Fuel Cell Test Station

Software User Manual

Version 1.3

2023/11/06

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1.   Introduction

This manual is for the operation of the Fuel Cell Test Station manufactured by SCITECH KOREA INC. The test station should not be altered by unauthorized disassembly or assembly by the user and must be operated safely following the procedures outlined in this manual. In case of malfunction during use, for safety reasons, the software and hardware should be immediately shut down. If repeated issues occur, refer to Chapter 7 and report to the manufacturer to discuss further procedures.

The manual includes the following contents:

Chapter 2: Basic Configuration of the Program

Chapter 3: Control of the User Manual

Chapters 4 and 5: Test Sequences and Automatic Control (Protocol)

Chapter 6: Program Configuration

Chapter 7: Procedures for Dealing with Equipment Malfunctions

2.   Getting Started

2.1   Hardware Connection

Before the main program loads, this software checks the hardware connections. Once all hardware is properly connected, the main program loads, and test station operation begins. Therefore, it is advisable to turn on all hardware before starting the program. If the hardware is not connected properly, click the 'QUIT' button to close the hardware connection window, recheck the hardware connection, and then restart the program. If hardware settings need to be modified, make the changes and save them in the configuration menu that appears later, and then restart the program.
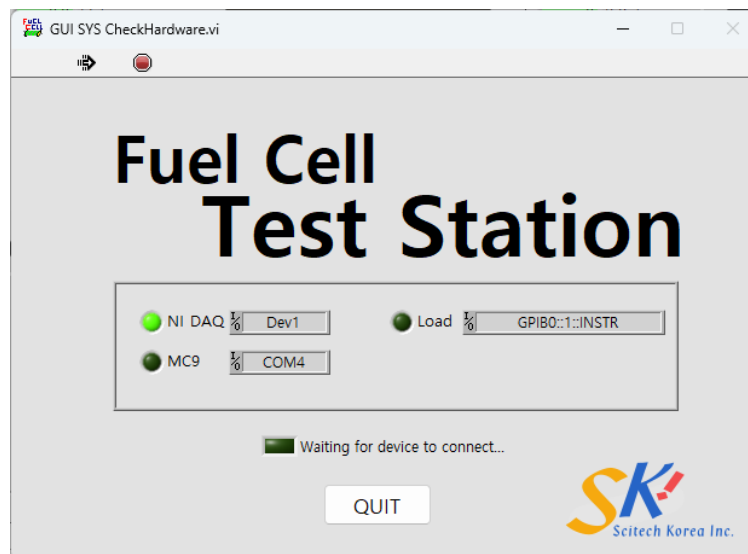
2.2   Start Up

Before starting the program, settings related to the log file can be made. The initial values of each item can be modified in the configuration menu.
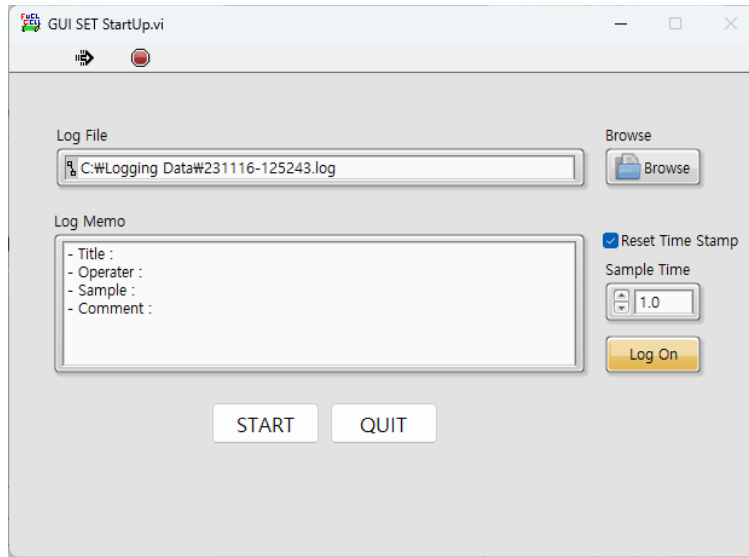
Log File: The default initial log file name is set in the [YYMMDD-HHMMSS] format. You can change the save path and filename by clicking the Browse button.

Log Memo: Simple notes related to the test can be added to the log file.
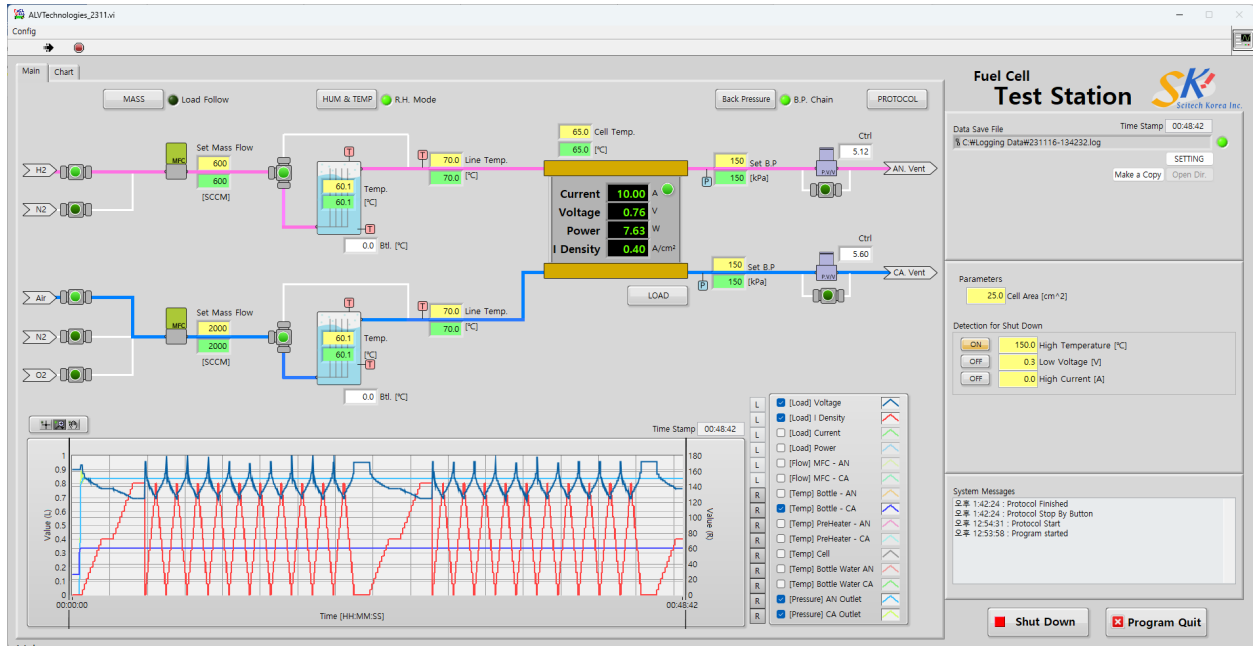
Reset Time Stamp: Sets the start time of the stored log to 0.

Sample Time: Sets the saving interval for logging data. The default is set to 1 second, and it can be adjusted in 100ms increments.

Log On: The storage of the log file can be set using a toggle button.

START & QUIT: Allows starting or exiting the program.

2.3   Main Panel

At the bottom right of the Main panel, there is a [Shut Down] button to reset the components of the test station to their initial state, and a [Program Quit] button to exit the program. The [Program Quit] button is programmed to perform a shut down before exiting the program, but for safety, it is strongly recommended to manually proceed with [Shut Down], verify the status of the test station, and then exit the program.

The upper left section is designed in a P&ID format for easy understanding of the current status of the test station. Here, you can check the set values (yellow) and sensed values (green) of each component. Surrounding the P&ID are buttons for operating the equipment, with their functions as follows (detailed usage can be found in chapters 3-5):

[MASS]: Sets the type and flow rate of the gas being used.

[HUMI&TEMP]: Sets the temperatures of the humidifier, line, and cell (or stack), thereby controlling humidity.

[Back Pressure]: Sets pressure levels for pressure testing.

[LOAD]: Sets the electrical load.

[Protocol]: Sets the system into automatic operating mode, using preset functions and additional features.

Located at the lower is a real-time chart where you can view the accumulated history of measured data. Through the signal list on the right side of the chart, you can select the display of signals and choose the left/right Y-axis.

On the right side, there are sections in the following order: Save file, Parameters, Shut Down setting, System messages.

Save file: Displays the saving path and status (LED indicator) of the log data. Directly opening a log file that is being saved by the running program can cause malfunctions. Therefore, if you need to check current log file, click [Make a Copy] to create a copy and then [Open Dir.] to open and check that copy.

Parameters: You can calculate current density (A/cm^2) by entering the Cell Area value.

Shut Down setting: Allows setting emergency shut down conditions based on temperature, voltage, and current.

System messages: Displays the operational status of the program, and errors occurring in the software can be checked here.

2.4　Chart Panel
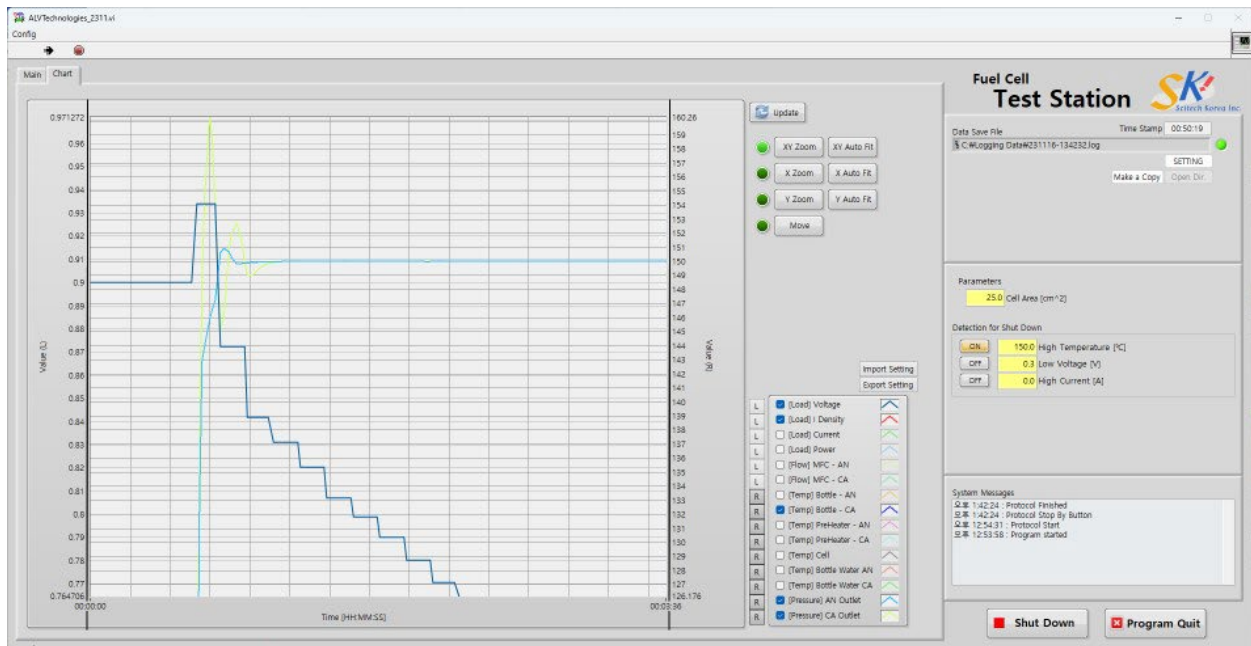
You can access the 'Chart' tab at the top of the main panel. This chart is suitable for analyzing fixed data. First, click the [Update] button to load the data recorded so far. Below the [Update] button, there are various buttons for graph analysis.

After selecting the [## Zoom] or [Move] buttons, you can enlarge or move the graph using mouse drag. Pressing the [## Auto Fit] button automatically adjusts the range of each axis to fit the data. This chart allows for independent signal display and axis selection, separate from the real-time chart. The [Import Setting] and [Export Setting] buttons enable you to import settings from the real-time chart or export the current chart settings to the real-time chart, respectively.

3. Manual Control (Ready to start)

In the configuration window accessible through the buttons on the main panel, you can set up the system's status. This is primarily used to establish the testing environment before beginning a test. Typically, you can adjust settings for mass flow rate, humidity, temperature, and back pressure, and if needed, settings for the electrical load can also be modified.

3.1   MASS (Mass Flow Control)
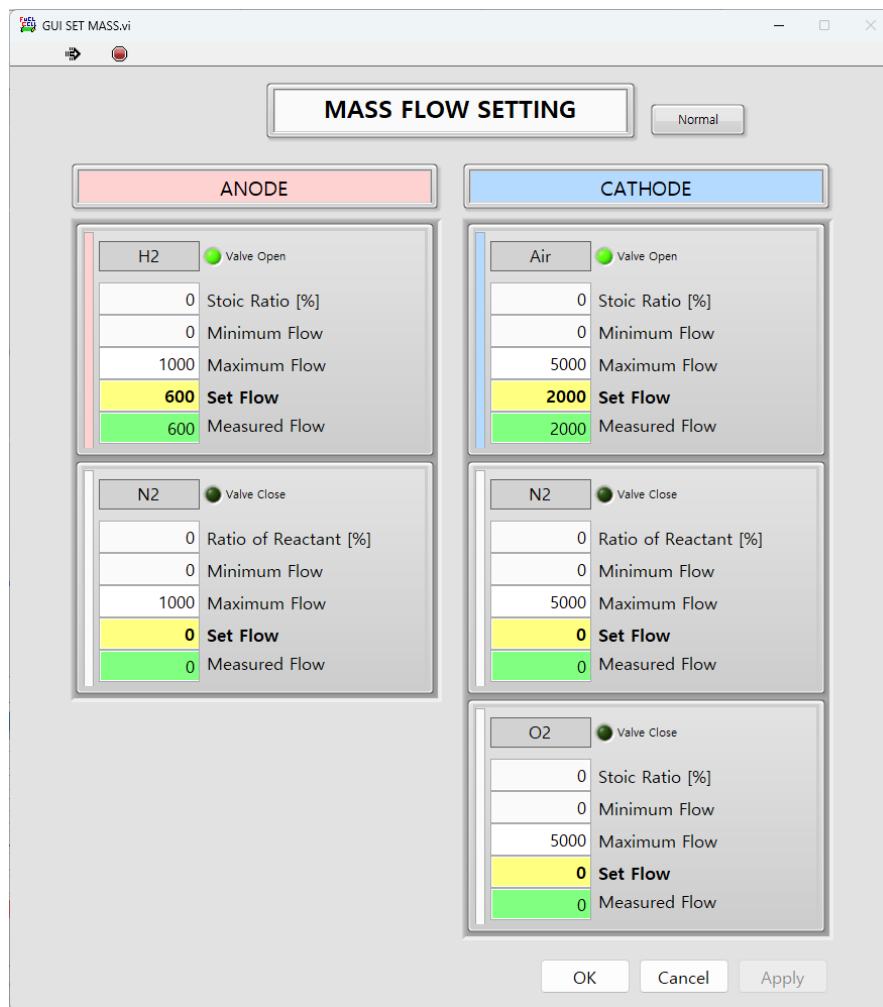
The settings can be adjusted in two modes: 'Normal' and 'Load Follow'. You can switch between these modes by clicking the [Normal] button at the top to switch to [Load Follow].

Normal Mode: Directly set the flow rate using Set Flow.

Load Follow Mode: This mode automatically adjusts the flow rate based on the current usage of the electric load connected to the cell or stack. Set the required flow rate ratio in Stoic Ratio. For example, to apply twice the required flow rate, enter 200%. In this mode, a minimum flow rate must be set. The default value is set at 10% of the MFC (Mass Flow Controller) range. This value can be modified. When using a non-reactant gas, the 'Ratio of reactant' is set, which refers to the ratio of the total flow rate of all reactant gases.

After entering the mode and values, complete the final settings by clicking the [OK] or [Apply] button.

3.2 HUMI & TEMP
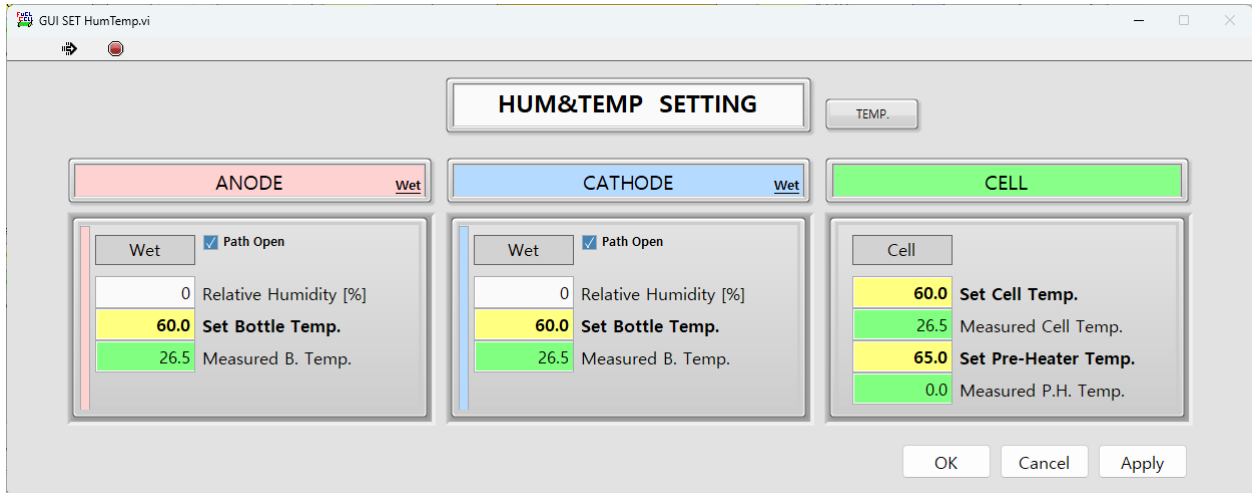
The humidification of gases for the Anode and Cathode can be set in either Temperature Mode or Relative Humidity Mode. To switch modes, click the [TEMP.] button at the top to toggle to [R.H].

**Temperature Mode:** Directly set the temperature for each humidifier on the Anode and Cathode.

Relative Humidity Mode: Set the relative humidity for the Anode and Cathode in percentage. The humidifier's temperature will automatically adjust to match the set relative humidity, based on the preset temperature of the Cell.

You can choose between Wet gas (humidified mode) and Dry gas (bypass mode) by clicking the 'Path Open' checkbox for each humidifier.

When you set the temperature for the Cell (or Stack), the temperature of the Pre-heater line is automatically set to +5 degrees Celsius. You can manually set the temperature of the Pre-heater line, but it cannot be set lower than the temperature of the Cell.

After setting the mode and values, click the [OK] or [Apply] button to finalize the settings.

3.3   Back Pressure
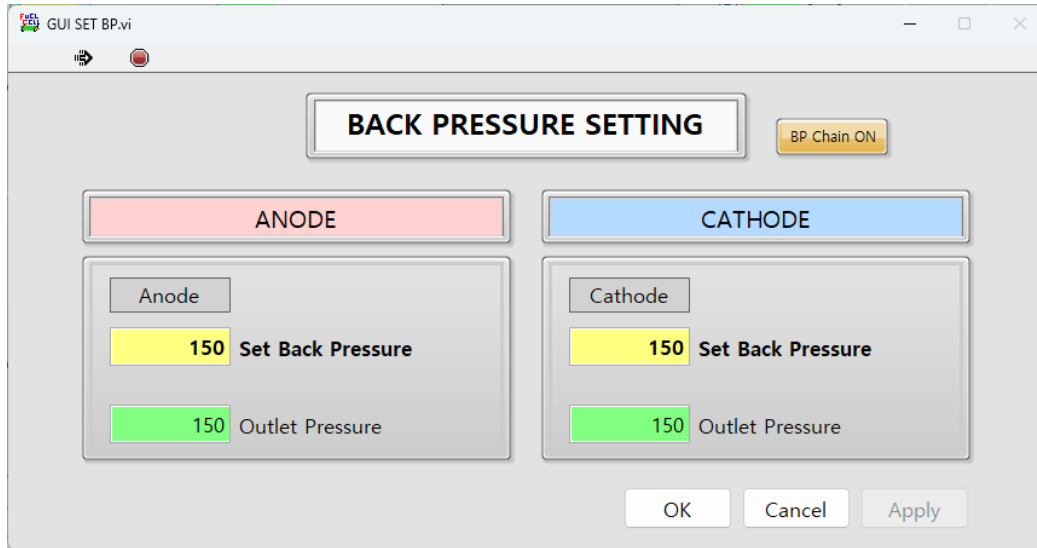
If pressurization is necessary, you can set the pressure for the Anode and Cathode lines. The 'BP Chain' mode can be turned on or off using the button at the top.

BP Chain ON: This mode minimizes the pressure difference between the Anode and Cathode to suppress any pressure disparity that might occur during pressurization. However, if the set pressure values differ or there is a significant flow rate difference, this mode may not operate correctly. In such cases, it is advisable to deactivate the BP Chain mode.

BP Chain OFF: Controls the pressure of each line independently. However, in this mode, a significant pressure difference between the lines might lead to damage to the Cell (or Stack) which cannot be prevented.
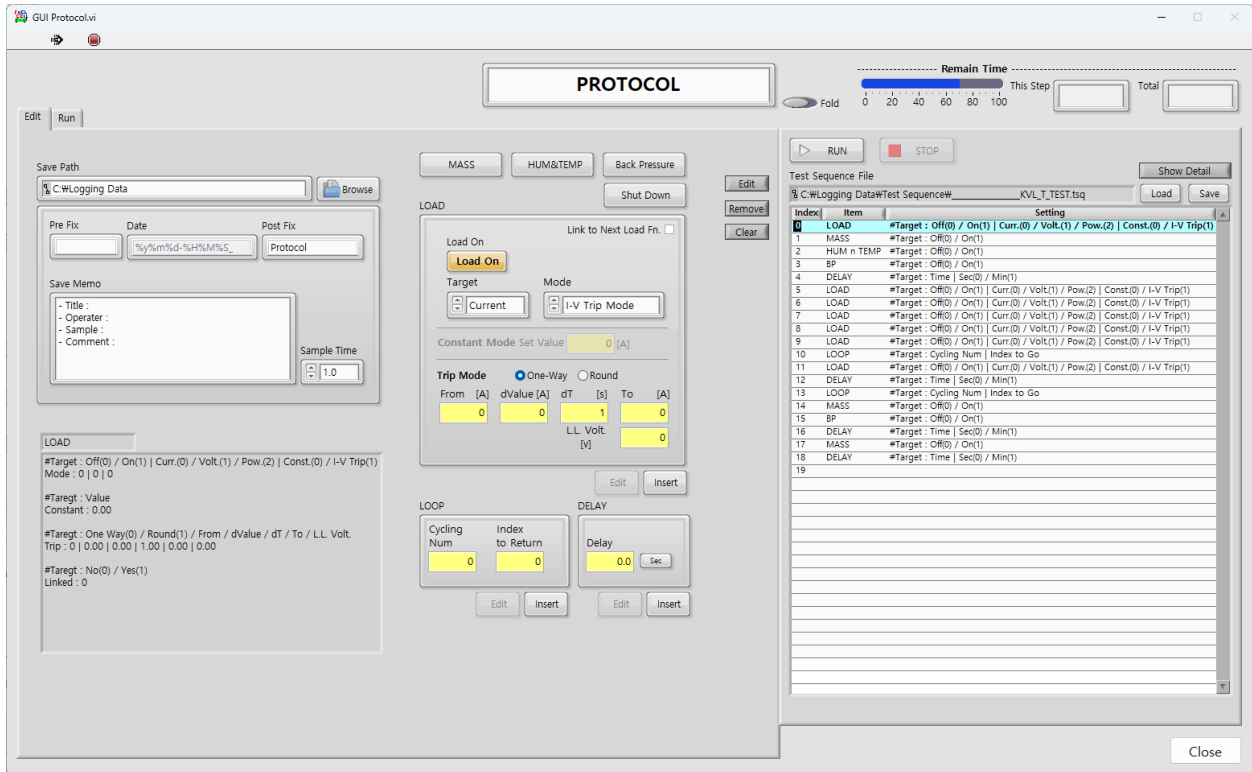
After setting the mode and values, click the [OK] or [Apply] button to finalize the settings.

3.4 LOAD
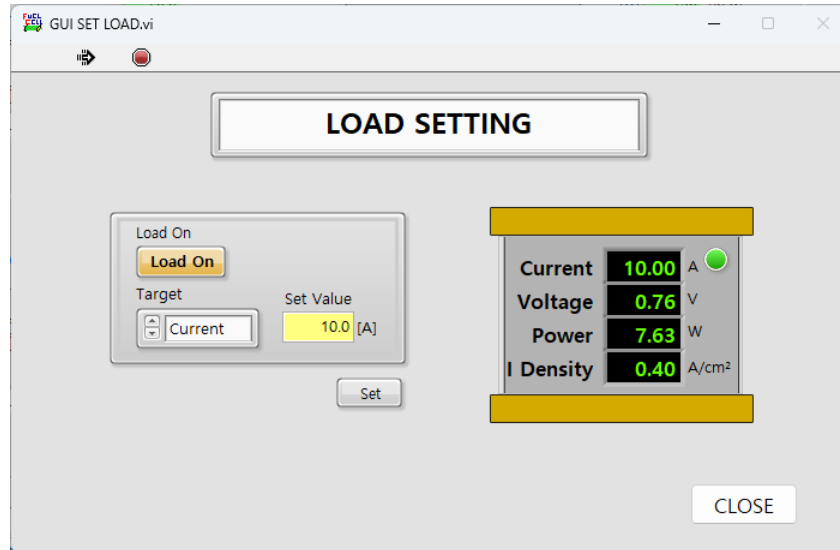
Here, you can remotely set the electrical load. After selecting the Load On/Off status, the target mode (Current, Voltage, Power), and entering the value, clicking the [Set] button activates the electric load.

4.   Automatic Control (Protocol - Edit)

In the protocol, you can write and execute test sequences according to user needs, utilizing gas flow, temperature and humidity, back pressure, and load operations for automatic execution. In the top left section, there's a setting area for the file where protocol results are saved. In the right section, you can review the written test sequences. The central section contains buttons and boxes for entering commands that go into the test sequences.

4.1   Save Path

The protocol data logging file is automatically saved while the protocol is in operation. The file name is automatically assigned in the format <Pre fix + Date + Post Fix>, and the save path can be changed by clicking the [Browse] button. Below, you can set a brief note and the save interval (Sample Time) through a box.

4.2　Test Sequence

4.2.1 Test Sequence Table

Above the Test sequence table are [Load] and [Save] buttons. You can click these buttons to load or save a Test sequence, with the file extension being '.tsq'. The Test sequence table consists of Index, Item, and Setting columns. The Index is automatically filled in sequence. The Item refers to the parameters you want to set, such as flow rate, pressure, and delay, while the Setting contains the values to be set. If you want to view more detailed input values, you can expand each row by clicking the [Show Detail] button at the top.

4.2.2　Run and Stop

To execute the protocol, press the [RUN] button, and the [STOP] button will be activated during execution. To stop the protocol, press the [STOP] button. However, be aware that each component of the Test Station will maintain its last operating state.
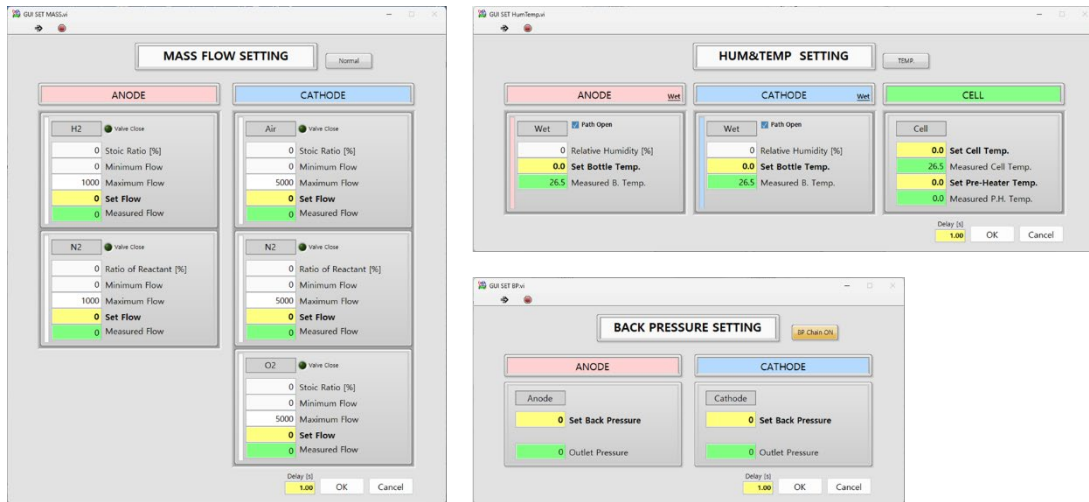
4.2.3　Edit, Remove and Clear

To modify or remove already entered content, select the desired row and then click the [Edit] or [Remove] button on the left side of the table. Use the [Clear] button to remove all contents of the table.

4.2.4　Insert

To add an Item to the Test Sequence, first select the row where you want to insert it. Then, after composing the desired Item, click the [OK] or [Insert] button. Detailed instructions for composing each Item can be found in the subsequent sections.
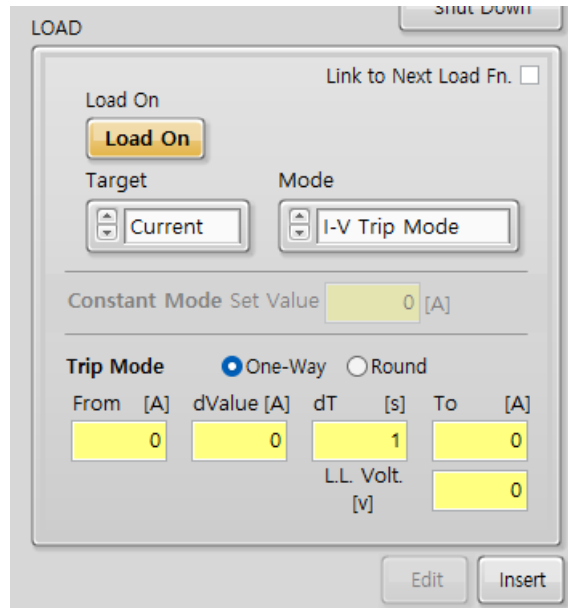
4.3   MASS / HUMI&TEMP / Back Pressure / Shut Down

The [MASS], [HUMI&TEMP], and [Back Pressure] buttons at the top of the central section open a settings window similar to the Manual Control described in Chapter 3. The usage is the same as previously explained. However, there is an option at the bottom to enter a Delay, which represents the time delay between the execution of a setting and the next one. The [OK] button can be used to insert these settings into the Test Sequence.

Clicking the [Shut Down] button inserts the command directly into the Test Sequence without a separate settings window, performing the function of resetting all components of the equipment. This is identical in function to the [Shut Down] button on the Main Panel.

4.4   LOAD

4.4.1   Load On / Off

You can turn the electrical load On or Off. In the Off state, the OCV (Open Circuit Voltage) of the Cell (or Stack) can be measured.

4.4.2   Target

Select the target for control among Current, Voltage, and Power.

4.4.3   Mode

For Current and Voltage, there are two modes available: Constant and I-V Trip. For Power, only Constant mode is available.

4.4.3.1   Constant Mode

This setting maintains the value of the Target constant.

4.4.3.2   Trip Mode

The Target value can be measured on the I-V Curve by increasing or decreasing in a stepwise manner.

In Trip Mode, you can choose between One-way and Round. One-way operates unidirectionally from the 'From' value to the 'To' value, while Round involves a round-trip operation, going from the 'From' value to the 'To' value and then returning to the 'From' value. When targeting Current, the L.L Volt. (Low Limit Voltage) setting window activates. During the operation from the 'From' to 'To' value, if the L.L Volt. is reached, the operation either ends at that point or returns to the 'From' value.

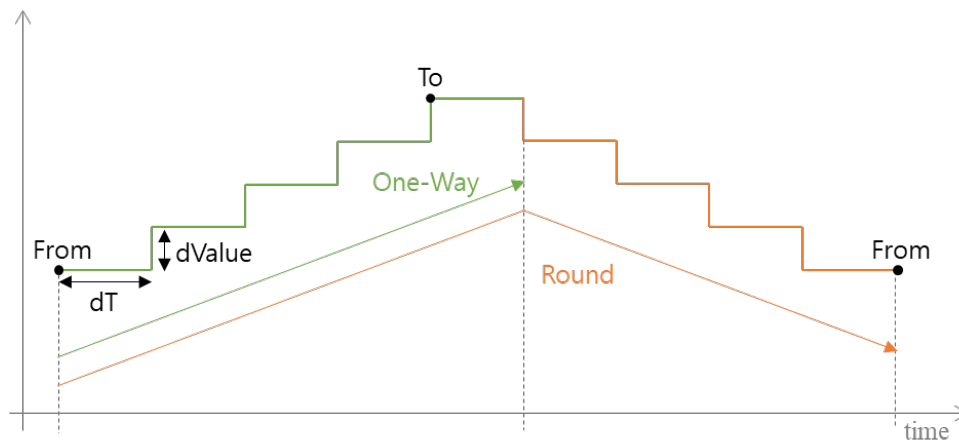**From:** The initial value at the start of the operation.

dValue: The value that changes during the operation. (delta Value)

dT: The interval time for changing the value. (delta T)

To: The final value to be reached from the 'From' value.

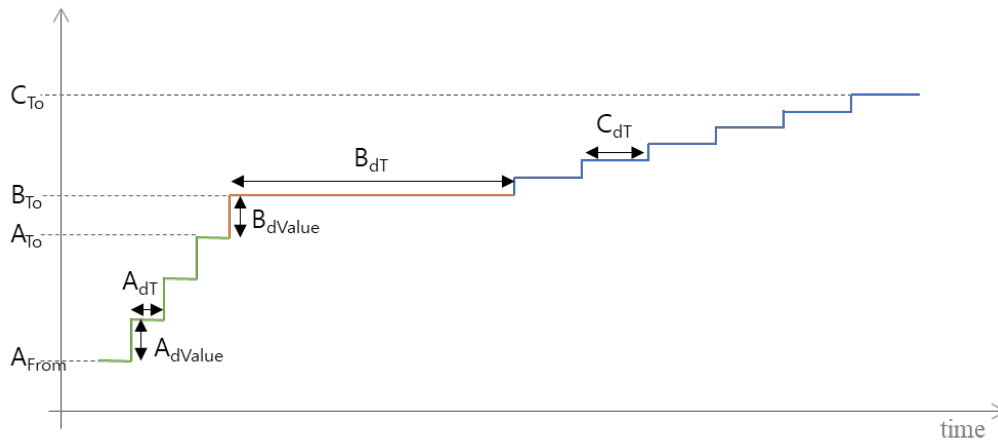**L.L Volt:** The minimum voltage value in the Current Trip Mode.

Thus, the operation starts from the 'From' value and changes by increasing or decreasing by 'dValue' every 'dT' time until it reaches the 'To' value. In Round mode, after reaching the 'To' value, it returns to the 'From' value by decreasing or increasing the 'dValue' every 'dT' time.
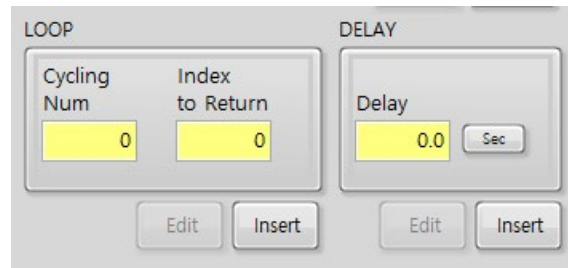
4.4.4 Link to Next Load Fn.

When this feature is activated, the I-V Trip function continues until the next Load Function. Essentially, it links multiple Load Functions together. For example, I-V Trips with different dValues or dTs can be treated as one, and even if a Trip is stopped by L.L. Volt, it moves on to the next Load Function. For a proper Trip chain to be completed, this feature must be deactivated in the last of the connected Load Functions. Below is a brief example of this.

	Link to...	Trip Mode	From	dValue	dT	To
Green	Checked	One-Way	A_{From}	A_{dValue}	A_{dT}	A_{TO}
Orange	Checked	One-Way	A_{TO}	B_{dValue}	B_{dT}	B_{TO}
Blue	Unchecked	One-Way	B_{TO}	C_{dValue}	C_{dT}	C_{TO}

To insert or modify values in the Test Sequence, simply click the [Insert] or [Edit] buttons.
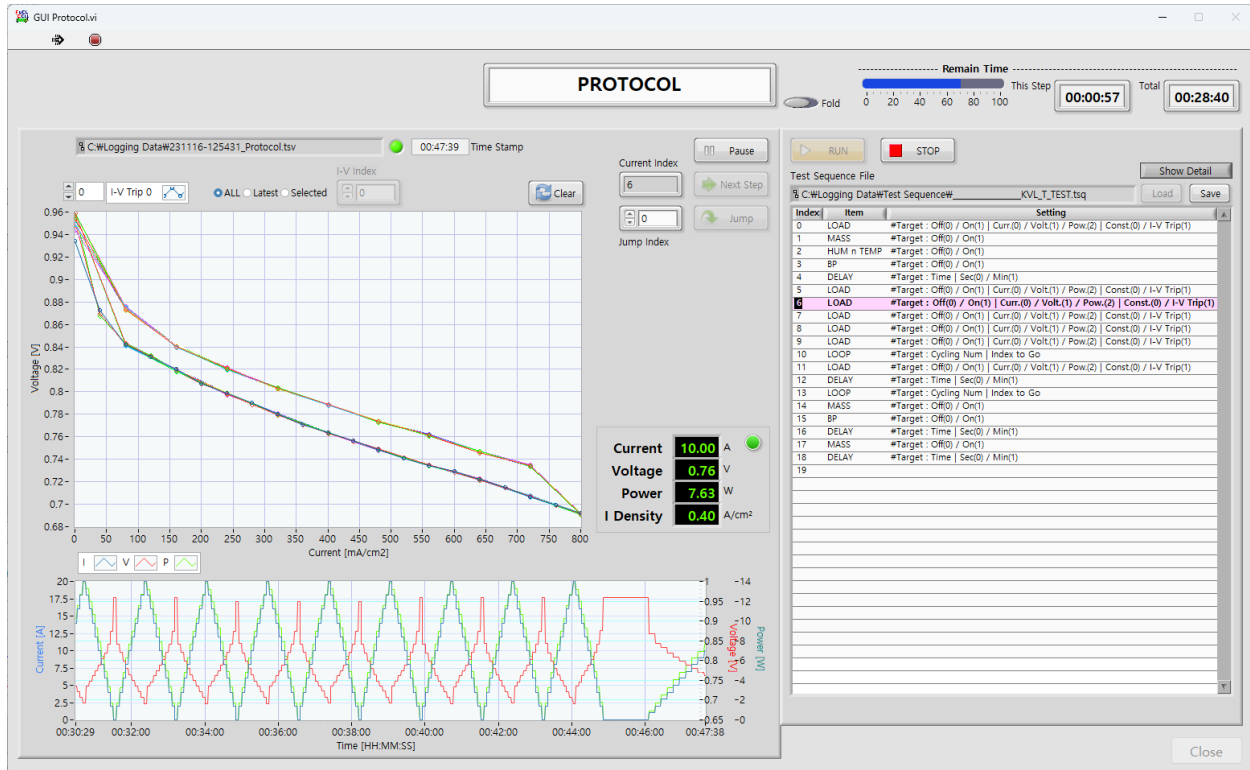
4.5 LOOP & DELAY

The LOOP feature in the Test Sequence is used to repeat a specific section of the sequence. When the Test Sequence reaches a LOOP item, it returns to the line specified in "Index to Return" and repeats this process for the number of times indicated in "Cycling Num". For example, if the LOOP item is on line 6 with a Cycling Num of 2, and Index to Return is 3, the sequence will operate as follows:

$[0 \to 1 \to 2 \to 3 \to 4 \to 5 \to \underline{\mathbf{6 \Rightarrow 3}} \to 4 \to 5 \to \underline{\mathbf{6 \Rightarrow 3}} \to 4 \to 5 \to 6 \to 7 \to 8 \ldots]$

The DELAY item allows for setting a time delay between preceding and following items, and can be switched from [Sec] to [Min] units by pressing the [Sec] button.

To insert or modify values in the Test Sequence, simply click the [Insert] or [Edit] buttons.
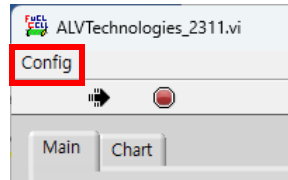
5. Automatic Control (Protocol - Run)

The image shows the state while the protocol is in progress. When the protocol is running, the data saving path of the protocol is displayed in the upper left corner of the screen. Right below it is the I-V Curve chart, which draws a trajectory as the I-V Trip of the electrical load progresses. Additionally, there is a chart below that allows real-time monitoring of data measured from the electrical load.

During the protocol execution, you can pause or move the Test sequence items using the [Pause], [Next Step], and [Jump] buttons. However, the [Next Step] button is disabled for safety during the I-V Trip. The [Jump] button becomes active when the Jump index is set higher than the Current Index. If you click the [Jump] button during an I-V Trip, the jump will be performed after the ongoing I-V Trip ends.

In the upper right corner of the screen, the remaining time for the current step and the estimated time until the protocol ends are displayed. In the Test sequence table, the row of

the currently ongoing item is highlighted in red. A Fold toggle switch is provided to facilitate viewing the protocol screen and main panel simultaneously, so it can be utilized as needed. The [Close] button is deactivated during protocol execution, and to exit the protocol, you must first press the [Stop] button to end it and then press [Close] to return to the main panel. However, be cautious as each component of the Test Station maintains its last operational state.

6.   Configuration

You can access the configuration window through the Config menu located at the top of the main panel. The configuration list is divided into two categories: User Config and Engineer Config. In User Config, you can set options related to file saving and the initial operation values of the system. In Engineer Config, you have the ability to adjust the PID values for back pressure control and set up hardware connectivity.

[Read]: Loads the settings currently entered into the program.

[Set]: Applies the settings to the current program.

(Settings are not applied when the program is restarted)

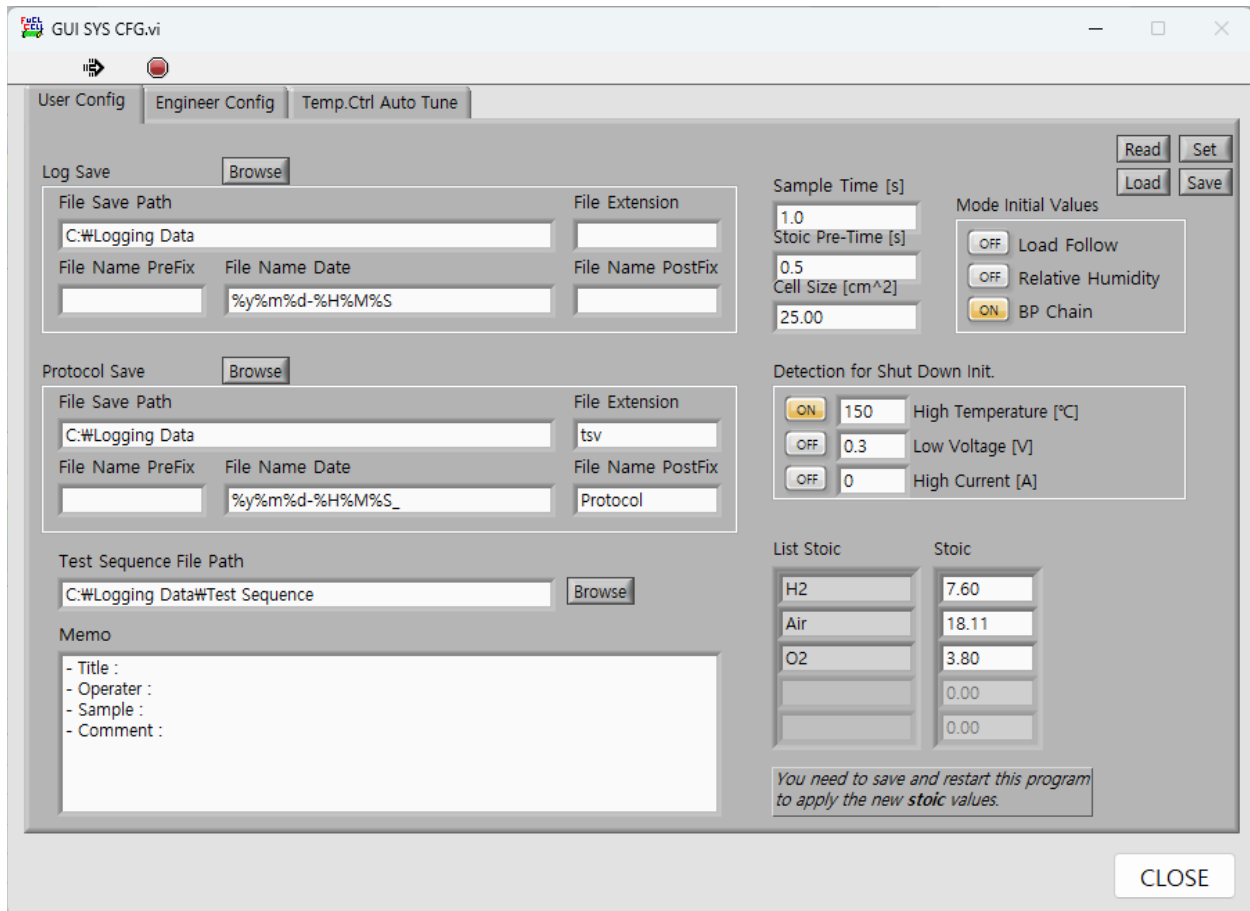[Load]: Loads the settings from the file referenced during program execution.

[Save]: Saves the settings to the file referenced during program execution.

(Settings are applied when the program is restarted)

6.1   Reset program parameters

To reset all parameters to their default states, please delete the following two files and then restart the program: (C:\Scitech Korea\Config User.ini, Config Engineer.ini)

6.2　User Config

Log Save: Allows setting the default save path and file for log files recorded while the equipment is operating.

Protocol Save: Allows setting the default save path and file name for measurement data files when the protocol is operating.

Test Sequence File Path: Allows setting the default save path for test sequence files.

Memo: Allows setting the initial template for memos.

Sample Time: Allows setting the default save interval for files.

Stoic Pre-Time: In Load Follow mode, when running the current I-V Trip, it allows setting the time to apply flow rate in advance.
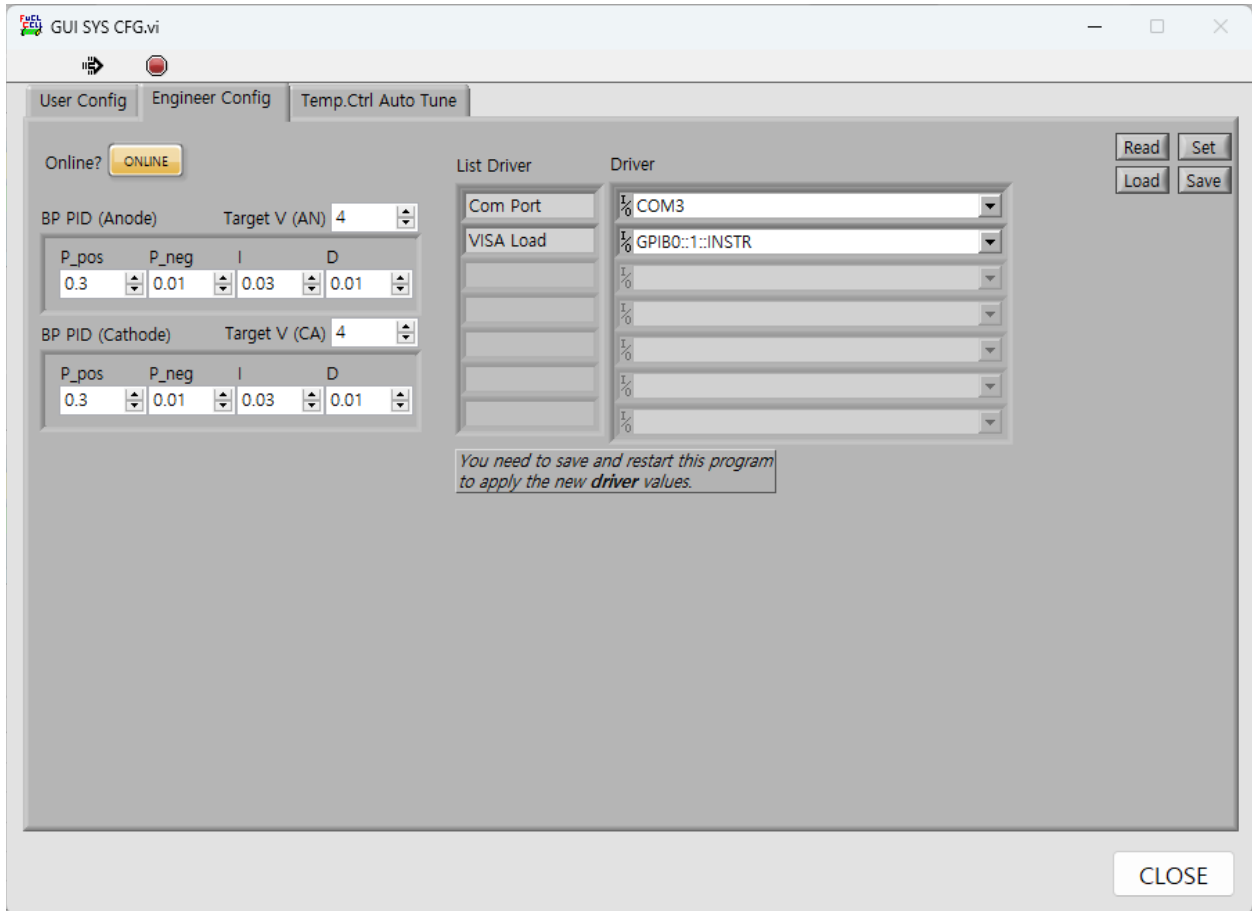
Cell Size: Allows setting the default cell size.

Mode Initial Values: Allows setting the initial values for each mode.

Detection for Shut Down Init.: Allows setting the default parameters and default activation for the shutdown logic.

Stoic: Allows setting the flow rate value required per ampere.

6.3   Engineer Config

Online?: This sets the program's mode of use. In 'ONLINE' mode, the hardware must be properly connected for use, while in 'OFFLINE' mode, simulation is possible with just the software.

BP PID: This is the PID parameter used for pressure control, requiring prior knowledge. Typically, as the flow rate increases, it's common to tune by lowering the P_pos and I values.

Driver: This sets the connectivity of equipment connected to the PC. Prior knowledge is required for setting this up.

7.   Troubleshooting & Support

This system has been custom-built based on user requests. As a result, unexpected issues may arise in the hardware or software. For resolving such issues, please follow the procedures outlined below.
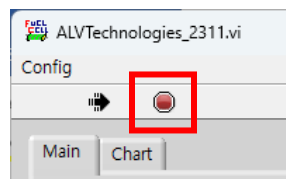
7.1   Error Messages

System error codes can be checked through the System Messages box and are automatically recorded in the log files. However, as there is a possibility of omission, it is recommended to record them separately.

7.2   Force Stop

In case the program unexpectedly stops or shuts down abnormally, the Test Station maintains its last state (flow rate, temperature control, power load, etc.). For safety, the program should be restarted as soon as possible, or if necessary, the hardware should be forcibly shut down. If you cannot exit the program, you can force it to close by clicking the red circular button below. In this case, it is imperative to follow safety procedures.

7.3   Support

As log files may be needed in case of problems, it is advisable to always keep the log file saving feature active during equipment operation, unless there is a special reason not to. If a problem occurs, please send the log file and a detailed description of the issue to the email address below. Including screenshots of the main panel or other screens where the issue occurred can assist in resolving the problem.

Email address: fc@scitechkorea.com

7.4 Program Update

For program updates, please overwrite with the new program files provided. Before proceeding with the overwrite, it is important to backup your existing program files as a precaution against any unforeseen issues.

Program Path: C:\Program Files (x86)\SingleStation\