PowerSpout TRG
Installation Case Study

 

This case study outlines the process of ordering, installing and commissioning a multi-turbine hydro site for domestic grid-connected power.

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1. Introduction

This case study relates to an installation of 3 PowerSpout TRG turbines to produce grid-connected power for a rural household in New Zealand. The client measured and/or estimated the site data and placed an order having used the online Advanced Calculator available at www.powerspout.com/advanced-calculator to calculate the site potential.

Site data summary as measured/estimated by client:

- 20m net head.
- 100m long 94mm ID MDPE pipe – 3 separate pipes.
- 11 l/s flow per pipe (turbine) in dry summer conditions, much more when wet.
- 400 metres of 16mm^2/cable

Two armour-plated cables were laid to convey the DC power, with each cable having 4 x 4mm^2 conductors (total 16mm^2/cable). For 3 turbines this equates to a cable size of 5.3 mm^2 per turbine.

2. Ordering

An order was placed for 3 TRG turbines with the following data inputs and results from online calculation tool (click here to view them in the Calculator).

	Inputs	Results
Preferences		
Units:	Metric	
Type:	TRG	
Hydro		
Flow:	11.0 lps	
Used Flow:		11.0 lps
Pipe Head:	20.0 m	
Pipe Length:	100 m	
Pipe Efficiency:		90 %
Pipe Diameter:	94 mm	
Number of Powerspouts:	1	
Nozzles:	4	
Jet Diameter:		15.1 mm
Actual Pipe Efficiency:		86 %
Speed:		1489 rpm
Output:		1029 W
Total Output:		1029 W
Electrical		
Output Voltage:		194 V
Cable Efficiency:		90 %
Cable Length:	400 m	
Load Voltage:	180 V	
Actual Load Voltage:		180 V
Cable Material:	Copper	
Cable Size:	5.3 mm^2	
Cable AWG:		10 AWG
Cable Current:		5.3 A
Actual Cable Efficiency:		93 %
Actual Total Output:		954 W

This calculation tool predicted this installation would generate 3 x 954 W = **2.86 kW**.

3. Preparations prior to site visit and installation

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

The three TRG turbines were fitted with 80-7s-2p-delta Smart Drive PMA's. This was one of the 6 SD stator/rotor options identified by the calculator. These were tested in the factory at 1489rpm for >1000W and the MPP voltage was noted to be in the range 160-180 VDC.

3.1. Data update following installation of pipes

There were two key changes in the data supplied:

- 20 PSI net head (measured by client on pressure gauge)
- 110m long 94mm ID MDPE pipe – 3 separate pipes

From the above data if was obvious that the client had made a significant error when measuring the head (always keep your optimism in check). 20 PSI is equivalent to 14.1m head, not 20m as initially stated. It might be that the client confused kPa and PSI readings. Revised calculations for each pipe from the online tool are shown below, with changes shaded.

	Inputs	Results
Preferences		
Units:	Metric	
Type:	TRG	
Hydro		
Flow:	11.0 lps	
Used Flow:		11.0 lps
Pipe Head:	14.1 m	
Pipe Length:	110 m	
Pipe Efficiency:		90 %
Pipe Diameter:	94 mm	
Number of Powerspouts:	1	
Nozzles:	4	
Jet Diameter:		16.9 mm
Actual Pipe Efficiency:		79 %
Speed:		1196 rpm
Output:		664 W
Total Output:		664 W
Electrical		
Output Voltage:		189 V
Cable Efficiency:		90 %
Cable Length:	400 m	
Load Voltage:	180 V	
Actual Load Voltage:		180 V
Cable Material:	Copper	
Cable Size:	5.3 mm^2	
Cable AWG:		10 AWG
Cable Current:		3.5 A
Actual Cable Efficiency:		95 %
Actual Total Output:		632 W

The previously projected output power of 2.86 kW is now reduced to 1.89 kW.

This site measurement error also results in some other issues.

- A 3kW inverter was purchased when a smaller and cheaper 2kW inverter would have been sufficient.
- The Smart Drive alternators fitted on the turbines were not optimised for the new site data. This will result in the MPP voltage being low, resulting in higher cable losses.
- The jets had already been cut to size and were too small for this reduced head. Larger jets are needed.

There was insufficient time to fix the PMA issue prior to installation so the job proceeded with less than ideal alternators fitted. This will be corrected at a convenient date after initial install and commissioning.

4. Installation process

4.1. Installing the turbines

Prior to arrival the client had installed all the pipe work, a timber frame and plywood base as shown.

The 3 turbines were positioned such that the fixing tech screws would screw into the timber frame not just the plywood top. These positions were marked and a battery operated jigsaw used to cut out the water exhaust openings.

With each turbine upside-down:

- Liberally grease all threads on all fittings.
- Tighten the 4 jets sleeves to the cam-lock fittings until snug; use a large pair of channel-lock pliers as shown.
- Fit the jets and hand-tighten the black jet caps.

Loosen the 4 x M6 bolts so that the protective top fairing can be removed. To remove rotate the fairing relative to the base while pressing at the fixing position. Some practice is needed and it is easier to do with the turbine upside down as shown.

Sit the turbine on its base with the fairing removed.

Attach a grease gun to the grease nipple on the grease tube as shown. Charge with grease: normally about 20-30 pumps will fill the bearing cavity with an initial grease charge.

Once complete remove the brass grease fitting and nipple from the grease line by pressing in the blue release collar while at the same time pulling on the fitting. Separate the grease nipple from the brass fitting.

Remove the automatic grease can from the holder clip (if fitted) and activate. It is activated by turning the grey cap until you hear the canister pop. There are detailed instructions on the canister to assist you if needed.

Once activated screw the brass fitting onto the thread of the grease canister (remove the black dust cap first). Clip the grease canister back into position and press the grease tube into position so the grease will flow automatically.

Replace the top fairing and attached the turbine with the tech screws supplied. A battery drill and socket will assist you.

Repeat this process for each turbine in turn.

Attach one end of the 50mm (2”) flexible hose as shown. This hose and pipe clamp are not supplied with the turbine; it can be purchased locally. The cam-lock fitting and valves are supplied with the turbine.

In cold climates placing the end of the hose in a bucket of hot water and liberally greasing the fittings will assist you. If you are still unable to push the fittings into the tube then a large wooden mallet will be needed.

The flexible pipes need to be rated for up to 30m of water head (up to 40m of head if you are running at maximum rated head and 33% pipe friction loss).

Tighten the pipe clamp with a drill and socket as shown.

Cut the flexible pipe to length and then attach to the cam-lock fitting that connects to your larger supply pipe.

Note the valves (supplied) are located on the supply pipe end and not at the turbines. This allows the turbine to be easily removed for servicing.

Try and keep these flexible pipes as short as possible.

Once all 4 flexible pipes have been cut and connected it will look like these pictures.

Repeat this process with the remaining turbines.

Once complete it should look like this.
Note the white power leads are yet to be put in protective conduit as required at this supply voltage.

Prior to turning the turbines on you need to do some important checks and engage the help of a qualified technician according to the electrical rules of the country in which the product is installed.

4.2. Electrical connections

Connect each turbine to the main supply cable via a 2 pole DC breaker of the correct amp and voltage rating as shown. If outside, these breakers must be in a UV resistant waterproof housing and comply with local wiring rules.

Ensure each turbine is connected to a permanent and reliable ground connection that complies with local wiring rules.

With the front cover removed:

- Use a volt meter to confirm the OCV (open circuit voltage) of each turbine in turn.

In this case we recorded about 360 +/-20 VDC. Differences of +/- 8% between turbines is fine since they will not all be identical.

Once your electrician has tested your supply cable (installed to local wiring code) and checked your earth connections you are ready to make connections at the other end of the cable.

Ensure the breakers are already off, and turn the turbines off. Replace all covers. You are now ready to work at the other end of the cable.

Connect the main supply cable via a 2-pole DC breaker of the correct amp and voltage rating as shown. If outside these breakers must be in a UV resistant waterproof housing and comply with local wiring rules.

This picture shows a temporary connection so that the turbine installer can check correct operation of the turbines prior to the electrician making permanent code-compliant waterproof connections.

4.3. Output testing and enhancements

The picture to the right shows an EnaSolar 3kW inverter installed above home meter box.

There is a temporary connection via an extension lead to the home AC supply for system testing. The electrician will make permanent code-compliant connections once correct operation has been confirmed by the hydro turbine installer.

The inverter when connected tracked down from 360 OCV to 120 VDC. Peak power was noted to be 1.61 kW at 120 VDC cable voltage, 15% lower than the calculated 1.89 kW.

The reason for this 15% difference is due to a number of installation issues that can mostly be corrected.

Cable voltage is too low and at the bottom end of the inverter operating range, so the cable and inverter losses are higher. This can be corrected by installing the correct Smart Drive PMA stator for the 14.1m head at this site.

At 120 VDC the loss in the cable is 100 W more than calculated at 180 VDC, so correcting this will lift generation to 1.71kW.

Installing a new PMA stator (for the site head) will lift the OCV from 360 to 500-550 VDC and the MPPV would increase to about 180 VDC. Note the inverter has a maximum input rating of 600 VDC which must not be exceeded. The head may increase by 1 m in floods so staying under 550 VDC is advisable.

The other issue is that the flexible pipes have not been correctly supported, which can lead to jet misalignment. Correcting this can result in 1-5% improvement in output power. Losses in flexible pipes and manifold fittings increase as the head drops.

This site has a total of about 20m of 50mm ID flexible pipe that flows at 2.75l/s. Losses in this pipe are calculated at 15 W of total power.

Another common source of increased loss depends on how you connect your flexible pipe to the main supply pipe. 90 degree sharp take-offs have 2 x the loss of a 45 degree take-offs. The extra loss due to 90 degree take off is estimated at 10W.

4.3.1. Loss Summary

- Incorrect cable voltage 100 W
- Jet misalignment due to pipe weight 3% 56 W
- Friction loss in flexible pipes 15 W
- 90 degree bends (x12) 10 W

Likely generation once adjustments are made = 1.61 + 0.81 = 1.79 kW which is within 5% of calculated figure. As accurate flow and pressure measurements are yet to be taken this can easily explain a 5% discrepancy between calculated power and actual power delivered on a site.

Most of above issues will be addressed once the installer can get back to site.

5. Site pictures

The river rapids fall 14.1m over a distance of 110m (pipe length)

Pipe securement, concrete and ratchet tie-downs are often employed

Pipe intake screens are yet to be fitted. A stainless steel mesh sock is planned for the 3 pipe intakes.

6. Return visit to tune TRG installation.

A few weeks later the installer was back in the area and was able to make a few adjustments, including:

- Fitting larger (19.9mm) jets so that the running head is 67% of the static head 9.5m = 95kPA. This means the pipe is transferring all the power is it capable of at a flow rate of 14.2 l/s.
- Installing plywood supports (cut on site) to prevent pipe weight altering jet angle.

Revised calculations indicated that the output would go up to 652 W/turbine at the input to the inverter with these changes (1.956 kW in total).

Once the changes were made the power input on the inverter display showed 1.96kW. The turbines were running exactly as predicted.

The observant reader will note the red earth fault light is on. This is because a cable was damaged during installation and the conductor is touching the earthed armour screen. The site electrician is yet to repair this damage to the cable, but when it is fixed the fault light will disappear.

Most inverters are fitted with earth fault detection: <u>DO NOT</u> ignore this fault warning. However, if your solar PV inverter or MPPT regulator is fitted with arc-fault detection then this should be disabled as the slight ripple of the rectified DC will often false trigger the arc detection software when there is no fault.

This is a timely reminder to check your cable for faults and have your electrician sign off that the system has been installed and tested in accordance with local codes.

If after installing PowerSpout hydro turbines you generate less that the calculations predict then it is often due to discrepancies in the data supplied at time of order and/or problems with the site installation.

This example illustrates well how a job that was started with a 2.86 kW expectation, based on client-supplied data, became 1.96 kW once correct “as installed” site data was used.

By tweaking the site installation the site installer lifted generation from 1.61kW to 1.96kW. This could be further increased to 2.045 kW by lifting the cable voltage to 175 VDC which would reduce the cable loss from 10% to 6%. This would require new PMA stators to be made and sent to the client, for which there will be a fee. The client will need to decide if the extra 85 W is worth the expense.

7. The benefit of hindsight

This example of how to install PowerSpout TRG Pelton turbines has been documented to illustrate the process and to learn from a few mistakes that have been made along the way.

The main error was the incorrect assessment of the site head. A 42% measurement error is large, but (surprisingly) not uncommon. If the head is wrong the pipe sizing advice will be wrong.

Starting afresh on a site with 14.1m head we would have advised a system with the following key changes:

- 200mm PVC culvert grade pipe with ends glued together to save costs i.e a single supply pipe at $15/m instead of 3 pipes each at $30/m.
- Saving in pipe fittings by using lower cost PVC fittings
- 3 x TRG HP turbines instead of 3 x TRG turbines
- 180-200 VDC cable voltage
- Up to 46l/s design flow rate

As shown in the Table below, the output power would be just over 3.0 kW.

	Inputs	Results
Preferences		
Units:	Metric	
Type:	TRG HP	
Hydro		
Flow:	46.0 lps	
Used Flow:		46.0 lps
Pipe Head:	14.1 m	
Pipe Length:	110 m	
Pipe Efficiency:		90 %
Pipe Diameter:	200 mm	
Number of Powerspouts:	3	
Nozzles:	4	
Jet Diameter:		19.2 mm
Actual Pipe Efficiency:		91 %
Speed:		1287 rpm
Output:		1071 W
Total Output:		3215 W
Electrical		
Output Voltage:		213 V
Cable Efficiency:		90 %
Cable Length:	400 m	
Load Voltage:	200 V	
Actual Load Voltage:		200 V
Cable Material:	Copper	
Cable Size:	16 mm^2	
Cable AWG:		5 AWG
Cable Current:		15.1 A
Actual Cable Efficiency:		94 %
Actual Total Output:		3013 W

The MDPE pipe installed on this site is very durable and will not be damaged by rock and tree falls. It would be a great solution on a 60m head site where the higher pressure pipe will pay for itself quickly.

For example a 330m length of 94mm ID MDPE pipe with a 60m fall will generate 3.3 kW at 14 l/s with 4 PLT turbines fitted. This might look similar to the picture below.

7.1. The Client, Dealer, Installer and Manufacturer relationship

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

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

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

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

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

- Refund of turbine price on return of the goods
- 3 x any charges made for professional advice