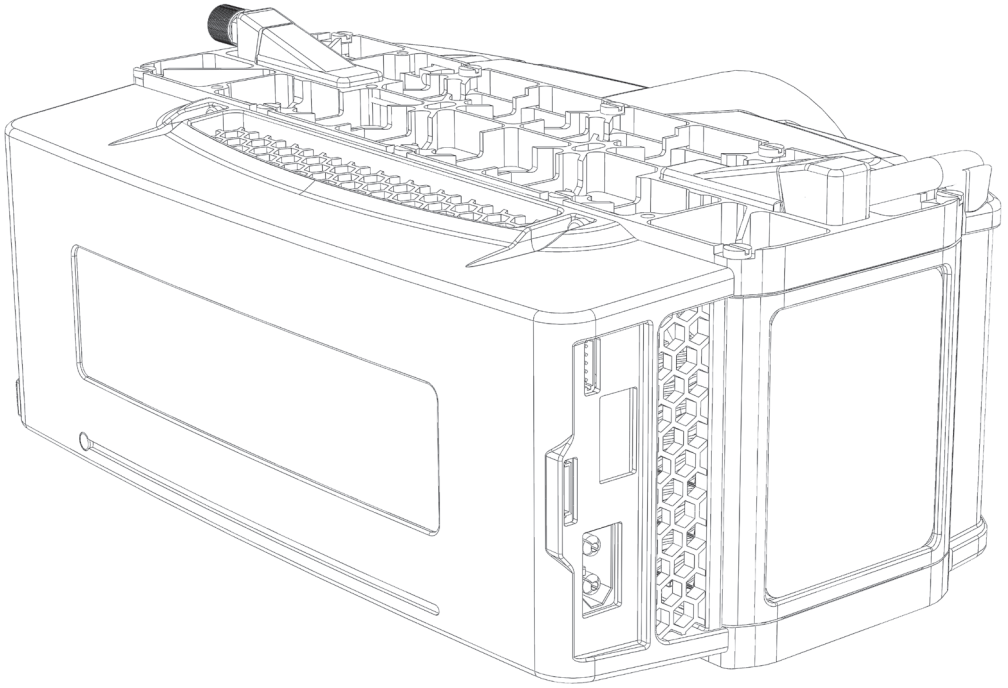
Intelligent Energy



650W Fuel Cell Power Module

User Manual

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

Federal Communications Commission (FCC) Statement

This equipment has been tested and found to comply with the limits for a Class B 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.

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

Contents

1 Safety warnings

- FCPM should only be used for UAV applications.
- 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.
- All UAV pilots must be trained in the safe operation of the target UAV and accredited by a regulatory body such as the FAA (US) or CAA (UK) or another National Agency.
- The customer is responsible for ensuring all technicians and pilots are suitably trained, accredited and in compliance with local laws and H&S regulations.
- The customer is responsible for ensuring the safe operation of the Fuel Cell Power Module and UAV at all times.
- This device requires oxygen to operate. FOR USE IN WELL VENTILATED AREAS ONLY – A MINIMUM OF 15 M^3/H OF FRESH AIR VENTILATION IS REQUIRED. This can be achieved by opening windows on opposite sides of a room, or by forced ventilation.
- FCPM not to be used in dusty, smoky or corrosive gas environments.
- Do not use FCPM in rain or snow.
- Do not open or dismantle the FCPM.
- Do not remove any external covers or cowlings.
- **Pressurised hydrogen present. Highly flammable!**
- Do not use FCPM if the unit is damaged.
- FCPM should be inspected for damage and leak checked prior to use.
- Keep away from vegetation.
- Not to be used in residential areas (EMC).
- Do not use this portable Fuel Cell Power Module if any part has been immersed or flooded with water. Immediately call the manufacturer or manufacturer's representative to inspect the Module and to replace any functional part that has been affected.

When shipping or transporting your UAV and FCPM, the FCPM must always be disconnected from the hydrogen source.

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.

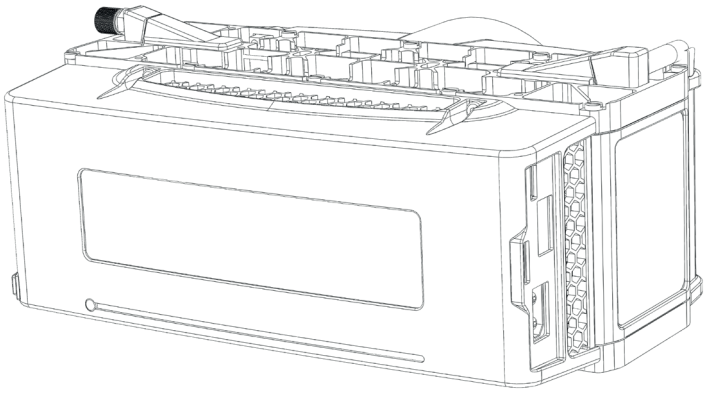
Intelligent Energy warrants to the recipient and it will repair and replace any defective equipment resulting from the authorised use of the equipment provided. Notwithstanding the above, Intelligent Energy, to the fullest extent permitted by law, accepts no liability (including liability in respect 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.

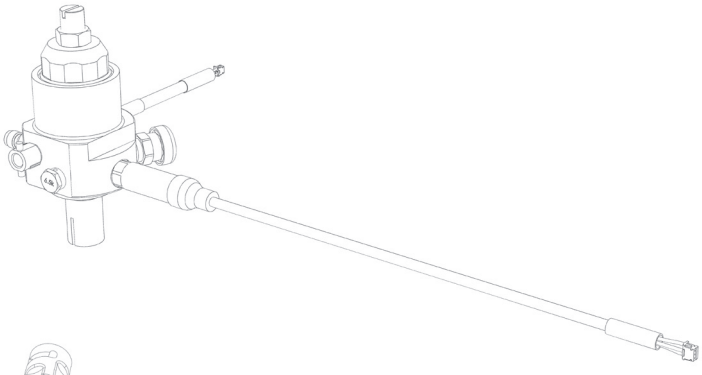
2 The 650W Fuel Cell Power Module Key Components

The major components of the 650W Fuel Cell Power Module (FCPM) are as follows:

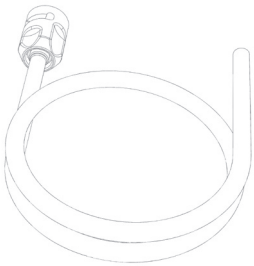
650W Fuel Cell Power Module



Lightweight pressure regulator



Hydrogen feed hose with quick connect fitting



Other items:

- Hydrogen cylinder (optional)
- Hybrid battery
- Interface cables
- SD card and SD adaptor

2 The 650W Fuel Cell Power Module Key Components

2.1 Product specification

Maximum continuous power		650W
Maximum peak power (not to be exceeded)		1000W
Output voltage		19.6V – 25.2V
Fuel Cell Power Module	Dimensions	196 × 88 × 140mm
	Mass	790g
Hydrogen Regulator	Mass	250g
	Maximum regulator (cylinder) pressure	300 Bar/4350 PSI
	Output pressure	0.5 Bar ± 0.25 Bar/7 PSI ± 3 PSI
	PRV set pressure	2 Bar/29 PSI
	Burst disc set pressure	450 Bar/6500 PSI
	Maximum cylinder mass	10kg
Hybrid battery	Dimensions	140 × 30 × 20mm
	Mass	230g
	Capacity	1300mAh
	Emergency flight time	2 minutes
Environmental operating conditions	Operating temperature (FCPM should not be operated outside of this range)	5 to 35°C
	Maximum altitude	3000m
	Storage temperature	-10°C to +70°C
	System lifetime	1000 hrs
Safety features	Automatic failure detection system and backup battery	
	650W FCPM is not IP rated	
	Certification of 650W FCPM	CE and FCC
Other features	Internal data storage for firmware update, performance and diagnostics	SD card
	Communication port; to UAV fuel cell module or accessories	UART
	Output electrical connector	XT-60

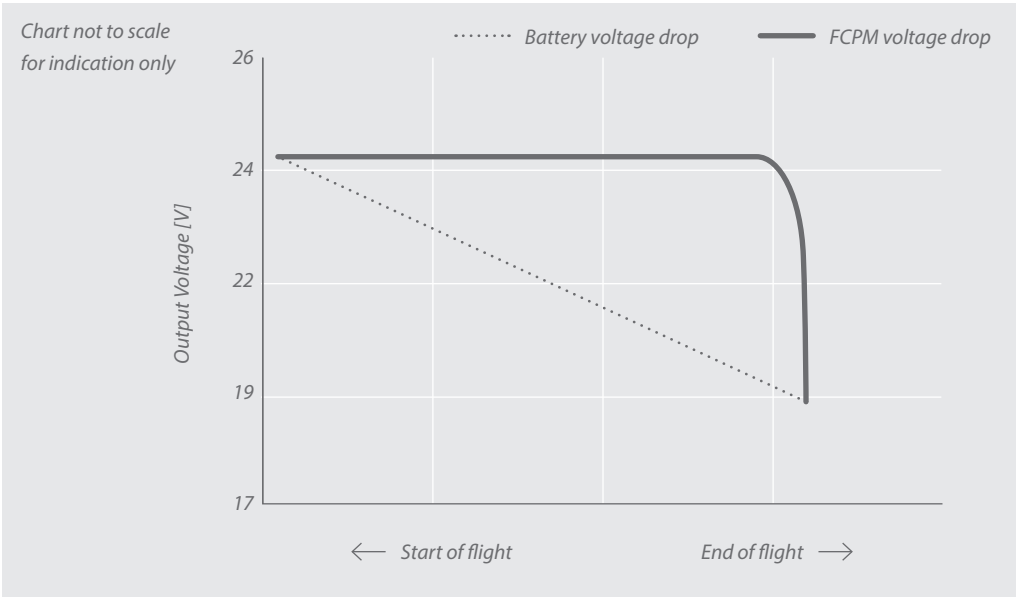
3 Hybrid battery architecture

The 650W Fuel Cell Power Module is designed to work alongside a hybrid battery. This hybrid battery provides some key functions:

Peak power draw – When a UAV is flying the power draw varies very quickly as the UAV brakes, accelerates, climbs etc. The FCPM is designed to run at a constant power of 650W. When the power draw of the UAV peaks, the hybrid battery provides power up to 1000W. When the power draw of the UAV hits a trough, the battery is charged.

Emergency flight time – The battery acts as an emergency backup power source. If a critical issue occurs with the FCPM, the battery will take over. The standard supplied battery will deliver 650W for around two minutes.

It is also important to note that the output voltage of the FCPM is a constant 25V (6S). Unlike a typical battery, voltage does not drop gradually throughout a run, so you must change the way you think about remaining fuel/flight time (voltage dips to battery voltage during hybridisation and returns).



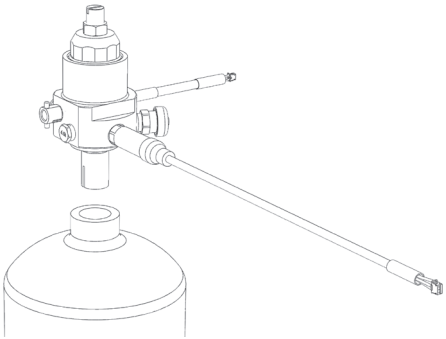
It is important to integrate the UART output of the FCPM into your UAV flight controller or fleet controller. This will monitor your fuel levels showing how much fuel remains. It will also tell you if fuel is low or if a critical fault has caused the fuel cell to fail and the emergency battery to take over.

4 Assembly and connection

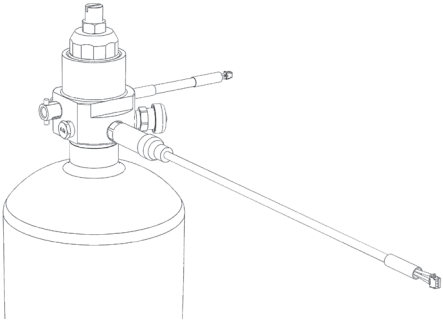
4.1 Assembly of regulator to cylinder

- Take the cylinder and regulator and inspect for physical damage or debris, reject if visible to the eye.
- Inspect the mating threads for damage or debris, reject if visible to the eye.

1 By hand carefully thread the regulator assembly into the cylinder.



2 Tighten the regulator until it is mated flush to the neck of the cylinder.



3 Once the regulator is flush, apply a maximum torque of 58Nm (42.8ft.lb).

4 Conduct a leak check on the completed assembly.

5 Prior to operation the cylinder will need to be purged to remove air impurities.

4 Assembly and connection

4.2 Filling of cylinder

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

Please conduct a leak check after filling cylinder.

Consult local H&S / facilities management for guidance on storage of cylinders and advisable safety equipment.

4.3 Hydrogen fuel

When installing and operating hydrogen systems, hydrogen general safety guidance should be considered:

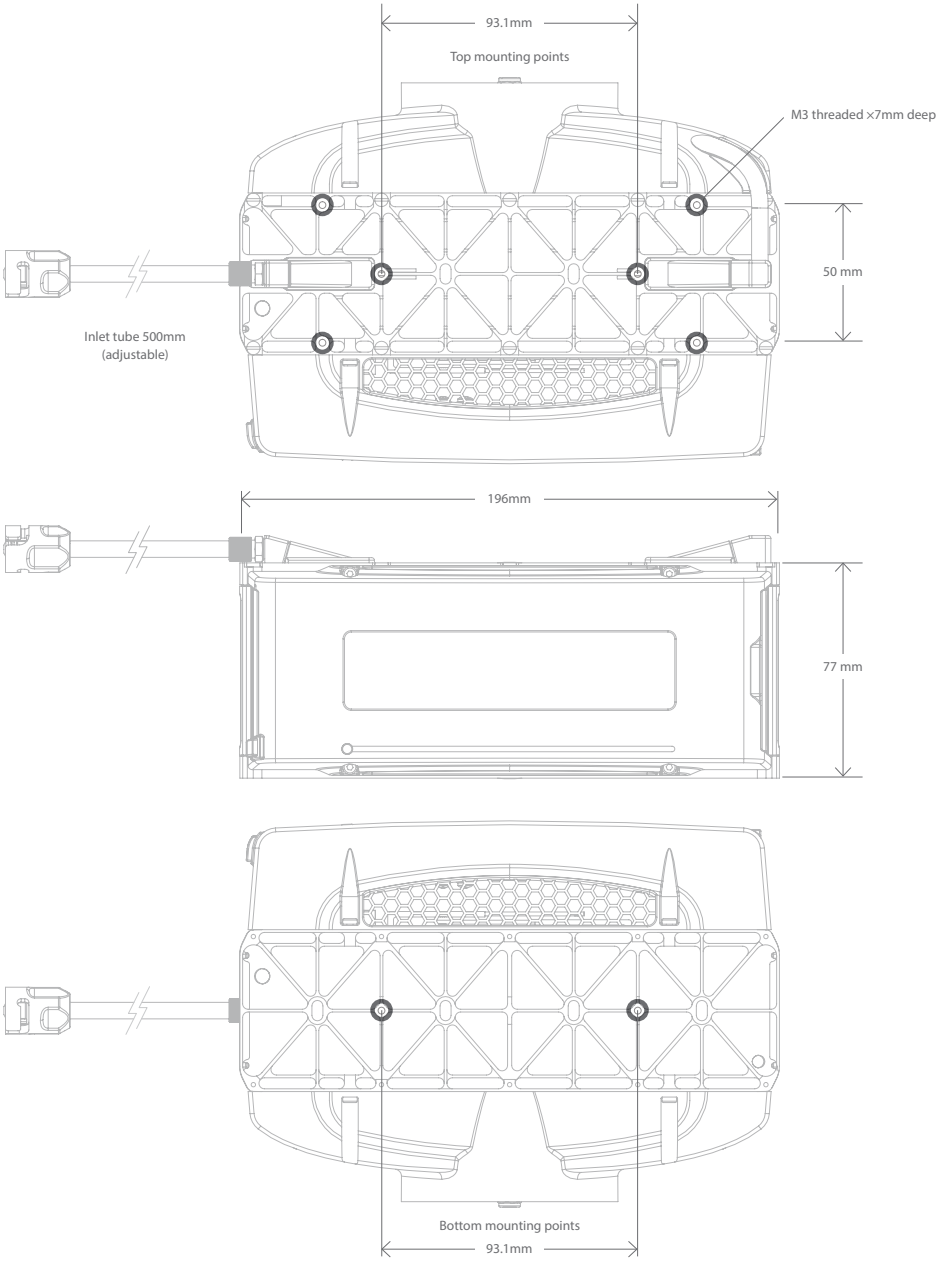
ISO/TR 15916 - Basic considerations for the safety of hydrogen systems for more detailed information.

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	*< 50 ppm*
Carbon Dioxide	*< 2 ppm*
Carbon Monoxide	*< 0.2 ppm*
Ammonia	*< 0.1 ppm*
Sulphur containing compounds	*< 4 ppb*
Max particle concentration	*< 1 mg/kg*
Max particle diameter	*< 75 µm*

4.4 Mechanical mounting points

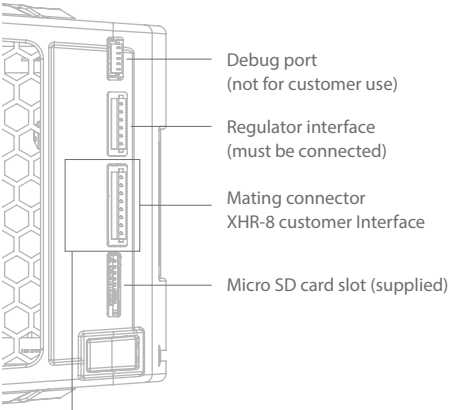
The following attachment points are included to aid mounting of the 650W Fuel Cell Power Module on your UAV.

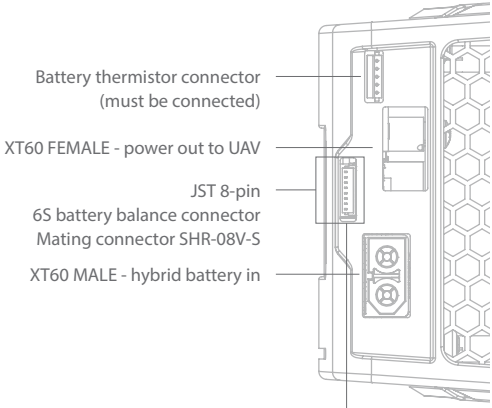


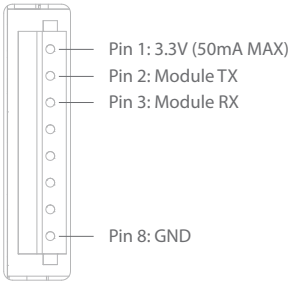
4 Assembly and connection

When mounting the 650W FCPM do not obstruct inlet and outlet air flow.

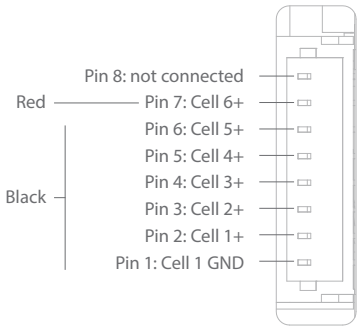
4.5 Electrical interfaces







UART: 9600 baud, 8 data bits,1 stop bit, and no parity
Format: <tankLevel_%, batteryLevel_%, psuState, faultCodes>



4.6 Hydrogen connection

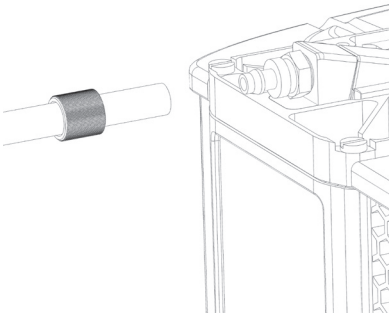
First time only – the hydrogen feed hose can be shortened depending on your UAV build.

1 Cut the hose to desired length using a tube cutter.

2 Unscrew the knurled locknut on the inlet fitting and feed it onto the tube.

3 Feed the end of the tube onto the barbed fitting.

4 Lock the tube in place by tightening, with your hand, the knurled lock nut.

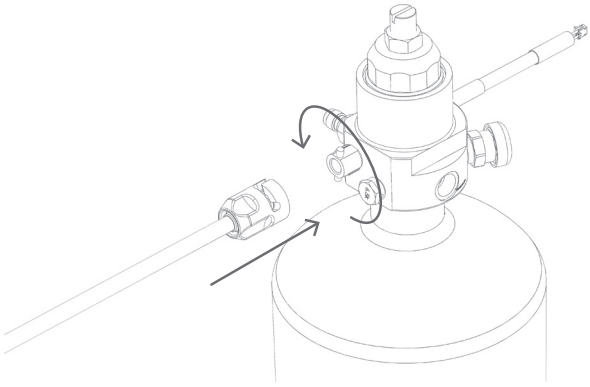


Ensure the hydrogen cylinder and FCPM are securely mounted before proceeding.

1 Verify that 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.



4.7 SD Card Format

The FCPM takes a micro SD card. This logs health and performance data, as well as fault codes. Useful if any fault troubleshooting is required.

The SD card format must be FAT32 and the following folder structure must exist for the FCPM to log correctly (the system automatically generates this folder):

\\IntelligentEnergy\data

5 Operation of 650W Fuel Cell Power Module

5.1 Start-up

1 Hold the FCPM power button for more than 2.5 seconds.

The LED will blink red twice then begin to blink green.

2 Wait for the start-up process to complete.

A solid green light indicates start-up is complete and the FCPM is ready to provide power.

3 When ready to power the UAV, press the button again for less than 0.5 seconds.

A blinking green LED indicates power output is enabled.

[See later section for LED error states]

5.2 Shut-down

To shut down entirely, hold the FCPM button for more than 2.5 seconds

5.3 Emergency battery usage during flight

If the on-board battery has been used for >1 minute at the end of a flight (i.e. fuel has been allowed to run low – indicated by flashing RED LED on FCPM) it is advisable to disconnect the battery from the 650W FCPM (as per above instruction) and 'balance charge' the battery on the ground.

Use a dedicated battery charger with 'balance' function (to maximum of 24V), this ensures all cells within the battery pack are of equal voltage before flying the UAV.

5.4 Start-up conditioning procedure

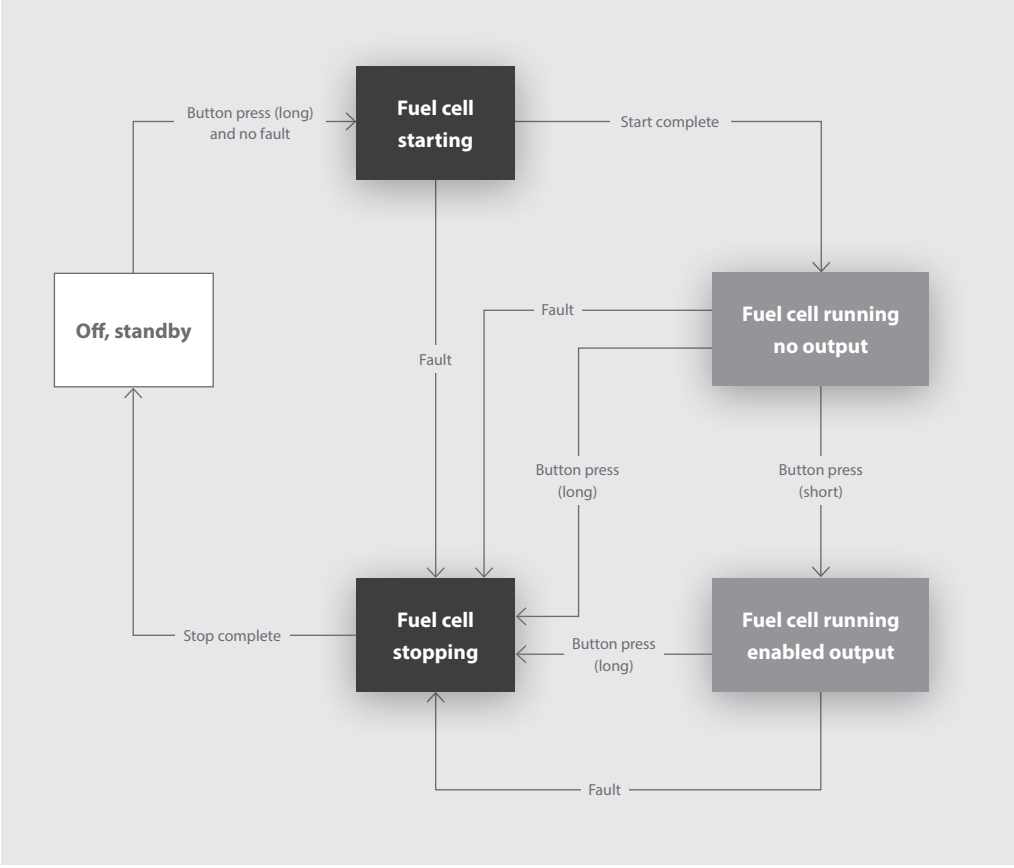
When you turn on the FCPM into stand-by mode it will automatically enter its own conditioning cycle. This cycle takes 90 seconds during which a number of valve clicks will be heard and the fan will stop for a short time. A single short press at any time will cancel this conditioning cycle and begin powering the UAV. The conditioning cycle is not compulsory but doing this on days when flying will increase the efficiency of the fuel cell and boost performance.

6 LED codes

The fuel cell status is indicated by the LED. The table below shows the condition of the LED in each state.

650W Fuel Cell Power Module State	State LED Condition
Off, Standby	None
Fuel Cell Starting	Flashing Green
Fuel Cell Running, No Output	Slow Green
Fuel Cell Running, Enabled Output	Solid Green
Fuel Cell Stopping	Solid Green

The above states are moved between as shown in the diagram below:



6 LED codes

When a fault is detected the following conditions are shown by the LED.

650W Fuel Cell Power Module Fault	State LED Condition
Gas pressure low	Flashing Amber
Hybrid Battery Under Voltage	Slow Amber
Fault	Flashing Red

7 Faults

Fault diagnosis should be carried out by trained and competent personnel only.

In addition to the LED state, faults can be diagnosed from the log files on the included SD card.

Code	Tag	Description
80000000	Stack OT #1	Stack temperature 1 above limit
40000000	Stack OT #2	Stack temperature 2 above limit
20000000	Battery UV	Battery voltage below limit
10000000	Battery OT	Battery temperature above limit
08000000	No Fan	No fan current when fans are set to run
02000000	Stack OT #1	stack temperature 1 above limit
01000000	Stack OT #2	stack temperature 2 above limit
00800000	Battery UV	Battery voltage below limit
00400000	Battery OT	Battery temperature above limit
00200000	Master Start Timeout	Master State set to 'starting' for unexpected length of time
00100000	Master Stop Timeout	Master State set to 'stopping' for unexpected length of time
00080000	Start Under Pressure	The under-pressure limit for allowing a start of the system
00040000	Tank Under Pressure	The under-pressure limit which will shut down the system
00020000	Tank Low Pressure	The under-pressure limit which will flash the LED lights amber
00010000	Safety Flag Before Master EN	Either of the two safety lines are low when the Master EN (output enable) has not been enabled

8 Contact Intelligent Energy product support

For all other issues and questions please contact your local Intelligent Energy representative or the Product Support Team.

9 End of life treatment and disposal

When the 650W Fuel Cell Power Module, lightweight regulator or cylinder reaches end of life please contact Intelligent Energy for support with reconditioning or disposal at servicing@intelligent-energy.com

10 EU Declaration of Conformity In accordance with EN ISO 17050-1:2010

Intelligent Energy Limited

of

Charnwood Building, Holywell Park, Ashby Road, Loughborough, Leicestershire, United Kingdom, LE11 3GB

In accordance with the following Directive(s):

· 2014/30/EC	The Electromagnetic Compatibility Directive
· 2014/68/EU	Pressure Equipment Directive
· 2014/95/EU	General Product Safety Directive

Hereby declares that:

· 650w Fuel Cell Power Module + Lightweight Pressure Regulator

Is in conformity with the applicable requirements of the Directives set out above and the following standards documents:

· EN 61000-6-2:2005	Electromagnetic compatibility (EMC) – Generic standards – Immunity for industrial environments
· EN 61000-6-4:2007+A1:2011	Electromagnetic compatibility (EMC) – Generic standards – Emission standard for industrial environments

A copy of the official version of this certificate duly signed by an authorised signatory of the manufacturer is available upon request by emailing sales@intelligent-energy.com

Intelligent Energy Limited, Charnwood Building, Holywell Park, Ashby Road, Loughborough, Leicestershire, United Kingdom, LE11 3GB

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