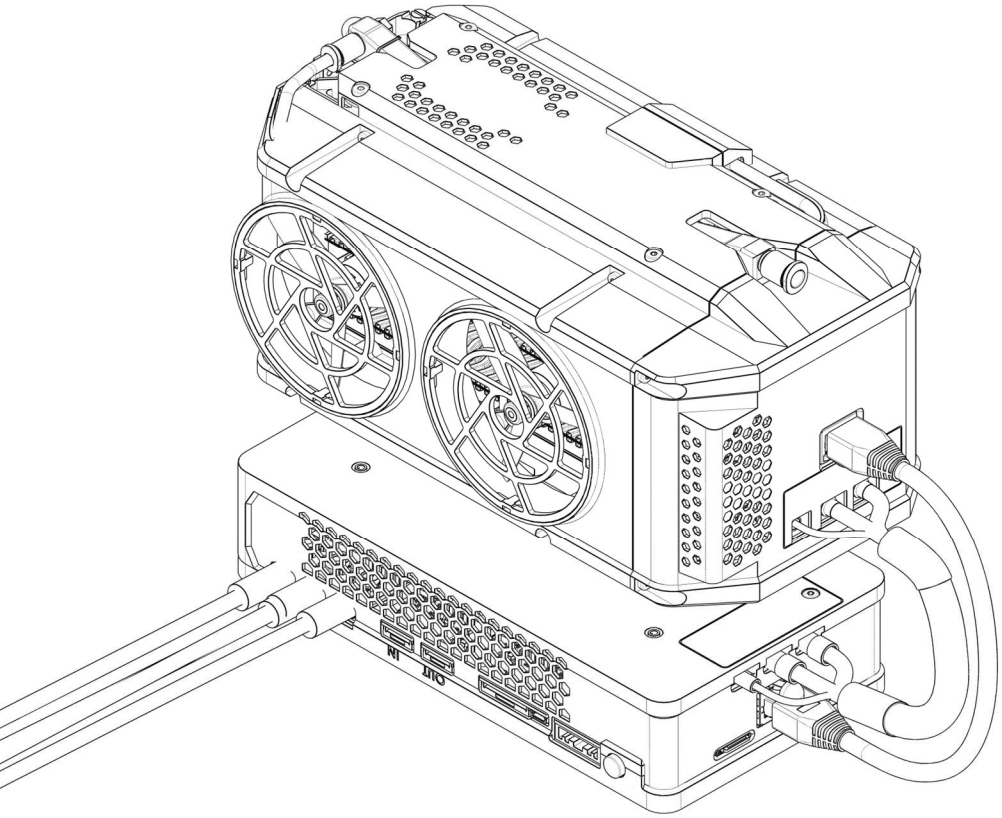
INTELLIGENT ENERGY

IE-SOAR™

User Manual

IE- SOAR 800 FUEL CELL POWER SYSTEM

Users must read all instructions and retain manual for future reference
Original Language Instructions



This is the User Manual for the IE-SOAR 800 Fuel Cell Power Module (FCPM) designed and manufactured by Intelligent Energy.
Users of the FCPM 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.
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 user is responsible for ensuring that all personnel have read and understood this User Manual before being allowed to handle, operate, install and store the FCPM. The user 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 user 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. Any failure to comply with the instructions and requirements in this User Manual may invalidate any potential warranty claims and Intelligent Energy, to the fullest extent permitted by law, accepts no liability for any losses, harm or damage caused as a result of the user's use of the FCPM other than in accordance with this User Manual. Intelligent Energy has made every effort to ensure that this User Manual is complete based on reasonably foreseeable use of the FCPM, and Intelligent Energy shall not be liable for any use or application of the FCPM that is not reasonably foreseeable.

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 when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his own expense.

Testing Partners LLC
18200 SR 306
Chagrin Falls, OH 44023
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CE Marking Statement

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

EU authorised representative:
Certification Company B.V.
Transistorstraat 91-12 1322 CL Almere The Netherlands
admin@certification-company.com

Product support webpage:
We have webpage dedicated to IE-SOAR product support; it contains:
- User manuals and guides
- Software updates
- CAD files (STEP)
- FAQ's

https://www.intelligent-energy.com/product-support/ie-soar-support/
Password: 341sL&A26Ypn

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

Document No. 1167544

This is manual revision 1.2, published 4 August 2026

Glossary of terms

Term	Definition	Description
6/12S	Refers to cell count of Hybrid battery	6S batteries have 6 cells in series, giving them a max voltage of 25.4V
CAN	Controller Area Network	Communication bus commonly used on UAV and automotive platforms
CFD	Computational Fluid Dynamics	Computerised simulation tool that helps predict fluid behaviour
CSA	Cross-Sectional Area	-
DCDC	Direct-Current to Direct-Current converter	Switching power converter that steps its input DC voltage up or down as necessary to provide a stable output voltage
EMF	Electromotive Force	Energy per unit charge. Measured in volts.
ESC	Electronic Speed Controller	Electronic component that supplies a brushless motor with voltage pulses and controls its RPM
FCPM	Fuel Cell Power Module	The entire fuel cell system
HFLW	High Flow Light Weight	High Flow Lightweight Regulator
LED	Light Emitting Diode	Electrical component that emits light
LW	Light Weight	-
MCU	Microcontroller Unit	PCBA in power module that runs main software
NVM	Non-Volatile Memory	Flash memory within the MCU chip
PCBA	Printed Circuit Board Assembly	Circuit board populated with components
PLU	Portable Load Unit	Electronic load
PM	Power Module	Houses power input/output connections, communications interfaces and SD slot
RPM	Revolutions Per Minute	Number of revolutions per minute
RTC	Real Time Clock	Digital clock with button cell battery
IE-SOAR 800	800W FCPM	Consists of the Power Module (PM) and Stack Module (SM)
SCV	Self-Closing Valve	A valve that complies with TPED stipulations
SD	Secure Digital	The IE-SOAR 800 writes log files to a micro-SD card
SM	Stack Module	Module containing fuel cell stack and associated electronics
SPM	Stack Power Module	DCDCs that take in stack voltage and output the target voltage
Stack	Fuel cell stack	Consists of fuel cells stacked in series
TPED	Transportable Pressure Equipment Directive	Directive covering transportable pressure containing devices
UART	Universal Asynchronous Receive/ Transmit	Serial communication protocol
UAV	Unmanned Aerial Vehicle	Remote controlled aerial vehicle.
UIB	Umbilical Interface Board	PCBA on stack module
VOC	Volatile Organic Chemicals	Common in cleaning products and spray cans. Harmful to fuel cells.
VTOL	Vertical Take-Off Landing	Aircraft that takes off and lands vertically

Contents

1 Safety Warnings

- The customer is responsible for ensuring the safe operation of the FCPM in line with the User Manual.
- Handle all equipment with care, use in a well-ventilated area.
- Only qualified technicians trained in high pressure flammable gases should carry out fitting of regulators and filling of cylinders and must do so in accordance with local laws and health and safety 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.
- During integration there is a risk of exposed electrical conductors.
- No switching elements (e.g. ideal diodes) should be placed in the power path between the battery and the FCPM.

- A minimum of 0.5m^3/min of oxygen is required for operation.
- The system may demand up to 10m^3/min of air for cooling. Therefore, any enclosed design must allow for this.
- Great care should be taken when designing airflow pathways to / from the stack module (SM), uniformity should be ensured and ram air minimised. An uneven airflow distribution will increase the likelihood of over/undercooling areas of the fuel cell stack, which may in turn compromise system reliability and safety. Outlet flow restriction can impact flow uniformity.

- Pressurised hydrogen present. Highly flammable!
- Do not transport the FCPM with the hydrogen supply connected.
- All hydrogen tubing should be regularly inspected for damage and leaks – especially where it mates with push fittings. Immediately replace any damaged tubing.
- Hydrogen supply tubing and connectors should be kept free from dust and debris. Plugs and caps should be used to maintain cleanliness.
- Avoid exposure to volatile organics (VOCs), poisonous/corrosive gasses and anything with a prominent scent. This includes but is not limited to cleaning products, air-fresheners, glues/adhesives/epoxies, chemical solvents, and ammonia. Particular care should be taken to avoid storing the fuel cell in an enclosed space (e.g. drawer, bag or box) with potential contaminants as this may accelerate the contamination process.

- Do not remove casings from the FCPM – apart from access hatches.
- Do not operate the FCPM if the casing is damaged or missing.
- Do not use the FCPM if any part has been immersed or flooded with water.
- FCPM not to be used in dusty, smoky, or corrosive gas environments.
- Do not use FCPM in rain or snow.

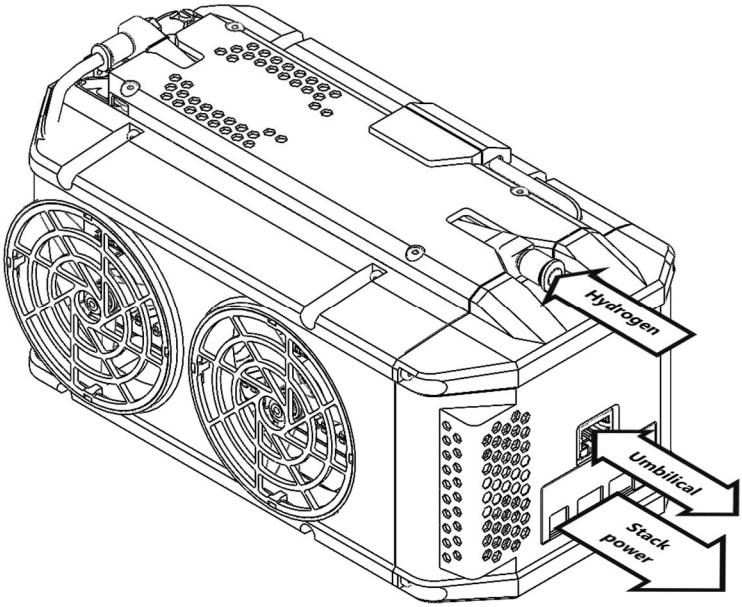
- Ensure the aircraft powered by the FCPM is maintained correctly, any loose bolts or metal parts that fall into the housing will cause damage to fuel cell componentry.
- For operational safety during flight, it is essential to monitor remaining hydrogen fuel pressure, hybrid battery voltage, run state and error codes. Not doing so could lead to unexpected loss of power.
- Keep fingers clear of the fans when the system is in operation.
- The IE-SOAR 800 must be securely attached to the vehicle or test fixture.
- Connecting multiple batteries could lead to rapid cross-charging where batteries are connected with different voltages. DO NOT CONNECT MULTIPLE BATTERIES.
- The hybrid battery must be balance charged regularly by the operator.
- FCC/CE EMC class A product, not for use in residential areas.

2 Product Specification

Power characteristics	Maximum continuous fuel cell power (after 1000h of runtime)		**800W**
	Peak power with 6S hybrid battery		**2500W**
	Peak power with 12S hybrid battery		**5000W**
	Power module output current	Continuous	**100A**
		Absolute max	**150A**
	Output voltage (configurable and regulated output)		**25 – 50V (default 50V)**
Physical characteristics	Fuel Cell dimensions		**120 x 230 x 109mm**
	Power module dimensions		**107 x 202 x 46mm**
	Fuel cell mass		**1000g**
	Power module mass		**430g**
	Combined mass with cabling		**1490g**
Hydrogen supply requirements	Inlet pressure limits		**0.9bar.g ± 0.1bar.g (13psi ± 1.5psi)**
	Hydrogen consumption rate g/hr @ 800W		**47-53g/hr**
	Hydrogen flow rate - peak		**17L/min (minimum)**
	Hydrogen flow rate at 800W		**9L/min**
Hybrid batteries	Default hybrid battery (configurable)		**12S**
	Dimensions (per battery)		**72 × 46 × 53mm**
	Mass (per battery)		**300g**
	Capacity (per battery)		**1800mAh (~40Wh)**
Environmental operating conditions	Start-up temperature		**0°C to 40°C**
	Operating temperature		**-5°C to 40°C**
	Storage temperature		**-10°C to 70°C**
	IP rating		**None**
	Maximum operating altitude (ASL)		**3000m**
Safety features	Redundant architecture with fuel cell power system and backup hybrid battery. Internal fault monitoring and startup leak checks.		
Other features	System warranty		**(See section 13)**
	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 IE-SOAR 800 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.		
	High power electrical connectors		**M4 ring terminals** **XT-60 hybrid battery input** **XT-90 power output**

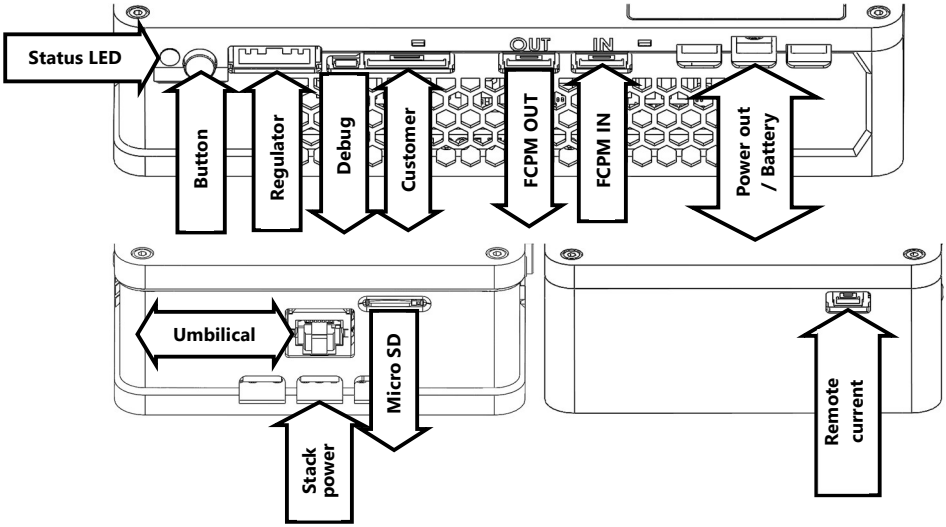
3 System Connections

3.1 Stack module inputs / outputs



Connector name	Information
Hydrogen input	6mm Outer-Diameter hose
Umbilical	CAT 6A ethernet to PM
Stack power out	All ring terminals
STK+	M4 1.2Nm
STK-	M4 1.2Nm
VBOP	M3 0.5Nm

3.2 Power module inputs / outputs



Connector name	Information
Debug	IE use only
Umbilical	CAT 6A ethernet to SM
Stack power	All ring terminals
STK+	M4 1.2Nm
STK-	M4 1.2Nm
VBOP	M3 0.5Nm
Power out / Battery	All ring terminals
BAT+	M4 1.2Nm
GND	M4 1.2Nm
OUT+	M4 1.2Nm
Customer port	UART and CAN interfaces, remote start/stop etc. See pinout in 3.2.1
Regulator	Connects to pressure transducer on regulator. See pinout in 3.2.2
Remote current	For external current sensor. See pinout in 3.2.3
FCPM IN / OUT	Used to connect systems in parallel. See pinout in 3.2.4

3.2.1 Customer port pinout

Connector is of the type JST GHR-15V-S.

Pin No.	Function	Information
1	3.3V	3.3V output (200mA limit)
2	Start 1	Digital in (pull high to simulate button press)
3	Start 2	Digital in (pull high to simulate button press)
4	UART Rx	Customer UART Receive
5	UART Tx	Customer UART Transmit
6	5V	0 to 5V output (350mA limit)
7	CAN_H	Customer CAN high
8	CAN_L	Customer CAN low
9	CAN termination 1	Loop together to connect internal 120ohm termination resistor
10	CAN termination 2	
11	Loop out	Loop together
12	Loop in	
13	0V	Ground
14	0V	Ground
15	Cable shield	0V filtered, use for cable shield only

3.2.2 Regulator port pinout

Connector is of the type JST 08-CPT-B1-2A.

Pin No.	Function	Information
1	5V	5V output (for cylinder transducer only)
2	Tank pressure signal 1	0.5-4.5V (0-100% range)
3	Tank pressure signal 2	0.5-4.5V (0-100% range)
4	Valve power supply	(not used at present)
5	Valve return	(not used at present)
6	0V	Ground
7	NC	-
8	Cable shield	0V filtered, use for cable shield only

3.2.3 Remote current sensor pinout

Connector is of the type GHR-4V-S.

Pin No.	Function	Information
1	5V	5V output (for cylinder transducer only)
2	Current signal	Configurable scaling & offset, 0-5V input
3	0V	Ground
4	Cable shield	0V filtered, use for cable shield only

3.2.4 FCPM In/Out pinout

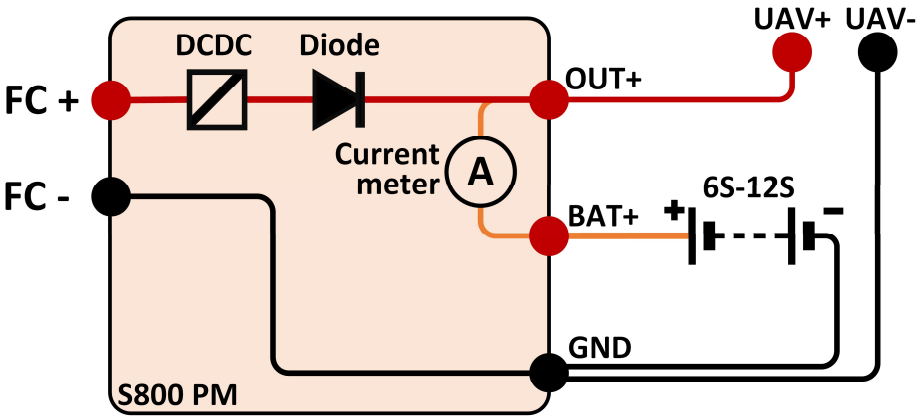
Connectors are of the type GHR-8V-S.

Pin No.	Function	Information
1	Power in/out	For use in parallel configurations
2	Master in/out	For use in parallel configurations
3	Assign in/out	For use in parallel configurations
4	Start 1 in/out	For use in parallel configurations
5	Start 2 in/out	For use in parallel configurations
6	CAN_H	For use in parallel configurations
7	CAN_L	For use in parallel configurations
8	0V	Ground

3.2.5 Power Module power electronics block diagram

See below a simplified electrical block diagram of the PM. The battery positive and output positive are connected in parallel via a shunt resistor which is used to measure battery output current and charge current.

Battery charging and discharging is controlled by the DCDC, which alters its target output voltage to achieve a desired battery charge / discharge current.



4 Assembly & Integration

During integration there is a risk of exposed electrical conductors

4.1 Connecting output power cables

Access to the output / input power ring terminals is via a hatch on the PM.
Follow the steps below to change the input / output cables that connect to the PM:

1. Check that the battery is isolated from the battery power input cables.
2. Remove the terminal access hatch using a 2mm Allen key.
3. If input / output power cables are already fitted, remove them using a 3mm Allen key.
4. Feed the new power input / output cables through the window in the PM. Connect load positive to OUT+, battery positive to BAT+ and both negative cables to GND.

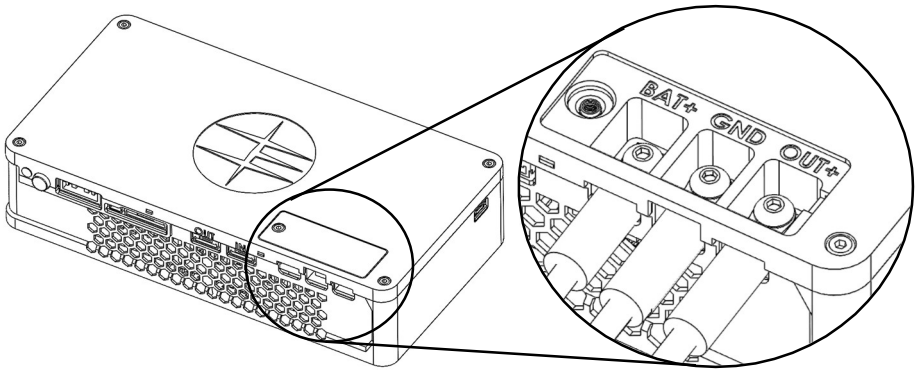
Note ***The negative terminal is common to the battery input and power output connections***

5. Tighten the three M4 bolts to 1.2Nm.

Note ***All power leads require an M4 ring terminal to be attached to the PM***

6. Refit the terminal access hatch using a 2mm Allen key.

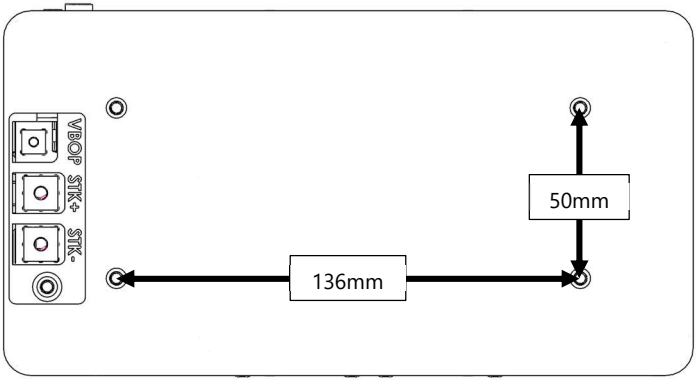
Where the connector type is changed, ensure that the selected connector type is rated for the application.



4.2 Mounting

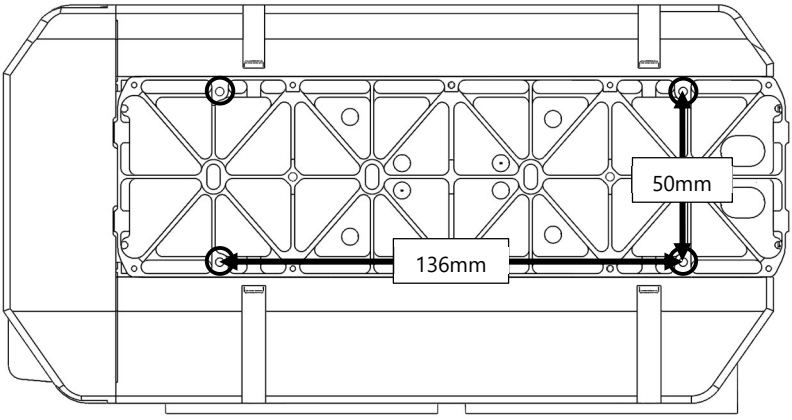
The mounting points all use an M3 thread and are spaced equally on the power module and stack module.

4.2.1 Power module



Note ***Bolts should be torqued to 0.3Nm, do not use thread-lock (threaded inserts may rotate upon removal).***

4.2.2 Stack module

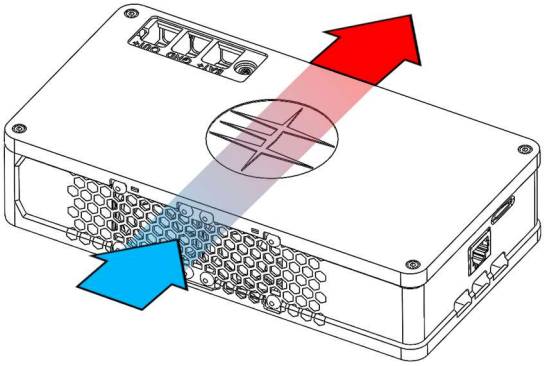


Note ***Bolts should be torqued to 0.5Nm.***

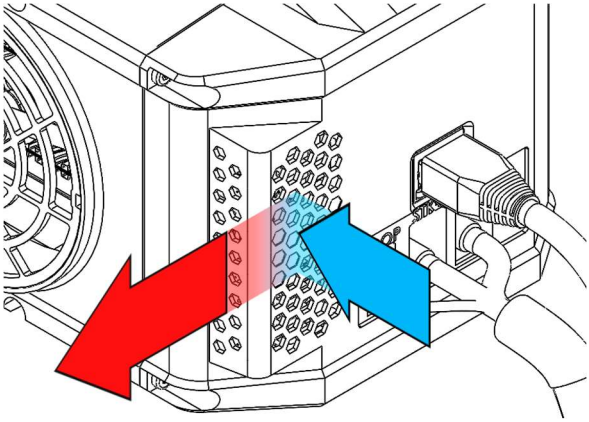
Do not remove casings from the FCPM – apart from access hatches.

4.2.3 Electronics airflow considerations

The power module electronics are cooled by two small fans which push air through the enclosure. The inlet and outlet grilles for this cooling airflow must not be obstructed. See the airflow direction below:



The stack module electronics are cooled by two small fans, again, the inlet and outlet airflow should not be blocked, see the airflow direction below:



4.3 Fuselage Integration

Integration of the IE-SOAR 800 FCPM into an enclosed fuselage necessitates consideration of airflow delivery to the fuel cell stacks, as well as ducting of the outlet airflow away from the stacks.

4.3.1 Airflow requirements

The following statements should help guide fuselage integrators in designing their airflow arrangements:

Airflow into the stacks should be uniform, CFD may be required to ensure that ducting does not lead to separation and / or stagnation of flow.

Non-uniform flow will lead to under-cooling of areas of the stack, which may compromise system lifespan, efficiency, and safety.

The system may demand up to 10m^3/min of air for cooling. Therefore, any enclosed design must allow for this.

A minimum of 0.5m^3/min of oxygen is required for operation.

- Ram air must be kept to a minimum, the system manages airflow using its fans, these must maintain authority over air flowrate for the system to function safely and efficiently.
- When in forward flight, the pressure difference generated by the integration between the inlet and outlet sides of the stack should be negligible. Any pressure difference should be generated by the system cooling fans.
- Ducting arrangements which slightly bias airflow to the edges of the inlet and exhaust are acceptable in arrangements where airflow bias is unavoidable. When in doubt, contact IE customer support who will be able to provide guidance and insights on integration best practice.
  servicing@intellignet-energy.com

5 Hydrogen Supply

5.1 Connector specification

The SM 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, SMC TAU0604B-20

All hydrogen tubing should be regularly inspected for damage – especially where it mates with push fittings. Immediately replace any damaged tubing.

5.2 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.

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

The hydrogen purity should comply with the specification in the table below:

FCPM not to be used in dusty, smoky, or corrosive gas environments.

5.3 Cylinder purging

Before using a cylinder to fuel the FCPM, it must first be purged of air using nitrogen, then purged of nitrogen using hydrogen. This sequence is a safety precaution, and prevents an explosive mixture of hydrogen and oxygen from forming.
The following table shows how many hydrogen purges must be completed at various fill pressures to bring the concentration of hydrogen in the tank to >99.9%. More purges at lower fill pressures will use less gas overall. The below number of purges at the respective pressure will yield >99.9% pure hydrogen in the cylinder after the last purge has been completed.

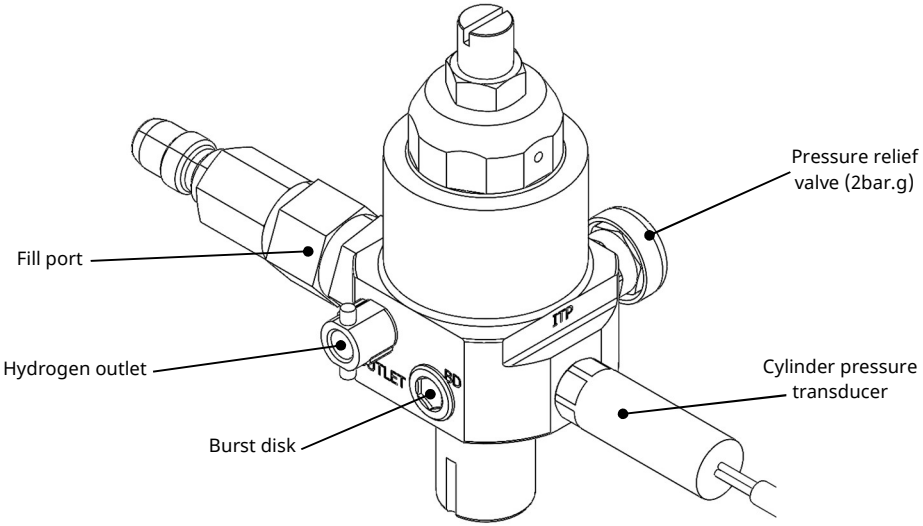
Fill pressure [bar.g]	2	4	6-8	10
Purges needed	10	5	4	3

Pressurised hydrogen present. Highly flammable!

5.4 Hydrogen High Flow Light Weight regulator (HFLW)

The 800W 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. 0.9bar.g ± 0.1bar.g (13psi.g ± 1.5psi) with flowrate of 50l/min are required.***



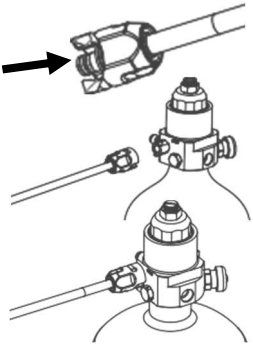
5.5 Connecting the FCPM and HFLW Regulator

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.

Only qualified technicians trained in high pressure flammable gases should carry out fitting of regulators and filling of cylinders and do so in accordance with local laws and Health and Safety (H&S) regulations.

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.
   Blow the hydrogen outlet free of dust / 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.



Do not transport the FCPM with the hydrogen supply connected.

5.6 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/ie-soar-fuel-cells-for-uavs/

5.7 Non-IE regulators

Other regulators may be used to supply the IE-SOAR 800 with hydrogen, so long as the outlet pressure is maintained at 0.9bar.g ± 0.1bar.g (13psi ± 1.5psi) in operation. Any non-IE regulator should also be fitted with a 50-micron filter to prevent debris from fouling either the regulator internals or the FCPMs.

To use a non-IE regulator, a configuration that disregards the high-pressure signal is required, see section 7.3.

5.8 Multiple cylinders

For some applications, use of multiple cylinders may allow for optimal mass distribution. The IE-SOAR 800 supports this, see section 3.2.2 for the regulator interface pinout, which includes provision for two tank pressure signals.

Where two cylinder pressures are present, the system will output an average of the two. For example, if one tank is at 100% and the other at 50%, the UART and CAN will read 75%.

This logic assumes cylinder volumes are equal to estimate the total remaining gas quantity, if the two cylinders have different volumes, the rate of average pressure depletion will vary depending upon which cylinder is supplying the hydrogen being consumed.

The low pressure warning error will be sent when the average tank percentage is 4.3%. See error 12 (9.1.4).

The tank empty shutdown will trigger when the highest tank percentage goes below 1.3%. See error 30 (9.1.4).

5.9 Dust and debris

To prevent the ingress of debris into the fuel cell system, the hose connector should be capped or covered when not in use.

5.10 Pressure related errors

5.10.1 Under-pressure shutdown

The IE-SOAR 800 monitors inlet pressure using its built-in pressure transducer. The system will not start (deny start), or will shut off whilst running when the inlet pressure is outside of the ranges specified below:

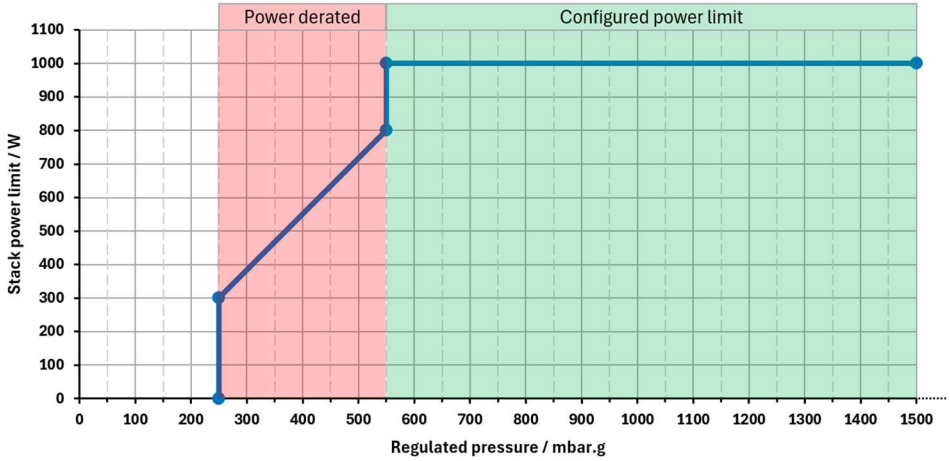
	Over-pressure [mbar.g]	Under-pressure [mbar.g]
Deny start / shutdown	1500	250

5.10.2 Low pressure power derate

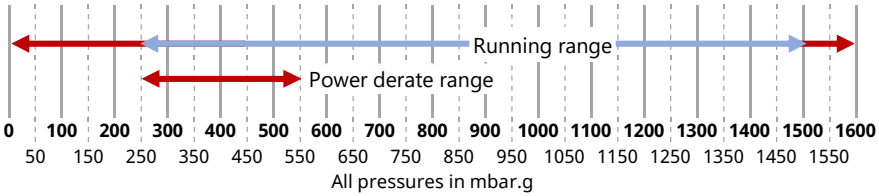
The IE-SOAR 800 derates power between 250-550mbar.g, this is to reduce the rate of hydrogen consumption when a regulator is unable to maintain its output pressure, minimising the chance of an under-pressure shutdown and ensuring that some power is generated.

The highest regulated pressure measured in the last 10s is used to calculate the power limit.

The derate applies to the power measured at the output of the DCDC converter (3.2.5) and is calculated as follows:



See below a representation of the full allowable pressure range, and the derate range.



6 Operating the FCPM

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.

6.1 Start-up

FCPM should be inspected for damage and checked for leaks prior to use. Do not operate the FCPM if the casing is damaged or missing.

6.1.1 Using the start button

Note ***As soon as the battery is connected – the output will be live.***

1. Check regulator interface is connected.
2. Check fuel line/s are connected.
3. Check that there is sufficient hydrogen fuel available, and that the cylinder has been purged, see 5.3.
4. Connect battery.

Note ***Output is now live.***

5. Press the start button until audible fan noise is heard (max 5 seconds).
6. Fuel cell start-up process will begin.
7. Check error codes to ensure the system has started correctly. See section 9.
8. When the LED is green, fuel cell power is available.

6.1.2 Using a digital signal

For remote start-up via a digital signal, use the process as outlined in 6.1.1. However, step 5 is changed to:

5. Pull Start 1 and Start 2 on the customer port (3.2.1) high for 4 seconds (3.3V/5V).

6.2 Shut-down

6.2.1 Using the start button

The procedure to shut down the FCPM:

1. Press button for 4 seconds.

Note ***The system "blasts" the fans on shutdown, this generates around 90db.***

2. Wait until LED stops flashing orange before moving to next step.

Note ***Removing battery early could corrupt the micro-SD card.***

3. Disconnect batteries.
4. Isolate hydrogen supply by disconnecting the bayonet fitting, see 5.5.

Note ***Always disconnect batteries after use, leaving them connected for extended periods could damage the battery and/or FCPM permanently.***

Always isolate the hydrogen supply after use to ensure a safe off condition.

6.2.2 Using a digital signal

For remote operation with a digital signal, use the process as outlined in 6.2.1. However, step 1 is changed to:

1. Pull Start 1 and Start 2 on the customer port (3.2.1) for 4 seconds (3.3V/5V).

6.3 Idle mode

Under certain conditions, idle mode will power the stack module down, closing the inlet valve to the stack, and switching the fans off. This feature was added to improve the reliability and longevity of the system, as well as overall efficiency.

The system will put the stack module into idle mode in two ways:

1. Automatic - Battery voltage is >4.0V/cell for 1s and output power is <80W for >300s.
   or
2. Manual - Battery voltage is >4.0V/cell for 1s and output power is <80W and the power button is tapped.

Power will be available from the battery when the stack module is idle.

The system will turn the stack module back on when:

1. Battery voltage is <3.8V/cell for 1s.
   or
2. Output power is >200W for 2s.
   or
3. Power button is tapped.

Full stack module power will be available 8s after one of the above three conditions is met.

Automatic idling is configurable and can be switched off (not recommended). See 7.3.

There are a series of error codes to notify the pilot of idle state, see section 9.1.4 for more information.
The code sequence is as follows:

1. 10s before idle mode is entered, code 9.19 will be output (IDLE MODE ENTERING).
2. When idle mode is active, 9.13 (IDLE MODE ACTIVE) will be output.
3. As soon as an idle exit condition is met, 9.20 (IDLE MODE EXITING) will be output.

6.4 Regenerated power

In certain conditions, power may be pushed back into the FCPM system. (e.g. when landing a UAV, power is generated by the ESCs as the kinetic energy of the rotors is recovered). This power fed back from the load is termed “regenerated power”, or “back-EMF”.
Because the hybrid battery is connected in parallel with the system output, regenerated power will be absorbed by the battery, as it would in a standard, battery powered UAV.

No switching elements (e.g. ideal diodes) should be placed in the power path between the battery and the FCPM.

6.5 Monitoring of data output

For operational safety during flight, it is essential to monitor remaining hydrogen fuel pressure, battery voltage, run state and error codes. Not doing so could lead to unexpected loss of power.

See section 9.

6.6 Software update procedure

To change the software on the system, follow the steps below:

1. Power off FCPM and disconnect hybrid batteries.
2. Download the latest software release from the product support webpage.
3. Remove micro-SD card from the IE-SOAR 800 PM, and copy the IntelligentEnergy folder from the software update onto the SD. Click *"replace all"* if prompted.
4. Re-insert micro-SD card to the FCPM.
5. Reconnect batteries.
6. Wait for LED to change from rapid amber flashing to rapid green flashing.
7. Remove hybrid batteries.
8. Software update has been completed.
9. The *"LoadUIB.txt"* | *"LoadMCU.txt"* file will be renamed to *"LoadedUIB.txt"* | *"LoadedMCU.txt"* by the system. These files may be left on the SD card.

6.7 Configuration update procedure

To change the configuration of the system, follow the steps below. The parameters for the configuration can be found in section 7.3.

1. Power off FCPM and disconnect hybrid batteries.
2. Remove micro-SD Card and open IntelligentEnergy folder on the micro-SD card.
3. Copy the new .fcc config file into the *"Configs"* folder, if this folder does not exist, create it. Example config file name - *"S800_2A_UART4_CAN2_HPI-OFF_AR-ON.fcc"*.
4. Create a *"ConfigMCU.txt"* file inside the IntelligentEnergy folder.
   Copy the name of the .fcc file (including extension) into the *"ConfigMCU.txt"* file.
   The .fcc file referenced by the *"ConfigMCU.txt"* will be loaded to the MCU.
5. Re-insert micro-SD card to the FCPM.
6. Reconnect batteries.
7. Wait for LED to change from rapid amber flashing to rapid green flashing.
8. Remove hybrid batteries.
9. Configuration update has been completed.
10. The *"ConfigMCU.txt"* file will be renamed to *"ConfiguredMCU.txt"* by the system. This file may be left on the SD card.

6.8 LED states

The colour of the LED (located on PM next to the button) denotes specific running states and errors, as follows:

Colour	State	Description
Off	Solid	FCPM off – output off
Green	Flash	Output live – fuel cell on – normal operation
Green	Double Flash	Output live – fuel cell off
Green	Slow Flash	Fuel cell starting
Amber	Slow Flash	Fuel cell starting – H_2 pressure low
Red	Flash	Fuel cell stopping
Amber	Flash	Output live - fuel cell on - low H_2 pressure
Amber	Double Flash	Output live - fuel cell off - low H_2 pressure
Amber	Rapid Flash	Software updating or entering sleep mode
Green	Rapid Flash	Software update complete
Red	Rapid Flash	Software update failed

6.9 Operation in cold environments

The system can be started where the ambient temperature is above 0°C and will run where the ambient temp is above -5°C.

Note ***When ambient temperatures are low, the fans will "blast", spooling up quickly and making a loud sound for short durations.***

Note ***When operating in colder conditions, ensure that the time between turning the system on and take-off is minimal, else the stack may be excessively cooled due to a lack of heat generation.***

Note ***Storage at <0°C can cause ice/freezing inside the fuel cell stack. Ensure that the system is not started from frozen. Defrost indoors (~20°C ambient) if necessary.***

Do not use FCPM in rain or snow.

Do not use the 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.

7 SD Format and System Configuration

7.1 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).***

7.2 SD card folders and files

The following folder structure is automatically generated on the SD if not already present:

\IntelligentEnergy\DATALOG	Contains encoded log files for use by IE
\IntelligentEnergy\CUSTLOG	Contains customer readable logs See section 8 for more information.

Additional folders that may be present are:

\IntelligentEnergy\Configs	Configurations, may contain multiple files
\IntelligentEnergy\Images	.bin software images, may contain multiple files

With the corresponding instruction files:

\IntelligentEnergy\ConfigMCU.txt	The **.fcc** file will be loaded to the non-volatile memory
\IntelligentEnergy\LoadUIB.txt	The software **.bin** referenced will be loaded to the UIB
\IntelligentEnergy\LoadMCU.txt	The software **.bin** referenced will be loaded to the MCU

These files should contain the name of the .bin or .fcc to be utilised.

“Config” and “Load” will be changed to “Configured” and “Loaded” once their instruction has been completed (see 6.6 / 6.7). The files may be left in the “IntelligentEnergy” folder.

Reconditioning SD cards will have:

\IntelligentEnergy\Special_Mode_1.txt	Presence of this empty file will cause the system to boot into **reconditioning** mode. (0)

Micro-SD card presence must be detected for the FCPM to start up. Logging may be disabled, contact IE product support for information.

7.3 System configuration

The IE-SOAR 800 has various parameters that are set at startup, such as the target output voltage and hybrid battery charge limit. These parameters are saved to non-volatile memory on the MCU PCBA in the power module. Thus, once a configuration has been written from the SD card to the NVM, the SD card may be replaced or the configuration file deleted, but the system will retain its configuration.

For instructions on loading a new configuration, see section 6.7. Note that the name of a configuration file is limited to 75 characters.

7.3.1 Configuration parameters

Parameter	Unit	Range	Factory Setting	Options
Auto reconditioning	–	True/False	True	Activates in-flight automatic reconditioning. See 12.3.2.
Battery Charge Limit	Amp	0 to 40	2	Sets maximum battery charge current
CAN Baud	Baud	125-1000kbit/s	500	0 – 125 kbit/s 1 – 250 kbit/s 2 – 500 kbit/s 3 – 1000 kbit/s
Customer CAN Data Format	–	0 to 3	2	0 – Off 1 – IE use only 2 – Single system 3 – Parallel systems
Customer Serial Port Format	–	0 to 6	6	0 – Off 1 – Legacy format 2 – Encoded test data – IE use only 4 – Default format 5 – Default + fan duties 6 – Default + fan duties + temperatures
Disable high pressure trips	–	True/False	True	Allows use of non-IE regulator, see 5.7 If set to false, the IE-SOAR 800 will not start if the high pressure is <4.3%.
Dynamic Control over Customer CAN	–	True/False	True	Allows for in-flight control of various system parameters. See 9.2.1.
Serial UART Baud	Baud	9600-921600	9600	0 - 9600 1 - 19200 2 - 115200 3 - 230400 4 - 460800 5 - 921600
SPM Power Limit	Watt	200 to 1200	1000	Maximum power the SPM is allowed to deliver. Limit may be lowered to make stack power more consistent by relying more heavily on the hybrid battery
Target Output Voltage	Volt	25 to 50	50	Allows use of 6S to 12S batteries

Before loading a configuration that alters the target output voltage, ensure that the IE-SOAR 800 is not connected to a Hydrogen source, and that the power output is disconnected. Connect the new hybrid battery to load the configuration update.

7.3.2 Generating configuration files

The customer configuration tool may be used to generate configuration files. Download the tool from our webpage.

8 LOG Files

8.1 DATALOG files

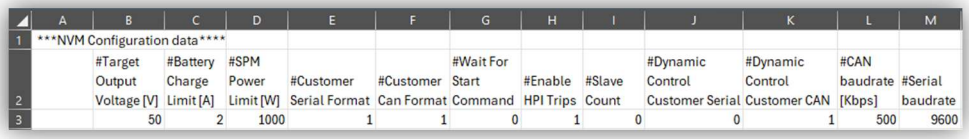
This file type is encoded and intended for use by Intelligent Energy product support; it contains proprietary information that can be useful for fault diagnosis and debugging. When engaging with product support, always send the DATALOGS and CUSTLOGS.

8.2 CUSTLOG files – 1Hz

This file type is in .CSV form, meaning it can be read and processed by any operating system using various programs such as Excel, LibreOffice Calc or Numbers.

Each CUSTLOG starts with a header that gives the system configuration installed when the LOG was generated. These parameters may change throughout the LOG if dynamic control over CAN is used.

Below is an example of the header showing the default system configuration:



	A	B	C	D	E	F	G	H	I	J	K	L	M
1	***NVM Configuration data****												
2		#Target Output Voltage [V]	#Battery Charge Limit [A]	#SPM Power Limit [W]	#Customer Serial Format	#Customer Can Format	#Wait For Start Command	#Enable HPI Trips	#Slave Count	#Dynamic Control Customer Serial	#Dynamic Control Customer CAN	#CAN baudrate [Kbps]	#Serial baudrate
3		50	2	1000	1	1	0	1	0	0	1	500	9600

CUSTLOG files have a number of columns that allow for analysis of FCPM performance. See below for a description of each:

CUSTLOG column name	Description
MCU Serial Number	Serial number of unit
MCU SW Version	Firmware version running on PM MCU
UIB SW Version	Firmware version running on SM MCU
MCU DateTime [ISO 8601]	RTC date and time
Total Run Time [h]	System runtime since build
Battery Power [W]	Battery power. Negative indicates the battery is supplying power. Positive indicates charging.
Battery Voltage [V]	Battery Voltage
Battery Current Ext [A]	External battery current sensor reading
Battery BiDir Current [A]	Battery current. Negative indicates the battery is supplying current. Positive indicates charging.
System Output Power [W]	Power supplied to UAV / load
System Output Voltage [V]	Voltage supplied to UAV / load
System Output Current [A]	Current supplied to UAV / load
Regulated Pressure [bar.g]	Hydrogen pressure supplied to SM
Minimum Regulated Pressure [bar.g]	Lowest measured regulated pressure from last 1s
Maximum Regulated Pressure [bar.g]	Highest measured regulated pressure from last 1s

Tank1 Pressure [%]	Hydrogen pressure in cylinder #1
Tank2 Pressure [%]	Hydrogen pressure in cylinder #2
Stack Thermistor 1 [deg C]	Internal stack temperature #1
Stack Thermistor 2 [deg C]	Internal stack temperature #2
Air Inlet Temperature [deg C]	Inlet thermistor temperature
SPM Output Power [W]	DCDC output power
SPM Output Current [A]	DCDC output current
SPM Output Voltage [V]	DCDC output voltage
Fan Duty [%]	Stack cooling fan duty (17-100%)
Stack Power [W]	Stack power
Stack Current [A]	Stack current
Stack Voltage [V]	Stack voltage
Fan1Telemetry Temperature [deg C]	ESC #1 Temperature
Fan1Telemetry Voltage [V]	ESC #1 Voltage
Fan1Telemetry Current [A]	ESC #1 Current
Fan1Telemetry Power [W]	ESC #1 Power
Fan2Telemetry Temperature [deg C]	ESC #2 Temperature
Fan2Telemetry Voltage [V]	ESC #2 Voltage
Fan2Telemetry Current [A]	ESC #2 Current
Fan2Telemetry Power [W]	ESC #2 Power
Master State [BitMask]	8.2.1
Button/Remote Start	Reads 1 when either the button is being pressed or the Start1/2 lines (3.2.1) are being pulled high - 6.1
Legacy Error Code	Legacy single error code - 9.1.2
Error Code	Main error code - 9.1.4
Error Subcode	Error subcode - 9.1.4

8.2.1 Master states

The master state is given as a bitmask, and because the master state will transition within one second, the mask is stacked so that all of the states transitioned through in the last second may be seen. If the Master State reads 6 for example, the system went from Starting (2) -> Running (4).
The states are as below:

State	Enumeration (UART & CAN)	Bitmask (CUSTLOG)
Off	0	0
Starting	1	2
Running	2	4
Stopping	3	8
Go to sleep	4	16

9 Data Outputs

9.1 UART output – 5Hz

There are 4 UART formats available from the system. These are as follows:
0 – Off
1 – Legacy single system format, this is supported by all versions of Ardupilot released since 2021.
4 – Default format, for use with Ardupilot 4.4.2 and above. Carries more information than legacy format.
5 – Format 4 with fan duties.
6 – Format 5 with inlet temperature, stack temperature and customer button status.

Formats 1 & 4 are directly compatible with Ardupilot, see the below link for more information:
https://ardupilot.org/copter/docs/common-ie24-fuelcell.html

9.1.1 UART Format 1 – Legacy

The output fields are listed below; the variables are comma separated as in the example.

UART Word number	Description	Unit	Comments
1	Tank Pressure	bar	
2	Hybrid Battery Voltage	Volt	Should be in the range of expected values for the selected hybrid battery's cell count
3	Output Power	Watt	Combined output of batteries and SM to UAV
4	SM Power	Watt	Stack module power
5	Hybrid Battery Power	Watt	Negative power indicates the hybrid battery is discharging. Positive power indicates charging.
6	Master State	N/A	0 – FCPM off 1 – Starting 2 – Running 3 – Stopping 4 – Go to sleep
7	Fault State	N/A	See section 9.1.2 for more detail

The baud rate is configurable (7.3.1), 8 data bit, no parity, 1 stop bit. The parameters available via UART are:

Example data output:
<300,48.7,1600,1700,100,2,0>
<Pressure, Hybrid Battery Voltage, Output Power, SM Power, Hybrid Battery Power, Master state, Fault Code>

9.1.2 Format 1 error codes

The UART fault codes are organised as follows into categories according to the severity of the associated fault.

Only the most severe error code is output to the UART, for example if both error 10 and 20 are active, only error 20 will appear on the data output.

Error number	Severity	Impact on FCPM
0-9	Least severe	No impact – power output unaffected
10-19	Moderate severity	Reduced power output
20-29	Medium severity	Risk of complete power loss
30-39	Highly severe	Complete power loss imminent
40+	Most severe	FCPM not outputting power

The table below describes all of the error codes and gives advice on how to respond to each.

Error code	Description	Effect on system	Action needed
0	No error	None	None, no errors present
1	Minor internal	None	None, may be an indication of faults to come
10	Reduced power	System is down-regulating power output	Usually due to environmental/ambient conditions leading to thermal limit being exceeded. May also occur due to input pressure being below derate threshold.
20	Pressure low	None	First pressure warning – 15 bar.g remaining
21	Hybrid Battery low	Hybrid battery no longer able to provide burst current	In case of further faults, battery is unable to provide power. Land immediately.
30	Pressure alert	None	Land immediately – tank pressure below 6 bar.g
31	Start denied	System will not power on	Usually indicates a hardware fault, assuming correct setup and use regarding H_2 supply etc.
32	System critical	No SM power – Hybrid battery sustaining flight	Land immediately, batteries will be unable to sustain flight in 1-2 minutes (depending on hybrid battery capacity)
33	Pressure critical	Regulated or cylinder pressure bad	Regulated / cylinder pressure should be investigated – regulator may be faulty
40	Hybrid Battery critical	All power lost	Control of the UAV lost

9.1.3 UART format 4 – Default

Two message types are sent by the system, the first, identified by square brackets ([]), is the system identifier. The second message type is the live data feed and is identified by angle brackets (<>).

Identifier string:

UART Word number	Description	Comments
1	MCU software part number	e.g. 10018734
2	Software version number	e.g. 4.2
3	UART format version	e.g. 4 (for current version, future versions will increment this)
4	System hardware serial number	e.g. IE12134DD80001
5	Checksum	See below

Checksum: the checksum is a text string containing the 8-bit result of adding the ASCII codes of all characters starting with and including the opening bracket up to and including the comma immediately before the checksum itself, then inverting the result by taking it away from 255. E.g. the checksum of "IE" would be 255-(73+69)=113.

Example Identifier String:
[10018734,4.2,4,IE12134DD80001,145]

Data string:

UART Word number	Description	Unit	Comments
1	Tank pressure	%	Percent hydrogen remaining
2	Regulated pressure	bar.g	Regulated (stack inlet) pressure, bar
3	Battery Voltage	V	Hybrid battery voltage
4	Output power	W	System output power, combined fuel cell and battery power
5	SM power	W	Stack module power
6	Unit in fault		Identifier for parallel system configurations
7	Battery output power	W	Hybrid battery power
8	Master state		0 – FCPM off 1 – Starting 2 – Running 3 – Stopping 4 – Go to sleep Same as in 8.2.1
9	Main error code		See 9.1.4 for detail
10	Subcode		
11	Info string		
12	Checksum		See 9.1.3 for detail

Example data output:
<48,0.91,49.7,1480,1098,0,2,4,0, RECONDITION NEEDED,89>

9.1.4 Format 4 error codes

The UART fault codes are organised as follows into categories according to the severity of the associated fault.

Error number	Severity	Impact on FCPM
0-9	Information	No impact – power output unaffected
10-19	Warning	Reduced power output
20-29	Low FC power	Risk of complete power loss
30-39	No FC power	Complete power loss imminent
40+	No FC or Batt power	FCPM not outputting power

Only the highest priority error code is output to the UART port, for example if both error 12 and 20 are active, only error 20 will appear on the data output.

The codes are detailed overleaf.

Main codes:

	Error code	Description	Cause of error code	Action needed	Info string	Possible subcodes
Information	*0*	No error	None	None, no errors present	-	-
	1	Minor internal	None	None	-	-
	3	Tank pressure high	Tank pressure is too high	Check the hydrogen tank pressure	TANK PRESSURE HIGH	-
	4	Reconditioning needed	System efficiency and power reduced	Recondition system at earliest convenience	RECONDITIONING NEEDED	-
	5	One tank empty	One of two tanks is empty	Warning, one tank remaining.	EMPTY “SUBCODE”	17, 18
	6	Auto recondition active (12.3.2)	System is in automatic reconditioning mode	Information only	AUTO RECONDITIONING	-
	7	Reconditioning active (12.3.1)	Manual (SD-Card) reconditioning mode active	Monitor system, remove load when reconditioning is complete	RECONDITIONING “SUBCODE”	13, 14, 254
	8	Recovery mode active	Deep recovery from poisoning active	Provide appropriate load until finished	RECOVERY MODE DO NOT FLY	-
	9	Idle mode (6.3)	SM deactivated, PM will reactivate SM if idle exit condition is met	None, short button press may be used to bring SM out of idle mode	IDLE MODE “SUBCODE”	13, 19, 20
Warning	*10*	Purge blocked	Two or more consecutive purges have been blocked	End flight and rectify blockage as soon as possible – stack damage will occur if no action is taken	PURGE BLOCKED	-
	11	Inlet temp high/low	Inlet temp <0C or >35C	Lower or raise inlet temp as appropriate where possible.	INLET TEMP XXC	-
	12	Tank pressure low	Tank percentage <4.3%	First pressure warning – 15bar.g remaining	TANK PRESSURE LOW	-
	14	Battery voltage low	Battery voltage <3.2V/cell	Allow battery to be recharged before vertical landing (for VTOL)	BATTERY VOLTAGE LOW	-
Low FC power	*20*	Reduced power	SM power derated, can be caused by low H2 pressure, high stack temp, poor stack condition.	Fly cautiously or land where appropriate. Often present for short periods after take-off.	REDUCED POWER “SUBCODE”	5, 9, 11, 15
No FC power	*30*	Tank/s empty	Tank percentage <1.3% System will shut down unless HPI-OFF config loaded	Land immediately – Hybrid battery sustaining flight	H2 TANK EMPTY	-
	32	Start denied	System will not power on	Check supply pressure and configuration	START DENIED “SUBCODE”	5, 6, 10, 21
	34	Recovery mode required	Minimal SM power available, put system into recovery ASAP	Deep reconditioning needed to recover poisoned cells. Most likely a result of VOC exposure.	DO NOT USE RECOVERY NEEDED	-
	36	System error	Fuel, temperature or airflow error causing shutdown	FC off, battery sustaining flight, land immediately.	FUEL CELL OFF “SUBCODE”	5, 6, 7, 8, 9, 10, 11, 22
No power	*40*	Battery critical	No fuel cell power, battery voltage <2.5V/cell.	Land as soon as possible	BATTERY CRITICAL	-

Subcodes:
Where applicable, subcodes are appended to the main error code to provide additional context.

For example, if a system shut off due to a stack undervoltage, error 36.9 would be output on the UART. Here 36 indicates “FC off - system error” and the .9 denotes the reason for shutdown being stack undervoltage.
The info string for this case would be “FUEL CELL OFF STACK LOW V”.

Another example might be error 32.5, which indicates that the system is not starting because the inlet pressure is too low.

Subcode	Description	Info string
0	No context	-
1	-	-
2	-	-
3	Stack	STACK
4	FC not running	STACK LOST
5	Inlet pressure low	STACK P LOW
6	Inlet pressure high	STACK P HIGH
7	Tank pressure low	TANK LOW
8	Tank pressure high	TANK HIGH
9	Stack voltage low	STACK LOW V
10	Internal test failed	INT ERR
11	Stack temperature high	STACK HIGH T
12	Stack temperature low	STACK LOW T
13	Active	ACTIVE
14	Reconditioning complete	COMPLETE
15	Thermal management	THERMAL MNGMT
16	Start faults	START FAULT
17	Tank 1	TANK 1
18	Tank 2	TANK 2
19	Entering	ENTERING
20	Exiting	EXITING
21	Config fault	CONFIG FAULT
22	Airflow fault	AIRFLOW FAULT
.		
.		
.		
254	Complete flight – contact customer support	CCS
255	Stop using unit – contact customer support	DO NOT USE

9.1.5 UART Format 5

UART format 5 builds on top of format 4, adding eight fan duties to the end of the string.

Identifier string:
Identical to the identifier string for format 4, see 9.1.3.
Example Identifier String:
[10018734,4.2,4,IE12134DD80001,145]

Data String:

UART Word number	Description	Unit	Comments
1	Tank pressure	%	Percent hydrogen remaining
2	Regulated pressure	bar.g	Regulated (stack inlet) pressure, bar
3	Battery Voltage	V	Hybrid battery voltage
4	Output power	W	System output power, combined fuel cell and battery power
5	SM power	W	Stack module power
6	Unit in fault	-	Identifier for parallel system configurations
7	Battery output power	W	Hybrid battery power
8	Master state	-	0 – FCPM off 1 – Starting 2 – Running 3 – Stopping 4 – Go to sleep Same as in 8.2.1
9	Main error code	-	See 9.1.4 for detail
10	Subcode	-	
11	Info string	-	
12	Unit 1 fan duty	%	Stack cooling fan duty (17-100%)
13	Unit 2 fan duty	%	Stack cooling fan duty (17-100%)
14	Unit 3 fan duty	%	Stack cooling fan duty (17-100%)
15	Unit 4 fan duty	%	Stack cooling fan duty (17-100%)
16	Unit 5 fan duty	%	Stack cooling fan duty (17-100%)
17	Unit 6 fan duty	%	Stack cooling fan duty (17-100%)
18	Unit 7 fan duty	%	Stack cooling fan duty (17-100%)
19	Unit 8 fan duty	%	Stack cooling fan duty (17-100%)
12	Checksum	-	See 9.1.3

9.1.6 UART Format 6

UART format 6 builds further on top of format 5, adding inlet temperature, stack temperature and customer button status to the end of the string.

Identifier string:
Identical to the identifier string for format 4, see 9.1.3.
Example Identifier String:
[10018734,4.2,4,IE12134DD80001,145]

Data String:

UART Word number	Description	Unit	Comments
1	Tank pressure	%	Percent hydrogen remaining
2	Regulated pressure	bar.g	Regulated (stack inlet) pressure, bar
3	Battery Voltage	V	Hybrid battery voltage
4	Output power	W	System output power, combined fuel cell and battery power
5	SM power	W	Stack module power
6	Unit in fault	-	Identifier for parallel system configurations
7	Battery output power	W	Hybrid battery power
8	Master state	-	0 – FCPM off 1 – Starting 2 – Running 3 – Stopping 4 – Go to sleep Same as in 8.2.1
9	Main error code	-	See 9.1.4 for detail
10	Subcode	-	
11	Info string	-	
12	Unit 1 fan duty	%	Stack cooling fan duty (17-100%)
13	Unit 2 fan duty	%	Stack cooling fan duty (17-100%)
14	Unit 3 fan duty	%	Stack cooling fan duty (17-100%)
15	Unit 4 fan duty	%	Stack cooling fan duty (17-100%)
16	Unit 5 fan duty	%	Stack cooling fan duty (17-100%)
17	Unit 6 fan duty	%	Stack cooling fan duty (17-100%)
18	Unit 7 fan duty	%	Stack cooling fan duty (17-100%)
19	Unit 8 fan duty	%	Stack cooling fan duty (17-100%)
20	Stack inlet temperature	°C	Ambient temperature
21	Stack core temperature	°C	Internal stack temperature
22	Customer switch status	-	Status of customer switch (start1/2) 1=HIGH 0=LOW Pull high for 4s to turn on/off Pull high for 1s to enter/exit idle mode
23	Checksum	-	See 9.1.3

9.2 CAN Output

The FCPM provides data through the CAN interface. Signals can be sent to the FCPM or transmitted by it.

The format of messages from the system is configurable, with the following options:
0 – Off
1 – IE use only
2 – Single system - when one system only is being used
3 – Parallel systems – when two more systems are being used

The CAN parameters will override the system configuration, until the CAN connection is lost.

The "Cyclic counter" variable sent to the FCPM must be updated at least every 500ms, else CAN connection will be deemed lost by the system. A 100ms refresh rate is recommended.

For all active CAN formats, the messages sent to the system are the same, as below.

9.2.1 Data to FCPM

Variable Name	Update Time [ms]	CAN message ID	Byte	Bit 0	Bit 1	Bit 2	Bit 3	Bit 4	Bit 5	Bit 6	Bit 7
Cyclic counter	100	(Extended) decimal 0d512 hex 0x200	0					X	X	X	X
Reserved				R	R	R	R				
Target Output Voltage [V]			1	X	X	X	X	X	X	X	X
			2	X							
Reserved					R	R	R	R	R	R	R
Reserved			3	R	R	R	R	R	R	R	R
SM Power Limit [W]			4		X	X	X	X	X	X	X
Reserved				R							
Reserved			5	R	R	R	R	R	R	R	R
Reserved			6	R	R	R	R	R	R	R	R
Reserved			7	R	R	R	R	R	R	R	R

Of the values that are not binary:

Variable Name	Scale (units per bit)	Offset (units)	Bits	MaximumValue	Minimum Accepted	Maximum Accepted
Target Output Voltage [V]	0.1	0	9	51.1	18.0	50.0
SM Power Limit[W]	10	0	7	1270	200.0	1200

9.2.2 Data sent by FCPM – Single system

Variable Name	Update Time [ms]	CAN message ID	Byte	Bit 0	Bit 1	Bit 2	Bit 3	Bit 4	Bit 5	Bit 6	Bit 7
Cyclic Counter	100	(Extended) decimal 0d1024 hex 0x400	0	X	X	X	X				
FCPM State								X	X	X	X
Tank Level [bar.g]			1	X	X	X	X	X	X	X	X
			2	X	X						
Hybrid Battery Voltage [V]						X	X	X	X	X	X
			3	X	X	X	X				
Output Power [W]								X	X	X	X
			4	X	X	X	X	X	X		
SM Input Power [W]										X	X
			5	X	X	X	X	X	X	X	X
Hybrid Battery Power [W]			6	X	X	X	X	X	X	X	X
			7	X	X						
Error code						X	X	X	X	X	X

For the values that are not binary:

Variable Name	Scale (units per bit)	Offset (units)	Bits	Minimum Value	Maximum Value
Tank Level [bar.g]	0.5	0	10	0	511.5
Hybrid Battery Voltage [V]	0.1	0	10	0	102.3
Output Power [W]	10	0	10	0	10230
SM Input Power [W]	5	0	10	0	5115
Hybrid Battery Power [W]	10	5000	10	-5000	5230

9.2.3 Data sent by FCPM – Parallel system

Variable Name	Update Time [ms]	CAN message ID	Byte	Bit 0	Bit 1	Bit 2	Bit 3	Bit 4	Bit 5	Bit 6	Bit 7
Cyclic Counter	100	(Extended) decimal 0d1024 hex 0x400	0	X	X	X	X				
FCPM State								X	X	X	X
Tank Level [bar.g]			1	X	X	X	X	X	X	X	X
			2	X	X						
Hybrid Battery Voltage [V]						X	X	X	X	X	X
			3	X	X	X	X				
Unit in fault								X	X	X	X
			4	X	X	X	X	X	X		
SM Input Power [W]										X	X
			5	X	X	X	X	X	X	X	X
Hybrid Battery Power [W]			6	X	X	X	X	X	X	X	X
			7	X	X						
Error code						X	X	X	X	X	X

For the values that are not binary:

Variable Name	Scale (units per bit)	Offset (units)	Bits	Minimum Value	Maximum Value
Tank Level [bar.g]	0.5	0	10	0	511.5
Hybrid Battery Voltage [V]	0.1	0	10	0	102.3
SM Input Power [W]	25	0	10	0	25,575
Hybrid Battery Power [W]	100	5000	10	-5000	97,300

10 Hybrid Battery

The hybrid battery is used by the system to provide load in excess of what the stack can provide. For example, if 2kW is being drawn from the output, 1kW may be delivered by the stack and 1kW by the battery.
This load sharing is managed by the system and is done by intelligently managing the DCDC output voltage (3.2.5).
Once the SM is running, there is no way for the FCPM to detect disconnection of the hybrid battery, therefore no warnings or errors will be present until the power draw exceeds the capability of the stack, at which point the output voltage will crash to 0V.

The operator should regularly balance charge the hybrid battery on a dedicated balance charger. The IE-SOAR 800 does not balance the hybrid battery cells.

The hybrid battery must be regularly balance charged by the operator.

10.1 Hybrid battery charge limits

The battery charging current can be set in the configuration file (7.3.1), it can also be set via CAN dynamically (9.2.1). If CAN communication is lost, the battery charge current will revert to the configuration file setting.

10.2 Emergency hybrid battery usage

The IE-SOAR 800 FCPM has redundancy offered by its architecture. If the SM has a critical fault and shuts off, the battery will provide emergency power.

Note ***The operator should monitor the data outputs, so they are aware of any fuel cell or other faults during flight. Section 9 details the data outputs.***

10.3 Specifying a hybrid battery

The IE-SOAR 800 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:

- 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 (Ah) – this will affect how long the battery can discharge for and will directly affect the batteries capability to provide peak or emergency power.
- Typical hybrid battery configurations used are 6-12S LiPo voltage range, with capacity from 1500mAh.
- Where the output power demand will never exceed the rated power (800W), a lower capacity battery may be used.

10.4 Specifying a hybrid battery cable

Cables must be specified that are suitable for the application. In particular, the current rating of the cable must meet or exceed the maximum current drawn by the load (typically UAV motors/ESCs).
For reference, the cable that comes fitted to the hybrid batteries is 12AWG (CSA 3.3mm^2) with 200^{o}C rated silicone insulation.

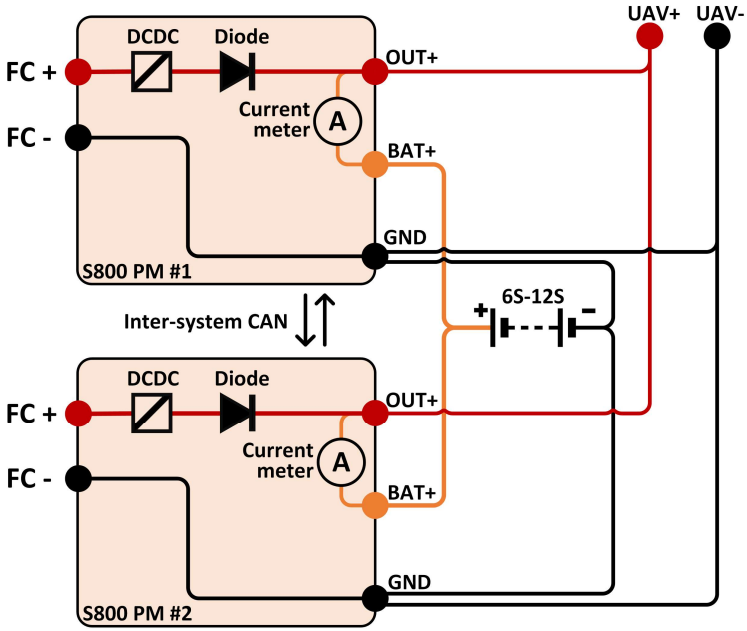
Note ***Incorrectly specifying a cable could cause sudden and immediate loss of output power.***

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

11 Parallel Connection of IE-SOAR 800s

It is possible to connect two or more IE-SOAR 800s in parallel to increase the effective continuous power rating.
The units communicate with one another over an inter-system CAN bus (see FCPM IN/OUT pinout in section 3.2), which allows for coordination of purges, battery charging, and output power delivery.

A single hybrid battery is mandatory, as shown in the simplified electrical diagram below.



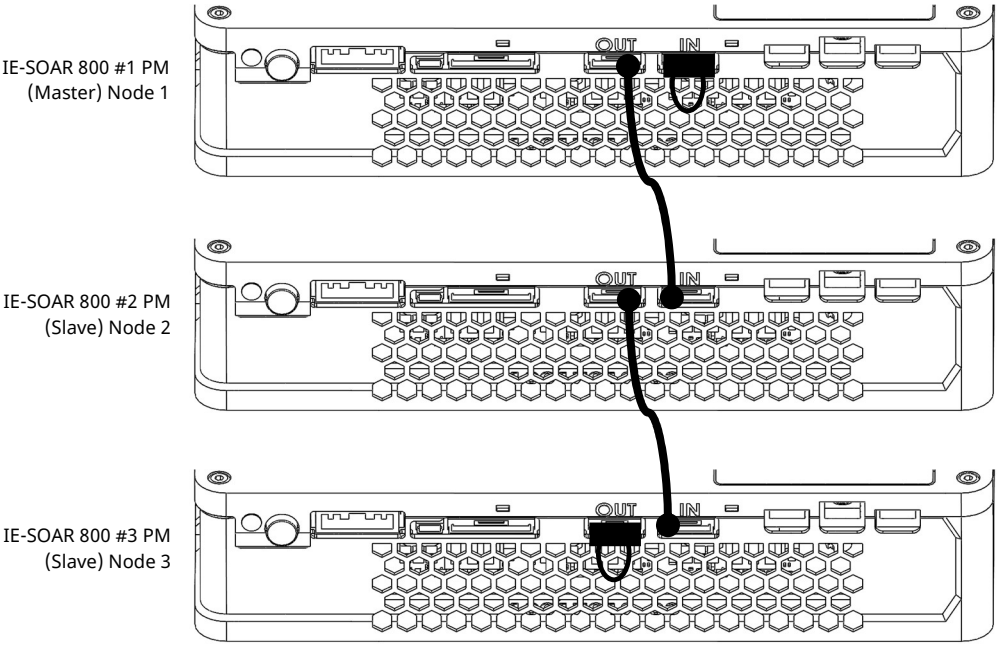
The **Red** circuit is the output power positive.
The **Black** circuit is the output and battery negative.
The **Orange** circuit is the battery positive.

The following must be in place for parallel operation:

1. Only one battery may be used, it may be connected to one or more of the
2. IE-SOAR 800 systems.
3. Configured battery charge current limits must be the same (7.3.1) on each system. The total battery charge current limit will be calculated as the sum of all systems configured limits. Systems where the battery charge limit is set to 0 are allowed, and will not contribute to the charge limit.
   e.g. four IE-SOAR 800s connected in parallel, two are set to 5A battery charge limit, two are set to 0A. The battery will be charged at 10A.

Connecting multiple batteries could lead to rapid cross-charging where batteries are connected with different voltages. DO NOT CONNECT MULTIPLE BATTERIES.

4. The string of IE-SOAR 800 units must be connected to one another through the inter-system CAN bus. The FCPM-OUT port of the master system connects to the FCPM-IN port of the first slave, as below. The first and last units on the CAN bus must also have an inter-system CAN termination resistor fitted to the un-populated port.



The following behaviours are present when two or more units are connected in parallel:

1. Turning one unit on or off will switch all units on or off.
2. A fault on one unit will turn only that unit off.
3. Load will be shared evenly between the systems where possible, but where airflow restriction is present or stack conditions vary, differing power outputs may be observed.
4. Fan pulses will be coordinated between systems so that only one is not delivering power at a time.
5. Purges will be coordinated and spaced out such that only one system purges at a time. This helps maintain the regulated pressure.

12 Storage and Maintenance

12.1 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.

Note ***Inspection and maintenance of the fan assemblies is recommended after 1,000 hours of operation.***

In the event of it being stored for more than 60 days, the FCPM should be reconditioned as per the instructions in section 12.3.1 below.

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.

12.2 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.
- The hydrogen supply should be isolated from the system before storage.
- Ideal ambient conditions are +20°C and >50% humidity.
- The recommended storage of the FCPM will increase the time between reconditioning cycles.
- If stored at <0°C, there may be ice/freezing inside the fuel cell stack. Ensure that the system is not started from frozen. Defrost indoors (~20°C ambient) if necessary.

Avoid exposure to volatile organics (VOCs), poisonous/corrosive gasses and anything with a prominent scent. This includes but is not limited to cleaning products, air-fresheners, glues/adhesives/epoxies, chemical solvents, and ammonia. Particular care should be taken to avoid storing the fuel cell in an enclosed space (e.g. drawer, bag or box) with potential contaminants as this may accelerate the contamination process.

12.3 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. The hybrid battery will see some load during the process. Users may notice fan speed variations during the reconditioning process.

There are two reconditioning modes:

- Manual – 12.3.1
- Automatic – 12.3.2

12.3.1 Manual reconditioning

Manual reconditioning is a maintenance procedure that helps maintain fuel cell performance and efficiency following periods of inactivity. For best results, systems that are not used regularly should be reconditioned at least once per month. A typical reconditioning cycle takes up to one hour, depending on the condition of the system.

Manual reconditioning requirements

- Fully charged hybrid battery
- Reconditioning SD card
- Hydrogen supply
- Electrical load
- Approximately 1 hour of uninterrupted operation

Manual reconditioning process:

1. Insert the reconditioning micro-SD card into the FCPMs SD card slot, this will enable manual reconditioning mode. See section 7.2.
2. Power the FCPM on.
3. After 15-20 seconds set the load unit to desired output power.
4. Wait until the system is delivering 800-1000W, depending on desired output power, and refer to customer error codes (see 9.1.4) for reconditioning outcome.

Note ***Monitor the hybrid battery voltage, if it is decreasing continuously, decrease the output power until it stabilises at 3.8V per cell.***

5. Upon reaching the reconditioning outcome, dial the load down to 0W, turn the system off, and disconnect the battery.
6. Remove the reconditioning micro-SD card and reinsert the standard micro-SD card.

12.3.2 Automatic reconditioning

The system configuration (7.3) includes an option for “automatic reconditioning”. When auto-Reconditioning is enabled, this mode will activate automatically in flight when required.
Information codes will be output on the UART to indicate that the system has engaged auto-reconditioning, see 9.1.4.

Note ***Manual reconditioning may still be required. The REDUCED POWER STACK message (refer to error table 9.1.4) would show that.***

13 End of Life Treatment and Disposal

The 800W product is designed for 1500 hours of operating life.
To refresh an IE-SOAR 800 that has reached end-of-life, the following maintenance is recommended:

1. Stack replacement
2. Cooling fan motor & propeller replacement

Servicing may be arranged via IE product support.
servicing@intelligent-energy.com

14 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.

For details on the warranty period, please refer to the sales contract provided with the IE-SOAR 800 system.

15 Spare parts

If you require spare parts for your system, please contact us at sales@intelligent-energy.com

Part number	Description
10023189	FCPM-IN/OUT CAN termination resistor (120ohm)
10023188	FCPM-IN/OUT Inter-system CAN cable (40cm)
10019679	Customer Interface cable assembly, 15-way JST-GH
10018459	Quick-disconnect hydrogen hose, bayonet
10009711	1800mAh LiPo battery
10019019	Power module power IO hatch door
10019040	Stack module power IO hatch door

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