



## PowerSpout Technical Manual



**This manual contains data and information which  
supplements the Installation Manual**

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- 1.2. Updated PowerSpout versions available and further minor revisions. Feb 2011.



## PowerSpout Contact details

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If you cannot find the answers to your questions about our product, renewable energy systems, or your site's potential in this document or on our website at [www.powerspout.com](http://www.powerspout.com), please visit [www.powerspout.com/faq](http://www.powerspout.com/faq) and submit a question. We will answer this as quickly as possible, and you will be notified by email when this occurs.

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## 1. Introduction

This manual is intended to supplement the PowerSpout Installation Manual and help you understand more about your renewable energy system. It will also provide you with more advanced options for using your PowerSpout or integrating it with other renewable energy components.

The manual starts with a section on electricity since there is often considerable confusion on this topic. Some additional detail is added for different versions of the PowerSpout, other system components and regulator function is described. The Manual ends with instructions for larger renewable energy systems incorporating other generators.

If you are interested in technical details you might also be keen on our Smart Drive Manual which provides detailed instructions for modifying Smart Drive (or equivalent LG) units for use as micro-hydro generators.

We also have range of photos and video clips on our website with installation examples.

## 2. Understanding Electricity

Electricity is difficult to understand as we cannot see it and have been told from a young age not to play with the plug sockets in our home. To some extent this has meant that for many people electricity is misunderstood and any contact with it feared.

An analogy with water can often help, since fluid flowing through pipes can behave like electricity flowing in wires. The main difference is that if you puncture a pipe, water will escape and fill the space whereas electricity will not. Electricity will only emerge from a bare wire to 'fill' another conductor.

The electricity generation capacity of your hydro system is determined primarily by two factors: the vertical distance the water falls (head) and the flow rate of water. These two properties of a river are analogous to two properties of electricity: voltage and current.

**Let's consider the vertical drop first.** A vertical drop is sometimes called potential, you may remember the formula for potential energy from school:  $PE = mgh$ . So a mass has stored potential energy by virtue of its height relative to the ground. Hydro electricity is the result of allowing this mass of water to fall through a turbine converting this potential energy into electrical energy.

Power is the result of doing energetic things quickly. Power = energy divided by time.

For example, if we have a bucket with 5 kg of water in it, and if every second we drop this water down the rain water spouting of a 20 m high building then we can work out how much power we can generate in theory from a hydro turbine attached to the bottom on the spouting. Hence the name PowerSpout.

$$\text{Water Power in theory} = mgh/t = 5 \text{ kg} \times 9.81 \text{ m/s}^2 \times 20 \text{ m} / 1 \text{ s} = 981 \text{ W}$$

$$g = \text{gravity} = 9.81 \text{ m/s}^2 \text{ (Newton came up with this after an apple fell on his head)}$$

In practice the pipe line, Pelton rotor, generator and wire all have losses. As a result small hydro turbines typically convert 50% of the available water power to electrical power.

$$\text{Electrical power in practice} = 981 \times 50\% = 490 \text{ Watts}$$

So what does all this have to do with voltage? Well voltage is also often called a potential difference and it is analogous to the vertical drop of the water. You can see how in a pipe full of water the greatest potential difference (often referred to pressure in a pipe) is at the bottom of the pipe. Hopefully you can relate this to voltage in an electrical system.

Voltage hurts, as does high pressure water (have you ever been hit by a water cannon?).

**So to recap, the head of water or pressure in a pipe line is analogous to the voltage in a cable.**

**Let's consider water flow rate next.** A small stream might take 10 seconds to fill a bucket where a large stream may fill 1,000 buckets in a second. The flow of a stream is often referred to as current. Likewise the flow of electrons (very small things we cannot see) is also called current and the unit of current in an electrical circuit is measured in amps.

Current in a stream is the quantity of water flowing by, this is the same as in an electrical circuit but the water molecules are now electrons.

**So to recap, the flow of water in a pipe line is analogous to the current flow in a cable.**

Power = Volts x Amps

So if we take the above hydro example and fit a 48 Volt generator to the turbine we will make 490 W. This means  $490 = 48 \text{ Volts} \times \text{Amps}$ .

Then we must have  $490/48 = 10.2$  Amps flowing in the circuit.

### **Head and Voltage**

In a water system the head (m or ft) is an indicator of water pressure. In an electrical system pressure is measured in Volts (V).

### **Flow rate and Current**

The water flow rate is the volume of water that flows in a given period of time e.g. litres per second or gallons per minute. The electrical equivalent is the current, measured in Amperes or Amps (A).

### **Resistance**

The size of a water pipe directly affects the losses in a hydro system, with a small diameter pipe causing higher losses. Resistance is the amount that the pipe 'resists' the flow of water. This is similar to the resistance in an electrical system which is measured in Ohms. In electricity, if a pressure of 1 Volt will drive a flow of 1 Amp then the resistance is 1 Ohm. 2 Volts would drive 2 Amps through 1 Ohm: pressure divided by current equals resistance.



### 3. Components of your hydro system

Additional detail is provided here regarding a few of the components described in the PowerSpout Installation Manual.

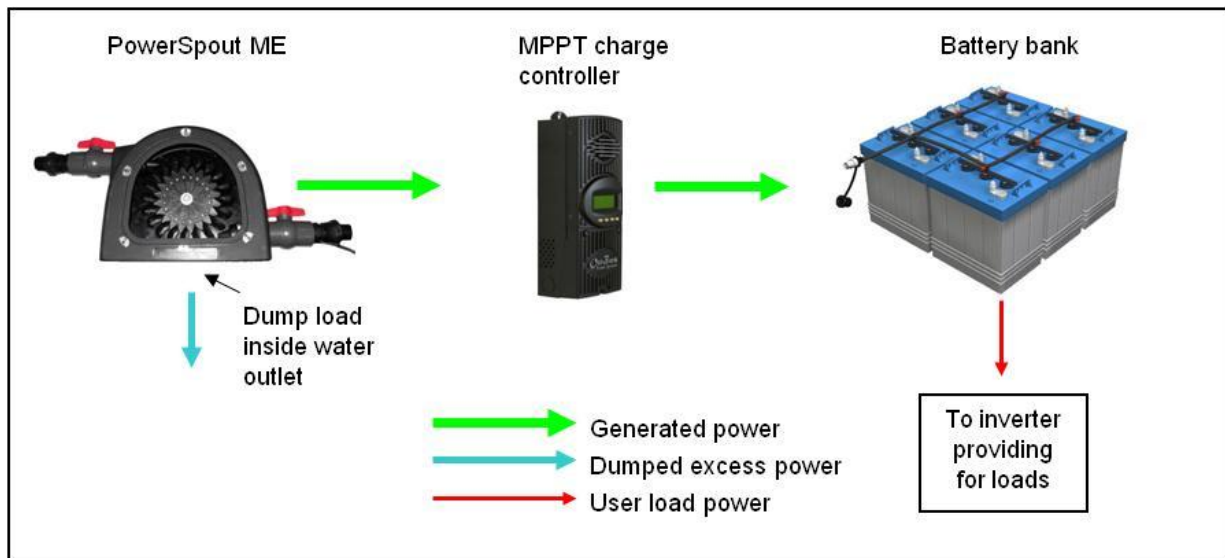
#### 3.1. Generator (PowerSpout)

The PowerSpout BE is the most common version installed and is the focus of the PowerSpout Installation Manual. An overview of different versions can be seen in Table 1 and more detail on is provided below.

**Table 1. Different versions of PowerSpout**

Version	Description	Cable length (m) approx.	Features
BE	Battery Enabled	0 - 250	Connected directly to a battery bank with a diversion load controller for system regulation.
ME 100	MPPT Enabled	50 - 750	Designed for inverters and MPPT regulators operating at less than 100 V DC (120 ELV *) or for the Latronic grid-tied inverters that are made in Australia.
ME 120	MPPT Enabled	50 - 1000	Connected to a battery bank through a MPPT controller such as the Outback FM60. Designed for inverters and MPPT regulators operating at less than 120 V DC (120 ELV *)
ME 140	MPPT Enabled	50 - 1500	Connected to a battery bank through a MPPT controller such as the Outback FM60. Designed for inverters and MPPT regulators operating at less than 140 V DC.
ME 250	MPPT Enabled	50 - 2000	Connected to a battery bank through a MPPT controller such as the Midnite Classic 250. Designed for inverters and MPPT regulators operating at less than 250 V DC.
GE 400	Grid Enabled	0 - 2000	Connected to a grid tied inverter to feed hydro generated power into the national grid or for use in mini grids via Sunny Island type inverters. Designed for inverters operating at less than 400 V DC.
HE (NZ only)	High-voltage Enabled	500 - 2000	Connected directly to a battery bank via three step-down transformers with a diversion load controller for system regulation.
EE	Educational Enabled	n/a	Runs off a tap, not for permanent use.
DE	Dealer Enabled	n/a	Sample for illustration only.

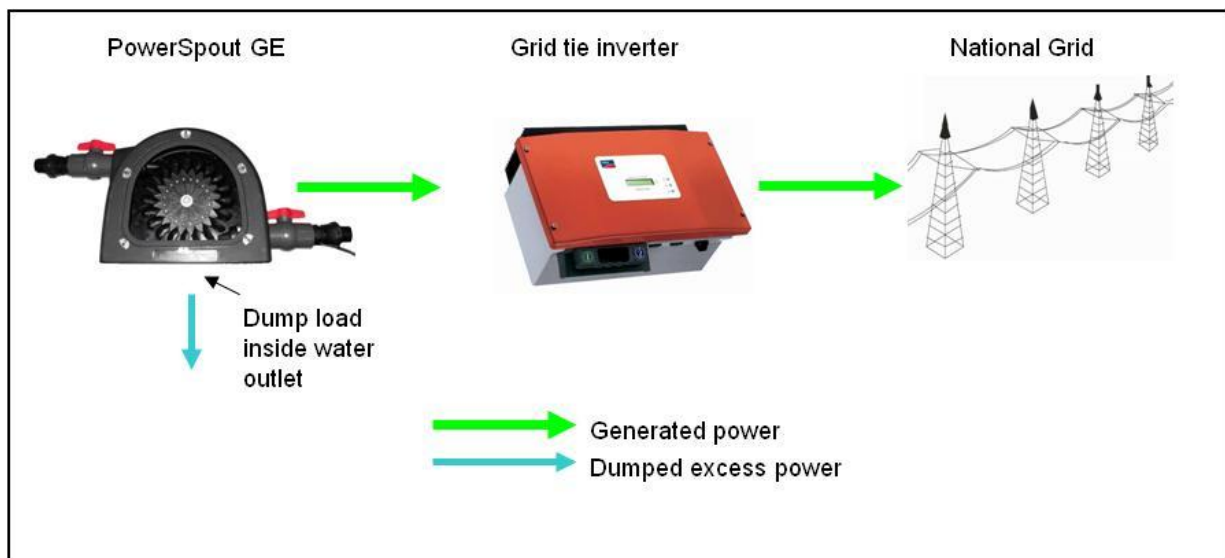
\*120 ELV (extra low voltage) laws in some countries allow home owners to install equipment up to 120 V DC without regulatory control applying to them.

3.1.1. ME option (MPPT Enabled)

**Figure 1. PowerSpout ME system setup**

The advantages of using a PowerSpout ME with an MPPT controller include:

1. PowerSpout ME meets the ELV (Extra Low Voltage) requirements of wiring regulations in many countries so that the home owner is permitted to do their own electrical installation wiring.
2. The PowerSpout ME output voltage can be up to 250 V DC (depending of version ordered 100,120,140,250 V DC). Compared with the typical battery system voltage of 48 or 24 V DC (nominal) this higher operating voltage means less cable current and less cable losses. The higher operating voltage permits the use of smaller cabling for the same losses for a more cost effective system.
3. Where the distance from the PowerSpout to the battery room is greater than 200-500 m the savings in cable costs is greater than the increased cost for the ME version and the MPPT controller.
4. The MPPT controller provides automatic tuning of the PowerSpout ME. This provides automatic adjustment of the turbine speed to match the water resource. This is very useful to accommodate different summer to winter water flow rates.
5. The PowerSpout ME uses high efficiency Schottky diodes for rectification. This can reduce rectification losses by up to 5 W depending on the operating power level, thus increasing electrical output.
6. MPPT of the Smart Drive permanent magnet generators results in a higher generator efficiency, as the voltage is not clamped by the battery voltage. This can result in up to 10% more power, but is offset to a large degree by losses in the MPPT regulator or inverter that are typically 5-7%.
7. MPPT of Smart Drive permanent generators results in a wider operating range. This is partly why we can offer a high power 1.6 kW version on the ME and GE versions.

3.1.2. GE option (Grid Enabled)

**Figure 2. PowerSpout GE system setup**

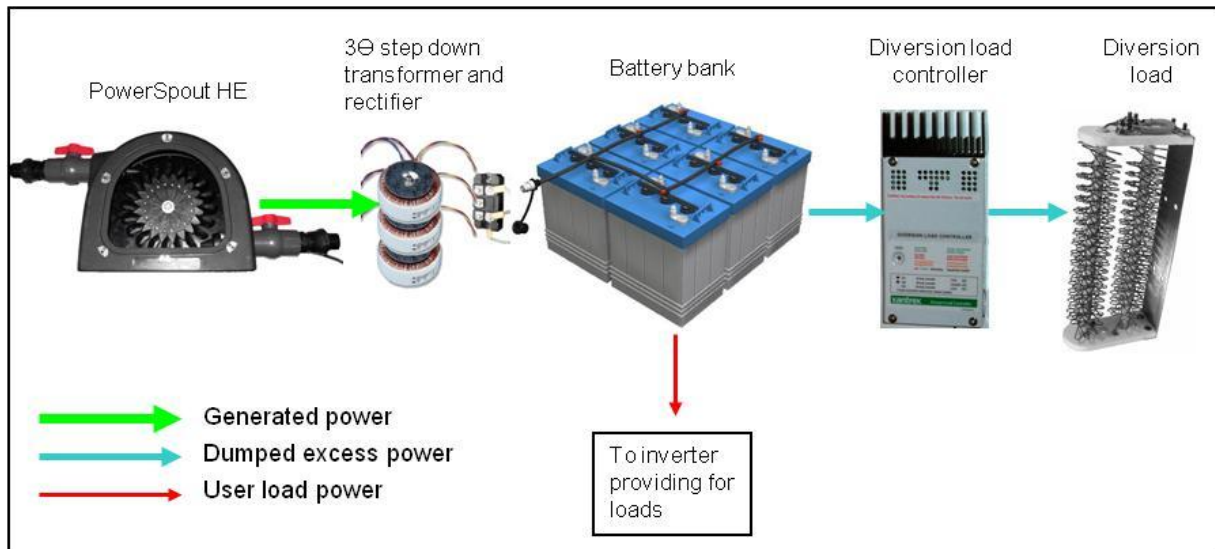
The PowerSpout GE is designed to be connected to a grid-tied inverter to feed hydro generated power into the national grid. The PowerSpout GE has built in electronics to limit its output voltage to less than 400 V DC. The PowerSpout GE can be used in off-grid mini-island situations; please contact EcolInnovation for further information.

Grid tied inverters include a MPPT function which automatically optimizes the PowerSpout GE for maximum electrical output.

The PowerSpout GE can also be used in off grid installations in place of the PowerSpout ME. Those with a long cable distance from the PowerSpout to the inverter/battery room may find it more cost effective to install a PowerSpout GE with SMA Sunny Island and Sunny Boy inverters. The savings in cabling cost at 400 V DC compared with an ME at 250 V DC (or lower) can be significant.

The payback period for hydro generated power is very impressive when compared with PV solar systems. Continuous running water means your PowerSpout GE and grid tied inverter will work 24 hours per day, in contrast to solar PV which only works for daylight hours.

### 3.1.3. HE option (High voltage Enabled)



**Figure 3. PowerSpout HE system setup**

The PowerSpout HE is essentially the same as the PowerSpout BE. The main difference is that the PowerSpout HE generates a high voltage AC which is then reduced at the battery banks via three transformers and then rectified to DC to charge the batteries.

In off-grid situations with a very large distance from generator to battery room it may be more cost effective to install a PowerSpout HE. The HE is rarely employed as most hydro wiring issues can be solved with the ME and GE turbines.

### 3.1.4. Education and demonstration

PowerSpout EE is an educational enabled unit for running off a tap, sold at a reduced price, not for use in the field or other permanent use - terms and conditions apply.

PowerSpout DE is a dealer enabled sample for visual illustration only, not for resale or use. Dealers should contact EcolInnovation for a sample – terms and conditions apply.

## 3.2. Rectifier

A rectifier converts the 3-Phase produced by the micro-hydro to DC for supply to the battery bank. There is no incorrect wiring sequence into the rectifier from the generator for the 3-Phase AC input. The DC output must be red or brown/+ /positive and black or blue/- /negative.

Generally DC is conveyed from the turbine to your battery bank as DC provides the lowest loss for a given cable size. However, depending on the distance of the generator from the battery bank, and the cable you have available, it may be advantageous to use AC with the PowerSpout HE version and operate the cable at a higher voltage to reduce cable losses between the turbine and your battery bank.

For example, if you have a 3-core cable already then supplying DC with 2 of the conductors in parallel for one of the two connections results in a 30% reduction in cable loss compared with 3-Phase AC operating at the same voltage.

If you have not already purchased the wire, then 2-core wire for DC transfer is a more efficient way to transfer electricity, a more efficient use of the materials and normally a more cost effective option.

### 3.2.1. Star or Delta wiring

Some PowerSpouts may be supplied as 6-Wire generators that can be connected in Star or Delta. A Delta connection can give more power (but at a higher rpm) than a Star connection. Both are provided in special cases to make the product more flexible if site data is not clearly defined, or to allow for future changes to the head of the system.

The wiring on the generator stator is provided by EcolInnovation so that the generator is optimized for your site's head, power and system voltage. If you ever move your PowerSpout to a different site then you should contact EcolInnovation as a new stator may be needed. Stators are not expensive and we have found that having a single 3-wire solution is less confusing than supplying a stator with many wiring options that installers often find confusing to work with.

For example:

1. 100-7S-2P - Delta
2. 100-7S-2P - Star
3. 100-7S-2P - 6-Wire

The above three generator names are examples that may appear on the back of your hydro generator (engraved into the stator trim plate). The Delta and Star options are hard wired for only one option and will have three wires coming out of the generator. If you see "6 Wire" then your unit can be connected in either Star or Delta on site, so you have two options you can try.

There are several hundred generator stator wiring options available to cater for the wide operation of the PowerSpout from 10 W to 1600 W and voltages from 12-500 volts.

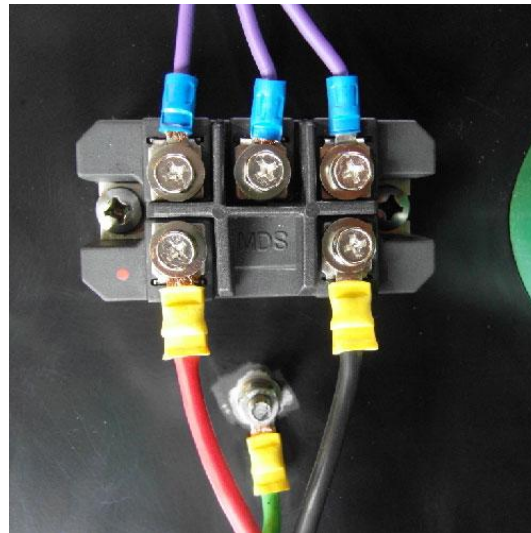
For Star connection:

- Connect wires 1, 2 & 3 electrically together with a fixing and insulate – this is called the star point. The wires of the star point are all the same color. Connect the remaining three wires onto the three AC pins (the order is not important).

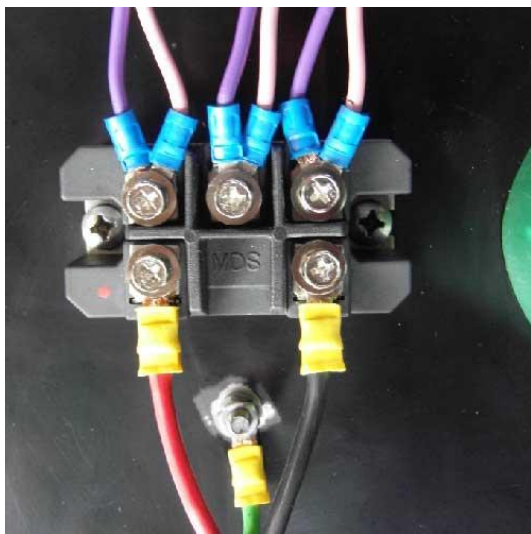
For Delta connection

- Connect wire pairs 1 & 4, 2 & 6, and 3 & 4 together onto each AC pin.





Star or Delta connection from a 3-Wire generator BE PowerSpout



Delta connection from a 6-Wire generator BE PowerSpout



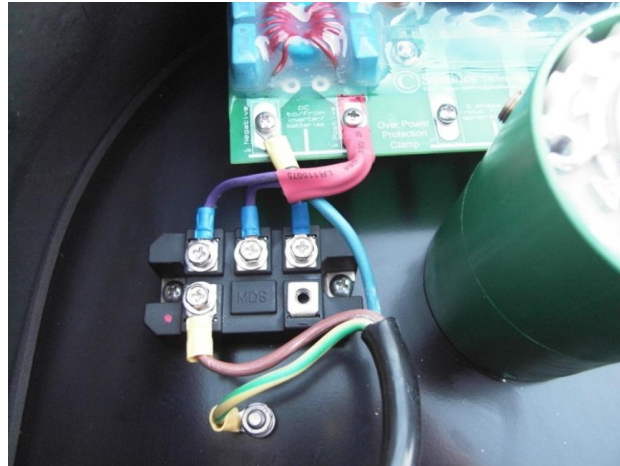
Delta connection from a 6-Wire generator ME or GE PowerSpout

For a star connection in the above two pictures remove the same colored wire from each wire pair, connect all three wires together electrically, insulate them and then cable tie them out of the way.

### 3.3. Revision of wiring method for ME/GE PowerSpout

After extensive stop/start testing of a PowerSpout ME it has become apparent that some MPPT regulators are able to supply a significant amount of energy from the battery and their internal capacitors back to the ME circuit board in certain conditions.

To overcome this potential problem with some MPPT regulators we require the following wiring method for the ME and GE PowerSpout, as shown in the picture below. This method uses the standard 3-phase rectify (used in the BE PowerSpout) as a diode block to any reverse energy flow.



Connect:

- Positive out wire (red or brown) to the positive on the rectifier (marked with a red dot and + sign).
- Negative out wire (blue or black) connects to the negative post on the ME circuit board marked "Negative".
- Earth (yellow/green), connects to the bulk head earth lug as shown.
- Combined wires on the three AC rectifier pins go to the positive post on the ME circuit board marked "Positive". This has been already connected for you.

### 3.4. Diversion within turbine ME/GE versions

In the PowerSpout ME and PowerSpout GE a circuit board provides a voltage clamp (VClamp) function. In the event of the output voltage exceeding a pre-set limit, power is diverted to a water cooled dump load inside the turbine. If the internal water cooled load fails, for example because of a loose connection, then a backup protection function will short circuit the output to protect connected equipment from over voltage.

### 3.5. VClamp: over-voltage protection for PMA (ME/GE versions)

When it comes to efficiency a permanent magnet alternator (PMA) provides the best performance, but they have poor voltage regulation.

The VClamp provides a defined voltage limit for a PMA that is never exceeded. Excess energy is dumped into a resistive load and provides voltage controlled shunt regulation. To guarantee complete protection in the event of a failure an internal crowbar shorts out the alternator to protect electronics powered through the VClamp.

Table 2 summarises different versions of the VClamp to suit different charge controllers and grid tied inverters. It includes:

- The preset voltage limit (V typ) at which excess energy is dumped, and
- The maximum voltage (V max) at which the failsafe mechanism is activated. VClamp max voltage is shown on the board. 120 V DC in the example above



The pre-set voltage limits are approximately 5% less than the maximum turbine voltage.

**Table 2. Different versions of VClamp**

Version	V typ (V)	V max (V)	I out (A) <sup>1</sup>	Rectifier type	Recommended dump load (Ω) <sup>2</sup>	Minimum dump load resistance (Ω)
VClamp 100	95	100	15	Schottky	5.0 – 6.3	4
VClamp 120	115	120	15	Schottky	5.5 – 7.6	5
VClamp 140	135	140	15	Schottky	7 – 9	6
VClamp 250	240	250	10	Fast silicon	15 – 25	12
VClamp 400	385	400	5	Fast silicon	37 - 74	20

<sup>1</sup> Maximum RMS current on any AC input terminal is 15A (includes crowbar operation)

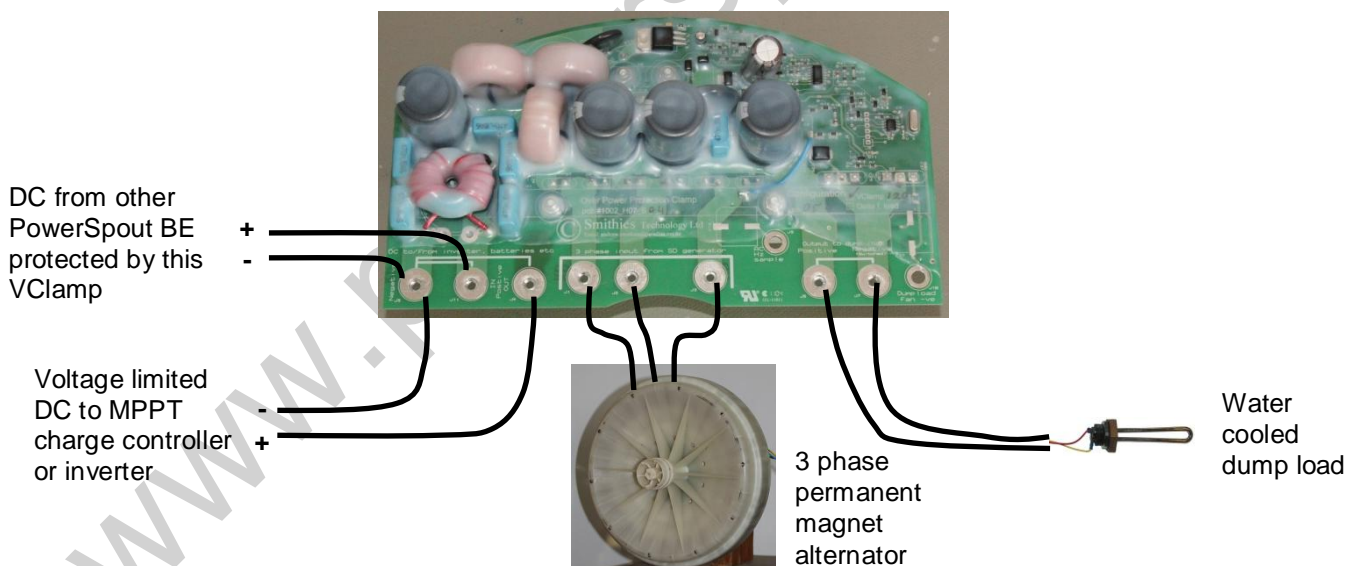
<sup>2</sup> Maximum dump load resistance depends on power level required. Max load current permitted is 25A at Vmax. Higher Ω dump loads are not destructive but may cause unwanted crowbar operation if the load is insufficient.

All versions are designed for the environmental conditions shown in Table 3.

**Table 3. Environmental range for VClamp**

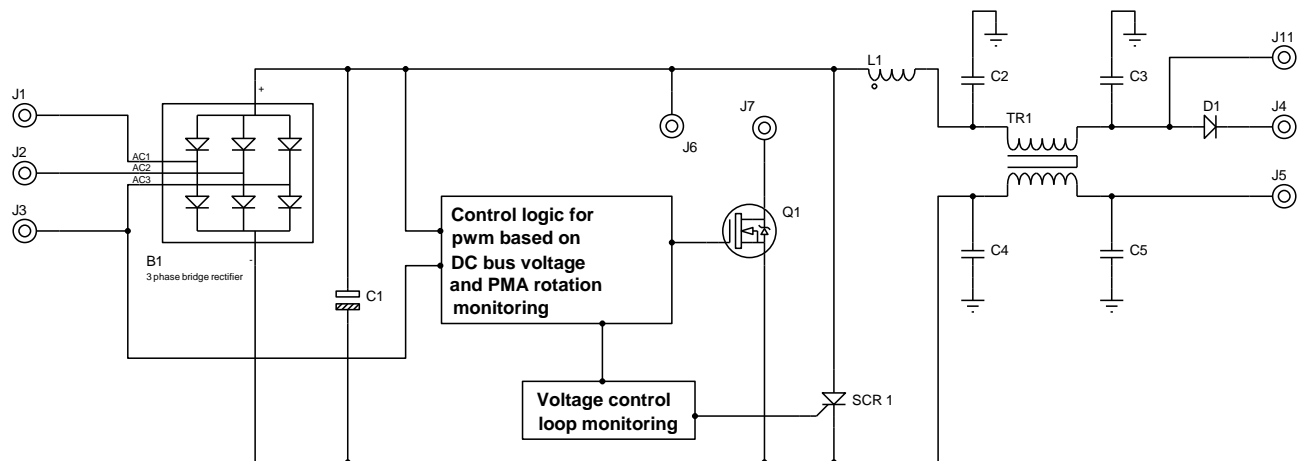
Temperature	-10 to 60°C
Humidity	0 to 100%. Non-condensing
Water contact/immersion	<b>Not</b> recommended. Sample units tested for operational immersion without issue up to 140 vdc.

Figure 4 and Figure 5 illustrate the use and operation of the VClamp.



**Figure 4. Typical VClamp system setup**





**Figure 5. Simplified VClamp wiring diagram**

Figure 5 shows that the 3 phase AC from the PMA is rectified and then smoothed by capacitors. The capacitor voltage is monitored; Q1 is controlled at 20 kHz rate using PWM to connect the capacitor voltage to the dump load connected on J6 and J7.

There is also a monitoring circuit which confirms the voltage control loop is operating correctly. If it sees an 'overvoltage condition' then SCR 1 is triggered to short the capacitors and prevent overvoltage. There is current-limiting circuitry to prevent internal fusing inside SCR1.

The control logic also confirms the PMA is actually rotating. This is for hydro applications where additional generation is connected with a bridge rectifier across J11 and J5. If the PMA is not rotating then there is no water cooling for the dump load. Operating a water cooled dump load without cooling is usually destructive.

When the PMA is not rotating the control logic uses the dump load to discharge the capacitors to make the unit touch safe within 10 seconds. Dump load power is limited to less than 3W during self-discharge. Should external DC from another source cause overvoltage while in discharge mode, then SCR1 will operate to prevent overvoltage.

Electrical noise within this circuit is filtered from the DC output by differential and common mode filters.

D1 is included to block external DC power in the load from entering this circuit during crowbar operation. Some MPPT regulators can send significant battery energy in reverse towards the VClamp during crowbar operation which can be destructive.

## 4. Batteries and voltage

Different versions of PowerSpout employ different methods for controlling power to avoid problems. Key aspects of each version are described below.

### 4.1. Voltage control (BE/HE systems)

Battery voltage is primarily controlled by the battery bank and its state of charge. The PowerSpout BE is designed to be connected directly to the battery bank. It is the battery bank that provides voltage stabilisation. Without having a battery connected, the output voltage can be very high (up to many hundreds of volts).

The PowerSpout BE provides a continuous charging current to your batteries. As the battery bank charges, its voltage will gradually rise until it reaches fully charged. Batteries have the longest lifespan when kept fully charged and never overcharged. In the usual situation where there is more charging power than electrical load then there must be a separate regulator to prevent overcharging of your batteries. A diversion load controller diverts excess energy to a resistive element, e.g. water heater, preventing battery overcharging.

Solar PV regulators work by switching the PV panels on and off to control the amount of incoming energy. If this type of regulator was used with a hydro turbine the voltage from the turbine would increase rapidly as the load was removed from the generator, and combined with the rapid acceleration of the unloaded generator, this high voltage output would destroy most solar PV regulators. Therefore, never use switching-type PV regulators with the PowerSpout.

If you disconnect a hydro turbine from the battery the voltage will no longer be clamped by the batteries and can increase up to three or four times higher than normal. This is potentially very dangerous. Never disconnect a hydro turbine from the battery bank while it is running.

Systems that generate high continuous output power (micro-hydro) often have smaller battery banks. These systems depend heavily on the diversion load to control state of charge. EcolInnovation recommends that a second voltage regulator be installed in such cases. Eventually, voltage regulators do fail. In the case of failure of a single regulator system the battery voltage will climb, which can result in the batteries being wrecked. Using two voltage regulators, with one set high and the other set normally, would prevent this failure. On wind and PV systems that typically have a large battery bank and less generating ability, then one regulator is acceptable provided that the user regularly checks it is working correctly. A second regulator ensures peace of mind and enables you to sleep well when away on holiday.

The PowerSpout HE is essentially the same. The only main difference is that the HE generates a high AC voltage, reduced at the battery bank via three transformers and then rectified to DC to charge the batteries. The comments above about regulation for the PowerSpout BE apply equally to the HE version.

#### 4.1.1. Voltage regulators (PowerSpout BE). How they work.

The Diversion Load Controller provides voltage regulation by repeatedly connecting and disconnecting the diversion load to the battery bank like a switch. This happens at high speed, spending time either connected or disconnected to control the amount of load applied. This is called Pulse Width Modulation (PWM) control.

PWM control only works when there is an energy storage device in the system to even out the voltage. Diversion load controllers require the use of batteries for stable operation.

Figure 6 provides an example of PWM operation at 10% duty for a small diversion load and at 90% representing a large diversion load.

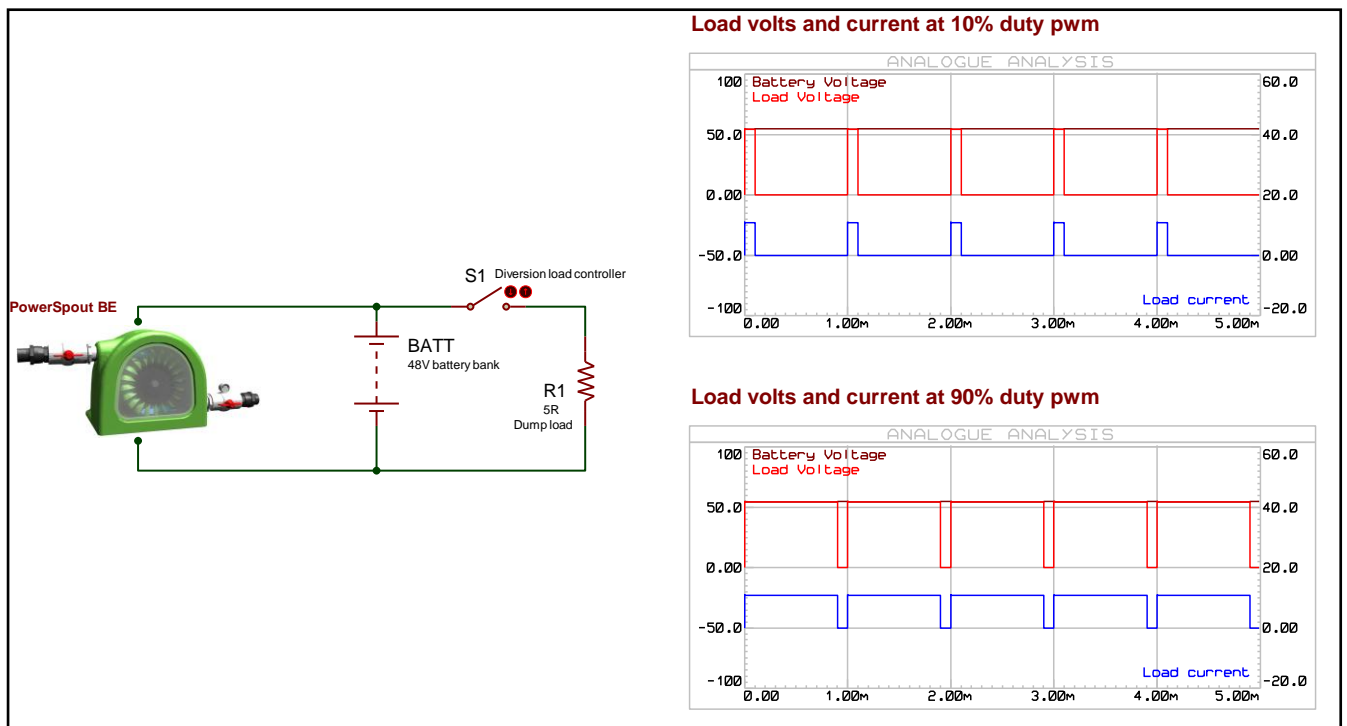


Figure 6. PWM operation

#### 4.2. Voltage control in my battery inverter system (PowerSpout ME)

The PowerSpout ME is designed to be connected to your battery bank through a Maximum Power Point Tracking converter (MPPT) such as an Outback FM60.

The MPPT charge controller continuously regulates battery charging to control the battery voltage. The PowerSpout output is higher than the battery voltage. Turbines are set for the following MPPT voltages +/-10%. Cable sizing calculations should be done at these voltages and not at the nominal battery voltage.

ME 100	– turbine MPP target voltage	85 V DC
ME 120	– turbine MPP target voltage	100 V DC
ME 140	– turbine MPP target voltage	120 V DC
ME 250	– turbine MPP target voltage	220 V DC
GE 400	– turbine MPP target voltage	350 V DC

For example the operation voltages for an ME 120 are:

- 120 V DC the maximum that cannot be exceeded (crowbar operates)
- 115 VDC the PWM diversion operates to hold voltage constant
- 100 VDC is the target operation voltage of the turbine and cable loss calculations are done at this voltage

As the battery bank becomes charged the MPPT charge controller reduces the amount of current it supplies to the battery bank to prevent overcharging. When the battery bank is well

charged the MPPT controller draws less energy from the PowerSpout and the output voltage supplied to the MPPT controller rises to values in Section 3.5 for V typical.

Only a PowerSpout ME/GE has the electronics to limit this voltage and so avoid permanent destructive damage to the MPPT charge controller. The PowerSpout ME has an internal dump load in the water outlet. The excess energy is lost as heat into the water passing through the PowerSpout ME.

Some customers will want to use the excess energy to heat hot water. This can be done by programming the MPPT controller (if equipped) to turn on an additional electrical load when the batteries are well charged.

If the PowerSpout ME turbine is not rotating the electronics will assume there is no water cooling available for the dump load. In this situation the secondary over voltage protection is activated to rapidly discharge voltage off the connection to the MPPT charge controller. This normally takes about a hundred milli-seconds. If there is an external connection to another source of DC power then high voltages may continue to be present. Many MPPT charge controllers maintain DC on the input connections for up to a minute. Always use a known good meter to test electrical components before touching them.

#### 4.2.1. MPPT charge controllers (ME option).

MPPT charge controllers are based on SMPS (Switch Mode Power Supply) techniques and can be very complex inside. From a practical point of view they provide an adjustable DC transformer where the input power and output power is equal, but at a different current to voltage ratio.

Power (Watts) = voltage (Volts) x current (Amps)

For a 500W example:

- The ME 120 produces 500 W at 100 V. 5 A x 100 V DC = 500 Watts.
- The battery bank is at 50 V and will be charging at 10 A. 10 A x 50 V DC = 500 Watts.

In practice MPPT controllers have some internal losses. In the above example you can expect the battery current to be a few percent less at 9.5 A

### 4.3. **Power control and over voltage protection (GE option)**

The PowerSpout GE has internal electronics to limit the maximum voltage just like the ME version. The GE 400 version ensures the voltage stays under 400 V DC to suit grid tie inverters designed for photovoltaic (PV) panels.

Inside the Grid tie inverter is a MPPT function. This function optimizes the load voltage to the PowerSpout GE to correctly match the water resource and deliver the maximum energy to the grid.

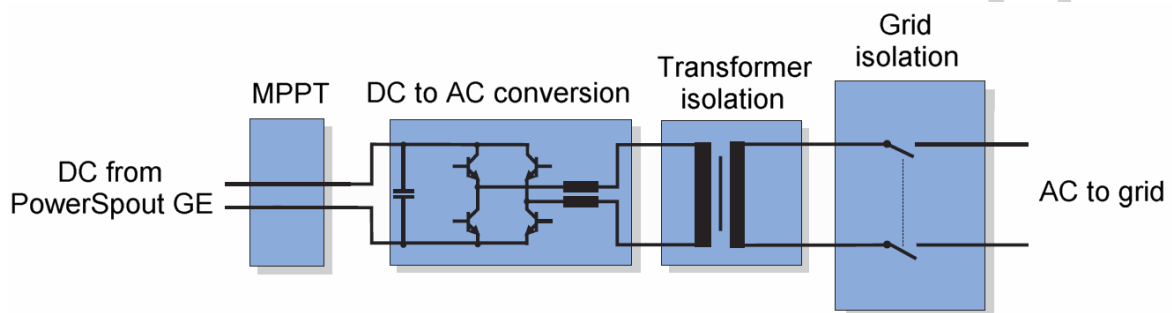
Grid tie inverters must meet stringent safety requirements to ensure the safe operation of the grid system. At any time a grid tie inverter may stop drawing energy from the PowerSpout GE. The internal over voltage protection in the PowerSpout GE will prevent any equipment damage.

Always turn off the water supply to the PowerSpout and check for no voltage before working on the electrical system. 400 V DC can deliver a fatal electric shock.

If the PowerSpout GE turbine is not rotating the electronics will assume there is no water cooling available for the dump load. In this situation the secondary over voltage protection is activated to rapidly discharge voltage off the connection to the MPPT charge controller. This normally takes about a hundred milli-seconds. If there is an external connection to another source of DC power then high voltages may continue to be present. Many grid tie inverters maintain DC on the input connections for up to a minute. Always use a known good meter to test electrical components before touching them.

#### 4.3.1. Grid tied inverters (GE option). How they work

Grid tie inverters are based on SMPS (Switch Mode Power Supply) techniques and are very complex inside. From an operational point of view they are an adjustable DC load and output the load energy to the AC connection. Internally they are often configured as two stages. The first converts the DC input voltage to a constant 400 V DC and a second stage then converts this to 50 Hz and 230 V AC synchronous with the local grid connection.



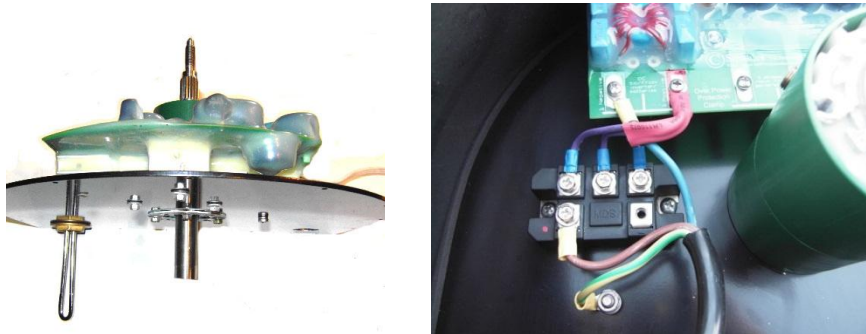
**Figure 7. Typical configuration in a grid tied inverter**



## 5. Installation extras (PowerSpout versions ME, GE and HE)

### 5.1. Assembling rectifier, wire and plug lead (PowerSpout ME and GE)

ME and GE versions of PowerSpout have a circuit board instead of a simple rectifier.



Front and rear views of a ME or GE circuit board and water element for 120 V DC and 400 V DC voltage protection. Circuit boards are plastic coated for protection.



Close up view of original ME or GE circuit board

This is the connector field of the voltage clamp PCB. From left to right the connections are as follows:

- J5 and J4 Negative and positive output from the GE/ME turbine. Ensure correct polarity via a blocking diode.
- J1, J2 & J3 3-Phase AC from the Smart Drive generator. Polarity is not required. Star and Delta options may apply.
- J6 and J7 Connection to water cooled dump load. Polarity not required.



Close up view of revised version of ME or GE circuit board with integrated output diode.

- J5 and J4 Negative and positive output from the GE/ME turbine via internal blocking diode
- J11 Use with J5 for external DC from PowerSpout BE turbines to be protected by this VClamp.
- J9 and J10 These terminals are not used with the PowerSpout

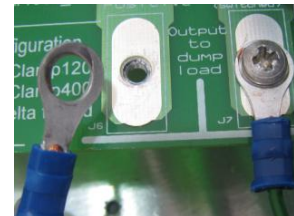
## 5.2. Electrical checks with covers off

Electrical checks can be conducted at the end of the installation with the covers off. Instructions for PowerSpout BE are included in the PowerSpout Installation Manual. These instructions relate to other versions of PowerSpout.

These tests ensure you have completed the output connections and have no unwanted connections through wiring faults to the PowerSpout chassis. Operation of the protection electronics in the ME/GE version is also confirmed.

### 5.2.1. PowerSpout ME (GE) electrical tests.

1. Warning: only qualified electricians to work on ME/GE versions.
2. Disconnect the internal dump load. See picture at right.
3. Connect a DC volt meter to the DC output from the generator.
4. Use an electric drill with a 19 mm (3/4") socket spin the rotor by slowly driving PS040.
5. Watch the voltmeter and increase the drill speed until the voltmeter reads approximately 80 V (300 V for GE).
6. The turbine should spin freely with little noise.
7. Increase drill speed and note the mechanical load on the electric drill when output reaches 115 V (380 V for GE). Backup protection circuits short the output voltage. It will then jump to less than 1 V. (If you miss this voltage step do not repeat the test for at least 20 seconds).
8. Ensure voltmeter reads less than 20 V and then reconnect the internal dump load.
9. Increase drill speed and note the mechanical load on the electric drill as the voltage clamp operates. Please refer to  $V_{typ}$  in Table 2 on page 11 for the expected clamp voltage. (Caution. Do not continue to operate the voltage clamp without water cooling for more than 10 seconds. The water cooled load may be damaged!).



If you are using the PowerSpout ME without a ground connection:

10. Connect an ammeter (Use a 10 A DC range) between the chassis ground connection and negative output and spin the turbine to near the same speed as in step 4 above.
11. The turbine should spin freely with little noise and the ammeter must read zero.
12. Repeat steps 9 and 10 above but with the ammeter between the chassis ground connection and positive output.

### 5.2.2. PowerSpout HE electrical tests.

1. Warning: only qualified electricians can work on PowerSpout HE.
2. Connect an AC volt meter (400 V range) to two of the three output wires from the generator.
3. Use an electric drill with a 19 mm (3/4") socket to spin the rotor slowly.
4. Watch the voltmeter and increase the drill speed until the voltmeter reads close to 400 V AC.
5. The turbine should spin freely with little noise.

6. Move one of the meter connections to the third output wire.
7. Spin the turbine to near the same speed as in step 3 above and confirm the same output voltage.
8. Connect an ammeter (10 Amps AC range) between the chassis ground connection and any one of the three output wires and spin the turbine to near the same speed as in step 3 above.
9. The turbine should spin freely with little noise and the ammeter must read zero.
10. Repeat steps 5 and 6 above but with the ammeter between the chassis ground connection and either of the other two output wires.

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## 6. Cable connections (non-BE versions)

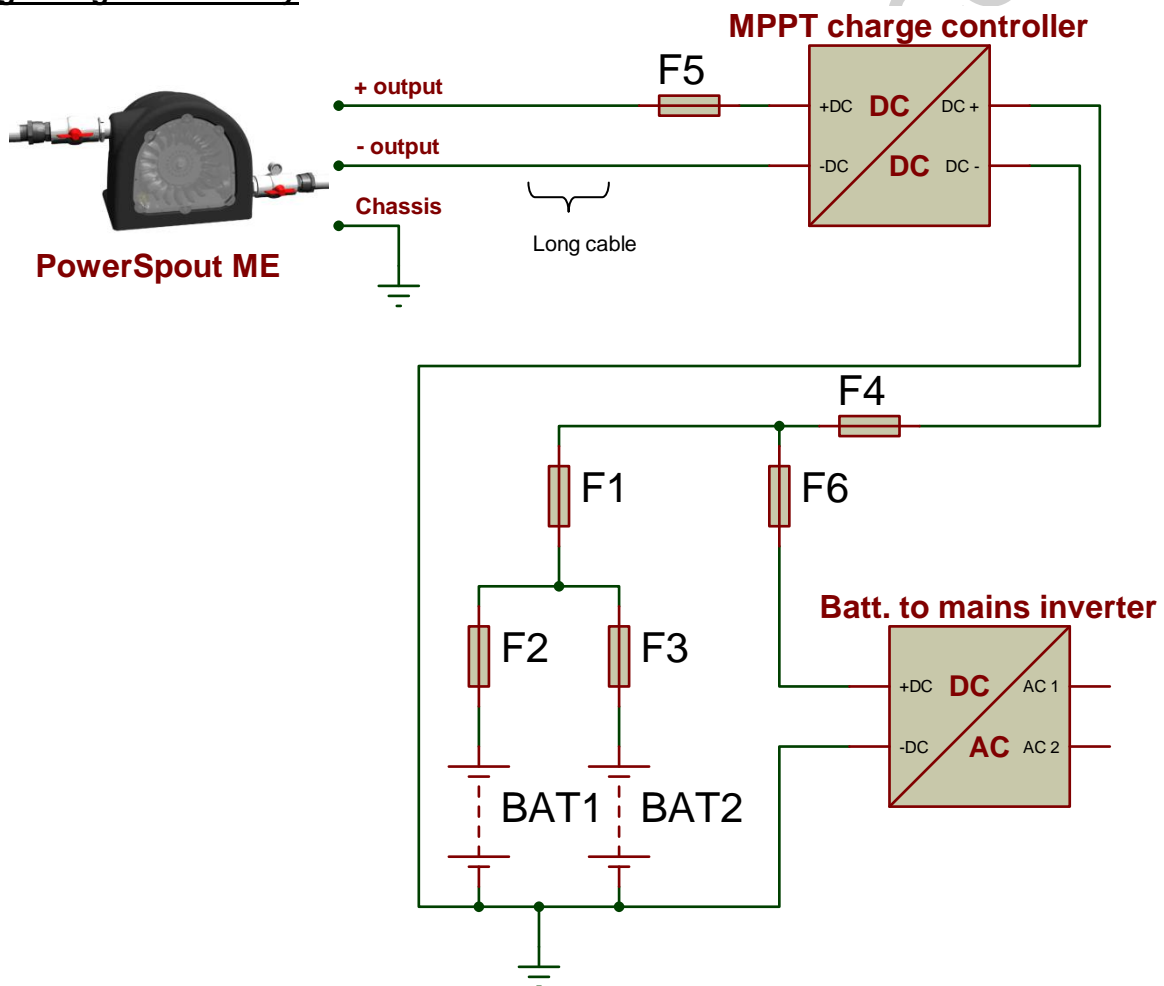
Please refer to the PowerSpout Installation Manual for general guidance and instructions for PowerSpout BE. This section is a supplement aimed at other versions of the PowerSpout.

### 6.1. ME option (MPPT Enabled)

The drawing below shows the minimum installation requirements for the PowerSpout ME. This drawing is appropriate for a battery negative ground installation.

If the negative ground connection is not to be installed then additional fuses are normally required by wiring regulations on each of the negative connections to the common negative battery terminal. Please refer to your local wiring regulations for what is required in your local area.

#### Negative ground battery



#### 6.1.1. Fuse 1

This fuse is required by most electrical jurisdictions around the world to protect against damage in the event of a short circuit within the wiring of the main switchboard. Should fuse 1 blow, the charge controller will not provide over charge protection for the batteries. If left with fuse 1 removed then the batteries and inverter may be damaged. This system relies on the diversion load controller for charge control so it is very important that this fuse never actually blows in normal operation.

Fuse 1 must be large enough so that the inverter can never draw enough current to break under maximum load conditions. Fuse 1 must also be small enough that the batteries have sufficient energy to break it in a fault situation.

It is normal for fuse 1 to be twice the rating of fuse 6. Or for fuse 1 to be a motor rated fuse while fuse 6 is not motor rated for the same current rating.

#### 6.1.2. Fuse 2 & 3

Each parallel string of batteries must have its own individual fuse. This is to limit the damage caused by internal failures such as an internal short-circuits within a cell in a battery string. These fuses are also an advantage when working on batteries so that an individual string can be isolated for testing without shutting down the entire system. Like fuse 1 these fuses should never blow in the event of an external fault.

Fuses F2 and F3 can be omitted when 1 battery string is used.

#### 6.1.3. Fuse 4

Fuse 4 and the MPPT charge controller are located close to the battery bank. Fuse 4 must be of sufficient rating to support the maximum current from the MPPT charge controller to the batteries. This current is greater than the input current to the MPPT charge controller.

Please refer to Section 4.2 to understand how a MPPT charge controller increases the current (as it decreases voltage) from the PowerSpout ME.

#### 6.1.4. Fuse 5

This fuse is normally required by local wiring rules so the MPPT charge controller can be isolated from external energy sources for servicing or replacement.

#### 6.1.5. Fuse 6

Fuse 6 carries all load current from the batteries to the AC inverter. It is important that fuse 6 will always blow before fuse 1. If there is a major fault in the inverter only fuse 6 should break and so leave the rest of the fuses in place.

This way the PowerSpout ME output will continue to be connected to both the batteries and the diversion load controller, and maintain DC voltage regulation.

#### 6.1.6. Chassis earth connection

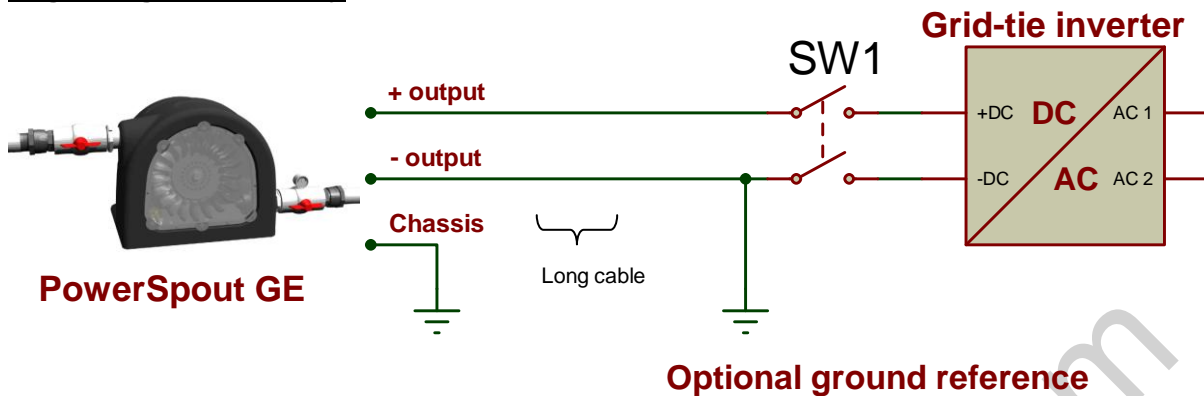
PowerSpout ME 100 and ME 120 meet the ELV (Extra Low Voltage) requirements of wiring regulations in many countries and do not require a safety earth connection. However, we recommend the installation of an earth connection at the PowerSpout to minimize the possibility of there being an electrical hazard and to minimize any electrical noise generated. A 1m metal rod driven into the ground is normally sufficient.

#### 6.1.7. Other solar charge controllers

PowerSpout ME may only be used with MPPT type charge controllers such as the Outback FM60. Charge controllers that use PWM regulation, such as the Morningstar's TriStar controller configured as a PV regulator, are not suitable for use with PowerSpout generators.

## 6.2. **GE option (Grid Enabled)**

The PowerSpout GE is designed to be connected directly to a grid tie inverter such as the SMA Sunny Boy 1100 inverter without the use of any additional equipment.

**Negative ground battery**

In most countries the wiring regulations require a disconnect function at the grid tie inverter to support maintenance functions. This can be a simple switch but must be rated for load breaking 400 V DC at 5 A. No fusing is required on the 400 V DC connection as there is no fault current possible. The use of a dual fuse instead of a dual switch is acceptable and could be a less expensive option.

In some countries a ground reference is required on the 400 V DC connection. It is acceptable for PowerSpout generators to have a ground reference to either one of the conductors.

Grid tie inverters often employ ground fault detection on the 400 V DC connection. PowerSpout GE provides a ground isolated output which is compatible with floating DC systems. Internally the PowerSpout GE has 0.4  $\mu\text{F}$  of capacitance between the floating DC and ground connections. This amount of capacitance is present in some 1 kW PV arrays.

The PowerSpout GE chassis needs to be grounded with a dedicated earth stake next to the PowerSpout GE. This ground connection needs to meet local wiring regulations. In New Zealand a 12 mm diameter 1.8m long stake in the ground meets this requirement.

The connection of the PowerSpout GE chassis to the inverter chassis through cabling is acceptable, optional and at the discretion of the installer.

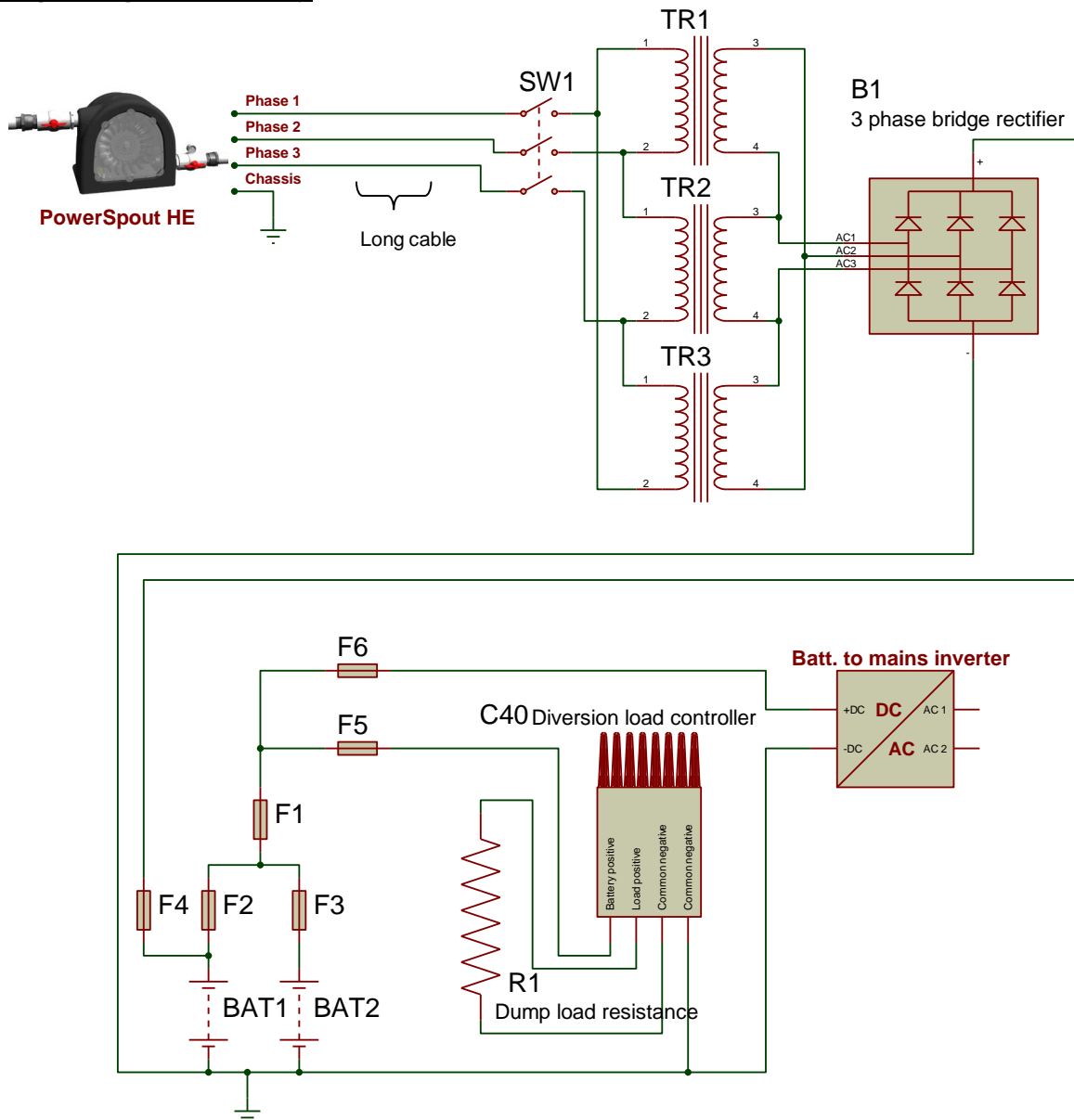
**PowerSpout GE has not been verified for use with transformer less grid tie inverters. Contact EcolInnovation to seek our approval prior to using in this application.**

### 6.3. HE option wiring (High voltage Enabled)

The drawing below shows the minimum installation requirements for the PowerSpout HE. This drawing shows a negative ground battery installation. Each component and its selection criteria are discussed below.

If the ground connection is not to be installed then additional fuses are normally required by local wiring regulations on each of the negative connections to the common negative battery terminal. Please refer to your local wiring regulations for what is required in your location.

**Negative ground battery**



**6.3.1. Fuse 1, 2, 3 and 6**

Please refer to the previous PowerSpout BE section (Section 6.1) regarding these fuses.

**6.3.2. Fuse 4**

The cable from the PowerSpout to battery room in the HE version operates at high voltages of around 400 V AC. This is much greater than the battery voltage and provides a significant saving in cabling costs. Transformers TR1, TR2 and TR3 are high frequency toroidal to reduce the high voltage down to battery voltage. A 3-Phase bridge rectifier then converts the AC power to DC for battery charging.

Fuse 4 is used to protect the cables in the event of a fault in the 3-Phase bridge rectifier. When you order your PowerSpout HE you will be advised of the maximum current your PowerSpout HE can deliver to the batteries at your site. Please make sure to use a fuse that is just large enough to carry this current.

Fuse 4 is connected to the battery side of all other fuses. This is essential to ensure that the failure of any one fuse will not result in damage to any other equipment. A battery must be connected when using a PowerSpout HE to prevent over voltage from damaging the inverter.

#### 6.3.3. SW1

A 3-Phase isolation switch is required to provide access to the transformers. This is 400 V AC 5 A rated switch.

#### 6.3.4. Fuse 5

Fuse 5 carries all excess current to the division load controller for dumping in the dump load resistor. Fuse 5 should not break unless fuse 4 has already broken or been disconnected. To achieve this, fuse 5 should be chosen to be twice the breaking rating of fuse 4.

#### 6.3.5. Earthing requirements

This configuration only fuses one side of all DC connections. In most countries an earth connection is required for the common side. Please refer to your local country wiring rules to determine the correct size of this conductor.

Only one earth connection should be provided to the common wire connection. Adding a second or more earth connection(s) to the common side may result in additional electrical noise which may interfere with radio reception.

The PowerSpout HE chassis shall be grounded with a dedicated earth stake next to the PowerSpout HE. This ground connection is to meet local wiring regulations. In New Zealand a 12 mm diameter, 1.8 m long stake in the ground meets this requirement.

The connection of the PowerSpout HE chassis to the batteries ground connection through cabling is acceptable, optional and at the discretion of the installer.

## 7. Adding other power system components

### 7.1. Multiple hydro turbines

Multiple PowerSpout units may be connected together for increased power output if required. Depending on the configuration there are other advantages such as being able to utilize different water resources and extract the most energy from both. An example would be a site with a medium flow and high head and another low head and high flow source.

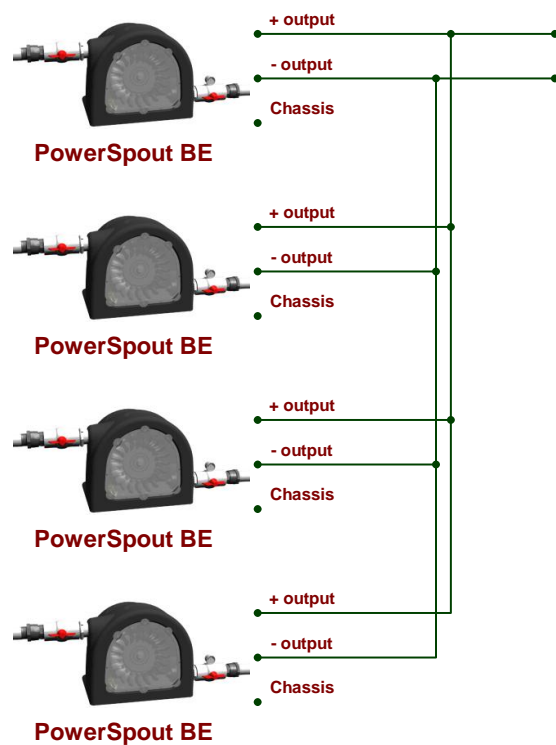
Examples are given below of more common configurations.

#### 7.1.1. Parallel wiring of BE option

Parallel operation of PowerSpout BE is a simple wiring together of each PowerSpout BE.

Each PowerSpout BE operates at the same output voltage which is defined by your battery charge voltage.

Each PowerSpout BE may be optimized for a different water resource. Please advise EcolInnovation of each water resource so your PowerSpout units arrive correctly configured.



7.1.2. Parallel wiring of ME option

PowerSpout ME may be wired in parallel for increased output.

Each PowerSpout ME must have a blocking diode fitted to prevent damage to the protection circuit inside each PowerSpout ME.

Each diode must be able to block 150 V in reverse and carry 15 A forward current.

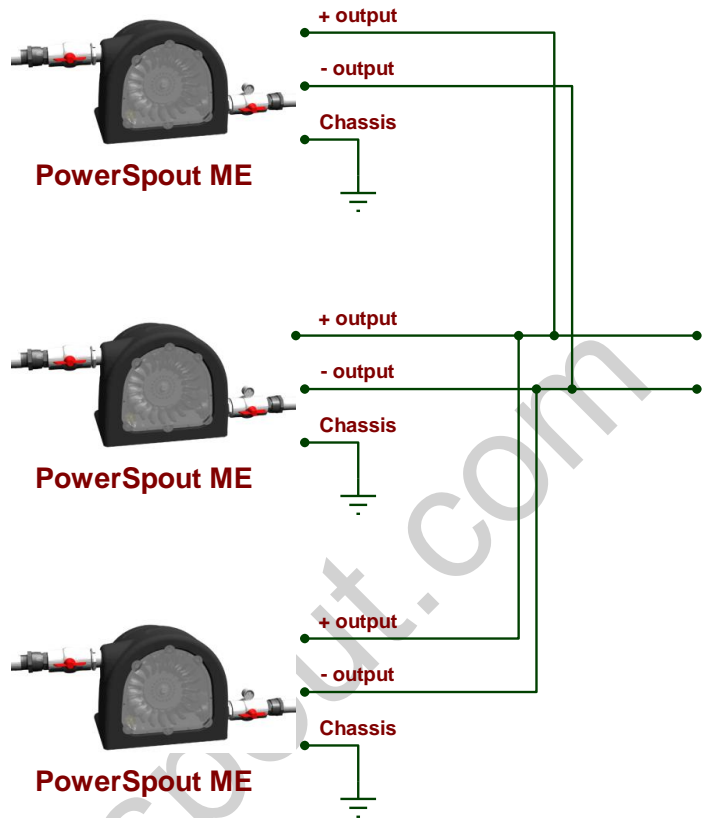
Each turbine must be configured for the same operating conditions so that the MPPT charge controller can correctly optimise all PowerSpout turbines.

If you are using a different water resource for any of the PowerSpout units please contact EcolInnovation for advice specific to your installation.

There is no technical limit to the number of PowerSpout ME that can be combined in this way.

If you are designing a large system with over 2 kW of electrical power please consult with EcolInnovation for additional design knowledge regarding fault management with PowerSpout ME.

Each PowerSpout ME has an internal output blocking diode. This ensures the VClamp protection operates independently for each turbine.



### 7.1.3. Combined wiring of ME and BE options

Note that in combined systems the PowerSpout ME has a grey rear cover so it can be easily identified.

For systems with less than 1.2 kW output a single PowerSpout ME can provide over voltage protection for up to five additional PowerSpout BE turbines.

If you combine ME and BE turbines we advise you to remove the red valve handle on one of the ME valves, this will ensure that the ME control turbine cannot be accidentally turned off first.

All outputs of the PowerSpout BE units are wired in parallel and input to the VClamp in the PowerSpout ME.

Note. In combined systems like this always spin up each turbine in turn with an electric drill and confirm voltage is clamped prior to connecting to your MPPT regulator.

- Spin up just the ME unit and see the voltage is limited to V typ as per Table 2
- Spin up each BE unit by itself and see the voltage crowbar to zero as soon as V typ is reached. You will also notice the load from the self-discharge function of the VClamp board. It is just a few Watts but a noticeable load for a battery drill.
- If you have a helper get them to quickly turn the ME unit by hand while you then use a drill to spin up one of the BE units. You will see the clamping operation as the VClamp will decide there must be water cooling for the dump load since the ME turbine is rotating.

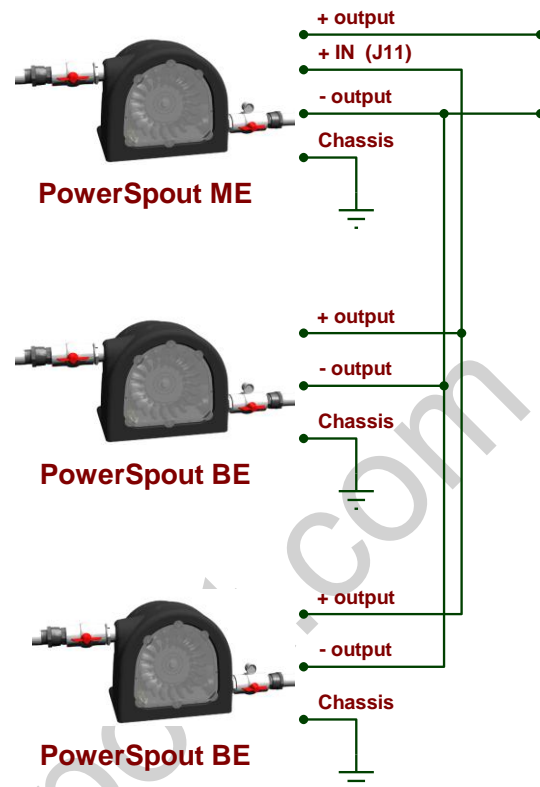
Ensure your PowerSpout ME has water flow at all times for correct voltage clamp operation. If the PowerSpout ME does not have water flow then the over voltage protection will cause the DC output to reduce to around 0.9 V to protect the MPPT charge controller. This may appear confusing in operation but ensures the protection of your MPPT charge controller.

Each turbine must be configured for the same operating conditions so that the MPPT charge controller can correctly optimise all PowerSpout turbines.

If you are using a single penstock and each turbine has the same jet size and are fitted with the same generator types then the PowerSpout units are balanced.

If you require the use of different water resources for any of the PowerSpout turbines please contact EcolInnovation for advice specific to your installation.

If you require disconnection devices then do not use any disconnection device on the interconnections between the PowerSpouts as excess voltages can occur if the PowerSpouts are operated unloaded. You will have been warned of this in the Advanced Calculator on the [www.PowerSpout.com](http://www.PowerSpout.com) web site.

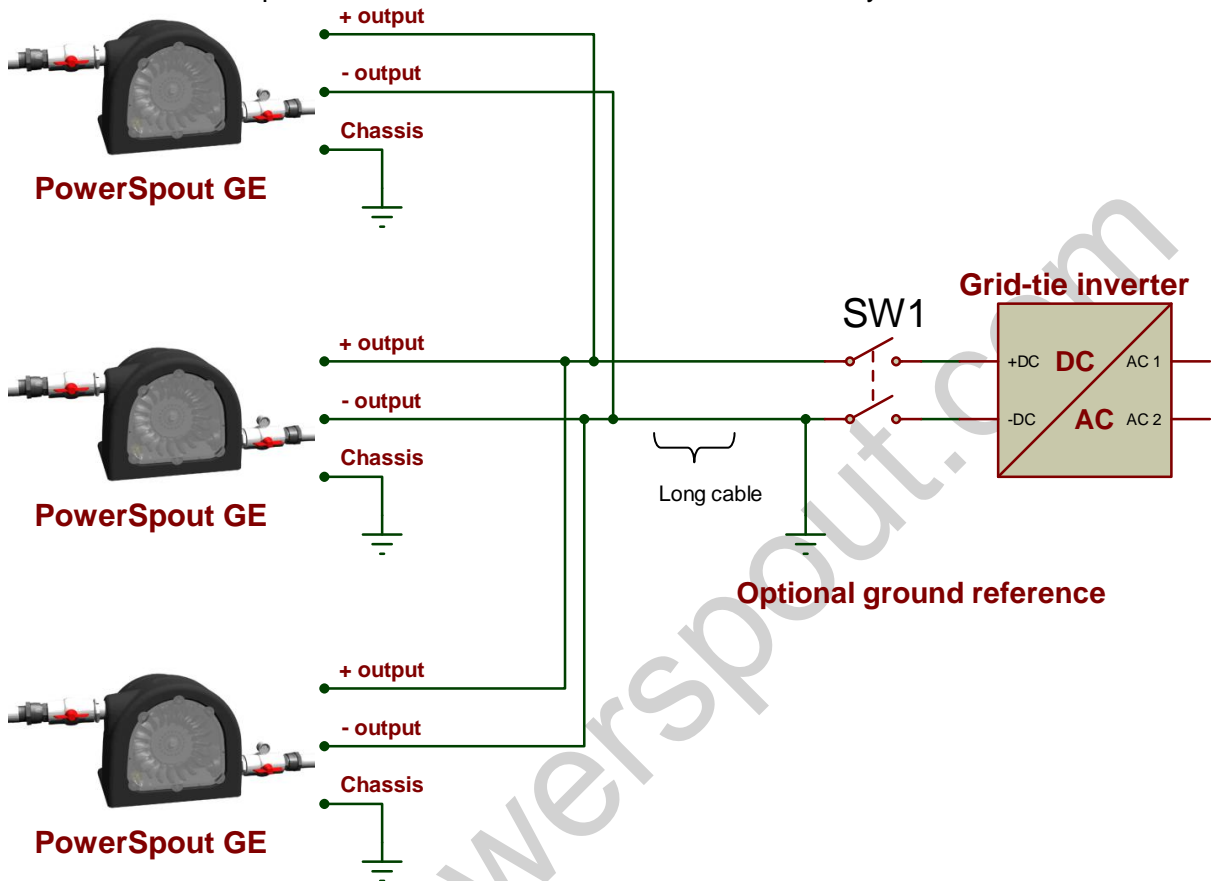




7.1.4. Parallel wiring of GE option

PowerSpout GE may be wired in parallel for increased output.

Note that a PowerSpout GE has a red rear cover so it can be easily identified.



Each PowerSpout GE has an internal blocking diode fitted to prevent damage to the protection circuit inside each PowerSpout GE, which could happen under some unusual circumstances.

Each turbine must be configured for the same operating conditions so that the MPPT function inside the grid tied inverter can correctly optimise all PowerSpout turbines. If you are using a single penstock and each turbine has the same jet size and are fitted with the same generator types then the PowerSpout units are balanced.

If you require the use of different water resources for any of the PowerSpout turbines please contact EcolInnovation for advice specific to your installation.

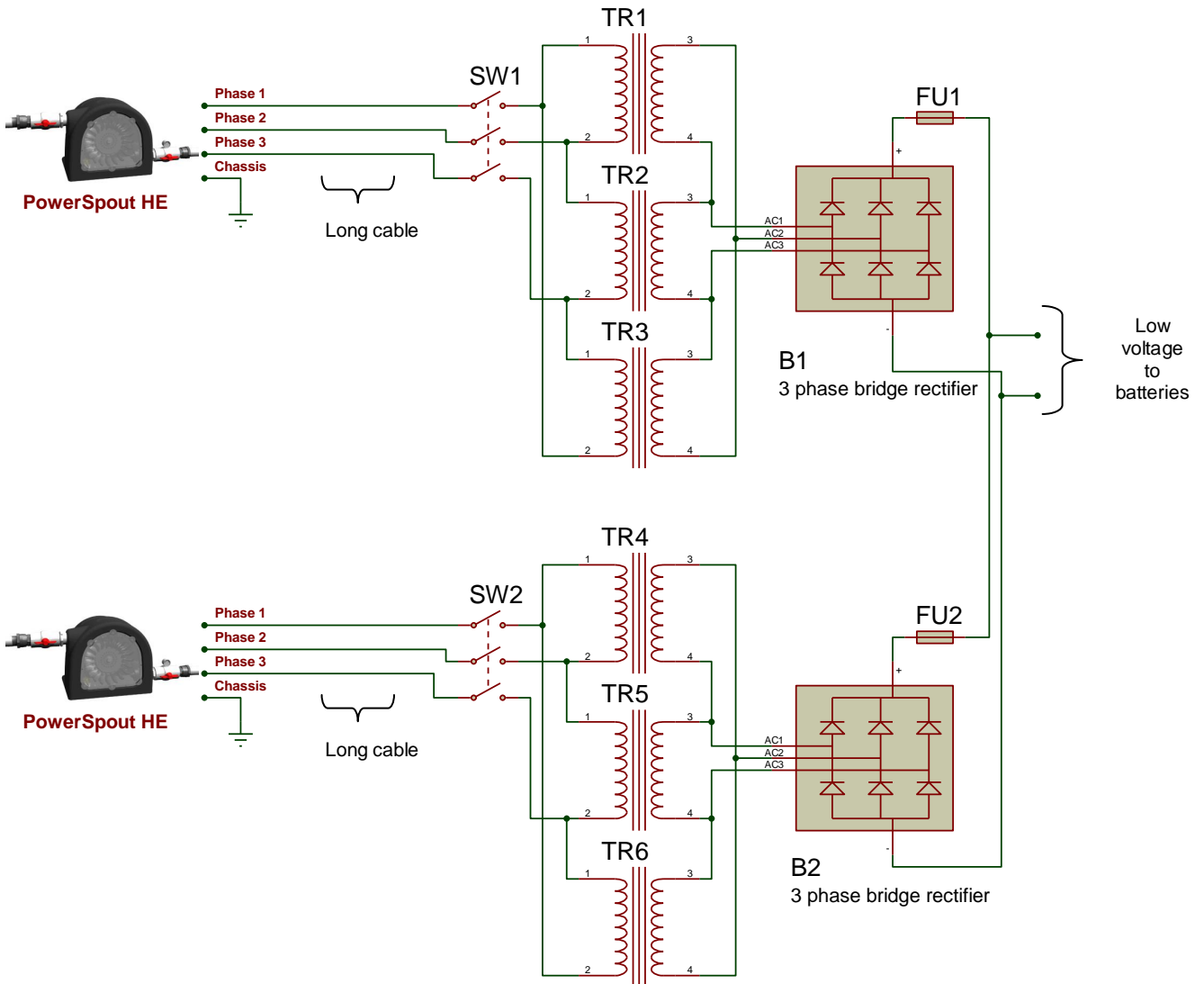
There is no technical limit to the number of PowerSpout GE combined in this way.

If you are designing a large system with over 2 kW of electrical power please consult with EcolInnovation for additional design knowledge regarding fault management with PowerSpout GE.

7.1.5. Parallel wiring of HE option

PowerSpout HE is not suitable for direct parallel operation. However, parallel operation can be achieved by installing an additional separate 3-Phase cable, transformers, bridge rectifier and fuse for each PowerSpout HE. This is usually not the best solution and we do not recommend it.

Note that a PowerSpout HE has a red rear cover so it can be easily identified.



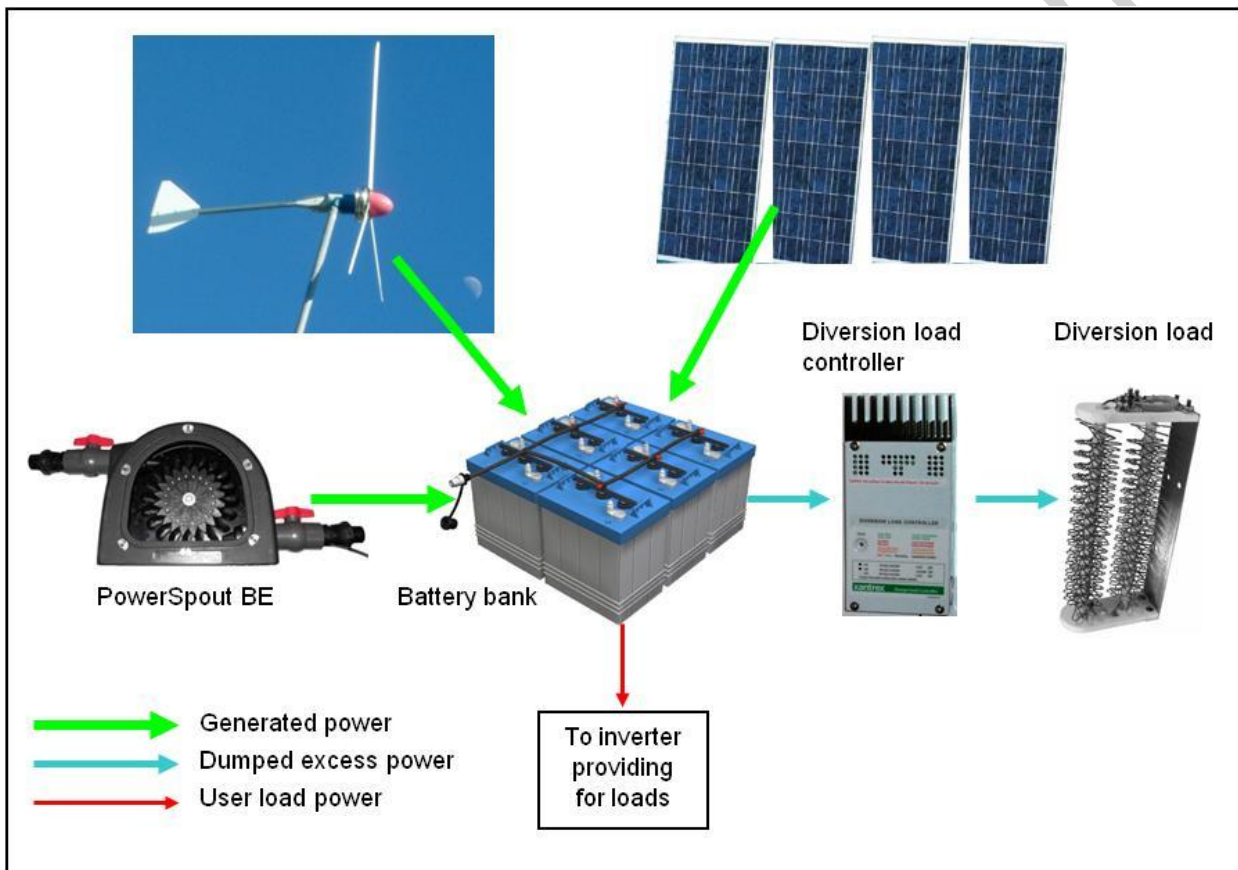
**7.2. Solar PV and wind generators with PowerSpout BE or HE**

If you are using a PowerSpout BE or PowerSpout HE then the diversion load controller can also provide charge control regulation for your solar PV or wind generator.

For this to operate correctly, ensure that the rating of the diversion load and the diversion load controller is greater than the maximum output of all of your energy sources at maximum ambient air temperature in the building that the equipment will be housed.

This configuration does not provide MPPT for your solar PV.

Additional energy sources using MPPT and PWM type controllers may also be connected to the battery without increasing the size of the diversion load or its controller.



**Figure 8. PV, wind and PowerSpout BE/HE**

### 7.3. Solar PV and wind generators with PowerSpout ME

Solar PV systems for standalone power systems provide a battery charging function. Multiple sources of energy may be connected to a single battery bank provided each energy source has its own charge controller and fuse for fault current protection.

In this configuration only one charge controller should be programmed to provide a battery equalization mode. If each charge controller attempts an equalization of the battery cells then the batteries will be equalized too often, resulting in excessive battery water use and reduced battery lifespan.

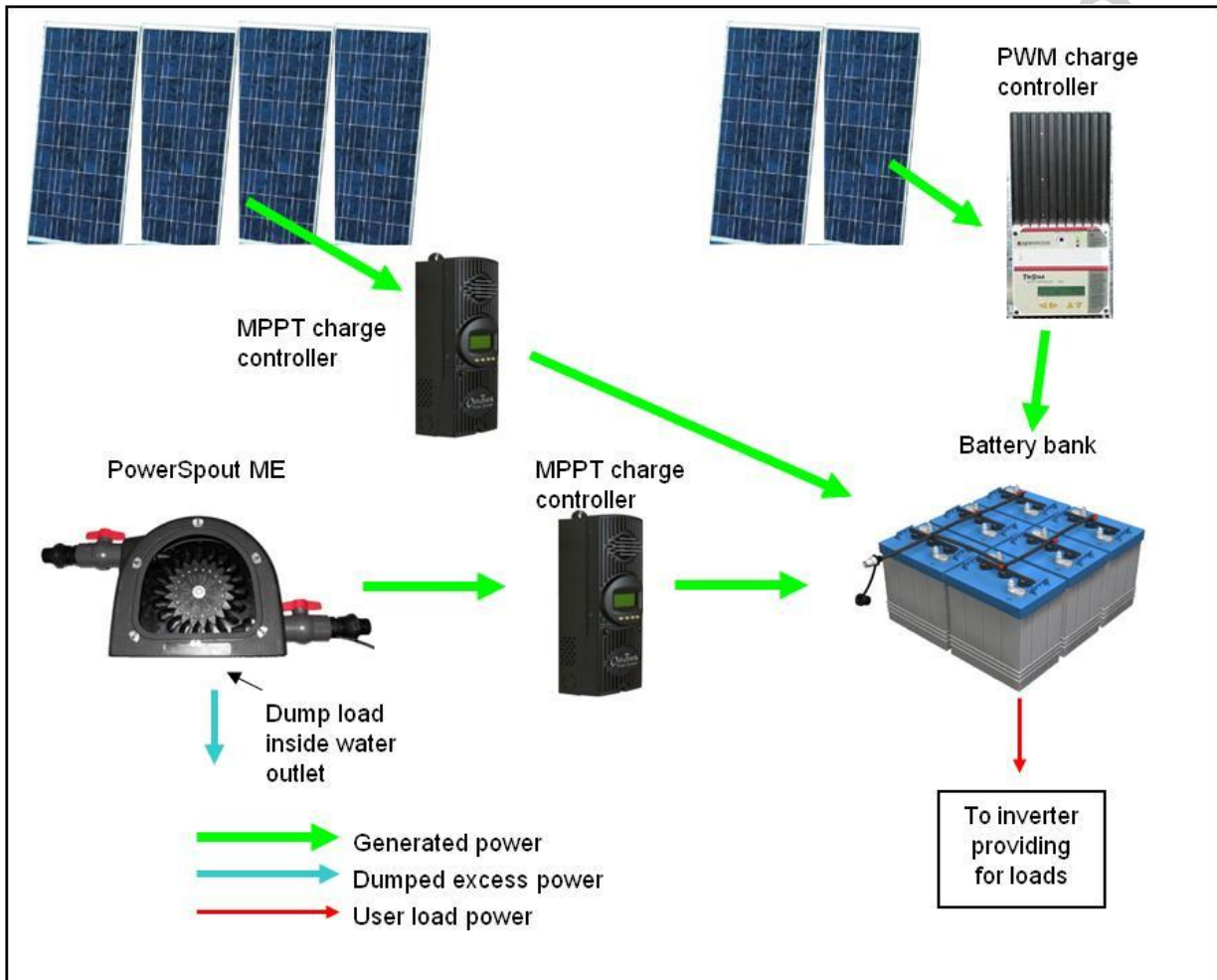


Figure 9. PV, wind and PowerSpout ME

**7.4. Generators**

Generators have an important role in standalone power systems to cover infrequent energy shortage problems.

*If you frequently use a generator, every week for example, then you do not actually have a renewable energy system.*

*It is be better to be connected to your local electricity supplier than to use a generator. ...Of course the power lines do need to be local...*

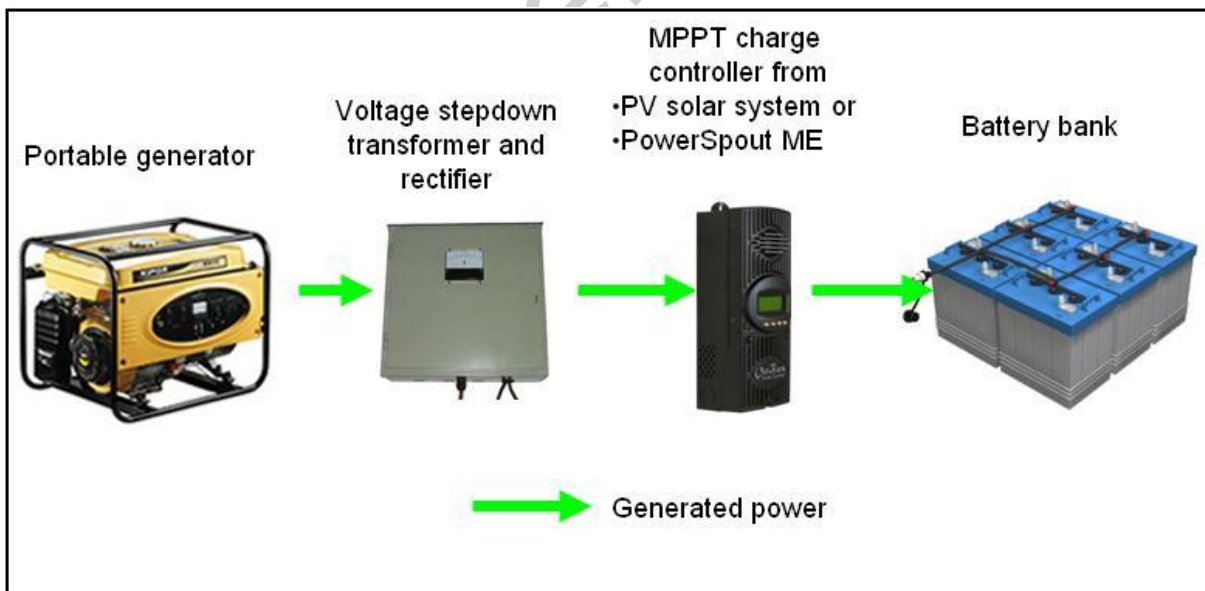
An infrequently used generator is an expense which is best minimized and therefore a low cost generator is often chosen. Low cost generators have poor output quality and should never be connected to your household appliances as the appliances are likely to be damaged from unstable voltage and frequency.

It is our view that a simple and robust battery charger that will tolerate a poor quality generator is the best choice. For some users, bringing in a hire generator for the “one or two days a year” when the batteries need charging is the most cost effective solution.

EcolInnovation offers a range of generator hookup options. Often these can use your MPPT controller from your PV solar or PowerSpout ME connection to reduce the cost of the generator only equipment. Some method of setting the charge rate is needed to prevent damage to your batteries and generator.

*Most cheap petrol generators will only operate at up to 50% of their rated capacity for extended periods.*

*EcolInnovation tested one generator and it stopped running after 10 hrs at full load with burnt valves making repair impractical.*



**Figure 10. Renewable energy system example with generator connection**