PowerSpout PLT

Installation and system outline for client

This document outlines the process of ordering, installing, commissioning and maintaining a multi-turbine hydro site for domestic off-grid power.

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Web: www.powerspout.com

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1. Introduction

The purpose of this document is to inform the end client (and other interested parties) of the process involved with the installation, operation and maintenance of a large domestic scale off grid power system.

This case study relates to an installation of two PowerSpout PLT80C turbines to produce power for a large off grid home in rural New Zealand. EcoInnovation with assistance from the client measured and/or estimated the site data and placed an order having used the online Advanced Calculator available at www.powerspout.com/advanced-calculator to calculate the sites potential.

Site data summary as measured/estimated:

- 46m net head.
- 700m long 94mm ID MDPE pipe.
- 3-10 l/s flow in dry summer conditions, much more when wet.
- 800 metres of 125mm^2 aluminium 2-core cable.

2. Ordering

An order was placed for 2 PLT80C turbines with the following data inputs and results from online calculation tool (click here to view them in the Calculator).

	Inputs	Results
Preferences		
Units:	Metric	
Type:	PLT HP	
Hydro		
Flow:	10 lps	
Used Flow:		9.8 lps
Pipe Head:	46.0 m	
Pipe Length:	700 m	
Pipe Efficiency:		90 %
Pipe Diameter:	94 mm	
Number of Powerspouts:	2	
Nozzles:	2	
Jet Diameter:		12.3 mm
Actual Pipe Efficiency:		69 %
Speed:		937 rpm
Output:		802 W
Total Output:		1605 W
Electrical		
Output Voltage:		70 V
Cable Efficiency:		90 %
Cable Length:	800 m	
Load Voltage:	80 V	
Actual Load Voltage:		80 V
Cable Material:	Aluminium	
Cable Size:	125 mm^2	
Cable AWG:		00000 AWG
Cable Current:		20.5 A
Actual Cable Efficiency:		89 %
Actual Total Output:		1467 W

This calculation tool predicted this installation would generate 1.467 **kW from 2 turbines**.

3. Preparations prior to site visit and installation

Prior to visiting the site the installer asked the client to send pictures of the installed pipes and data on static pressure in the pipes.

The two PLT turbines were fitted with 100-7s-2p-star HP Smart Drive PMA's. The long cable was laid on the ground through the bush, under NZ law it must be under 120 VDC to comply. Burying the cable or putting it on poles was not an option at this site.

2 x PLT80C turbines were installed with a 76 VDC MPP.

4. Installation process

4.1. Installing the system

5.25 kW PV array was installed to allow the home to be built over the summer
21 x 250W panels in 7 strings of 3 (ELV)

7kW Outback Radian system installed with FM60 ready for hydro input - once turbines installed

The pipe was laid by the owner, the terrain becomes very difficult in places and this resulted in about 15 high points that needed to be vented to prevent air locks.

A large vent was fitted at the first high point to allow air to escape

At the other 14 high points stainless screws were inserted and allowed to weep. This method purges air locks while only allowing a small amount of water to escape the pipeline. Note the red tape is used to mark these positions so they can be easily located in the future

The client made a small temporary perforated tube intake. These are generally not suitable and will block quickly with leaves as shown. The client upgraded this is line with our advice in the installation manual.

Intake after 1 day of operation – is it not an adequate solution

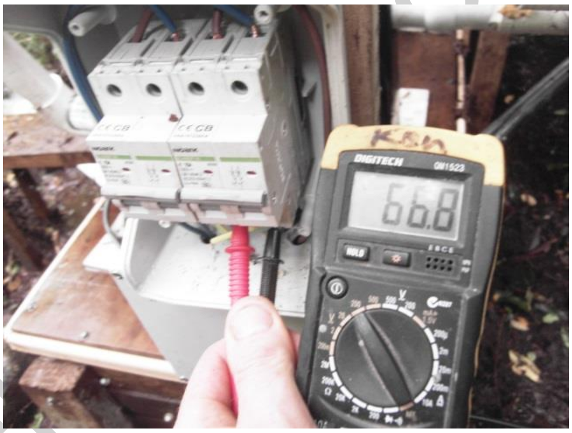
Upgraded inclined intake made from stainless steel. This is one of the most important parts to get correct, do not cut cost on the intake.

The pictures shows a 4mm hole drilled in the pipe, 15m down from the intake and about 800mm lower. There is very little pressure as can be seen from the low height of the water jet. An improved intake design will help. Always try and get a good fall on the initial 20 m of pipe if possible. In this example a partially blocked intake will result in negative pressure at this vent, which can draw air into the pipe line. The concrete structure in the picture is part of a road culvert (a convenient place to put the intake for access). <u>It is not part of this hydro scheme</u>.

Upgrading temporary air release vents to automatic air release valves.

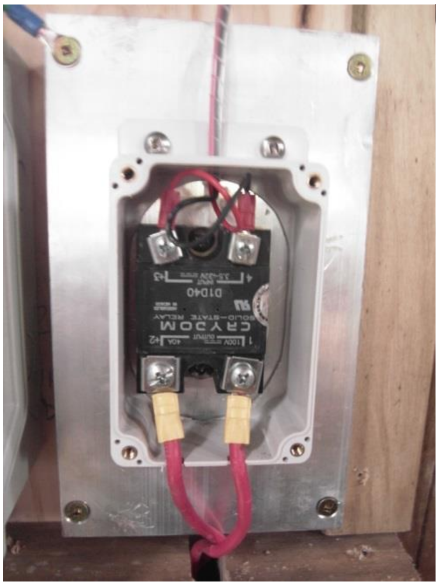
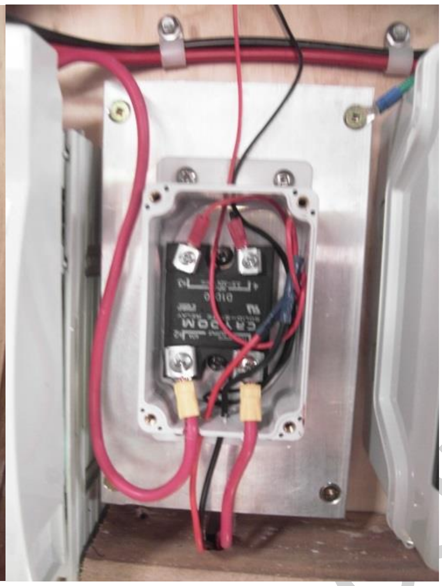
Mock-up of turbine and pipe manifold prior to carrying parts 800m into the bush. Do as much work as you can close to a workshop and not at the site. This will save time and keep costs down.

Charge with grease and activate grease cans



Check Klampits operate at 120 VDC unloaded

Static pressure almost 460 kPa, dynamic pressure 310 KPA. 2/3 of 460 = 306 kPa. Hence jet sizes are correct for maximum pipe power transfer. Pressure drop is about 31% as indicted in calculation tool.

Check SSR connected via FM80 and “AUX PV trigger” to air heater on wall is working
Check SSR connected via FM60 and “AUX solid state” to water heater is working

Close breakers and turn turbines on

Output varied from 1340-1430 Watt, prior to sorting out intake issue.
MPPV 76VDC, PV trigger was set to 85 VDC

4.2. Output testing and enhancements

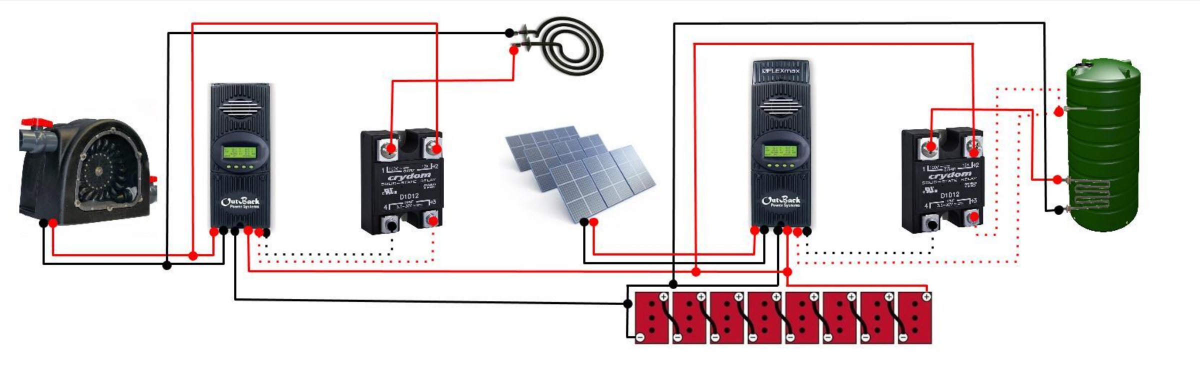
All systems will need some fine tuning. The calculations predicted 1467W at the output of the cable to the MPPT regulator. An FM60 is about 96% efficient, from the picture above almost 1400W is being delivered by the system to the input side of the FM60. We have also observed output as high as 1500W, the 100W variation may be due to factors such as:

- Air locks in pipe
- Cleanliness of intake
- Losses due to the 14 weeping vents
- Pipe ID size tolerance (1mm variation is 30W)
- Many curves in the pipe around trees and obstacles
- Accuracy of FM60 display

The system when installed was observed to operate within -4 / +2% of calculations.

4.3. Balance of System and system design

The simplified wiring diagram is as follows (no inverter shown).



Surplus power from <u>both hydro and solar PV</u> are sent to the hot water tank, the thermostat prevents boiling of the tank. This is controlled by the FM80 AUX solid state relay function that PWM's the SSR when the batteries are close to full. The element is 1.8kW at 56V.

It is the FM60 in the picture opposite that controls the hydro turbines surplus power by using the internal AUX relay and the "PV Trigger" function and the SSR (directly below the FM60). It is set to turn on the air heaters (directly above) if the incoming hydro voltage gets over 85VDC.

It is the FM80 in the picture opposite that controls the solar PV and hydro turbine surplus diversion to a water element, this only happens if the thermostat indicates that the water tank needs heating. Surplus power is diverted at the battery voltage to a special 1.8kW water element.
The heat sink for this SSR is fan cooled.

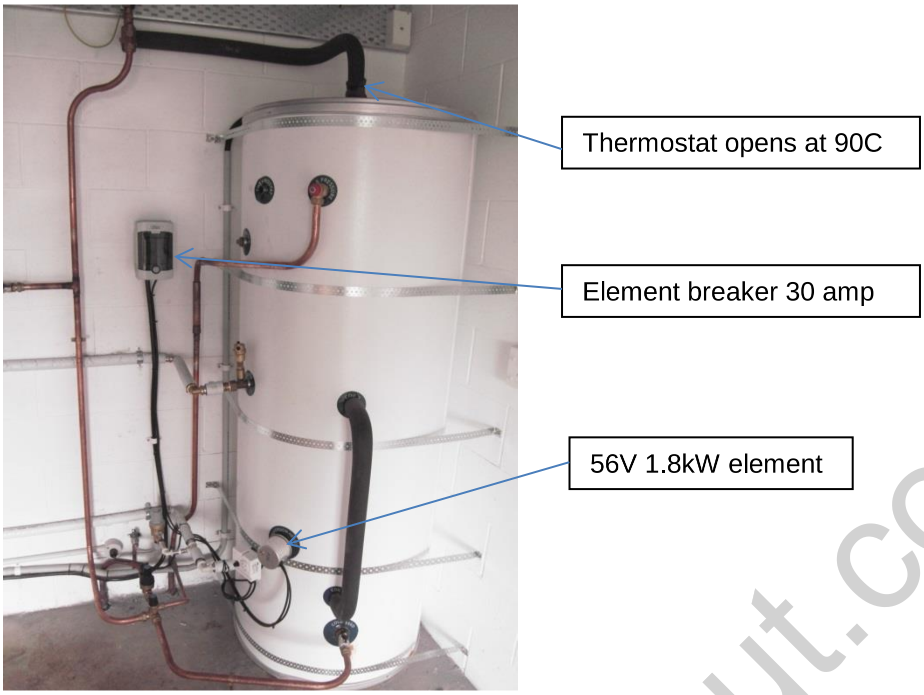
Peak generation of the system is about 5.5kW. Once the thermostat trips the following sequence will occur if the sun is shining and home AC loads are low:

1. The FM80 (charge settings) are set so that it will back off the solar PV generation before the hydro generation is reduced.

2. If battery voltage continues to increase (with FM80 solar PV fully backed off) the voltage on the hydro turbine incoming cable will climb as the batteries must be close to fully charged, if this voltage reaches 85 VDC then the FM60 "PV trigger" will activate and connect the resistive air heater. This will drop the hydro generation significantly.

3. If for any reason step 2 above fails the Klampits inside both turbines will activate at 120 VDC and all hydro generation will cease. Klampits do not automatically reset and the turbines will have to be turned on/off to restart hydro operation.

In the event that this air element fails (two electric stove elements shown), the internal 120 VDC Klampits will short the PMA's in the hydro turbine and stop hydro generation, solar PV generation will not be affected.



5. Final Site Install pictures

6. System settings

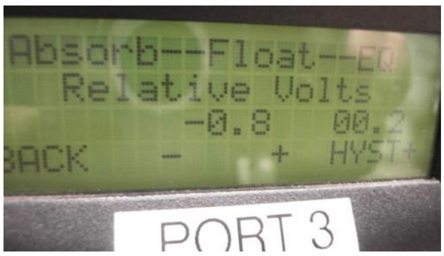
This document does not cover operation of the Outback Radian inverter system; comprehensive manuals (stored in the battery enclosure) are available for study. System operational data can be viewed on the Mate 3 and saved to the memory card.

FM60 settings
Absorbing 58.7V
Float 55.0V
Mate 3 port 4
Correct battery settings

FM80 settings
Absorbing 58.2V
Float 54.5.0V
Mate 3 port 3
Battery settings -0.5V. This ensures that the solar PV array will back off 0.5V before the hydro generation.

EQ settings
Auto battery equalisation is set for every 30 days. EQ has been set to Absorb + 1 V = 59.7, this is lower than advised by the battery makers but in situations where the batteries are full most of the time a lower EQ will result in less water loss. This can be increased if regular s.g. checks with a hydrometer indicate the batteries are not getting to 100%.

The picture opposite shows the AUX solid state diversion settings. These are set so that the water heater comes on when the battery voltage gets to within 0.8V of the FM80 settings and will be off after a 0.2V voltage drop. On a sunny day generation will easily exceed the 1.8kW element size, so these diversion settings will not prevent the battery bank from getting fully charged.



7. System performance

7.1. System performance (June/July 2014 NZ winter)

62 days data for Sampson Job from yesterday					
Day	kWhrs PV	kWhrs Hydro	PV+ hydro		
1	12.5	20.5	33.0		
2	15.7	22.0	37.7	Best PV day	
3	7.4	16.8	24.2		
4	5.3	22.8	28.1		
5	5.2	27.1	32.3		
6	12.8	14.1	26.9		
7	12.8	13.1	25.9		
8	10.4	13.2	23.6		
9	11.3	19.3	30.6		
10	13.4	27.1	40.5		
11	7.6	27.5	35.1		
12	1.7	22.8	24.5		
13	6.0	26.3	32.3		
14	9.1	27.1	36.2		
15	4.3	27.2	31.5		
16	9.0	27.2	36.2		
17	5.8	27.2	33.0		
18	8.5	27.5	36.0		
19	3.3	27.7	31.0		
20	3.6	27.6	31.2		
21	6.4	27.7	34.1		
22	5.5	27.6	33.1		
23	3.3	38.0	41.3	Best hydro day	
24	1.1	27.9	29.0		
25	5.5	28.0	33.5		
26	9.0	27.3	36.3		
27	2.9	27.1	30.0		
28	4.1	27.5	31.6		
29	0.4	18.5	18.9		
30	0.8	13.4	14.2		
31	9.5	13.0	22.5		
32	10.9	13.4	24.3		
33	4.9	20.4	25.3		
34	8.2	27.3	35.5		
35	9.2	25.5	34.7		
36	8.2	11.2	19.4		
37	4.4	2.1	6.5	Klampit tripped?	
38	1.0	27.4	28.4		
39	7.7	27.5	35.2		
40	12.0	27.4	39.4		

	41	13.7	28.2	41.9			
	42	4.6	29.1	33.7			
	43	3.0	29.7	32.7			
	44	1.2	28.8	30.0			
	45	1.4	28.6	30.0			
	46	10.2	28.2	38.4			
	47	1.6	17.6	19.2			
	48	6.8	13.3	20.1			
	49	13.4	20.0	33.4			
	50	8.6	5.0	13.6			
	51	6.7	6.4	13.1			
	52	13.9	28.1	42.0			
	53	14.3	28.5	42.8			
	54	14.4	28.6	43.0			
	55	12.8	28.6	41.4			
	56	1.4	36.6	38.0			
	57	4.4	29.3	33.7			
	58	14.7	29.1	43.8	Best day		
	59	11.1	28.3	39.4			
	60	9.0	26.5	35.5			
	61	1.4	22.1	23.5			
	62	1.3	22.2	23.5			
Total	**62 days**	**451**	**1465**	**1916**			
Average		**7.3**	**23.6**	**30.9**			
	3.25	times more power is made from hydro than from PV					
Range	13.6 to 43.8 with 30.9 average						
Excludes power sent to air dump that is not measured							
At 30c/kWhr and $1 per day connection fee this is a saving of $						10.27	per Day

7.2. System performance (October 7th- 20th NZ Spring)

	14 days data for Sampson Job Spring						
	Day	**kWhrs PV**	**Whrs Hydr**	**PV+ hydro**			
	1	9.8	24.4	34.2			
	2	13.1	24.5	37.6			
	3	11.7	24.1	35.8			
	4	2.4	20.5	22.9			
	5	10.8	21.9	32.7			
	6	12.9	24.3	37.2			
	7	11.7	23.9	35.6			
	8	11.5	27.1	38.6			
	9	20.3	23.4	43.7	Best day and best PV day		
	10	11.5	27.3	38.8			
	11	12.1	28.0	40.1			
	12	9.6	27.9	37.5			
	13	3.1	28.1	31.2			
	14	11.4	28.4	39.8	Best hydro day		
Total	**14**	**152**	**354**	**506**			
Average		**10.9**	**25.3**	**36.1**			
	2.33 times more power is made from hydro than from PV						
Range	22.9 to 43.7 with 36.1 average						
Excludes power sent to air dump that is not measured							
At 30c/kWhr and $1 per day connection fee this is a saving of $						11.84	per Day

The above exercise should be repeated for summer and spring

What is interesting to note is that the reliance factor on hydro power reduces from winter to spring from 3.23 to 2.33. It will be interesting to look again during a dry summer period.

8. System use and support

8.1. Supply of electricity

This system can supply AC loads of up to 7.0kW. A typical home in New Zealand will consume 24kWhrs/day and this home consumes between 30-36kWhrs/day. Clearly limiting electrical loads is important, especially during **overcast and dry** periods.

Ensuring the electrical load of the building is less than the energy produced is the responsibility of the user.

Common causes of system failure
Electronic equipment will fail prematurely if exposed to:

- Excessive load
- Damp
- Condensation
- Dust
- Excessive heat/cold

- Poor battery ventilation
- Battery fumes
- Generator exhaust fumes
- Water
- Mice nesting inside cases
- Insects – in particular spiders

Check your system on a regular basis to prevent the above issues from affecting your system performance/life.

8.2. Photo Voltaic Panels (PV)

PV panels normally require little maintenance other than regular cleaning. If birds tend to perch and dirty the panels then a fine wire can often be employed to prevent this problem. Ensure the PV panels are always clear of shading, cut trees regularly to prevent shading.

This install picture clearly shows a hedge that is due for removal or a severe trim.

In dry dusty areas regular cleaning will improve performance.
Organic plant growths can establish particularly in the wet/damp environments of NZ and should be regularly cleaned, once per year is normally sufficient for growths.

8.3. Hydro Turbines

Detail hydro turbines maintenance is outlined in the install manual
Installation manual PLT/TRG/LH

8.4. Batteries

Refer to suppliers manual for general care of your batteries

Batteries must be in a well-ventilated room and not combined with electrical equipment unless in an open shed environment. Battery terminal must be protected from falling objects.

A battery disconnect fuse is located under the inverter system; in an emergency open this large fuse holder.

Ventilation and laminate signs have been provided, please ensure that over the passage of time vents are cleaned and signs are not removed.

Batteries -Crown CR395
395 amp hr at 20 hr rate
3 strings of 8 batteries
Mass 55kg each, total = 1320kg

Before disconnecting the battery from your system make sure you have turned off both generation sources (PV and hydro) and turned off the inverter.

Once every year check your battery terminals for corrosion and clean if required. Always turn off all generation and your inverter before doing so. When working with batteries have a bucket of clean water close by, wear goggles, overalls and gloves. Always use insulated tools.

Check your battery acid level initially every week (then once a month is acceptable), check the specific gravity and top up as required. Normally top up water is needed every 3-6 months, only use distilled water, you must not use rain or river water.

All battery terminals must be protected with a permanent insulated cover that cannot be easily removed by children. A cover with a latch and padlock has been provided.

The following data and safety signs have been attached on the lid on the battery enclosure.

Battery type: Wet cell lead acid

- Battery make: Crown CR395
- Amp hour capacity/battery: 395
- Number of batteries per bank: 8
- Number of parallel banks: 3
- Short circuit current: >1000 amps

Voltages, Specific Gravity and State of Charge
The information below describes how to correctly use and interpret both specific gravity and voltages readings and how to determine when your battery bank requires charging.

Your battery state of charge can be located in 3 ways:
- On the Mate 3 display – keep in the range70-100% SOC
- On the Radian battery monitor traffic light (open lower stainless door to see it)
- Check with a hydrometer (the most accurate measure of SOC)

The Crown batteries are a flooded wet cell lead acid, and like a car battery, the electrolyte level must be maintained.
Some protective equipment and demineralized water has been provided so the user can check and refill as required.

An absolute measure of a batteries state of charge is obtained with a hydrometer. A hydrometer measures the density of the electrolyte which depends on the batteries state of charge. The float in the hydrometer has a green and red section marked on it. Green is for more charged. Please read the units on the float and refer to the table below.

Personal Protection Equipment use

The specific gravity (SG) of the battery acid or electrolyte is the truest and most absolute measure of a battery's state of charge. The SG reading is NOT greatly or adversely affected by the load on the battery. Basically if a battery is 50% charged, it will read a specific gravity of 1.200 (see Table), regardless of whether the battery is on charge, being discharge or being stored. This is not the case for voltage readings.

SG vs. Voltage

% Charged		Specific Gravity
100%		1.255 – 1.275
75%		1.215 – 1.235
50%		1.180 – 1.200
25%		1.155 - 1.165
0%		1.110 - 1.130

On this system we suggest you check s.g. on the Mate 3 once a week and with a hydrometer once a month.

If you experience prolonged dry and overcast periods you may have to plug in a fuel generator for system support.

Complacency is your worst enemy and if you are using your low voltage inverter trip as a reminder to charge your batteries then they will normally only last 1-2 years, but they could have lasted 10+ years if correctly cared for.

Top up batteries every 1-3 months with distilled water.
Re-combiner vents have been fitted to these batteries, these will help reduce the amount of top up water needed.

If your experience significant water loss then you might want to reduce your equalize charge voltage and the bulk voltage slightly. Check with a hydrometer that your batteries are still getting fully charged if you do this.

Usage
Keep usage records. On a weekly average you should generate at least 20-30% more than you use (allowing for inverter and battery losses). Your generation and usage is recorded in your system.

8.5. Balance of system equipment

All other equipment in your system comes with manufacturers manuals, read and retain them for future reference.

General
Keep your power shed clean and dust free as cooling fans can suck dirt into equipment. Never run your generator inside the building that houses your electrical equipment unless it is externally exhausted.

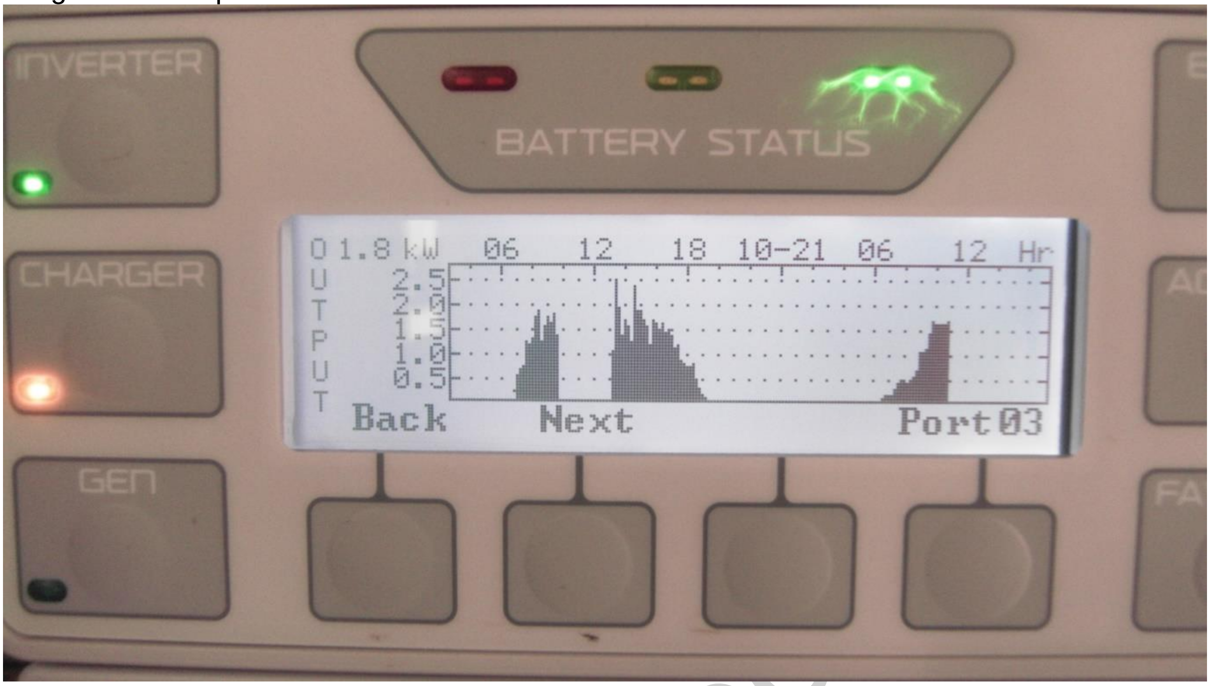
System labels
We have provided sufficient labelling so that a competent untrained person can carry out basic operation of the system, for example turn on and off and not get hurt.

Electrical trades people unfamiliar with SPS (stand alone power system) should have sufficient warning to avoid basic errors which might result in personal injury or property damage.

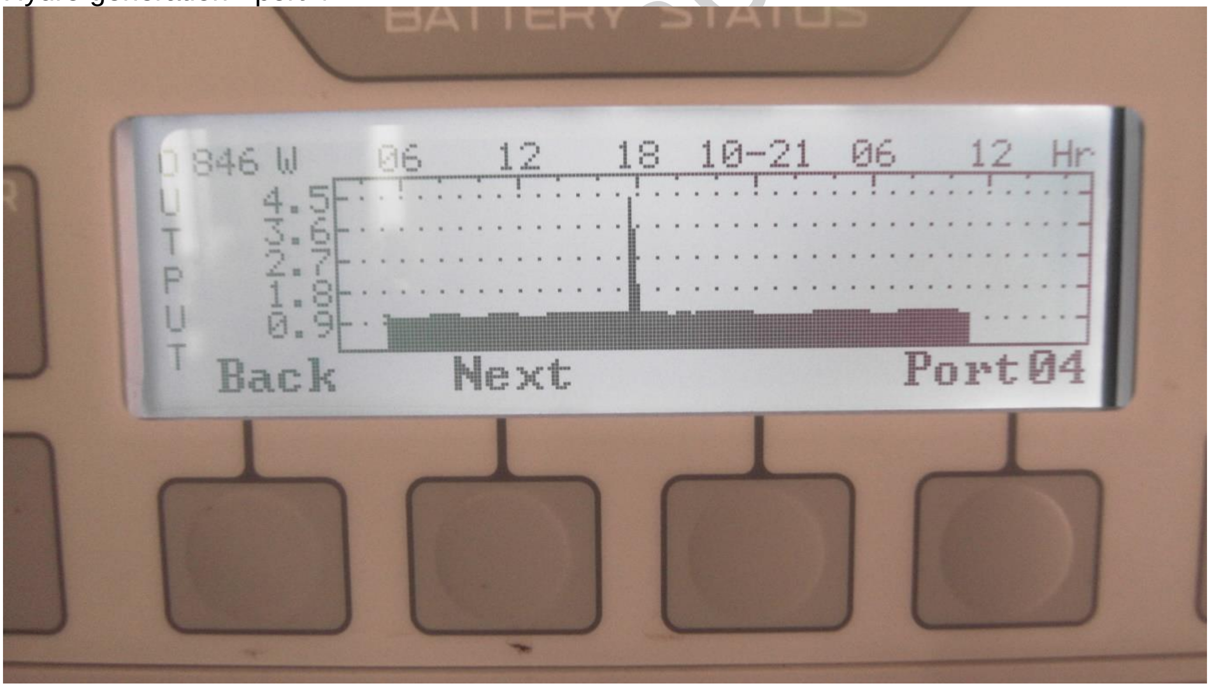
Emergency services personal should be able to avoid, or make safe, any risks in the event of a fire or similar event.

9. Typical Mate 3 data display

PV generation - port 3

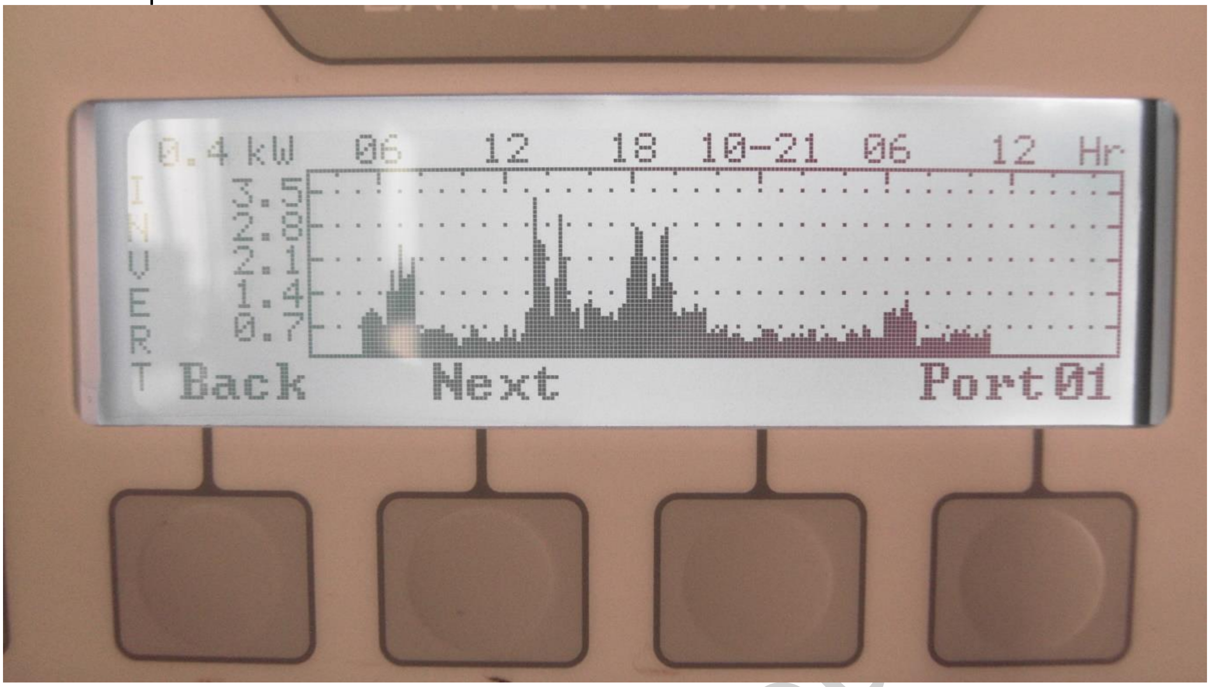


Hydro generation - port 4



The generation spike is due to the FM60 getting a new VOC. Only 2 of the 4 jets were running when this picture was taken

AC loads - port 1



Base load is about 700W
Peak load is about 3.5kW
The above does not show kW sent to the water heater which is significant.

10. System maintenance in general

Detailed maintenance instructions (where required) are normally included in the user/install manual for each system component.

A general system maintenance guide is outlined below.

After a flood event:

- Check system operation, clean away flood debris, check for any flood damage and repair as required.

Inverter:

- Check for any red lights on the Mate 3 display and investigate further. There is an error log which will be helpful.

There is no routine maintenance required for the inverter other than keeping the front air vents clean of dust.

Intake screen:

- Keep clean of debris, check every 1-2 weeks and clean as required, more cleaning may be needed after floods, high winds and during Autumn.

10.1. Detailed periodic maintenance (modified from AS/NZS5033:2012)

After a flood event

- Check system operation, clean away flood debris, check for any flood damage and repair as required
- Keep intake clean of debris

Every month

- Clean hydro intake screen, more cleaning may be needed after floods, high winds and during Autumn
- Check battery water level and top up as required
- Check battery s.g. to make sure that your batteries are getting 100% charged
- Check for any red lights on the Mate 3 display and investigate further. There is an error log which will be helpful

Every year:

- Remain aware of safety warnings and manufacturer's recommendations
- Check battery terminals are clean and tight
- Check safety signs are still in place
- Clean inverter air grill
- Replace auto grease canister on hydro turbine every 12 months - refer to manual
- Check for any play in hydro turbine bearings and replace if required
- Clean the 3 air intake vents on hydro turbine
- Clean PV array
- Clean power shed as required
- Periodic inspections should be carried out to check wiring integrity, electrical connections, corrosion and mechanical protection of wiring.
- Verify open circuit voltage and short circuit current values.
- Check PV array mounting structure
- Test operation of switches regularly
- Check for module defects (fracture, moisture penetration, browning, etc.)
- Check hydro mounting structure for any flood damage and repair
- Walk the power cable route and check/clear any tree falls
- Walk the penstock route and check/clear any for tree falls and slips

Every 5 years:

- Clean pipe of internal deposits, this is done with a pipe pig
- Verify mechanical integrity of conduits and outside breaker enclosures, tightness of connections, water accumulation/build-up, integrity of lid seals, integrity of cable entrance and/or conduit sealing, integrity of clamping devices
- Load test battery bank to determine loss of life storage capacity to date

Every 10 years:

- Replace battery bank
- Have the hydro turbines fully overhauled and reconditioned

11. The benefit of hindsight

11.1. The Client, Dealer, Installer and Manufacturer relationship

The above example identifies potential problems that all parties can get into.

The Client laid the pipe and the course chosen resulted in many air locks. Try and keep high points to a minimum and an always descending pipe line where possible. This long pipe was difficult to fully purge of air and the poor intake did not help the situation.

Site data collected by the installer indicated 50m of head, we ended up with 46m as the site chosen for the turbines had better access than the site surveyed. The survey conducted with 2 altimeters and a tape proved to be very accurate.

Incorrect site data from clients is extremely common, so treat such data with caution. Clients are often very optimistic people and live in remote places with limited survey equipment on hand: this can be bad news for hydro calculations. This can be bad news for new dealers and installers who often lack the experience to understand what has gone wrong.

Clients need to supply accurate site data. Clients that supply “best guess” site data need to be aware that calculated output can differ significantly from “as installed” data. Clients need to be aware that extra fees will be payable for additional installer time and parts needed if site data is wrong and a fix has to be implemented.

To avoid liability issues, dealers and installers must insist the client supplies site data in writing or by email. Where the client verbally communicates site data you must forward the calculations back to the client and make them confirm in writing the site data is correct before you accept their order. If the Installer or Dealer measures and supplies this site data they may be liable if they get it wrong.

When things go wrong, EcoInnovation will often review the situation for free (but may publish the site data and pictures to help educate dealers, installer and clients around the globe). EcoInnovation will only pay to fix issues where our advice has been incorrect or goods supplied have been faulty or incorrect.