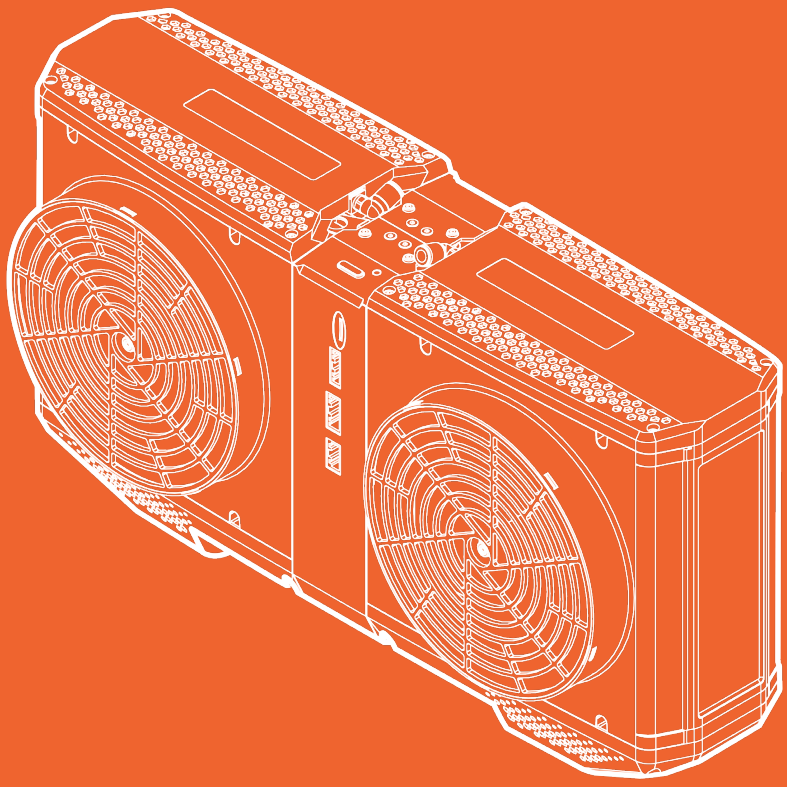
INTELLIGENT ENERGY

IE-SOAR™

User Manual

IE-SOAR 2.4kW FUEL CELL POWER MODULE

Users must read all instructions provided and retain the manual for future reference
A more detailed manual is available to customers and integrators
Original Language Instructions



This is the user manual for the 2.4kW Fuel Cell Power Module (FCPM) designed and manufactured by Intelligent Energy.

Users of this product must follow the instructions and warnings laid out in this user manual at all times and must be aware of the hazards present when using high pressure flammable gas products and high voltage electronics.

This User Manual is intended as a general guidance only and does not purport to address the specific situations that could potentially arise from the use of fuel cell systems and their usage in connection with UAVs. The recipient is responsible for ensuring that all personnel have read and understood this User Manual before being allowed to handle, operate, install and store any equipment supplied by Intelligent Energy.

The recipient must ensure that any personnel responsible for handling hydrogen cylinders and operating UAVs are suitably trained and certified in compliance with any applicable local, state and federal laws and regulations and good industry practice. The recipient is responsible for complying with any relevant health and safety policies and procedures that may apply to the operation of UAVs and use and storage of hydrogen on any sites.

Intelligent Energy warrants to the recipient and it will repair and replace any defective equipment resulting from the authorised use of the equipment provided. Notwithstanding the above, Intelligent Energy, to the fullest extent permitted by law, accepts no liability (including liability in respect of any error or defects in the fuel cell system and UAVs) for any damage caused as a result of recipient's unauthorised use of the equipment provided. The recipient acknowledges that the manner in which the equipment is stored, used or operated is not under the control of Intelligent Energy Limited. Intelligent Energy has made every effort to ensure that this User Manual is accurate and disclaims liability for any inaccuracies or omissions that may have occurred.

Federal Communications Commission (FCC) Statement

This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

Reorient or relocate the receiving antenna.

Increase the separation between the equipment and receiver.

Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.

Consult the dealer or an experienced radio/TV technician for help.

This device complies with Part 15 of the FCC Rules. Operation is subject to the following two conditions:

1. This device may not cause harmful interference and
2. This device must accept any interference received, including interference that may cause undesired operation. You are cautioned that changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

CE Marking Statement

The CE label shows that the product complies with the basic requirements of the applicable directives. For the declaration of conformity contact the manufacturer at **servicing@intelligent-energy.com**.

Glossary of terms

Term	Definition	Function or Description
FCPM	Fuel Cell Power Module	The entire fuel cell system
SPM (1&2)	Stack Power Module	There are two SPMs housing the two fuel cell stacks and associated power electronics
PCM	Power Control Module	PCBA comprising digital and analogue HMI ports, micro-SD card and regulator interfaces, part of central module
BDM	Battery Diagnostic Module	Not currently used
POM	Power Output Module	PCBA comprising battery in and power out connections, part of central module
UART	Universal Asynchronous Receiver/ Transmitter	Serial communication protocol
CAN	Controller Area Network A & B	Communication bus
LW	Light Weight	
HFLW	High Flow Light Weight	High Flow Lightweight Regulator
LPI	Low Pressure Interface	Pressure transducer that measures regulator output pressure
TPED	Transportable Pressure Equipment Directive	Directive covering transportable pressure containing devices
SCV	Self-Closing Valve	A valve that complies with TPED stipulations

Users must read all instructions provided and retain the manual for future reference

Document No. 10010371

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Contents

1 Safety Warnings

- Only qualified technicians trained in high pressure flammable gases must carry out fitting of regulators and filling of cylinders and do so in accordance with local laws and Health and Safety (H&S) regulations.
- The customer is responsible for ensuring all technicians and pilots are suitably trained, accredited, and operate in compliance with local laws and health and safety regulations.
- The customer is responsible for always ensuring the safe operation of the FCPM in line with the User Manual.
- This device requires oxygen to operate.
- A minimum of $1m^3$/min of oxygen is required for operation.
- Up to $20m^3$/min of air is required for cooling.
- FCPM not to be used in dusty, smoky, or corrosive gas environments.
- Do not use FCPM in rain or snow.
- During integration there is a risk of exposed electrical conductors.
- Pressurised hydrogen present. Highly flammable!
- Do not operate the FCPM if the casing is damaged or missing.
- FCPM should be inspected for damage and checked for leaks prior to use.
- All hydrogen tubing should be regularly inspected for damage – especially where it mates with push fittings. Immediately replace any damaged tubing.
- Do not transport the FCPM with the hydrogen supply connected.
- Do not remove casing from Module.
- Ensure the aircraft powered by the FCPM is maintained correctly, any loose bolts or metal parts that fall into the housing will cause damage to fuel cell componentry.
- Do not use this FCPM if any part has been immersed or flooded with water. Immediately contact Intelligent Energy or a representative of the distributor from whom the FCPM was purchased to inspect the FCPM and to replace any functional part that has been affected.

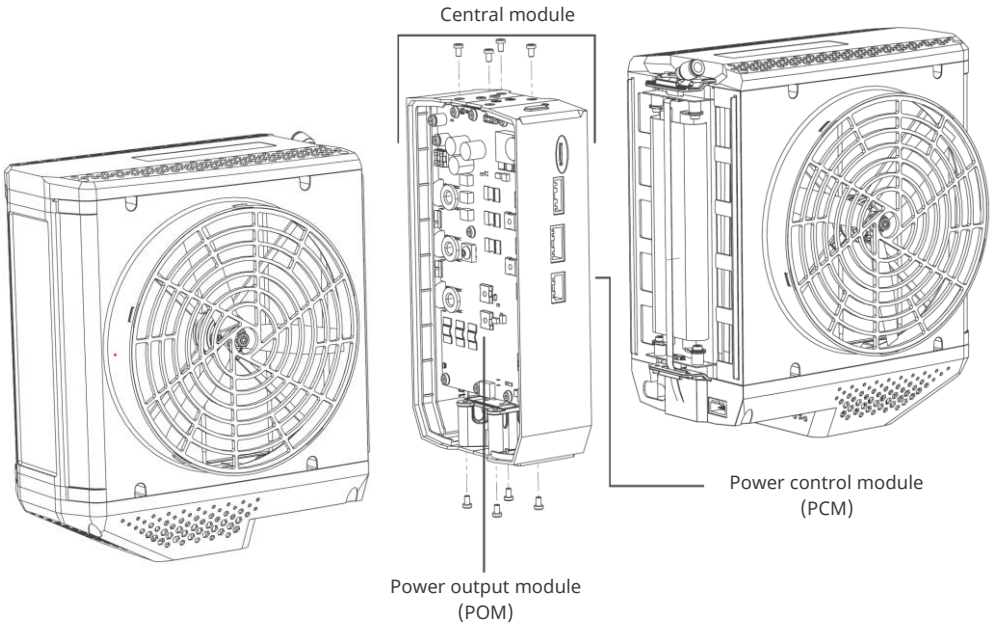
2 Key components

2.1 Product specification

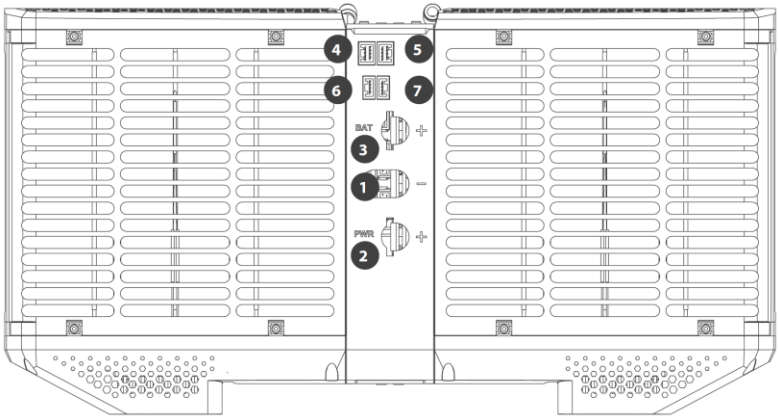
Power characteristics	Maximum continuous fuel cell power	**2400W**
	Peak power with default hybrid battery	**4800W**
	Maximum power with suitable hybrid battery (not to be exceeded)	**8000W**
	Output voltage (configurable, regulated, and steady output)	**40 – 70V**
Physical characteristics	Fuel Cell Power Module (FCPM) dimensions	**130 × 440 × 230mm**
	Mass (of FCPM only)	**4800g**
Hydrogen supply requirements	Inlet pressure limits	**0.9Bar.g ± 0.1Bar.g (13PSI ± 1.5PSI)**
	Hydrogen consumption rate g/hr @ 2.4kW	**140-160g/hr**
	Hydrogen flow rate - peak	**50l/min (minimum)**
	Hydrogen flow rate at 2.4kW	**27l/min**
Hybrid batteries	Two default hybrid batteries (configurable)	**2 × 6S in series**
	Dimensions (per battery)	**130 × 40 × 40mm**
	Mass (per battery)	**535g**
	Capacity (per battery)	**3300mAh (~75Wh)**
Environmental operating conditions	Start-up temperature	**+5°C to 40°C**
	Operating temperature	**-5°C to 40°C**
	Storage temperature	**-10°C to 70°C**
	IP rating	**None**
Safety features	Dual redundant fuel cell power system and backup battery	
Other features	System warranty	**1000hrs**
	Micro-SD card port for firmware updates and data logging for diagnostics. UART/CAN communications port for FCPM telemetry transmission	
	Compatible with Intelligent Energy's HFLW regulator – **we strongly recommend using the 2.4kW FCPM with the HFLW regulator.** If using another hydrogen regulation system, please check pressures and flow rates always remain within specification. Failure to maintain the correct input pressure to the fuel cell will result in permanent fuel cell damage, which will not be covered by warranty.	
	Output electrical connector	**M8 ring terminal/AS150**

2.2 System diagram

2.2.1 FCPM exploded rear view



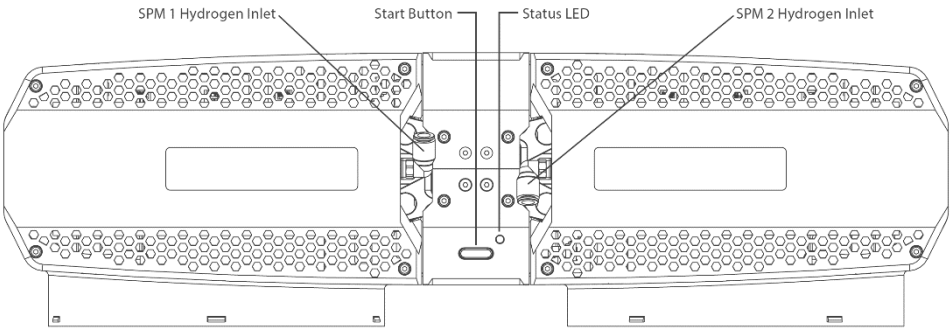
2.2.2 FCPM front view



SPM 2 SPM 1

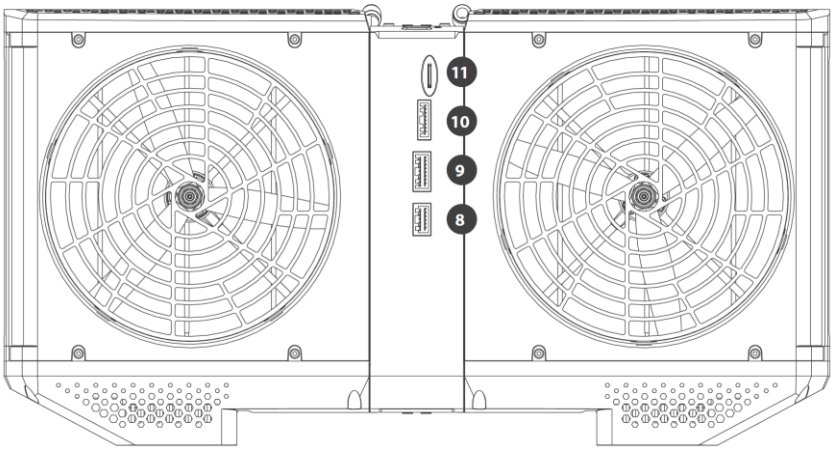
1. Common Ground
2. Positive Output
3. Battery Positive
4. FCPM In (not used)
5. FCPM Out (not used)
6. Battery Diagnostic Module (BDM) 2
7. Battery Diagnostic Module (BDM) 1

2.2.3 FCPM top view



SPM 1 Central Module SPM 2

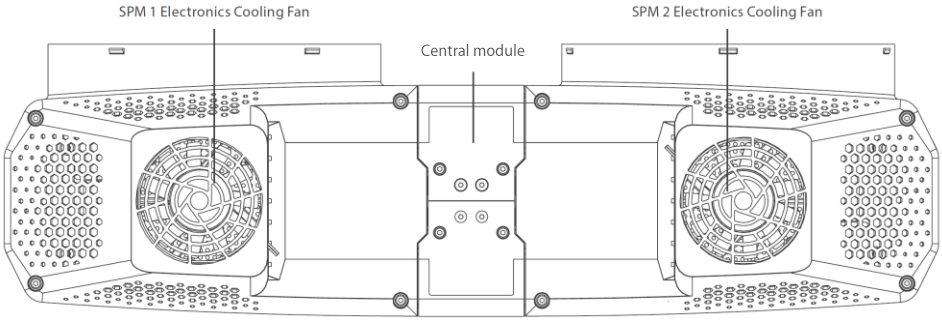
2.2.4 FCPM rear view



SPM 1 SPM 2

8. HMI (UART/CAN)
9. HMI(Digital/Analogue)
10. Regulator Interface
11. SD Card slot

2.2.5 FCPM bottom view



3 Assembly

3.1 Connecting output power cables

The output power leads can be connected to the POM once the SPMs have been disconnected.

Note ***All power leads require an M8 ring terminal to be attached to the POM***

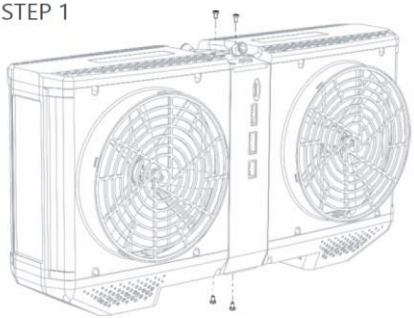
1. Ensure battery is isolated from the cables before connecting to the POM, use a suitable connector between battery and ring terminals for the power rating of the application - AS150 connectors are suggested.
2. Complete the steps to open the FCPM as shown in section 3.1.1.
3. Feed the battery cables through the central module housing. Connect battery positive M8 Ring to 'Batt +' and battery negative to common ground 'GND'.
4. Feed the load cables through the central module housing. Connect load positive to 'PWR +' and load negative to common ground 'GND'.
5. Tighten all three M8 terminal screws to max torque of 2Nm.
6. Once the cables are in place reconnect the SPM's to the central module as in section 3.1.2.

Note ***The negative terminal is common to the battery input and power output connections***

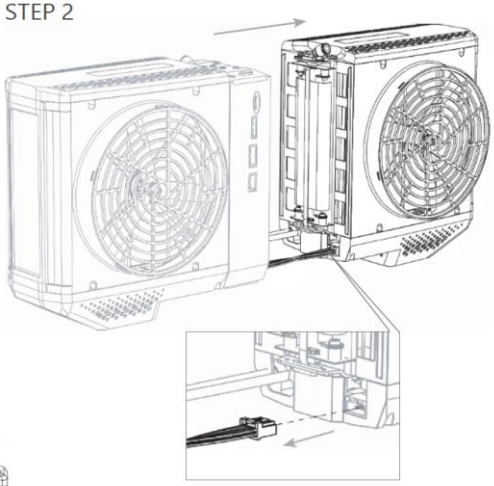
Do not under any circumstances connect a battery to the power output terminals of the FCPM, doing so will void warranty and cause irreparable damage.

3.1.1 Disconnecting SPM from central module

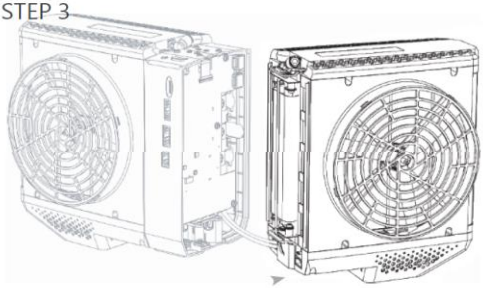
STEP 1



STEP 2

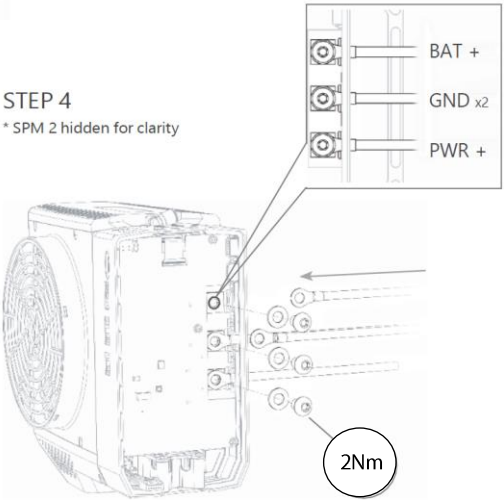


STEP 3



STEP 4

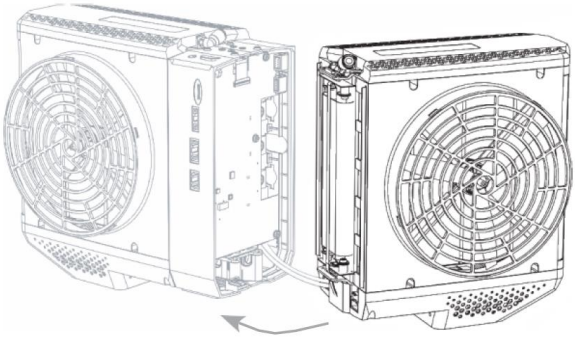
* SPM 2 hidden for clarity

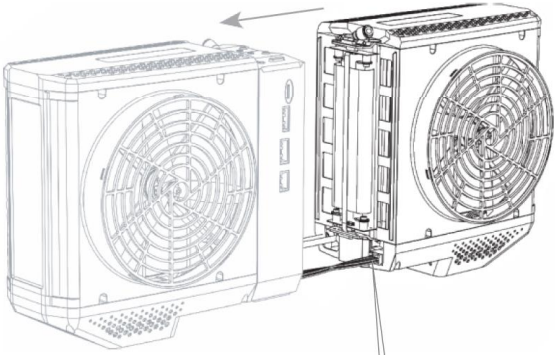


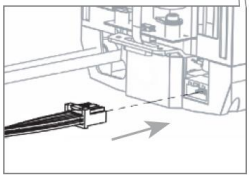
3.1.2 Connecting SPM to central module

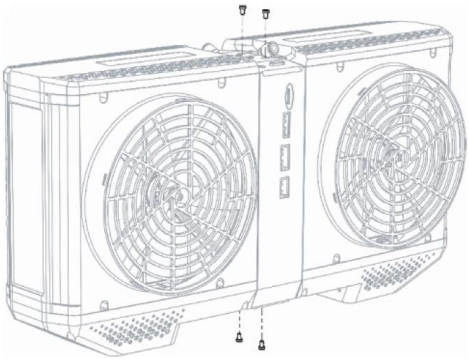
STEP 5

* Steps 1-3 in reverse





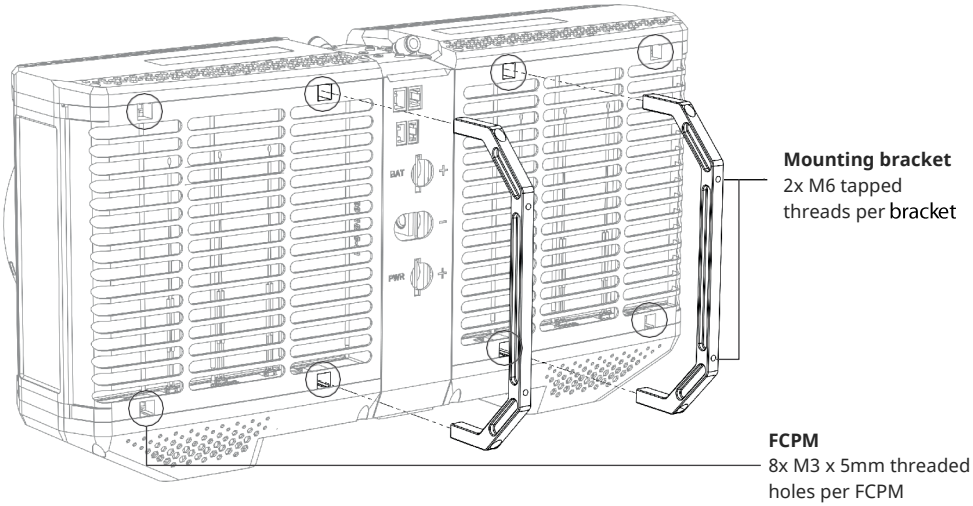




3.2 Mounting

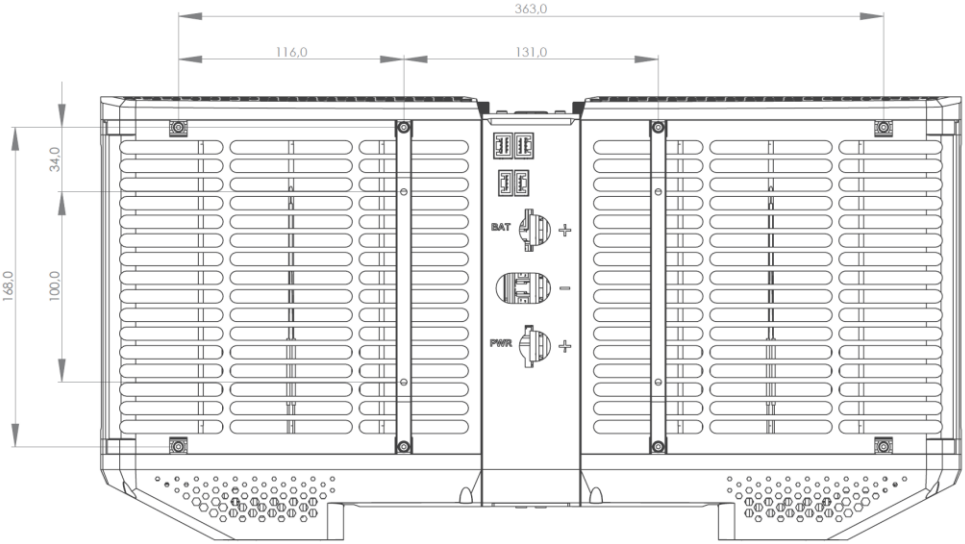
3.2.1 Mounting point information

Each SPM has four mounting points which accept an M3 bolt. Mounting brackets are provided which can be fixed to the SPMs and have two M6 threaded through holes for customer use. The complete assembly must have a minimum of two mounting brackets in total. Each SPM must have at least one bracket attached.
Recommended mounting points on the system are labelled in the figure below. Two optional mounting brackets are included. These can be used to aid integration and can be attached to any of the labelled mounting points.
The 2.4kW unit must be securely attached to the vehicle or test fixture.



3.2.2 Mounting dimensions

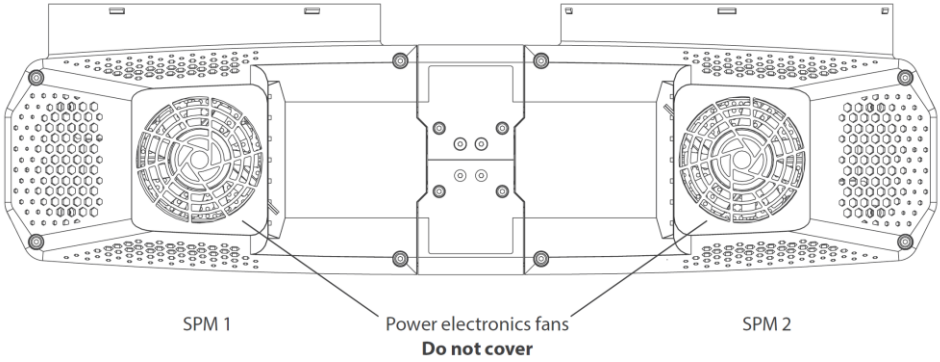
The locations of the mounting points are shown in the diagram below.



3.3 Airflow restrictions

3.3.1 Electronics airflow

Up to 1m^3/min of airflow is required to the power electronics located on the underside of each SPM. Do not cover the vents when mounting, airflow must not be blocked when operating the FCPM.



3.3.2 SPM cooling fans

The two mounting brackets are included to aid the creation of a 40mm air gap. This is required to allow up to 20m^3/min of airflow through the FCPM. It is important to have an even airflow distribution to both SPMs for the system to work efficiently. If the air is being recirculated a minimum of 1m^3/min of supplemental oxygen is required.

4 Hydrogen connection

4.1 Connector specification

Each SPM has a 6mm push in tube connector for connecting a hydrogen supply. A hydrogen compatible material with flame retardancy and low hydrogen permeability, suitable for use down to -5°C is required.
Recommended tubing: 6mm OD x 4mm ID, Legris 1025U06K01

4.2 Hydrogen specification

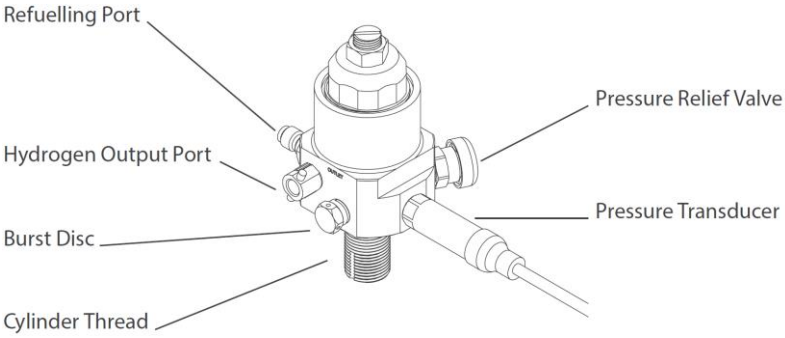
When installing and operating hydrogen systems, hydrogen general safety guidance should be considered:
ISO/TR 15916 – basic considerations for the safety of hydrogen systems for more detailed information.
The hydrogen purity should comply with the specification in the table below:

Fuel Characteristics	Fuel Requirements
Hydrogen concentration	> 99.90%
Nitrogen, Helium, Argon	< 0.10%
Oxygen	< 50ppm
Carbon Dioxide	< 2ppm
Carbon Monoxide	< 0.2ppm
Ammonia	< 0.1ppm
Sulphur containing compounds	< 4ppb
Max particle concentration	< 1mg/kg
Max particle diameter	< 75µm

4.3 Hydrogen High Flow Light Weight regulator (HFLW)

The 2.4kW FCPM is designed to be operated with an Intelligent Energy HFLW Regulator. We strongly recommend users operate the FCPM with a HFLW regulator.

Note ***The FCPM could be permanently damaged if operated with incorrect hydrogen inlet pressure or insufficient hydrogen flow. Inlet pressures of 0.9bar.g ± 0.1bar.g (13PSI ± 1.5PSI) with flowrate of 50l/min are required.***

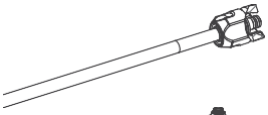


4.4 Connecting the FCPM and HFLW Regulator

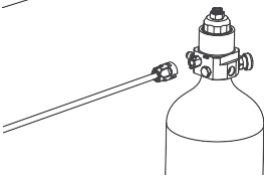
The HFLW Regulator is designed to be connected to an Intelligent Energy FCPM. Please refer to the Light Weight (LW) Regulator user manual for details of how to mount the Regulator to the cylinder.

Note ***Ensure the hydrogen cylinder and FCPM are securely mounted before proceeding***

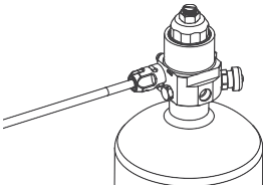
1. Verify the connector O-rings are in place and free from damage or debris.



2. Align the hose connector path with the regulator pins.



3. Push the hose connector and twist anti-clockwise. It will click when located.



4.5 TPED SCV

For transportation of pre-filled hydrogen cylinders, the Intelligent Energy SCV can be threaded between the cylinder and HFLW regulator. More information can be found at:
www.intelligent-energy.com/our-products/uavs

5 Electrical connections

To function, the FCPM should have the following attached to the unit. See section 2.2 for reference to connection locations.

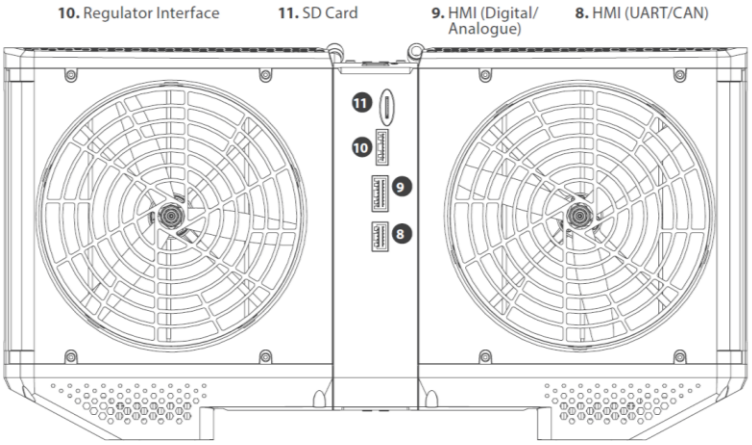
Connection No.	Description	Comments
1	Output negative	Common ground
1	Battery negative	Common ground
2	Output positive	Output is live once battery connected
3	Battery positive	Ensure battery has isolating connector
8	HMI UART/CAN	At least one HMI interface must be in place
9	HMI Analogue/Digital	At least one HMI interface must be in place
10	Regulator interface	

The following ports are optional or are currently not used.

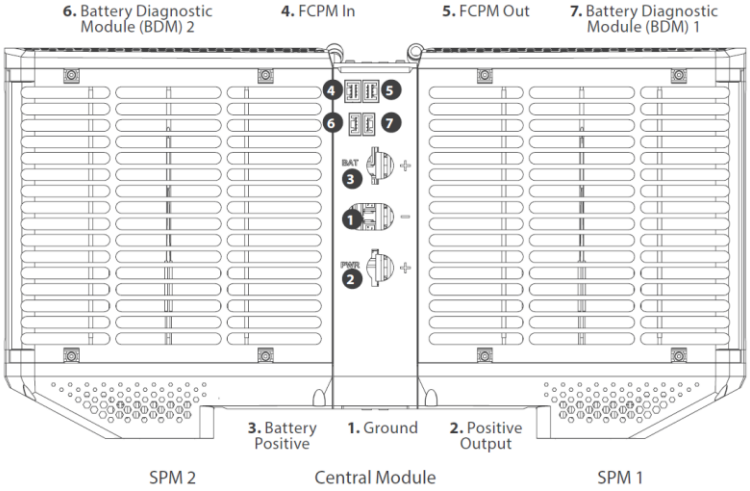
Connection No.	Description	Comments
4	FCPM Out	Do not use – If connected unit is slave
5	FCPM In	Do not use – unit is master if not connected
6	Battery diagnostics out	Do not use
7	Battery diagnostics in	Do not use
8	HMI UART/CAN	**At least one HMI must be in place**
9	HMI Analogue/Digital	**At least one HMI must be in place**

Note ***Port 8 or port 9 must have its respective connector in place for the FCPM to turn on. Each connector has a pair of looped pins that enable power output.***

5.1 System electrical connections labelled



FCPM Rear view



FCPM Front view

6 Logging and data connections

6.1 SD card formatting

The FCPM takes a micro-SD card. This logs health and performance data as well as fault codes. The micro-SD card format must be FAT32. No files are required for initial operation, the FCPM will create the necessary files for operation.

Note ***Where SD data has been deleted, warranty claims may be denied (except where specific exemption has been granted by an Intelligent Energy representative for sensitive applications).***

6.2 SD card data format

The following folder structure is automatically generated on the SD if not already present: \\IntelligentEnergy\data
Micro-SD card presence must be detected for the FCPM to start up.

6.3 Configuration format

The behaviour of the FCPM can be adjusted via the configuration file. This is set at build but can be adjusted if required. Please contact Intelligent Energy Product Support for the necessary tools.
The configuration file has the following parameters:

Parameter	Unit	Range	Factory Setting (12S)
Target Output Voltage	Volt	40.0 to 70.0	51.4
Battery Charging Current Limit	Amp	0.0 to 7.5	7.5
SPM Power Limit	Watt	500 to 2000	1500
Customer Serial Port	–	NA	NA
Debug Serial Port	–	NA	NA
CAN Data Format	–	NA	NA
Wait for Start Command	–	True/False	False
Allow Single SPM Running (1.2kW mode)	–	True/False	False
Expected Slave Count	–	0 to 7	0
Dynamic Control over Customer Serial	–	True/False	False
Dynamic Control over Customer CAN	–	True/False	True

6.3.1 Configuration parameter definitions

Target Output Voltage	The voltage the FCPM will output at if delivering at or less than rated power (2.4kW).
Battery Charging Current Limit	Maximum current that the combined SPMs will deliver to the batteries.
SPM Power Limit	Maximum power that each SPM can deliver to the output load and the battery charging circuitry combined.

7 Electrical considerations

7.1 Battery charge limits

The battery charging rate can be set in the configuration file (see section 7.3), battery charging functions can be set via CAN dynamically. If CAN communication is lost battery charging settings will revert to configuration file settings.

7.2 Emergency battery usage

The 2.4kW FCPM has redundancy offered by its dual SPM architecture. If one SPM has a critical fault, the remaining SPM and the battery are still able to provide power.

Note ***The operator should monitor the data outputs, so they are aware of any fuel cell or other faults during flight.***

7.3 Specifying a battery

The 2.4kW FCPM is designed to support a number of different aircraft and power architectures. Modularising the unit gives freedom to integrators to change battery capacity, voltage, and discharge rates to suit particular applications. Batteries must be specified that are suitable for the application. Things to check specifically are:

- Battery discharge rate (or 'C' rating) – the battery must be able to supply the current required by the load.
- Battery voltage (or number of cells) – must be aligned with the configured voltage of the fuel cell system.
- Battery capacity – this will affect how long the battery can discharge for and will directly affect the batteries capability to provide peak or emergency power.
- Typical battery configurations used are 12S-16S LiPo voltage range.

7.4 Specifying a hybrid battery cable

The 2.4kW FCPM is designed to support a number of different vehicles, airframes and power architectures. Modularising the unit gives freedom to integrators to change battery and output cables to suit particular applications. Cables must be specified that are suitable for the application. In particular, the current specification of the cable must be able to handle the maximum current drawn by the load (typically UAV motors/ESCs).

For reference, the cable that comes fitted to the hybrid batteries is 8AWG (CSA 8.3mm^2)

Note ***Incorrectly specifying a cable could cause sudden and immediate loss of output power.***

If you have any questions about the electrical configuration of the FCPM or how to customise to a particular application, please contact servicing@intelligent-energy.com

8 Storage and maintenance

8.1 User maintenance

Before every operation, the FCPM should be inspected for damage.
Hydrogen systems must be inspected prior to each use to verify that no gas leaks are present.
In the event of a heavy impact the following should be checked on the FCPM:

- All coverings are still in place and undamaged.
- Hydrogen pipework is still in good condition with no leaks.
- Fans rotate freely.
- In the event of it being stored for more than 60 days, the FCPM should be reconditioned as per the instructions in section 9.3 below.

8.2 Recommended storage conditions

To maintain the condition of the FCPM between operational uses, the FCPM should be stored as follows:

- The hybrid battery should be removed from the unit before storage.
- Ideal ambient conditions are +20°C and >50% humidity.
- The recommended storage of the FCPM will increase the time between reconditioning cycles.

8.3 Reconditioning

After a period of inactivity, the performance of the fuel cell may degrade. The main reason for this is the fuel cell drying out when unused. A reconditioning cycle can reverse this degradation and restore lost performance.
There are two ways to operate the 2.4kW FCPM during reconditioning:

1. With a load unit (preferred).
2. With a UAV whilst hovering / loitering (if using this method please read relevant section below beforehand)

Note ***Do not recondition the IE-SOAR™ 2.4kW unit with an Intelligent Energy PLU, it is not designed for operation above 25V.***

Both methods require the reconditioning micro-SD card be inserted before powering the system on. The reconditioning SD-card should not be used for operational flight. Additionally, the process does require a hydrogen supply, so the hydrogen cylinder supplying the fuel cell should be checked to ensure sufficient gas availability.
A fully charged hybrid battery should be connected to the 2.4kW unit before reconditioning. The battery will see some load during the process.

9 End of life treatment and disposal

When the 2.4kW FCPM or HFLW regulator reaches end of life please contact Intelligent Energy for support with reconditioning or disposal at

servicing@intelligent-energy.com

10 Warranty and data

Where no user misuse or error is present, and whilst products remain under warranty, Intelligent Energy offers free repairs. Any warranty repair claim made must be supported with SD log data, failure to provide said data on request may jeopardise the chance of a specific claim being accepted.

Thus, it is imperative that SD log data is not ever deleted.