



PROTIUM-150

FUEL CELL SYSTEM

USER GUIDE



SAFETY, HANDLING & SUPPORT

WARNING: *Failure to follow these safety instructions could result in fire, electric shock, other injuries, or damage to PROTIUM-150 Fuel Cell System (PROTIUM-150) or other property. Read all the safety information below before using PROTIUM-150.*

Handling Handle PROTIUM-150 with care. It is made of thin sheet metal, graphite, and plastic and has sensitive electrochemical membrane and components inside. PROTIUM-150 is not designed for extreme conditions, rough handling, vibration, shock or drop. Keep PROTIUM-150 away from heat, flame, strong sunlight, water, dust, soil or mud. Do not use a damaged PROTIUM-150.

Repairing PROTIUM-150 is assembled under high compression. Do not disassemble or tamper with PROTIUM-150. Do not troubleshoot, repair or replace any component by yourself.

Hydrogen Use only high purity (99.999%) dry Hydrogen gas with PROTIUM-150. Hydrogen is a colorless, odorless and highly flammable gas. It is non-toxic but can cause asphyxiation. Follow all local rules and regulations for safe handling, storage and usage of Hydrogen gas. Do not smoke when operating PROTIUM-150.

Ventilation Operate PROTIUM-150 in a well ventilated environment. Fresh air intake for the fuel cell oxidant and cooling air entry from the front of the protective mask, and hot air exit from the cooling fans shall not be obstructed or restricted.

Purging PROTIUM-150 periodically flushes its anode during operation, releasing Hydrogen gas and water from the Hydrogen gas outlet. Do not block the Hydrogen gas outlet. Do not bring flame or electric spark close to the Hydrogen gas outlet. It is advisable to attach a longer gas tubing to the Hydrogen gas outlet connector and safely guide the purge exhaust far away from the fuel cell.

CAUTION: *always put the Hydrogen gas outlet tubing behind the cooling fan and never in front of the fuel cell stack. Purged Hydrogen mixed with air intake into the fuel cell's cathode channels may cause fire and irreversible damage to the fuel cell.*

Connectors, ports and buttons Never force a connector into a port or apply excessive pressure to a button. If the connector and port do not join with reasonable ease, they probably do not match. Check for obstructions and ensure that the connector matches the correct port.

Disposal and recycling As PROTIUM-150 contains electronic components, it must be disposed of separately from household waste. When PROTIUM-150 reaches its end of life, follow local laws and regulations for proper disposal and recycling options.

High-consequence activities PROTIUM-150 is a customized system with pending safety tests and certifications. It is not intended for use where the failure of the system could lead to death, personal injury or severe environmental damage.

Disclaimer Every effort has been made to ensure that the information in this manual is accurate. This manual serves to adequately recommend safe operating procedures, but shall not be treated as comprehensive. Do not use PROTIUM-150 in any other way than the one recommended in this manual. Spectronik reserves the right to change system specifications, appearance or discontinue the product at any time.

Warranty Spectronik warrants the included hardware product and accessories against defects in materials and workmanship for the first 30 days after delivery. Spectronik does not warrant against normal wear and tear, nor damage caused by accident or abuse.

To obtain service, contact support@spectronik.com

1 OVERVIEW

1.1 PROTIUM-150 SYSTEM OVERVIEW

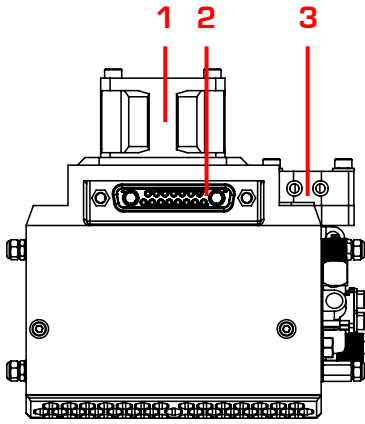


Figure 1.1.1 Top view of PROTIUM-150

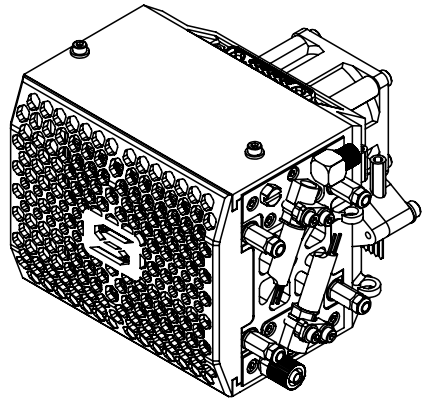


Figure 1.1.2 3D view of PROTIUM-150

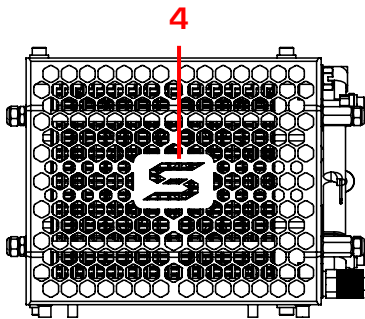


Figure 1.1.3 Front view of PROTIUM-150

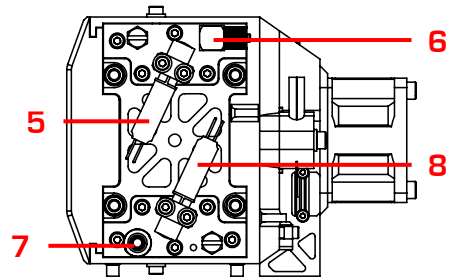


Figure 1.1.4 Side view of PROTIUM-150

ITEM DESCRIPTION

- | | | | |
|----|------------------------|----|---------------------------|
| 1. | Cooling fan (x1) | 5. | Gas supply solenoid valve |
| 2. | FC power/signal socket | 6. | H2 gas inlet port |
| 3. | Gas pressure sensor | 7. | H2 gas outlet port |
| 4. | Protective mask | 8. | Gas purge solenoid valve |

1.2 ELECTRONIC CONTROLLER

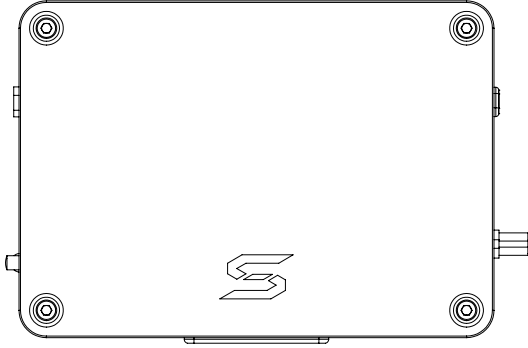


Figure 1.2.1 Top view of Electronic Controller

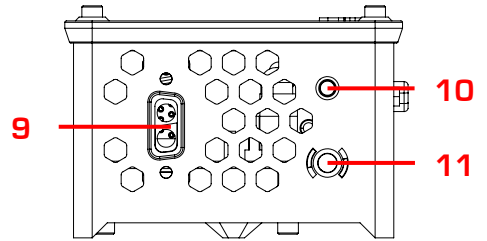


Figure 1.2.2 Left side view of Electronic Controller

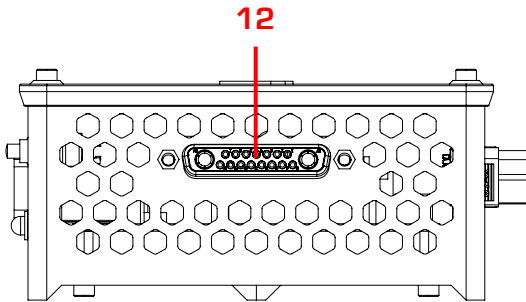


Figure 1.2.3 Front view of Electronic Controller

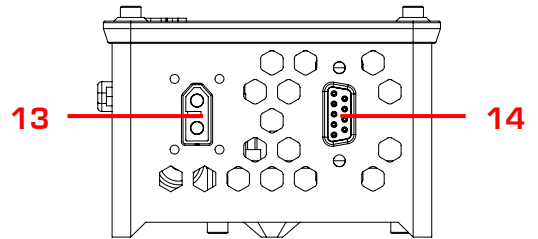


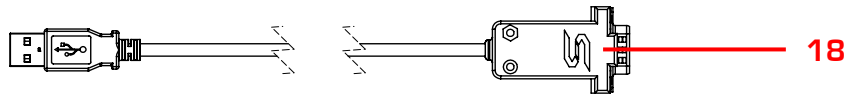
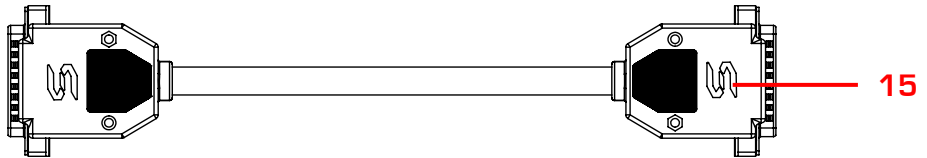
Figure 1.2.4 Right side view of Electronic Controller

ITEM DESCRIPTION

- 9. External power supply socket
- 10. On/Off push button
- 11. Status LED

- 12. FC power/signal plug
- 13. XT60 Female load connector
- 14. RS-232 socket

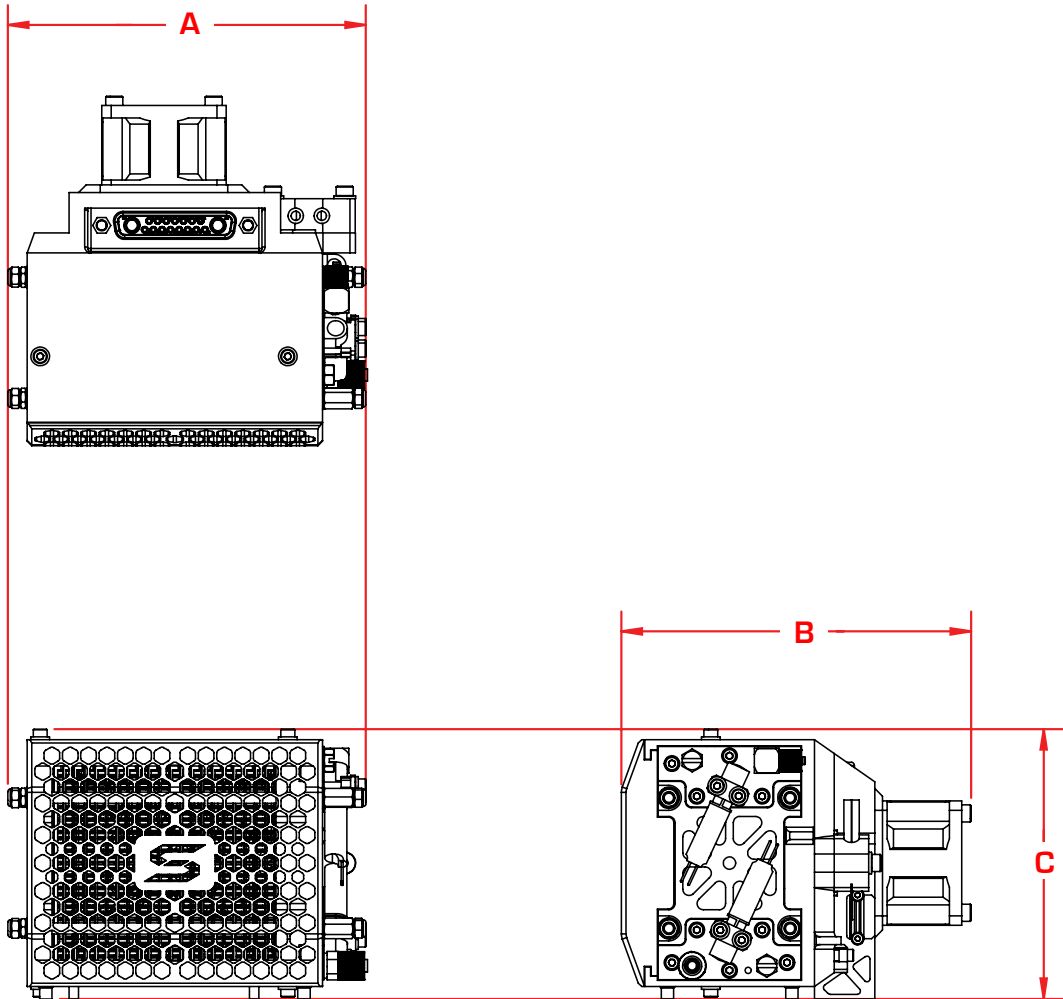
1.3 STANDARD ACCESSORIES



ITEM DESCRIPTION

- | | |
|--|---------------------------------------|
| 15. FC power/signal extension cable | 17. External power supply plug |
| 16. AWG-18 free and wires | 18. RS-232 to USB cable |

1.4 MECHANICAL DIMENSIONS – PROTIUM-150



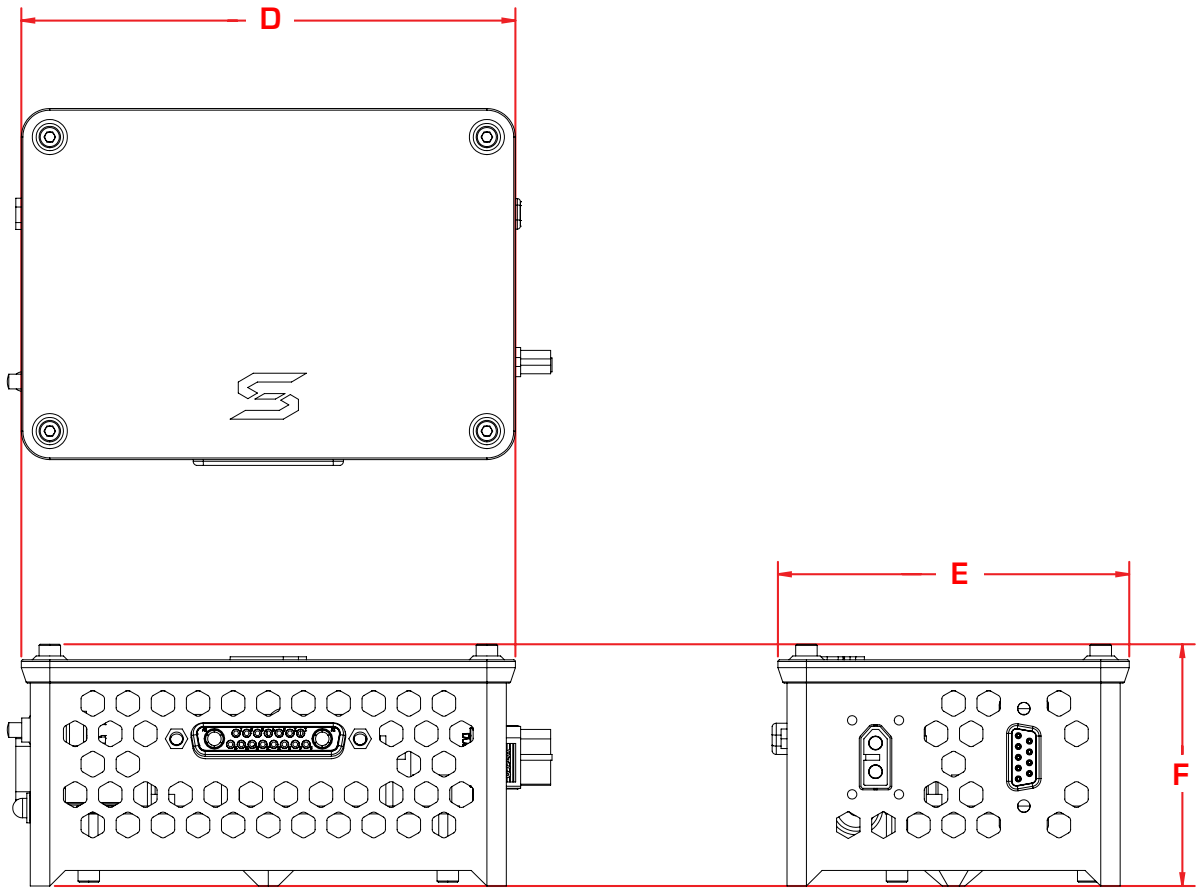
ALL DIMENSIONS IN MM

A 115.10

B 112.50

C 86.80

1.5 MECHANICAL DIMENSIONS – ELECTRIC CONTROLLER



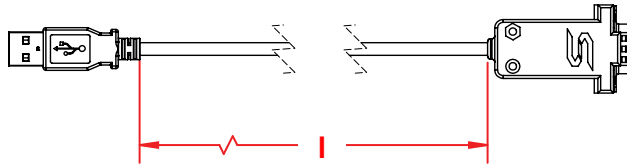
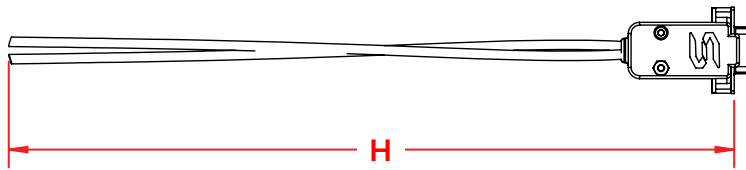
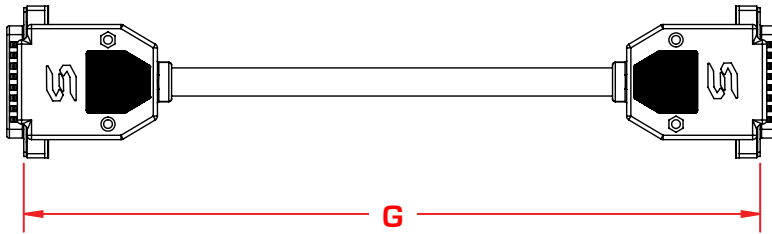
ALL DIMENSIONS IN MM

D 126.60

E 90.00

F 62.00

1.6 MECHANICAL DIMENSIONS – STANDARD ACCESSORIES



ALL DIMENSIONS IN MM

G 300.00

H 300.00

I 1500.00

2 SPECIFICATIONS

2.1 PROTIUM-150 TECHNICAL DATA SHEET

Fuel Cell System	PROTIUM-150
Type	PEM, 20 cells
Flow Field	S-flow technology
Cooling	1x 12V fan, pwm controlled
Operating Ambient Temperature	1-40°C
Load Interface	XT60 female
Fuel Cell Dimension	116 x 113 x 87 mm
Fuel Cell Weight	600g
Electronic Controller	FLY 3.0
Electronic Controller Dimension	127 x 90 x 62 mm
Electronic Controller Weight	240g
Net Performance	
Rated Power	150W (12.5A @12V)
Voltage Range	12-18V
Start-up Time	5s
Efficiency	48% (based on LHV of H ₂)
Fuel Supply	
Hydrogen Gas	Dry, 99.999% purity
Delivery Pressure	0.4-0.7bar (6-10psig)
Max Consumption	1.9L/min @ 150W
Gas Tubing Requirement	PU, 4mm OD
Supply & Purge Control	Solenoid valves
Protections & System Monitoring	
Low Voltage Shutdown	11V
High Temperature Shutdown	65°C
Low Battery Warning	<11.1V
Low Hydrogen Shutdown	<0.3bar
Data Acquisition, Graphic User Interface	RS232/USB

2.2 VI CURVE

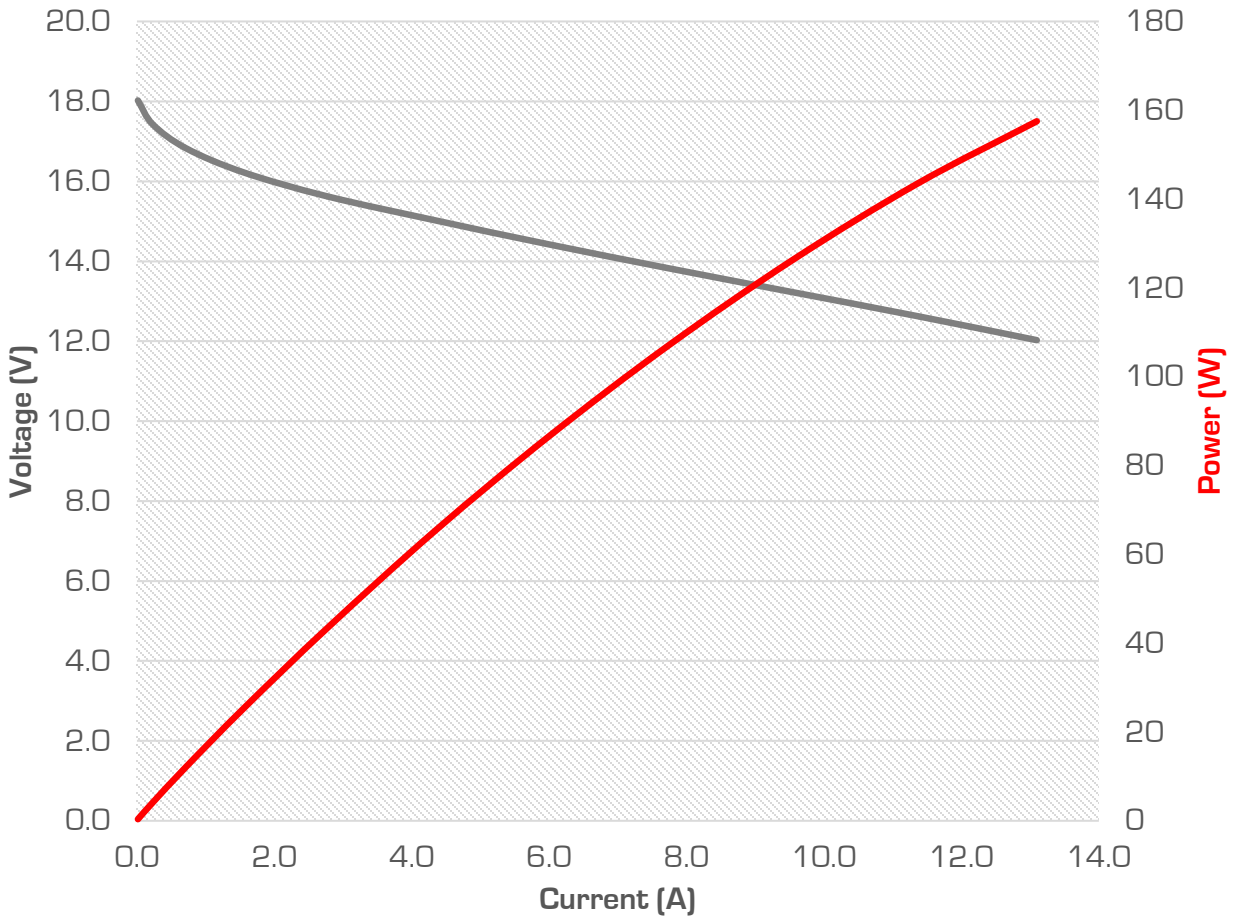
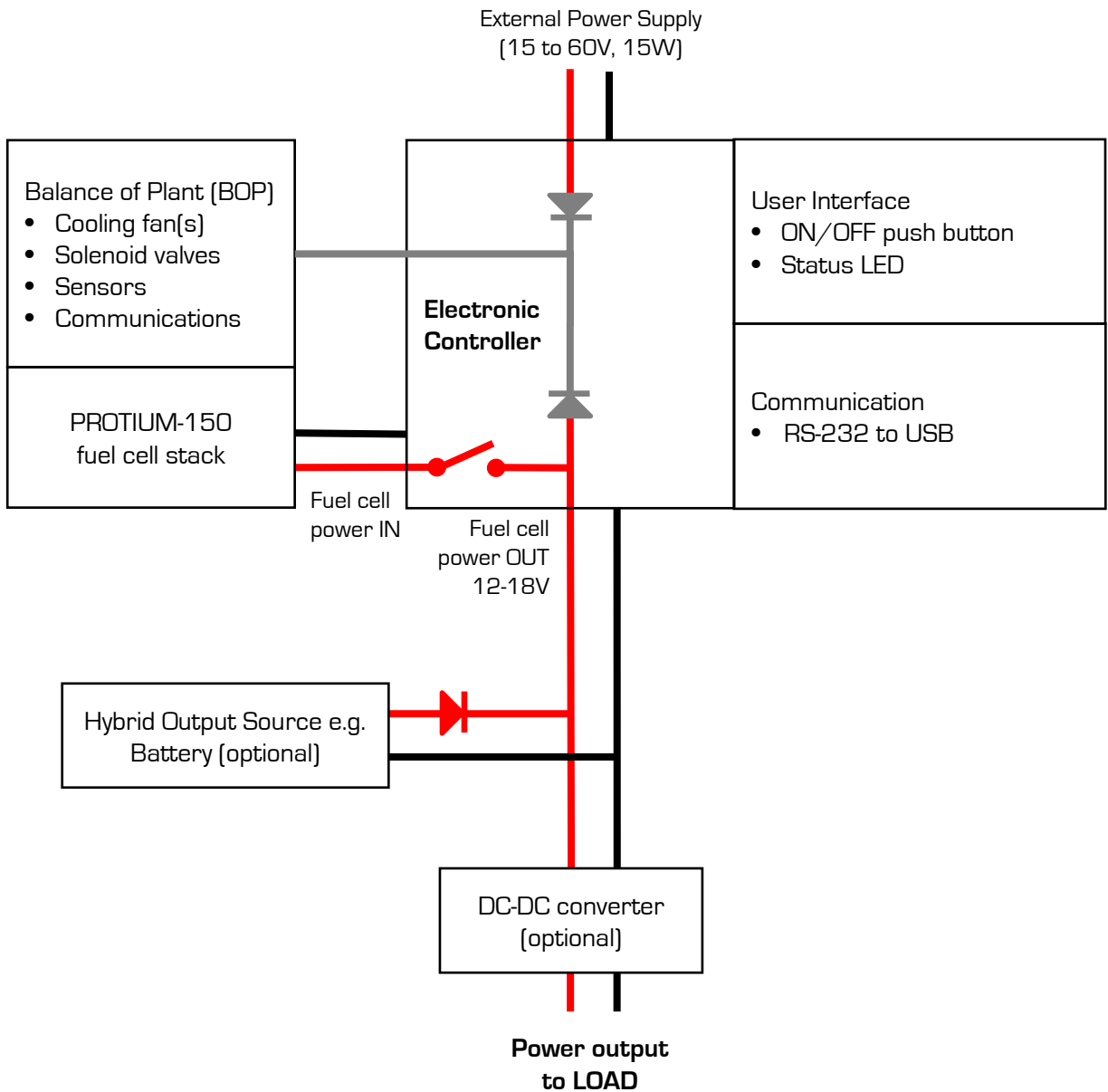


Figure 2.2.1 Nominal polarization curve for a fully conditioned PROTIUM-150 at its Beginning-of-Life (BOL).

TEST CONDITIONS

- Ambient temperature: 24°C
- Relative humidity: 60%
- H₂ supply pressure: 10psig
- Dead-ended operation
- Balance-of-plant (BOP) powered by fuel cell
- T_{cell} at 150W: 54°C

2.3 SYSTEM BLOCK DIAGRAM



NOTE

1. An External Power Supply is required to initially turn on the Electronic Controller, and to momentarily power the BOP when the fuel cell stack undergoes Current Pulsing (see Section 3).
2. If you connect a Hybrid Output Source (e.g. battery), you can choose not to include an External Power Supply. Make sure that the Hybrid Output Source voltage matches the Fuel cell power OUT voltage.

Tip: use a 3S LiPo battery (12V) as the Hybrid Output Source to ensure that the maximum fuel cell power goes to the LOAD before the Hybrid Output Source contributes to additional power output.

3 OPERATING PROCEDURES

3.1 SETTING UP PROTIUM-150

1. Connect the FC power/signal socket [2] to the FC power/signal plug [12] using the FC power/signal extension cable [15].
2. Connect your External Power Supply (15 to 60V, 15W) to the AWG-18 free end wires [16], and the External power supply plug [17] to the External power supply socket [9].

Tip: ensure correct polarity and that your External Power Supply is OFF at this stage.

3. If you wish to monitor the fuel cell performance live (see Section 4), connect the RS-232 socket [14] to a PC using the RS-232 to USB cable [18].

Tip: the latest Data Acquisition Graphic User Interface (GUI) software and user manual can be downloaded from the PROTIUM-150 product webpage.

4. Connect your load to the XT60 female load connector [13]. Check that the polarity is correct.

Tip: for safety, ensure that your load has a switch and is switched OFF at this stage.

5. Connect your Hydrogen gas supply to the H₂ gas inlet port [6]. By default, H₂ gas supply tubing is already connected to H₂ gas inlet port [6] and has a push-in connector for OD 4mm PU tubing. Make sure that the Hydrogen gas supply is OFF at this stage.

PROTIUM-150 is now ready to turn ON.

3.2 TURNING ON PROTIUM-150

1. Turn ON your External Power Supply.
2. Turn ON your Hydrogen gas supply. *Caution: ensure that the gas pressure is regulated to 0.5-0.7bar gauge. Insufficient delivery pressure may cause cell flooding and drop in performance, while excessive pressure may rupture the fuel cell membrane, causing dangerous gas leakage and irreversible cell damage. Ensure that your pressure regulator can provide Hydrogen gas flow rate of more than 4L/min.*
3. Press and hold the On/Off push button [10] for 2s. The LED will light up. PROTIUM-150 will do a series of gas purging and internal diagnostic checks. The cooling fans will turn on. If everything is normal, the system will enter its "Running Phase" – indicated by the message in the GUI and a solid white Status LED. All system parameter values can now be seen in the GUI.

PROTIUM-150 is now ready to power your load.

3.3 POWERING YOUR LOAD WITH PROTIUM-150

1. Turn ON your load and draw power as per normal. **Caution: never pull the fuel cell voltage below 12V or draw power beyond 150W.**

Mode	Range	Ramp-rate
Constant Voltage (CV) Load	Open circuit voltage to 12VDC min or 150W max	-0.5VDC/second
Constant Current (CC) Load*	0A to 12.5A or 150W max	+1A/second
Constant Power (CP) Load*	0W to 150W max	+15W/second

* PROTIUM-150 performs periodic Current Pulsing (once every 15-30s, for a duration of around 100ms) to rejuvenate its cell hydration and maintain optimal performance. During Current Pulsing, Fuel cell power OUT is momentarily cut off for safety. CC and CP load can be performed only if Hybrid Output Source is connected. Ensure that the Hybrid Output Source is powerful enough to support the entire load by itself.

2. During Running Phase, the following live status of the fuel cell can be monitored from the GUI.

Parameters	Description
V	Fuel cell voltage [V]
A	Fuel cell current [A]
W	Fuel cell power [W]
°C	Fuel cell internal stack temperature [°C]
Wh	Energy delivered by the fuel cell during this operation [Wh]
Aux 1	Hybrid Output Source voltage [V]
Aux 2	H ₂ supply pressure [Barg]

NOTES & REMINDERS

- Ensure all gas tubing and electrical wire connections are firm and secure.
- Do not block the purge outlet. During operation, it is normal to see water coming out of the purge tubing. Ensure that water does not drip to any electrical components. **Caution: there might be unreacted Hydrogen gas coming out of the purge tubing. Keep away from fire and electric spark. Ensure sufficient ventilation. Channel the purge tubing behind the cooling fans and away from the fuel cell air inlet.**

3.4 SHUTTING DOWN PROTIUM-150

1. Turn OFF your load. The cooling fans will turn faster to cool down the fuel cell, before returning to their minimum speed.
2. Press and hold the On/Off push button (10) for 2s. PROTIUM-150 will do a series of shutdown procedures. The message <System OFF> can be seen in the GUI. The status LED light will also turn off.
3. If you do not intend to restart the system soon, turn OFF your Hydrogen gas supply and remove your Hydrogen gas supply tubing from the push-in connector that is connected to the H₂ gas inlet port (6).
caution: some remaining gas in the tubing will be released into the atmosphere.
4. Turn OFF the External Power Supply. All the cables can now be disconnected.

PROTIUM-150 is now ready to be kept for storage.

4 PROTECTIONS & WARNING MESSAGES

PROTIUM-150 has in-built system protections. During normal running phase, the Status LED (11) will be solid white. When an error is detected, the LED will flash and a message will appear. The message can be viewed on a PC using Spectronik's Graphic User Interface (GUI) data acquisition software. Connect the Electronic Controller to a PC using the RS-232 to USB cable (18).

Note: instruction on how to use the GUI is separately listed in the GUI user guide.

Follow the basic troubleshooting guide below. Most errors should be rectified once the suggested action has been done and the system restarted.

If the error persists, contact support@spectronik.com.

During Start-Up

Message	Corrective Action
Low H ₂ supply	Check and ensure sufficient hydrogen supply and correct delivery pressure.
High temperature	Disconnect everything and wait for system to cool down. Restart after 10 min.
Error: Temperature	Internal temperature sensor might have been compromised. Contact Spectronik.
Error: Low voltage	Check and ensure sufficient hydrogen supply and correct delivery pressure. Restart after 1 min.

In Operation

Message	Corrective Action
High temperature	Fuel cell temperature has reached 60°C, load is temporarily auto-disconnected. Reduce load.
Error: High temperature	Disconnect everything and wait for system to cool down. Restart after 10 min. If system fails to restart, internal temperature sensor might have been compromised. Contact Spectronik.
Low voltage	Fuel cell is overloaded and the load is temporarily auto-disconnected. Reduce load.
Error: Low voltage	User has drawn power way beyond the fuel cell capacity. Restart the system and reduce load.
Low H ₂ supply	Hydrogen gas supply is depleted, reduce load or prepare to end operation.
Error: Low H ₂ supply	Hydrogen gas supply is way too low to support operation. Refill the supply and restart the system.
Low battery	Hybrid Output Source voltage is low (<11.1V).

5 MAINTENANCE AND STORAGE

5.1 MAINTENANCE FOR PROTIUM-150

When not in use, Spectronik recommends that PROTIUM-150 is reconditioned at least once a month.

1. Follow the steps in Chapter 3, using a DC electronic load in lieu of your regular load.
2. Set a constant voltage (CV) load of 12V and run the system for 1 hour.
3. PROTIUM-150 is now ready for usual operation or can be stored again for future use.

5.2 STORAGE

Keep PROTIUM-150 in an open, cool (standard room temperature of 25°C) and dry place.