PowerSpout
WATER GOES IN POWER COMES OUT

PowerSpout Installation Manual
PLT, TRG and LH turbines

Industrial PLT

Off grid domestic PLT

Grid connected domestic PLT

Domestic TRG

Domestic LH

Please read this manual carefully before beginning installation.

ecoinnovation

December 2013. Version 1.6

Educational Installations PLT

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1.4. Updated pictures and text and change of product names June 2013. Removal of ME and GE product lines
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PowerSpout Contact details

Web: www.powerspout.com

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, please visit 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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If you need to contact EcoInnovation by phone then email first via our web site and check the local time in NZ if calling from overseas. Business hours are 9:00am to 5:00pm weekdays only. EcoInnovation is closed for up to 3 weeks over the Christmas break from 24th December.

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Abbreviations

BSP	British standard pipe thread
DOD	Depth of discharge
EMC	Electromagnetic compatibility, is the branch of electrical sciences which studies the unintentional generation, propagation and reception of electromagnetic energy with reference to the unwanted effects.
GFPD	Ground-fault protection device
HP	High power – refers to higher output turbine capable of 1.6 kW
HRC	High rupture current
ID	Inside diameter of pipe
LH	PowerSpout Low Head propeller turbine
LPG	Liquid propane gas
MDPE	medium density polyethylene
MC4	MC4 connectors are single-contact connectors commonly used for PV panels. MC4 stands for the **M**ulti-**C**ontact **4**mm2.
MPP	maximum power point
MPPT	maximum power point tracking
MPPV	maximum power point voltage
NPT	National pipe thread (USA)
OCV	open circuit voltage
OD	Outside diameter of pipe
PLT	PowerSpout Pelton turbine
PMA	Permanent magnet alternator
PWM	Pulse width modulation regulators, used in the text to describe regulators that can divert surplus power to a resistive load.
PV	Photo-voltaic
PVC	Polyvinylchloride
rms	the root mean square, is a statistical measure of the magnitude of a varying quantity, rms is used in various fields, including electrical engineering.
rpm	revolution per minute
TRG	PowerSpout Turgo turbine
SD	Smart Drive PMA
UV	Ultra violet light

1. Safety

This document is part of the product.
This section addresses safety concerns as required by international standards.
If you are not technically competent, experienced and qualified you should not install this equipment alone and should engage the services of a suitably trained professional.

Electrical equipment can be installed or operated in such a manner that hazardous conditions can occur; compliance with this manual does not by itself assure a 100% safe installation. If the equipment is properly selected and correctly installed and operated according to this manual, then any such hazards will be minimized.

The installation shall be carried out by installers with recognized and approved qualifications, and experience relating to general electrical installations and micro-generators.

To meet good working practices and safety requirements for this installation the installer must:

- check for any transit damage to the product prior to installing it, if damaged it must not be installed.
- connect equipment in compliance with the relevant national standards.
- read and comply with this installation manual.
- install an earth connection on the exposed metal bulkhead; a labelled earth connection point is provided - protective class I.
- not connect a DC pole of the turbine to earth - unless local rules require it.
- provide a suitable DC rated disconnection breaker close to the turbine that is clearly labelled (a 2-pole DC breaker is the good recommended solution).
- protect the supply cable in conduit as per local wiring rules, ensure wiring, insulation, conductors and routing of all wires of the equipment is suitable for the electrical, mechanical, thermal and environmental conditions of use.
- not use pluggable connections, hard wiring is required. “MC4” type waterproof connectors may be used. If “MC4” type connectors are used do not open under load.
- finger tighten all cable glands to secure supply cable.
- securely fix the turbine base prior to operation.
- tighten all electrical connections inside the turbine.
- Comply with safety advice in this manual when installing batteries.
- avoid salt water and sea spray - contact EcoInnovation if this applies to you.
- complete turbine testing and commissioning.
- train the end owner/user of the turbine in routine care and maintenance of the hydro system.
- complete all documentation as required in this manual and local wiring rules.
- ensure that all protective fairing/enclosures are in position after commissioning and prior to client hand over.
- not intentionally run turbine unloaded (for other than short duration OCV testing).
- not run turbine at a head significantly above the name plate rating.
- if interfacing to the grid do so via a compliant inverter designed for this purpose and approved by the makers for hydro generation connection.
- ensure that the local Distribution Network Owner (DNO) is made aware of the micro-generator installation at, before or within the time allowed after commissioning.
- comply with signage requirements as listed in relevant national standards
- asses fire risk of the installation site, and if high implement extra fire precautions as appropriate. This product is intended to be used only in areas free of combustible materials. In environments where combustible materials are present the turbine must be mounted in a concrete or metal enclosure.

- in a turbine runaway situation turn off the water supply by closing the water supply valve(s).
- check for excessive noise.
- not install in situations where the pipe line may freeze or in temperatures below -15°C.
- make relevant notes in the manuals that will be of assistance to future service personal.
- in grid connected situations wait 5 minutes for internal capacitors to discharge. Also note that MPPT regulators and grid tied inverters may have internal capacitors that require a time to discharge. Always check prior to touching conductors on equipment that have been recently turned off.
- not install stop valves at pipe intakes, unless there is an air vent to prevent negative pressure pipe collapse. A stop valve should be fitted at the end of the pipe prior to the turbine. A sign at this turbine stop valve to “turn off slowly” may be a good reminder to reduce water hammer effect.
- ensure that the installation includes the following: voltmeter, ammeter, wattmeter, pressure gauge and overcurrent protection. Most PWM, MPPT and grid connect inverters include some basic metering.
- use standard MDPE or PVC pipe. It should be verified that penstocks can withstand 1.5 times the maximum total pressure including surge to which it is subjected, taking into account the “water hammer” effect produced by the shut-off valve.
- fitting air riser vents in the pipe at appropriate positions in the pipeline will help to reduce pressure rises, pressure drops and air locks.
- if necessary bury the penstock to protect it against rock falls, tree falls, slips, avalanches, freezing etc.

The following safety warning signs are used throughout this manual.

Caution Risk of electric shock that could result in personal injury or loss of life

Caution Cautions identify condition or practices that could result in damage to equipment or personal injury, other than by electric shock.

1.1. CE and FCC Declaration

Refer to http://www.powerspout.com/compliance/ for compliance declarations documentation and EMC test reports.

PowerSpouts products are CE, FCC and C-tick compliant.

PowerSpout dealers may request to see the Compliance Folder if required by authorities.

1.2. Standards and certification

All PowerSpout turbines have been evaluated against major international standards.
Refer to http://www.powerspout.com/compliance/

1.3. Pre-requisites

All PowerSpout hydro schemes are assumed to be:

- Run of river (unless advised otherwise).
- 24/7 operation off grid to batteries or a grid connect via an approved inverter.
- Terrain that can be walked over safely for pipe laying etc. (i.e. no large vertical drops).
- Clean river water that will not corrode aluminium parts (sea water is permitted by special request only).
- The client confirms that the site is unlikely to: slip, have rock falls, flood, earthquake etc. Where such conditions exist the client has taken appropriate measures.
- The client has read manuals, viewed online videos and read installation examples before starting on this project.
- The client has engaged an experienced/qualified installer who has good electrical, mechanical and plumbing skills.

Where water flows are irregular and in situations where this hydro plant supports solar PV generation the client needs to supply:

- A flow duration curve with an indication of the limiting flows (guaranteed water supply, irrigation, drinking-water).
- Information about their solar PV generation and water flows that exist when sunlight hours are low.
- Specify the extreme water-levels at the intake and at the tail-race in meters.
- Specify the power needed at the site in Watts 24/7 or kWhrs/day.
- Common MDPE and PVC pipe sizes available locally.

The efficiency and the number of turbines required are determined by the Advanced Calculation tool: http://www.powerspout.com/calculators/
You must submit this data when you place your order for a PowerSpout turbine.

The client must state:

- For direct battery connection the battery voltage 12/24/36/48 etc.
- For MPPT units to batteries the model, make and voltage range of the unit (max and min).
- For grid connected units the model, make and voltage range of the inverter (max and min).

All other information required from the client and data needed by the client are contained in the advance calculation tool.

Flooding risks:

- On the upstream side the limit is normally the intake screen (trashrack and the rack cleaning machine - if installed).
- On the downstream side the limit is normally the flooding height that can engulf equipment.

Generally the following are not included for clients outside NZ; these might be provided by a local dealer/supplier/installer:

- Civil works
- Intake screen
- Pipe
- Wire
- Regulator, battery and inverter system or grid connect inverter
- Installation service

This manual covers the installation of PowerSpout hydro turbines only. For more technical applications and where this product is connected to MPPT regulators (with the Klampit 75,120,240 – denoted “C” in the turbine name) and grid-tied inverters you must also refer to the PowerSpout technical manual. A new technical manual will be available in 2014. There is also a service manual for each turbine that will be available in 2014.

1.4. Turbine serial numbers

As of September 2013 all turbines have identification plates and serial numbers.

PowerSpout
WATER GOES IN POWER COMES OUT

CE FC Read manual	IP24 ingress IK10 impact RoHS
Model type: PLT, TRG, LH, LH Pro	Rated Power: Watts
Serial number:	Rated Amps Short circuit Amps
Rated speed: rpm Maximum rpm 3000	Head: m (x10 kPA) Flow: l/s
Rated volts loaded: DC	New Zealand – country of origin Mass: < 25 kg
Rated volts unloaded: DC	Date manufactured:
Protective class I - earth connection required	Possible residual voltages - always check first
Klampit 75 120 240 not fitted	Capacitor discharge time mins (if fitted)
Annual inspection needed refer to manual	Guarantee 2 3 5 10 years

For example:
You might see 100-7S-2P-S HP F 3061 A as the serial number.

This means you have a 100 series stator, connected 7 Series and 2 Parallel fingers per phase, High Power rotor upgrade, Filter installed for conducted emission compliance, invoice number 3061 and other identical units were supplied at the same time labelled A, B, C, D etc.

If you ever need to query an installation or order spares for a product take a picture of the identification plate and forward it with your query. The generator code is also engraved on the back of the PMA stator.

2. Components of your hydro system

A typical hydro system includes a good water supply, a generator and electricity storage.

The generation capacity of your site is determined by the water supply, primarily by the vertical distance the water falls (head) and how much water flows in a given time (flow rate). A rough estimate of generation potential can be calculated as follows:

Generation (Watts) = head (metres) x flow (litres per second) x 5

Generation (Watts) = head (feet) x flow (gallons per minute) / 10

Please refer to http://www.powerspout.com/calculators/ for more information and to use the Advanced Calculator tool. There is also an Advanced Calculator manual available for download, giving instructions and worked examples.

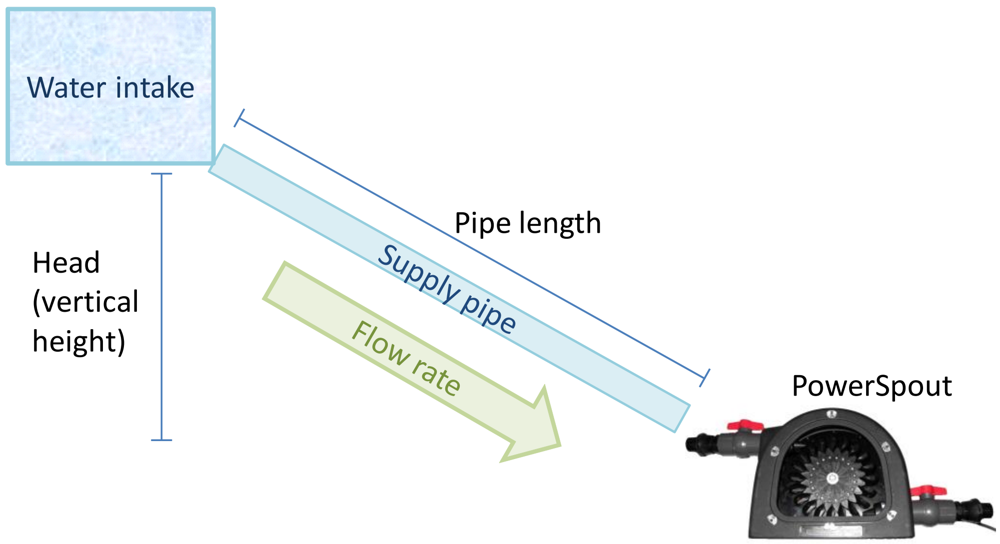


Figure 1. Water supply system.

2.1. Generator (PowerSpout)

A micro-hydro generator like the PowerSpout converts the potential energy of a watercourse to electricity. This is achieved in two ways:

- TRG and PLT turbines by water jets impacting on the turbine runner, spinning the runner and hence the generator, which generates electricity. These are normally referred to as impulse turbines.
- LH turbines direct the water through guide vanes that spirals on to a propeller shaped runner, causing it to spin. These are normally referred to as reaction turbines.

PowerSpout hydro generators produce 3-phase AC power that is rectified internally to DC.

There are different versions of the PowerSpout available to suit different situations[1]. These are briefly described above in Section 3 and further information is provided in the PowerSpout Technical Manual. Seek advice if you are unsure on the best PowerSpout option to meet your needs.

[1] There are also Education and Demonstration versions available. Please contact us for more information.

Cable choice is a key factor in selecting your PowerSpout turbine operating voltage, since this can have a significant impact on the installed system cost. Some versions enable you to reduce cable costs by increasing the system voltage.

The best way to select the correct PowerSpout turbine is to use this selection chart. www.powerspout.com/assets/Published/public/PowerSpout-Model-Selection-Chart-Metric.pdf

After you have selected the correct turbine, use the Advanced Calculation tool to do accurate design calculations www.powerspout.com/calculators/. There is a manual to assist you in the use of these calculation tools.

2.1.1. Setup for different systems

Different systems use different configurations of components as shown in the diagrams below. Instructions for electrical connections, including wiring schematics, are in Section 8.

Pictures of systems are provided in Section 12, demonstrating examples of good practice and installations with issues, and identifying improvements that can be made.

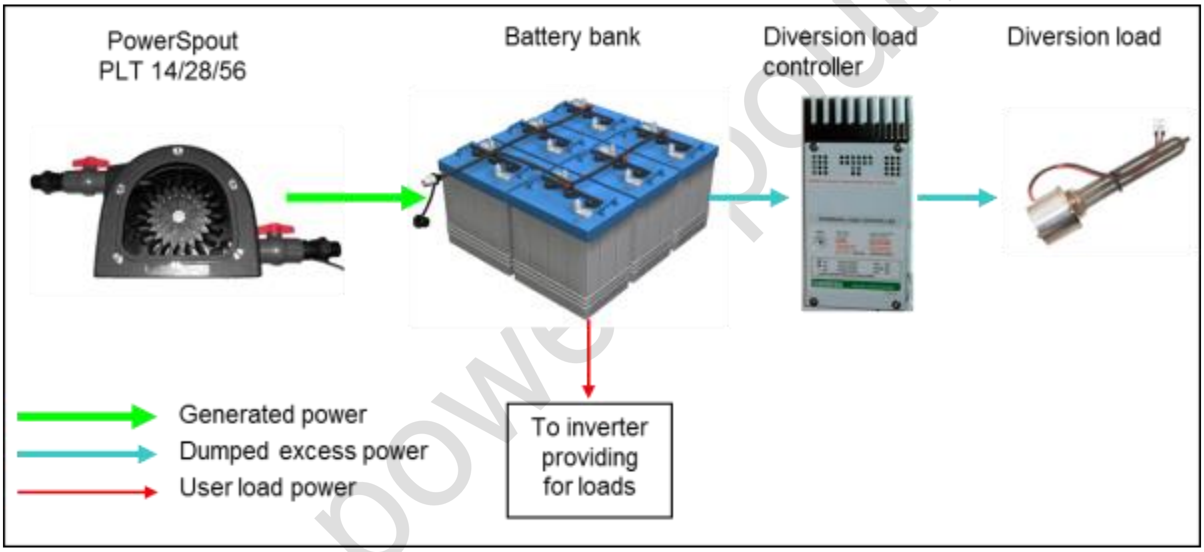


Figure 2. PowerSpout PLT 14/28/56 system setup with PWM regulation

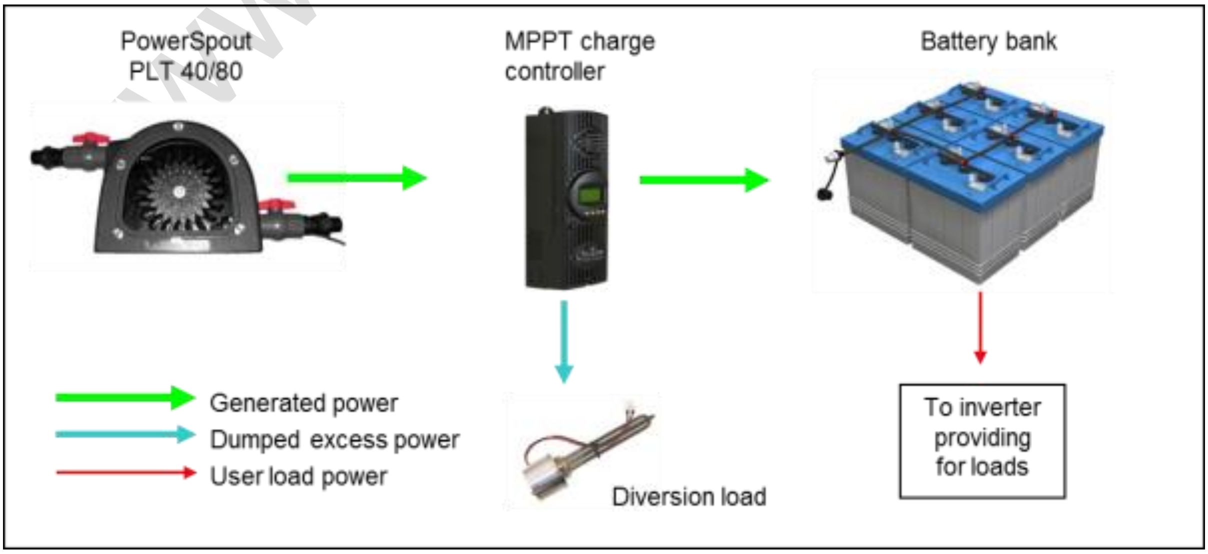


Figure 3. PowerSpout PLT 40/80 system setup with MPPT regulation.

The diversion of surplus power is possible using the AUX relay found in many good MPPT regulators. A solid state DC relay and resistive load is also required, refer to section 8.3. Surplus power can provide/supplement your hot water needs and will ensure that turbine speed and noise levels are lower.

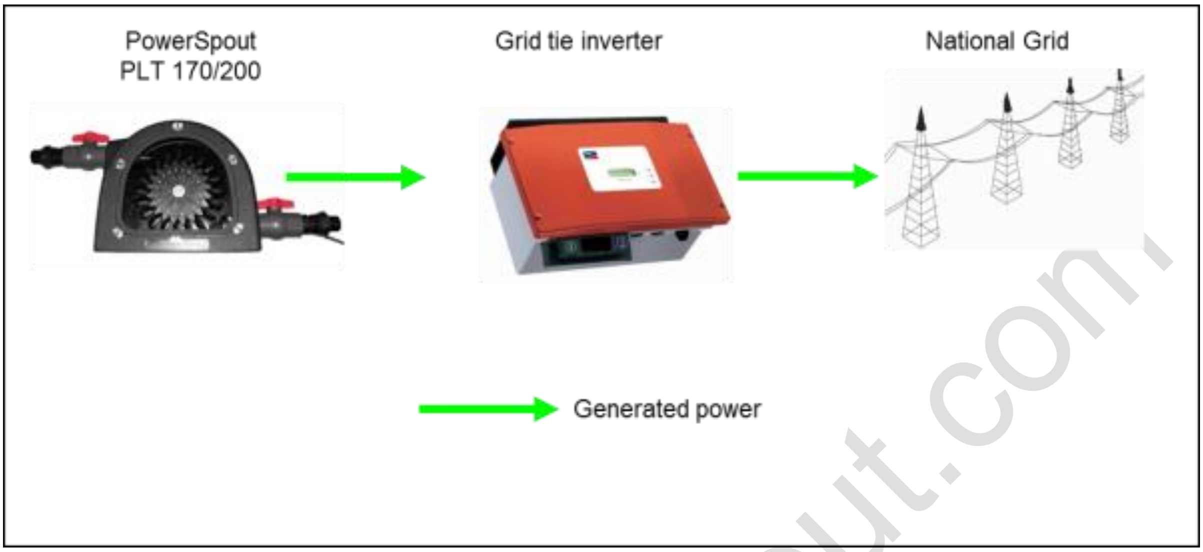


Figure 4. PowerSpout PLT 170/200 system setup

The inverter selected must have an MPPT operating range lower than 170/200 V DC. Maximum input voltage for the inverter must be 500/600 V DC. There is no guarantee that an inverter will MPP track and work well unless it is approved for hydro applications by the inverter manufacturer. Only a small number of grid connect inverters are approved for hydro input, most that we have tested worked well. The manufacturers may refuse to cover failures under warrantee if the equipment is not approved for hydro applications.

2.1.2. AC or DC power

Contrary to the common myth, it is more efficient to send DC along a cable than AC for the same cable size and rms voltage. The only exception is where you already own a cable with 3 conductors suitable for 3-phase AC; if we rectified the 3-phase AC and sent it as DC down 2 of the cables then the losses would be more, because the cable area used is less. If you do have a 3-core cable installed then combining 2 of the cables into one and sending DC down these 2 cables is more efficient than sending AC.

If you do not already have such a cable then you should use DC for transmission in most cases.

2.2. Rectifier

A rectifier converts the 3-Phase AC produced by the micro-hydro to DC for supply to your battery bank or grid-tied inverter. Generally DC is conveyed from the turbine to connected equipment.

3 phase rectifier

In order to comply with standards for conducted and radiated emission noise, the 3-Phase rectifier in your PowerSpout PLT may include a noise filtering module for conducted emissions. This EMC filter in only included if your turbine was ordered for a grid-connect application.

Rectifiers get hot due to losses and lower voltage systems have greater losses. On new off grid systems the preferred battery voltage is 48 V DC, though 24 V DC is also common provided cable costs are not too high. PLT14 (12 V DC) cannot be used at sites where more than 50m of cable is needed due to high cable losses, unless MPPT type regulators are used. Cable losses are much less of an issue if you install a PLT40 or PLT80, and the MPPT regulator then converts to 12/24/48 V DC to suit your battery bank.

2.3. Battery Bank

In off-grid systems a battery bank is required to store power. The voltage of the battery bank dictates the voltage of the system (12 V, 24 V or 48 V DC) with 48 V being the most common. The quantity of batteries in the bank is dependent on the power requirements and the intermittency of power generation at your site. It is typical to have a number of batteries arranged in parallel and series to provide the desired voltage and capacity. Lead-acid batteries are most commonly used, although most other types are also suitable.

Battery bank

Batteries can also be used in on-grid systems to provide power when the grid is down. If there is a grid power outage your PowerSpout connected via an on-grid inverter will disconnect itself from the grid, so your home will also lose power. The extra cost to install a backup battery bank is difficult to justify unless you have frequent grid outages.

2.4. Inverter

Inverters convert the energy generated by your PowerSpout or stored by the battery bank to a voltage and frequency suitable for typical household appliances – usually 230/240 V in Europe/Australasia and 110/120 V in North America. Square wave inverters tend to be cheaper but pure sine wave inverters produce a higher quality waveform that is necessary for more sensitive electronics commonly found in the modern home. Induction motors (as found in most refrigerators, workshop machine tools and air compressors) tend to overheat when used on square wave or 'modified sine wave' inverters. Large induction motors starting direct on line may fail to start even on large pure sign wave inverters.

Outback inverter and regulator system

Inverters are available in a variety of power ratings (depending on the intended loads) and with a variety of surge ratings. A high surge rating allows loads with a high start-up power surge to run without overloading/tripping the inverter, or failing to start at all. Some inverters can also serve as charge controllers to regulate input from backup petrol/diesel/LPG generators.

2.5. Unloaded rpm and Open Circuit Voltage (OCV) explained

The unloaded (or maximum) rpm of a turbine is reached when it is free spinning with no electrical load applied. Electrical load is analogous to the brakes on a car, if you want to go down a steep hill at constant speed, you need to apply the brakes. Not applying the brakes means you will increase speed in relation to the steepness of the hill until you reach a maximum speed.

In a hydro turbine that is unloaded (the output wires are left unconnected), the rotor reaches almost the same velocity as the water jet, this speed can be easily calculated for your site data by the advanced calculation tool.
The voltage of any PMA when unloaded is proportional to the rpm of it. In theory (if we ignore friction) the voltage output of a PLT or TRG turbine can increase up to 4 times for two reasons:

- The rpm increases to 2 x normal speed
- The OCV for an SD PMA is about 2 x MPPV

In practice due to friction the maximum voltage output is about 3 x normal loaded voltage for PLT and TRG turbines.

2.6. Regulator (charge controller)

There are 2 main types of regulator for off-grid battery charging.

PWM (Pulse Width Modulation):

- Lower cost
- Do not convert voltage, so manual turbine rpm adjustment may be needed
- Requires external diversion load
- Internal losses are low <1%
- Hydro may not run at optimum efficiency as battery clamps generation voltage
- May not be fail-safe – batteries can be flattened or overcharged if PWM unit or resistive load fails.

MPPT (Maximum Power Point Tracking):

- Higher cost
- Converts voltage so turbine adjustment is not needed (other than jet sizing)
- External diversion load is optional on some models
- Internal losses are normally 3-7%
- Hydro runs at optimum efficiency as MPPT adjusts voltage for maximum Watts
- Generally fail-safe – in the event of failure generation stops so the batteries are not damaged.

2.7. PWM regulators

The following are common PWM regulators for use with hydro

Power Master PM60

Morningstar TS60

Xantrex C40

PWM regulators, also known as diversion load controllers or charge controllers, are an essential component of your renewable energy system. Regulators are responsible for ensuring correct charge rate and to protect your battery bank from overcharging. Once the regulator recognizes that your battery bank is fully charged it diverts additional incoming power to a diversion load. Such regulators normally allow you to set the voltage threshold at which power diversion starts.

Charge control is provided using any good quality charge controller such as a Power Master PM60, Morningstar TS60 or Xantrex C40. Most PWM controllers can be configured as either solar or diversion load controllers, so it is acceptable to buy one of these controllers and configure it for diversion.
Low cost solar regulators are NOT suitable for micro-hydro and wind applications as they do not have a diversion mode option.
The positioning and type of regulator used in a renewable energy system is critical for protecting not only the generator but also the rest of the system from damage. It is highly recommended that two regulators be used to reduce the likelihood of damaging your system should a single PWM regulator fail.

PWM type diversion regulators can make a significant buzzing noise that might be unwelcome in a living space.

2.7.1. Backup PWM Regulator

A secondary or backup regulator is recommended in all hydro energy systems that use PWM regulators. Since PWM regulators are relatively inexpensive components, redundancy will protect the higher value components in your system in the event of failure of the primary regulator.

This picture illustrates two PWM regulators and their diversion resistors. If there is a regulator failure, the expensive battery bank will remain protected from overcharging. Check regulator operation on a regular basis.

2.8. MPPT regulator operation

MPPT regulators (grid tied inverters also use MPPT) have become common in recent years mainly for the large solar PV market. These regulators/inverters can also be used on hydro and wind applications in some cases; additional voltage protection is often needed but not always if you are careful in your selection. Different PowerSpout turbines are available to match the maximum input voltages of common MPPT regulator/inverters and local wiring rules (see Section 3).

While not all MPPT tracking equipment is the same, modern inverters/regulators tend to have very fast MPPT tracking. Since a hydro turbine has rotational inertia, a fast tracking increment (many track every 0.2 seconds) may not correctly locate the maximum power point. This is because the rotor takes time to change speed and stores kinetic energy, which can fool the logic of the MPPT trackers in some cases. Equipment that has been designed for solar, wind and hydro input will work fine as they have a slower tracking rate or special tracking algorithms for hydro/wind input. They may cost a little more but it is money well spent.

PowerSpout turbines have been tested for compatibility with a number of MPPT inverter/regulators and results are available on the website. This list is anticipated to grow as testing continues so please check the website www.powerspout.com/compatibility for updates.

If you are in any doubt you should seek the MPPT manufacturer's advice.

2.8.1. MPPT regulators

There are many MPPT market on the market these days. Common MPPT regulators can be grouped according to the voltage input rating as below.

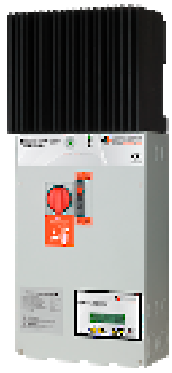
140-150 V DC input rated units

 Midnite Classic 150 (Manufacturer approved for hydro use)	 Outback FM80 and FM60 (Manufacturer approved for hydro use)	 Xantrex XW MPPT 60-150
 Apollo T80	 Morningstar TriStar TS-MPPT-60	 Power Master PM-SCC-80AM
 Victron Energy Blue solar MPPT 150/70	 Micro Care 20-60amp MPPT with intergrated DC breakers	 Midnite Solar The Kid 162VOC – 35 amp (Manufacturer approved for hydro use)

200-300 V DC input units

 Midnite Classic 200/250 (Manufacturer approved for hydro use)	 Apollo T80HV	 Power Master PM-SCC-80AMW
 Steca Tarom MPPT 6000 (Manufacturer approved for hydro use)	 AERL Coolmax SRHVW (Manufacturer approved for hydro use)	

600 V DC input units

 XW MPPT 80- 600 Solar (24 & 48 V DC output)	 TriStar MPPT 600 Volt Solar	 TriStar MPPT 600 Volt Solar with DC disconnect

In selecting an MPPT regulator you need to carefully consider the following points:

- Cost
- Current rating (Amps)
- Upper voltage rating
- Cost and size of power cable needed to connect your PowerSpout
- MPPT tracking stability when used on PowerSpout hydro turbines

- Does the manufacturer of MPPT regulator give a warranty for hydro input?
- Programmable relay(s) to divert surplus power to a hot water tank
- Approved by the makers of the MPPT unit for hydro connection
- Approved by the makers of the PowerSpout turbines for connection
- Local support and warranty for the MPPT unit

Although many MPPT products will work, some of which are listed above, the issue is normally the lack of warranty for the MPPT regulator offered by the manufacturer or lack of knowledge of the product when connected to PowerSpout turbines.

When using a MPPT tracking charge controller an additional backup controller is not required as they tend to fail safe. Overvoltage protection using our optional 120/240 clamp may be needed. Refer to the Technical Manual for more information.

2.8.2. MPPT regulators for PowerSpout turbines

We have noticed a trend by hydro manufacturers to approve MPPT regulators without any voltage limiting control in the turbine or good advice in their manuals on how to do this safely. Our standard PLT/TRG turbine (without extra over-voltage protection inside the turbine) may be used with MPPT regulators but you must be careful if you do this. This is because the risk of over-voltage and hence regulator damage is greatly increased.

- The turbine must not produce more than the controller's maximum operating voltage when at maximum speed unloaded at your site.
- In most cases this means that the turbine design voltage on load cannot safely be more than 33% of the controller maximum operating voltage.
- Turbine voltage on load must be more than the battery voltage, so the maximum battery voltage you can have is this 33% figure.
- For example a 150 V controller has maximum operating voltage 140 V which means you cannot use it to charge a battery with higher than 140 x 0.33 = 46 V.
- In reality this means you need to choose a 24V nominal battery for the 150V MPPT controllers.
- This means you need to choose a 200/250V MPPT controller for 48 V nominal battery voltage.

If you intend to use a PowerSpout turbine directly connected to a MPPT regulator/inverter then you must do a runaway voltage test prior to connection.

For a PLT/TRG80 the cable calculations are done at 80 V DC to determine cable size required (in the Advanced Calculator tool).

For example:

- A PLT40 turbine has been installed and when tested on site had a recorded runaway voltage of 130 V DC. It is to be connected to an Outback FM60.
    - PLT cable voltage = 130 * 0.33 = 43 V DC approx.
    - Hence it can only be used to charge 12 or 24 V DC systems
    - Cable loss calculations are done at 40 V DC

- A PLT80 turbine has been installed and when tested on site had a recorded runaway voltage of 230 V DC. It is to be connected to a Midnight Classic 250.
    - PLT cable voltage = 230 / 3 = 76 V DC approx.
    - Hence it can be used to charge 12, 24 or 48 V DC systems
    - Cable loss calculations are done at 80 V DC

It is important to remember that a PLT80 (for example) is nominally 80 MPPV but in practice could be in the range 70-90 MPPV, this range could be even wider if the site data you supplied at time of order was not accurate.

It is therefore very important that the runaway OCV is measured on site prior to connection to your MPP regulator.

For installations done by those who are not registered electricians, the maximum DC voltage you are allowed to work at replaces the maximum input voltage. 120 V DC is the upper limit in Australasia and some other parts of the world, and 75 V DC is also common globally.

If the ELV (extra low voltage) limit in your country < 75 V DC then you can only use our unregulated PLT turbines on 12 or 24 V DC battery bank via an MPPT regulator to comply with both the Law and over voltage limit of your MPPT regulator. 12 V DC systems are not common these days with the majority of systems being 24 or 48 V DC.

If you intend to run a PLT turbine on a MPPT regulator/inverter you must:

- Tell us prior to ordering
- Have a cable run < 1000m
- Have an accurate measure of the head of your system
- Check runaway OCV prior to hook up

2.8.3. Future trends

As the cost of MPPT regulators falls we will see a move towards more MPPT regulation, for the following reasons:

- MPPT regulators are generally fail safe, unlike PWM regulators
- Clients have less time/inclination to manually optimise the turbine, so automatic optimisation is great.
- Professional installers prefer a ‘plug in and go’ solution that MPPT regulators offer.
- You will generate more power from your PowerSpout turbine.

We are also starting to see off-grid MPPT regulators that can operate at up to 600 V DC, though this is still relatively new with few products on the market. This may soon result in PLT turbines charging 24/48 V DC batteries with a cable voltage of up to 200 V DC and no need for extra voltage protection.

2.9. Water and air diversion resistors

Many of the wiring schematics (Section 8) show air and/or water diversion elements. This is done for 2 main reasons:

- To convert energy not needed into useful heat
- To keep MPPT system voltage stable once batteries are fully charged

The schematics show diversion of surplus energy on the DC side of the system. It is also possible to divert surplus energy to heat on the AC side of the inverter. This is normally done with an AC relay (fitted with a 12 VDC coil) controlled by the AUX relay function in the MPPT regulator.
Such advanced applications are covered in the new 2014 technical manual.

In domestic systems where there is plenty of hydro power (>2kW available), a standard thermostat controlled AC element (small element in the range 750-1500W) may be used. This method puts more AC load on the inverter and cycles the batteries more, so is only done on larger systems.

2.10. Diversion Load: Hot Water Element

Hot water diversion element

A diversion load is required for PWM regulators to dissipate excess power.

For MPPT regulators it is optional but highly recommended; you may as well benefit by using surplus generation in your hot water cylinder. If you do not fit a diversion load your hydro turbine will speed up by about 30-50% once the batteries are fully charged resulting in a little more noise and wear on the bearings.

Typical hydro systems often produce much more power than the battery needs, and it's a waste not to divert this into useful heating.

Some MPPT regulators also contain programmable relays that allow 230/240/110 V AC loads to be turned on when there is surplus power. For example, when there is excess power, a water pump or water heater can be turned on to soak up this surplus. These relays can also be used to control larger DC/DC solid state relays that can be used to send surplus DC generation to hot water elements.

If your MPPT regulator is not fitted with an internal programmable relay and you wish to divert surplus power to a heater then you have several options:

- Change the MPPT regulator to one that does
- Fit a PWM regulator alongside the MPPT regulator
- Fit a Morningstar relay driver

Generally diversion loads need to be very robust and where there is any chance of failure a secondary diversion load to an air resistive element should be installed. Always ask yourself what are the consequences of a regulator failure? Your answer will assist you in making the correct regulator choice.

2.10.1. Common water elements 120/240V

In some colder countries cars/trucks have block heaters to prevent the engine block from freezing. These are normally in the 400-1000W range at 120 V and make excellent small water heaters.

There are also 120V and 240V water elements made for motor home hot water tanks. These are typically 1500W.

Then there are the larger 2000-4000W elements at 120 and 240V made for domestic homes. These are rarely used as they are too large.

2.10.2. Common water elements 12/24/48V

A quick search of Ebay located the following elements all with 1" BSP/NPT threads.

- 12V 200W
- 12V 600W
- 24V 400W
- 24V 600W
- 48V 1000W

2.11. Diversion Load: Air-Resistive Coil

Where hot water is not required or if a secondary regulator is fitted air resistive elements should be used.

2.11.1. Common air elements 120/240 V

A common source of air elements are:

- Elements for electric towel rails 100/150/200/300/400/500/600/750 Watt
- Hob elements in electric stoves typically 1500W

2.11.2. Common air elements 12/24/48 V

Air elements can be easily made from stainless steel wire, a baking tray and a cooling rack as shown.

These can be made to suit your specific requirements. Whatever diversion element you decide to use make sure it is robust, reliable and commonly available.

Large 1kW 0.8 Ohm resistors are also common. 2 such resistors are well suited to 12/24/48 VDC applications when connected in series or parallel.

2.11.3. Common 120 V and 240 V elements used at different voltages

Operating Voltage	Power of 120V element available in Watts											
	100	200	300	400	500	600	700	800	900	1000	1200	1500
14	1	3	4	5	7	8	10	11	12	14	16	20
28	5	11	16	22	27	33	38	44	49	54	65	82
56	22	44	65	87	109	131	152	174	196	218	261	327
120	100	200	300	400	500	600	700	800	900	1000	1200	1500
240	400	800	1200									

Operating Voltage	Power of 240V element available in Watts											
	100	200	300	400	500	600	700	800	900	1000	1200	1500
14	0	1	1	1	2	2	2	3	3	3	4	5
28	1	3	4	5	7	8	10	11	12	14	16	20
56	5	11	16	22	27	33	38	44	49	54	65	82
120	25	50	75	100	125	150	175	200	225	250	300	375
240	100	200	300	400	500	600	700	800	900	1000	1200	1500

These tables illustrate that if you take a standard 120 V 1500 W element and use it as a diversion element on a 48 V battery system (56 V when fully charged) it will draw a maximum of 327 W. If 2 were used in parallel you could divert up to 654 W. 327-654 W continuously is sufficient to meet the hot water needs of many homes. If you have a 12 or 24V battery bank then such elements cannot be used as their ratings are just too low, hence you will need to buy a special element for these applications.

2.11.4. 120V -1500W water elements using AUX "PV trigger" relay settings

Some MPPT regulators have an AUX relay that will activate on the MPPT incoming voltage. For example the Outback FM60/80 has a "PV Trigger" setting. You can program the AUX relay to close when a voltage is reached.

This has a number of advantages when used with our PLT/TRG 40/100C and LH150 turbines namely:

- The turbine can be turned on quickly.
- You will not get nuisance tripping of the internal clamp (100C version) while the MPPT unit sweeps.
- As the incoming voltage increases (as the battery reaches fully charged) more power will be diverted to the water element.

This is best illustrated by way of an example. Let us assume you have a PLT40 turbine that is rated for 750W at 40 vdc. We want to use a 120V 1500W water element as they are common in the USA.

The table shows the Wattage of the element in 10 volt increments from 40-120 VDC.

Operating Voltage	Power Watts
40	167
50	260
60	375
70	510
80	667
90	844
100	1042
110	1260
120	1500

As a PLT turbine will develop maximum power at about 40 VDC we can set the PV trigger to operate at say 50V. Once the batteries no longer require all the 750W being generated the MPPT regulator will allow the incoming voltage to increase, this will turn on the water element and at 50 vdc and 260W will go to hot water heating.

Once the batteries are fully charged we might see the incoming voltage rise to 70 VDC and 510W will be diverted to the water heater.

If the incoming voltage is less than 50 vdc, all the available 750W will be going to the batteries.

If a PLT/TRG 100C turbine was uses, then the turbine is inherently stable and safe in operation. If any of the following conditions were to occur:

- Water element failure
- Breakers to FM60/80 accidently turn off
- Turbine breakers turn off
- FM60/80 failure
- Cable break

The 120V internal clamp inside the PLT100C would operate and the generation voltage would drop to almost 0 VDC and the generation current would increase to the short circuit rating. As the load on the turbine decreases the turbine will increase in speed.

If hydro generation stops it is almost certain that the clamp has activated due to one of the above conditions. If you go to the log data for the day you will almost certainly see a recorded maximum voltage close to 120 VDC. To get the turbine going again, stop the turbine at the valve, locate and fix the cause, turn the turbine back on.

Diversion of surplus power with the large variety of MPPT regulators can get complicated. For this reason more information on the setup on MPPT regulators is contained in the 2014 Technical Manual that will be available from early 2014.

2.11.5. 240V -1500W water elements using AUX "PV trigger" relay settings

This is best illustrated by way of an example. Let us assume you have a PLT80 turbine that is rated for 750W at 80 VDC and you intend to use a Midnite Classic 250 VDC MPPT regulator. We want to use a 240V 1500W water element as they are common globally.

The table shows the Wattage of the element in 10 volt increments from 80-240 VDC.

Operating Voltage	Power Watts
80	167
90	211
100	260
110	315
120	375
130	440
140	510
150	586
160	667
170	753
180	844
190	940
200	1042
210	1148
220	1260
230	1378
240	1500

As a PLT turbine will develop maximum power at about 80 VDC we can set the PV trigger to operate at say 90V. Once the batteries no longer require all the 750W being generated the MPPT regulator will allow the incoming voltage to increase, this will turn on the water element and at 90 vdc and 211W will go to hot water heating.

Once the batteries are fully charged we might see the incoming voltage rise to 140 VDC and 510W will be diverted to the water heater.

If the incoming voltage is less than 90 vdc, all the available 750W will be going to the batteries. The trigger point can be adjusted until a good result is achieved.

More detailed information on the setup on MPPT regulators is contained in the 2014 Technical Manual that will be available from early 2014.

2.12. Fuses


Main battery HRC fuse

In order to prevent system damage through shorts and malfunctions, and for general ease of maintenance, it is recommended that a number of fuses be placed in the system for protection. Fuse ratings will be dependent on the overall power rating and type of components in your system.

2.13. Breakers

Modern Non-Polarized DC breakers are common, mainly thanks to the large solar PV industry.

Until recently Polarized DC breakers were also common. Such breakers can normally be identified by the "+" sign at one of the two ends, as can be seen in the picture. This type of breaker has been outlawed in many countries as it has caused fires when installed incorrectly. Avoid this type of breaker on new installations.

2.13.1. Common DC Breaker sizes

Due to the large solar PV industry, non polarised 2-pole (500 VDC) and 4-pole (1000 VDC) are very common and affordable. Single pole are also available.

Common sizes are:

- 10 Amp
- 16 Amp
- 20 Amp
- 25 Amp
- 32 Amp
- 40 Amp
- 50 Amp
- 63 Amp

Common brands that are widely used include: Noark, Schneider and ABB.

2.14. Ground-fault protection for PV and DC hydro systems

In the USA the National Electrical Code (NEC) Article 690.5 states ground-fault protection requirements for <u>grounded</u> DC solar PV systems. Ground fault protection is also required for <u>ungrounded</u> systems detailed in 690.35(C). The purpose of ground-fault protection devices (GFPD) is to reduce the risk of fire associated with a ground fault. If the ground fault is a short-circuit, the fault current can be high, which creates a significant fire hazard.

Because of this fire hazard, ground-fault protection circuits are required for roof-mounted residential PV installations, where the risk of fire is greater than a system mounted in a field at some distance from a building. Ground-fault protection is not just for residential roofs. The 2008 *NEC*, requires ground-fault protection for all "grounded DC photovoltaic arrays."

The *NEC* lists two exceptions to general GFPD requirements. The first exception is for ground-or pole-mounted systems that are isolated from any buildings and limited to one or two parallel source circuits. This exception might apply to a remote water pumping system. The second exception is granted to systems installed at "other than dwelling units".

Where hydro turbines are remote from dwellings GFPD is not therefore required, but can be installed if required. In grid connected systems inverters have GFPD fitted as standard, but most off grid MPPT regulators do not. If your hydro turbine in situated in a very dry bush/forest environments where the fire risk is high, then GFPD should be installed. There are many such products on the market and some MPPT regulators include GFPD. .

You may not need to earth your PowerSpout bulk head if a GFPD is installed; consult with your local installer and codes prior to making this decision.

2.15. Metered output

A meter enables you to see any change in the output power, which could indicate a problem that needs your attention. A separate meter is only needed if you purchased a PowerSpout PLT with a PWM regulator. MPPT regulators or grid tied inverters will display the generation information for you. A digital volt and amp meter can be purchased on Ebay from under $20 delivered

2.16. Labelling requirements

Local codes and standards list many labels and notices that must be installed on these systems, consult these documents and your local installer to make sure you comply.

Generally labels cover the following:

- Breakers should be clearly labelled and state what it is they do.
- DC wire should be clearly labelled to avoid confusion with AC wires.
- Emergency shutdown procedure should be clearly stated, markers on your property may be required to direct emergency services.
- Normal start up and shut down procedures should be clearly stated. System manual should be supplied.

It should be noted that durable label kits for on and off grid solar PV systems are available that comply with relevant standards from your local renewable energy installer. Hydro systems should have similar labels.

2.17. Turbine pipe connecting options PLT and TRG

1-5+ hydro turbines are commonly connected to a single penstock. It is helpful if at the end of the penstock there is a large valve so the pipe can be flushed to purge sand/silt.

This section covers different ways that turbines can be connected in a cost effective manner. Parts for many of these options can be ordered at the same time as you order your PowerSpout turbine.

There are two main considerations:

1. The connections made to the penstock
2. The pipes from the penstock that connect to the turbine

For every PLT turbine you will need up to 2 penstock connections and up to 4 for TRG turbines.

The ability to quickly remove the turbine from the pipework is important so that turbines can be easily serviced.


There are 2 common ways that a quick connection can be made:

1. Plastic Camlocks
2. PVC mac-unions

50mm (2”) camlocks are more suited to lower head sites of 60m and less. PVC mac-unions are rated for heads up to 160m.

Connection to the penstock can be made in the following ways:

- Bolt over saddles
- Pipe fittings - T’s and Y’s
- PVC 4 jet manifold – for PVC pipes and the TRG turbine
- PVC 2 jet manifold – for PVC pipes and the PLT turbine

2.17.1. Thread types BSP/NPT

PowerSpout can supply PVC manifolds for our PLT turbines with either 2” BSP/NPT threads or 2.5” BSP threads. As PVC sizes are often different from one country to another, using a common thread size as a connection method is often the best way to avoid problems on site.

The picture shows two turbines connected via PVC manifolds to a mac-union and then to the black plastic MDPE pipe via a threaded connection.

The penstock was separated into 2 lines prior to feeding each manifold by using a T and 90 degree elbows.

2.17.2. Bolt over saddles

These are available to order with your turbine for pipes with outside diameters of:

- 160 mm
- 110 mm
- 90 mm

You can install as many as are needed. They are double sided so provide 2 x 50mm BSP male threads per saddle set. Pictures below show how you install them on your pipes.




Once the saddles are fitted, use the valves and camlocks (often supplied with your turbine) as shown.

Saddles have the following advantages:

- Low cost
- Less freight bulk and light in weight
- Easy to fit, no special tools needed

Saddles have the following disadvantages:

- Sharp take-off so higher fitting losses
- Not suited to low head, high flows

Note that the valves are fitted to the saddle and not to the turbines. This ensures that the turbines can be easily removed for servicing leaving the off valves in place.

Saddles connected to camlocks via flexible pipes suit sites >10m < 60m and flows up to 3 l/s per turbine jet with 50mm ID pipework. Most PLT turbines can be connected in this manner. For TRG applications the next option should also be considered.

2.17.3. Pipe fittings - Y's

PVC "Y" fittings suit higher flow TRG sites that commonly use 160 or 200mm OD PVC pipes. PowerSpout can supply this optional PVC manifold kit as shown. The end user has to glue it together. It suits sites in the head range 5-20m and flows up to 4 l/s per jet with 50mm ID pipework. For sites in the 2-5m range, 3" camlocks and flexible pipe connections should be considered. Manifold losses are more critical as there is little head to start with, and such losses can result in reduced performance.

The TRG PVC manifold kit comprises:

- 1 x 200-160mm PVC reducer
- 2 x 160mm joiner pipes (120mm long)
- 2 x 160mm to 110mm double "Y" fittings
- 1 x 160mm screw end plug
- 4 x 110x75mm reducers
- 4 x 75x65mm reducers
- 4 x 65mm joiner pipes (100mm long)
- 4 x 65mm to 2" BSP male fittings
- 4 x 2" BSP ball valves – often supplied with your turbine
- 4 x 2" BSP male camlocks and hose-tail fittings

When all glued together it is more compact and looks like this.

Your TRG turbine can be positioned as shown and then hooked up with flexible pipes. Unless you buy the discounted TRG twin pack, camlocks fittings and valves are supplied with the turbines. All you need to buy is 10m of 50mm ID (2") flexible pipe.

2.17.4. Pipe fittings - T's and 90 degree elbows

For many sites HDPE pipe fittings can be used.
You are likely to need

- T's
- 90 degree elbows
- Joiners
- Thread adaptors

If you are installing just 1-2 PLT turbines then it is likely you are using 63-110 mm OD MDPE pipe. Offcuts of this pipe with some fittings can be used to make a low cost splitter manifold combined with a factory made PVC manifold as shown.

All the bends in the manifold below do not result in significant losses since the penstock pipe is 80mm ID; this splits into 2x80mm ID pipes, then this is split again into 2x65mm ID PVC pipes. This means that the water velocity in the PVC pipes is 1/3 of that in the penstock, so losses will be very low. We will show you how to check for penstock losses later with a pressure gauge.

2.17.5. Mock up your manifold off-site first

You will save a lot of time if you mock up your manifold and exhaust water collection off site where it is easier to work. This picture shows 2 x PLT100C turbines trial fitted off site prior to carrying all the parts 800m into dense forest.

2.17.6. PVC 4 jet manifold – for PVC pipes and the TRG turbine

A common comment from dealers and clients is that flexible pipe manifolds need supports and are rather unsightly.

We tend to agree but note they are:

- Cost effective
- Easy to align
- Easy to remove

A PVC manifold option is available to special order, as shown. These are tricky to put together and final gluing must be done by the end client. They do give a very clean and professional look and some clients will prefer this option.

2.17.7. Advantages of flexible hoses

In general a PVC manifold is more likely to distort the turbine casing, unless it is very accurately built and rigidly mounted. With flexible hoses you can make fine adjustments to the nozzle by manipulating the hose itself and then securing it in this position.

Other manifold options

There are many possible manifold solutions; there are some pictures below to give you ideas for your situation.






2.17.8. Measuring pressure in your pipe and manifold

Pressure losses in your Penstock and manifold are typically in the range 5-33%, with a 10% loss typical (used as the default in the online calculator). It is very helpful if you can measure both the static and dynamic pressure at the end on the Penstock and just prior to the turbine jets. From these readings you are then able to determine the losses in the Penstock and the losses in the manifold. All PowerSpout turbines (other than discounted twin packs) include a pressure gauge.

The pressure tapping kit (optional extra) allows you to insert a quick release pressure fitting at points of interest. You will need to drill and tap the pipes ¼ BSP to use these fittings. When a reading is not being taken they can be plugged with a length of solid tube supplied.

If turbine performance is less than estimated in the Advanced Calculation tool, check that you have not installed an undersized manifold by measuring the pressure loss across the manifold.

3. PowerSpout turbines - Introduction

Congratulations on your choice of a PowerSpout turbine. This ingenious little device will give you years of trouble free generation, avoiding the need for expensive generators or power bills. Not only does the PowerSpout give you renewable energy, it is also made of predominately recycled materials, making it one of the most eco-friendly micro-hydro generators available on the global market.

All PowerSpout products are named with one of the following model abbreviations:

- PLT (PeLTon turbine)
- TRG (TuRGo turbine)
- LH & LH Pro (Low Head propeller turbine)

Standard PowerSpout turbines are rated for up to 1200 W but a special high power (HP) version is available that is capable of 1.6 kW at 1600 rpm.
All turbines are rated for up to 32 amps as standard; an upgrade to 50 amps is available on request for high power low voltage applications (fee applies).

PowerSpout turbines are available for sites as follows:

Version	Head (m)	Flow (l/s)
PowerSpout PLT (Pelton)	3 – 130	0.1 – 10
PowerSpout TRG (Turgo)	2 – 30	8 – 16
PowerSpout LH (Low Head)	1 – 5	25 – 56

This manual will help guide you through the process of installation so that your PowerSpout is installed correctly and runs efficiently. PowerSpout turbines have been shown to achieve up to 60% efficiency and with multiple units up to 16 kW. You can estimate your generation capacity with our online Advanced Calculator (www.powerspout.com/calculators/). You will see that our calculations take into account pipe and cable losses, so we will not fall into the common trap of overstating output. Most installations exceed our power predictions as we use a conservative calculation model. See user feedback www.powerspout.com/testimonials/

Before commencing the installation process you should have selected the appropriate components and consulted your local regulations concerning use of water and undertaking electrical work. This manual includes information and links to relevant tools to facilitate this process. It should take no more than one day for two people to install a PowerSpout PLT, depending on site terrain. Pipe and cable laying can take much longer in difficult terrain.

The manual is intended to guide you through PowerSpout assembly[2] and the installation process. Please note from December 2012 all PowerSpout turbines are shipped fully assembled with only the jet holders removed (in some cases the Smart Drive PMG may also be removed). This has been made possible due to an improved freight arrangement with DHL.

This manual starts with an overview of micro-hydro systems and then proceeds through each stage of the installation. Advice is provided on basic maintenance in the service manual to ensure a safe and reliable supply of power for years to come.

[2] The PowerSpout has been fully assembled and tested prior to freight. What little assembly is needed will only take a few minutes.

Videos to introduce PowerSpout turbines and demonstrate PowerSpout assembly and bearing replacement are available via www.powerspout.com. Please note that video clips do become outdated quickly and may not be updated. Where instructions differ, the latest written manual (available online) will always be the correct method to follow.

A video on the history of the Smart Drive generator over the last 20 years may interest many customers.

3.1. PowerSpout Standard Turbine Options

PowerSpout PLT and TRG turbines are identified by voltage to suit the site and system design e.g. connected directly to battery banks, connected to battery-based MPPT regulators or to grid-connect inverters. The turbine abbreviation (PLT, TRG) is followed by a number that indicates the approximate MPPV, which is also the operating cable voltage. For example:

- PowerSpout PLT 28 has an MPPV of 28 V (connects to 24V battery bank via PWM regulator). 28 V is the bulk voltage for a 24 VDC battery.
- PowerSpout PLT 200 has an MPPV of 200 V (connect to grid via grid-tied inverter)

For PowerSpout LH turbines, for example the LH200, the 200 is not the MPPV but the maximum OCV at turbine runaway. This is because there are no LH turbines that connect directly to batteries. All LH turbines require MPPT regulation for battery charging or the use of a grid connect inverter.

The relationship between OCV and MPPV is stated below:

- PLT and TRG turbines OCV is approximately 3 x MPPV
- LH turbines OCV is approximately 2 x MPPV

3.2. PowerSpout PLT

Common versions of PowerSpout PLT with no overvolts clamp

	Off-grid*					On-grid	
PLT model	**14**	**28**	**40**	**56**	**80**	**170**	**200**
Max cable length m	50	150	250	500	1000	1000	1000
MPPV	14	28	40	56	80	170	200
Max open circuit V	38	75 ELV US/EU	120 ELV NZ/AUS	150	220	<450	<550
Regulator/inverter	PWM	PWM	MPPT	PWM	MPPT	Grid-tie	Grid-tie

* All off grid MPPT turbines can charge 12, 24 or 48 V battery bank except PLT40 which can only be used in 12 and 24 V systems.

Common versions of PowerSpout PLT with overvolts clamp fitted*

	Off-grid 75vdc clamp	Off-grid 120vdc clamp	Off-grid 240vdc clamp		On-grid Aurora PVI wind interface
PLT model	**56C**	**100C**	**170C**	**200C**	**350**
Max cable length m	500	1000	1000	1000	1000
MPPV	56	100	170	200	250-350
Max open circuit V	<75	<120	<240	<240	<400
Regulator/inverter	PWM	MPPT	MPPT	MPPT	Grid-tie

* refer to Technical Manual

3.3. PowerSpout TRG

Common versions of PowerSpout TRG with no overvolts clamp

	Off-grid				On-grid	
TRG model	**28**	**40**	**56**	**80**	**170**	**200**
Max cable length m	150	250	500	1000	1000	1000
MPPV	28	40	56	80	170	200
Max open circuit V	75 ELV US/EU	120 ELV NZ/AUS	150	220	<450	<550
Regulator/inverter	PWM	MPPT	PWM	MPPT	Grid-tie	Grid-tie

*All off grid MPPT turbines can charge 12, 24 or 48 V battery bank except PLT40 which can only be used in 12 and 24 V systems.

Common versions of PowerSpout TRG with overvolts clamp fitted*

	Off-grid 75vdc clamp	Off-grid 120vdc clamp	Off-grid 240vdc clamp		On-grid Aurora PVI wind interface
TRG model	**56C**	**100C**	**170C**	**200C**	**350**
Max cable length m	500	1000	1000	1000	1000
MPPV	56	100	170	200	250-350
Max open circuit V	<75	<120	<240	<240	<400
Regulator/inverter	PWM	MPPT	MPPT	MPPT	Grid-tie

* refer to Technical Manual

3.4. PowerSpout LH

Common PowerSpout LH and LH Pro products

All LH and LH Pro products connect via MPPT regulators or grid-tied inverters. There are no direct battery options available as propeller rpm is critical for best performance.

- **LH150 and LH150Pro** – use with MPPT regulator rated for up to 150 VDC charging 12/24 VDC batteries. MPP cable voltage may be as low as 50 VDC.
- **LH250 and LH250Pro –** use with MPPT regulator rated for up to 250 VDC charging 12/24/48 VDC batteries. MPP cable voltage may be as low as 80 VDC.
- **LH400 and LH400Pro** – use with MPPT regulator or grid connect inverter rated for up to 400 VDC. MPP cable voltage may be as low as 140 VDC.

3.5. Special PowerSpout options

PowerSpout products can be tailored to meet specific requirements as required. MPPT regulators, voltage regulators and grid connect inverter technology changes quickly. PowerSpout turbines can be made to suit these new products.

3.5.1. Regulated Products

PowerSpout turbines no longer have internal PWM regulation. This change was made in May 2013 due to the fact than many MPPT regulators and grid connect inverters can now operate over a very large voltage range, thus minimising demand for such a product. As long as the correct combination of PowerSpout turbine and MPP regulator/inverter are selected then internal regulation is rarely needed. The main exception is where the turbine is a very long distance away from the home.

PowerSpout ME and GE products are no longer made. The ME has been displaced by a combination of suitable MPPT regulators and PowerSpout products for MPP operation at up to 240 V DC. This is achieved with an overvolts clamp that operates at 75, 120 or 240 V DC which will prevent over voltage damage to the MPPT regulator. These are called PLT56C, PLT100C and PLT200C (20% under clamp operation voltage).

The GE400 has been displaced by a PLT350 option using the Aurora Power wind interface. Please note that the popular SMA Windy Boy inverter range has been recently withdrawn from the market. This leaves the Aurora wind inverter range that is globally available and approved for wind and hydro input. For the UK, NZ and AUS markets there is also the EnaSolar inverter range. MPPT and grid applications of the PowerSpout products are covered in detail in the new Technical Manual.

Aurora PVI-4000 wind interface for 230 VAC markets. Aurora PVI-7200 wind interface for 120 VAC markets. The wind interface is only needed for cable voltages above 200 VDC; use the PLT350 in such applications. 	The UNO-2.0-I-W and UNO-2.5-I-W are the latest single phase string inverters for wind and hydro applications. 

It should be noted that our global dealers have reported good results with many makes of grid connect inverter, and most will work well. The main issue is that many makes do not warrant their equipment for hydro input and have only be designed and tested on solar PV panels.

4. Final assembly of your PowerSpout turbine

TRG and PLT turbines from 2013 are shipped fully assembled other than jet holders and PVC manifolds (if ordered).

LH turbines are shipped fully assembled except the PMA. The PMA is packed in a box inside the turbine box to give extra drop protection.

As soon as you receive your PowerSpout please unpack it and check your turbine for transit damage. Please inform the dealer from which you purchased the turbine immediately if you find any parts that appear to have been damaged in transit or are missing. If the turbine is being freighted on to the end client then you must check it prior to this next freight leg.

If you purchased your PLT turbine prior to April 2013 then you should refer to earlier versions of this manual (e.g. February 2012, version 1.3) as there have been some changes. See our web site archive section. http://www.powerspout.com/archive/

Videos of full turbine assembly are also available from www.powerspout.com. Product manuals are updated on a regular basis and should be used in preference to video material for ensuring compliance with the latest updates.

4.1.1. Jets

Your PLT/TRG turbine will come delivered with pre-sized jets, based on calculations supplied; final adjustment in the field is often necessary to optimize output as part of the commissioning stage. As flow conditions change throughout the year, jet sizes may need to be altered to optimize turbine output.

Extra jets are supplied with your turbine and spares are readily available from your PowerSpout dealer.

4.1.2. Adjustable jet options

Adjustable spear jets are available (to order) for the PowerSpout PLT. However, adjustable jets may cause more problems than they solve and demand for them is generally low.

Adjustable spear valves as shown can be supplied for a surcharge and operate in the range 3-14mm (circular jet equivalent).

They allow you to quickly adjust the flow rate to suit the stream flow. However, there are some disadvantages of adjustable spear valves:

- They are more easily blocked by debris in the flow.
- The efficiency of the jet (and hence output Watts) is a little less.

4.1.3. Cutting the jets to correct size

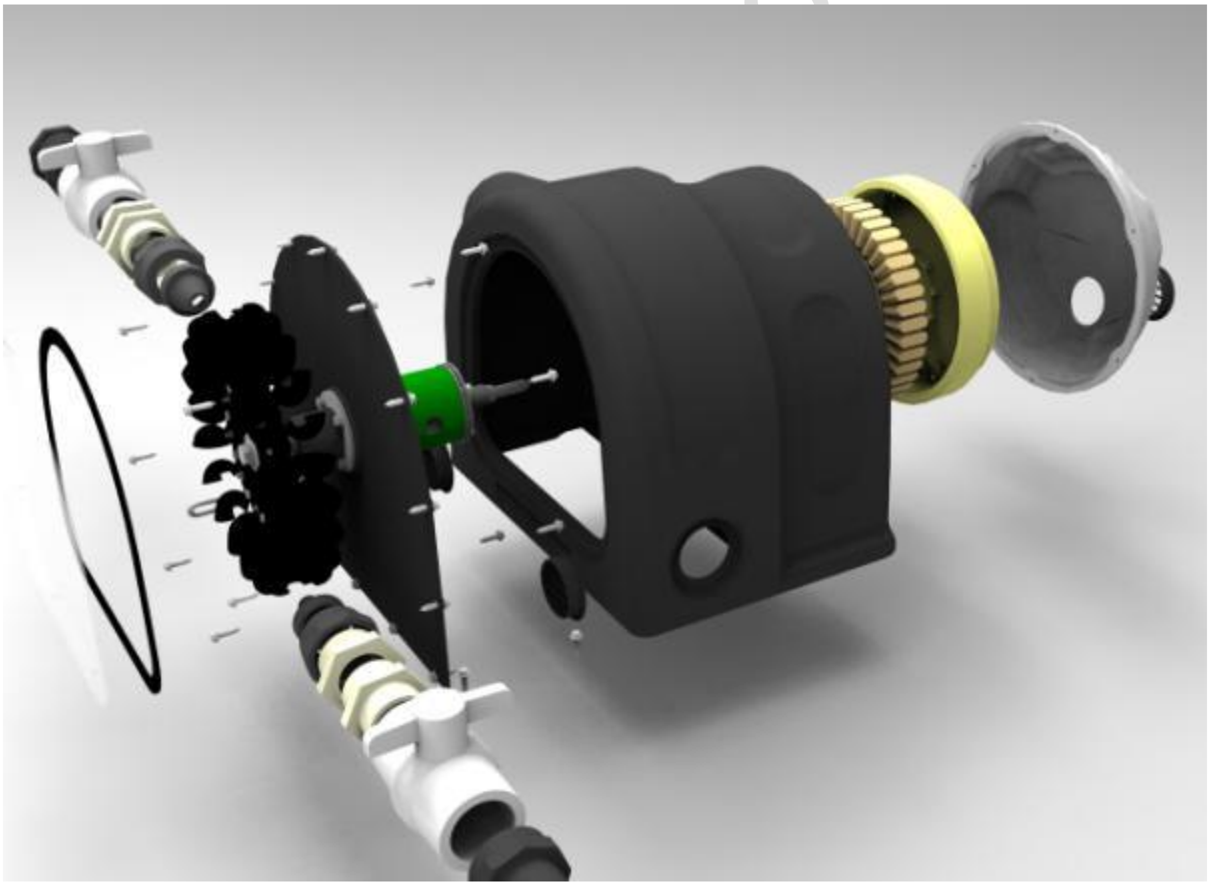
The plastic tapering jets can be cut on site with a sharp knife. The jets are inexpensive so a trial and error approach can quickly determine the correct jet size. It is important to cut your jet to the correct size cleanly so that the water jet can break smoothly without spray. We recommend using a sharp knife and paring away at the jet, cutting from the inside edge out. With practice a very accurate and sharp edged jet can be prepared in the field. The taper gauge and knife supplied in the optional PLT tool kit helps to make this task easy.

Holding the plastic jet within a spare holder sleeve and end cap will ensure the jet is held firmly while you cut it to size. Take care as it is easy to slip, which could result in a significant flesh wound. If you have Kevlar gloves wear them.

Cutting the jet to size and checking it with the taper gauge

If you have plenty of water and want to generate the most amount of power that your pipeline can deliver (before pipe friction chokes the output power) you should set the jet size so that the pressure on the gauge drops to 2/3 of the static pressure.

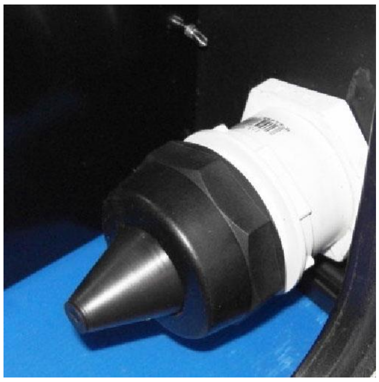
4.2. Pelton (PLT) turbine assembly



Turbine arrives fully assembled, other than the jet holders. This exploded diagram will assist you once it comes time to service the turbine

4.2.1. Installing jet assemblies

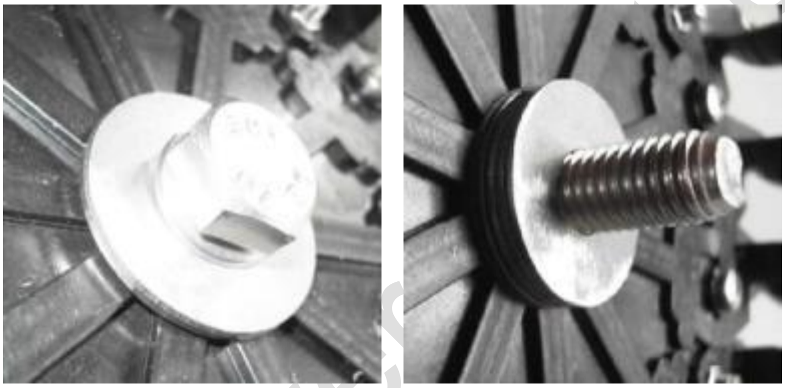
It may be necessary (depending on the PLT model) to remove the Pelton runner in order to install the jet assembly as shown. If so then follow the procedure below in reverse order. The PVC jet sleeve is mounted inside the turbine with the PVC ball valve on the outside. Note that there is also a Jet ‘O’ ring that fits on the jet sleeve thread after being inserted through the casing. This ‘O’ ring ensures that the valve and jet sleeve seals onto the casing and does not leak. The ‘O’ ring is on the **outside of the casing**. Grease all threads.



Jet assembly in position

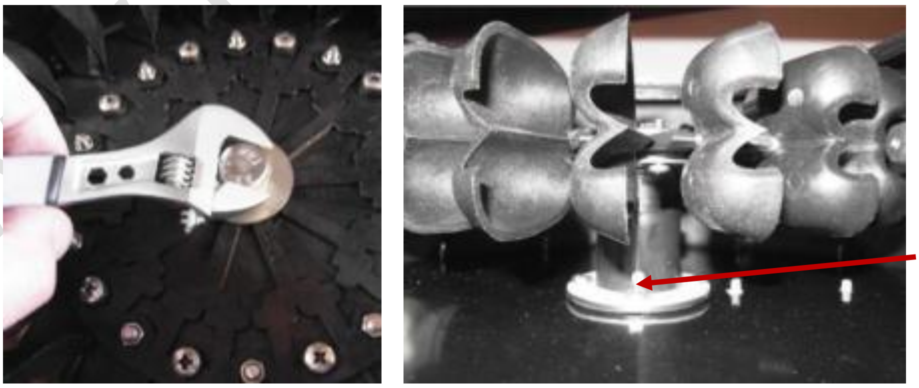
4.2.2. Installing the Pelton runner

Ensure that when you mount the Pelton runner you fit it the correct way round. The water jet should hit the splitter (the straight knife edge) of the Pelton spoons.



Pelton fixing washers front and rear views

- Insert M12 bolt, spring washer and washers as shown.
- Install alignment washers as shown. Note you will need to alter the position of the washers until the centre of the jet aligns with the splitter of the Pelton spoons.
- Attach the Pelton runner to the shaft as shown below.



Top hat drain hole points down

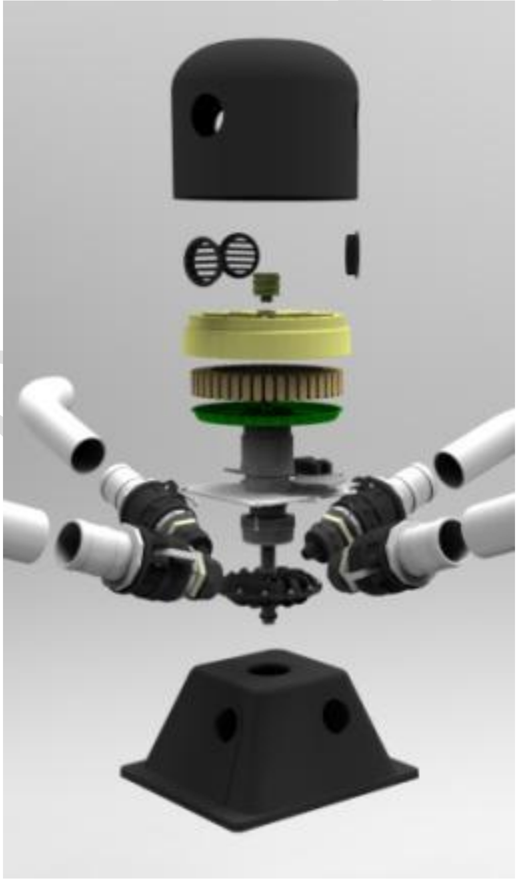
Attach Pelton runner to the shaft and tighten to 50 Nm (35 lb/ft).

Ensure that the drain holes in both the slinger housing top-hat and the bearing block are pointing downwards.

4.2.3. Pelton Runner Alignment

You can view the Pelton runner by looking through the jet as shown. The water jet needs to hit the middle of the Pelton spoon splitter. If the jet is misaligned then pack the runner across using the washers supplied. You can see in the picture that the Pelton runner needs packing to move the rotor to the left.

4.3. Turgo (TRG) turbine assembly

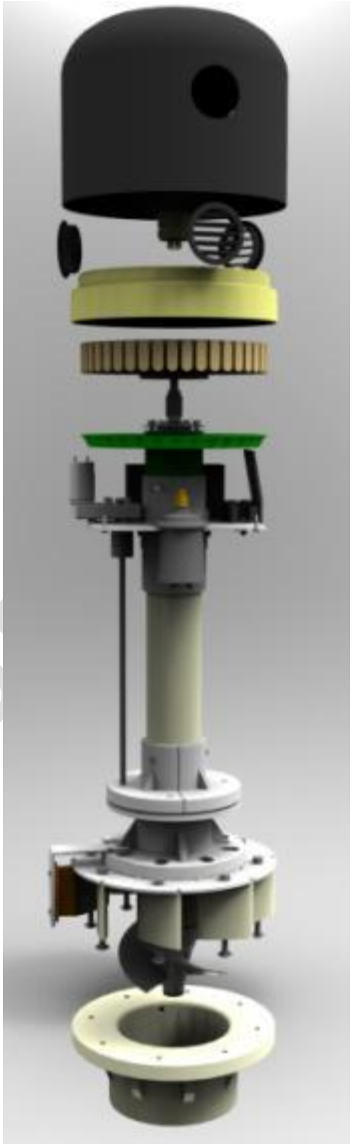


Turgo turbines are fully assembled apart from the 4 jets.

These are assembled as shown. Grease all the threads and tighten until snug. This is best done with the turbine upside-down.

There is a TRG case study that will further assist you with the installation of this product.
www.powerspout.com/trg-manuals/

4.4. Low Head (LH and LH Pro) turbine assembly



The LH and LH Pro are fully assembled apart from the PMA stator and rotor.

To attach the stator and rotor follow this procedure:

- Remove the top black fairing
- Open the PVC enclosure that houses the rectifier
- Remove the 4 fixings and washer from the bearing block
- Remove the SD stator from the wrapping
- Attached the 3 wires to the rectifier and tighten; the order of the wires is not important
- Replace the lid on the PVC enclosure
- Place the stator over the shaft
- Align holes in stator with the bearing block holes
- Place the large washer on the stator
- Insert the 4 fixings and tighten
- Insert the extractor knob in the SD rotor
- Grease the splined shaft
- Place the SD rotor over the shaft
- Tighten the knob; this will draw the SD rotor over the stator
- Finger-tighten the knob only.
- Replace the black fairing

4.5. Electrical checks with covers off - before install.

These tests ensure you have completed the output connections and have no unwanted connections through wiring faults to the PowerSpout chassis.

1. Connect a DC volt meter to the DC output from the generator.
2. Use an electric drill with a 19 mm (3/4") socket to spin the magnetic rotor by slowly driving the M12 bolt that fixes the wet side rotor into position. Never drive the PMA using the plastic rotor extraction knob as you will damage the PMA.

3. Watch the voltmeter and increase the drill speed until the voltmeter reads close to your desired operating voltage.
4. The turbine should spin freely with little noise. LH turbines will be tight and require 1-2 hours of running in before they will spin freely.
5. 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 3 above.
6. The turbine should spin freely with little noise and the ammeter must read zero.
7. Repeat steps 5 and 6 above but with the ammeter between the chassis ground connection and positive output.

5. Where and how to site the turbine

5.1. Regulations and good practice guidance

In many jurisdictions around the world electrical work on equipment with operating voltages over 50 V AC and 120 V DC must be carried out by a registered electrical worker. The voltage limits are defined as the maximum voltage across any two points in the system.

For more information refer to http://en.wikipedia.org/wiki/Extra-low_voltage

In most Australian States and New Zealand there are no formal constraints as to who can work on ELV systems. Generally most countries allow individuals to work on DC systems up to 60 VDC as telephones operate at up to this voltage.

The PowerSpout PLT/TRG 14/28/56C meets the requirements for unregistered electrical workers in many countries if connected directly to your battery bank and PWM diversion regulation is used. If in any doubt ask your countries electrical regulator what you can legally do yourself.

The PowerSpout PLT/TRG 40/100C meets these requirements for unregistered electrical workers in New Zealand (NZ) and Australia (AUS) when connected to MPPT regulators.

For higher voltage PowerSpout PLT/TRG options please ensure that an electrician, who is also a registered electrical worker, completes your installation.

All LH turbines require installation by an electrician.

In many cases you can install the equipment yourself and then have the electrician complete the final hookup and turn on, but you should talk to your electrician before you start. The electrician will be responsible for your workmanship and may be reluctant to certify your workmanship, which may not be accessible after the work has started.

5.2. Siting your PowerSpout turbine

Some tips for locating a good site for your turbine include:

- Choose a place that is accessible. If necessary make steps and put in rope handrails to ensure that your turbine can be accessed safely.
- Choose a site that has the most fall, even if it lengthens the cable needed to send the power to the usage site.
- In many situations it is possible to divert the pipeline closer to the home to provide a pressurised water supply as well as electrical generation. In combined power and water schemes electric power is often employed to UV treat the water. In some cases the PowerSpout is only used for UV treatment at remote water storage tanks for small communities; this is often more cost effective that installing grid power to the site.
- Place it as close to your battery bank or point of grid connection as possible.
- Hydro turbines do make some noise, so keep them at least 30 m from your home.
- Keep your PLT/TRG turbine as low as possible while ensuring that it is above maximum river flood level.
- Your PLT/TRG turbine should be positioned at least 50-100 mm above ground height to allow exhaust water to escape.
- Choose a site where the exhaust water can be returned back to the river cleanly.

The distance between your turbine and batteries has a significant bearing upon the cable size required. To keep cable size (and hence cost[3]) down we usually recommend that off grid clients install 48 V DC battery systems if they are using a PWM regulator. In such cases we generate a voltage at the turbine about 5% higher that your battery voltage (due to voltage sag in the cable). Turbine sites up to 500 m away are often economically viable using 2-core aluminium cable.

The PowerSpout TRG/PLT80 with a Midnight Classic 250 offers an opportunity to reduce the cost of the cable by generating at a higher voltage. For example the PowerSpout PLT80 generates and transmits at about 80 V DC to a MPPT regulator close to your battery bank. If you have a 24 V DC battery bank this can reduce the cost of the cable by up to 80%. The regulator changes the voltage to suit your 12/24/48 V DC battery bank.

The benefit of this approach is that existing 12/24 V DC systems can be cost effectively integrated with the PowerSpout PLT/TRG. For example, solar PV systems can struggle in winter time when you have viable stream flows. Adding a PowerSpout to your system can often eliminate the need for fossil fuel generation support, as solar and hydro resources tend to complement each other.

Good PLT installs

Good TRG and LH install

[3] EcoInnovation holds considerable stocks of cable at very good prices for our NZ customers

5.2.1. Cable sizing

The Advanced Calculator www.powerspout.com/calculators/ will work out the cable size for you for a given % loss or the % loss for a given cable size. This tool clearly demonstrates the effect that increasing the cable % loss has on the cable size (and hence the cost of the cable).

Try to keep losses as low as possible, particularly if you have limited hydro generation and need all the power you can get. A loss of 5% in cables is normal. Cables with losses greater than 10% should only be used in cases where the cable cost is very significant in the total equipment cost and/or where you can generate plenty of power (more than needed).

5.2.2. Connecting two small streams into one PowerSpout

We are often asked if two small streams can be piped into a common two jet turbine. This is not recommended, unless the head and pipe friction losses for each pipe are very similar. Generally we would advise two turbines, one for each site. The electrical output of both would then be joined together into a common supply cable.

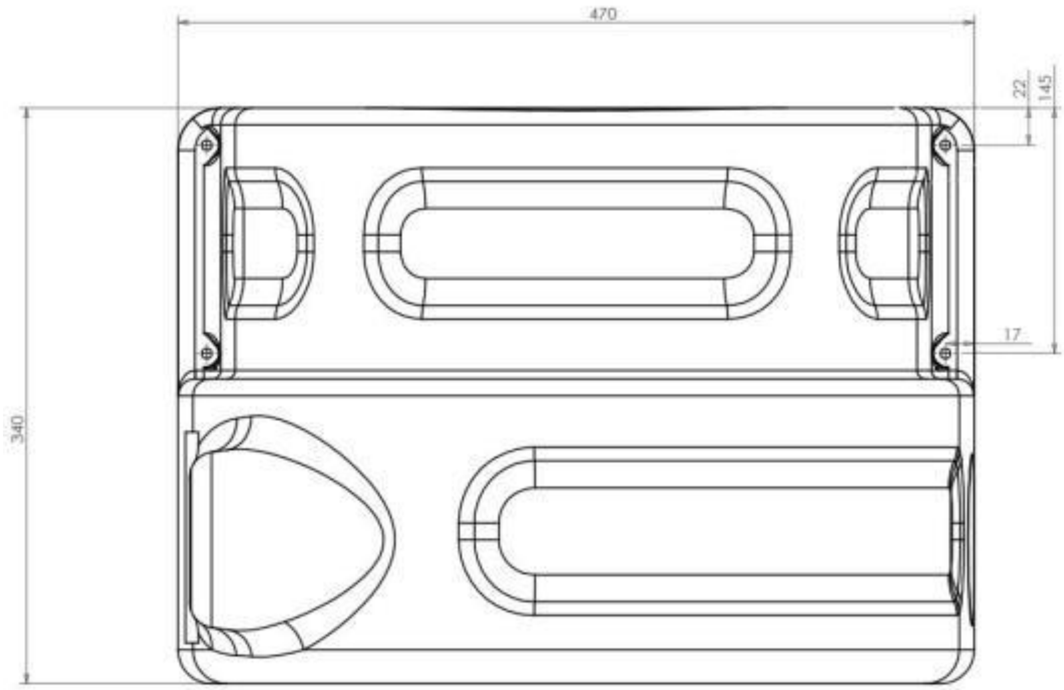
Dual install, one unit runs on 30m (98 ft) head the other 10m (33 ft) head

5.3. Mounting

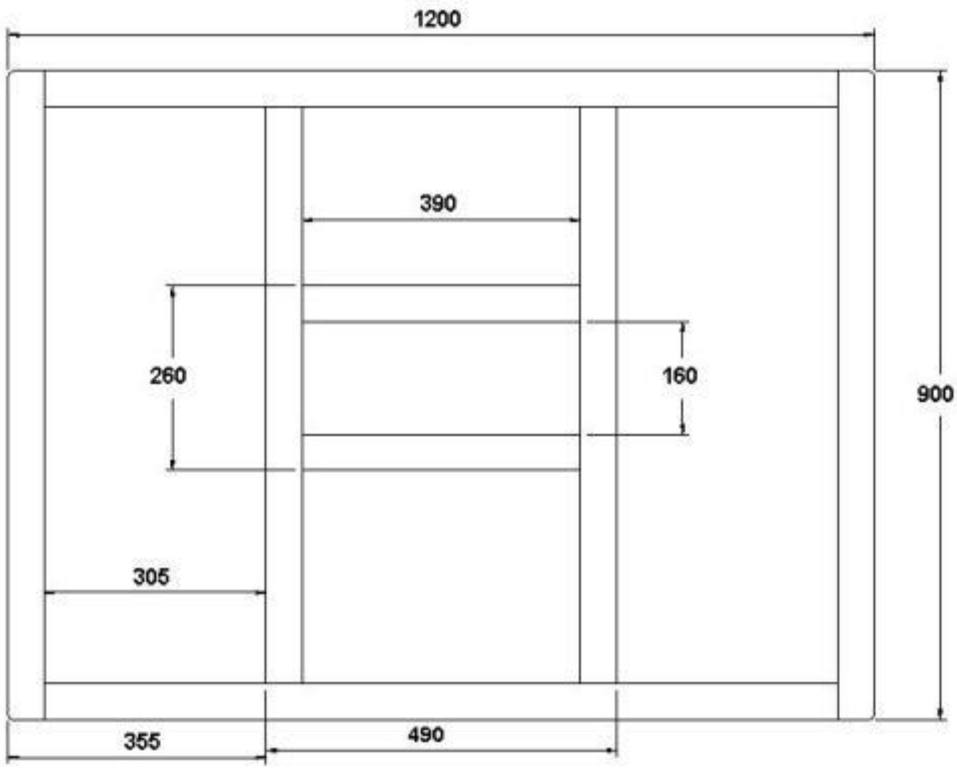
Clients often want to build the base for their turbine while their order is still being processed. It is best to wait until your turbine has arrived before you complete this detail. There is nothing to beat having the turbine on site to avoid errors. Do not try and be too clever. What follows is helpful dimensional information in the planning of your turbine location.

5.3.1. Mounting PLT

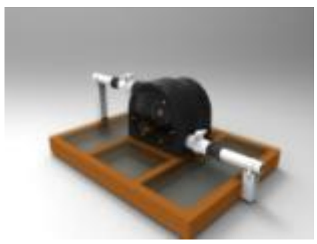
The main case dimensions (mm) and the four holes in the PowerSpout casing for turbine mounting are illustrated in the plan view below. Fixings are provided with the PowerSpout for connection to a timber framed base. These dimensions are sufficient to plan for the mounting of the turbine prior to its arrival on site. A PowerSpout PLT unit is 400 mm high.



Plan view of a PowerSpout turbine

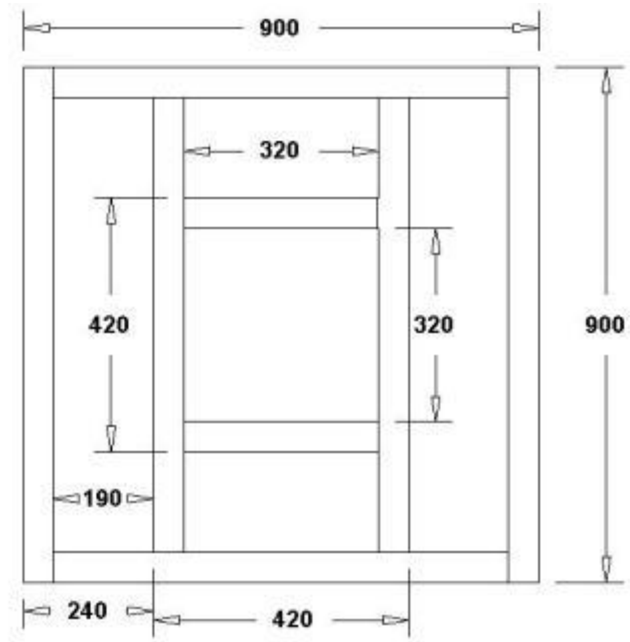


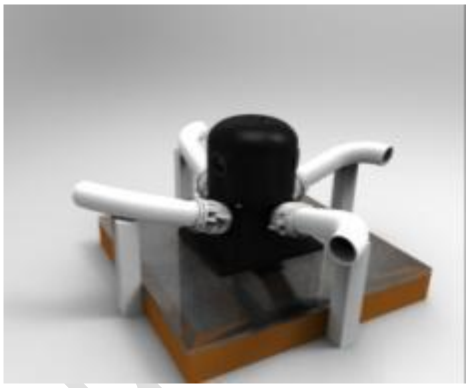
A framed timber base made from 100x50 timbers and covered in 12-17mm thick plywood sheet on top with a hole 160 x 390 mm cut for the exhaust water is a typical PLT turbine base. Remember to drill a hole so that condensation can drain from the turbine dry side (refer to section 5.4).



5.3.2. Mounting TRG

A framed timber base made from 100 x 50 timbers and covered in 12-17mm thick plywood sheet on top with a hole 320 x 320mm cut for the exhaust water is a typical TRG turbine base. A PowerSpout TRG unit is 430 mm high.





A timber or concrete turbine base is less likely to produce resonant noise issues than say a steel or aluminum base.

5.3.3. Inside turbine mounting

At sites where no water leakage can be allowed (slip hazards for staff etc) you can attach sealing strips of adhesive neoprene to the base of the turbine before bolting it down to ensure the turbine is completely sealed around the base. On the PLT turbine the hold down fixings are at the rear of the case, to ensure complete sealing at the front of the turbine under the glazing you can insert screws (remove front glazing to do this) through the inside plastic lip to pull down the case at the front and ensure a tight seal all round.

Fixing a turbine to a timber base

We also advise that for indoors situation you have a perimeter lip on your turbine base. Some water seepage is inevitable over time, a lip will trap this seepage and it can then be diverted to exhaust rather than drip on the floor.

In situations where there is a high risk of dropping tools into the floor sump you should cover the floor opening with stainless steel mesh so that any dropped tools or parts will not disappear under the floor. This tends to apply to industrial sites, including common applications such as city water intake reservoir facilities for control valves and instrumentation power, and power for large hydro schemes at the intake. This precaution is not required at domestic sites where the turbines are typically mounted outside.

A mesh (or exhaust pipe) over the exhaust water opening will prevent access into the rotating parts from underneath, thus preventing serious damage to the

fingers of inquisitive children. It is important that the installer makes the site safe and that no rotational or electrical hazards exist.

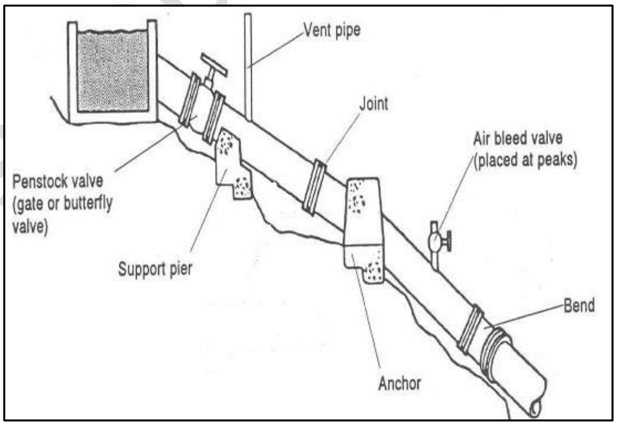
5.3.4. Pipe Supports

Pipes full of water are heavy and will sag over time. It is very important to provide support to all pipes close to where they connect to the turbine. Pipes are normally supported as follows:

- A steel fence post, also called a T-post, a Y-post or a star post. These steel posts are hammered into the ground either side of the pipe. There are holes in the posts and timbers can be used to sandwich the pipes in place. Screws are used to hold the timbers to the posts.
- Aluminium rails and connectors commonly used for the mounting of solar PV panels can be used to support flexible pipes and provide adjustment as shown.

5.3.5. Pipe thrust blocks

On larger hydro schemes using rigid pipes, thrust pads and anchor blocks may be required to prevent movement of the pipe work. On these larger hydro schemes professional engineering advice must be engaged to calculate the supports needed.



5.4. Turbine Protection

The PowerSpout is encased in a very durable LDPE housing, ensuring all internal parts are protected from rain, rodents, children and UV etc.

The LDPE enclosure also helps reduce noise and dampens any slight vibrations. The main benefit, however, is that there are no exposed rotating hazards that might catch the fingers, clothes or hair of interested children - ensuring a very safe product. Access to the rotating parts is only achieved with the use of a tool to remove the covers. All tools to do this for the PLT turbine are supplied in the optional tool kit.

The internal aluminium bulkhead has been designed to help control the temperature in the enclosed generation compartment of the PowerSpout. The Smart Drive generator has a peak efficiency of up to 80% and will get warm. Heat is dissipated from the generator core by rotor air flow. The water cooled aluminium bulkhead and cooler outside air acting together ensure sufficient cooling for up to 1600 Watts of generation per turbine.

2 x side air vents
1 x rear lid air vent

This warm enclosure helps to ensure that the generator and electrical junction box do not become corroded from moisture ingress.

The generator temperature should always to be checked as part of the turbine commissioning by the installer, particularly if installed in very hot climates.

In some environments moist condensing air will result in heavy condensation on the bulkhead. This will run down the bulk head and out of the drain hole. You must ensure that a 15-20mm unrestricted hole is drilled at the lowest point to ensure that condensation can drain away freely.

6. Ensuring good water supply

The online advanced calculator at www.powerspout.com/calculators/ will have advised the appropriate size of pipe based on the site data you entered. You should position the PowerSpout to obtain the greatest fall possible in the shortest distance. Try to lay the pipe to avoid high spots in the line that might trap air bubbles. If this is unavoidable you will need to place a bleed valve at the high point in the pipeline to purge air. Air locks in the line will significantly affect the power output of the turbine. The longer the pipeline the more of a problem this tends to be. Pipelines over 1 km long can be problematic if there are many high spots trapping air.

6.1. Pipe sizes

Many different standards exist for pipe sizes which vary depending on industry and geographical area. The pipe size designation normally includes two numbers - one that indicates the outside diameter (OD) and the other that indicates the wall thickness. American pipes were categorized by inside diameter (ID) in the past but this was abandoned to improve compatibility with pipe fittings and joiners that usually fit the OD of the pipe.

Inside diameter is critical for calculation of pipe friction loss since a variation of as little as 1 mm can have a very significant effect on the output power of the turbine. Take care with which diameter you are referring to since if calculations are done based on pipe ID and the pipe is then purchased based on OD your turbine will generate less power than predicted due to increased pipe friction. Pipes below 40 mm ID cannot normally be used as friction losses are too high.

Pipe sizes commonly used with our hydro products include:

- PVC for larger sizes based on OD (110-300 mm normally)
- MDPE or HDPE based on OD (50-110 mm normally)
- LDPE based on ID in NZ/AUS (40-50 mm normally)

MDPE and HDPE pipes

Pipes have different pressure ratings so a given pipe size is often available in a number of pressure ratings. These different ratings are achieved by either altering the material grade or increasing the pipe wall thickness. The OD is kept constant so standard pipe joiners still fit.

In NZ for example, polyethylene (PE) pipes can be purchased from 35 m (50 psi) head rating to 160 m (230 psi) head rating. Some sizes are based on ID but most are based on OD sizing, so be careful and double check with your supplier the OD and ID of the pipe.

6.2. Pipe criteria

A pipe should be:

- Equal to or larger than recommended from the calculations that specified the output power (Watts) of your turbine.
- Cost effective, tough and durable for 20-50 years.
- Able to handle the static pressure of the head of water.
- Able to handle the running head x a factor 1.5 to allow for water hammer
- Easy to lay and bend around obstacles.
- Able to be purchased in long lengths.

The PowerSpout PLT has a maximum running head rating of 130 m and allowing for up to 30% pipe friction loss, sites up to 160 m static head can be used. A higher water head can be used successfully but with reduced lifespan and warranty.

MPDE and HDPE pipes can work in this range. The range and the fact that they are durable, low cost and commonly available in a wide range of sizes, pressure ratings and lengths makes these pipes the obvious choice for the PowerSpout PLT turbines.

Remember that you can change the pipe grade to minimise costs. For example, if you have a 100 m head you can use a length of low grade 35 m (50 psi, 3.5 bar) pipe, a length of 6 bar, then 9 bar and finally 12 bar. Laying 12 bar pipe all the way would almost double the cost of the pipeline. If you do this the pipe ID will change so the calculated output may not be correct. To avoid disappointment use the smallest pipe ID in the online calculator and your turbine should generate a little more than predicted.

Table 1. Pipes common in NZ (Rural Direct)– indicative prices 2013

Pipe OD mm	Pipe ID mm	Material	Pressure rating PSI	Pressure rating M	Pressure rating kPa	Pressure rating Bar	Approx cost/m NZ$	Approx cost/ft US$
57	**50**	MDPE	102	70	700	7	4.00	1.05
63	53	HDPE	131	90	900	9	5.00	1.30
63	50	HDPE	174	120	1200	12	7.00	1.80
75	65	HDPE	116	80	800	8	6.80	1.75
90	79	HDPE	116	80	800	8	8.60	2.25
110	94	HDPE	116	80	800	8	11.50	3.00

Bold indicates the change from ID to OD sizing

6.3. PVC pipes

PVC pipes are widely used in applications ranging from low cost road culverts to mains pressure water distribution networks in cities. PVC pipe sizes vary around the world (see Annex II: Common PVC pipe sizes) and frequently the available pipe sizes differ between countries. Most countries seem to either use the American or British pipe size dimensions, or develop their own standards for pipe sizes.

PVC pipes are often more cost effective than PE pipes in sizes above 110 mm. As PVC pipes glue together the cost to join them is low, so short lengths can be used (normally 4-6 m). They can be bent in-situ by applying heat to the tension side of the bend. We therefore see them mainly used at lower head sites where more water flow is available and often on sites running multiple turbines from a common pipe line.

PVC is not as durable as PE and can be shattered by falling rocks and trees. Where these risks can be managed and the price is right for the application they are commonly used. PVC left in direct sunlight will weaken and become brittle with age.

We see larger PVC pipes (150 mm and larger) used for lower head applications below 30 m and often with less than 200 m of pipe needed. Our PowerSpout TRG turbine has been specifically designed for this application.

PVC culvert grade farm pipes glued together are the lowest cost PVC pipe you can obtain.

There are also larger sized HDPE culvert pipes up to 450 mm but these often require expensive joiners as they cannot be glued together, though plastic welding is possible.

6.4. Pipe myth

We often get told that the pipe has to reduce in size in order to keep up the pressure. This is a huge misconception and arises from confusion with irrigation schemes. If you decrease the pipe size you decrease the pressure, you do not increase it.

The pipe for an irrigation scheme supplying many farms will reduce in size as the last farm has to convey a smaller amount of water. The start of the pipe has to be larger because it has to convey the water needed for all the farms on the line. The pipe myth arises because pictures of irrigation schemes have often been incorrectly used to depict hydro schemes.

People also confuse pressure with velocity; if you increase the velocity by reducing pipe size the pressure will decrease. Reducing pipe size increases water velocity, which increases pipe friction and reduces even further the pressure in the pipe, resulting in less power generation.

Another common myth is that pipe bends are the cause of a lot of losses. In reality, relative to the long hydro pipe, a few correctly sized bends will make no noticeable difference as most friction loss occurs in the long penstock.

6.5. Manifold pipe sizes

For flows up to 3l/s per jet, manifold pipe size ID should be 50mm or larger
For flows up to 5l/s per jet, manifold pipe size ID should be 65mm or larger

6.6. Laying and securing pipes

When laying the pipe try to do the following:

- Install a good strong intake structure.
- Secure the pipe against flash floods during the installation process.
- Obtain a good fall in the first 5-10 m of pipe.
- Lay the pipe on a gradual, always descending line where possible.
- Keep the number of high points to a minimum and vent these to avoid air locks.
- Avoid siphon systems if possible.
- Once the pipe is in position, securely fasten the pipe line to rocks, trees, or ground anchors to prevent it moving down the incline or being washed away in flood events.

6.7. Intake design and placement

The intake for a PLT or TRG turbine should be positioned at the base of a small set of rapids typically no more than 300-500mm high (to allow room for a sloping intake screen as shown below). Water flows over the top of the screen falling into the chamber below that feeds the supply line. Leaves and twigs are washed away with surplus water preventing the intake from blocking.

Intakes often need to be made to suit each site. The examples below illustrate different ways to do the same job. The picture of the angled guides and screen is the recommended way to make a good strong maintenance free intake screen. You must ensure you securely attach the intake screen to the riverbed by driving galvanized stakes into the ground or attaching to large boulders with brackets, bolts and cement.


Angled screen


Flat screen in road culvert


Stainless steel perforated tube


Perforated galvanized cable tray intake


Angled guides and screen - the best!


Perforated box in concrete

Commercial intake on road culvert

Perforated box

Stainless woven tube from scrap yard

Intake made from stainless steel scrap

Intake screens such as these can be purchased. However, they are easy enough to make to suit your site. You can use a stainless steel mesh and a plywood box, make sure you support the screen from behind with stainless steel rods/frame otherwise during floods the mesh will be pushed in. A fine, smooth stainless steel gauze with a hole size typically 1-3mm should then be placed over the stronger frame. This smooth gauze will allow debris to slide off easily and prevent small aquatic life forms from entering the pipe line.

Some ideas for intakes made from scrap stainless steel components

6.8. Water diversion and return

Micro-hydro systems may potentially affect:

- Plants and fish in the water.
- Plants and animals beside the water.
- Stream banks and surrounding land.

You must check with your local authorities to see if you need to obtain consent either to build any structures or to take/return water from a waterway. The impact of your system on stream ecology will usually be considered during this process. EcoInnovation have some consent application examples for NZ that we can email you that might help in your application.

Most micro-hydro systems divert a fraction of the main water flow through an intake screen to the generator. A good intake will lead to negligible erosion and the screen will minimize the chance of fish, leaves, etc entering the supply pipe. Taking less than 50% of the minimum seasonal flow rate in your water source means there is no impediment to fish moving up or down stream and hence gives aquatic life a better chance to survive.

You should take care to ensure that the exhaust water from the turbine can return to the river without scouring the bank of your waterway. Line the bank with concrete, timber or plastic sheet as required. Some systems utilise the exhaust water for irrigation, allowing the water to percolate through the soil before returning to the waterway.

Good example showing:

- Concreted river bank
- Timber boards to prevent river bed erosion

6.9. Connecting the pieces

6.9.1. Connecting your pipe to the PowerSpout

No penstock pipe fittings are provided, as every site is different. The ball valves supplied have either 2” female BSP threads or 2” female NPT threads supplied.
NPT valves are automatically supplied to the USA and Canada. All other countries are sent BSP valves unless you advise us otherwise at the time of order.

For larger pipe sizes we have pipe joiners available for purchase that fit onto MDPE and HDPE pipe with the following OD: 63 mm (2.5”), 75 mm (3”), 90 mm (3.5”) and 110 mm (4.5”). These larger fittings if needed are supplied for an extra charge.

6.9.2. Advice for USA and all countries that use NPT threads

Fittings obtained in the USA will have 2” National Pipe Tapered threads (NPT threads). A PowerSpout sent to these destinations will have a ball valve with a 2” BSP thread on one side and 2” NPT thread on the other side. These clients connect to our turbine and the pipeline by buying a suitable fitting locally.

7. Getting the best from your batteries

7.1. Battery type, size and life

Flooded or wet cells are the most common lead-acid battery type in use today. They are available in a wide range of sizes and are often the most cost effective solution.

- Light duty batteries are for cars (thin plates with lots of surface area).
- Heavy duty batteries are for trucks and boats
- Deep cycle batteries have thick plates and more acid capacity, suitable for renewable energy applications.

Gel cells are sealed and cannot be re-filled with electrolyte. Controlling the rate of charge is important or the battery will be ruined.

Absorbed Glass Mat (AGM) batteries, instead of using a gel, use a fiberglass like separator to hold the electrolyte in place. Since they are also sealed, controlling the rate of charge is important or the battery will be ruined.

Many people are often confused by terms such as voltage (V), amp hours (Ahrs), Watts (W) and Watt hours (Whrs). Your batteries store energy (power is the rate of delivery of energy)[4].

Energy stored in a battery (Watt hours) = amp hours x volts. For example:

- A 6 volt 225 amp hour battery can store 6 x 225 = 1350 Watt hours
  this will have a mass of about 30 kg = 66 lbs.
- A 12 volt 200 amp hour battery can store 12 x 200 = 2400 Watt hours
  this will have a mass of about 55 kg = 120 lbs.

Do not make the mistake of evaluating batteries only by amp hours as this is not an indication of total energy storage. Battery weight is often a good measure by which to compare batteries. This quality can be used to help spot the over enthusiastic sales person.

7.1.1. What is electricity and what is a battery?

Electricity is the flow of electrons along a wire. Metal is a good conductor of electricity as the electrons in each atom of metal are free to move from one atom to another.

Consider how difficult it is to store the energy of a car that is moving. Understanding the fact that electricity is the flow of electrons helps us to understand that electricity is also difficult to store as it is energy in motion.

Batteries do not store electricity as such but use the flow of electrons to alter the number of electrons in the chemicals inside the battery. Then when the battery is discharged the chemicals return to their original state. However, the chemical process means that batteries degrade with use and time.

Renewable energy systems normally use batteries based on lead-acid chemistry as they are still the most cost effective and readily available type. Lead-acid batteries are made from plates of lead in a solution of sulphuric acid. While the discharging and recharging of lead acid batteries is a reversible process all lead acid batteries lose health when not charged.

[4] For further information on energy and units refer to the PowerSpout Technical Manual

The car battery is a lead-acid battery. A car battery is designed for starting a car's engine and so has thin plates to provide as much surface area as possible, allowing the chemical reaction to occur in a short time. This type of battery can provide large currents to meet the high power demands of starting an engine. As the duration of engine starting is very short the total amount of energy is not that great. However, automotive batteries suffer when significantly discharged. The thin plates are quickly damaged and may even disintegrate. The plates also have a high resistance, so lose energy, making a car type battery less efficient as an energy storage device. They can be employed in some hydro situations where there is plenty of power to meet the base load of the home, with the battery merely providing storage for short-duration peak loads.

A deep cycle battery designed for standby energy systems has heavy plates that are much more robust against deep discharges. However, a deep cycle battery has limited surface area and cannot convert stored energy as quickly. Thus deep cycle batteries must not be subjected to heavy currents or there will be damage to the battery.

For battery bank sizing we generally refer to the 10:10:10 rule of thumb.

For a 10 year life:

- Cycle batteries no more than 10% depth of discharge (DOD) each day.
- Limit the maximum sustained draw to 10% of battery capacity.
- Limit the maximum charge rate to 10% of battery capacity.

For example for a hydro turbine generating 500 W (0.5 kW) into a 48 V DC battery bank that consists of two banks at 200 Ah each:

- DOD each day = 10% x 2 x 200 x 48 = 1920 Whrs.
- Maximum sustained draw of 10% x 200 x 2 x 48 + 500 = 2420 W for a time not exceeding 1 hour.
- The charge rate is 500/48 = 10 A, maximum allowable = 10% x 2 x 200 = 40 A. This 40 amp limit is a concern only when backup charging from a gen-set.

Average daily draw from the battery bank (allowing for 10% battery loss and 10% inverter loss 500W x 0.9 x 0.9) is 400 W = 9.6 kWh/day (0.4 kW x 24 hrs/day) total consumption. This is normally fine for an energy efficient home using a 3 kW inverter. If you wish to draw more than 2.42 kW for a sustained period you should install a larger battery bank and inverter.

In practice battery life is generally around 3-12 years, with 7-8 year life typical. Batteries are occasionally flattened accidentally and this can have a significant impact on their total life.

Although there are many instruments to help determine battery state of charge, the most reliable method is a hydrometer. A hydrometer can only be used with wet cell batteries. Check your battery state of charge weekly and keep a log book. Either increase generation or decrease consumption if your state of charge is falling. You need to generate at least 20% more than you use to allow for system losses.

Two parallel battery strings are better than one - if you do get a loose connection or forget to turn off the hydro turbine when working on your system you may not face any ill effects. Generally it is regarded as good practice not to have more than three parallel banks.

Connecting batteries in series increases the voltage but not the amp hour capacity. Connecting batteries in parallel increases the amp hour capacity but not the voltage.

7.2. Battery housing

Batteries need to be understood for what they are. Here are some key points:

- Batteries operate best when kept cool, around 10ºC to 20ºC, but never freeze them. Fully charged batteries are hard to freeze but flat batteries are more easily frozen.
- Batteries are full of sulphuric acid, lead and small amounts of other chemicals which must not leak into the environment.
- Chemicals must not fall on or into batteries as this may cause a chemical reaction. Rain water should be avoided as it may wash other material into the cells.
- Batteries store energy in chemical form and can release this as electricity very quickly if there is a short circuit. A short circuit can convert a steel ruler or spanner to molten metal spray and cause significant personal injury. Protection from falling objects is required.
- Batteries are heavy and need a solid flat supporting surface. Good access for installation and replacement to avoid lifting injuries is required.
- Batteries give off hydrogen and oxygen gas during charging in the correct proportions for an explosion. Ventilation is required.
- Batteries are not maintenance free. All batteries need to be measured individually for voltage and flooded batteries also need to be checked with a hydrometer.
- Batteries need to be checked for electrolyte level regularly and topped up. If this is not done they will be ruined and the risk of explosion increases.
- It is important to plan the accommodation of the batteries so that topping up with water is easy to do. Batteries will use more water as they age.
- Consider fitting battery recombination vents, these catalytically recombine the hydrogen and oxygen gasses into pure water that is returned to the battery cell. These significantly reduce the need to top up with water, watering intervals can be as long as 12 months with such vents fitted.
- Batteries are not for anyone to touch. Sufficient security is required to prevent a child or unknowing adult from tampering with them.
- Not everybody understands batteries. There are recommended safety signs that must be displayed above your battery bank warning people of the possible hazards.

You should always take care when working with batteries. Burns, acid splashes and electric shocks can occur. If you do not have sufficient skill and/or experience to install and care for this equipment you should engage a renewable energy professional to do it for you.

Myth: The old myth about not storing batteries on concrete floors is just that - a myth. This story has been around for 100 years, and originated back when battery cases were made up of wood and asphalt. The acid would leak from them, and form a slow-discharging circuit through the now acid-soaked and conductive floor.

7.2.1. Battery recombination vents/caps

Recombination caps can reduce the watering interval from every 3 months to once a year, they are well worth the extra cost.

The recombination of hydrogen and oxygen is an exothermal process in which heat is released. Wet cell batteries with recombination vents fitted will give the longest life (and little need to top up with water) of any lead acid battery type. Lives over 20 years are possible using top quality batteries. We strongly advise you size your battery bank correctly and fit recombination vents as shown.

7.2.2. Battery explosion hazards

On a day to day basis the largest danger is explosion of the gasses within the battery and not within the battery enclosure. Extreme care is required to avoid sparks in the vicinity of the battery that might ignite gas and cause a fire or explosion. Often too much emphasis is made about removing the gas from the enclosure and not on good working practices.

Do not install any fuses in the battery enclosure as this is a potential source of ignition.

Take care that the wrench/spanner handle does not bridge between terminals when connecting batteries as this can cause arcs, burns and explosions. Insulate all tools with insulating tape prior to any work on your battery bank.

A well ventilated enclosure to outside air will help to reduce battery temperature on hot days and in the very rare event of an internal battery short allow the explosive mix of hydrogen and oxygen to quickly leave the enclosure.

Due to the small risk of explosion and fire, batteries should be installed in a locked and ventilated enclosures away from dwellings.

The author of this section was once on a site where a client accidental dropped a large spanner on the battery terminals which then became wedged. Almost immediately the sparks from the shorted spanner ignited gases at the battery vents. After 2-3 seconds the first battery in the string exploded showering the owner in acid, as the owner turned to run out of the battery shed the 2nd battery exploded. This second explosion sheared off the battery terminals and the short circuit was broken.

Fortunately help was quickly on hand to wash the client of battery acid as the client was in a state of severe shock and unable to help himself or comprehend what had just happened.

The fire extinguisher in the battery room was quickly used to extinguish the fire that was being fuelled on hydrogen and melting plastic of the battery cases. Helpers on site quickly cut through the battery links to make the site safe, as at this stage is was no known to them what had caused the explosion.

The battery bank consisted of 2 x 48V DC strings of 500 amps hours each. The bank was in an adequate enclosure, but once the lid was opened there was no fall protection on the battery terminals.

This is how you can avoid such an event:

- Cover all exposed battery terminals with petro-tape. This will give protection in the event that a metal object accidently falls on the battery terminals while the battery lid is open.
- Insulate all tools handles prior to use.
- Have a large drum of water close by.
- Never work alone, make sure help is close to hand.
- Wear an overall and eye protection

7.2.3. Battery installation example 1

Here each battery is in a separate battery case. Each case provides ventilation and prevents accidental contact with the terminals.
Note the very clear safety warnings making it obvious what is inside the boxes.
Access for servicing is straight forward.

7.2.4. Battery installation example 2

This example provides excellent mechanical protection for batteries and ensures safe seismic restraint.

Ventilation slots at ground level on the front and at the top of the lid behind the hinge provide through flow ventilation so any hydrogen gas produced can rise easily up and away from the batteries.

Ideally the lid should be slanted to prevent incidental use of the lid as a shelf. (Objects will slide off).The use of a child proof catch and signage on the outside (top) of the lid is also required.

7.2.5. Battery installation example 3

This example inside a shipping container provides excellent mechanical protection for batteries and ensures safe seismic restraint.
Note:

- Safety signs
- Fire extinguisher
- Battery maintenance kit
- Battery top up water
- Seismic restraints

Large ventilation grates at ground level and at the top of the container provide through flow ventilation.

Heavy container doors are locked ensuring no unauthorized access.

7.2.6. Battery installation example 4

Battery box close to inverter system in a hydro solar hybrid system comprising:

- Battery bank - 3 x 48 VDC strings of 400 amp hours.
- 7kW Outback Radian inverter system
- 5.25kW solar PV array on roof via FM80
- 1.5kW hydro via FM80

The battery enclosure is externally vented nd lockable.

7.3. Safety clothing

Minimum safety clothing includes:

- Plastic apron
- Rubber gloves
- Eye protection
- Boots
- Eye wash on hand

8. PowerSpout cable connections

8.1.1. DC Earthing explained

There is much confusion about what earthing means. It can mean 3 things:

1. That all metal exposed parts (cases, conduit, hydro bulk head etc.) are connected to an earth rod.
2. That a battery bank pole (normally the negative) is connected to an earth rod.
3. That one pole of the DC supply (normally the negative) is connected to an earth rod.

For the purpose of this manual (definition 1), earthing of exposed metal is always required, unless local rules do not require it (this will only apply to 12/24 V DC battery systems).

This manual does not cover AC earthing requirements as this must be done by a registered electrician.

Earthing of your renewable energy generation system may be required for personal safety and protection of the system from electrical faults. Not all 12/24/48 V DC systems are earthed and the rules vary from country to country. Systems operating over 120V should almost always have an earth connection.

8.1.2. What happens to a hydro turbine when not connected

A free spinning hydro turbine will produce damaging and often dangerous voltages if it is run without a sound, direct connection to the battery. Clients new to hydro turbine installation need to be aware that a hydro turbine designed to connect to a 48 V DC battery, when free spinning can develop up to 200 V DC. 200 VDC is potentially lethal.

8.1.3. What happens if no regulation is installed

Unregulated charging of the battery will cause it to dry out, overheat and explode. You must install a regulator and check on a regular basis that it is working.

8.1.4. Cable connections

New Zealand electrical regulations allow you to work on systems up to 50 V AC and 120 V DC without qualifications. Outside NZ you need to check your rules to see what you can legally do yourself. Your local installer or PowerSpout dealer can assist you with local wiring rules.

In the USA the National Fire Protection Agency (NFPA) provides wiring rules that are generally adopted by each state. You can access these wiring rules free on line. Please also check with your local state authority if you are in the USA, as each state may vary from the NFPA wiring rules.

Many home owners attempting to install a renewable energy system themselves for the first time can make some fairly serious errors. All the following errors we have observed over the last 20 years:

- Connecting a hydro turbine to a solar regulator not designed for a hydro turbine.
- Connecting the hydro turbine polarity in reverse (this normally destroys the rectifier).
- Connecting the hydro turbine to the inverter leads and then removing the battery and regulator fuses. This results in a high voltage input to the inverter, which damages it.

- Using a poor quality second hand battery bank with dirty/corroded terminals, which results in the battery not being connected in the system. This is fatal to inverters as the battery is the primary voltage regulation and must remain connected to the turbine at all times when the turbine is running.
- Forgetting to tighten the battery terminal bolts, resulting in the battery bank being disconnected from the systems, result as above.
- Not checking that the regulator is working correctly prior to leaving the site.
- Installing a regulator that is too small or one that does not work and not knowing how to determine if the regulator is working.
- Installing a PWM regulator (close to its maximum amp rating) in a tin shed that works most of the time but in summer trips out resulting in the batteries being overcharged/damage. The backup PWM regulator (if fitted) also trips. It is not the regulator(s) that have failed but the summer environment in the tin-shed that is too hot. You have to de-rate regulators in summer when above 20 degrees Celsius. Such a failure is the result of an incorrect installation environment.
- Installing equipment in a damp/humid environment resulting in corrosion problems.
- Insect infestation in equipment resulting in corrosion damage from insect excrement.
- Rodent infestation in equipment resulting in shorted wires cause by rodents eating the insulation off the wires.
- Installing electronic equipment (with cooling fans) in a dirty/dusty environment and never cleaning it.
- Bird and rat nests inside and behind cooling fans or inside electrical enclosures resulting in failure and fire hazard. In most cases this would have been avoided if good installation practice had been followed.
- Connecting the plug supplied with the PowerSpout turbine in reverse polarity. This will result in the turbine wire fuse blowing and may damage the rectifier in the turbine.

NEVER work on your renewable energy system with the hydro in operation.

EcoInnovation will not be liable if you connect this equipment incorrectly and in doing so damage other equipment in your system. If you are not skilled then have a suitably qualified professional install the equipment for you.

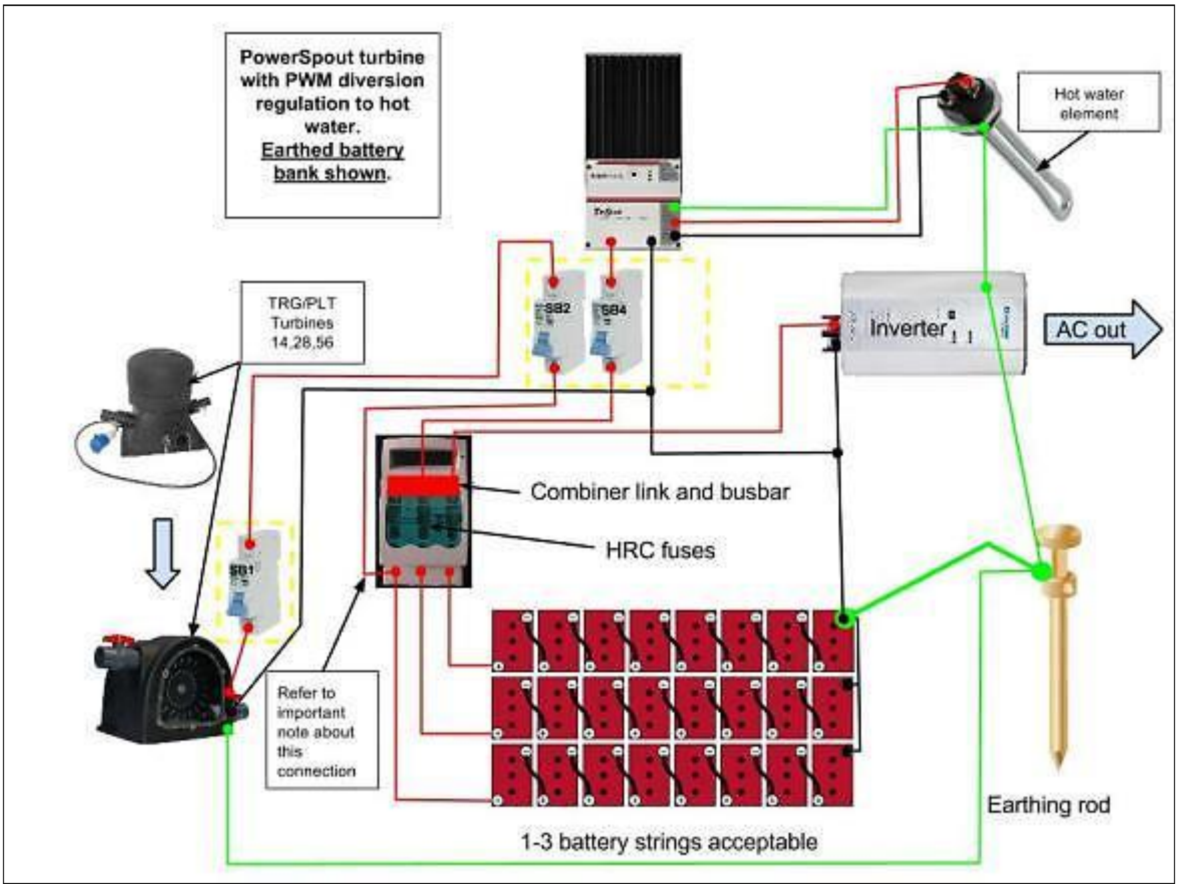
8.2. PowerSpout wiring PWM regulation

The drawings below illustrate the minimum installation requirements for PowerSpout turbines connected to a PWM regulator. This drawing shows both an ungrounded and a negative ground battery installation. Each component and its selection criteria are discussed below.

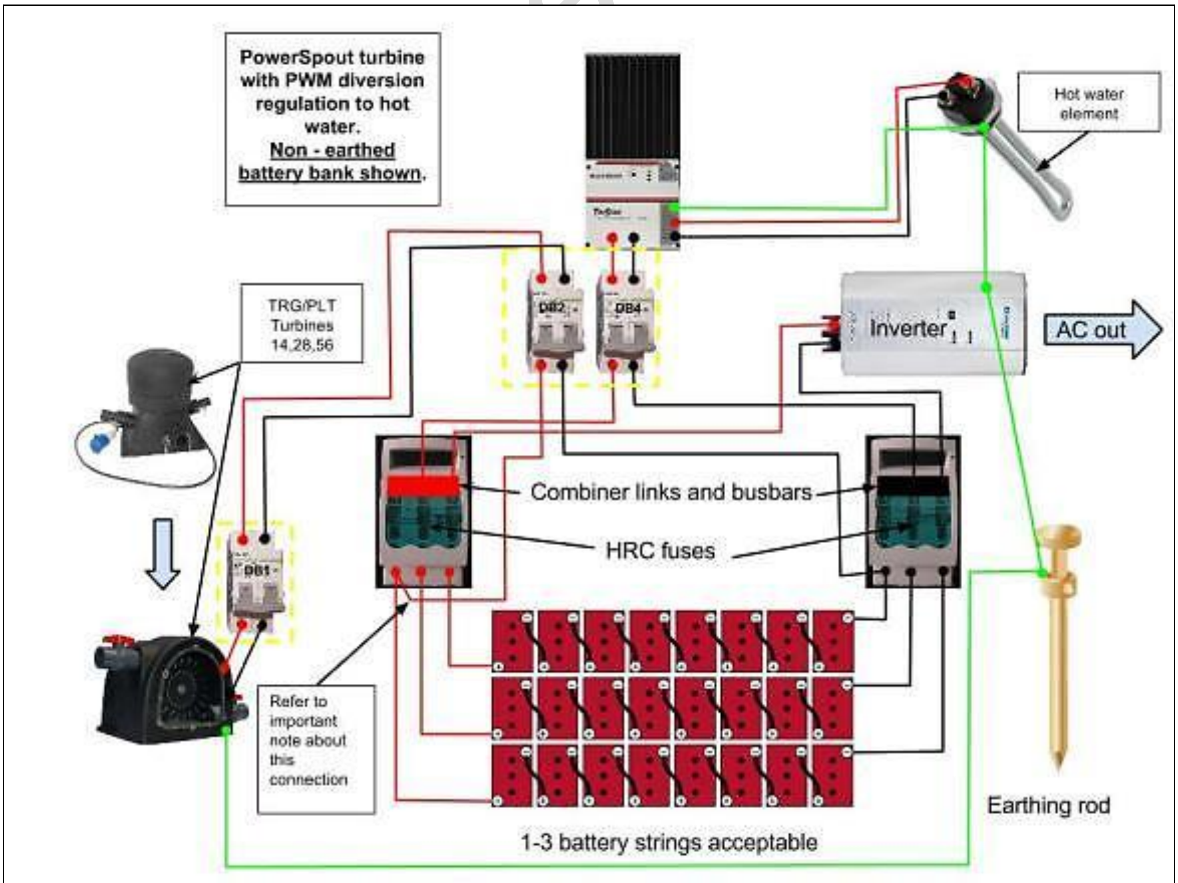
If the ground connection is not to be installed, then additional fuses are normally required by local wiring regulations on each (positive and negative) battery terminal. Please refer to your local wiring regulations for what is required in your location.

The diagrams that follow are indicative only, always check with your local installer that they meets the rules in your country.

8.2.1. PWM - negative ground battery



8.2.2. PWM - ungrounded battery



8.2.3. Excessive hot water with PWM & MPPT regulation

The dump load is shown as a water heater but this can also be an air resistive heater if hot water is not needed.

Overheating your water tank can be a problem on larger hydro installs or when the home owners are away on holiday. Low pressure copper water tanks that are fitted with tempering valves can generally be allowed to boil.

Other system may have an upper temperature limit, as may the connected pipe work.
In such systems the simplest method to prevent overheating damage to your system is to fit a temperature display with audible upper temperature warning, just use more hot water when you have too much of it.

A simple way to automate this is to fit a radiator via a small AC circulation pump that will turn on when the water tank reaches say 70 Celsius and off at say 60 Celsius. Low cost thermostat switches commonly used in dishwashers can be employed to switch on a small AC hot water circulation pump to dump heat to a radiator.

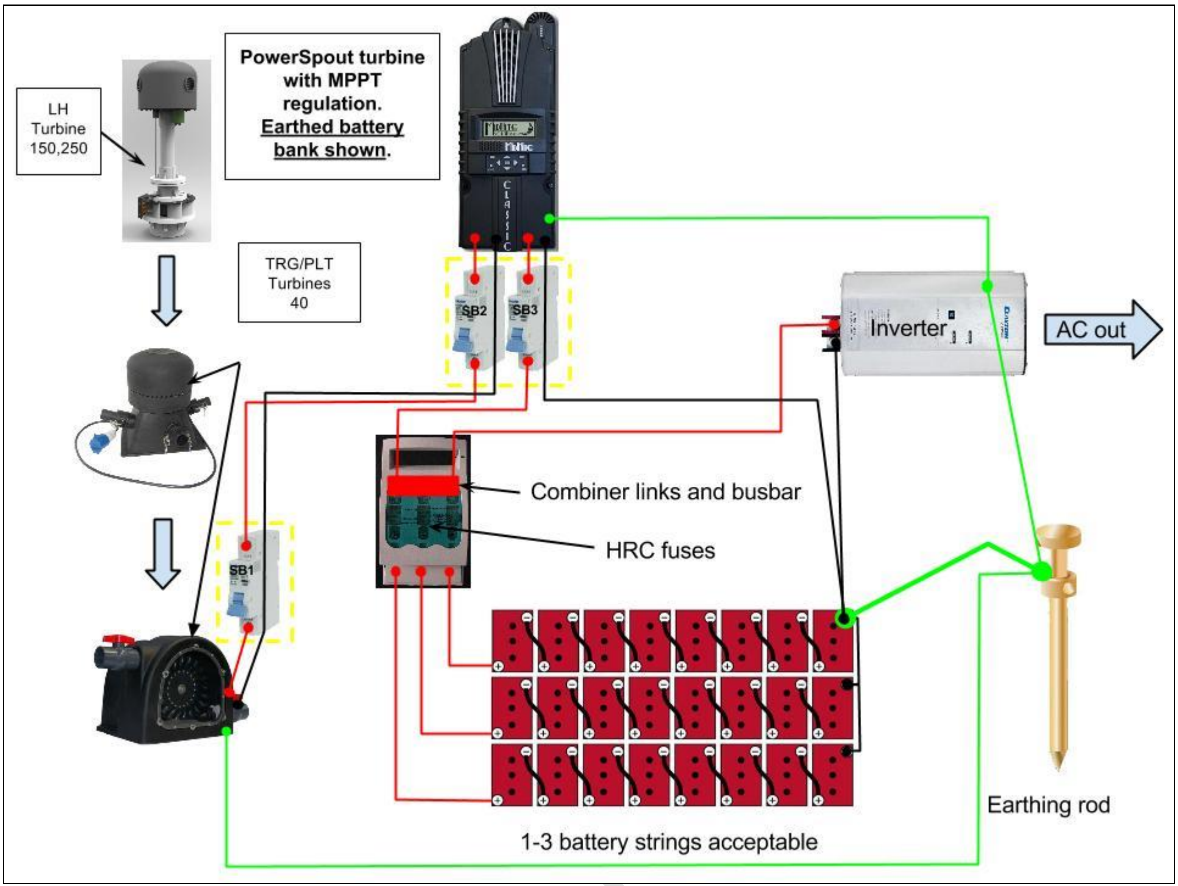
Never try to switch DC in this manner as the thermostat will arc and burn out.
Also remember all AC wiring has to be completed by a registered electrician.

8.3. PowerSpout wiring MPPT regulation

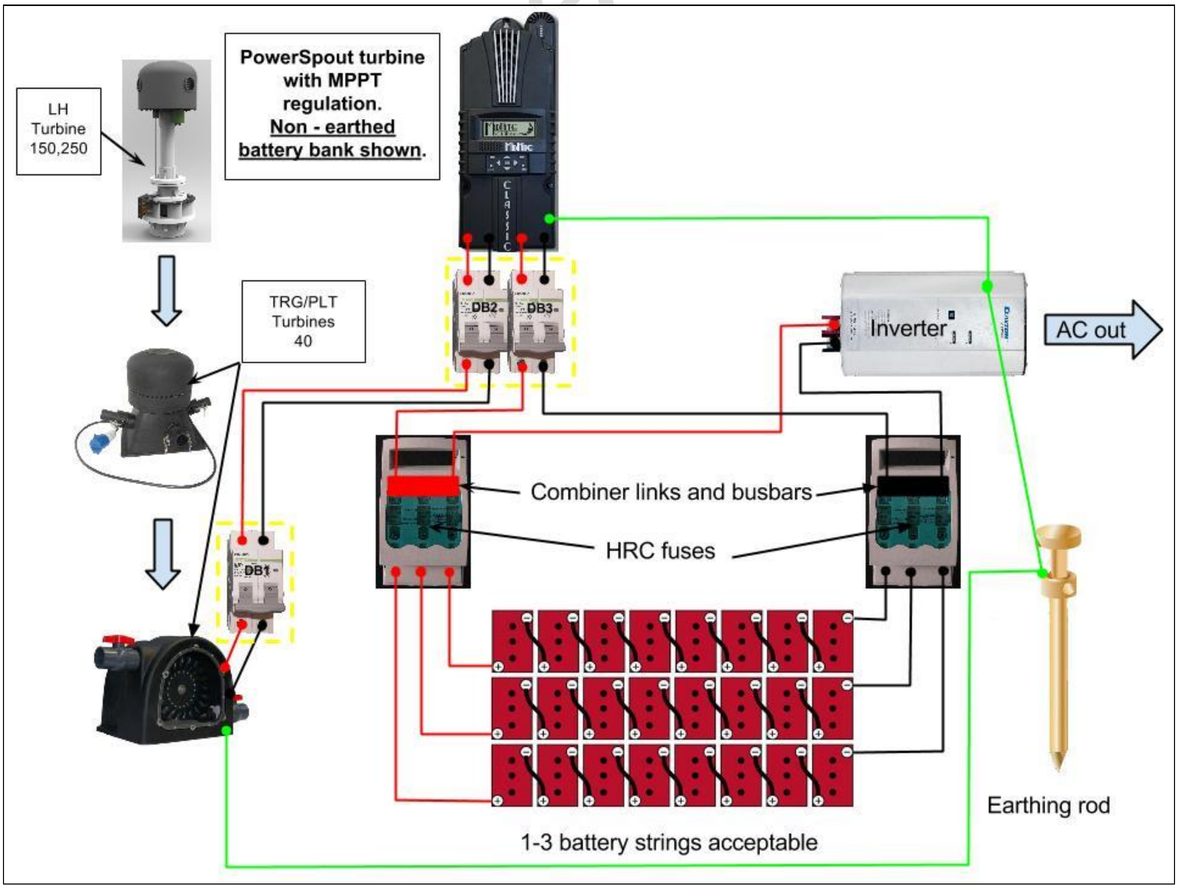
The drawings below illustrate the minimum installation requirements for PowerSpout turbines connected to MPPT regulators. These drawings show both ungrounded and a negative ground battery installation. Each component and its selection criteria are discussed below.

The diagrams that follow are indicative only, always check with your local installer that they meets the rules in your country.

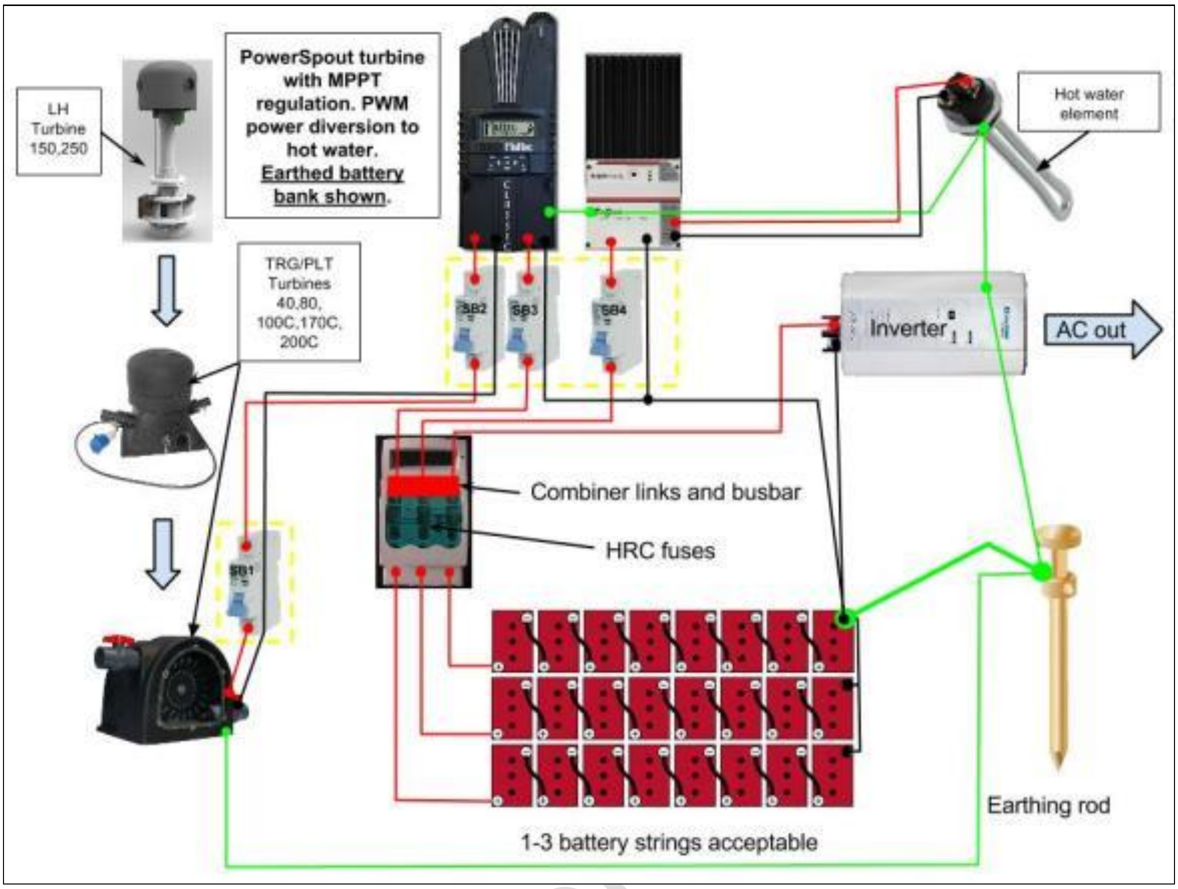
8.3.1. 150-200 V DC MPPT - negative ground battery



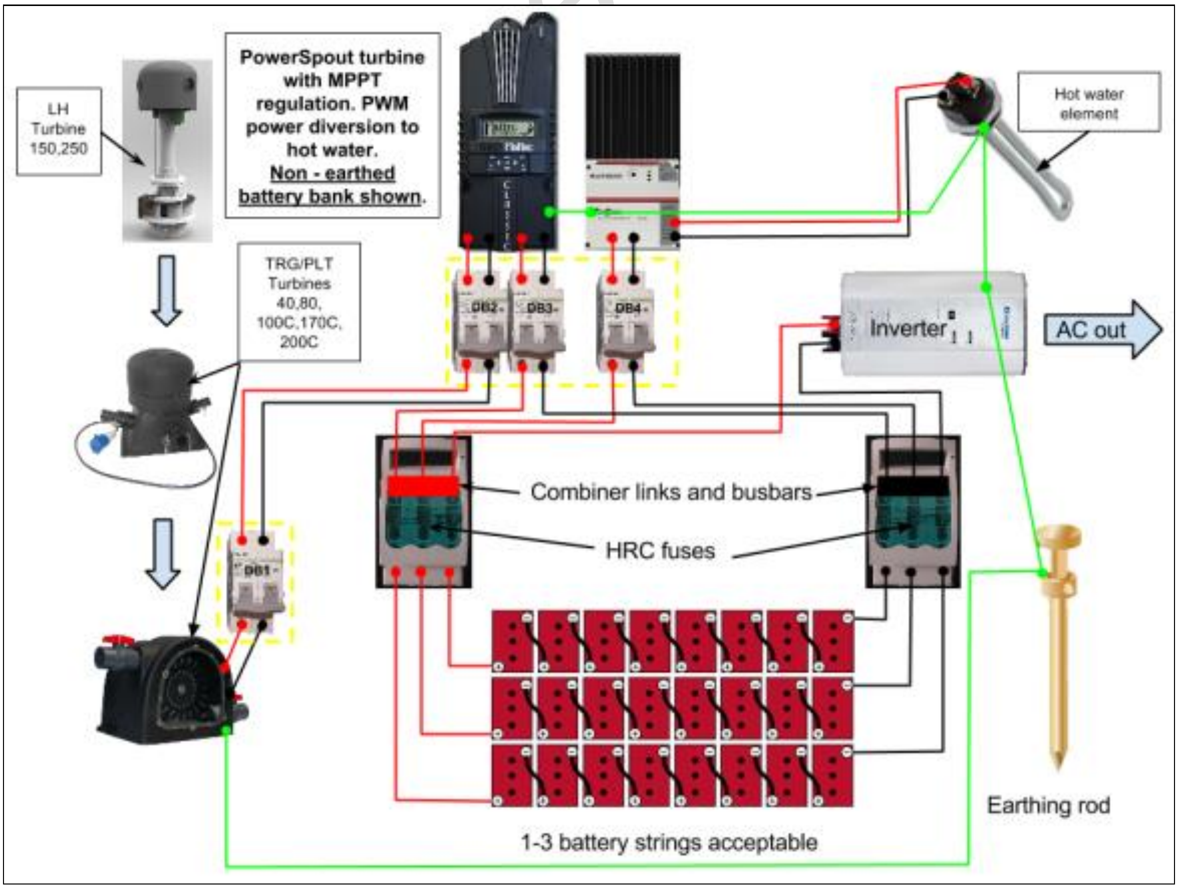
8.3.2. 150-200 V DC MPPT - ungrounded battery



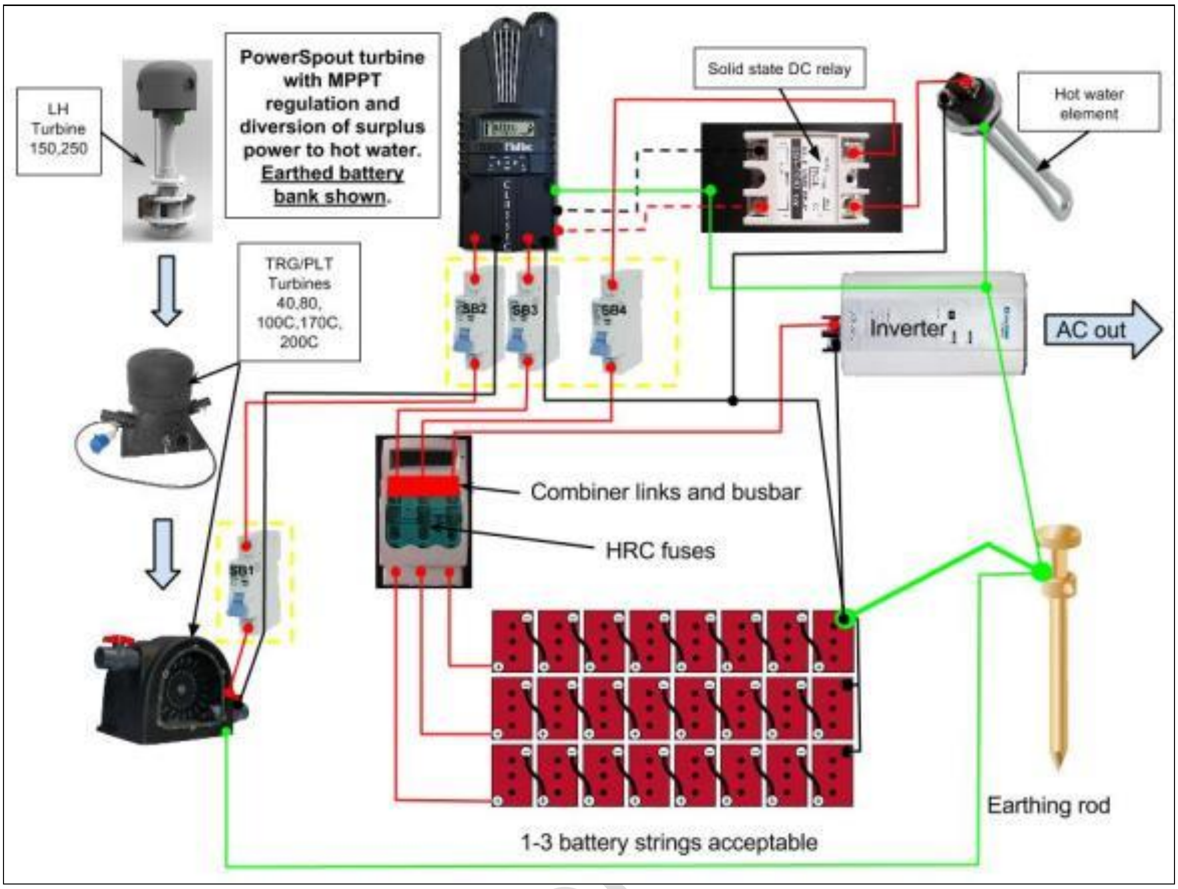
8.3.3. 150-250 V MPPT, PWM hot water diversion negative ground battery.



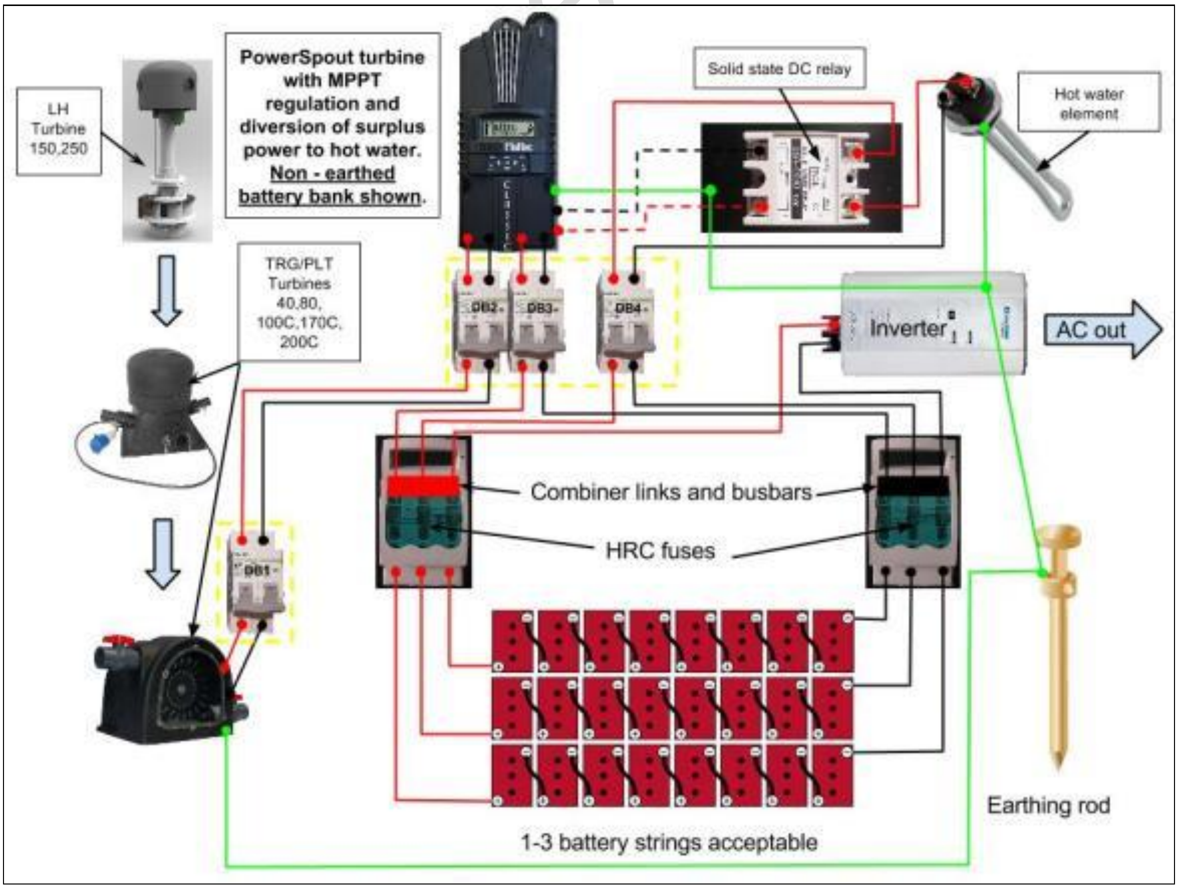
8.3.4. 150-250 V MPPT, PWM hot water diversion ungrounded battery.



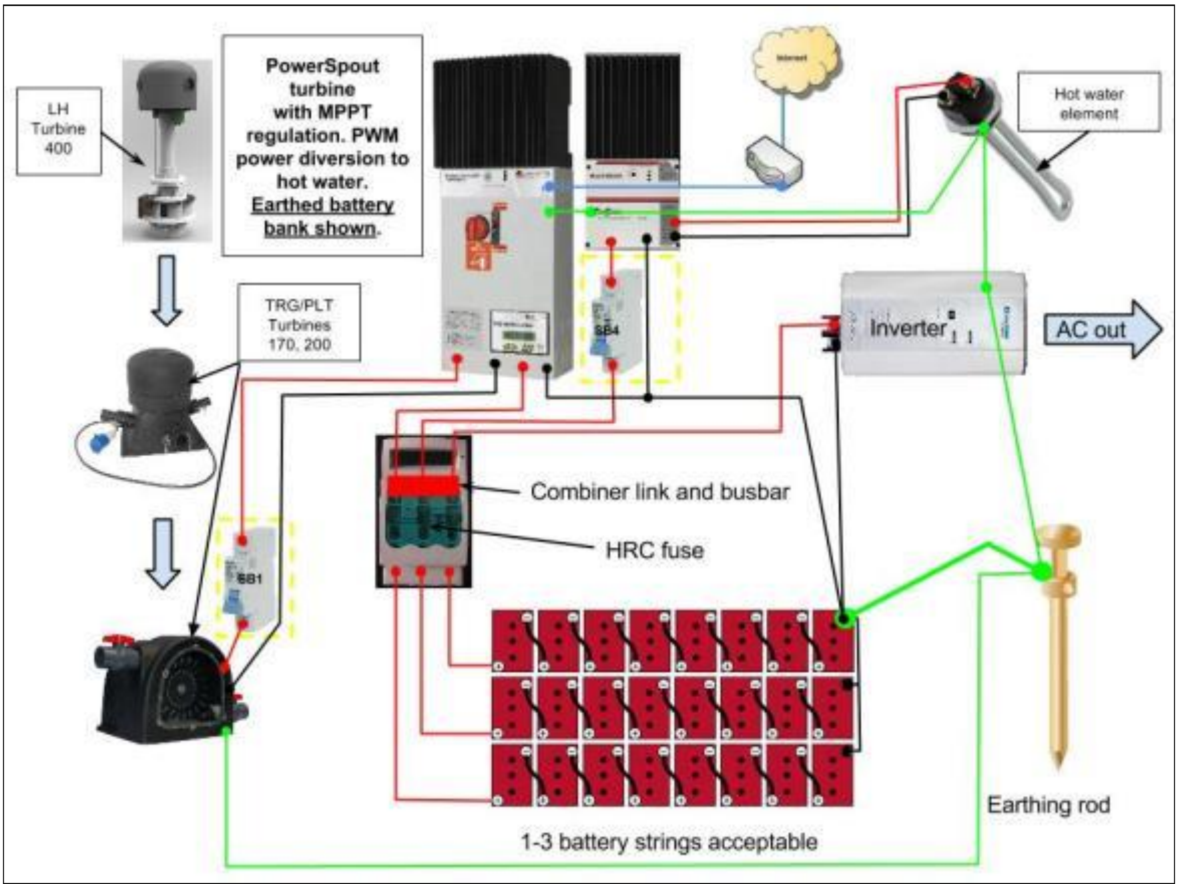
8.3.5. 150-250 V MPPT, solid state hot water diversion, negative ground battery.



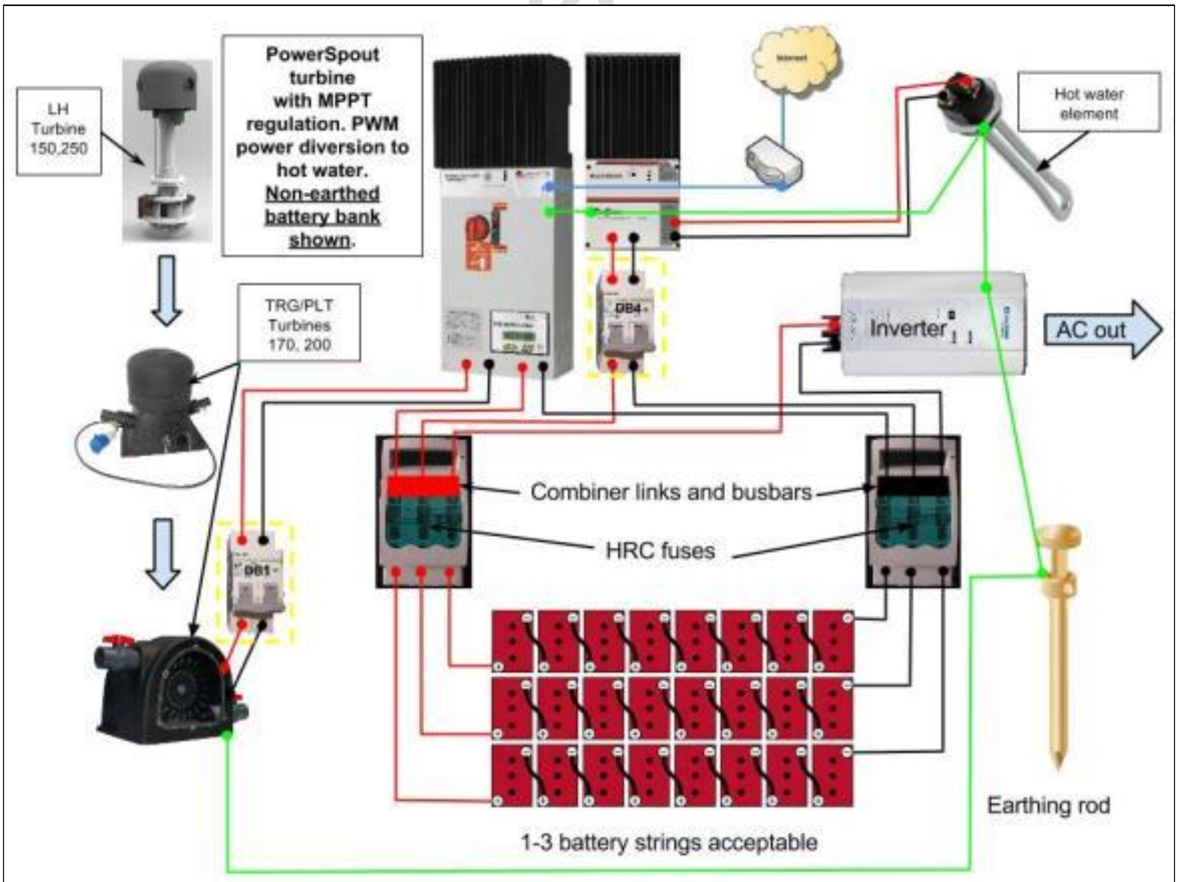
8.3.6. 150-250 V MPPT, solid state hot water diversion, ungrounded battery.



8.3.7. 600 V MPPT, solid state hot water diversion, negative ground battery.



8.3.8. 600 V MPPT, solid state hot water diversion ungrounded battery.



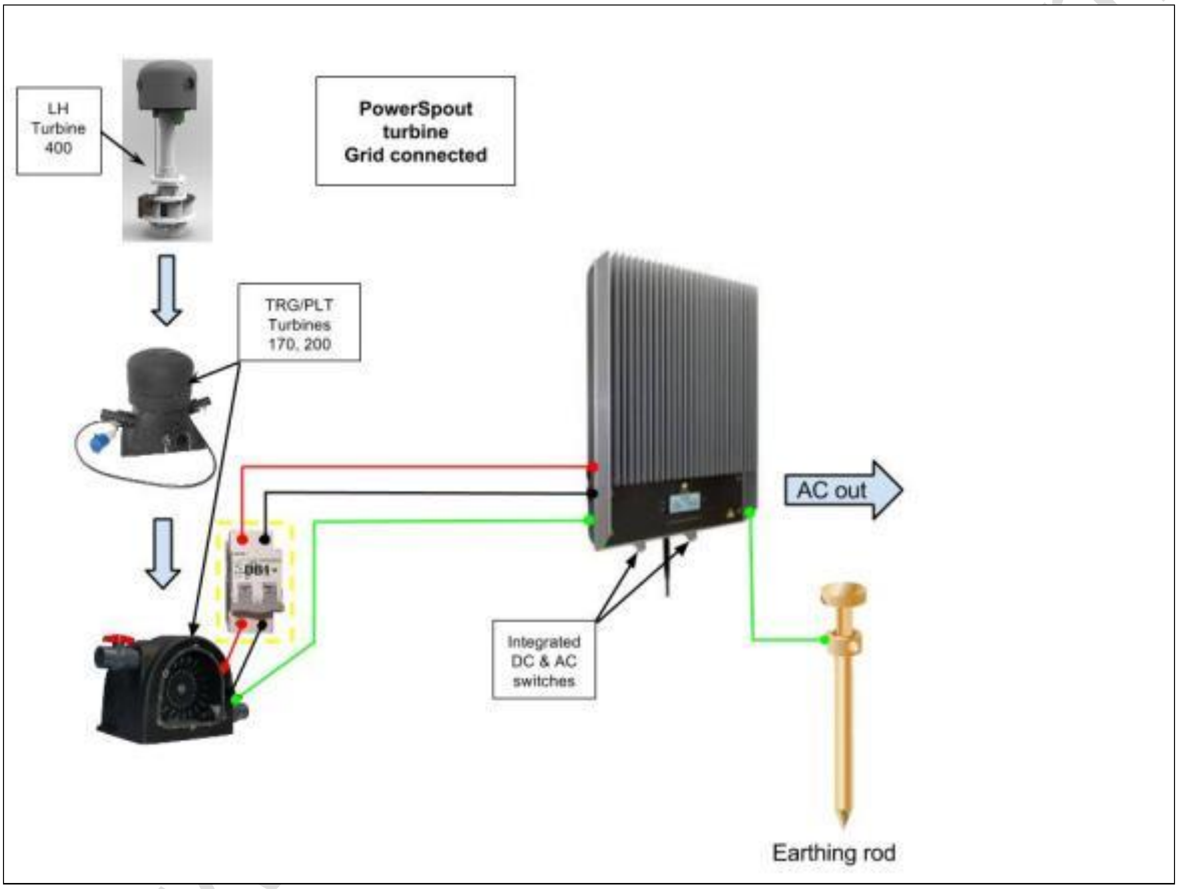
8.4. PowerSpout wiring for grid connection

The drawings below illustrate the minimum installation requirements for the PowerSpout turbines connected to a grid tied inverter. Each component and its selection criteria are discussed below.

Other grid connect options with external voltage regulation are covered in the new 2014 Technical Manual.

The diagrams that follow are indicative only, always check with your local installer that they meets the rules in your country.

8.4.1. 500-600V Grid connected systems



8.4.2. Key to wiring diagrams.

These wiring diagrams are an easy to follow representations of typical systems. All installations must give regard to:

- Local and national regulations
- Advice in this document
- Advice in manuals for supporting products shown

Where such advice conflicts or is unclear, you should seek advice from an experienced renewable energy installer who is familiar with these products and regulations that apply in your country.

DB - Double Pole DC breakers (HRC fuses can also be used).
SB - Single Pole DC breakers (HRC fuses can also be used).
DB1 - DC breakers (in waterproof enclosure if turbine is outside) rating should be between 25 and 50% more than rated amps and be 25% less than the short circuit amps. This information is provided on the turbine name plate. DB1 is a termination point for the turbine power lead, enables OCV measurements to be taken at this location and provides overcurrent protection to the cable. DB1 may be omitted if the cable length is short, then only install DB2.

DB2 - DC breaker is of the same rating as DB1. It is located at the end of the supply cable from the hydro turbine and prior to the battery bank, MPPT regulator or grid-connect inverter. It may be omitted if a suitable breaker is already provided in the connected equipment. DB2 is a termination point for the turbine supply cable, enables OCV measurements to be taken at this location and provides overcurrent protection to the cable.
DB3 - DC breaker on the output of the MPPT regulator. Rating should be similar to the maximum output rating of the MPPT regulator or 25% more than the maximum output generation amps. For example 63 amp breakers are commonly used on 60 amp MPPT regulators. It may be omitted if MPPT manufactures' instructions do not require it. DB3 is a termination point, enables easy on/off selection and provides overcurrent protection. Picture shows DB2 and DB3 in common housing external of the MPPT regulator.

DB2 and DB3 may be integrated into the MPPT regulator as shown on the right.

DB4 - DC breaker on the diversion load circuit. Rating should be 1.5-2.0 x the maximum rating of the element when connected directly across a fully charged battery bank. It may be omitted if the MPPT/PWM regulator instructions do not require it but we advise installing this breaker. DB4 is a termination point and provides overcurrent protection to the cable. Installers must put a large sign by the hot water tank that says "Do not drain this tank without first turning off the hot water element in the power shed at the location indicated". In the power shed put a label that says "before draining the hot water system turn off this breaker". If you have PWM regulator you will also need a note to "turn off the hydro turbine before draining this tank".

DB5 - DC breaker just prior to inverter. DB5 is not shown for clarity and because it is often integrated into the inverter. If may be omitted if the inverter instructions do not require it. Rating should be similar to the surge rating of the inverter.

SB1-SB5 provide the same functions as BD1-BD5 above but are single pole breakers.

AC Out - AC wiring guidance is not provided as this has to be done by a registered electrician and this is already well covered in national standards that your electrician will be familiar with. AC and DC wiring must be separated at all times. Consult your local regulations for minimum separation distances and other methods of ensuring separation.

An electrician without good off-grid experience may be confused by the need to earth the AC neutral and may need to be shown the directions in the inverter manual regarding the earthing arrangements of the system. In some countries the electricity company are responsible for earthing the neutral and hence some electricians do not commonly do this work. In off grid systems where there is no power company they have to do all the wiring required to comply with regulatory requirements.

Green lines - These show the earth connections; most electrical systems need to be connected to earth in case the exposed metal becomes energized by an equipment failure. Earth-grounding reduces the danger of shock if the exposed metal is subsequently touched. Equipment grounding may also help protect the electrical system and appliances from lightning surges although the level of protection is less than commonly believed. Some inverters and MPPT regulators may include lightening surge protection.

Most important is that equipment earthing connects the metalwork of various pieces of equipment together so that there cannot be a dangerous potential between them. Touching any two pieces of equipment cannot then make your body a pathway for current. A fault that creates a voltage between the cases will create a large current in the earth bonding that will blow a fuse and disable the system.

Attach equipment grounding wires to all the exposed metal in your system. Make sure to establish a good electrical "bond" that can last the lifetime of the system. Read the equipment instruction manuals to see what is recommended. Check local regulations for sizes, these will generally be $4mm^2$ green insulated copper wire. If your battery bank is earthed then a heavy wire is required to make this connection normally $16\text{-}50mm^2$ or larger.

Generally only 1 wire should go to your earth rod. If earth wires need to be combined prior to the earth rod this is done with an earth busbar in a suitable enclosure.

HRC fuses - The wiring diagrams show HRC fuses where batteries are in the system. It is very costly to purchase high amp rating DC breakers but HRC fuse holders are relatively inexpensive. The 3-pole HRC fuse holders can serve a multi-purpose of providing current protection for each battery string (normally required by regulation), act as a combiner for multiple strings and act a busbar termination point for other connections needed in the system.

Where 1-2 battery strings are used the spare position in the HRC fuse holder can be employed to break the incoming generation and replace DB2. This then provides a single point of system shutdown; this method is regarded as best practice. Label "In emergency pull this handle for complete system shut down".

One or two 3-pole HRC fuses can be used in many ways and provide a very cost effective solution. You can remove the handles and fuses thus ensuring your safety while working on the system. The picture on the right shows a HRC 3-pole fuse holder with a top combiner link and busbar for 3 battery strings.

Depending on if you have a non-earthed or earthed battery bank you will need 1-2 of these items to complete your installation.

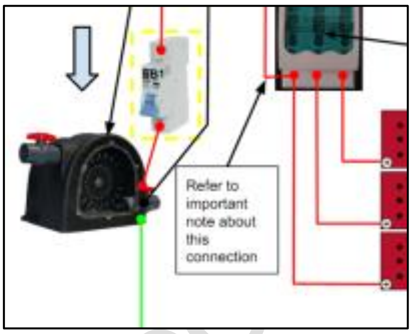
Another possible option is shown for 2 battery strings: the spare fuse position can be used for the incoming hydro generation.

There is another possible option for 1 battery string, in this case the battery + and battery – are in the same 3-pole HRC holder. The spare fuse position can be used for the incoming hydro generation.

8.4.3. Important note when using PWM regulators

PWM regulators divert surplus power to a resistive element, you must be very careful not to make a common wiring error with this method of regulation.

PowerSpout turbines (PLT/TRG 14/28/56) are wired directly to the battery bank. The positive wire must be wired to the battery side of the HRC fuse as shown. If the HRC fuse is opened (while the turbine is still running) then the voltage will remain stable since it is still connected to the battery bank. The regulator will cease to work and the first battery string may be overcharged if left in this condition.



PWM regulation may not fail safe; failure of the PWM regulator or attached element can result in severe overcharging of your battery bank or complete flattening and damage (resistive element locks on). MPPT regulation generally fails safe but costs a little more. As the battery bank is often the most expensive part of the system, you need to carefully consider if the small saving is worth the risk.

8.4.4. A word of warning about PWM regulation

Over the years we have seen the electronics of many systems killed by incorrect connection of the hydro turbine. If you wire your PowerSpout turbine directly to your battery and use PWM regulation and do not follow our advice above, then it is important to reiterate that you do not want the main battery fuse to blow because the battery is the primary protection against over-voltage in the system. The hydro turbine going open circuit voltage will likely destroy all of your electronics in the event of the fuse blowing.

8.4.5. Important note on cable sizing

If a breaker is omitted then the cable is still protected by the battery fuse but this is often too large. Any unprotected cables must be sufficiently large to safely handle the full short circuit current if breakers are omitted. We do not advise that you omit breakers.

Cable sizes need to be adequate for the circuit protection in each case.

8.4.6. Earthing of PowerSpout hydro systems

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. There is little global experience with small DC hydro turbines, however, DC solar PV systems are very similar and hence we advise you to follow the same general rules as for solar PV systems. The main difference is that hydro turbines are not installed in your home and hence any fire risk is much lower.

- On a 12/24 VDC battery systems, DC earthing **<u>may not</u>** be required.
- Where the hydro turbine is close to the power shed, a green earth wire from the turbine bulk head must be connected to the earthing rod.
- Where the hydro turbine is distant to the power shed, the turbine bulk head should be connected to a local earthing rod. Please check your local wiring rules as some jurisdictions only advise one earth rod location.

In cases where an earthing rod can be local to the hydro turbine this represents a significant cost saving in wire and it will be safer, as long cables are much more likely to be accidentally cut than a short local one. In these cases the long run earth wire can be replaced with a short wire as shown.

The main reason to earth the PowerSpout bulkhead is to stop users touching metalwork which may have become live through an electrical fault. This metal bulkhead is connected to the same ground the user is standing on so no shock can occur.

8.4.7. Important note for grid connected systems

Grid connected versions of the PowerSpout have EMC output filters fitted; it is therefore important that the turbine DC is not externally tied to earth though wiring options. Unless legally obliged the DC turbine output (inverter input) should not be tied to earth or EMC performance may be compromised.

8.4.8. Earth cable size

PowerSpout hydro turbines are fitted with 2m long leads depending on the maximum current rating of the turbine:

- 2.5 mm^2 < 16 amp
- 4 mm^2 < 32 amp
- 6 mm^2 < 50 amp (upgrade fee applies)

8.4.9. Earth Rod (electrode size)

An earth rod driven 1.8m into the ground is normally sufficient, but always check your local codes. Earth rods are typically made of the following materials:

- 16mm diameter hot dipped galvanised steel
- 20mm diameter hot dipped galvanised steel pipe
- 15mm copper pipe 2.5mm thick

8.4.10. Installation example

A potential customer wants to purchase a PLT80 PowerSpout hydro turbine that will generate up to 1000 W on their site data. The rated voltage is 80 VDC and the unloaded voltage 240 VDC. They intend to use a Midnight Classic 250 regulator and the aux relay will be used to turn on a 327 W water heater (1500W at 120 V element is used) with surplus energy not needed to charge the batteries. There will be a 5kW inverter in the system and two x 48 VDC battery strings each of 400 amp hours. The advanced calculation tool has sized the cable for you at 6mm^2 for 3% power loss in the cable.

Question: What is the size of breakers needed DB1-DB5?

Answer:

DB1 and DB2.
Cable amps=12.5 (1000/80) and the short circuit amps = 20 (listed on the turbine nameplate). Breaker rating should be between 25 and 50% more than rated amps.

Minimum breaker size = 1.25 x 12.5 = 15.6 amp. Maximum breaker size = 1.5 x 12.5 = 18.8 amp. Hence a 16 amp breaker is selected, in the event of a cable short the breaker will trip.

DB3
As the MC250 is rated for 63 amps, you can therefore fit a 63 amp breaker or if you prefer a breaker rated at least 25% more than the output amps of the MPPT unit in operation = 1.25 *1000/48 = 26 amp. So you need to fit at least a 32 amp breaker.

DB4
As the diversion element is rated for 327W, the minimum breaker size is 1.5 x 327/48 = 10.2 amps, so a 16 amp breaker should be used.

DB5
The inverter is rated for 5kW but can surge to 9,000W. Hence 160 amp inverter fuse/breaker is a good choice. A 160 amp HRC 3-pole holder was used to do this just under the inverter as this was more cost efficient than a 160 amp breaker.

Main HRC battery fuse
The battery bank will not be earthed in this case, so both poles have to be fused. As we have 2 battery strings these also need to be combined and separately fused.

Two 3-pole HRC holders are used to combine both strings and top combiner links are fitted to both holders as shown. The spare positions are used to break the incoming hydro DB2. As DB2 needs to be 16 amp rated, a copper link (to replace the fuse) is put in the spare position and a 16 amp breaker is installed for DB2. Opening any one HRC holder will completely shut down the system.

The final system looked like this.

8.4.11. Charge controllers

Be careful not to confuse PWM regulators with MPPT regulators. Such a mistake is likely to result in equipment damage.

8.4.12. Grid connect inverters

PowerSpout PLT turbines have been verified to work with SMA Windy Boy inverters and EnaSolar inverters. Generally where the inverter manufacturer approves hydro connection the PowerSpout turbines will operate and track correctly. With 100's of grid connect inverters on the market it is not possible to test compatibility with more than a few. Only a few manufacturers warrant hydro input.

If you try an inverter and it works and tracks well please advise us so we can add it to the list of inverters that have been shown to work. Refer to our technical manual for more information.

9. Turbine Commissioning

Ensure the electrical checks (Section 4.5) have been carried out before field commissioning.

It is important to formally commission the turbine and associated system to ensure it is working correctly prior to leaving the site for the day. Once you are happy that you have successfully commissioned the turbine you should record (see Section 14.2):

- Jets sizes installed
- Flow rate through turbine
- Output Watts (= amps x volts)
- Static pressure of pipe (turbine valves turned off)
- Dynamic pressure of pipe (turbine running)
- Generator equilibrium temperature, (see Section 9.3)
- Picture of installation
- Date for next service check (see Section 10.3)

Once the turbine has been mounted on a suitable base, the pipe attached and secured, and the power cable connected to the MPPT regulator or battery bank you may turn on the turbine slowly with supply cable breaker off or fuse removed.

- Allow pipe to run and purge of air bubbles (this can take a few hours). Check that the intake has surplus overflow water.
- While it is purging check for pipe and turbine fittings for leaks, and remedy as required. If outside small water drips will often stop by themselves after a few days.
- While it is purging, walk the pipe and lift sections (it will feel light) to locate any air locks and fit riser vents as required. You can often hear airlocks if you put your ear to the pipe.
- Check that the OCV is less than the maximum voltage rating of the MPP regulator, if it is then close the breaker.
- Check for current flow to the load.
- Check PWM regulators are working.
- Check MPPT regulator locates the correct maximum power point. It will not do so if the batteries are full, so ensure there is a load on the system. MPPT display should read “Bulk”, if it reads “Float” then the turbine is not running at full power.
- If a PWM controller is fitted you will need to manually optimise the turbine to locate the maximum power point.
- Check any diversion loads fitted to the MPPT auxiliary relays are working.
- Check that the intake still has surplus overflow water. If not fit smaller jets so you are not drawing air into the pipe at the intake.
- Check that the drain hole in the rear turbine case is at the lowest point. Condensing water from the bulk head will pool onto the floor of the turbine case, drill a small (20mm) hole at this low point to allow this water to drain out.

- Check there is no water leaking from the drain hole in the rear bearing block, you can used a small mirror and light to see this. If you see a leak make sure you have installed the top cap seal correctly.

Meter cabinet and resistive load

The meters above confirm that both units are operating: hydro 1 at 20 amps and hydro 2 at 11 amps respectively. The air diversion meter shows 3 amps diverted to the resistive load. The picture shows the air diversion element with a slight glow, indicating that it is working.

Make sure the pipe is secured firmly just prior to the turbine (note metal supports in picture). A large pipe full of water can be heavy and may need support. You can support the pipe by installing a wooden/steel post either side of the pipe with a horizontal member above and below the pipe to secure it.

As a check it is recommended that the exhaust water from the turbine is collected to determine the flow rate of water through the jet, measure this by noting the time to fill a container of known volume.

Cutting and aligning the jets are fundamental to turbine optimization. Please refer to relevant sections above for more details.

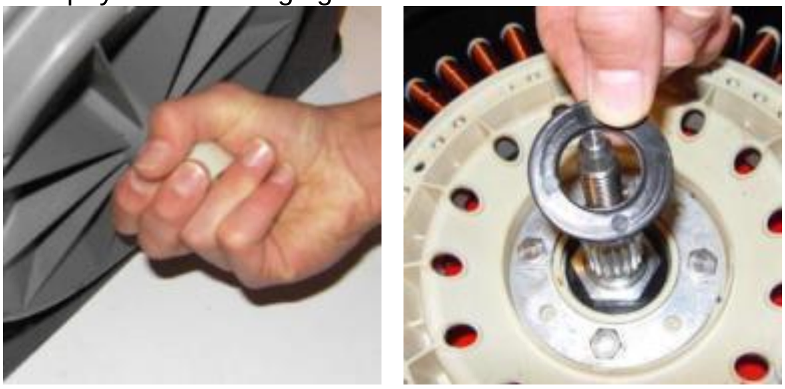
9.1. Packing out the magnetic rotor (PWM regulators only)

Once plumbed in, the jets should be turned on and the output of the turbine generation performance optimised.

Optimisation in required for all PowerSpout turbines connected directly to battery banks. This is very important and will make a significant difference to power generation. Once this point has been found the rotor should be packed with the packing washers provided and the rotor tightened - finger tight only.

Optimisation is to ensure you get the maximum output current from the turbine. You monitor the current whilst making the changes described, visual optimisation is also possible as described later.

Optimum magnet packing will change with changing pressure (smaller jets when dry will increase the pressure) and changing battery voltage. Optimisation can be repeated when flow conditions change so you can decide what compromise to make with the packing and what penalty you will pay for not changing it.



Turn knob to optimise, pack with washers and tighten to ensure rotor stays in position set (note 1mm thick stainless steel washers are supplied for packing).

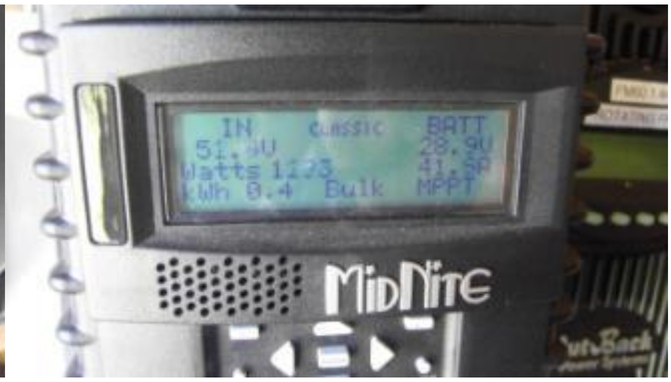
If you are using a PowerSpout connected to an MPPT regulator, this equipment will automatically adjust the speed of the turbine and optimise it for you, no packing required.

9.2. Manual MPPT tracking

If the MPPT controller is unable to automatically find the correct operating point then manually set the MPPT controller load voltage, some MPPT regulator allow you to do this. Adjust MPPT set point (load voltage) from highest to lowest voltage and note power output at each setting. Then select best power result.

Some MPPT regulators can take minutes to locate the maximum PowerPoint, and certain models will sometimes go to sleep and not wake up. If this happens restart the MPPT regulator (by removing all power from the unit or by selecting the restart option in the display menus), and on seeing a turbine voltage above the battery voltage it should wake up and track until it locates the maximum power point.

FM60 locating 1.6kW MPPT from a PLT80



MC250 tracking 1.23 kW MPPT from a PLT80

FM60 tends to track down from the OCV and MC250 (in hydro mode) tends to track up from the battery voltage. Once it gets to about 80 VDC input it will also have 1.6kW on the display. Both units were connected to a PLT80 running at maximum output.

For more detailed information on the set up of FM60/FM80 and MC150/200/250 MPPT regulators refer to the new 2014 Technical Manual.

9.2.1. Visual optimization of PLT turbines

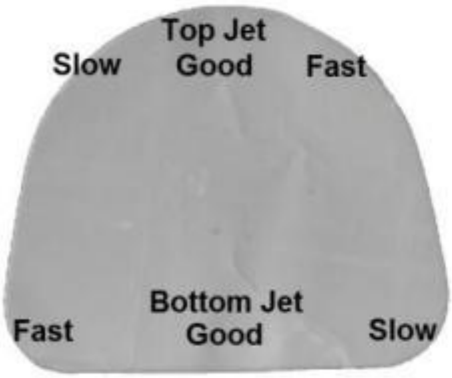
Once optimisation of PLT turbines is complete the turbine exhaust water should be hitting the clear glazing at 90 degrees to the jet. If the exhaust water bounces back towards the jet then the turbine is running too slow and you should pack the magnetic rotor more. If the exhaust water travels through and hits the opposite side of the casing then the turbine is running too fast and you should reduce the packing.

Top and bottom jet exhaust water is bouncing back towards the jet, indicating turbine is running slow. A little more magnetic rotor packing is needed.

Too slow

Good

Too fast



The above illustration shows where the top and bottom jet exhaust water should be hitting the clear screen for optimal performance

If the exhaust water does not hit the clear front at 90 degrees to the jet, then there are a few possible issues that should be checked.

- Note the output power and compare this to what you were advised prior to purchase. If this is similar then it is likely all is well and no further adjustment is needed.
- Check that the Pelton runner knife edge aligns with the centre of the jets and adjust by altering the packers behind the turbine rotor.
- Apply downwards, upwards and sideways pressure to the jet to alter the angle slightly and see what effect this has on output. The jet position can be moved slightly within the casing. Once optimized, secure and support the pipe. The jet retaining cap should only be hand tight and ensure the thread is well greased so it will come apart in the future.
- Check that the running voltage for your turbine is close to the expected voltage. As we have a limited selection of stator voltages a variation of +/- 15% is normal when used with MPPT regulators.
- Try increasing the swept range of the MPPT controller or grid tied inverter, so that they sweep over a wider range near the open circuit voltage of the generator.
- If you cannot resolve a problem email all your data and pictures of the install to us via our web site at www.powerspout.com and we will try to help you find a solution. Also send a copy of this email to the dealer that supplied the PowerSpout turbine.

Take note of the number of magnetic rotor packing washers required for a particular jet size and when running on one or two jets. Change the packers with the corresponding jet sizes as your river flow changes with the seasons. Hang the jets and packing washers on nails in your power shed for wet, normal and dry period flows.

9.2.2. Visual optimization of TRG turbines

It is not as easy to visually optimise a TRG turbine as you cannot normally see the exhaust water flow. A trial and error approach can be used: you pack out the magnetic rotor, if the Watts increases then you keep going until you find the MPP manually. This is only needed for PWM type regulation.

9.2.3. Optimization of jet size

You may be able to further increase the power output from your turbine using larger jet sizes. This has the effect of increasing the flow rate. There comes a point when the increase in flow rate causes a dramatic drop off in pressure due to increased pipe friction losses. This occurs when the pressure in the pipe (just prior to the jet) drops to 2/3 of the static pressure (pressure when valve closed). When this point is reached increasing the jet size further will reduce the power output but consume more water. The jet sizes required will have been calculated based on the head, pipe size and flow indicated. Some fine-tuning on site will be required.

When operating your Smart Drive generator near the maximum power level for the rpm it is operating at, you will notice that a little more or less Smart Drive rotor packing does not make a significant difference. A 10% reduction in rotor magnetism results in approximately a 10% drop in Smart Drive generator input torque which results in an approximately 5% rise in Pelton wheel rpm which results in a 5% increase in Smart Drive torque. The two 5% rises will be almost as much as the 10% reduction in rotor magnetization.

This is best illustrated in the Smart Drive test graph (Figure 5). A 10% reduction in the rotor magnetism to the stator reduces the power line’s height by 10% and the amps / volts lines by 5% approximately.

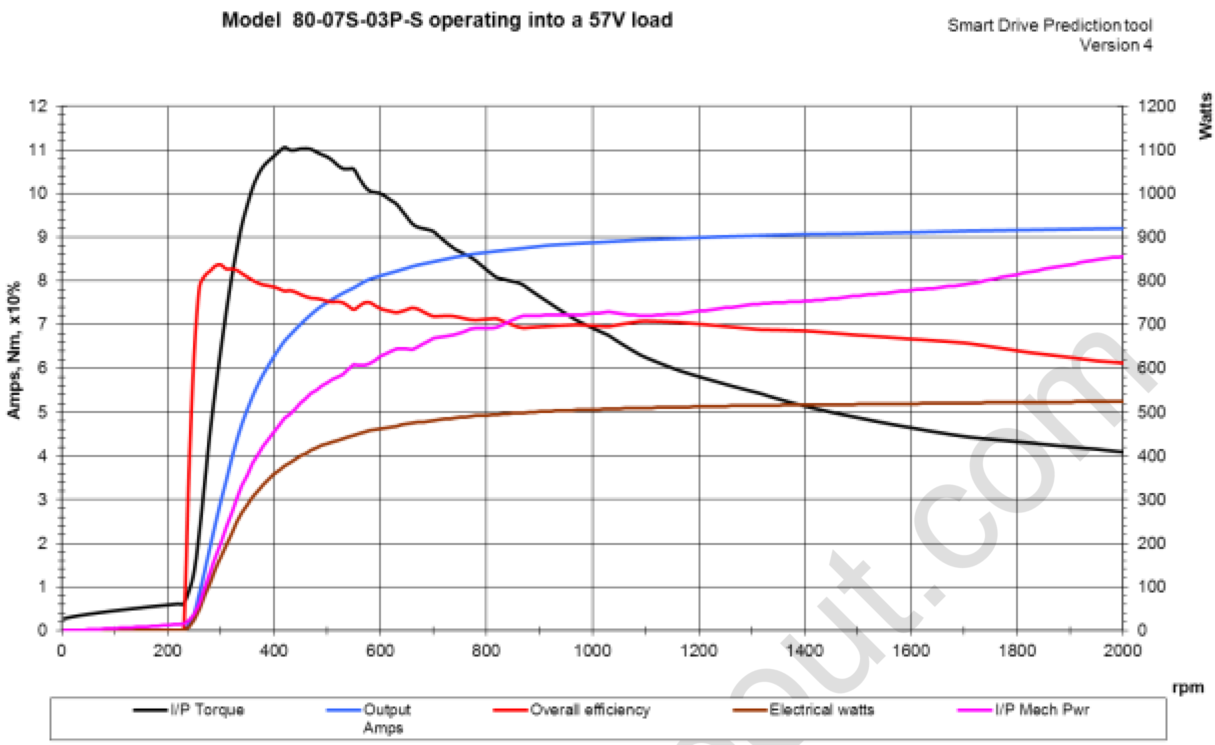


Figure 5. Simplified Smart Drive test graph

This example assumes that calculations for your site data predicted that you could get 530 W at 1000 rpm (brown line) and 70% generator efficiency (red line) on a fully charged 48 V DC bank at 56 V DC.

At maximum power, increasing or decreasing the rpm of the Smart Drive by packing will make little difference to the output power it can produce, as the gradient of the brown line is shallow.

In summer when a smaller jet is used and generation potential falls to only 200 W, the turbine operates at close to the static pressure of the pipe line and the power curve has a steep gradient. The speed of the turbine will be slow due to an oversized generator combined with poor Pelton runner efficiency (because it is not running at the optimum speed). Packing the magnetic rotor out a small amount will have a dramatic effect. This rotor packing flattens and moves to the right of the brown power line and the red efficiency line; this allows the Pelton rotor to pick up speed and become more efficient at extracting power from the water jet, increasing the rpm even more.

Your PowerSpout will have been shipped with a Smart Drive generator optimised for maximum efficiency at your maximum power level expected. This has the result of reducing the requirement to pack the rotor. However, if you are using your PowerSpout PLT over a wide range of flow rates some rotor packing will be needed. To improve efficiency at low flow rates you should purchase a reduced core stator specially made to suit low flow conditions. As low flow often coincides with very sunny weather, solar PV can normally make up any shortfall in hydro power during dry periods.

9.3. Thermal Checks

A PowerSpout has an enclosed generator. The inside stator core temperature of the generator will depend on:

- Output power of the turbine
- Revolutions (speed) of turbine – higher rpm has more cooling
- Ambient air temperature
- Water temperature
- Voltage of operation (lower voltage have more rectification losses)

The generator core is cooled by air flow across the stator. The warmed air then transfers this heat through the aluminium bulk head into the exhaust water of the hydro turbine. The air temperature inside the housing is typically 30-40 degrees Celsius. This warm environment ensures a near constant temperature of the Smart Drive bearings thus reducing moisture ingress due to condensation that is common in the damp environments in which hydro turbines are often installed.

Make sure the above thermal checks are done on the hottest day of the year. We have seen some industrial applications where the air and water temperatures have exceeded 40°C, resulting in the generator running too hot.

2 x side air vents and 1 x rear lid air vent – keep them clean

More cooling may be required in warmer climates. The ideal stator core temperature should be in the range 40-60°C after 2-3 hours of operation.

EcoInnovation will have fitted 3 air vents; if your turbine is running too hot (hot climate, high output and 12 V operation) then more cooling may be required. Contact EcoInnovation and we will send out extra vents that you can easily install with a hole saw.

The person responsible for installing and commissioning the turbine needs to do a thermal check as outlined above and this needs to be repeated at the hottest time of the year.

At our test site in NZ, the temperature inside the bottom of a PowerSpout PLT (operating at 1.6kW on a 130m running head) reached 36°C. Due to a farm animal breaking the water pipe, the unit was left not operating. The following data was inadvertently collected by a data logger inside the turbine:

- Case temperatures rose up to 39°C caused by sunlight heating. Ambient air temperatures were around 25°C.
- Relative humidity was around 40% during operation and increased to 95% when not operating.

This observation is interesting and shows that a turbine should not be turned off for extended periods of time. If your turbine is only used for winter generation, then the turbine should be greased and removed to a dry indoor storage area with the back rear cover left off while in storage.

9.4. Turbine case flooding

On low head hydro sites, turbines are more exposed to flooding risk. PLT turbines (up to 120 VDC) can handle submersion on rare occasions.

Immediately following a submersion of the turbine you must:

- Remove the magnetic rotor and clean off any magnetic grit carried by the water
- Regrease the bearings and run the turbine so that internal generator heat will dry it out.
- Clean out any excess grease from the front of the bearing block and top-hat drain hole as this can block with grease preventing water from draining away.

Damage caused by water submersion is not covered under warrantee.

Flooded turbine

10. Operating your system efficiently

The PowerSpout is a durable machine but it runs 24/7 so regular checks and maintenance are advised. A PowerSpout may do more revolutions in one year than a car engine during the life of the car. A car engine has a filtered and pumped oil lubrication system, whereas a small hydro turbine does not. You must pay special attention to the bearings. A bearing maintenance schedule is outlined below and you are required to follow it if your 3-year warranty is to be honoured. Should you have a bearing failure during the 3-year warranty period we will ask to see your log book as proof you have followed the maintenance schedule. A PowerSpout service manual will be available in 2014 for more detailed service information than is contained in this document.

To maintain your hydro scheme in a good condition for years to come we recommend you keep a log book and regularly (every week initially, and once you become familiar with your system every 2 weeks) do the following:

- Check the specific gravity of your batteries with a hydrometer and reduce your power usage if battery charge is falling.
- Check the acid level in your batteries and top up with distilled water as required.
- Check PowerSpout air vents are clean
- Check hydro output is normal and has not changed since last checked.
- Check your diversion load is working (if fitted)
- Check you have surplus water at the intake. If not, reduce your jet sizes.
- Check there are no obstructions (twigs and stones) that have got in your pipe and are partially blocking the jets.
- Walk the pipe line each year and check for any damage to the pipe.
- Once a year check termination points on your battery, regulator, inverter, fuses and diversion load. Clean and tighten as required. If you observe any heat damage or corrosion at terminations attend to these and repair. Remember to turn off all generation, your inverter and remove battery fuses before cleaning/tightening any termination points. You should pay special attention to your diversion load and battery terminals.

We also suggest you are wary of complacency. Since these systems work and give free power, people tend to keep adding more and more loads until they reach the limit of the system. Hence we recommend you:

- Fit a remote power meter to your inverter that will alert you if you exceed your peak load and advise you how many kWhrs you are using each day.
- Tell your guests about living off the grid and that they cannot plug in large resistive heaters, as these can knock years off your battery life and overload your inverter system.

Power meter

10.1. Power meters

It is important that you have a means of permanently displaying the power generated by your hydro turbine. A separate meter is only needed if you purchased a PLT turbine with PWM regulation.

MPPT regulator or grid tied inverter will display the generation Watts and often log this information for you.

A meter enables you to see any change in the output power, which could indicate a problem that needs your attention, such as:

- Blocked intake screen or
- Reducing river flow requiring smaller jets to be fitted.

You may notice a gradual decline in output power that may be due to sediment and organic growths in the pipeline. This may need to be cleaned out using a pipe pig or by flushing the pipe with high velocity water.

As the voltage of most systems is relatively constant, the output Watts is determined by multiplying the system voltage and the generation amps. Annual output can be calculated as follows.

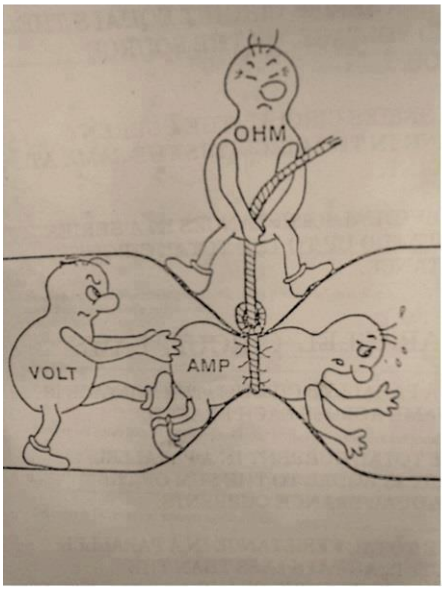
kWh/year = generation Watts x 24 x 365

For example a 500 W (0.5 kW) hydro will generate 4380 kWh/year

To read amps in the cable you should buy a DC clamp meter (be careful not to buy the cheaper AC clamp meter).

Such a DC clamp meter is required so that the PLT turbine with PWM regulation can be optimised for your site.

We strongly recommend that any household living off the grid buys a good quality DC clamp meter, as this will be very useful in a Renewable Energy (RE) system, and learn how to use it. We also advise you to learn the difference between volts, amps, ohms, Watts and Watt-hours as it is very difficult for installers/advisors to assist over the phone or by email if you confuse these terms. The Technical Manual has further information and there are numerous websites on this topic.



Volt, Amp and Ohm at play

10.2. Spare parts

If you live in a remote part of the world you should consider having a full spare parts kit on the shelf. This will mean that whatever the problem you can get your system going again quickly. At the very least you should hold spare bearings; parts from NZ can take up to 10 working days to arrive to global destinations.

10.3. Lubricating the bearings

Factory fitted bearings in your PowerSpout hydro turbine are top quality SKF explorer series sealed bearings (or a close equivalent) which can last many times longer than low cost bearings in the same application:

PLT

- Front SKF 6205-2Z OD52mm ID25mm
- Rear SKF 6005-2Z OD47mm ID25mm

TRG & LH

- Front and Rear SKF 6005-2Z OD47mm ID25mm

10.3.1. Manually applied lubrication

Sealed bearings do need to be re-greased at times as hydro turbines run 24/7 and see very high cycle rates. The PowerSpout is provided with a re-greasing nipple so this can be easily done with the turbine in operation.

You should lubricate your PowerSpout bearings at the time you first use it and then:

- Every 12 months for generation up to 300 W.
- Every 6 months for generation up to 600 W.
- Every 3 months for generation up to 1600 W.

A good quality grease must be used. We recommend SKF LESA 2 grease for all PowerSpout applications or a close equivalent.
http://www.skf.com/group/products/lubrication-solutions/lubricants/grease-developed-for-SKF-Energy-Efficient-spherical-roller-bearings/index.html

Remember to grease your new PowerSpout

With the turbine running connect your grease gun onto the grease nipple provided. Pump into the bearing block about 20 mL of grease when first commissioning. This is normally about 20-30 pumps of a domestic type grease gun. Subsequent re-greasing should be about 5 mL of grease (about 5 pumps).

If you remove the magnetic rotor you should see a band of new grease on the bearing dust seal. If not you need to grease a little more.

If you turn your turbine off during the dry season or for any period greater than 2 weeks you should lubricate as above prior to turning off.

Remember, your PowerSpout 3-year warranty is conditional on bearing replacement every 12 months and the above lubrication regime that you should document in your log book.

10.3.2. Auto-grease cans

If you purchase 3 auto-grease cans at the same time as your turbine, all you have to do is replace and activate the grease can every year; the bearings can then be replaced every 3 years. An annual inspection is still required.

Before activating the auto-grease can you have to manually charge the bearing block as described earlier or an early bearing failure may occur.

10.4. Changing the bearings

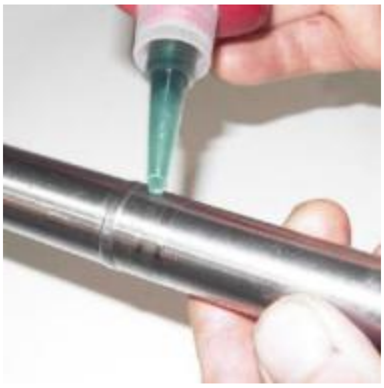
You will need to check the bearings every year and replace if required (note our warranty terms require annual replacement if automatic grease cans are not installed). Bearings are inexpensive and easy to replace. We recommend you hold a spare set of bearings on the shelf. Some of our Pelton turbines have been running on original bearings at customer sites for over three years, though we do not recommend that you do this unless an automatic grease can is fitted.

For turbines running at high pressures (above 130 m head) or at high output power (above 1600 W) you should seek our advice. Generally units running above our approved ratings only carry a limited 1-year duration warranty. The PowerSpout PLT is available in a high power (HP) special version that is capable of 1.6kW at 1600 rpm on a 120m running head. Standard turbines are rated for up to 1200W.

To replace bearings

- Remove the bearing block, shaft and bearing from the turbine.
- Remove shaft retaining nut. Hold the shaft in vice to do this.
- Hit the end of the shaft with a raw-hide mallet (hit the end the Smart Drive attaches to). You may need to use a small workshop press to push the shaft out.
- Remove the shaft.
- Use a punch to knock out the old bearings from the bearing block and recycle.
- Thoroughly clean the bearing block
- Using a large socket as a drift (on the outer ring of the bearing) tap the new front bearing fully home as shown.
- The rear bearing can be tapped home on the outer ring of the bearing with a hammer as shown.

- Clean the inside contact surfaces of the bearings and shaft with a solvent so the locate will adhere well.
- Apply Loctite 680 (bearing mount or similar anaerobic adhesive) using the rear bearing inside diameter as shown.

- Loctite 680 the front bearing shaft position as shown.
- Smear the loctite evenly over the surfaces (1-2 drops per surface is sufficient).
- Insert shaft the correct way around (spline protruding through rear bearing). You may need to use a small workshop press to press the shaft home.


- Clean up any excess loctite with a clean rag.
- Apply 1 drop of loctite to the shaft thread. Attach shaft retaining nut and snug up but do not over tighten. Shaft should spin freely without any tightness. Spin the shaft in your fingers. There should be no tight spots, but if there are it is likely you have not pushed the bearing fully home. Remove the shaft and press the bearings home.

For PLT turbines ensure that the drain holes in the top hat and bearing block are free of grease and obstructions so any water can drain out freely.

10.4.1. Reinstalling bearing block, shaft and slinger, PLT turbine

The pictures below indicate how to re-assemble the shaft into the turbine housing. Note that the bearing block and the plastic top cap have a drain slot/hole which should always be pointing downwards.

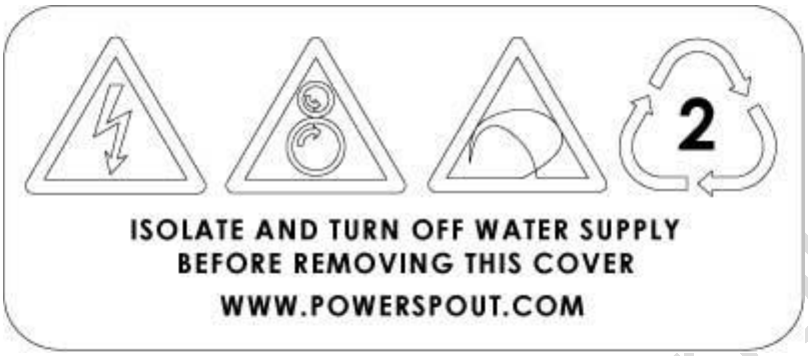

Assemble the seal into top cap and then attach to bulk head as shown.
A screw driver assists with alignment of holes
Tighten fixings to 5 Nm (4 lb/ft).

11. Safety

We strive to ensure that you can install and operate your PowerSpout with little or no damage to you, others or your environment. You can also contribute to this by ensuring you are aware of the potential hazards that exist when dealing with moving parts, batteries, electricity, access to your hydro site, high pressure water, and taking steps to help others recognize and avoid such hazards.

11.1. Fairing safety warnings

The fairing on your PowerSpout turbine forms part of an electrical enclosure and carries the following warning sign. There are both rotational and electrical hazards present. Turbines must be turned off and unplugged (or breaker turned off) prior to removing this cover.



- Electrical hazard
- Rotating machinery hazard
- Made in New Zealand identification
- Recycling identification

Once the turbine has been commissioned, any glazing and fairing need to be fastened in place with the fixings provided.

PLT turbines have quick release toggle latches. The toggle latches are intended for commissioning and jet optimisation. Once this is complete permanent fixings need to be used in addition to the toggle latches. This precaution ensures that children cannot remove the front cover and be exposed to a rotational hazard. The Pelton runner spoons are sharp and could cause serious hand injury.

The turbine installer should ensure that the turbine is mounted such that children cannot reach up under the turbine and be able to touch the spinning rotors.

11.2. Pressurised water pipes

Legislation covering pressurized pipes applies in most countries for pipe pressures over 10 Bar. The PowerSpout runs at less than 10 Bar in most approved applications. Check with your local authority if you have any legal requirement that may concern this installation in your country.

Generally there is little risk at less than 10 Bar pressure. The biggest risk is insecurely fastened pipe joiners that blow off, with the free end of the pipe hitting people. Securing the pipe at regular intervals, particularly near the joins, and checking all joiners are tight will eliminate such risks.

Ensure you install pipe with the correct pressure rating.

11.3. Connecting to the Grid (power network)

PowerSpout PLT/TRG/LH grid-tied options (no batteries required) are available for clients that are already connected to the grid and have a good water resource close by.

Figure 4 shows the system configuration for a grid tied PowerSpout using a WindyBoy inverter from SMA. The new 2014 PowerSpout Technical Manual contains further details including a wiring diagram and guidance on multiple PowerSpout turbines.

Please note that SMA have recently withdrawn the Windy Boy range from the market. In NZ, Australia and the UK the EnaSolar inverter can be used if the MPP tracking rate is slowed. www.enasolar.net

Also Aurora wind turbine inverters from Power-One can be used in most global markets www.power-one.com/

WARNING

Operating voltage within a PowerSpout PLT200 disconnected from the grid and free spinning is normally > 500 V DC. At this voltage contact means electrocution is likely. DC is much more dangerous than the 230 VAC found in many European countries and must only be installed or serviced by persons trained in electrical work.
Please ensure you use a registered electrical worker who is familiar with this type of equipment and voltages.
You should also seek guidance from your grid operator before attempting to connect.

12. Examples of good hydro system installations

Taking care in planning and installation, completing all commissioning tests, and observing and documenting correct operation are all the responsibility of the installer. Pictures of various installs follow, in the hope that these assist you in doing a quality job.

12.1. Good installations

This turbine install includes:

- Pressure gauge
- Good solid mounting platform
- Good water exhaust system
- Clean and tidy install
- Good all round access for servicing

Note the following in this Outback prewired inverter system:

- Dry and insect/pest free install location
- Clean and tidy
- Smoke alarm
- Dry powder fire extinguisher
- Meter for permanent record of kWhrs AC supplied
- DC hydro off breaker (left white box)
- Clear labels

Features of this 48 V DC battery room include:

- Well vented, clean and tidy, lockable
- Battery retention strap (earthquake restraint)
- Distilled battery top up water on hand
- Dry powder fire extinguisher
- Emergency eye wash
- Tool box with goggles, gloves and apron
- Smoke alarm
- All battery terminals covered to prevent corrosion and drop hazards
- Safety emergency signs and log book
- Main DC disconnection point and fuse

In this grid tied system note the:

- Tidy installation
- Installer identification label
- Clear labels

6.4kW from 4 x PLT200's (running at 171 VDC) feeding into 2 x 4kW EnaSolar inverters

Features of this PLT install:

- Earthing of all metal parts
- Clearly labelled
- Good solid mounting platform
- Good water exhaust system
- Clean and tidy install
- Good all round access for servicing

1kW LH install

Features of this LH install:

- Clean and tidy install
- DC disconnect near turbine
- Safe site with platform and hand rail

Features of this TRG install:

- Well supported pipes
- Quick release camlocks used

12.2. Poor quality hydro systems

With a little more effort the installs below could have been made tidy, safe and compliant with wiring codes and recommended install procedures. Your system should be an asset not a liability.

Poor aspects of this hydro install include:

- Turbine is not securely attached
- Main support (old chair) will rust out and the structure will collapse
- Wire path is not clear
- Site is not safe for access and service work

Issues with this inverter/regulator install include:

- Untidy install; it might work but is hard for outside help to assist you.
- Almost certainly does not comply with the local wiring rules

Poor features in this battery install include:

- Untidy install
- Different battery types combined
- Unprotected terminals
- Not a secure site - children can get access
- Inverter mounted by batteries is a source of ignition
- Almost certainly does not comply with the local wiring rules

12.3. Hydro installations with room for improvement

This example has a few issues which could have been avoided:

- The turbine is difficult to access for servicing
- With the door closed, the humidity in this plastic enclosure can get very high. If you do this ensure good ventilation to outside air.
- Plastic PVC pipe work could be tidier with fewer bends

This example shows the turbine and inverter enclosed in same structure. If you do this you should ensure:

- Ease of removal for servicing
- Good ventilation to limit humidity

Do not confuse AC and DC wiring runs when you order your turbine.

On this site we were advised of a long cable DC run, but it was installed on a long AC cable into the grid.

DC lines can have losses from 0-10% and higher in some cases. AC cables need to be run with much less loss or the inverter may trip, causing a nuisance. Always follow recommended wiring sizes in your inverter installation manual for grid connected inverters.

12.4. Poor quality turbine install, maintenance and servicing

With a little more care and more careful attention to the detail in this manual your turbine will last much longer between service intervals.

The pictures opposite show water stains caused by not installing the O-ring seals on the case/valve and then leaving the joints to leak.

Such leaks can result in water spray/mist that is then drawn into the casing via the cooling system. This may result in moisture ingress into the bearings and cause a premature bearing failure.

This turbine had been returned to our factory for service, but it was clear the turbine had not been installed correctly from new.

Examination of the bearings showed that that bearing block had been greased but not with sufficient quantity to reach the bearings.

The best ways to make sure you have put in sufficient initial grease charge is to remove the magnetic rotor and ensure that grease has excited through dust shields.

This turbine was sold in April 2011 and returned for service in April 2013, so had run for 2 years.
Failure was a due to a seized bearing that could have easily been avoided if:

- Auto grease canisters had been fitted after a manual charge
- Correct manual greasing had been undertaken
- Prevention of water mist due to missing O-ring seals

A picture of the bearings journals cut open shows that dry bearings combined with insufficient lubrication and a moisture rich condensation environment has resulted in the early on-set of corrosion. This bearing would have been noisy in operation indicating there is a problem that needs attention.

13. Troubleshooting

The fault finding procedure here is concerned with only the PowerSpout operation. For assistance with your system please contact your equipment installer or provider. The following is designed to locate the majority of possible faults.

If you do not understand the electrical measurements below then please consult your installer or electrical worker for assistance.

If you are concerned your system is not operating correctly then measure the PowerSpout output voltage and current at the PowerSpout and compare with the data supplied with your PowerSpout. Multiply the voltage (V) reading by the current (A) to determine the Watts your PowerSpout is producing.

- If the Watts from your PowerSpout is within 10% of the design Watts provided for your site then the PowerSpout is working correctly but may be in need of further optimisation.
- If the Watts are between 20% and 80% of the design Watts.
  - Confirm you have sufficient water. If a first assessment of your PowerSpout installation then also check the accuracy of your water resource information supplied when you ordered your PowerSpout.
  - Check your penstock for leaks, blockages, airlocks, clogged intake, jet sizes etc.
  - Check your PowerSpout turbine for correct jet alignment, bearing health, correct Pelton runner and magnetic rotor mounting and that no moving parts are rubbing and all wires are connected internally.
- If Watts are less than 20% then do the above plus the following for your PowerSpout.
    - If output voltage is 0V and current is 0A then check water flow, is the turbine spinning and is the turbine electrically connected.
    - If output voltage is 0V and current is at or above the design current then check electrical connections for a short circuit and correct fault.
    - If output voltage is much higher than the battery voltage then check and correct electrical connections to batteries, check for blown fuse (current will be near 0A).

13.1. Making the most of your pressure gauge

Your pressure gauge is essential in locating possible problems.
If the pressure is correct but your output power is low you may have a blocked jet, or an electrical problem. If the pressure is low then there may be air in the pipe (lack of water) or a blocked intake or leaking penstock.

It is suggested you:

measure pressure before jet
measure pressure at pipe manifold connection
measure both static and dynamic pressures
compare with calculations

14. Site data for hydro specification and manufacture

14.1. PowerSpout site data

In order to assess your hydro site potential you can either

- Visit our web site www.powerspout.com and complete the advanced calculator, or
- Complete the table below and email it to questions@powerspout.com we will reply promptly with the best hydro option available for your site.

Your turbine will be designed for the site data you supply above. If you operate it on a different site, the output power will differ and not necessarily match the prediction of the advanced calculator. A new generator core may be required to obtain the best results in such cases. If you intend to run your turbine over a wide range of flow rates, you need to state this at the time of ordering. A different generator core can be supplied for an additional charge.

Table 2. Hydro site data required for PowerSpout product manufacture

Question	Units	
PowerSpout turbine type	PLT, TRG, LH or LH Pro	
Have you read the PowerSpout product manuals? You must do so before placing an order	Yes/No	
Head at site (vertical drop/fall of pipe)		m or ft
Pipe or flume length required to get fall		m or ft
Supply pipe inside diameter if installed		mm or inch
Do you want us to advise your pipe size?	Yes / No	-
Flow available at intake		l/sec or gal/min
What is the cable length from turbine to the power shed?		m or ft
If cable is installed, what size is it?		mm^2 or sq inches
Do you want us to advise cable size?	Yes / No	-
For MPPT applications state your battery voltage	12/24/48	Volts
For MPPT applications state the regulator make and model		
For Grid connect applications state the inverter make and model you intend to use		
How much power do you require at your site on average?		kWhrs/day

Additional Hydro site data required for PowerSpout LH and LH Pro manufacture

Questions	Units		
Can a vertical draft tube be installed?	Yes / No		
Can you buy 200mm and 250mm OD thin-walled PVC pipes locally to make the draft tube?	Yes / No		
If No above then state the inside and outside dimensions of the PVC pipes you can obtain of a similar size. State these dimensions for both the plain and flared ends on the pipe. (read LH Installation manual for more information)	Flared end ID Flared end OD Plain end ID Plain end OD	____ ____ ____ ____	mm or Inch mm or Inch mm or Inch mm or Inch

14.2. Installation details

We recommend you take note of and let us know the final system details (as below) for future reference and to help with ordering replacements or upgrading the system.

This information and a picture of the final installation is required for all warrantees greater than 12 months.

Installation details	Serial number ______________________
Date installed	
Location of installation	
Pipe inside diameter	m or inch
Pipe length	m or ft
Jet size	mm or inch
Static pressure on gauge (turbine off)	kPa or PSI
Dynamic pressure on gauge (turbine running)	kPa or PSI
System nominal voltage	V
Cable length	m or ft
Cable wire size	mm^2/conductor
Generator name (e.g. 100-14S-1P delta)	100/80/60/60dc - ____S-____P delta/star
Performance data	
Flow rate of water through turbine	l/s or gal/min
Voltage on DC rectifier pins at hydro	V
Voltage at battery terminals	V
Current generated	A

We would also like you to let us know your performance data so that we can determine conversion efficiency at your site. This helps us refine our calculations for future clients. As every site is different, efficiency will vary from site to site.

14.3. Noise

Noise is not normally an issue. Our turbine in normally quieter than others as it turns slower and is fully enclosed. Hence if noise is an issue at your site you should check the following:

- The runner is not hitting the jets, it has been packed out correctly and packer washers have not been missed out
- The magnetic rotor turns freely, you have not picked up magnetic debris on the magnets when putting in together
- The bearings have been greased correctly as per the manual
- The bearings are in good condition (likely the cause if noise has increased gradually over time)
- The unit is running at the correct speed. This can be caused by clients installing jets that are too large for the generator power rating resulting in excessive RPM
- The noise is not related to how the turbine has been mounted. A heavy timber or concrete base will be quieter than steel/aluminum framed base
- The line is free from air, compressed air expansions at the jet are very noisy

We have not taken noise level readings, as all hydro sites are different and it does not seem to be an issue. That said some clients have installed turbines too close to their homes.

Generally the higher the head the more noise from the unit. At our test site at 160m head and 1.6 kW you can talk normally standing by the turbine, but you are very aware it is there. You can just hear it at 30-40m away. It sounds like a washing machine in spin.

On low head sites less than 10m (30ft) the river is likely to make more noise than the turbine. A turbine can be closer to a dwelling in such cases.
Vegetation around the turbine will dramatically reduce the distance that noise carries.

14.4. Feedback

We welcome your constructive feedback on how we can improve our products, including this manual. Testimonials for our hydro products can be viewed at www.powerspout.com/testimonials/

As EcoInnovation endeavors to reduce their footprint in many different ways, e.g. to save on paper and airfreight, this manual is only supplied electronically to customers. We encourage users to minimise printing where appropriate and to provide feedback via our website or via email (see contact details inside front cover).

15. Units and conversions

- An **ampere** (amp, A) is the unit of measurement of electric current produced in a circuit by 1 volt acting through a resistance of 1 ohm.
- A **current** is a flow of electrons in an electrical conductor. The strength or rate of movement of the electricity is measured in amperes.
- An **ohm** is the unit of measurement of electrical resistance. It is the resistance of a circuit in which a potential difference of 1 volt produces a current of 1 ampere.
- A **Watt** is the electrical unit of power: that is, the rate of energy transfer equivalent to 1 ampere flowing under a pressure of 1 volt at unit power factor.
- A **Watthour** (Wh) is an electric energy unit of measure equal to 1 Watt of power supplied to (or taken from) an electric circuit steadily for 1 hour.

Volts x Amps = Watts

To convert	To	Multiply by
centimeters	inches	0.3937
sq millimeters	sq inches	0.0015
meters	feet	3.2808
miles per hour	feet per second	1.4667
litres	gallons	0.2641
litres per second	gallons per minute	15.900
kilowatts	horsepower (electrical)	1.3405
degrees Celsius	degrees Fahrenheit	x 9/5 +32

To convert	To	Multiply by
inches	centimeters	2.5400
Feet	meters	0.3048
feet per second	miles per hour	0.6819
gallons	liters	3.7854
gallons per minute	liters per second	0.0631
horsepower (electrical)	kilowatts	0.7460
degrees Fahrenheit	degrees Celsius	-32 x 5/9

16. Warranty and disclaimer

The following applies to complete PowerSpout turbines only and hence excludes kit sets and parts. Trade customers on selling this product must facilitate warrantee claims with the final client. EcoInnovation will only deal with the Trade customer in such cases.

Our warranty is valid provided the turbine has been correctly installed, commissioned and maintained over the duration of its use. The end user must return installation details[5] to EcoInnovation and keep a log book to record maintenance activity. EcoInnovation may request to see the log book and pictures of the installation and failed component prior to processing any warrantee claim. The claimant must respond promptly to such an information request to ensure speedy processing of your claim.

Please also refer to warranty upgrades and support options as detailed on our web site.

EcoInnovation is confident in the performance, reliability and cost effectiveness of our range of water turbines. Hence we offer you:

- Full refund if you are not satisfied after the turbine has been running at your site for a 30-day period (this must occur within 3 months of dispatch) and EcoInnovation must be given the opportunity to rectify the problem. Clients need to pay for return freight cost, and the turbine must be returned in as new condition for a full refund. Site data supplied at time of order must be correct.
- Performance guaranteed if our installation advice is followed for turbines that have output power greater than 200 W. Below 200 W a margin of +/- 20% applies.
- A 3-year warranty from the time of purchase (invoice date) for PLT turbines operating at less than 1,200 W. A 2-year warrantee applies to PLT turbines running in the range 1,200-1,600 W. A 2-year warrantee applies to LH and TRG turbines. A 1 year warrantee applies in all other cases and to all twin pack discounted product lines. All warrantees are conditional on maintenance as specified in the PowerSpout Installation Manual including re-lubrication and replacement of bearings.
- Customers that purchase the optional grease canister upgrade and 2 extra grease canisters (and use them) will have their warrantee extended to cover the bearings.
- Extended warranty available up to 8 years (extra premium applies).
- If there is a problem email us a picture of the failed part and we will fix it by dispatching a replacement part to you promptly. The labour cost to fit this part to your turbine is not covered under this warranty. The 1, 2 or 3 year warranty is limited to the supply of replacement parts within 1,2 or 3 years of initial purchase.
- The cost of any single replacement part outside the warranty period for the original purchaser of our turbine will not be more than $200 US plus freight (5 year limit from purchase date of turbine). This offer excludes electronic circuits (made by other companies) supplied for PowerSpout turbines.
- Our maximum liability is limited to the full amount paid for the turbine. If you are an overseas customer that has purchased this equipment by mail order over the internet then this is the maximum extent of our liability.
- EcoInnovation reserves the right to improve the product and alter the above conditions without notice.

EcoInnovation takes safety very seriously and we endeavour to reduce all risks to the extent possible and warn you of hazards. We encourage you to have the PowerSpout installed by a professional renewable energy installer if you do not have the skill, qualifications and experience to install this equipment safely. Customers that ignore such risks and advice do so at their own risk.

[5] The warranty is only valid for 12 months if no documentation (see Section 14.2) is returned within 11 months of sale

17. Exclusion and liability

The manufacturer can neither monitor the compliance with this manual nor the conditions or methods during the installation, operation, usage and maintenance of the turbine. Improper installation may result in damage to property and injury.

Therefore, the manufacturer assumes no responsibility and liability for loss, damages or costs which result from or are in any way related to incorrect installation, improper operation, incorrect execution of installation work and incorrect usage and maintenance.

18. Contacts

In the case of complaints or faults, please contact the local dealer from whom you purchased the product. They will help you with any issues you may have.

19. Notes

Turbine type	………………………………………………………
Serial number	…………………………………………………......
Date purchased	………………………………………………….......
Date installed	………………………………………………………..
Supplier contact details	………………………………………………………..
Installer contact details	………………………………………………………..

20. Annex I: Jet sizing tables

Jet sizing tables have been removed from this update of the installation manual.
The advanced calculation tool can perform jet size calculations in metric and imperial for 1-4 jets, it is faster and more accurate than using a table.
http://www.powerspout.com/calculators/

21. Annex II: Common PVC pipe sizes

The tables below are to assist in the understanding of the PVC pipe sizes available in your country. Countries that have sizes very similar to other countries are shown coloured the same, so they are easy to spot.

Table 3. NZ PVC Pipe sizes

OD of pipe	PN6 Wall mm	PN6 pipe mm	PN9 Wall mm	PN9 pipe mm	PN12 Wall mm	PN12 pipe mm	PN15 Wall mm	PN15 pipe mm	PN18 Wall mm	PN18 pipe mm	NB
48.3	1.7	44.9	2.1	44.1	2.8	42.7	3.4	41.5	3.9	40.5	40
60.4	1.8	56.8	2.6	55.2	3.4	53.6	4.1	52.2	5.0	50.4	50
75.4	**2.2**	71.0	**3.3**	68.8	**4.2**	67.0	**5.2**	65.0	**6.1**	63.2	65
88.9	2.6	83.7	3.8	81.3	5.0	78.9	6.1	76.7	7.2	74.5	80
114.3	3.3	107.7	4.9	104.5	6.3	101.7	7.8	98.7	9.2	95.9	100
140.2	4.0	132.2	5.9	128.4	7.7	124.8	9.5	121.2	11.3	117.6	125
160.3	**4.5**	151.3	**6.7**	146.9	**8.8**	142.7	**10.8**	138.7	**12.8**	134.7	150
225.3	5.8	213.7	8.4	208.5	11.1	203.1	13.7	197.9	16.2	192.9	200
250.4	**6.4**	**237.6**	**9.4**	231.6	**12.3**	225.8	**15.2**	220.0	**18.0**	214.4	225
280.4	7.1	266.2	10.5	259.4	13.8	252.8	17.0	246.4	20.2	240.0	250
315.5	8.0	299.5	11.8	291.9	**15.5**	284.5	**19.1**	277.3	**22.7**	270.1	300
400.5	10.1	380.3	14.9	370.7	19.7	361.1	24.3	351.9	28.9	342.7	375

NB refers to nominal bore which is the approximate inside diameter of the pipe series

Table 4. China PVC pipe sizes

OD of pipe	0.63 Mpa Wall mm	0.63 Mpa ID pipe mm	0.8 Mpa Wall mm	0.8 Mpa ID pipe mm	1.0 Mpa Wall mm	1.0 Mpa ID pipe mm	1.25 Mpa Wall mm	1.25 Mpa ID pipe mm	1.6 Mpa Wall mm	1.6 Mpa ID pipe mm	2.0 MPA Wall mm	2.0 Mpa ID pipe mm	2.5 MPA Wall mm	2.5 Mpa ID pipe mm
50	2.0	46.0	2.2	45.6	2.4	45.2	3.0	44.0	3.7	42.6	4.6	40.8	5.6	38.8
63	2.0	59.0	2.5	58.0	3.0	57.0	3.8	55.4	4.7	53.6	5.8	51.4	7.1	48.8
75	**2.3**	**70.4**	**2.9**	**69.2**	**3.6**	**67.8**	**4.5**	**66.0**	**5.6**	**63.8**	**6.9**	**61.2**	**8.4**	
90	2.8	84.4	3.5	83.0	4.3	81.4	5.4	79.2	6.7	76.6	8.2	73.6	10.1	69.8
110	2.7	104.6	3.4	103.2	4.2	101.6	5.3	99.4	6.6	96.8	8.1	93.8	14.6	80.8
160	**4.0**	**152.0**	**4.9**	**150.2**	**6.2**	**147.6**	**7.7**	**144.6**	**9.5**	**141.0**	**11.8**	**136.4**	**18.2**	**123.6**
200	4.9	190.2	6.2	187.6	7.7	184.6	9.6	180.8	11.9	176.2	14.8	170.4		
250	6.2	237.6	7.7	234.6	9.6	230.8	11.9	226.2	14.9	220.2				
315	7.7	299.6	9.7	295.6	12.1	290.8	15.0	285.0	18.7	277.6				
355	8.7	337.6	10.9	333.2	13.6	327.8	16.9	321.2	21.1	312.8				
400	9.8	380.4	12.3	375.4	15.3	369.4	19.1	361.8	23.7	352.6				

Table 5. USA PVC pipe sizes

OD of Pipe	Schedule 40 Pipe ID mm	Schedule 80 Pipe ID mm	OD of pipe	Schedule 40 Pipe ID inch	Schedule 80 Pipe ID inch
48.3	40.4	37.5	1.9	1.6	1.5
60.3	52.0	48.6	2.4	2.0	1.9
73.0	62.1	58.2	2.9	2.4	2.3
88.9	77.3	72.7	3.5	3.0	2.9
101.6	89.4	84.5	4.0	3.5	3.3
114.3	101.5	96.2	4.5	4.0	3.8
141.3	127.4	121.1	5.6	5.0	4.8
168.3	153.2	145.0	6.6	6.0	5.7
219.1	201.7	192.2	8.6	7.9	7.6
273.1	253.4	241.1	10.8	10.0	9.5
323.9	302.0	286.9	12.8	11.9	11.3
355.6	332.1	315.2	14.0	13.1	12.4
406.4	379.5	361.0	16.0	14.9	14.2
457.2	426.9	406.8	18.0	16.8	16.0
508.0	476.1	452.5	20.0	18.7	17.8
609.6	572.6	544.0	24.0	22.5	21.4

Provided in metric and imperial