PowerSpout Basic System Design and 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.

CONTENTS

Educational Installations PLT

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Revisions history

1.1. Minor text and picture revisions. Jan 2011.
1.2. Updated PowerSpout versions available and further minor revisions. Feb 2011.
1.3. Updated PowerSpout versions, added system example photos. Feb 2012.
1.4. Updated pictures and text and change of product names June 2013. Removal of ME and GE product lines
1.5. Updated for CE, FCC and standards compliance August 2013
1.6. Updated to include TRG and LH turbines in common manual December 2013
1.7. Edited by H.P. to improve readability and layout, removed wiring diagrams to the cloud - April 2014

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.

1. Scope of Application, and 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.

1.1. Turbine serial numbers

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

PowerSpout
WATER GOES IN POWER COMES OUT

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.

1.2. Installation checklist

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, <u>the installer must</u>:

IN GENERAL

- 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.

PENSTOCK / PIPELINE

- do 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.
- 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.
- if necessary bury the penstock to protect it against rock falls, tree falls, slips, avalanches, freezing etc.

ELECTRICAL WORK

- tighten all electrical connections inside the turbine.
- install an earth connection on the exposed metal bulkhead; a labelled earth connection point is provided - protective class I.
- do not connect a DC pole of the turbine to earth - unless local rules require it.
- provide a suitable DC rated disconnection device close to the turbine that is clearly labelled (a 2-pole DC breaker is the good recommended solution).
- do not use pluggable connections, hard wiring is required. However “MC4” type waterproof connectors may be used. If “MC4” type connectors are used, do not open under load.
- 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.
- finger tighten all cable glands to secure supply cable.
- 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.
- 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.
- before working on wiring in grid connected or MPPT situations wait 5 minutes for internal capacitors to discharge. Always check for voltage prior to touching conductors on equipment that have been recently turned off.
- Comply with safety advice in this manual when installing batteries.

COMMISSIONING THE TURBINE

- securely fix the turbine base prior to operation.
- do not intentionally run turbine unloaded (for other than short duration VOC testing).
- do not run turbine at a head significantly above the name plate rating.
- in a turbine runaway situation turn off the water supply by closing the water supply valve(s).

- check for excessive noise.
- complete turbine testing and commissioning.
- ensure that all protective fairing/enclosures are in position after commissioning and prior to client hand over.
- comply with signage requirements as listed in relevant national standards
- complete all documentation as required in this manual and local wiring rules.
- make relevant notes in the manuals that will be of assistance to future service personal.
- train the end owner/user of the turbine in routine care and maintenance of the hydro system.

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.

1.3. 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.

1.4. Standards and certification

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

1.5. Pre-requisites

All PowerSpout hydro schemes are assumed to be in the following conditions:

- Run of river (unless advised otherwise).
- Areas free of combustible materials. Assess fire risk of the installation site, and if high implement extra fire precautions as appropriate. In environments where combustible materials are present the turbine must be mounted in a concrete or metal enclosure.
- Clean river water that will not corrode aluminium parts (sea water is permitted by special request only).
- Temperate climate. Do not install in situations where the pipe line may freeze or in temperatures below -15°C.
- Terrain that can be walked over safely for pipe laying etc. (i.e. no large vertical drops). 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.
- We advise engaging an experienced/qualified installer who has good electrical, mechanical and plumbing skills.

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.

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).

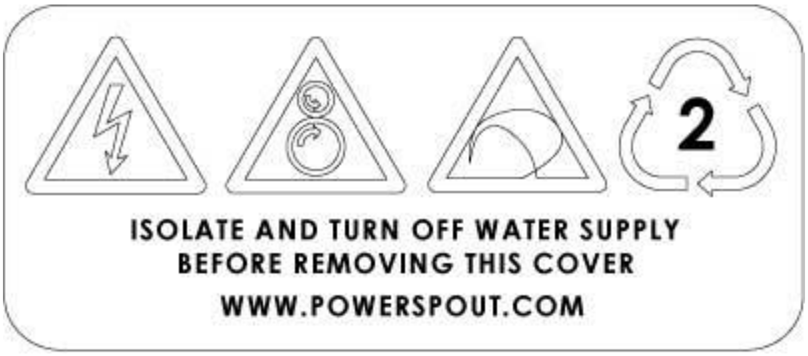
All other information required from the client and data needed by the client are contained in the advance calculation tool.

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
- Controller, battery and inverter system or grid connect inverter
- Installation service

1.6. Fairing safety warnings

The fairing on your PowerSpout turbine forms part of an electrical enclosure and carries the following warning signs. There are both rotational and electrical hazards present. Turbines must be turned off at the valve and the electrical 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.

1.7. Pressurised water pipes

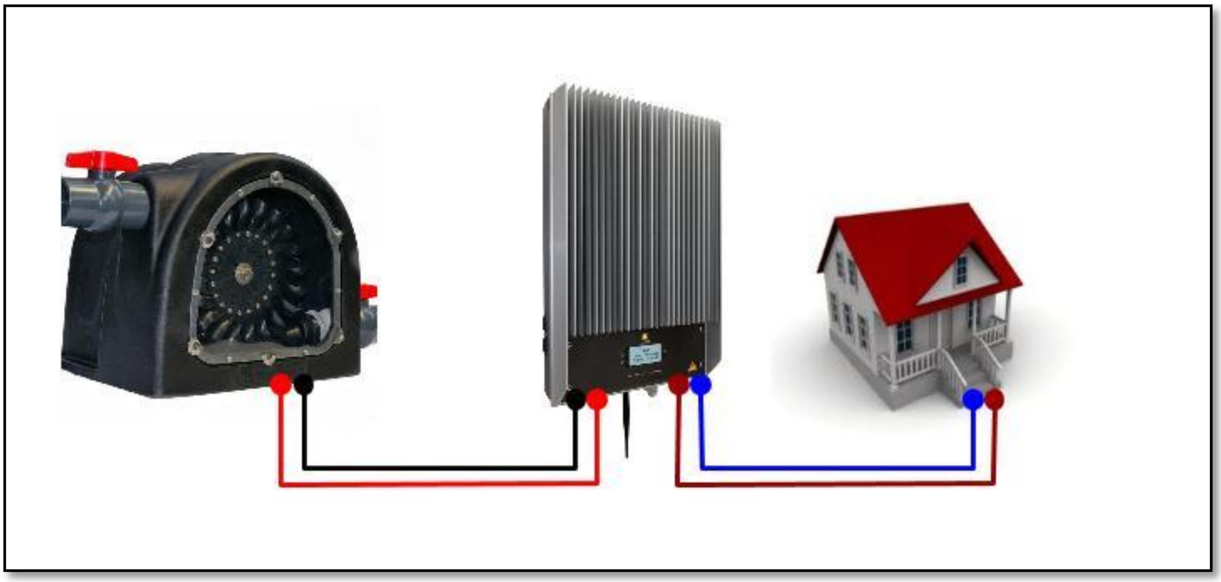
Legislation covering pressurised pipes applies in most countries for pipe pressures over 10 Bar. The PowerSpout runs at less than 10 Bar in most approved applications. Check with your local authority if you have any legal requirement that may concern this installation in your country.

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.

1.8. 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.



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/

Also Ginlong wind turbine inverters can be used in most global markets http://ginlong.com/Products/wind_GCI_2G.htm

Please note that SMA have recently withdrawn the Windy Boy range from the market.

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.

2. Step by step design overview

This section briefly outlines the main choices you will need to make in the design of your system and ordering the delivery.

2.1. Survey your site

Section 4 describes how to measure the head and flow of your hydro power site. You will also arrive at a length for the "penstock" or pipeline between the intake and the turbine site, and the length of the cable to your point of use. Take this information to the online Advanced Calculator or to a dealer. You will learn how much energy to expect from the turbine and what size of pipe you will need. Once you have decided the best layout you may need to get permissions, and take more accurate measurements before proceeding.

2.2. On or off-grid electrical system?

If you are able to connect to the utility grid and it is reliable then we strongly recommend that you choose an on-grid system without batteries. This will be simpler, cheaper and more environmentally friendly. Batteries need careful attention, and regular expensive replacement.

If you are on-grid then you can ignore large parts of this manual that deal with the various controllers required for battery systems. See section 5.14 for details of how to use a "grid-tie" inverter to connect your hydro to the grid so as to save electricity bills.

2.3. Battery voltage choice

12 V batteries were popular for small renewable energy systems in the past, but nowadays we see 48 V as a more practical choice. However the decision will depend on your needs.

Some very small systems may work better at 12 V because the battery is cheaper to buy and some of the load equipment may itself be 12 V for example. 24 V offers some of the advantages of each (and some of the drawbacks). Lower voltage systems are less efficient on the whole due to higher losses in rectifier and wiring.

If you have an existing battery system then you will probably wish to add the turbine to this system alongside the solar, wind or engine driven sources of energy that you already use.

2.4. Direct connection or MPPT?

PowerSpout turbines can be connected directly to the battery, and this can often be the cheapest option. In this case make sure that you provide sufficiently for charge control of the battery. This can be done using a "diversion load controller" or PWM controller (see section 5.5.1). But there are drawbacks with direct connection of the turbine to the battery.

PowerSpout recommend connection via Maximum Power Point Tracking devices (controllers and inverters) that have several advantages:-

- **MPPT adjusts voltage automatically for maximum Watts output**. This has two advantages: you tend to get more power, and you don't have to manually tinker with the turbine to optimise it. (You will still need to adjust the flow to suit available water.).
- Higher transmission voltage often results in significant cable cost savings.
- Generally fail-safe – in the event of controller failure generation stops so the batteries are not damaged.
- The controller will display (and log) production data.
- Precise battery setting of bulk, float, EQ - this is often needed for battery warranty proof.

PowerSpout turbines have been tested for compatibility with a number of MPPT inverter/controllers 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. More information on MPPT regulators is included in the 2014 Technical manual.

2.5. Cable voltage

You need a cable to carry the DC power from your turbine to your point of use. This cable will waste some power, depending on the current it carries and the size and length of the wire. A heavier wire will always be more efficient but for long cable runs the cost can become significant. Using a higher voltage can help to dramatically reduce the size of wire and the cost. This is one reason for using a 48 V battery rather than 12 V. But with MPPT you may be able to use higher voltages and make further savings. See section 5.7 for a discussion of different MPPT controllers and their voltage parameters.

2.6. AC coupling

It's possible to use a 'grid-tie inverter to connect your PowerSpout to an off-grid battery-based inverter's output wiring, if it is suitable for such connections (for example SMA, Outback, Victron and many others). This option is useful for larger systems with long wire runs and a high AC power demand. The grid-tie inverter is actually quite similar to the MPPT controller, except that it feeds the AC side of your power system. Your battery is charged via the main inverter working backwards when there is surplus energy. This is an advanced application of the PowerSpout that is not covered fully in this manual but we mention it for completeness. For more information on AC coupling refer to the 2014 Technical manual.

2.7. Over-voltage protection or not?

Hydro turbines that are not connected to anything that harnesses their power will overspeed and produce 2-3 times higher voltage than their operating (Maximum Power) voltage. This "open circuit" voltage or Voc can be a danger to equipment in some cases, although not always. If you are working at a high cable voltage or your controller has a low Voc rating then you may need to use one of our Klampit "crowbar protection" circuits to safeguard your equipment. See section 5.3.3.

2.8. Using surplus energy

Hydro turbines can produce a lot of energy at times when you do not need a lot of electricity and your batteries may already be full. A diversion load controller will burn this excess off as heat which can be used to heat water for domestic use.

It is much cheaper in capital cost to store heat in a water tank than it is to use a battery to provide heating. "On demand" heating should be used with caution. Electric kettles, induction hobs etc can work well on off-grid renewable energy systems, but the user needs to monitor the battery voltage prior to use. Discharging the battery excessively and repeatedly will shorten its life.

MPPT controllers can offer this heating benefit via external load relays, automatically operated by their auxiliary relays. In some cases it's important that the energy is safely disposed of, or your batteries or equipment may suffer, but with care you can direct this energy to useful ends and save burning propane or other fuels.

2.9. Optional extras you may wish to order

Check the pricelist for additional items that you may wish to have shipped with your turbine at no extra shipping cost in many cases. The list includes some useful tools, for example, the DC current clamp meter, which is indispensable for trouble-shooting battery systems of all kinds.

2.9.1. Bearings

You will need to check the bearings every year and replace if required. (Note that **our warranty terms require annual replacement** if automatic grease cans are not installed). Bearings are inexpensive and easy to replace, see section 9.4. 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.

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.

Many customers order a spare shaft and bearing block unit for quick replacement and minimum downtime. Then the bearings can be changed at your leisure.

2.9.2. Manifold fittings

The PLT and TRG models of turbine require pipework and fittings to connect them to your main pipeline or "penstock". You can buy these items from PowerSpout or locally. It's worth checking the pricelist to see what can be delivered directly and save effort. (See section 4.9)

The PLT turbine comes with valves and pressure gauge. Unless you buy the discounted TRG twin pack, camlocks fittings as well as valves and pressure gauge are supplied with the TRG turbines. All you need to buy is 10m of 50mm ID (2”) flexible hose, and arrange for your penstock branching to threaded outlets using saddles etc.

2.9.3. Spare jets

Each turbine in supplied with jets cut to the size that was calculated to your design in the Advanced Calculator. If your original measurements were accurate then these will work well, you can also close valves to adjust the flow. You will also get four spare jets that you can cut to any size (see section 8.3.2).

More spare jets can be ordered with the turbine to save on carriage costs later if you think you might need them.

2.9.4. 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.

3. Renewable energy from a PowerSpout turbine

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.

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/

The manual is intended to guide you through PowerSpout selection, design, assembly[1] 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 PMA may also be removed). This has been made possible due to an improved freight arrangement with DHL. But the installer is advised to check all internal electrical connections are tight and familiarise himself with the turbine assembly.

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. How much power will the PowerSpout produce?

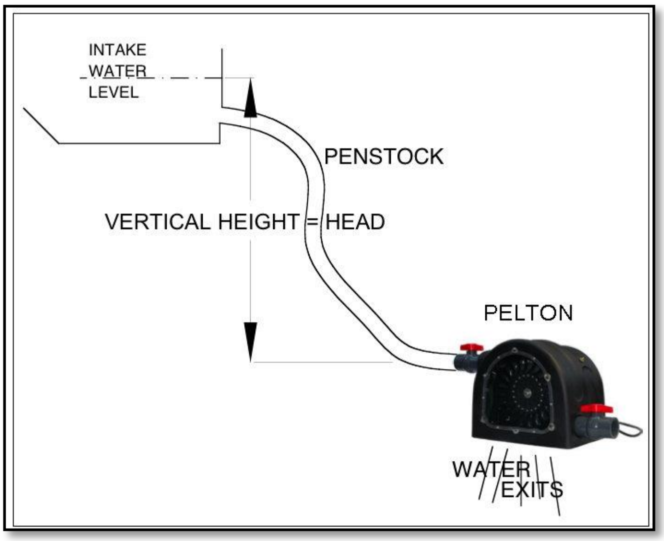
3.1.1. Head and Flow

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).

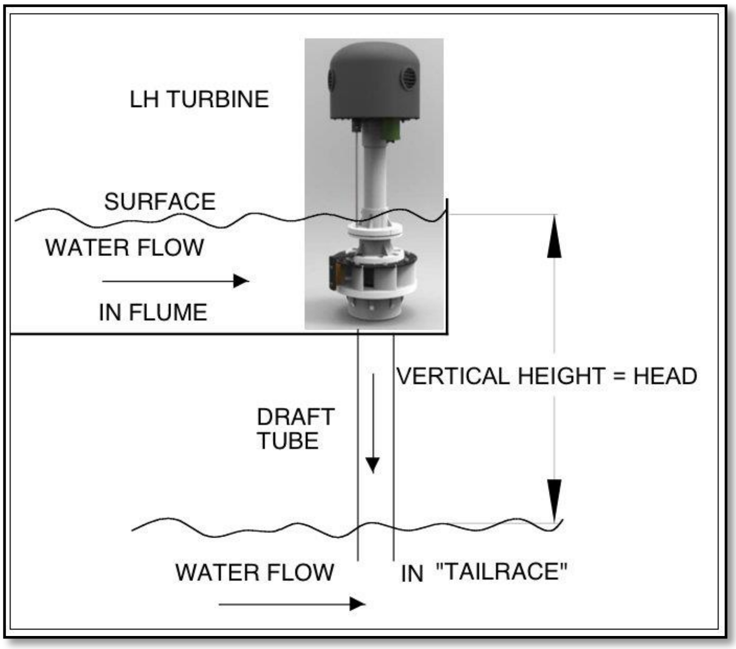
Flow rate at any given time can often be measured by simply watching a bucket filling up and measuring the time it takes, and the capacity of the bucket. Flow changes around the year though and you will need to be realistic about how this impacts on the output. Solar PV is a very good choice to supplement hydro power during drier months on some sites.

For the Pelton and Turgo turbines the head is measured between intake water level and the turbine jets below. Water exits the turbine at atmospheric pressure back into the stream.

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



In the case of the LH turbines, the propeller turbine is normally near to the surface in an elevated flume. You can measure the head from the intake surface level down to the water surface in the tailrace below.



3.1.2. Estimating the power output

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

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, given suitable water pressure and flow conditions. Maximum current that the turbine wiring can carry is 32 amps as standard; an upgrade to 50 amps is available on request for high power low voltage applications (fee applies).

3.1.3. Worked example

If for example the head is 20 metres and the flow is 10 litres per second then the power generated is about 1000 watts or 1 kW continuously (20 x 10 x 5 = 1000). The turbine will therefore produce 24 kWh of energy per day and over 700 kWh units of energy per month. This exceeds typical household energy consumption in most countries. If the power output is only 500 watts then you would get half as many units per month, which would still suffice in many cases. (The same arithmetic applies to solar PV although obviously that will only work in daytime hours so that a 1kW PV array is unlikely to produce more than 6 units of energy per day in summer and may average 4/day or less over a typical the year.)

3.1.4. Supply and Demand issues

Renewable energy is different from (for example) a diesel generator. In the case of a generator, you can run your house (or whatever, known as the "load") directly from its AC output. The governor in the generator will adjust the fuel consumption to meet your needs. If you run it continuously then you will get through a huge amount of fuel.

In the case of renewable energy, the fuel is free, so you will not want the turbine to reduce its output to suit the load. You will probably want it to produce as much energy as possible all the time. That way you make best use of the investment in money and effort that went into setting up the turbine. The only problem is that at any given moment you will often need more power than the turbine is producing and you will often need less.

3.2. How to match the constant power supply to our changing demands?

The solution is to store the energy produced by the turbine in a battery, or to feed it into the electricity grid. When you need more than the turbine can give you then you will draw the extra from the battery or from the grid. This is how we build a renewable energy "system" with a PowerSpout turbine (and perhaps also some solar PV panels) and a battery or grid-tie backup. If the grid is available then this will normally be the more cost-effective way to store the unused energy.

3.3. What happens if there is not enough water for the turbine?

The flow of water through the PLT or TRG turbines depends on the head of pressure and on the size and number of jets that direct the water onto the Pelton or turgo runner. If there is not enough water entering the penstock at the intake to keep this flow supplied then air will enter and the pipe will gradually empty. This reduces the head and consequently the flow in the jets is reduced and an equilibrium is found. However this will not produce the best power output due to reduced head. If the power output is observed to decline then the **user should intervene** and adjust the turbine jets to match the new flow. Closing one of the turbine's valves may be enough to reduce the demand enough that the penstock refills and full pressure is restored. Power output will be less than full power but at least with a full pipe the best use is being made of the available water.

The user should check the pressure gauge and make sure that the pipe is always full by choice of the number and size of jets in use. If the pressure is low then it may be a good idea to close all the valves and wait until the pipe refills before opening a reduced number of jets or changing to smaller jets to match the prevailing flow conditions.

On a good site this adjustment may rarely if ever be needed as there will always be sufficient flow of water to produce full power. But where necessary the PowerSpout can make good use of partial flows provided that the jets are adjusted to suit.

3.4. How can we be sure of getting the right voltage out of the turbine?

Your turbine will have been designed to produce maximum power at the chosen operating voltage. Turbine voltage depends on speed. The design process involves predicting the best rotational speed for the turbine, which depends in turn on the pressure of the water, which depends on the head you measured.

Accurately measure the head at your site, and use the recommended pipe size, so that the actual pressure of the water ends up being close to the value that the turbine is designed for. Every site is different, so the design process is critical and the measurement of head is key.

3.4.1. Voltage and turbine speed

The voltage produced by your turbine will vary depending on how fast it is running.

Renewable energy sources such as turbines and PV panels are actually quite volatile in their voltage. You need a load (for example a battery) connected to keep that voltage stable. If a turbine or a PV panel is hooked up directly to a battery, it has no choice: its voltage is the same as the battery voltage. Two things that are connected to each other in parallel must have the same voltage. If the turbine tries to push its output up to a higher voltage then there will be a charging current into the battery that holds the turbine voltage down through its internal impedance. The extra current will raise the battery voltage a little, but the battery is very stable compared with the turbine or PV. So **the battery itself actually governs the runner speed**, by loading (restraining) the turbine when it runs fast enough to produce the desired voltage.

Your turbine will be designed to work best at the head you have reported for the site and the voltage of your battery (or controller). We recommend that you opt for an MPPT controller in the electrical design of the system (later) because this gives more flexibility. The controller will automatically adjust the voltage (within its operating range) to find the best speed. This maximises the power. Hence the title Maximum Power Point Tracker.

3.4.2. Manual optimisation of the turbine

If the voltage is fixed (turbine feeding the battery directly without MPPT) then we can still manually adjust the speed of the alternator by tweaking a third variable: magnetic field strength.

The voltage actually depends on several factors: the rpm, the design of the windings in the stator, and the strength of the magnetism moving past it. By putting spacers behind the magnet rotor we can move it slightly away from the stator and then the runner will move faster to create the same voltage. So, if we find that the turbine is a little too slow compared to it's best speed we add spacers and optimise the output. (see 3.58.4.3 for more on this) This may be tricky to do and may not achieve the best operating speed and conversion efficiency for the turbine. It may not be easy to optimise the turbine for all flow conditions, using packing washers.

One big advantage of MPPT controllers is that they will alter the turbine voltage until they find the maximum power (corresponding to the maximum speed). So we get the best out of the turbine under all conditions and we don't have to take it apart and play with spacers to achieve this.

3.5. Understanding open circuit voltage (Voc)

When there is no current, because the turbine spinning is disconnected, we can measure the "open circuit voltage" (Voc). The Voc depends directly on the turbine speed in rpm. Double the speed and you double the Voc. Different turbines will have different Voc/rpm ratio, depending on the site and the required voltage. But any turbine will have a much higher voltage when it is running faster off load than it will when working optimally.

Imagine you put your foot on the accelerator/gas pedal in a car when the engine is out of gear. The rpm will go up quickly and the engine will race. Let in the clutch and the rpm slows down as the engine comes under load. If you open the valves for the turbine when it is electrically disconnected then it will overspeed to almost double the best operating speed for energy production. The Voc will now be much higher than the design operating voltage. If it is designed to work at 56 volts (to directly charge a 48-volt battery) then the Voc may rise above 150 volts. This could endanger you if you touch it, and it most likely would kill any inverter that is designed to connect to a 48-volt battery. So it's very important **never to disconnect the battery** when the turbine is running and connected to an off-grid inverter.

In the case of solar PV the Voc is also somewhat higher than the battery voltage, but the difference is not so huge, and the dangers are less. Most controllers designed for solar PV will disconnect the PV to control current to the battery. They can withstand the Voc from a PV array but may be destroyed by the high Voc of the hydro turbine.

Never connect a controller in series **between the PowerSpout and the battery** unless:

- It's an MPPT controller
- you have checked rigorously that the Voc will not damage it.

If the battery voltage is 48 V then you will need to either use a protection crowbar (for example a PLT100C turbine) or you will need to choose a controller with a high enough Voc rating.

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

- Tell us prior to ordering
- Report an **accurate** measure of the head of your system
- **Check** runaway Voc prior to hook up

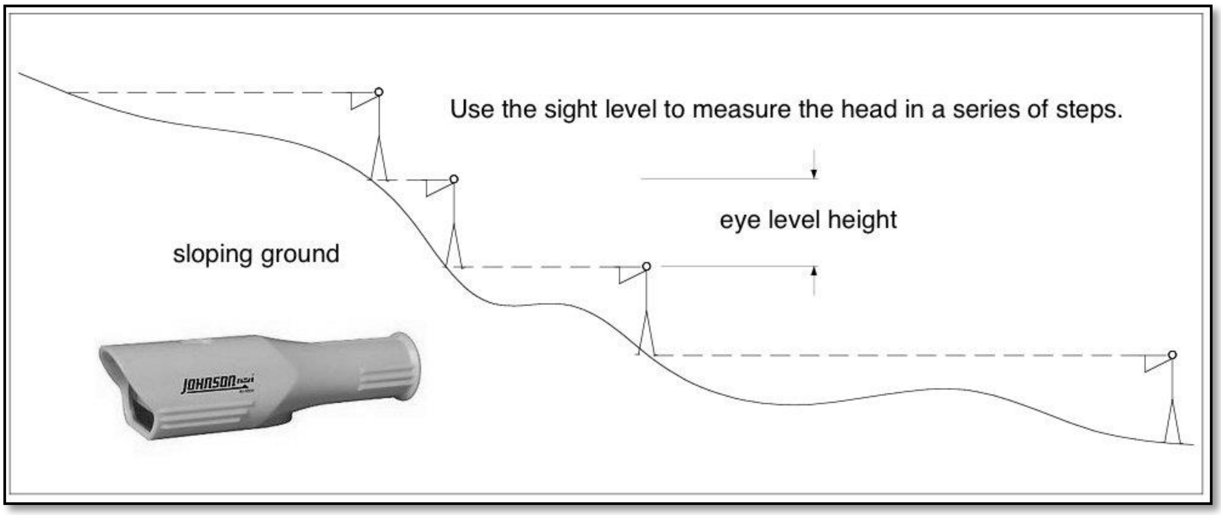
4. Designing your site layout and choosing your turbine model

4.1. Measuring Head

You will need to measure the vertical drop in feet or meters (referred to as head or fall). A map with contours can be useful for initial feasibility study followed by a site survey using the methods below. It's a good idea to use more than one approach, so you can check accuracy.

Altimeter - obtain an altimeter accurate to 10 feet (3m), this is good for measuring falls greater that 70 feet (20m). Take the average of several readings. Some modern hand-held GPS instruments that are fitted with internal altimeters can read altitude to 1m if the air pressure is stable during the survey.

Builder’s optical level ("sight level") - measure the fall between intake and turbine in steps as you progress along the pipe route. This is good for lower falls and it is very accurate. You can use the height of the spotter's eye level as a unit of measure and move up the slope in a series of equal steps. Use a helper to mark the spot, or simply keep your eye on that spot until you are standing on it ready to sight the next one.



Low cost laser level - at dusk or in low light conditions project a horizontal beam and using a long staff measure the vertical drop, as you progress down alongside the stream. You may have to repeat this at a few locations.

Pressure gauge - lay a length of small bore plastic pipe or hose, fix a pressure gauge to the end and measure the pressure of the water with the pipe full. 14.5 psi is 33 feet of fall (100 kPa is 10m of fall). Make sure you clear the line of all air first. This is a very accurate method and easy to do.

Click here for a recent Home Power article on how to measure the head.

4.2. Measuring Flow

IMPORTANT: "Gallons," "gals," and "gpm" refer to the US Imperial Gallon (3.8 litres), as opposed to the UK Imperial Gallon.

Try and find a place in the stream where it drops quickly over a rock, place your bucket below and measure the time to fill it.

At lower flow rates, less than 150 gpm (10 l/s) you need to be accurate in measuring the flow. If you have a 2 gallon paint pail and the river can fill it in 2 seconds you have 1 gps = 60 gpm, which equates to 227 l/min, 3.8 l/s.

Use the largest possible bucket you can find as the longer it takes to fill the more accurate your reading will be.

For flows greater than 150gpm try to estimate your flow using a larger bucket in the river and measure at various places across the river. It will not be as accurate but at higher flows it is not that critical.

A "notched weir" is useful for monitoring flow over time as it can be used to take quick readings on a regular basis, but it takes some effort to construct.

Click here for a recent Home Power article on how to measure flow rate.

4.3. Choosing the correct turbine for your site

Different sites will need different PowerSpout models depending on the head and flow.

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

- PLT (PeLTon turbine)
- TRG (TuRGo turbine)

TRG and PLT model turbines are connected to pressurised pipework that feed water through jets towards the turbine runner, spinning the runner and hence the generator, which generates electricity. These are normally referred to as "impulse turbines".

- LH & LH Pro (Low Head propeller turbine)

LH model 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". The turbine sits close to the intake water surface with the alternator on a stalk above flood levels. Water is actually driven by suction created by the weight of water in the draft tube **below** the turbine. The head is measured from the water surface at the turbine to the water surface of the tail race where the draft tube discharges.

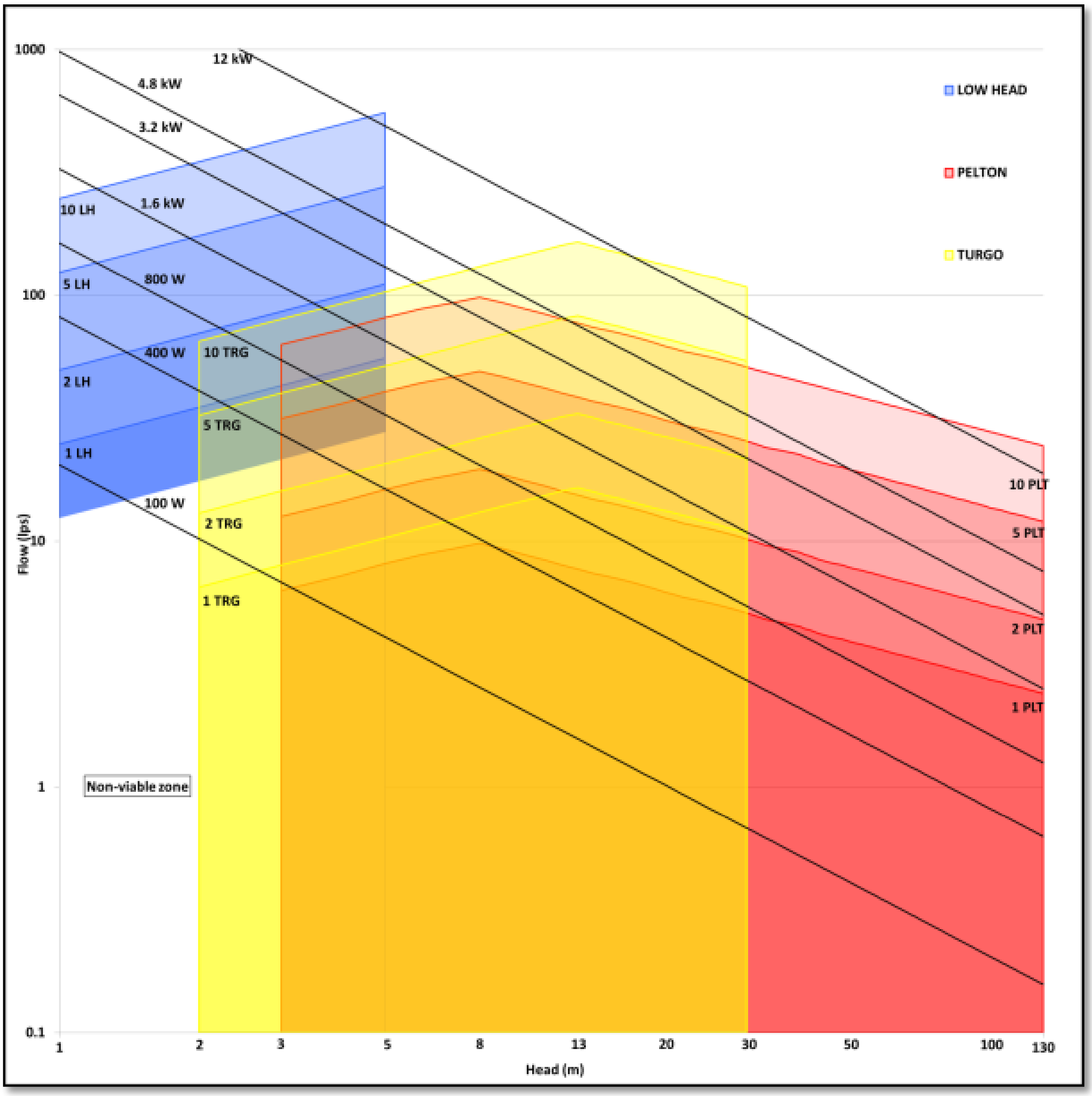
Version	Head (m)	Flow (l/s)	photo
PowerSpout PLT (Pelton)	3 – 130 m	0.1 – 10 l/s	
PowerSpout TRG (Turgo)	2 – 30 m	8 – 16 l/s	
PowerSpout LH (Low Head)	1 – 5 metres (below turbine in draft tube)	25 – 56 l/s	

When you have found out the head and flow rate at your site, the chart on the next page will quickly tell you the maximum power you can generate (refer to black angled lines indicate 100W to 12kW).

The coloured zones refer to the range for each product type:
The red lines are 1, 2, 5, 10 PowerSpout Pelton (PLT) turbines respectively
The yellow lines are 1, 2, 5, 10 PowerSpout Turgo (TRG) turbines respectively
The blue lines are 1, 2, 5, 10 PowerSpout Low Head (LH) turbines respectively

For example a site with a head of 20m, and flow of 10l/s can generate about 1000 W with 1 TRG or 2 PLT turbines.

Once you have identified the most suitable turbine type(s), use the Advanced Calculation Tools at www.powerspout.com to perform accurate site calculations. The Advanced Calculator will help you find the best sizes of pipe and cable for the site, and predict the net power output for each possible size that you might choose.



4.4. Siting your PowerSpout turbine

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

4.4.1. Choose a place that is accessible.

If necessary make steps and put in rope handrails to ensure that your turbine can be accessed safely.

4.4.2. Choose a site that has the most fall

You should position the PowerSpout to obtain the greatest fall (head of pressure) possible with the shortest length of pipe. If it makes the cable unacceptably long then look at using MPPT to raise the cable voltage.

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.

4.4.3. Keep your PLT/TRG turbine as low as possible

Maximise the head, but do ensure that it is above maximum river flood level.
Your PLT/TRG turbine should also 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.

4.4.4. Place it as close to your battery bank or point of grid connection as possible,

The cost of the cable is important, although cost depends on the chosen voltage. A low cable voltage means that a short, heavy cable is desirable.

The distance between your turbine and batteries has a significant bearing upon the cable size required. To keep cable size (and hence cost[2]) down we usually recommend that off-grid clients who are not using MPPT choose 48-volt battery systems rather than lower voltage. 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.

Using an MPPT controller offers the 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 cable voltage to a Midnight Classic 250 MPPT controller 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 controller changes the voltage to suit your 12/24/48 V DC battery bank.

One benefit of this approach is that **existing** 12/24 V DC systems can be cost effectively integrated with the PowerSpout PLT/TRG/LH. 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.

4.4.5. Hydro turbines do make some noise, so keep them at least 30 m from your home.

Some clients have installed turbines too close to their homes. Measured noise levels are listed section 19

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.

4.5. Connecting two small streams into one PowerSpout

We are often asked if two small streams can be piped into a common 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 could then be joined together into a common supply cable, but only for PLY/TRG 12/24/48 VDC turbines. If you want to use MPPT then you will need a wire for each turbine.

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

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

4.6. PowerSpout site data requirements

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.

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 controller 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

4.7. The Penstock

The online advanced calculator at www.powerspout.com/calculators/ will have advised the appropriate internal diameter (ID) of pipe for the "penstock" or pipeline, based on the site data you entered. You should position the PowerSpout to obtain the greatest fall possible in the shortest distance.

For initial feasibility you can use a map and/or gps to survey penstock options. When you have chosen the locations for the intake and the turbine, measure the pipe length using a long tape or wheel, be accurate, as this information will be required to buy the pipe and it’s important to get it right.

Try to lay the pipe to avoid high spots in the line that might trap air bubbles. Use a level to check that it is always graded downward. If a high spot is unavoidable you will need to place a bleed valve at the highest point in the pipeline to purge air. Air locks in the line will significantly affect the power output of the turbine. The longer the penstock the more of a problem this tends to be. Penstocks over 1 km long can be problematic if there are many high spots trapping air. Automatic bleed valves may be useful in such cases.

4.7.1. Pipe sizes

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)

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.

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 (Low, Medium or High Density PE) 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.

4.7.2. Pipe material

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 25% 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.

4.7.3. MDPE and HDPE pipes

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 PE pipes the obvious choice for the PowerSpout PLT turbines.

Remember that you can vary the pipe pressure rating to minimise costs. For example, if you have a 100 m head you start with low grade (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 2014

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

4.7.4. 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.

4.7.5. Pipe myths

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 increase the friction, which will actually decrease the final pressure.

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 pipe velocity by reducing pipe size the pressure at the turbine 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.

If the penstock simply discharges "full bore" (for example, to flush out sediment) then the flow will be large, and there will be no pressure left. Pressure is all used up in pipe friction. Normally the turbine uses jets to restrict the flow and convert the pressure into velocity to drive the runner. The flow in the penstock will be controlled by the size(s) of jet(s) that you use in your turbine(s). Larger jets will demand more flow, which will in turn create more friction loss, and may reduce the pressure at the turbine. Smaller jets will minimise the flow and the pressure will be slightly higher. Using a small bore **jet** may result in higher pressure (due to lower flow rate) but using a smaller bore **pipe** will not, as it simply increases the friction.

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

4.7.6. 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, pressure rises and pressure drops.
- 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.

4.7.7. Penstock valves

You may wish to install a valve below the intake, but this is rarely useful. If you do install a valve at the top end of the penstock then the weight of water below will cause a vacuum that may collapse your pipe or draw debris into it. It is good practice to fit a vent pipe just below any such valve so the penstock can drain. This vent often helps air to escape while the penstock is filling.

The turbine comes with valves that control the individual jets, but you may also wish to put a larger valve on the penstock just prior to the manifold. Closing this valve allows you to work on the manifold without draining the penstock. It also means that the penstock can be filled and bled of air in advance of installing and commissioning the turbine itself. The air can take time to find its way out via the intake and vents fitted.

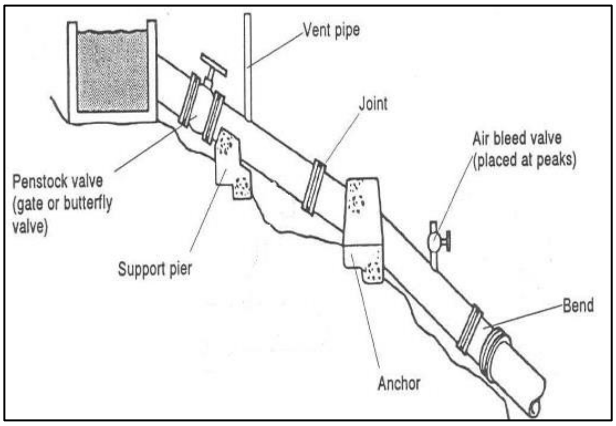
You may need bleed valves at high points if the penstock slope is not continuous. These are only used to remove air and can be closed during operation.

Finally you may wish to install a flush valve at the bottom end of the penstock so that you can flush out sediment.

None of these valves are always essential - each has possible merits.

4.7.8. 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.



4.8. 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

4.8.1. Water usage with minimum impact on the environment

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

4.9. Turbine "manifold" connecting options PLT and TRG

The manifold is the system of pipes that connects your penstock to your turbine jets.
The penstock is what we call the main pipeline from the intake.

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. Turbine manifold pipes are often branched off the main run before this flush valve.

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.

4.9.1. Connecting your pipe to the PowerSpout

The ball valves supplied have either 2” female BSP threads or (for the USA and other countries that use NPT threads) a 2” BSP thread on the jet side and 2” NPT thread on the other side. Customers in the USA can buy NPT threaded fittings locally. (PowerSpout can also supply PVC manifolds for our PLT turbines with 2” BSP/NPT threads, see below.)

Penstock pipe fittings must be bought separately, as every site is different. 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.

4.9.2. Recommended 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

The table below indicated the power loss in Watts per metre of pipe.
(Also an elbow or Tee fitting equals roughly 2 more metres of pipe.
Such losses tend to be negligible on a penstock, but important on small-bore manifolds.)

	Pipe bore in mm			
Flow l/s	40	50	65	90
1	1.8	0.6	0.2	0.04
2	3.6	1.2	0.35	0.07
3	5.4	1.8	0.5	0.1
4	7.2	2.5	0.7	0.15
5	9	3	0.9	0.2

4.9.3. Quick connections

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:

- Plastic Camlocks 50mm (2”)
  Camlocks with flexible pipes (hoses) are more suited to lower head sites of 60m and less.

- PVC mac-unions (for rigid pipes)
  PVC mac-unions are rated for heads up to 160m.

4.9.4. The connections made to the penstock

You will need up to 2 penstock connections for every PLT turbine, and up to 4 for every TRG turbine.

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

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

4.9.5. 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.
These saddles can also be used for making a large pipe vent just after the intake.

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

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

Saddles have the following disadvantage:

- Sharp take-off so higher fitting losses, meaning they are not suited to low head, high flows

Saddles connected to turbines via camlocks and flexible pipes suit heads between 10m and 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.

4.9.6. 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 below. 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 looks like the picture above.

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 hose.

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 - With flexible hoses you can make fine adjustments to the nozzle by manipulating the hose itself during optimisation at set-up and then securing it in this position.
- Easy to remove
- Use fewer elbows, so have lower losses for a given ID.

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

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.

4.9.8. PVC manifolds for our PLT turbines

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.

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

For many sites HDPE pipe fittings can be used to build a manifold.
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 opposite 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.

4.9.10. 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. Note the mac unions so that the turbines can be easily removed.

4.9.11. Other manifold options

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

4.9.12. 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.

Sharp elbows create as much head loss as a 1-2m of pipe length. If your penstock is 1000m long a few fittings are of little consequence, but if you are on a short small diameter penstock at a low head then this can result in significant power loss, multiple elbows are to be avoided in small bore manifolds.

4.9.13. Pipe supports

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. Bear in mind when securing moveable pipes that you may wish to manipulate the pipe itself during optimisation at set-up so as to find the best jet position/angle.

5. Electrical System Components

From the coils in the alternator to the heaters that control the battery charge, every part of the electrical system needs to be compatible with the others so that the whole thing works properly. Your PowerSpout dealer can design your system for you but it is helpful to understand these relationships and to be familiar with the options and the safety issues of your system.

5.1. "Smart Drive" Permanent Magnet Alternator (PMA)

3-phase permanent magnet generator, adjustable for speed and voltage, up to 80% efficient.
Maximum power: 0.7 W/rpm standard, 1.0 W/rpm high power version
Speed: up to 1600 rpm depending on turbine runner and site head.

Magnet rotor The rotor is directly driven by the turbine runner via the shaft. Magnetic field strength can be adjusted to optimise the rpm in the case of direct battery-charging systems, using packing washers (See 8.4.3)	
Stator The stator contains coils that produce a 3-phase AC output when the magnet rotor spins. Your stator has been chosen based on data provided in the advanced calculator, so as to provide the correct voltage at the best RPM for your turbine runner to operate with your chosen head of pressure.	
Bearing block and shaft This supports the above parts and also the turbine runner. Bearings need to be greased and replaced periodically. Automatic grease dispensers are available as an optional extra.	

5.1.1. Rectifier

A rectifier within the PowerSpout converts the 3-Phase AC produced by the PMA to DC for supply to your battery bank or grid-tied inverter. 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.

In order to comply with standards for conducted <u>and</u> radiated emission noise, the 3-Phase rectifier in your PowerSpout may include a noise filtering module for <u>conducted emissions</u>. 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. In a 12 V system you lose approximately 10% of the energy you generate in the rectifier, whereas this figure is only 3% for a 48 V system.

5.2. Unloaded rpm and Open Circuit Voltage (Voc) revisited (see also 3.5)

In a hydro turbine that is unloaded (the output wires are left unconnected), the rotor reaches almost the same velocity as the water jet. The resultant rpm can be easily calculated for your site data by the advanced calculation tool. The voltage of any PMA when unloaded is proportional its rpm. This "open circuit voltage" or Voc can be high enough to cause damage or danger.

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 theoretically increases to almost 2 x normal speed
- The Voc for an Smart Drive PMA is almost 2 x MPPV even at constant rpm

In practice due to friction the relationship between Voc and MPPV (maximum power point voltage) is roughly as follows:

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

5.3. PowerSpout standard voltage options

5.3.1. PowerSpout **PLT and TRG turbines**

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 controllers or to grid-connect inverters. The turbine abbreviation (PLT, TRG) is followed by a number that indicates the approximate "maximum power point" voltage or MPPV, which is also the operating cable voltage. This will be close to the voltage the turbine produces when the speed is optimised for maximum power depending on how accurate the design data (estimated head, etc) proves to be in reality. For example:

- PowerSpout PLT 28 has an MPPV of 28 V (connects directly to 24-volt battery bank with PWM diversion controller). 28 V is the "bulk charging" voltage for a 24-volt battery.
- PowerSpout PLT 200 has an MPPV of 200 V (connect to grid via grid-tied inverter)

5.3.2. PowerSpout **LH turbines**

For PowerSpout **LH turbines**, for example the LH200, the 200 <u>is not</u> the MPPV but the **maximum Voc** 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.

5.3.3. Klampit "crowbar" protection circuits (optional)

A Klampit is a proprietary safety device that short circuits the PowerSpout at a pre-set voltage. Shorting the turbine does not harm it, but removes the dangerous voltage until the Klampit is manually reset (usually by stopping the turbine). This type of device is called a crowbar circuit and is given the abbreviation “C” in the turbine product name. You may or may not need to use one.

There are 3 options:

PLT/TRG Turbine designation	Klampit crowbar voltage	statutory significance	Used with
56C	75 VDC	ELV in many countries	direct connection to 48-volt battery at ELV
100C	120 VDC Or 140 VDC	ELV in some countries (NZ and Australia)	MPPT controllers up to 150 VDC
170/200C	240 VDC	LV ("Low" voltage)	MPPT controllers up to 250 VDC

Note - 140 VDC Klampit are normally installed in turbines for delivery outside Australasia.

5.3.4. PowerSpout PLT versions

Common versions of PowerSpout PLT with <u>no overvolts crowbar</u>

	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	120 ELV NZ/AUS	150	220	<450	<550
Controller/inverter	PWM	PWM	MPPT	PWM	MPPT	Grid-tie	Grid-tie

* PWM signifies direct connection to battery with diversion load control. 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 <u>with overvoltage protection fitted</u>

	Off-grid 48-v battery 75vdc crowbar	**Off-grid** 120vdc crowbar	**Off-grid** 240vdc crowbar		**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
Controller/inverter	PWM	MPPT	MPPT	MPPT	Grid-tie

5.3.5. PowerSpout TRG versions

Common versions of PowerSpout TRG with no overvolts crowbar

	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	120 ELV NZ/AUS	150	220	<450	<550
Controller/inverter	PWM	MPPT	PWM	MPPT	Grid-tie	Grid-tie

* PWM signifies direct connection to battery with diversion load control. 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 overvoltage protection fitted

	Off-grid 48-v battery 75vdc crowbar	Off-grid 120vdc crowbar	Off-grid 240vdc crowbar		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
Controller/inverter	PWM	MPPT	MPPT	MPPT	Grid-tie

5.3.6. PowerSpout LH

Common PowerSpout LH and LH Pro products

All LH and LH Pro products connect via MPPT controllers or grid-tied inverters. There are no direct battery options available as propeller rpm is critical for best performance. Numbers refer to maximum Voc. An LH150 for example has a maximum runaway voltage (Voc) of 150 VDC. It may be less, and is generally in the band 110-140 VDC .

- **LH150 and LH150Pro** – use with MPPT controller rated for up to 150 VDC charging batteries. In a few cases with long cables, the MPPV could be slightly low for 48 V batteries. Check with us if you plan to do this.

- **LH250 and LH250Pro** – use with MPPT controller rated for up to 250 VDC charging batteries. Cable voltage will be higher for better efficiency.

- **LH400 and LH400Pro** – use with MPPT controller or grid connect inverter rated for up to 400 VDC. MPP cable voltage may be as low as 140 VDC in a few cases.

5.3.7. Special PowerSpout options

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

5.4. Cable sizing

Some energy will be lost in the cable due to the heating effect of the current. This manifests as a voltage loss in the cable, usually expressed as a % of the operating voltage. The Advanced Calculator www.powerspout.com/calculators/ will either work out the minimum cable size for you (given a target % loss), or the % loss for a given cable size. This tool clearly demonstrates the effect that changing the cable % loss has on the cable size (and hence the cost of the cable). Changing the "design load voltage" will also have a dramatic effect, which may lead you to choose an MPPT controller for sites with long cables.

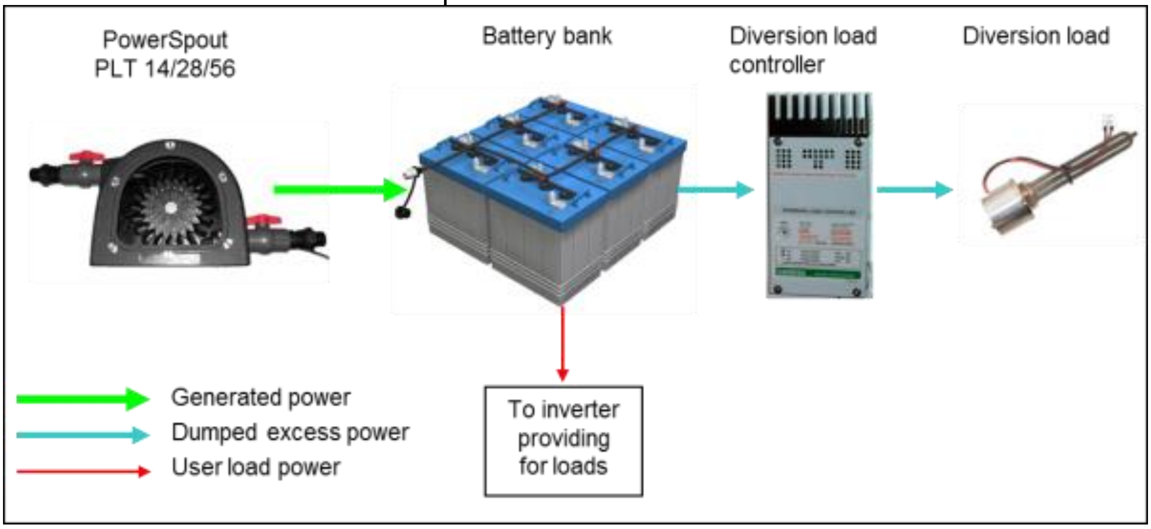
Try to keep losses as low as possible, particularly if you have limited hydro generation and need all the power you can get. A loss of 5% in cables is normal. Cables with losses greater than 10% should only be used in cases where the cable cost is very significant in the total equipment cost and/or where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

5.5. Charge controller choice

A vital part of battery systems is the charge controller. This device protects the battery by regulating the current fed into it, so as to limit the rising battery voltage to a particular maximum limit. This "set-point" is automatically chosen for the battery type and temperature and its state of charge. There are two types of controller to choose from:

5.5.1. Diversion load controllers

PWM (Pulse Width Modulation) diversion load controllers are needed when the turbine is connected directly to the battery. They work by diverting excess current into a heating load known as a "diversion load" or "dump load". More details follow in the next section.



Pros and cons of diversion load controllers versus MPPT controllers:
Pros:

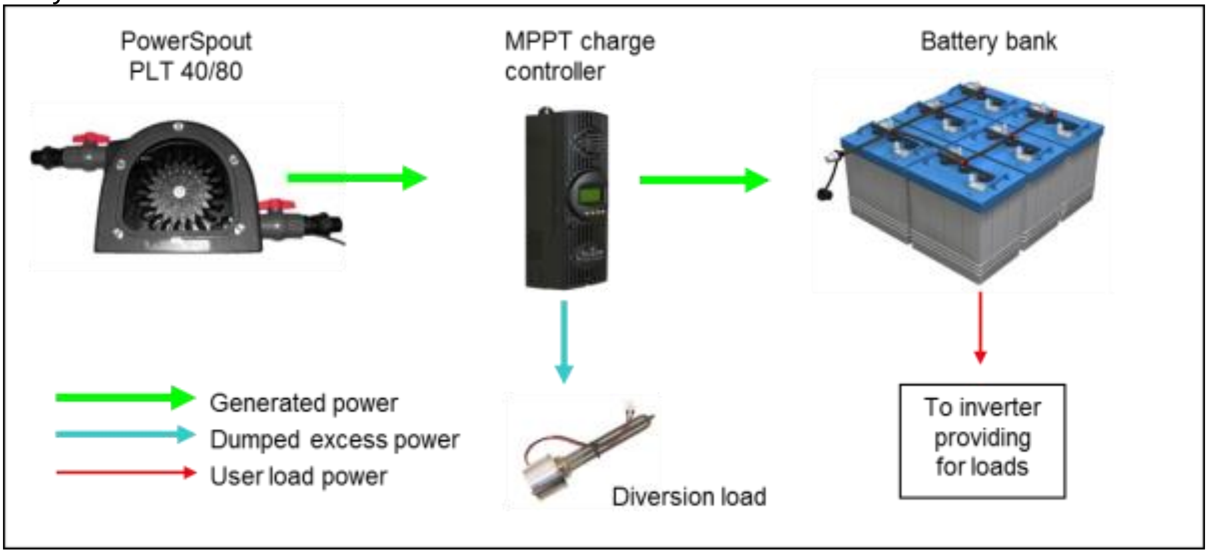
- Lower cost
- Simpler wiring at safer voltages with fewer things to go wrong
- Provides useful heating output for hot water etc.
- Internal losses are low <1%
- Displays how much energy it has dumped on a screen in some cases

Cons:

- Turbine runs at battery voltage, so manual turbine rpm optimisation is often needed
- Hydro rpm can never be perfectly optimised as it varies with the battery voltage
- Direct connection of turbine to battery does not fail safe; failure of the PWM controller 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.
- PWM type diversion controllers and their heating loads can make a significant buzzing noise that might be unwelcome in a living space.

5.5.2. MPPT (Maximum Power Point Tracking) controllers

MPPT (Maximum Power Point Tracking) controllers work with higher voltage turbines, and convert this voltage down to charge the battery. The MPPT function is especially useful for optimising the turbine speed automatically. They control battery charge by restricting the current that reaches the battery but often allow you to harvest surplus energy via an auxiliary relay.



Pros:

- **MPPT adjusts voltage automatically for maximum Watts output**. This has two advantages: you tend to get more power, and you don't have to manually tinker with the alternator to optimise it. (You will still need to adjust the flow to suit available water.)
- Higher transmission voltage often results in significant cable cost savings
- Generally fail-safe – in the event of controller failure generation stops, so the batteries are not damaged by over-charging.
- The controller will display (and log) production data and battery charge settings, which helps with trouble-shooting and with battery warranty claims.

Cons:

- Higher cost (though the New Classic KID is not that costly)
- Internal losses are normally 3-7%
- must be able to withstand Voc as the turbine may become disconnected

5.6. Diversion (PWM) load battery-charge controllers in detail

The following are common PWM controllers for use with hydro turbines and dump loads. Use internal settings to configure the controller for **diversion**. Do not use 'solar charge control' mode with these controllers. See 6.5 for details of how to wire the system.

Power Master PM60

Morningstar TS60

Xantrex C40

Once the controller recognizes that your battery charge rate has reached the highest safe level it diverts any **additional** incoming power to a diversion load. Such controllers normally allow you to set the voltage threshold at which power diversion starts according to the type of battery in use. This threshold will also be automatically adjusted for the stages of battery charging (absorb, equalise, float) and the battery temperature.

A non-MPPT controller should **never** be placed **between** the hydro turbine and the battery. This is normal practice for solar PV and a battery only. Many clients new to hydro think the same applies for hydro **- it does not**. Installing a solar controller that is not designed for MPPT between the turbine and the battery will usually destroy the controller through the hydro's high Voc off load.

Low cost solar controllers are NOT suitable for micro-hydro and wind applications as they do not have a diversion mode option.

5.6.1. Multiple energy sources and diversion load controllers

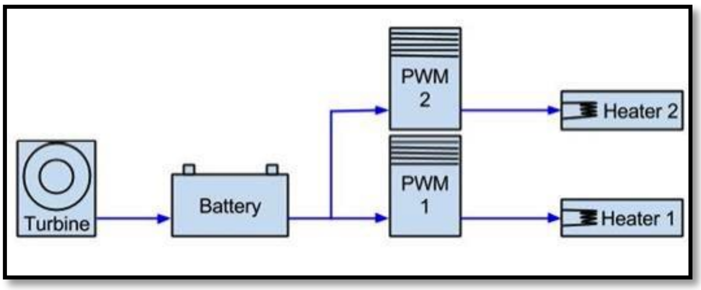
A PowerSpout turbine can charge the same battery as a solar PV array, wind turbine and/or other sources. This is a very normal arrangement, with many advantages for the user. Diversion load controllers need to be sized large enough to divert all of the current from all unregulated sources (such as direct-connected hydro and wind turbines).

If your solar system has its own controller then the diversion controller can work alongside this but you may see some error indications on one of the two controllers as they are unlikely to exactly agree on the best charging voltage. This need not be a problem so long as the battery charge rate is effectively regulated.

When charging the battery from an engine driven generator you may find that the energy is being diverted into a heater by the controller. If this is unwelcome (waste of fuel) then you may need to adjust downward the charge voltage settings of your inverter/charger unit so that the diversion control is not triggered. It's also possible to use a relay on the generator output to modify the 'battery sensing' voltage to the controller so as to defeat it during generator operation.

5.6.2. Backup diversion load controller

A secondary or backup controller is recommended in all hydro energy systems where the turbine connects directly to the battery. Since PWM controllers are relatively inexpensive components, redundancy will protect the higher value components in your system in the event of failure of the primary controller.



This picture illustrates two PWM controllers and their diversion resistors. If there is a controller failure, the expensive battery bank will remain protected from overcharging. Over-charging batteries can dry out and even explode if the problem is not recognised. Check controller operation on a regular basis by monitoring the battery voltage and electrolyte levels and observing the indicator lamps and load temperature.

USA NEC Requirements

To comply with NEC 690.72 (B), the following requirements will apply when using a diversion charge controller on an unregulated charging source:

- <u>Second Independent Means</u> If the diversion load controller is the only means of regulating the battery charging, then a second independent means to prevent overcharging the battery must be added to the system. The second means can be another diversion controller, or a different means of regulating the charging.
- <u>150 Percent Rating</u> The current rating of the diversion load must be at least 150% of the source current rating (combined maximum hydro and PV input currents).

These requirements make sense for safety in the context of a hydro system, where the diversion load is likely to work hard, and the consequences of failure will be certain damage to the battery, and danger of explosion and fire. The backup need not be the same as your primary controller. Often a simpler, relay-based solution can be found.

5.7. Maximum power point tracking (MPPT) controllers in detail

The "maximum power point tracking" controller is a device that sits between the solar array and the battery, converting the voltage down (rather like a gearbox for voltage) so as to allow the solar panel to deliver its maximum power.

The "MPPT controller" actually does two things:

- Its MPPT function is to step the voltage down from a high input level to battery voltage whilst maximising the power, and
- Its charge control function which restricts the turbine current when the battery voltage reaches its "set-point" for optimum charging. (This results in an even higher voltage from the turbine which may cause damage if it has not been allowed for.)

5.7.1. Maximising power

This type of controller can also be used to optimise the speed of your PowerSpout turbine automatically. It will work through a range of relatively high input voltages from the turbine and choose the best operating voltage to give maximum power. This will coincide with the voltage at which the turbine is running at its best speed for the water pressure at that time. This is useful when commissioning the turbine as it avoids the need to dismantle and modify the alternator. It can be a "life-saver" if the original head measurement was incorrect. It also helps to maximise the output under changing conditions of battery voltage and water pressure.

5.7.2. Higher cables voltages

The MPPT function has several advantages. Not only will the controller optimise the turbine speed for us (as described above) but it will also allow us to use a higher voltage turbine. This reduces the current in the long cable from the turbine to the battery. Charging a 12-volt battery with a turbine at a distance is likely to incur a very high cable cost or a lot of energy will be lost in heating up the cable. Even with a 48-volt battery the cable can be a significant part of the installation budget. Using an MPPT device allows us to work at hundreds of volts, and slashes the cost of the transmission cable.

5.7.3. Compatibility issues

Open circuit voltage (Voc) is relatively high in wind and hydro systems compared with PV, so the controller often needs protection from over-voltage. This can be provided using a "voltage clamp" but is not always needed, if you are careful in your selection. Different PowerSpout turbines are available to match the maximum input voltages of common MPPT devices and local wiring rules.

Tracking is the process by which the MPPT device changes the voltage to find the maximum power. Modern inverters/controllers 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/controllers 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 device manufacturer's advice.

5.7.4. MPPT battery-charge controllers on the market

There are many MPPT controllers on the market these days. Common MPPT controllers can be grouped according to their **maximum** input voltage 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)	 Midnite Solar The Kid 150Voc – 35 amp (Manufacturer approved for hydro use)
 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	 Xantrex XW MPPT 60-150

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 controller you need to carefully consider the following points:

- Maximum DC voltage rating
- Current rating (Amps)
- Cost of MPPT controller
- Cost savings in the size of power cable needed to connect your PowerSpout at this voltage
- Programmable "auxiliary" relay(s) to divert surplus power to a hot water tank
- MPPT tracking stability when used on PowerSpout hydro turbines
- Does the manufacturer of MPPT controller give a warranty for hydro input?
- 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 <u>lack of warranty</u> for the MPPT controller 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 for safety as they tend to fail safe. The turbine will become disconnected and run in overspeed. The battery will not usually be over-charged in the event of failure.

If the turbine Voc is close to or above the controller's rated maximum then overvoltage protection using our optional 75/120/140/240 VDC crowbar (called a Klampit) will be needed. <u>In such cases you need to verify that the controller (or an auxiliary relay load) will keep the turbine voltage low enough in normal operation to prevent nuisance tripping of the crowbar.</u> Long DC cables are reactive and do not behave as a solid unchanging link, you can get a sort of whip action where a small change at one ends gets amplified at the other end, it is similar to resonance in mechanical systems that most readers can relate to. On long DC cable runs it advised that you have a 40V difference between the Klampit trigger voltage and the nominal MPPV and that very fast load switching is employed. For example PLT/TRG100C (with 140 V Klampit fitted) or PLT/TRG80C (with 120 V Klampit fitted) combine Midnight Classic MPPT regulators and high speed switching features on the input side generally work very well. Refer to 2014 Technical Manual for more information.

5.7.5. Battery voltage options for MPPT controllers

We have noticed a trend by hydro manufacturers to approve MPPT controllers 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 built in) may be used with MPPT controllers but you <u>must be careful</u> if you do this. This is because the risk of over-voltage and hence controller damage is greatly increased.

The turbine operating voltage on load (known as maximum power point voltage MPPV) needs to be above battery charging voltage. In fact even higher voltages are useful in reducing the cost of the cable. But when the turbine runs without load it will overspeed and produce a higher open circuit voltage (Voc) that is 2-3 times higher than MPPV, depending on the turbine type.

In the case of 12 and 24 V batteries (using for example the PLT40 turbine) this will not impact on your choice of controller, but to charge a 48 V battery you will need an operating MPPV above 60 V. Losses in the cable may well push this figure higher still. The Voc may be 3 times higher, reaching over 180 V and ruling out the 150 V range of controllers. If you wish to use a 150V controller with a 48 V battery then you will need to choose the additional crowbar option PLT/TRG100C. Or you can use a 250 V controller with the PLT/TRG 80 and no crowbar.

If you intend to use a PowerSpout turbine directly connected to a MPPT controller/inverter without crowbar protection, then you must do a runaway voltage test prior to connection.

Very often during early trial runs of the turbine the pipe has air locks in it, it is worth repeating this test the next day when the pipe has fully purged of air and the full head is available for an accurate measurement.

5.7.6. Factoring in the cable voltage drop

PowerSpout turbine notation lists many voltage options. For PLT and TRG turbines the number indicates the approximate voltage the turbine is designed to best run at. Voltage drop in the cable has to be allowed for when working out the maximum possible battery voltage.

For example a PLT/TRG80 turbine the cable calculations are done at 80 V DC to determine cable size required (in the Advanced Calculator tool). Voltage drops of 5% (5% of your power will be lost) are common, so the voltage at the MPPT controller would only be 76 V.

For example:

- A PLT40 turbine has been installed and when tested on site had a recorded runaway (open circuit) 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 in the calculation tool

- 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 in the calculation tool

It is important to remember that a PLT80 (for example) will nominally give maximum power at 80 V 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 <u>very important</u> that the runaway Voc is measured on site prior to connection to your MPP controller.

5.7.7. Summary: Matching your turbine to an MPPT controller and your battery

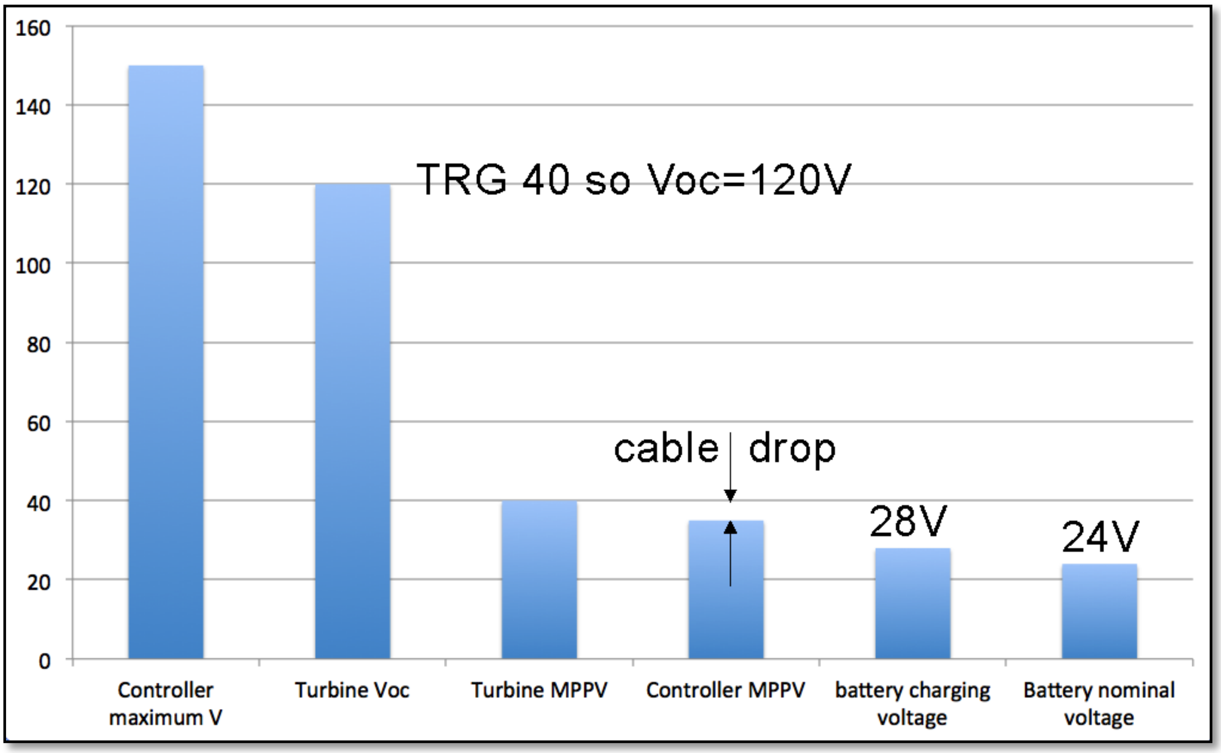
The various voltage criteria are as follows:

- Maximum power point voltage (MPPV) at the controller must be greater than battery charging voltage
- MPPV at the actual turbine will be controller MPPV plus cable losses
- Turbine design MPPV will determine turbine open circuit voltage (Voc = 3 x MPPV)
- Controller maximum voltage must be **higher** than turbine Voc

(Where there are large % losses in the pipe and the cable, you may see even larger differences between MPPV and Voc. It may be harder to find a controller or inverter that will work in such cases without a voltage clamp.)

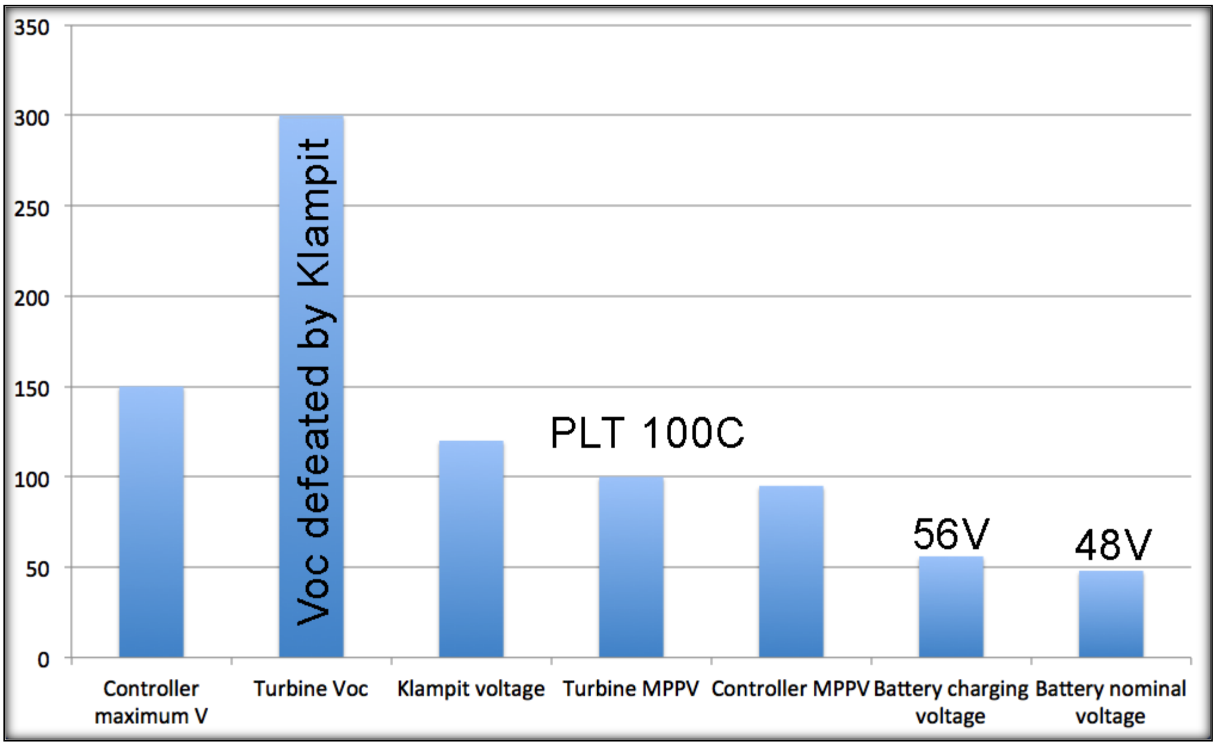
5.7.8. Illustrative example

Here is a practical example using a TRG40 on a 24V battery. The controller maximum voltage is 150V and so the above criteria are all met.



This set-up could also be used to charge a 12V battery (within the current limit of the controller) but it would not charge a 48V battery. Also, the cable voltage is only 40V which may lead to a costly cable or high cable losses, if the distance is more than a hundred metres.

What are our options for a higher MPPV? We can either use a controller with higher maximum voltage (a 250V controller with 80V MPPV) or we can use a crowbar to clamp the voltage. The next chart shows the PLT100C with crowbar circuit in the turbine:



The PLT/TRG 100C turbine allows us to operate at a cable voltage of 100V with reduced costs and reduced losses. It also allows us to use a 48V battery, popular with modern systems. The downside is that the Klampit may operate too frequently if the controller allows the voltage to rise above 120V. This would then have to be manually reset by stopping the turbine. We can avoid this by careful choice of controller operating mode, such as:

- "PV trigger" or "Diversion: Solid state" function (in the Outback FM series controllers see 5.11) or
- "Hydro mode: PWM Divert" function (in the Classic KID controller) or
- "Hydro mode: Twiddle Dither function (in the Midnite Classic 150-250 controllers) or
- PWM diversion controller fitted adjacent to the MPPT controller (in the case of the Tristar TS/MPPT-60).

More details (with set up instructions for the above controllers) are covered in the 2014 Technical Manual.

5.7.9. Legal limits to voltage (extra low voltage)

For installations done by those who are not registered electricians, the maximum DC voltage you are allowed to work at may be constrained by law. 120 V DC is the upper limit in Australasia and some other parts of the world, and 75 V DC is also common globally. You should check for local legislation that may prescribe a limit that applies to you. The turbine rated voltage can be chosen so that it cannot exceed these limits, even in overspeed. A crowbar voltage-clamp may be necessary to comply with legal constraints.

If the ELV (extra low voltage) limit in your country is 75 V DC or less, you are not a registered electrician, and you do not wish to use a crowbar, then our PLT and TRG turbines will be limited to 12 or 24 V DC battery charging, complying with the Law. 12 V DC systems are not common these days with the majority of systems being 24 or 48 V DC. To charge a 48 V nominal battery at 56 V you would need to choose the PLT/TRG56C with voltage clamp to prevent exceeding 75 V DC.

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

- Tell us prior to ordering
- Have an accurate measure of the head of your system
- Check runaway Voc (with various numbers of jets) prior to hook up

Cable run up to 1000m can be affordable at higher operating voltages.

5.7.10. Future trends

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

- MPPT controllers are generally fail safe, unlike PWM controllers
- 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 controllers offer.
- You will generate more power from your PowerSpout turbine because of improved efficiency.
- Cables can be smaller at higher voltage.

MPPT controllers do require a higher level of knowledge and expertise to set up correctly relative to PWM type diversion controllers.

We are also starting to see off-grid MPPT controllers 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.

5.8. Water and air diversion resistors

Many of the wiring schematics (Section 6.5) show air and/or water diversion elements. The heaters are used for 2 main purposes:

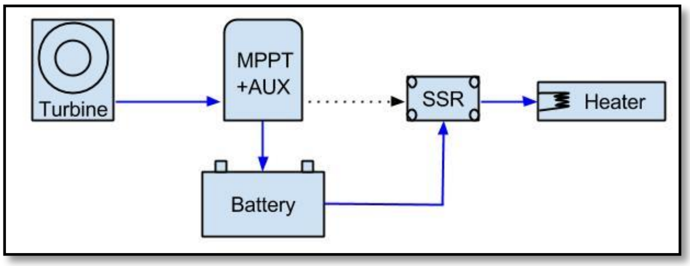
- To convert energy not needed for battery charge into useful heat (or dispose of it safely)
- To keep MPPT system voltage stable once batteries are fully charged

PWM controllers must have diversion loads connected to them so that they can regulate the battery voltage to a safe level. These loads need to be suitable for the DC voltage at which the battery is fully charged (for example 56VDC for a 48V battery). The heater will often make a buzzing noise in operation due to the current pulses from the PWM.

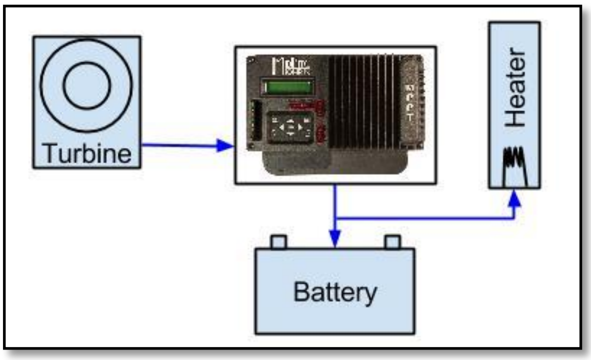
For MPPT controllers a diversion load is optional but highly recommended; you may as well benefit by using surplus generation in your hot water cylinder. If you do not fit a diversion load your hydro turbine will speed up by about 30-50% once the batteries are fully charged resulting in a little more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

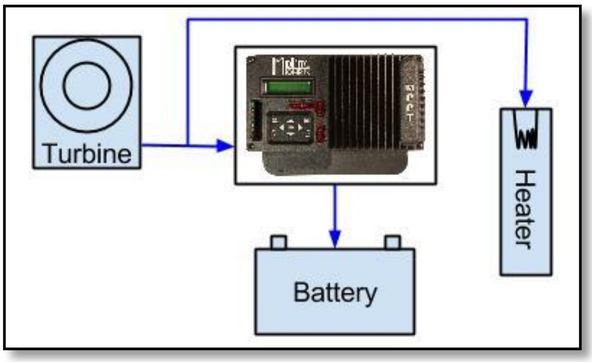
Typical hydro systems often produce much more daily energy than the battery needs to meet daily usage, and it's a waste not to divert this into useful heating.

Some MPPT controllers contain programmable "auxiliary" relays that can be used to control larger DC/DC solid state relays (SSRs) to send surplus DC generation to hot water elements.



A new MPPT controller made by Midnite Classic and called the "KID" can divert directly to a resistive element and no external SSR is needed. This is the only product we are aware of that can do this. The "KID" can also divert on the input or output sides of the regulator as shown.

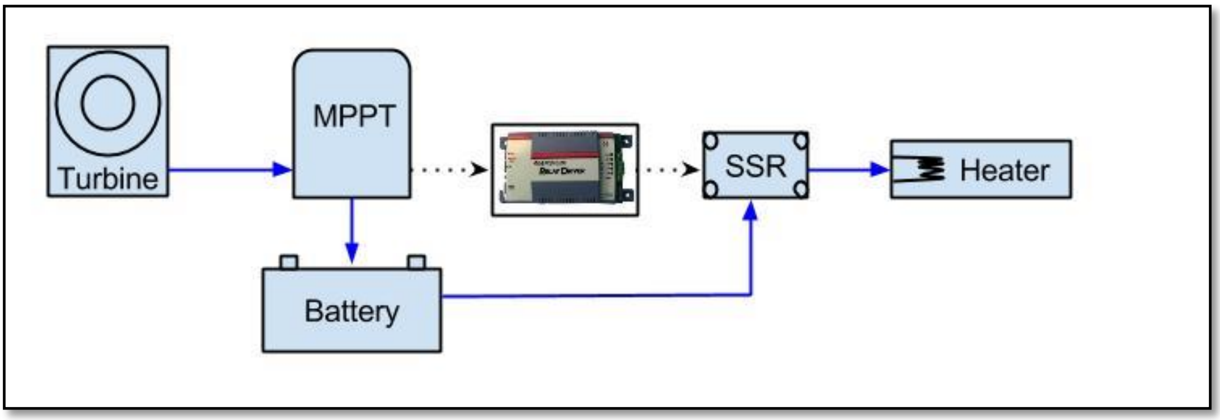




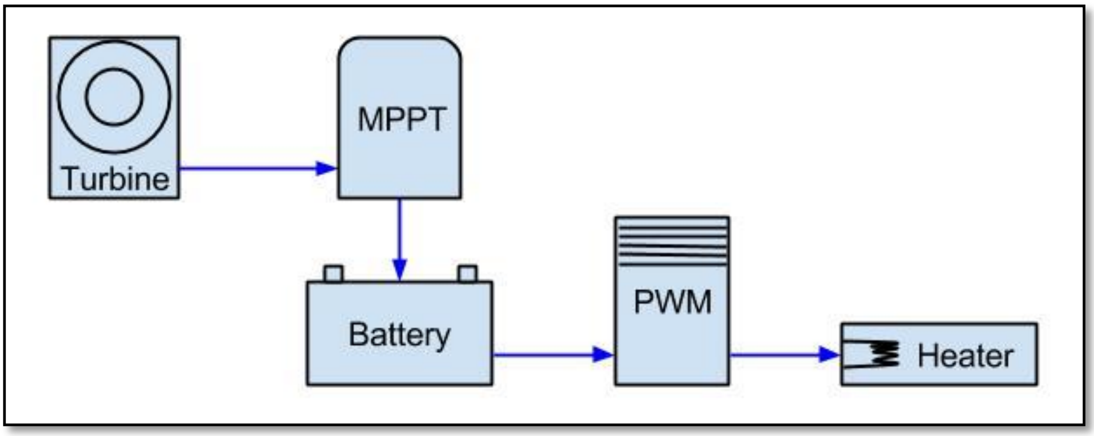
Often it will be a better idea (as standard 120V water element can be used) to divert the incoming power to a heater as in the "PV trigger" configuration shown in section 5.11. This will operate the heater at a higher voltage, and prevent nuisance tripping of the Klampit crowbar (if fitted).

If your MPPT controller is not fitted with an internal programmable relay (not needed if you use a KID) and you wish to divert surplus power to a heater then you have several options:

- Use an auxiliary relay in your inverter if it has one
- Change the MPPT controller to one that has one
- Fit a Morningstar relay driver or similar standalone device for controlling relays, based on battery voltage levels (as shown in picture below).

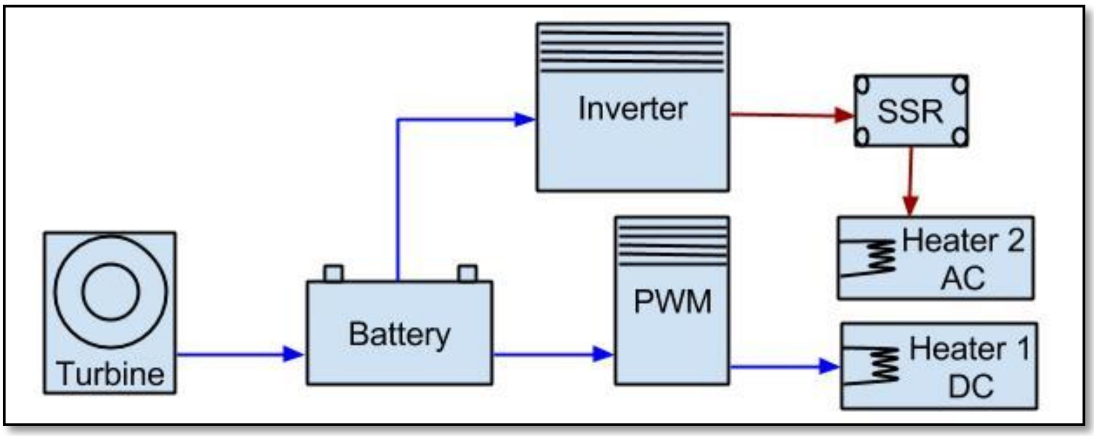


- Fit a PWM controller (with lower settings) to the battery as well



5.8.1. Diversion via the inverter output

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 230/240/110 V AC output side of the inverter.



A water pump or water heater can be turned on to soak up this surplus.
In domestic systems where there is plenty of hydro power, a standard thermostat-controlled AC element or elements (small element in the range 250-1500W) may be used. This method puts more AC load on the inverter and cycles the batteries more. Multiple small elements will give smoother operation. The advantages of AC diversion over using a PWM controller at the battery are:

- you can use standard grid-voltage heating elements (for water tanks etc). Note: standard 120 V elements can be used with many MPPT regulators
- the wiring to the heater can be normal AC house-wiring
- the heaters are silent in operation.
- the built-in thermostat can switch the AC current safely

5.9. Diversion Load: Hot Water Element

Diversion loads used with the PWM type of controller need to be very robust, and where there is any chance of failure a secondary diversion load controller to an air resistive element (space heater) should be installed. Always ask yourself what are the consequences for your battery if a controller fails? Your answer will assist you in making the correct controller choice.

Hot water diversion element

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 a PWM controller you will also need a note to "turn off the hydro turbine before draining this tank".

5.9.1. 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

5.9.2. 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.

5.10. Diversion Load: Air-Resistive Coil

Where hot water is not required or if a secondary controller is fitted as backup, air resistive elements should be used.

5.10.1. 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 wire wound resistors are also available from electronic component suppliers. Such resistors (1kW 0.8 Ohm for example) are well suited to 12/24/48 VDC applications when connected in series or parallel.

Find the maximum voltage of the resistor as follows. Divide the Watts by the Ohms, and take the square root of the answer. 1000W/0.8R = 1250 and the square root is 35VDC. These resistors will work in parallel for diverting 12 or 24V systems but you need to connect them in series for 48V batteries or they will be overloaded.

A 24V system will divert power at about 28VDC and the current in one resistor will be V/R = 28/.8 = 35A maximum (depending on the PWM duty cycle of the diversion load controller).

This should be adequate for one PowerSpout turbine. For 12V systems, use two in parallel. For 48V systems, use two in series.

If this particular size of resistor is not to be found, or costs too much then a search through stock lists may well throw up a bargain in a different size.

5.10.2. Common air elements 120/240 V

Common sources 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

5.10.3. 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									

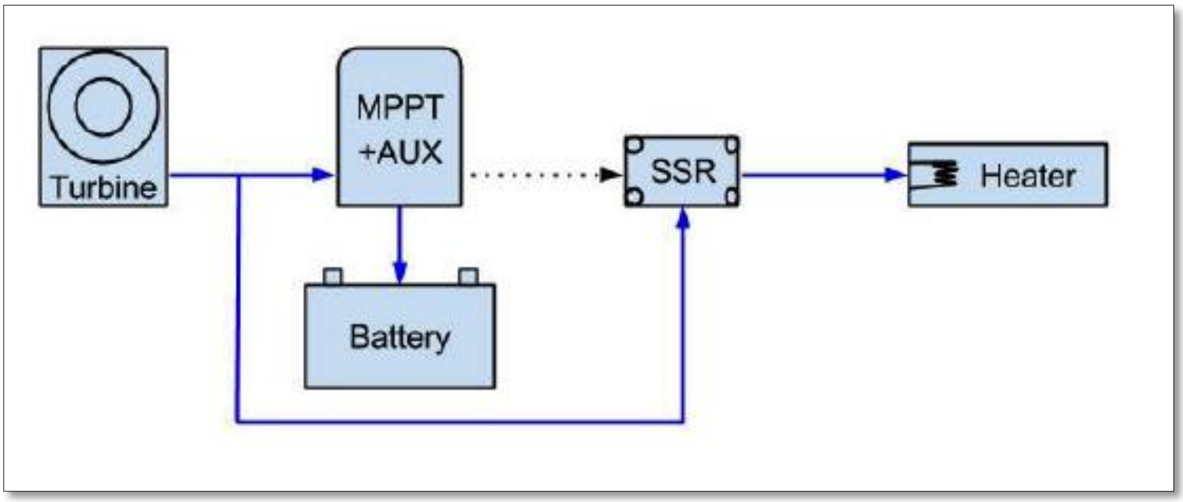
Operating Voltage	Power of 240V element available in Watts											
	100	200	300	400	500	600	700	800	900	1000	1200	1500
14	0	1	1	1	2	2	2	3	3	3	4	5
28	1	3	4	5	7	8	10	11	12	14	16	20
56	5	11	16	22	27	33	38	44	49	54	65	82
120	25	50	75	100	125	150	175	200	225	250	300	375
240	100	200	300	400	500	600	700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

Power consumed by a heater depends on the square of the voltage applied to it. 1/4 the voltage means 1/16th of the power. 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.

5.11. Using AUX "PV trigger" relay settings

Some MPPT controllers have an AUX relay with a function that will activate it based on the controller's incoming DC voltage (from the turbine side). For example the Outback FM60/80 has a "PV Trigger" setting (Midnite Classic products can also do this as can some other makes). You can program the AUX relay to close when a voltage is reached. Using the relay to connect a heater directly to the turbine allows the controller to load the turbine, preventing its voltage rising high enough to activate the over-voltage crowbar.



Why use "PV trigger"?

PV trigger prevents nuisance tripping of the crowbar protection in the following scenario.

A PLT/TRG 100C turbine (with an internal crowbar) is needed (for Outback FM60/80 controllers) because otherwise the turbine voltage might exceed 150V and damage the controller. The crowbar short circuits the turbine for safety if the voltage exceeds 120V (see 5.3.3).

If any of the following conditions were to occur:

- Water element failure
- Breakers to FM60/80 accidently turned off
- Turbine breakers turned off (while turbine running)
- FM60/80 failure
- Cable break

the 120V internal crowbar 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 crowbar 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 (note that due to cable voltage drop the MPPT maximum recorded voltage will be less than 120 VDC to activate the Klampit, if your cable has a high voltage drop you may still get nuisance tripping, this can be fixed by changing the Klampit from 120 to 140 VDC). To get the turbine going again, stop the turbine at the valve, locate and fix the cause, turn the turbine back on.

Using "PV trigger" (or similar settings in other MPPT regulators) has a number of advantages when used with our PLT/TRG 40,100C and LH150 turbines namely:

- The turbine can be turned on quickly without fear of tripping the internal crowbar (100C version).
- You will not get nuisance tripping 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.

MPPT regulators that can switch the input at high speed will generally work better. The KID or the Midnite Classic MPPT range do a better job of input side switching and should be used in preference to other products listed. This is covered in more detail in the 2014 Technical Manual.

120V -1500W water elements

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

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

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

As a PLT turbine will develop maximum power at about 40 VDC MPPV we can set the PV trigger to operate at say 50 V. Once the batteries no longer require all the 750W being generated the MPPT controller will draw less current from the turbine, allowing the rpm and incoming voltage to increase. At 50 VDC, the water element will turn on 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. Make sure the PV trigger voltage is at least 10 V above the MPPV.

240V -1500W water elements

This is also best illustrated by way of another 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 controller. We want to use a 240V 1500W water element as they are common globally.

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

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

As a PLT turbine will develop maximum power at about 80 VDC we can set the PV trigger to operate at say 90V (note in a Midnite Classic 250 the PV trigger function is called AUX - Diversion HI, refer to 2014 Technical manual on how to set this up correctly). Once the batteries no longer require all the 750W being generated the MPPT controller will allow the incoming voltage to increase, this will turn on the water element and at 90 VDC, 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.

5.12. Preventing excessively hot water with PWM & MPPT regulation

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

Other systems 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 degrees Celsius and off at say 60 degrees 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. If you need to switch DC current, then use a slave relay. Also remember all AC wiring has to be completed by a registered electrician.

5.13. Battery Bank (see also Section 7)

In off-grid systems a battery bank is required to store power. The nominal voltage of the battery bank dictates the nominal 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.

So for example, in a very small renewable energy system we could have a 12-volt battery and a turbine that charges it at around 12 volts DC, and we take our "load" power from the battery. Most people then use a battery-based inverter to convert the DC battery power to AC power (just like the grid) for using their loads.

In reality a 12-volt battery will have a slightly higher than nominal voltage when on charge, the optimum being around 14 volts or so. If the battery is overcharged, then the voltage will rise above 15 volts and the battery is in danger of being overheated, dried out and damaged.

We consider 12 volts as a classic example, but in modern renewable energy systems the nominal battery is more often 24 or 48 volts. The system will actually work at 28 or 56 volts, charging the battery most of the time and using it on demand.

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 controllers are used. Cable losses are much less of an issue if you install a PLT40 or PLT80, and the MPPT controller then converts to 12/24/48 V DC to suit your 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 and your PowerSpout is connected via an on-grid inverter (without battery), then it 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 though, unless you have frequent grid outages.

Inverter

There are two types of inverters: battery-based ones for stand-alone off-grid systems, and grid-tie ones that do not use batteries. Both convert DC to AC power.

Outback inverter and controller system

Battery based 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 or ‘modified sine 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 inverters. Large induction motors starting direct on line draw high currents and need an over-sized inverter to start even on pure sign wave inverter.

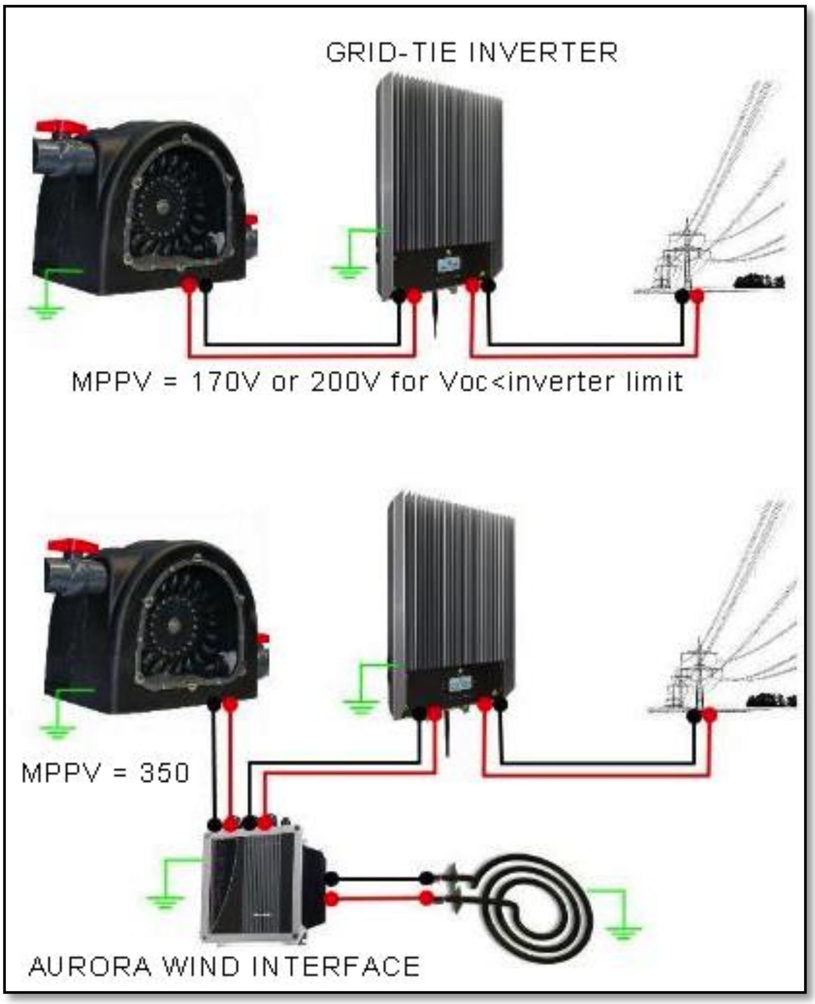
Inverters are available in a variety of power ratings (depending on the intended loads) and with a variety of surge ratings. A high surge rating allows loads with a high start-up power surge to run without overloading/tripping the inverter, or failing to start at all. Some inverters can also serve as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

5.14. Grid connect inverters

Where the utility grid is present, you will not need to use a battery. Connect the turbine to the grid using a grid-connect (or "grid-tie") inverter. This is different from a battery inverter. It only works in the presence of the AC grid. It is manufactured for the purpose of converting solar PV panel output into grid power. It will use a Maximum Power Point Tracking (MPPT) technique to keep your turbine running at the optimum speed. As with MPPT controllers above, your need to be sure that the inverter cannot be damaged by the turbine's "open circuit voltage" or Voc when running "off-load" (see Section 3.5).

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.

We no longer make PowerSpout turbines with internal PWM regulation of cable voltage (ME and GE products that limited their output voltage to avoid damaging the inverter). This change was made in May 2013 due to the fact than many MPPT controllers and grid connect inverters (for example the Enasolar and Power-one) 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 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 and the maximum possible cable voltage is required.



The old GE400 has been displaced by a PLT350 option using the Aurora Power wind interface to regulate Voc. 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.

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 Aurora UNO-2.0-I-W and UNO-2.5-I-W are the latest single phase string inverters for wind and hydro applications. 

Our global dealers have reported good results with many makes of grid connect inverters, 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. For more information refer to our 2014 Technical Manual.

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.

5.14.1. MPPV and Voc considerations

Operation with MPPT controllers and with grid-tied inverters are very similar situations for PowerSpout turbines. It's important to make sure that the turbine best operating voltage ("maximum power point voltage" or MPPV) is within the range that the MPPT device can work over. It's also important that the Voc of the turbine is not so high as to damage the MPPT device.

Any 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 warranty if the equipment is not approved for hydro applications.

6. System Wiring

This section covers the items you will need to safely wire the components of your system together. There are wiring diagrams to cover all typical system configurations.

For electrical safety you need to protect against fire and shock hazards.

6.1. Fuses and Circuit Breakers

Batteries are very unlikely to give you an electric shock because their voltage is low, but a battery is a source of energy that can deliver thousands of amps of current into a short circuit that will turn wire red hot. Any circuit that comes from a battery should be protected by fuses or circuit breakers that will never trip under normal operating currents, but that will trip or blow before the safe operating current of the wiring is exceeded. High rupture capacity (HRC) fuses are preferred where very high currents can arise from large batteries.

Fuse ratings will be dependent on the overall power rating and type of components in your system. Different circuits use different currents and different wires sizes and need different fuses/breakers. When a fuse blows or a breaker trips due to a fault in one circuit, only that individual circuit should be isolated from the battery.

If the turbine is directly connected to the battery without an MPPT controller then you must take care to **never disconnect the battery** from the system as a whole. By all means disconnect all of the individual circuits but keep the turbine circuit separate from the others as it is likely to damage the connected equipment with its high open circuit voltage (Voc).

In order to prevent system damage through shorts and malfunctions, and for general ease of maintenance, it is recommended that a number of fuses or breakers be placed in the system for protection. If an overcurrent occurs they will break the current path. If a "live" wire touches the earthed metalwork in the system then this will also create a fault current which will trip the protection and isolate the faulty circuit.

6.1.1. Circuit Breakers

Breakers are another good way to protect against over-current in the wiring. Take care to use DC rated breakers on DC circuits, because AC breakers may not be able to handle the arc. 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.

6.1.2. 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.

6.2. DC Earthing/grounding explained

Earthing (aka grounding) is done to protect against **electric shock hazard**. It also helps to protect against equipment damage from lightning-induced voltage surges in the system. There is much confusion about what earthing means. The words can mean any of 3 things:

1. Earth electrode: Connecting something to an earth rod or buried conductors.
2. Equipment earthing: Connecting all metal exposed parts to protective "earth" wires that "bond" cases, conduit, hydro bulkhead etc. together (and to earth).
3. System earthing: Connecting one pole of the supply (for example the DC negative) to the earth wiring. The earthed pole is known as the neutral pole.

6.2.1. Earth electrode or earth rod

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

Simply connecting something to an earth rod will **not** automatically make it safe unless you have a "residual current device" to detect small leakages. An earth rod usually has a relatively high impedance (resistance). Any small fault current in an earth rod is unlikely to trip a circuit breaker or to blow a fuse, hence alerting the user to the fault. A very low resistance earth electrode would be needed to ensure safety if things are not hard-wired to each other using equipment earth wiring as below. Connecting an earth rod in no way replaces proper bonding of external metallic parts that could give you a shock due to differences in voltage between them.

6.2.2. Equipment earthing

For the purpose of this manual, earthing of exposed metal (equipment earthing) is always required, (but follow your local rules). Use protective conductors (called earth wires) to join all exposed metal objects together. Make sure you 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. Earth wiring must be able to safely carry heavy fault currents in the event that a live wire touches the case of an item of equipment.

Bonding items to each other protects people and livestock against getting a shock from touching two items that might accidentally have a dangerous voltage between them. A fault that creates a voltage between items will create a large current in the earth bonding that will blow a fuse and disable the system. Also connect this protective wiring to an earth electrode so you are protected from electric shocks when you are also touching earth or earthed objects.

This is very basic electrical safety. It is also the front line of protecting sensitive equipment against lightning induced surges of voltage. Equipment grounding will help protect the electrical system and appliances from lightning surges although the level of protection is less than commonly believed. Some inverters and MPPT controllers may include lightning surge protection.

6.2.3. System earthing

Earthing of the DC negative of your renewable energy generation system (known as "system earthing") 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 a system earth connection. Equipment should always be earthed as above, regardless.

Without system earthing you will need to use double-pole fuses and breakers. An "earthed system" only needs protection in the "live" side (single pole fuses, etc).

6.2.4. AC side system earthing

This manual does not fully cover AC system earthing requirements, as this must be done by a registered electrician. A battery based inverter provides an AC supply where neither side of the circuit is earthed, and so this "system earth" connection must usually be made as part of the installation if desired or required. The AC neutral should be bonded to earth in one place only. The main distribution board is a good choice.

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 of the supply, and hence some electricians have never done 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.

6.2.5. Earthing of the PowerSpout turbine bulkhead

We recommend the installation of an earth electrode at the PowerSpout to minimize the possibility of there being an electrical hazard and to minimize any electrical noise generated. 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 the user is protected from shocks. However this protection depends critically on the impedance of the earth connection being low enough to make it safe.

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 on your home and hence any fire risk is much lower.

On a 12/24 VDC battery systems, earthing of the bulkhead **may not** be required.

- Where the hydro turbine is close to the power shed, a green earth wire from the turbine bulkhead must be connected to the main earthing rod via the equipment earthing.
- Where the hydro turbine is distant to the power shed, the turbine bulkhead should be connected to a local earthing rod. You may be able to rely on this rod for earthing or you may also need an earth wire in your supply cable. Please check your local wiring rules as some jurisdictions advise only 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 may 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. But you must ensure that the impedance of the connection (whether by wire or by direct earth electrode) is low enough that the bulkhead cannot be at a dangerous voltage when there is a fault current to earth.

6.2.6. Important note for grid connected systems

Grid connected versions of the PowerSpout have EMC output filters fitted. Unless legally obliged the DC turbine output (inverter input) should not be tied to earth, or EMC performance may be compromised. The bulkhead should be earthed in every case as it is not connected to the output wiring.

6.2.7. Earth cable size

PowerSpout hydro turbines are fitted with 2m long earth 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)

6.2.8. Earth Rod (electrode size)

An earth rod driven 1.8m into the ground may be sufficient, but always check your local codes. You may also need to measure the impedance to ensure safety.

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

6.3. 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 grounded DC solar PV systems. Ground fault protection is also required for ungrounded 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 by the NEC, but can be installed to reduce fire risk. In grid connected systems inverters have GFPD fitted as standard, but most off grid MPPT controllers do not. If your hydro turbine is 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 controllers 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.

6.4. Avoiding other hazards

6.4.1. Meters to monitor your system

It is important for your safety and for reliable system performance that you monitor the battery voltage and the hydro production. If the battery voltage falls too low there may be damage, whereas if it rises too high there may also be danger of explosion. Check also that the turbine output is normal so that you can investigate any problems before the battery becomes excessively discharged.

MPPT controllers 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. It's good practice to install meters in a prominent position where it will be easy to check the status of the system as part of your routine.

6.4.2. What happens to a hydro turbine when not connected

If a hydro turbine is "open circuit" or disconnected from any load then there will be no production of current to slow the turbine. A free spinning hydro turbine will immediately produce dangerous voltages that may also damage your equipment. 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 to human contact and to your electronics.

6.4.3. What happens if no controller is installed

Unregulated charging of the battery will ultimately cause it to dry out, overheat and explode. You must install a controller and check on a regular basis that it is working. Look at the voltmeter and check the level of the electrolyte.

6.4.4. Cable connection errors

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. You may also need to hold insurance and comply with various safety regulations.

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 controller not designed for a hydro turbine.
- Connecting the hydro turbine polarity in reverse, for example swapping the wires in the plug supplied with the PowerSpout turbine. This will result in the turbine fuse blowing, and may damage the rectifier in the turbine.
- Connecting the hydro turbine to the inverter leads and then removing the battery 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 charge controller is working correctly prior to leaving the site.
- Installing a controller that is too small or one that does not work and not knowing how to determine if the controller is working.
- Installing a PWM controller (close to its maximum amp rating) in a confined tin shed with the diversion heaters. It works most of the time, but in summer trips out resulting in the batteries being overcharged/damage. The backup PWM controller (if fitted) also trips. It is not the controller(s) that have failed but the summer environment in the tin-shed that is too hot. You have to de-rate controllers 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.

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.

6.5. Diagram of direct-to-battery wiring using diversion controllers

In order to reduce the size of this manual wiring diagrams have been removed as they will not be relevant for many readers. Only links to the diagrams are provided below, this way the manual is shorter and resolution of the wiring diagrams can be maintained.

Prior to each wiring diagram link, a simple energy flow diagram is presented to indicate what the wiring diagram achieves.

The drawings below illustrate the minimum installation requirements for PowerSpout turbines connected directly to the battery, with PWM diversion mode charge controllers. The drawings show both an ungrounded and a negative ground battery installation. Each component and its selection criteria are discussed in section 6.8.

If the system ground connection to battery negative is not to be installed then additional fuses are normally required by local wiring regulations on each (positive and negative) battery terminal. Breakers should then also be double-pole. 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 meet the rules in your country.

All customers using PWM type controller must read section 6.8.1

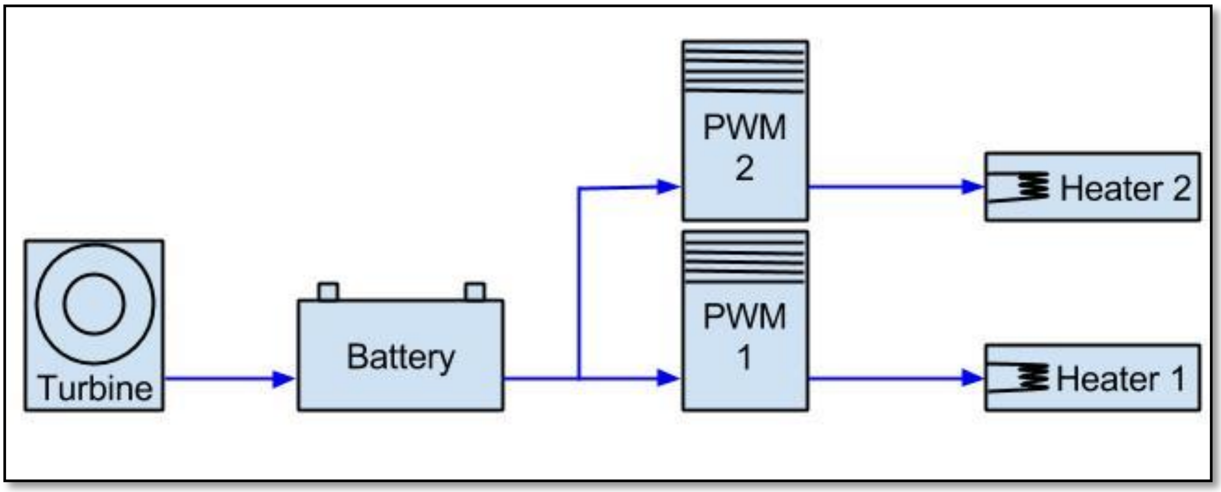
Please note that all wiring diagrams presented show a single operation point for emergency system shutdown, this may not be a legal requirement but is considered good practice in some countries. There are many ways to wire a system, different laws, different training and the preferences and experience of local installers means you rarely get consensus on such matters.

6.5.1. PWM battery regulation

Turbine types that can be used:

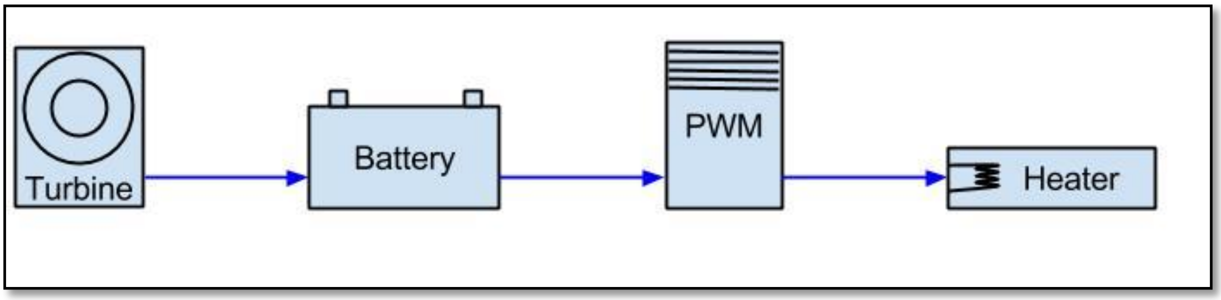
- PLT 14/28/56/56C
- TRG 28/56/56C

Two PWM regulators - Complies with NEC 690.72 (B)



Simple diagram	Full diagram grounded battery	Full diagram ungrounded battery

Single PWM regulators – not allowed in some jurisdictions



Simple diagram	Full diagram grounded battery	Full diagram ungrounded battery

6.6. Diagrams of wiring with MPPT controllers

The drawings below illustrate the minimum installation requirements for PowerSpout turbines connected to MPPT controllers. These drawings show both ungrounded and a negative ground battery installation. Each component and its selection criteria are discussed in section 6.8.

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

In some of the diagrams there are diversion loads which harvest surplus energy beyond what the batteries need to recharge (see 5.8 for more details). These loads can be for water or air, they can be DC or AC, operated by PWM charge controllers, by relays connected to an AUX output on the MPPT controller or by MPPT controllers that do not require external relay like the Midnite Classic "KID".

Solid state relays (SSRs) are ideal for this job as they are silent and can operate rapidly without wearing out. We advise the following high quality SSRs mounted on a suitable heat sink and enclosure. A D1D40 can be shipped with your turbine order as required.

- <100 VDC Crydom D1D40 for PDF click here
- <200 VDC Crydom D2D40 for PDF click here

Please note that all wiring diagrams presented show a single operation point for emergency system shutdown, this may not be a legal requirement but is considered good practice in some countries. There are many ways to wire a system, different laws, different training and the preferences of experienced local installers means you rarely get consensus on such matters.

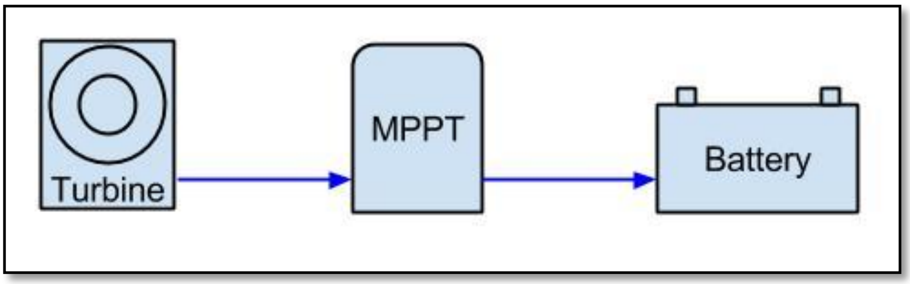
Please note the following wiring diagrams (for systems that include MPPT regulators) show battery string fuses combined in a 3 way HRC holder. All jurisdictions require a battery fuse but may not require a fuse on each battery string.

6.6.1. 150-250 V DC MPPT

Turbine types that can be used:

- PLT 40/80
- TRG 40/80
- LH & LH Pro 150/250

MPPT regulators no diversion load



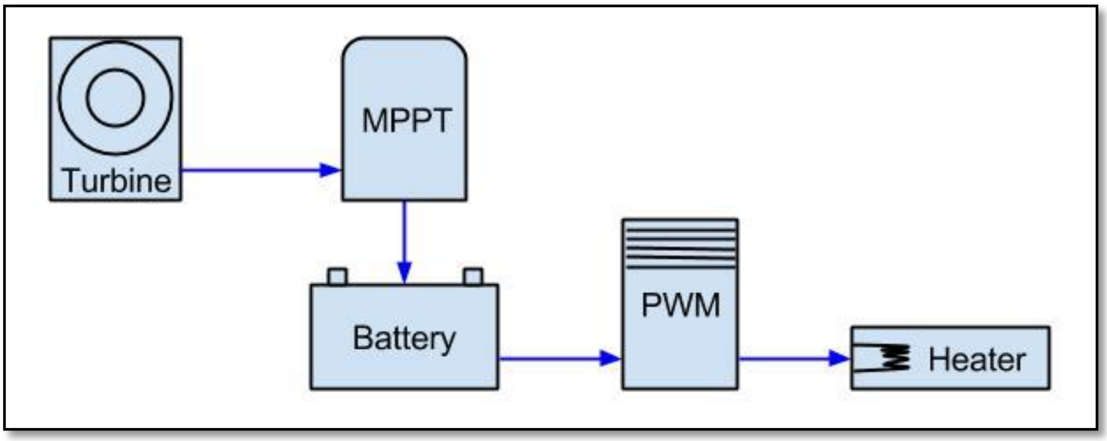
Simple diagram	Full diagram with grounded battery	Full diagram with ungrounded battery

6.6.2. 150-250 V MPPT with PWM hot water diversion

Turbine types that can be used:

- PLT 40/80/100C/170C/200C
- TRG 40/80/100C/170C/200C
- LH & LH Pro 150/250

MPPT regulators with PWM diversion load



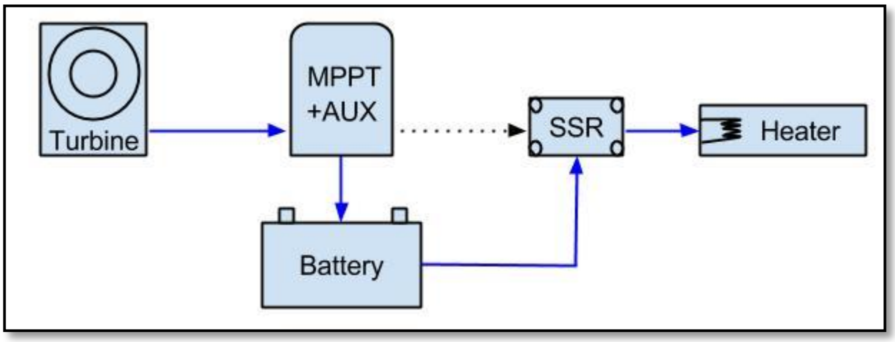
Simple diagram	Full diagram with grounded battery	Full diagram with ungrounded battery

6.6.3. 150-250 V MPPT with aux SSR relay diversion on battery side

Turbine types that can be used:

- PLT 40/80/100C/170C/200C
- TRG 40/80/100C/170C/200C
- LH & LH Pro 150/250

MPPT regulators with SSR relay diversion load



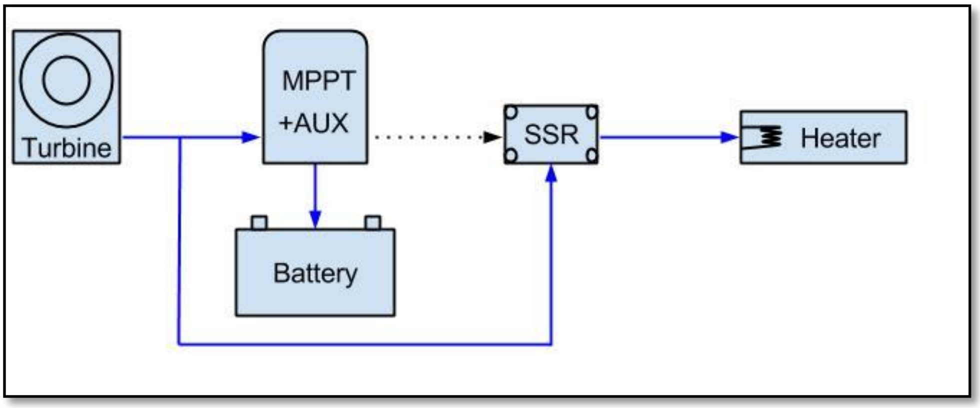
Simple diagram	Full diagram with grounded battery	Full diagram with ungrounded battery

6.6.4. 150-250 V MPPT with aux SSR relay diversion on MPPT input side

Turbine types that can be used:

- PLT 40/80/100C/170C/200C
- TRG 40/80/100C/170C/200C
- LH & LH Pro 150/250

MPPT regulators with SSR relay diversion load on MPPT input side



Simple diagram	Full diagram with grounded battery	Full diagram with ungrounded battery

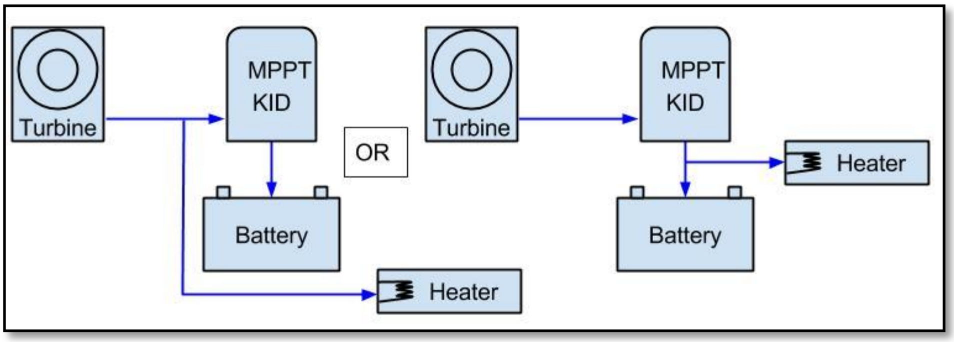
6.6.5. 150 V MPPT – Midnite Classic KID

The KID is able to divert surplus power (in excess of that needed to charge the connected batteries) to a diversion load, typically a water heater. It can divert either at the battery voltage (Load side) or at the input voltage (Clipper side) and no change of wiring is needed, all you do is move the green 30 amp automotive fuse and change the diversion element. No external SSR is needed to do this.

The KID combines the features of MPPT and PWM diversion regulators into a single unit.

Turbine types that can be used with the KID:

- PLT 40/80C/100C
- TRG 40/80C/100C
- LH & LH Pro 150



Simple diagram	Full diagram with grounded battery	Full diagram with ungrounded battery

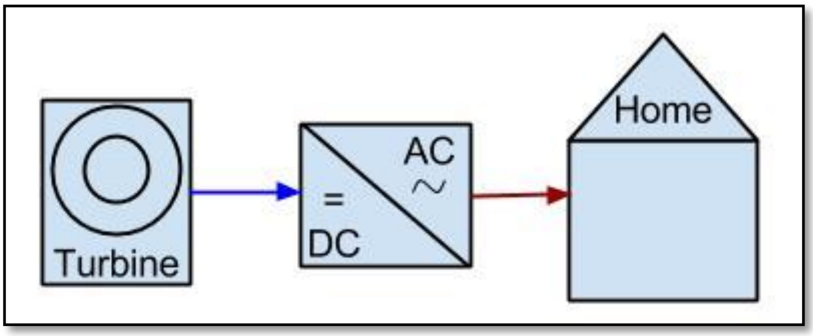
For output side diversion use the same diagram as above but move the green 30 amp fuse to the Clipper position. The 2014 Technical manual includes setup information for KID MPPT controllers.

6.7. Diagrams of 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 in section 6.8.

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

6.7.1. 500-600V Grid connected systems



Simple diagram	Full diagram

6.8. 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).
SB1-SB5 provide the same functions as BD1-BD5 below, but are single pole breakers.

DB1 - DC breakers (in waterproof enclosure if turbine is outside) rating should be at least 25% more than turbine's rated amps (see nameplate), and be low enough to protect the cable if necessary. Bear in mind that the turbine may produce more than expected, so the size of this breaker may need to be re-evaluated once installed.
Short circuits will not damage the turbine alternator. Provided the cable is large enough to handle the turbine's short circuit current then there is no upper limit to breaker size. In such cases an isolator switch could be substituted if desired.
DB1 is a termination point for the turbine power lead, enables Voc measurements to be taken at this location and provides overcurrent protection to the cable if necessary. 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 controller 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 Voc measurements to be taken at this location and provides overcurrent protection to the cable if necessary.

DB3 - DC breaker on the output of the MPPT controller. Minimum size is 25% more than the maximum output generation amps into the battery. Maximum rating should be similar to the maximum output rating of the MPPT controller, or its battery cable (which ever is the lower).
For example 63 amp breakers are commonly used on 60 amp MPPT controllers (provided the wiring is suitable for this current). The breaker 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 controller.

DB2 and DB3 may already be integrated into the MPPT controller 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. It may be omitted if the MPPT/PWM controller instructions do not require it but we advise installing this breaker. DB4 is a termination point and provides overcurrent protection to the cable. It may be necessary to remove power to the controller when changing settings etc, so a point of local isolation is valuable.

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 controller you will also need a note to "turn off the hydro turbine before draining this tank". Regardless off your system configuration, turn off the hydro turbine prior to working on your system.

DB5 - DC breaker or fuse in the wire supplying the inverter. DB5 is not always shown for clarity and because it is often integrated into the inverter. It may be omitted if the inverter instructions do not require it.
Rating should be similar to the surge rating of the inverter. It may be possible to rely on the main battery fuse to protect the inverter cables in the event of a short circuit, but make sure that the turbine does not remain directly connected to the inverter in the event of such fuses blowing or being removed.

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. The neutral may need to be earth-bonded to ground the AC system see section 6.2.4.

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. See section 6.2.2.

Yellow dotted lines – These lines indicate that enclosures are required.

Wiring HRC fuse-holders at the battery
The wiring (where batteries are in the system diagrams) show HRC fuses.

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

It is very costly to purchase high amp rating DC breakers but HRC fuse holders are relatively inexpensive. 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 3-pole HRC fuse holders can serve a multi-purpose of providing current protection for each battery string (maybe required by regulation in some jurisdictions), act as a combiner for multiple strings and act a busbar termination point for other connections needed in 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.	
Where 1-2 battery strings are used the spare position in the 3-pole HRC fuse holder can be employed to break the incoming hydro cable connection and replace SB2 or DB2. This then provides a single point of system shutdown, which is regarded as best practice. Label **“In emergency pull this handle for complete system shut down”**	

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

6.8.1. Important note when MPPT controllers are not used

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 system (no MPPT between) and do not follow our advice below, then it is important to reiterate that **you do not want the main battery fuse to blow** or be removed with the turbine running, because the battery is the primary protection against over-voltage in the system. The hydro turbine's open circuit voltage will likely destroy all of your electronics in the event of the fuse blowing.

PowerSpout turbines PLT/TRG 14/28/56 (non-MPPT turbines). The positive wire should be **wired to its own HRC battery** fuse, as shown in the diagram. If the HRC fuse is opened (while the turbine is still running) then the turbine will produce a higher voltage but it will be isolated from the electronics. It is not possible to wire each battery string to its own fuse in this situation, but it is more important to separate the turbine from the electronics when the battery isolator is operated.

6.8.2. 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.

6.9. 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 (Voc) is 240 VDC. They intend to use a Midnight Classic 250 controller 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:

In all cases the breaker must protect the wiring of the circuit, so the wiring should never be smaller than the breaker's rated current.

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

Minimum breaker size = 1.25 x 12.5 = 15.6 amp.
Hence a 16 amp breaker is selected.
In the event of a 20A cable short the breaker may trip, but a larger breaker would also be acceptable in this case, since the short circuit current cannot overload the 6mm^2 cable.

DB3
As the MC250 is rated for 63 amps, you can therefore fit a 63 amp breaker. (In this case make sure the battery wiring is suitable for 63 amps.)
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. A 32 amp breaker is the smallest size above 26 amp.

DB4
As the diversion element is rated for 327W, the minimum breaker size is 1.5 x 327/56 = 8.75 amps, so a 10A or larger breaker should be used (within the rating of the battery cable). Note that we use 56 V and not 48 V for diversion load calculations.

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. A copper link (to replace the fuse) is put in the spare position and a 16 amp breaker is installed for DB2. The breaker can be used to check open circuit voltage and in some cases might be needed to protect the cable from overload.

Opening any one HRC holder will completely shut down the system.
The final system looked like this.

7. Getting the best from your batteries

7.1. Lead acid battery type, size and life

7.1.1. Flooded or wet cells (can be topped up with distilled water)

These 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.

7.1.2. Sealed batteries

Sealed batteries cost more than "flooded" ones but have the advantage that no topping up is required (or even possible).

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, but AGM are often more robust than gel.

7.1.3. Electrical terminology revised

Many people are often confused by terms such as voltage (V), amps (A), amp hours (Ah), Watts (W) and Watt hours (Wh).

A battery will be specified according to its **nominal voltage** (e.g. 12 V) and its **capacity** in amp-hours (e.g. 200 Ah).

Power is the rate of delivery of energy at one instant in time.
Power (in W) = current (in A) x voltage (in V)

Your batteries store energy, which depends both on power and time elapsed. Units of electrical energy are kilowatt-hours or kWh, which equate to 1000 Watt hours.

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

- A 6 V 225 Ah battery can store 6 x 225 = 1350 Watt hours (equals 1.35 kWh units)
  This will have a mass of about 30 kg = 66 lbs.
- A 12 V 200 Ah battery can store 12 x 200 = 2400 Wh (2.4 kWh units)
  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.

(Note that the amp-hour rating varies with duty, expressed as a number of hours discharge. "C20" is the amphour capacity when the battery is discharged over a 20 hour period and this will be less than "C100".)

7.1.4. 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.

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.

7.1.5. Battery bank sizing with the 10:10:10 rule of thumb.

For a 10 year life:

- Cycle batteries through no more than 10% of their capacity each day.
- Limit the maximum sustained power draw in W to 10% of battery Wh.
- Limit the maximum charge current in A to 10% of battery Ah.

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

- Depth of discharge (DOD) each day = 10% x <u>2</u> x 200 x 48 = 1920 Whrs.
- Maximum sustained draw of 10% x 200 x <u>2</u> x 48 + 500 = 2420 W for a time not exceeding 1 hour.
- The charge rate is 500W/48V = 10 A.
Maximum allowable = 10% x 2 x 200 = 40 A.
This 40 amp limit is therefore only a concern 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 adequate 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.

7.1.6. Battery life expectancy

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. Keeping them in a good state of charge (near full charge) will prolong their 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. If your state of charge is falling, either increase generation or decrease consumption. You need to generate at least 20% more than you use to allow for system losses.

Two parallel battery strings are better than one - a loose connection in a single battery string can expose the whole power system to overvoltage from the runaway turbine. Two battery strings provide more redundancy. 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. Energy capacity is the same for a given weight of batteries.

7.2. Battery housing

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

- Batteries operate best when kept at around 10ºC to 20ºC. Never freeze them. Fully charged batteries are hard to freeze but flat batteries are more easily frozen. At low temperatures battery performance is sluggish but life expectancy is good.
- Batteries are full of sulphuric acid, lead and small amounts of other chemicals which must not leak into the environment. Lead and its compounds are persistent poisons.
- 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 checked periodically for individual 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 to 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 even 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.

Some recombination caps are unsuitable for equalising charge of batteries and must be removed prior to equalising them. If a controller is used with an automatic equalise function, then take care to buy caps that do not have to be removed during equalise charges.

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 a small 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, not within 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 not 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, apron 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 and lockable.

7.3. Safety clothing

Minimum safety clothing includes:

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

8. Turbine Installation and Commissioning

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/TRG turbine, depending on site terrain. Pipe and cable laying can take much longer in difficult terrain.

8.1. 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 controllers.

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.

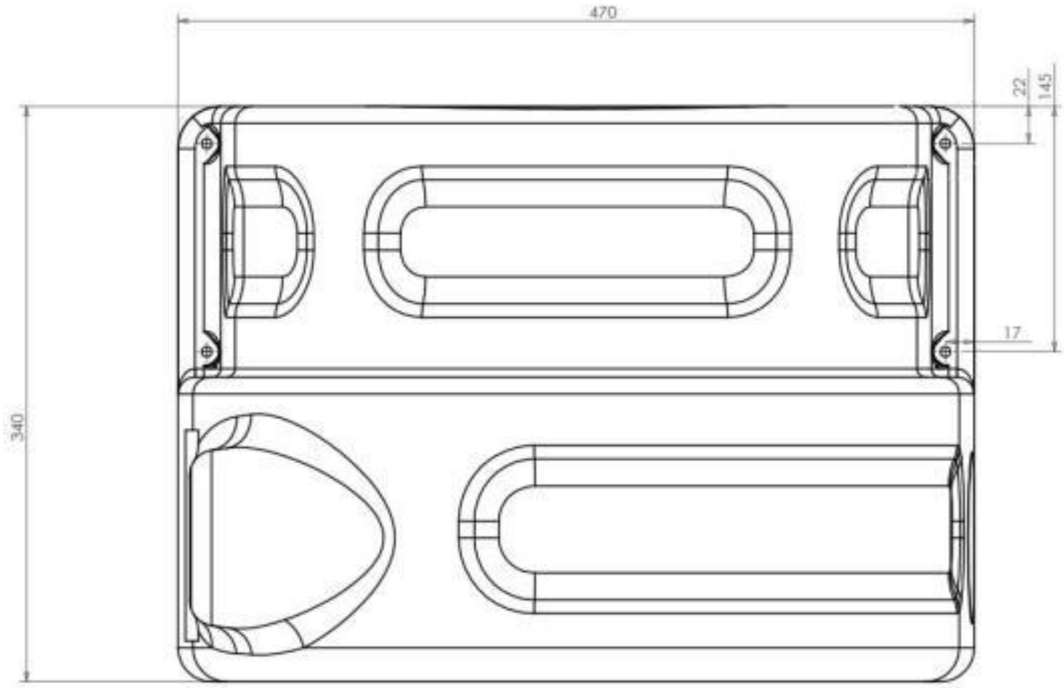
8.2. Mounting

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.

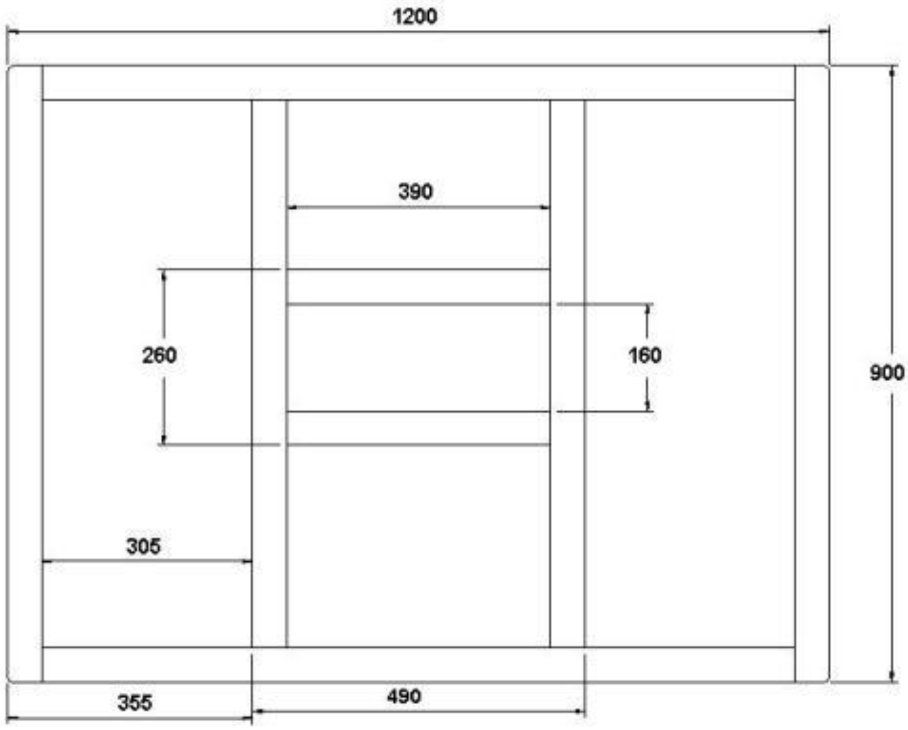
Fixing a turbine to a timber base

8.2.1. Mounting PLT

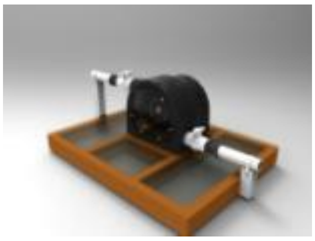
The main case dimensions (mm) and the four holes in the PowerSpout casing for turbine mounting are illustrated in the plan view below. Fixings are provided with the PowerSpout for connection to a timber framed base. These dimensions are sufficient to plan for the mounting of the turbine prior to its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



Plan view of a PowerSpout turbine

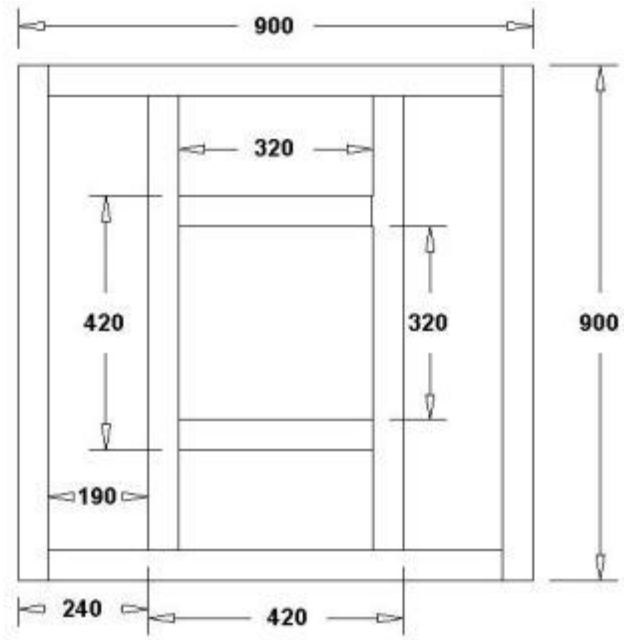


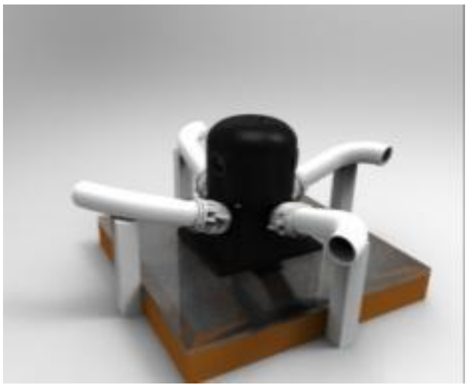
A TYPICAL PLT TURBINE BASE:
A framed timber base made from 100x50 timbers and covered in 12-17mm thick plywood sheet on top with **a hole 160 x 390 mm** cut for the exhaust water. Remember to drill a hole so that condensation can drain from the turbines dry side.



8.2.2. 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 aluminium base.

8.2.3. Indoor 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 remove front glazing and insert screws through the inside plastic lip to pull down the case at the front and ensure a tight seal all round.

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 drained off rather than spread over 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.

Manifold pipe Supports
Pipes full of water are heavy and will sag over time. It is very important to provide support to all manifold 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.

8.3. 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.

8.3.1. Jets

The jet sizes determine the flow through the turbine, and hence the rate of water usage and the turbine power output. Water usage may need to be adjusted to the available flow. If the jets are too many or too large then the available flow may not be sufficient to keep the penstock full of water.

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.

8.3.2. 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.

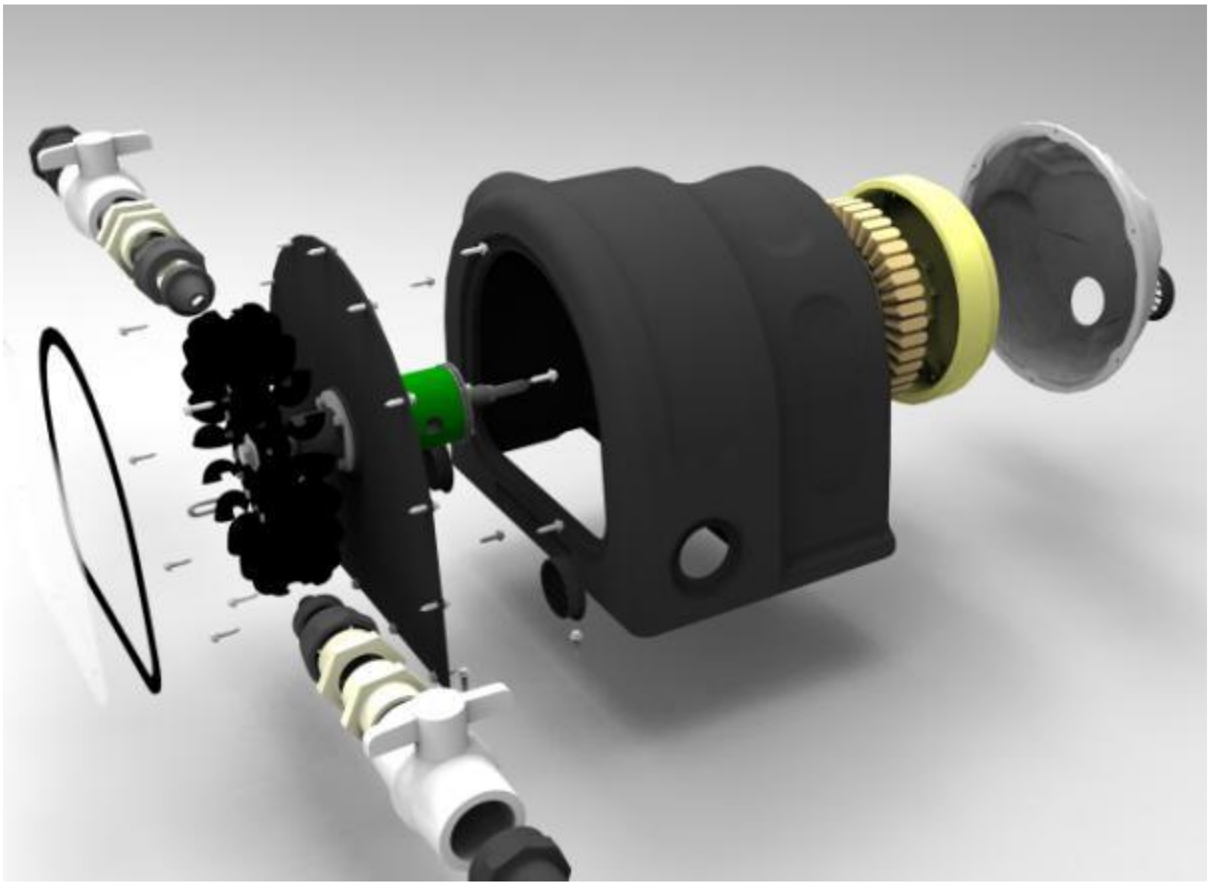
Holding the plastic jet within a spare holder sleeve and end cap will ensure the jet is held firmly while you cut it to size. Take care as it is easy to slip, which could result in a significant flesh wound. If you have Kevlar gloves, wear them.

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.

This will only increase power output as your turbine is generating less than its nameplate rating. Also note that you could have problems if the operating pressure is taken down much below the value calculated in the original system design. It may no longer be possible to optimise turbine speed whilst staying within the acceptable output voltage range,

8.3.3. Pelton (PLT) turbine assembly

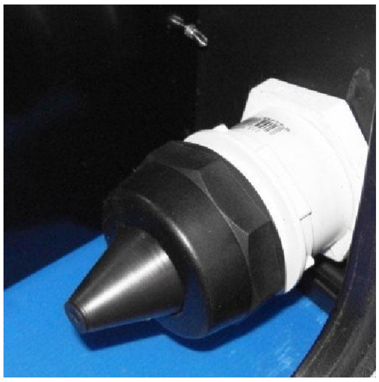


Turbine arrives fully assembled, other than the jet holders. This exploded diagram will assist you once it comes time to service the turbine.

It would be prudent for the installer to remove the PMA and check that all connections are tight and familiarise themselves with the product so the can quickly service it in the future.

Installing jet assemblies

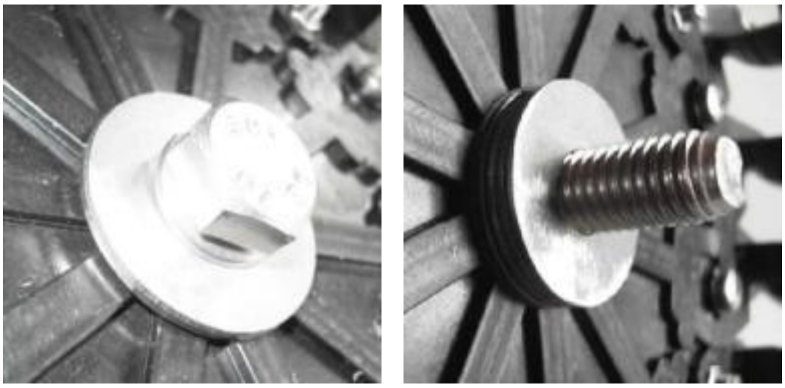
It may be necessary (depending on the PLT model) to remove the Pelton runner in order to install the jet assembly as shown. If so then follow the procedure below in reverse order. The PVC jet sleeve is mounted inside the turbine with the PVC ball valve on the outside. Note that there is also a Jet 'O' 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

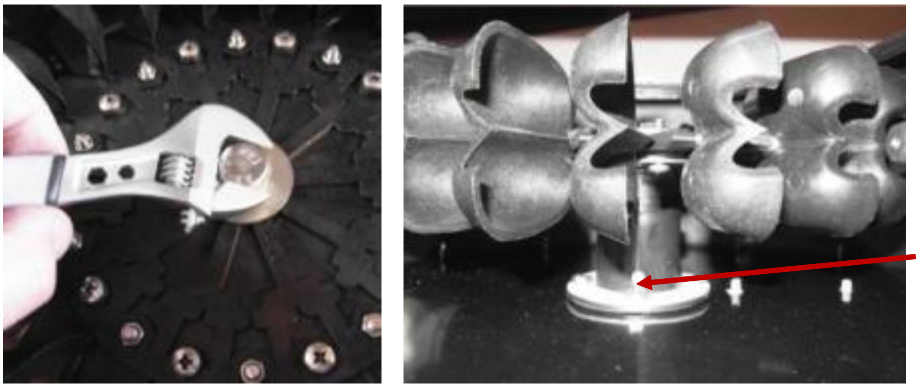
Installing the Pelton runner

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 may 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.



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.

Quick release glazing tabs

These tabs are provided with the PLT turbine to secure the glazing during commissioning. Use them during set up, as they make it easy to remove the glazing. The other fixings should be used later, for safety, if children have access.

Pelton Runner Alignment

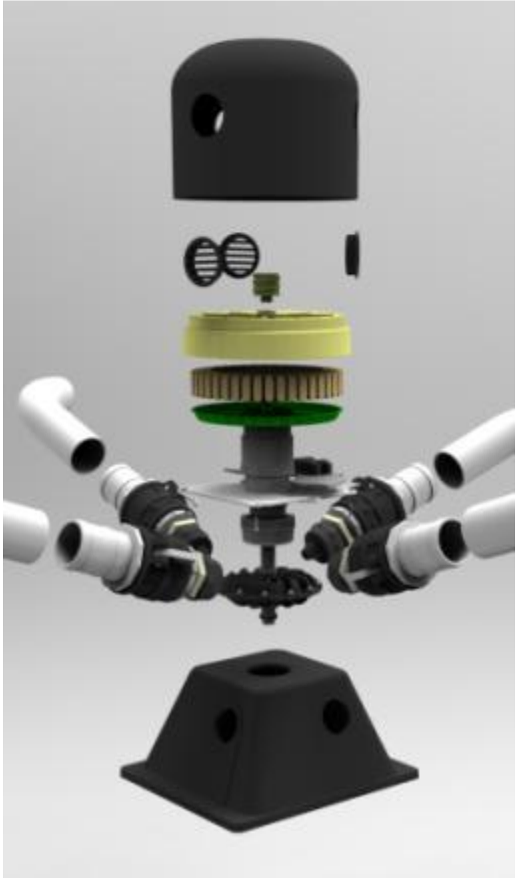
You can view the Pelton runner by looking through the jet as shown. The water jet needs to hit the middle of the Pelton spoon splitter. If the jet is misaligned then pack the runner across using the washers supplied. You can see in the picture that the Pelton runner needs packing to move the rotor to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

8.3.4. Turgo (TRG) turbine assembly

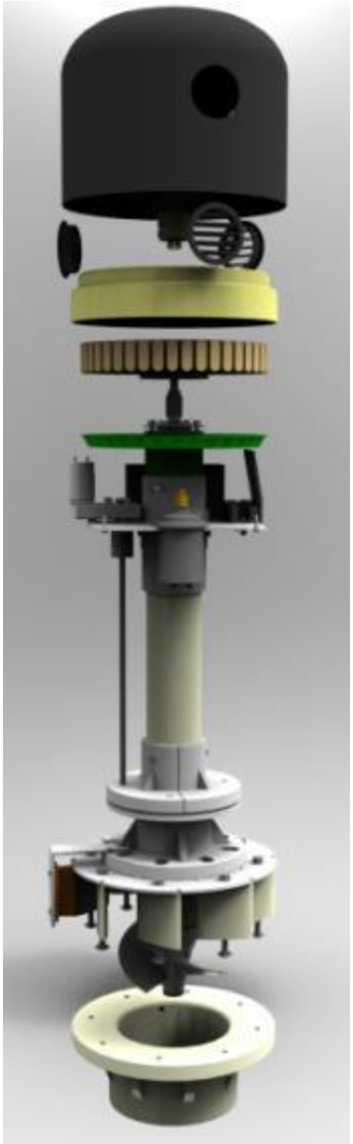
Turgo turbines are fully assembled apart from the 4 jets.

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/



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

8.3.5. 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 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 bulkhead 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.

8.4. Commissioning procedures

8.4.1. 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. It may be easier to perform these checks before taking the turbine on site.

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. (But LH turbines will be tight and normally 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.

A short circuit in the wiring will cause an internal current that "brakes" the turbine and so these tests will reveal wiring faults. If any of these tests show mechanical or electrical problems, then remedy these before installing on site.

8.4.2. Commissioning the turbine

Ensure the above electrical checks (Section **8.4.1**) 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. It may take time to test everything because the pipe may need to be purged of air and the battery may need charging before the diversion loads can be verified as working.

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

Purging the pipe

- Allow pipe to run and purge of any air bubbles (this can take a few hours). Keep checking the pressure gauge until it reaches a steady reading. It may help to close the turbine valves and allow air to escape upwards to the intake for a few hours while you check the pipe for high spots and adjust its gradient to remove airlocks.
- 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. Small stainless screws (as shown) and marked with red tape can be drilled into the pipe (at air locks) and left to weep, in this way air can get out but very little water will be lost.

- While it is purging check the pipe line and turbine fittings for leaks, and remedy as required. If outside small water drips will often stop by themselves after a few days.

Operating checks (with pipe purged)

- Check that the intake has surplus overflow water. If not then you may need to close some valve(s) or fit smaller jets before you can operate continuously.
- If your system has no MPPT regulator then make sure that the battery is connected and the fuses are in place, ready for the turbine to connect. Then close the turbine breaker.
- If using an MPPT controller, check that the Voc is less than its maximum voltage rating. If it is then close the breaker. If not then you will need to adjust the alternator voltage - see 8.4.3 for the description of how to pack the rotor.
- Check for current flow to the load.
- Check that the MPPT controller 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. The MPPT display should read “Bulk”, if it reads “Float” then the turbine is not running at full power.
- Once the full output has been obtained, check that the circuit breakers ratings are 25% over the working current(s) in their circuits.
- If no MPPT controller is fitted you may need to manually optimise the turbine to locate the maximum power point (see section 8.4.3).
- When the battery is sufficiently charged, check that the PWM diversion controllers are working. Or if applicable check that any diversion loads fitted to the MPPT auxiliary relays are working.
- PLT turbines: Check that the drain hole in the rear turbine case is at the lowest point. Condensing water from the bulkhead 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.
- PLT turbines: Check there is no water leaking from the drain hole in the rear bearing block. You can use a small mirror and light to see this. If you see a leak make sure you have installed the top cap seal correctly.
- Do not forget to grease the bearings as described in section 9.3

Documenting the system

Once you are happy that you have successfully commissioned the turbine you should record the following details (see Section **8.5**):

- Jets sizes installed
- Flow rate through turbine (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.)
- Output Watts (= amps x volts) (A DC current clamp meter is ideal for checking DC current in different parts of the system during commissioning or troubleshooting.)
- Static pressure of pipe (turbine valves turned off)
- Dynamic pressure of pipe (turbine running)
- Generator equilibrium temperature, (see Section 8.4.8)
- Picture of installation
- Date for next service check (see Section **9.3**)

Typical meter observations


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 battery voltage is appropriate for this diversion load to be operating. The picture shows the air diversion element with a slight glow, indicating that it is working.

8.4.3. Optimisation of speed (PLT or TRG with no MPPT controller)

Optimisation is 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 used for lower flows will increase the pressure by reducing losses) and also with changing battery voltage. Optimisation can be repeated when flow conditions change (differing jet sizes used) so you can decide what compromise to make with the packing and what penalty you will pay for not changing it.


Optimisation is a trial and error process whereby you run the turbine, check the output current, stop the turbine, adjust the knob on the magnet rotor, run and test again. Once you have found the best position for the rotor you can pack behind it with washers to lock it gently in that position. (Note: 1mm thick stainless steel washers are supplied for packing). Do not over-tighten the plastic nut.

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.

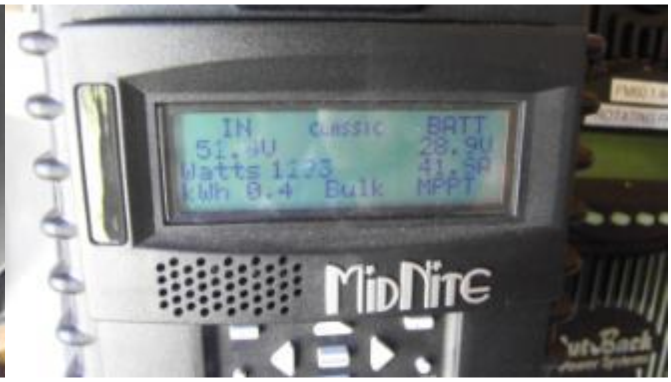
8.4.4. Manual adjustment of MPPT settings to optimise turbine speed

Some MPPT controllers allow you to manually set their input voltage settings. If the controller is unable to automatically track the correct operating point this can be useful. Adjust MPPT set point (turbine voltage) from highest to lowest voltage and note power output at each setting. Then select best power result.

Some MPPT controllers 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 controller (by removing all power from the unit or by selecting the restart option in the display menu), and on seeing a turbine voltage above the battery voltage it should wake up and track until it locates the maximum power point.

Here are examples of what you might see. In this example both MPPT units were connected to a PLT80 running at maximum output.

FM60 locating 1.6kW MPPT from a PLT80



MC250 tracking 1.23 kW MPPT from a PLT80

FM60 tends to track down from the Voc 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.
For more detailed information on the set up of FM60/FM80 , MC150/200/250, MC KID and other makes of MPPT controllers refer to the new 2014 Technical Manual.

8.4.5. 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 (or raise the MPPT voltage).

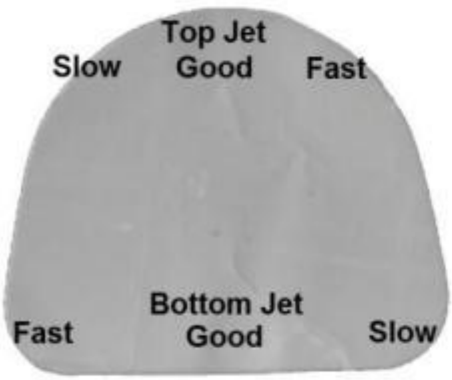
If the exhaust water travels through and hits the opposite side of the casing then the turbine is running too fast and you should reduce the packing (or lower the MPPT voltage).

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. The spray pattern may also give clues to any misalignment of the jet axis relative to the turbine buckets.

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 controllers.
- 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.

8.4.6. Visual optimisation 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 until the maximum power point is located, by adjusting the magnet rotor packing and the jet positions as described above.

8.4.7. Optimisation 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, so it depends on having more water available. There comes a point when the increase in flow rate causes a dramatic drop off in pressure due to increased pipe friction losses. The maximum potential output from a given pipe 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 actually reduce the power output but consume even more water.

If your turbine has been designed to use the maximum flow for the pipe then the jet sizes required will have been calculated based on the head, pipe size and flow indicated. Some fine-tuning on-site will still 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 magnetisation.

This is best illustrated in the Smart Drive test graph (Figure 1). 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.

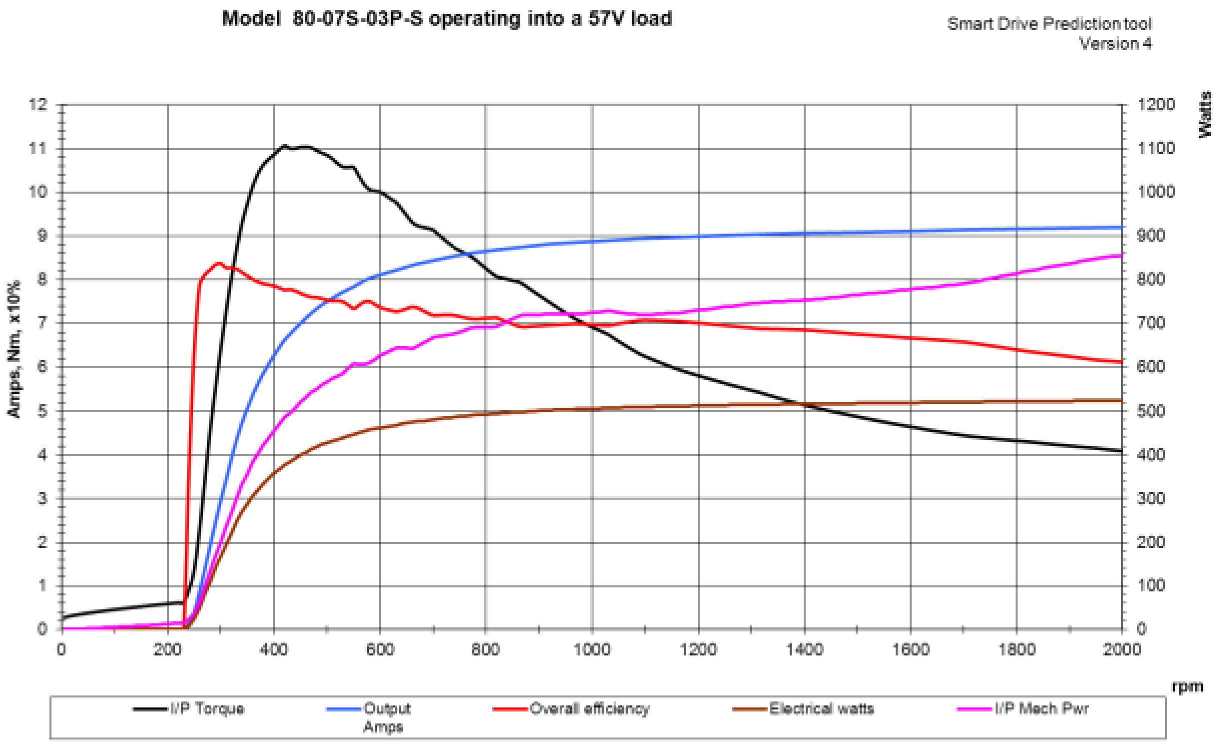


Figure 1. Simplified Smart Drive test graph

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.

8.4.8. 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 voltages 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 bulkhead 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 <u>not operating</u>.

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.

8.5. 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.


Good PLT installs

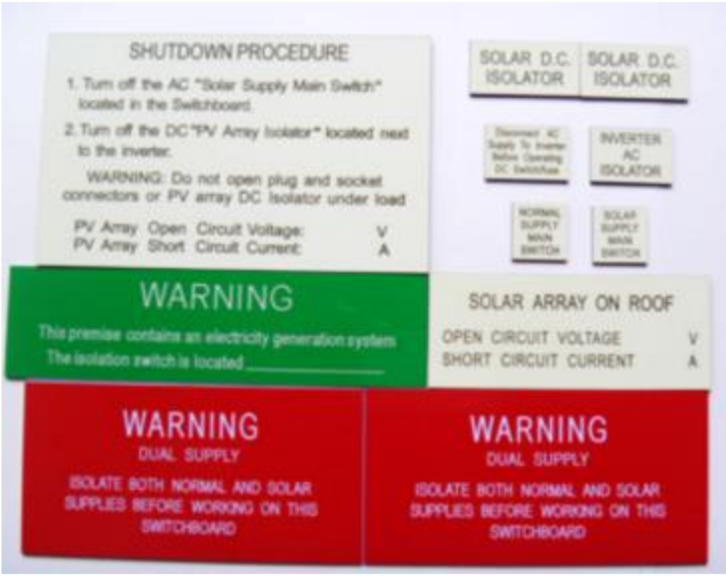

Good TRG and LH install

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.

8.1. 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 endeavours 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).

9. 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, controller, 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

9.1. 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 controller 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.

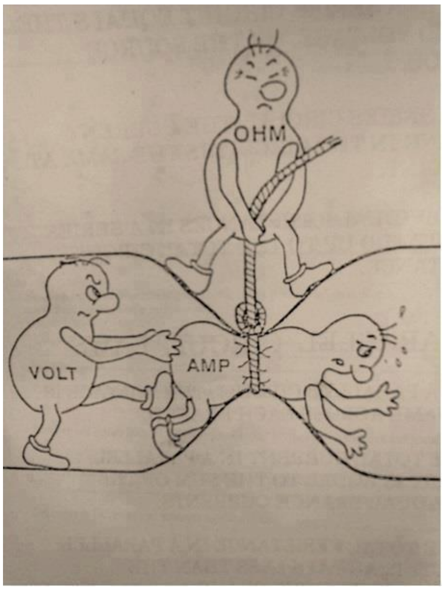
kWh/year = generation Watts x 24 x 365

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

9.2. 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 some global destinations.

9.3. 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

9.3.1. 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.


Remember to grease your new PowerSpout

A good quality grease must be used. We recommend SKF LESA 2 grease for all PowerSpout applications or a close equivalent.

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 20-50 pumps of a domestic type grease gun. Subsequent re-greasing should be about 5 mL of grease (about 5-10 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.

9.3.2. 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.

9.4. Changing the bearings

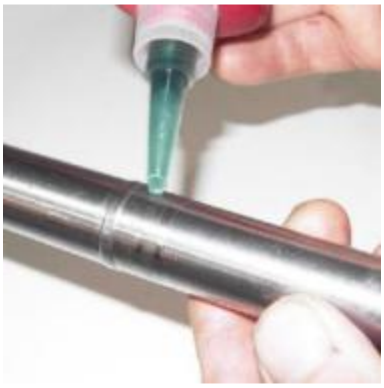
You will need to check the bearings every year and replace if required (note our warranty terms require annual replacement if automatic grease cans are not installed). Bearings are inexpensive and easy to replace. We recommend you hold a spare set of bearings on the shelf. Some of our Pelton turbines 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 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.

9.4.1. 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 Loctite 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.

9.4.2. 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 bulkhead as shown.
A screw driver assists with alignment of holes
Tighten fixings to 5 Nm (4 lb/ft).

10. 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 this is 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 a Klampit is fitted check this has not triggered.
    - 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).

10.1. 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

10.2. 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 warranty.

10.3. Noise

Noise is not normally an issue. Our turbines are normally quieter than others as they turn slower and are 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 it 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. Incorrect speed can be caused by clients installing jets that are too large for the generator power rating resulting in excessive RPM. If you have MPPT regulation with no diversion load fitted then the turbine will speed up and the noise will increase when the batteries are full.
- The noise is not related to how the turbine has been mounted. A heavy timber or concrete base will be quieter than steel/aluminium framed base.
- The line is free from air. Compressed air expansions at the jet are very noisy

See Section 19 for some noise data. We have not taken extensive 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. If allowed to free spin unloaded the noise can travel 200-300m.

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.

11. 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.

11.1. 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

11.2. 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/controller 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

11.3. 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.

11.4. 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.

12. 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

13. 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 warranty 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 (within 12 months of sale), commissioned and maintained over the duration of its use. The end user must return installation details[3] 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 warranty 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 price list.

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. Customers that order the PLT14 product will generate less power due to high rectification losses, due to this fact, PLT14 turbines may deliver (after rectification losses) up to 10% less power than stated, this is additive to the < 200W tolerance stated above.
- A 3-year warranty from the time of purchase (invoice date) for PLT turbines operating at less than 1,200 W. A 2-year warranty applies to PLT turbines running in the range 1,200-1,600 W. A 2-year warranty applies to LH and TRG turbines. A 1 year warranty applies in all other cases and to all twin pack discounted product lines. All warranties 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 1-2 extra grease canisters (and use them) will have their warranty 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.
- To avoid any doubt, warranty starts from the date of manufacture as stated on the invoice from EcoInnovation to the buyer or dealer. As goods are made to order and dropped shipped (in most cases), this will mean that the end client may have 1-4 weeks less warranty by the time they receive the goods.
- 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.

[3] The warranty is only valid for 12 months if no documentation (see Section 8.5) is returned within 11 months of sale

- 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.

14. 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.

15. 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.

16. Notes

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

17. 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/

18. 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 2. 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 3. 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 4. 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

19. Annex III Noise measurements

Noise test at PowerSpout on PLT turbine

Test parameters:

Watts:	1000
Flow:	3,05 l/s
Pressure:	95,5 psi
Head:	600 kPa

In front of running turbine: 93.8 dBA

On top of running turbine: 81.7 dBA

 1m away from running turbine: 83.3 dBA	 2m away from running turbine: 81.9 dBA
 6m away from running turbine: 73.9 dBA	 12m away from running turbine: 56.7 dBA