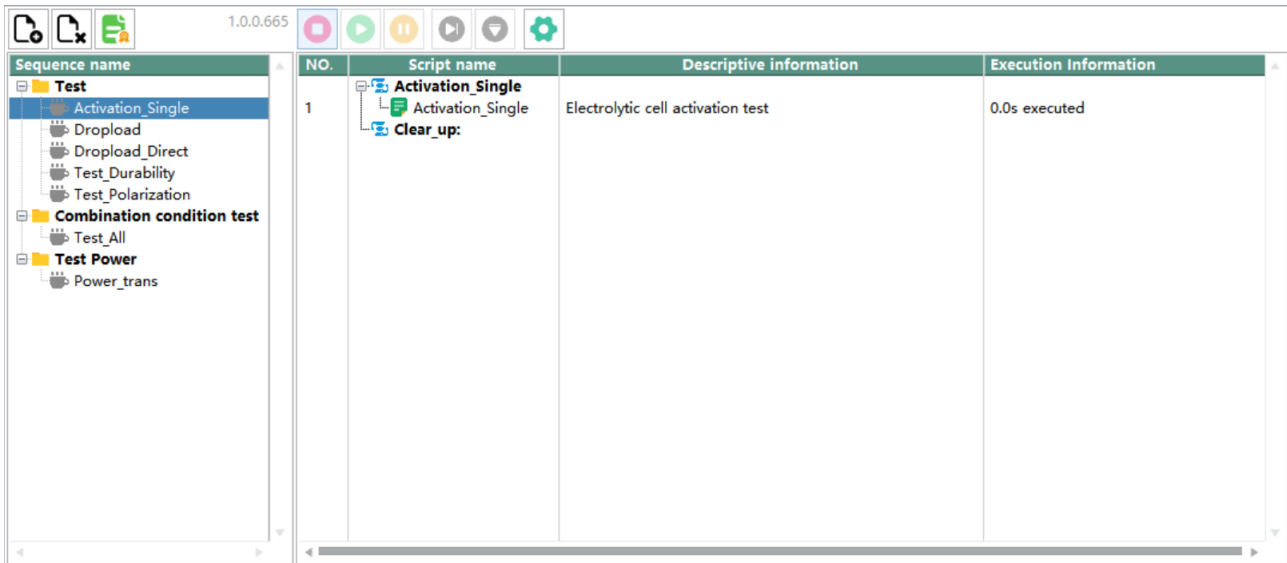
Automatic numbering

Multi-select in the list of tags to change the Sort Bar number of those tags

Save

8) Sequence function, based on steps, i.e., edit the operating conditions for each step, such as nitrogen purging flow and purging time. Multiple steps constitute a complete test condition, which, like

the script customization function, supports unattended operation.



6. Equipment and Document List

6.1 Main Equipment Configuration List

No.	Type	Model	Qty.	Note
1	Electrolyzer Test System	HETS-AEM-S series	1	Composition: electricity control module, anode/cathode system module, sampling control unit, PC, safety module, CVM, etc.

Note: Including the TestWell test software.

6.2 List of Documents and Materials

No.	Print Documents	Qty.	Note
1	Packing List	1	Come with standard equipment
2	User Manual	1	Come with standard equipment
3	Maintenance Manual	1	Come with standard equipment
4	List of Spare Parts	1	Come with standard equipment
5	Product Factory Certificate	1	Come with standard equipment