GGGI

Module 10 - **Trainers Guide**

Pico-hydro Operation and Maintenance Basics

ENGLISH - FIJI ISLANDS

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Rerevaka na Kalou ka doka na Tui

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Cover photo: Pico-Hydro turbine internal wiring. Source: Powerspouts, New Zealand.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

The "Pico - Hydro Operations and Maintenance Basics" training module is meant for technical learners who wish to know more about hydro installation and maintenances.

Upon completion of the course, the learners will be able to achieve the following learning outcomes:

KEY LEARNING OUTCOMES

- Describe the various types of Hydro Power Systems.
- List the components used in Hydro Power Systems.
- Explain the requirements of components used in Hydro Power Systems.
- Identify tools used in Hydro Power Systems.
- Describe procedures for installing and maintaining Hydro Power Systems.
- List the safety requirements for Hydro Power Systems.
- Identify and resolve common faults in Hydro Power Systems.
- Demonstrate the use a Hydro Power maintenance checklist.

HOW TO USE THIS GUIDE

The trainer guide is provided with the class notes and includes activities which need to be done after each section of the course. The guide acts as a recommendation only. After seeing the situation on the ground in each community, the experienced trainers may use their judgment to modify their delivery and assessment techniques to achieve better results.

The Trainer Guide provides detailed notes written in the form that can be directly delivered to the learners. However, the very detailed notes are intended to broaden the knowledge of the learner as well. You are not required to read each paragraph from the Trainer Guide, but you are expected to know the materials sufficiently to train others. Firstly, you must know what key concepts the learners need to learn. These are normally called learning outcomes. The learning outcomes are all listed at the start of the Trainer Guide, and you must ensure that at minimum, every learner achieves those 8 learning outcomes. You are required to take at least a week to go over the TG and go through the activities in the Learner Workbook. During the actual training you can refer to the Trainer Guide and explain it to the learners in your own words. If you are unsure of something always refer to the TG notes. Also note to take heed of the time recommended for each session and activity.

In case where learner literacy levels are low, trainers are advised to adapt to the situations and modify activities as appropriate. It is advisable to keep a continuous record of competencies of learners. All competencies are achieved when learners fulfil all learning outcomes.

HOW TO CONDUCT ACTIVITIES

- Activities are best done in groups or pairs. It is recommended that in each group there is at least one who is more literate or a more active learner who can help to translate and explain the training contents to learners who are slower to understand.
- You may divide the learners into groups of at least 2 and preferably 3-4 learners and ask them to carry out a rigorous discussion within the group. Some activities can be given to the groups for overnight preparation. The trainer needs to be aware of the dynamics of relationships in the community when dividing learners into groups. Sometimes women and youth are not free to share their views when the men from the communities are present. The trainer should ideally ask learners for their guidance when organising them into groups for discussions.
- Ideally the learners may present the results of their activities to the class and have a class discussion based on their findings.
- It is not necessary that all groups present in the same activity.
- However, it is important that all groups are given opportunity to present or verbally discuss their answers.
- At all times, encourage learners to be interactive and participative in class.
- Learners must be encouraged to be vocal and to contribute actively in class discussions.
- To better improve learning, the learners must be encouraged to strongly inquire about the topics through questions.
- The activities allow trainers to observe if the learners have achieved the learning outcomes. If possible, do keep record of the learner's achievement of learning outcomes so that you can help them learn better. A sample record table is given in this guide.
- Adapt existing activities and/or alternative suitable activities in case the desired literacy levels of learners are not met or the desired resources are not available.

TEACHING TOOLS

The following tools/items may be required to enhance learner learning:

- Laptop/ computer and projector to play videos or present notes to the whole class. This will depend on availability. In case this is not available, you are recommended to take large prints of the key concepts and display to the learners while teaching.
- Provide each learner with pen or pencil, and paper to allow them to participate.
- Whiteboard and markers or black board and chalk can be made available to allow both facilitator and learner to state a point.
- The Learner Progress Record sample given below can be used to observe learners, note their feedback, and assess if they have achieved the specific learning outcome. This recording is useful for both the learner and trainer so you can focus on those who are falling behind. Note there are no marks to be awarded and the record is only to improve learning. This is entirely optional.

TABLE 1: Learner Progress Record – Optional for Trainers to Use

Learner Progress Record (Optional)	Date:
Learner Name:	
Learning Outcome	Achieved Outcome (Yes or No) and Comments
1. Describe the various types of Hydro Power Systems.	
2. List the components used in Hydro Power Systems.	
3. Explain the requirements of components used in Hydro Power Systems.	
4. Identify tools used in Hydro Power Systems.	
5. Describe procedures for installing and maintaining Hydro Power Systems.	
6. List the safety requirements for Hydro Power Systems.	
7. Identify and resolve common faults in Hydro Power Systems.	
8. Demonstrate the use a Hydro Power maintenance checklist.	

TABLE 2: Lesson Plan and Recommended Timing of Each Session

Chapter	Lesson Type	Recommended Time
1. Ice Breaker - Introductions	Theory and Activity 1	30 minutes
2. Components of Hydro Power systems	Theory	30 minutes
	Activity 2 (Optional)	30 minutes
3. Component Requirements	Theory	30 minutes
	Activity 3	30 minutes
	Activity 4 (Optional)	30 minutes
4. Types of Pico-Hydro Systems	Theory	40 minutes
	Activity 5 (Optional)	45 minutes
5. Tools used in Hydro turbine System	Theory	30 minutes
	Activity 6 (Optional)	30 minutes
6. Installing Hydro turbine systems	Theory	40 minutes
7. Safety Requirements of Hydro turbine Systems	Theory	20 minutes
	Activity 7	30 minutes
8. Identifying and Resolving common faults in Pico hydro systems	Theory	40 minutes
	Activity 8	90 minutes
9. Hydro turbine Maintenance checklist	Theory	30 minutes
	Activity 9 (Optional)	45 minutes

1

Ice Breaker – Introductions

Trainers must understand that the learners who are attending the module have taken time from their usual daily activities which sustains their livelihood. Most will also be very nervous and unclear regarding what the module is all about. Hence the trainer must ensure that the learners are comfortable and not too nervous. It is important to make them feel at ease so that they can focus on the module and absorb as much knowledge as possible.

Tell them that this is an informative module and there will be no tests or marks in this. You must inform them that this module is being run so that they can take the information to help themselves to transition to renewable energy. Even if they do not use it, they can always use the knowledge to help others. In any way this module will better equip them to help grow their communities. Tell them to be at ease and focus on enjoying the day and asking as many questions as they want. Also tell them to not worry too much about complicated things as you will guide them through this.

ACTIVITY 1

Introduce yourself briefly to the learners. Ask if they are all comfortable at the venue. One by one ask them their names and tell them to give some details about themselves – such as what they would normally be doing at that time and what they hope to gain from the module at the end of the day. In addition, if time permits – ask them what they think about hydro energy. There is no correct answer, and the goal of this activity is simply to get them relaxed and engaged into the session. You may crack few light jokes as laughter always lightens the mood and helps learners relax. Ask the learners about their prior experiences in hydro energy and how much they know about the topic. Also ask them what they wish to gain from this training session and record their answers on paper so that it helps the trainer in setting a direction to the course. For example, if participants expect to know about installation more and less about repair or maintenance, the participants can be taught more of that.

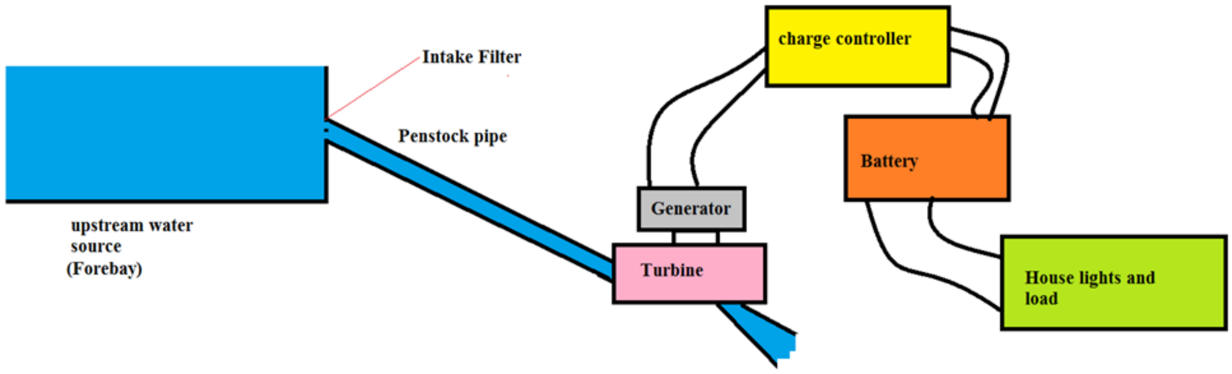
This input will help the trainer direct the training to the learners needs.

2

Components of Pico – Hydro System

A Pico-Hydro system is typically a smaller version of the larger hydropower system and in most cases contains a similar set of equipment. The figure below shows the different components that make up a typical pico-hydro system.

FIGURE 1: Components of a Pico Hydro System[1]



2.1 Weir

This is a man-made barrier across the river which is built to keep the water level at that point at constant level to maintain a continuous flow through the intake.

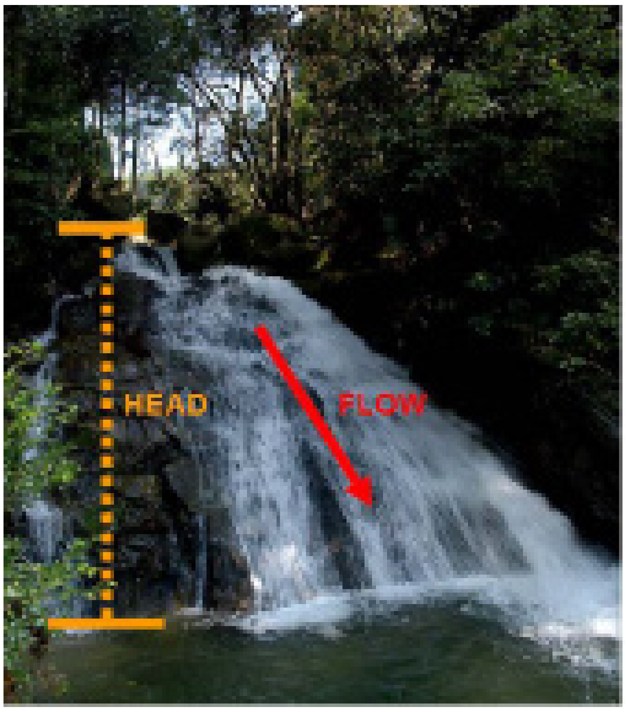
2.2 Intake

The intake of a hydro power is designed to divert only a portion of the stream flow or the complete flow depending upon the flow conditions and the requirement. The intake is usually protected by a rack of metal bars which filters out water-borne debris such as grass or pieces of timber.

2.3 Forebay - Upstream water source

This is simply a creek or stream which is slightly higher than the location of the turbine so that the water will come down at a high flow rate. Both head and flow of water are important to generate electricity. Head is the height of the water source from the turbine location. Figure 2 explains what head and flow are:

FIGURE 2: Head and Flow of water source[2]



1 Source: GGGI, Fiji.

2 Source: DocPlayer, Manual for Renewable Energy Source, https://docplayer.net/45114164-Manual-per-burimet-e-energjive-te-rinovueshme.html, accessed 21 June 2021.

2.4 Penstock pipe and valves

Sometimes the turbine is not directly mounted on the weir or dam. While the weir may be built upstream, we desire to have the powerhouse at a lower stream level. This is because we wish to have as much head as possible. In order to transfer the water directly from this water catchment to the turbine, we use a large diameter pipe. This is called the penstock. and has valves at both ends. Valves are meant to stop or regulate the flow of water to the turbines. Typically, there is a tank referred to as the forebay tank which is fed by a canal from the stream or river, and this helps settle out silt and debris before entering the penstock. Most penstocks also have screens at the start to prevent stones and debris from entering the turbine. Filters are also placed just before the turbine for the same purpose as well.

FIGURE 3: Penstock and inlet valve[3]

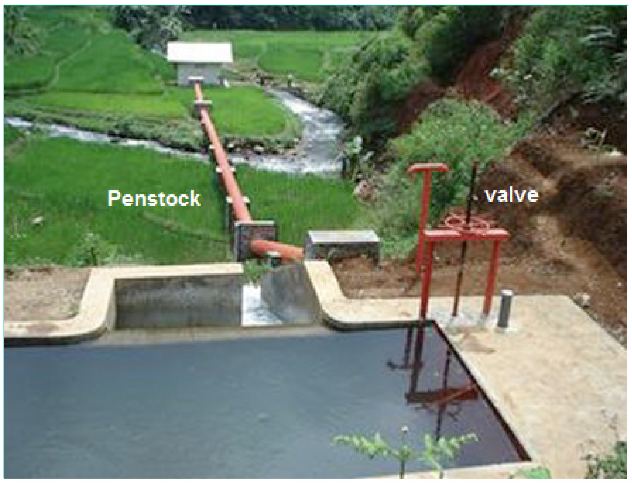


FIGURE 4: A PVC pipe penstock[4]

2.5 Valves and filters

Different types of valves may be used on Pico Hydro systems to control the flow of water.

FIGURE 5: Flanged Butterfly valve[5]

FIGURE 6: Flanged gate valve[6]

Flange type connections are common in steel penstocks. It allows valves to be connected onto flanges as shown below.

3 Source: Daily Frontier Post, adapted from Energy Central, "Micro Hydro Power Plant inaugurated", https://energycentral.com/sites/default/files/styles/article_body/public/ece/nodes/88088/micro-hydel_power_project.jpg?itok=Q57ENvjU

4 Source: Creative Commons, adapted from Energypedia, https://energypedia.info/wiki/File:Penstock_La_Laguna.JPG

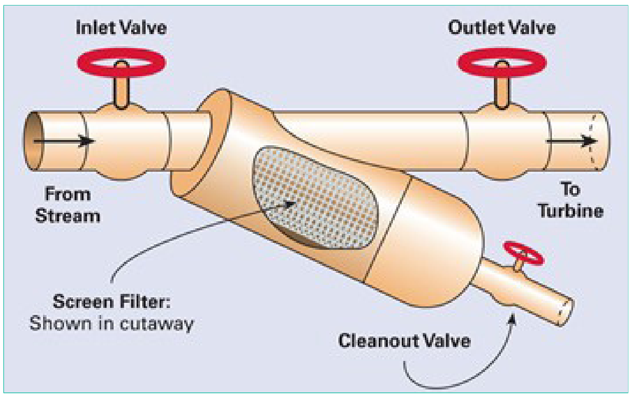
5 Source: Eriks, "Butterfly Valve", https://eriksdigitalcdn.azureedge.net/shop/detail/hlr-system/econosto/sync/01_fotos/publicatie/6333n.jpg

6 Source: Hard Hat Engineers, https://hardhatengineer.com/gate-valve-types-parts/

FIGURE 7: Flange connected gate valve for Penstock flow regulation[7]

Some penstocks have "Y" type piping which allow installation of screen filters in between the inlet and outlet. Cleanout valves are placed to clear out debris and dirt which would move down this pipe due to gravity. The setup is shown in the figure below:

FIGURE 8: Y type filter on penstock notice the different valves[8]



2.6 Turbines

A turbine converts the energy of water dropping from a height to rotational energy. The turbine is connected to a generator to generate electricity.

Turbines are either impulse, reaction, or gravity turbines. Impulse turbines rely on a jet of water to push the turbine. A reaction turbine relies on the flow of water through the turbine and are totally submerged in water. A gravity turbine uses the weight of water flowing over the turbine to turn it.

Head (m)	Turbine Type		
	Impulse	Reaction	Gravity
High (>50m)	• Pelton • Turgo		
Medium (10-50m)	• Pelton • Turgo • Multi-jet pelton	• Spiral case Francis	
Low (<10m)	• Crossflow • Undershot waterwheel	• Propeller • Kaplan • Open-flume Francis	• Archimedes screw • Overshot waterwheel

7 Source: Kknews, https://i2.kknews.cc/SIG=2vusqbk/ctp-vzntr/153590072663593s5rs4r3p.jpg, accessed 21 June 2021.

8 Source: Home power, www.homepower.com

Several types of water turbines can be used in pico-hydro installations, selection depends on the head of water, the volume of flow, and factors such as availability of local maintenance and transport of equipment to the site. For mountainous regions where a waterfall of 50 meters or more may be available, a Pelton wheel or Turgo can be used. For low head installations, Francis, propeller-type, or Archimedes screw turbines can be used. Very low head installations of only a few meters may use propeller-type turbines in a pit. The very smallest hydro installations may successfully use industrial centrifugal pumps, run in reverse as prime movers; while the efficiency may not be as high as a purpose-built runner, tits relatively low cost makes the projects economically feasible.

In low-head installations, maintenance and mechanism costs often become important. A low-head system moves larger amounts of water and is more likely to encounter surface debris. For this reason, a Cross flow also called Banki or Ossberger turbine, a pressurized self-cleaning crossflow waterwheel, is often preferred for low-head micro hydro power systems. Though less efficient, its simpler structure is less expensive than other low-head turbines of the same capacity. Since the water flows in, then out of it, it cleans itself and is less prone to jam with debris.

2.6.1 Pelton Turbine

Pelton's paddle geometry was designed so that when the rim ran at half the speed of the water jet, the water left the wheel with very little speed; thus, his design extracted almost all of the water's impulse energy—which allowed for a very efficient turbine (80-90%). Nozzles direct forceful, high-speed streams of water against a series of spoon-shaped buckets, also known as impulse blades, which are mounted around the outer rim of a drive wheel (also called a runner). As the water jet hits the blades, the direction of water velocity is changed to follow the contours of the blades. The impulse energy of the water jet exerts torque on the bucket-and-wheel system, spinning the wheel; the water jet does a "U-turn" and exits at the outer sides of the bucket, decelerated to a low velocity.

FIGURE 9: A Large Pelton Turbine Runner[9]

FIGURE 10: A Pico hydro Pelton turbine[10]

2.6.2 Turgo Turbine

The Turgo turbine is an impulse water turbine designed for medium head applications. Operational Turgo Turbines achieve efficiencies of about 87%. In factory and lab tests Turgo Turbines perform with efficiencies of up to 90%. It works with net heads between 15 and 300 m. A lot of Pico Hydro turbines are made using Turgo turbines due to the simplicity of construction and ease of installation.

9 Source: Techno-science.net, https://www.techno-science.net/illustration/Definition/220px/Pelton-400kW-roue-1.JPG, accessed 21 June 2021.
10 Source: PowerSpout, https://www.powerspout.com/, accessed 21 June 2021.

FIGURE 11: Turgo Turbine[11]

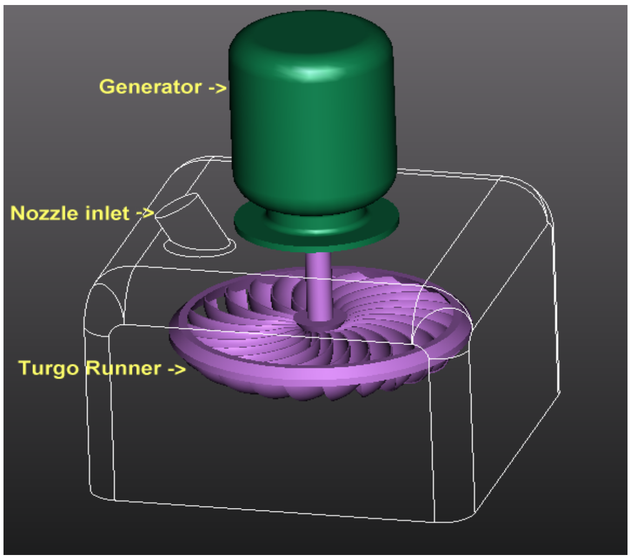


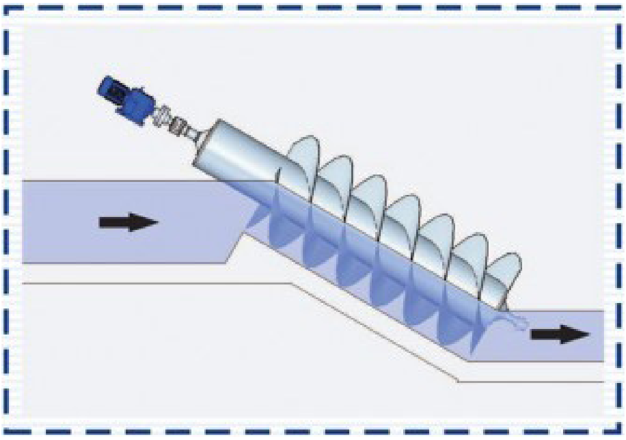
FIGURE 12: Water hits the buckets at an angle in Turgo turbines[12]

2.6.3 Screw Turbine

(Reverse Archimedes' screw): two low-head schemes in England, Settle Hydro and Torrs Hydro use an Archimedes' screw which is another debris-tolerant design. Efficiency 85%.

The screw turbine is a water turbine which uses the principle of the Archimedean screw to convert the potential energy of water on an upstream level into work. It may be compared to the water wheel. The turbine consists of a rotor in the shape of an Archimedean screw which rotates in a semi-circular trough. Water flows into the turbine and its weight presses down onto the blades of the turbine, which in turn forces the turbine to turn. Water flows freely off the end of the turbine into the river. The upper end of the screw is connected to a generator through a gearbox.

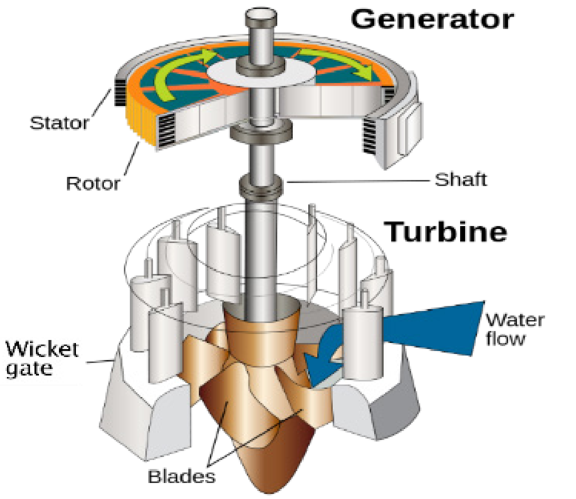
FIGURE 13: Screw type turbine[13]



2.6.4 Kaplan Turbine

An alternative to the traditional kaplan turbine is a large diameter, slow turning, permanent magnet, sloped open flow (very low head) VLH turbine with efficiencies of 90%. A variation of the Kaplan turbine is the bulb turbine. These turbine blades are called propellers.

FIGURE 14: Vertical axis Kaplan turbine with generator[14]



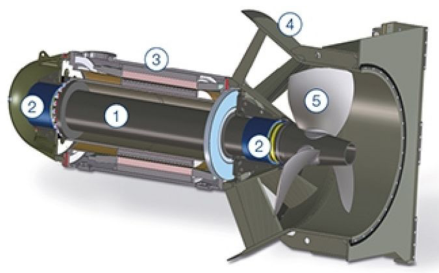
11 Source: Wikipedia, "Position of nozzle and generator in relation to Turgo blades", https://en.wikipedia.org/wiki/File:Turgo_turbine.png

12 Source: SCRIBD, "Impact of jet impulse momentum principle", https://html.scribdassets.com/2k5s3iose83t52ii/images/1-453f23ae7b.jpg

13 Source: www.freeflowhydro.co.uk

14 Source: green-mechanic.com also adapted from Linquip.com, "Schematic of a Kaplan turbine and its components", https://www.linquip.com/blog/wp-content/uploads/2020/12/parts-of-Kaplan-1.png

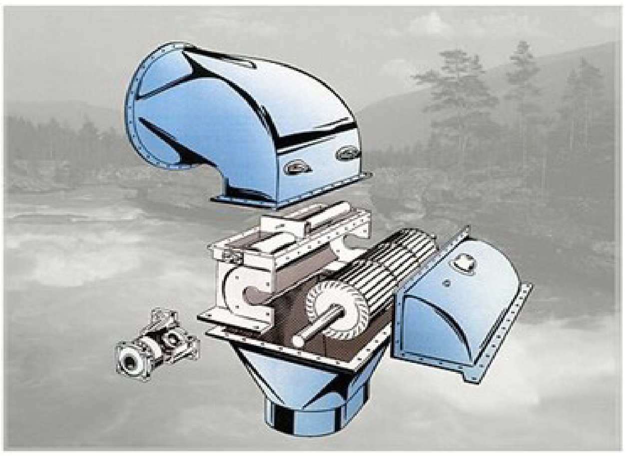
FIGURE 15: A bulb type VLH Kaplan turbine[15]



2.6.5 Crossflow Turbine

Crossflow turbines are also called Banki, Mitchell or Ossberger turbines. Figure 15 provides an expanded view of a crossflow turbine. The runner is drum shaped with curved blades and the runner horizontal shaft is horizontal. A rectangular jet of water is directed across full length of the runner turning the shaft.

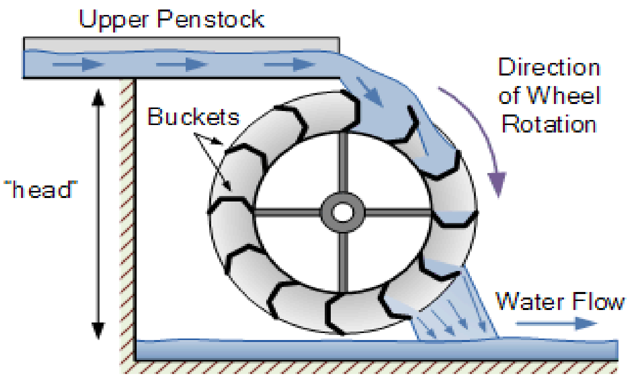
FIGURE 16: Crossflow Turbine[16]



2.6.6 Water Wheel

Advanced hydraulic water wheels and hydraulic wheel-part reaction turbine can have hydraulic efficiencies of 67% and 85% respectively. A water wheel is a machine for converting the energy of flowing or falling water into useful forms of power, often in a watermill. A water wheel consists of a wheel (usually constructed from wood or metal), with a number of blades or buckets arranged on the outside rim forming the driving surface. Most commonly, the wheel is mounted vertically on a horizontal axle, but can also be mounted horizontally on a vertical shaft, for example the tub or Norse. Vertical wheels can transmit power either through the axle or via a ring gear and typically drive belts or gears; horizontal wheels usually directly drive their load. It is one of the earliest and simplest types of water turbines.

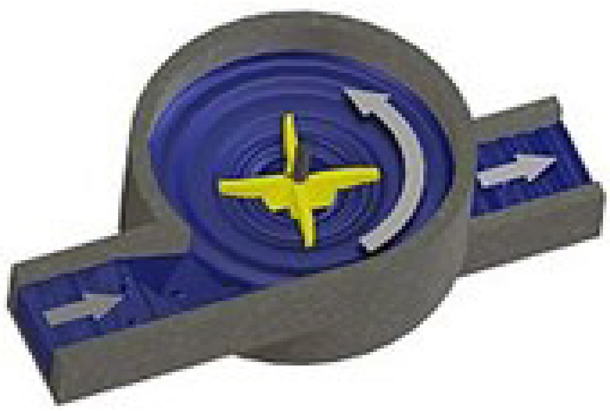
FIGURE 17: Overshot water wheel[17]



2.6.7 Gravitation Water Vortex Power Plant

The gravitation water vortex power plant is a type of micro hydro power plant which is capable of producing energy using a low hydraulic head of 0.7–3 metres (2 ft 4 in–9 ft 10 in). The technology is based on a round basin with a central drain. Above the drain, the water forms a stable line vortex which drives a water turbine. Part of the river flow at a weir or natural waterfall is diverted into a round basin with a central bottom exit that creates a vortex. A simple rotor (and connected generator) is moved by the kinetic energy.

FIGURE 18: A simple gravitation water vortex turbine[18]



15 Source: Voith, "Stream Diver design", https://commscockpitimf.voith.com/im/imf/100_35699/s,x,960/f,j/teaser.jpg

16 Source: Wikimedia Commons, "Ossberger turbine", https://upload.wikimedia.org/wikipedia/commons/5/54/Ossberger_turbine.jpg,accessed 21 June 2021.

17 Source: Alternative Energy Tutorials, "The Overshot Waterwheel", https://www.alternative-energy-tutorials.com/images/stories/hydro/alt74.gif

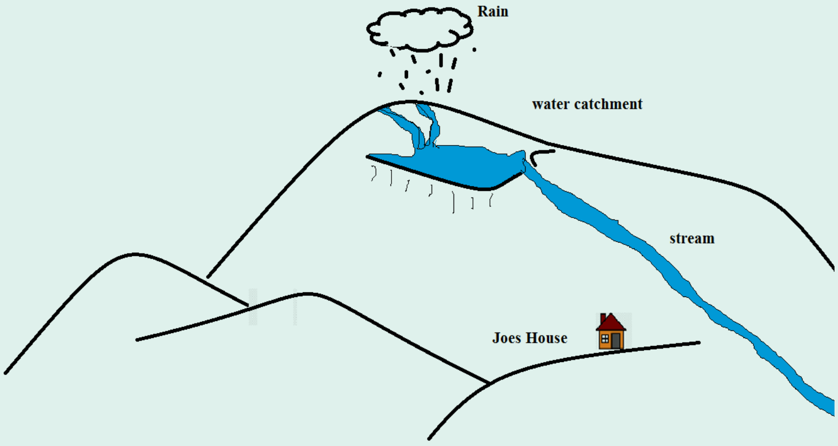
18 Source: Wikimedia Commons, "Gravitation water vortex power plant", https://en.wikipedia.org/wiki/File:Wasserwirbelkraftwerk.jpg,accessed 21 June 2021.

2.6.8 Common Pico Hydro Turbines

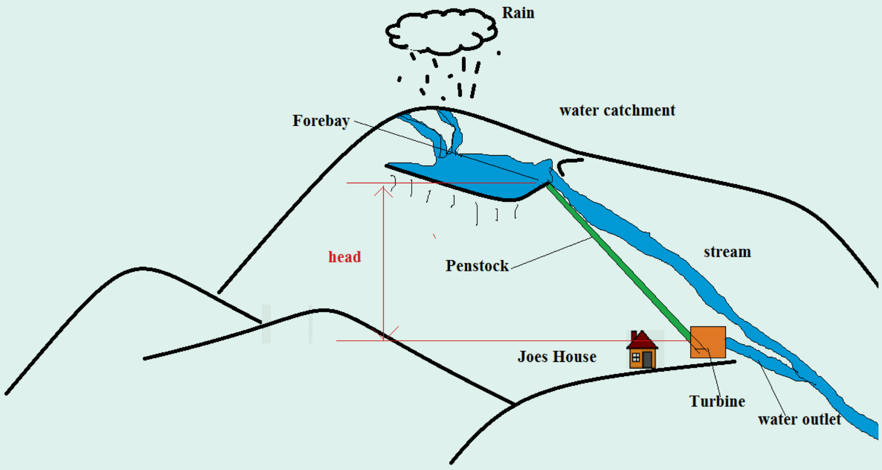
Small scale Pelton turbines are commonly used for pico scale hydro power along with propeller turbines and cross flow turbines. However recently, Turgo turbines have emerged on the market for pico hydro turbines simply because of the ease of manufacture and lower price. Turgo turbines normally have their axis placed vertically and the generator is on top. This also puts the generator far away from the water itself and it is also easier to maintain. Most turbine rotors last up to 10-15 years depending on maintenance. Bearings and other components may fail earlier and can be replaced. Buckets or blades of such turbines can be replaced readily.

ACTIVITY 2

Consider the drawing of an upper stream catchment area and Joe's house. In the same drawing, you are required to sketch in how a Pico hydro turbine will be situated for Joe to use. Where will the forebay be located? Where will the penstock go? Where will the turbine be located? This can be done in teams. On the same drawing mark, the total head available to the turbine.



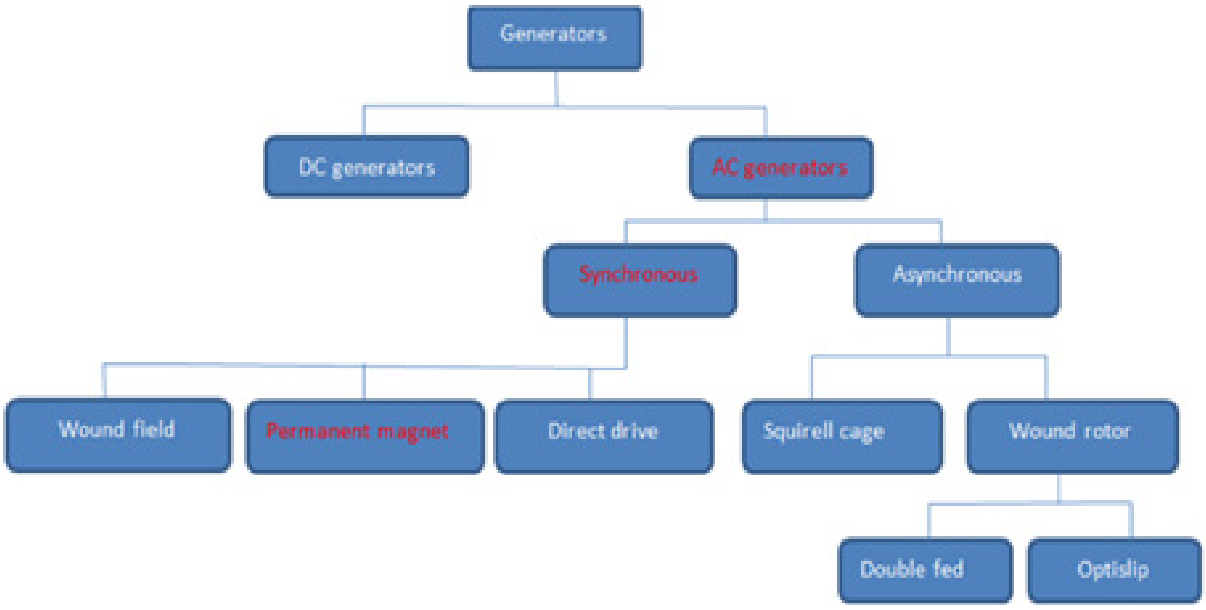
Answer: The turbine is located below the catchment or forebay and as close to the house. The location also allows the used water to re-enter the stream and not create another stream as outlet. The head is from the forebay to the turbine location.



2.7 Generators

Most hydro systems come with a generator coupled to the turbine. However, it is still important to understand the different types of generators in use. A generator is a device that converts mechanical energy to electrical energy for use in an external circuit.

FIGURE 19: Generator types of AC expanded[19]



Permanent Magnet (PM) generators are quite common in micro hydro power applications. These are simple generators that are self-excited.

A permanent magnet synchronous generator is a generator where the excitation field is provided by a permanent magnet instead of a coil. On large hydropower systems induction or asynchronous turbines are used.

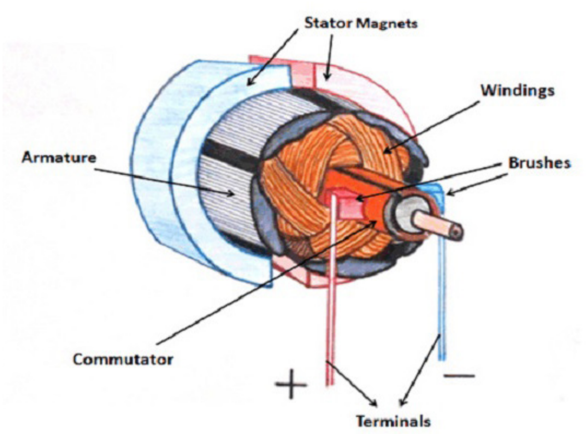
2.7.1 PM DC generators (Synchronous)

The Permanent Magnet DC Generator also called Synchronous can be considered as a separately excited DC brushed motor with a constant magnetic flux. In fact, nearly all permanent magnet direct current (PMDC) brushed motors can be used as a permanent magnet PMDC generator, but as they are not really designed to be generators, they are typically used in pico-hydro systems due to their simplicity. In larger hydro systems the asynchronous generators are used. These PMDC generators consist of a stator having rare earth permanent magnets such as Neodymium or Samarium Cobalt to produce a very strong stator field flux instead of wound coils and a commutator connected through brushes to a wound armature as before.

The term synchronous refers here to the fact that the rotor and magnetic field rotate with the same speed, because the magnetic field is generated through a shaft mounted permanent magnet mechanism and current is induced into the stationary armature.

19 Source: GGGI, Fiji.

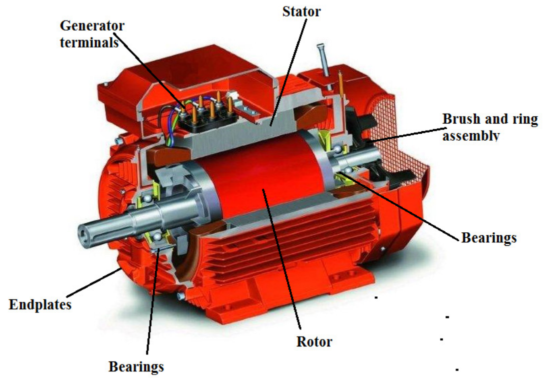
FIGURE 20: A PM DC Generator [20]



2.7.2 Induction Generators

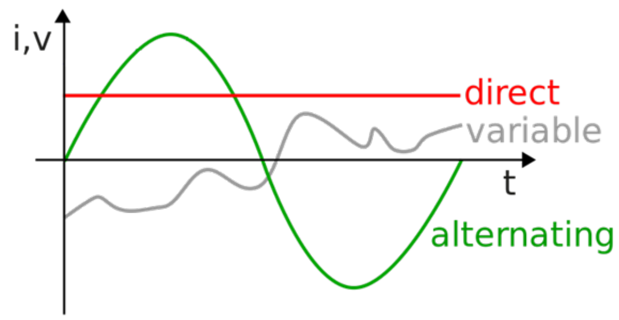
An induction generator or asynchronous generator is a type of alternating current (AC) electrical generator that uses the principles of induction motors to produce electric power. Induction generators operate by mechanically turning their rotors faster than synchronous speed. A regular AC induction motor usually can be used as a generator, without any internal modifications. An induction machine requires an externally supplied armature current. Capacitors or batteries can be used to externally excite induction generators. This type of generator is typical in large grid connected hydro power systems.

FIGURE 21: Parts of an induction generator[21]



The electricity that is supplied on the grid is typically alternating current (AC) electricity. This is an even sinusoidal wave as in Figure 22.

FIGURE 22: Direct, variable, and alternating current[22]



To generate this even sinusoidal wave the generator must spin at set revolution per second. This is possible to control with the flow of water through the turbine. Careful control of the flow ensures the voltage and frequency remains within set parameter. Generating higher or lower voltages at different frequencies can damage or shorten life expectancy of electrical equipment.

2.8 Charge Controller

A charge controller limits the rate at which electric current is added to or drawn from electric batteries. It prevents overcharging and may protect against overvoltage. Pico Hydro Charge controllers operate under much higher current than solar charge controllers.

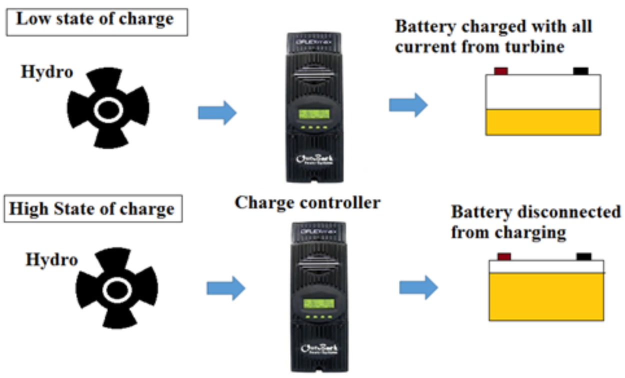
FIGURE 23: A Hydro-Power Charge Controller[23]

20 Source: Linquip.com, "DC Motor Parts", June 2020, https://www.linquip.com/blog/wp-content/uploads/2020/06/DC-motor-parts-2.jpg
21 Source: ePowerMetals.com, "Gate Valve Rising Stem", https://www.epowermetals.com/wp-content/uploads/2019/09/OS-Y-Gate-Valve-Rising-Stem-1024x559.png
22 Source: PNGWing.com, "Alternating current Direct current Electric current Electricity Electric power", https://www.pngwing.com/en/free-png-czyuz
23 Source: Amazon.ca, "Charge Controller", https://www.amazon.ca/OutBack-Power-FM60-150VDC-FLEXMax-Controller/dp/B00IVC7BYC

Over-charge protection

- When battery voltage is low, the charge controller continues to connect Hydro turbine to battery to charge it.
- When battery voltage is high, the charge controller automatically disconnects Hydro turbine from battery to stop charging.

FIGURE 24: Over-charge protection[24]



Over-discharge protection

- When battery voltage is high, the charge controller automatically connects load to battery.
- When battery voltage gets low, the charge controller automatically disconnects load from battery.

This following circuit configuration is recommended

FIGURE 25: Over discharge protection[25]

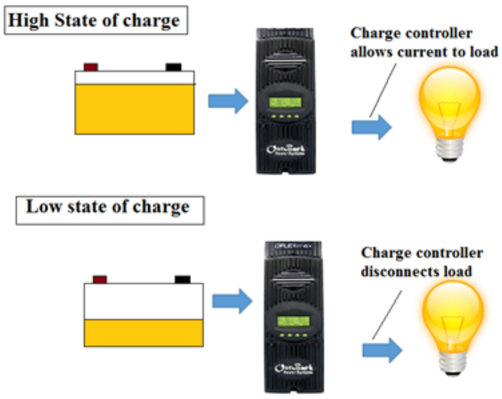
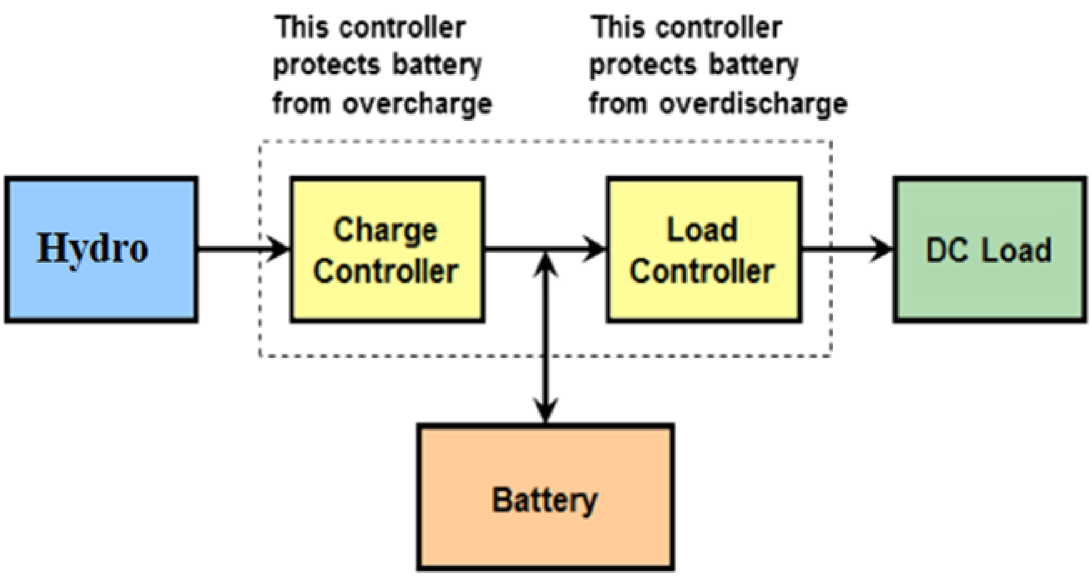


FIGURE 26: Recommended configuration[26]



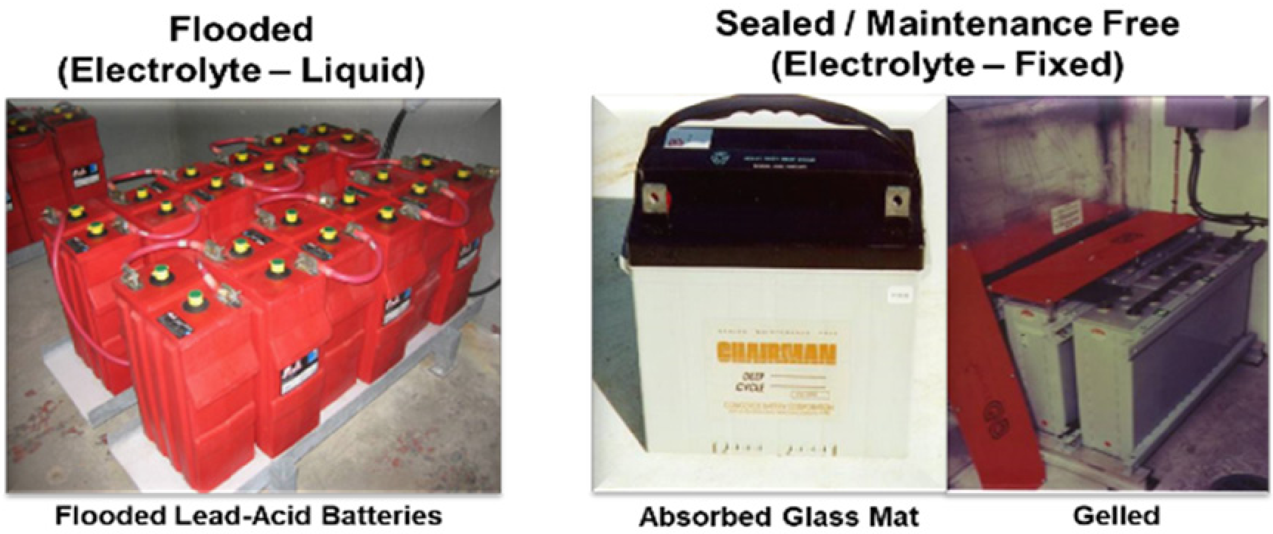
24 Source: JICA
25 Source: JICA
26 Photovoltaic Systems, Dunlop 2nd Ed.

2.9 Batteries

A battery is a device that is able to store electrical energy in the form of chemical energy and convert that energy into electricity. These are the same batteries used in solar or wind power systems. Battery capacity is measured in Amps Hour. That is how many Amps it can deliver in one hour.

FIGURE 27: Sealed Battery[27]

FIGURE 28: Different types of batteries[28]



- Batteries are commonly constructed using Lead and Lead Oxide electrodes and contains diluted sulfuric acid inside.
- Other types of batteries are also available, such as Lithium and Nickel Cadmium.
- Automotive batteries are not recommended for hydropower system. They are designed to give a large amount of current over a short amount of time.
- Hydro or solar batteries are the opposite. They are designed to give a small amount of current over a large amount of time.
- Sealed batteries have a maximum voltage of 14.1 V, flooded batteries can be charged up to 14.4V.
- Battery Capacity:
    - Capacity is a measure of the stored electric charge or stored energy that a battery can deliver under specified conditions.
    - An ampere-hour (Ah) is the unite measurement of battery energy storage capacity, and equals to the transfer of one ampere for one hour.
    - Capacity depends on the battery temperature, discharge rate and cut-off voltage.
- The battery has the highest failure rate among all the components in a DC or AC load.
- The flooded lead-acid batteries have liquid electrolyte, while the sealed batteries have fixed electrolyte.

27 Source: JICA

28 Source: Adapted from "System Components- Batteries", Arizona State University, VOCTEC, http://voctec.asu.edu

2.9.1 Flooded Batteries

This is the traditional engine starter battery and deep cycle-style battery. The liquid electrolyte is free to move in the cell compartment. The user has access to the individual cells and can add distilled water as the battery dries out. Popular uses are engine starting and deep cycle designs.

2.9.2 Sealed Batteries

This term can refer to a number of different constructions, including only a slight modification to the flooded style. In that case, even though the user does not have access to the cell compartments, the internal structure is still basically the same as a flooded battery. The only difference is that the manufacturer has ensured that a sufficient amount of acid is in the battery to sustain the chemical reaction under normal use throughout the battery warranty period. Other types of lead acid batteries are also sealed, as explained below. Very popular uses are engine starting and limited starting/deep cycle applications.

2.9.3 AGM Batteries

The Absorbed Glass Mat construction allows the electrolyte to be suspended in close proximity with the plate's active material. In theory, this enhances both the discharge and recharge efficiency. Popular usage includes high performance engine starting, power sports, deep cycle, hydro and storage batteries.

2.9.4 GEL Batteries

The Gel Cell Battery is similar to the AGM battery style because the electrolyte is suspended, but different because technically the AGM battery is still considered to be a wet cell. The electrolyte in a gel cell battery has a silica additive that causes it to set up or stiffen. The recharge voltages on this type of cell are lower than the other styles of lead acid battery. Gel batteries are best used in VERY DEEP cycle application and may last a bit longer in hot weather applications.

2.10 Cables

FIGURE 29: **Cables**[29]

Electrical cables are used to connect two or more devices, enabling the transfer of electrical signals or power from one device to the other.

2.11 Circuit Breaker/Isolator

A circuit breaker's basic function is to interrupt current flow after a fault is detected. An isolator is a mechanical switching device that, in the open position, allows for isolation of the input and output of a device.

Circuit breaker has different amperage ratings such as 5A, 10A, 16A, 32A etc. This breaker will automatically disconnect if the amps through the breaker reach the specified amps. For example, if you are using 10A breaker and if you have connected 12Amps load, the breaker will disconnect (commonly known as "trip"). This is to protect overcurrent in the circuit for safety.

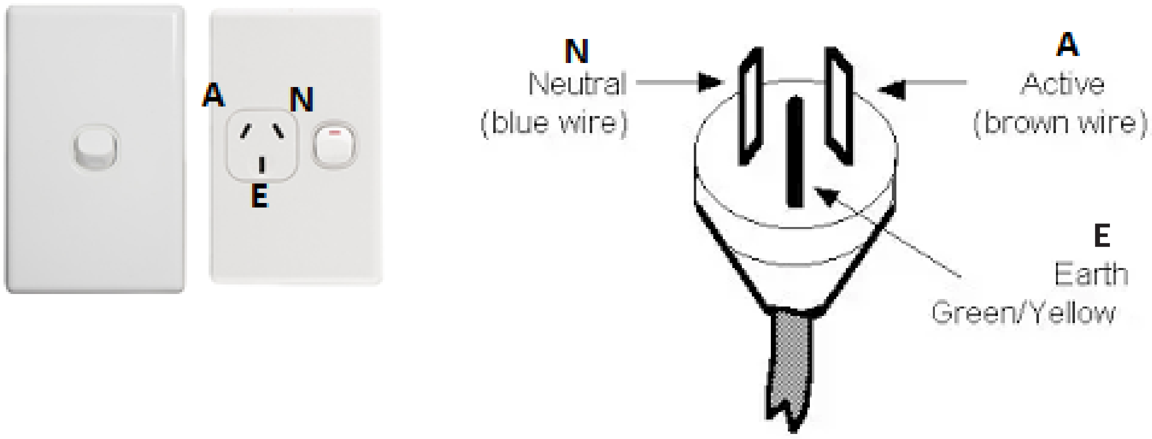
29 Source: Global Market, http://newimg.globalmarket.com/PicLib/group0/5e/73/c477defc613ecc9a0e47b82452f4_l.jpg

FIGURE 30: Circuit Breaker and Isolator[30]

2.12 Switch and Power Socket

Switch isolates electricity and power socket is used to connect/disconnect appliance to use electricity.

FIGURE 31: Switch and Power Socket[31]



2.13 Inverter

An inverter is an electronic device or circuitry that changes direct current (DC) to alternating current (AC). There are different types of inverters for different functions. Selecting an inverter for stand-alone systems is based on the following specifications:

- Battery input voltage (12, 24 or 48 V).
- AC output voltage (120 or 220V).
- High AC power required for cumulative load (in watts).
- Surge current (e.g., motors) requirements, if any (in amps).
- Additional features (battery charger, etc.).

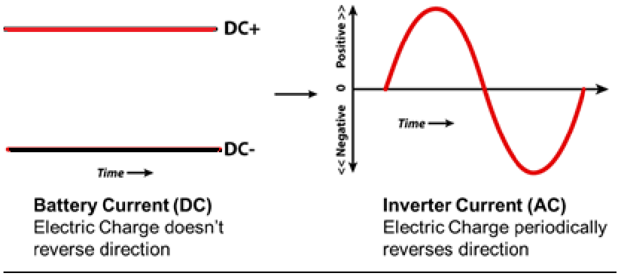
FIGURE 32: Inverter[32]

30 Source: Wave inverter.co, https://waveinverter.co.nz/shop/solar/solar-connectors/pv-dc-isolator-switch-mc4/ and POSO.com, http://poso.com.vn/wp-content/uploads/2020/04/1-2.png

31 Source: University of Newcastle Australia, "Electrical General Purpose Outlets", https://www-eng.newcastle.edu.au/eecs/ect/oh&s/Hazards/ElectricalGPOs.html

32 MorningStar, May 2021, https://www.morningstarcorp.com/products/suresine/

FIGURE 33: Function of Inverter[33]



2.14 Diversion Loads or Dump loads

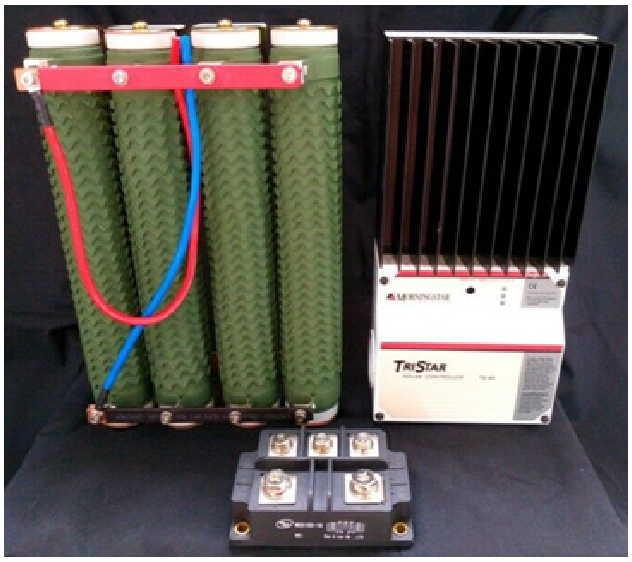
In some hydro power systems, it is possible to connect the load directly to the hydro generator. In such systems where the output is AC, there is no battery bank to store the excess energy which is generated. Normally these systems are sized in such a way that the loads can be run at minimum capacity of the hydro turbine in such cases. What happens to the excess energy? We cannot simply ignore the excess power which is generated but not used. In most cases a diversion load is used to absorb all the excess power safely. This is also called a shunt resistor or a dump load.

FIGURE 34: Dump load or diversion load in form of resistors[34]

FIGURE 35: Dump load with cooling[35]

Such diversion loads which absorb the electricity can also be used with batteries too in DC systems when the batteries can no longer absorb the excess energy. While it is common to use power resistors to dissipate the energy – there are also instances where heating elements with a hot water tank are used to dissipate the energy into water.

FIGURE 36: Some charge controllers come ready built with dump loads and circuits[36]



33 Adapted from System Components: Charge Controllers &Inverters, Arizona State University (VOCTEC), http://voctec.asu.edu

34 Source: Michigan Wind and Solar, "Diversion Dump Load Resistor", http://badasstreestands.com/uploads/3/4/2/3/34230874/1320806591.jpg

35 Source: Green Energy Star, "Dump Load Interior", http://greenergystar.com/products/wind/dumploadopen%5Bgs%5D.jpg

36 Source: PicClick UK, https://picclick.co.uk/Micro-hydro-turbine-26-kw-with-a-Dump-load-154173045313.html

2.15 Electronic Load Controllers

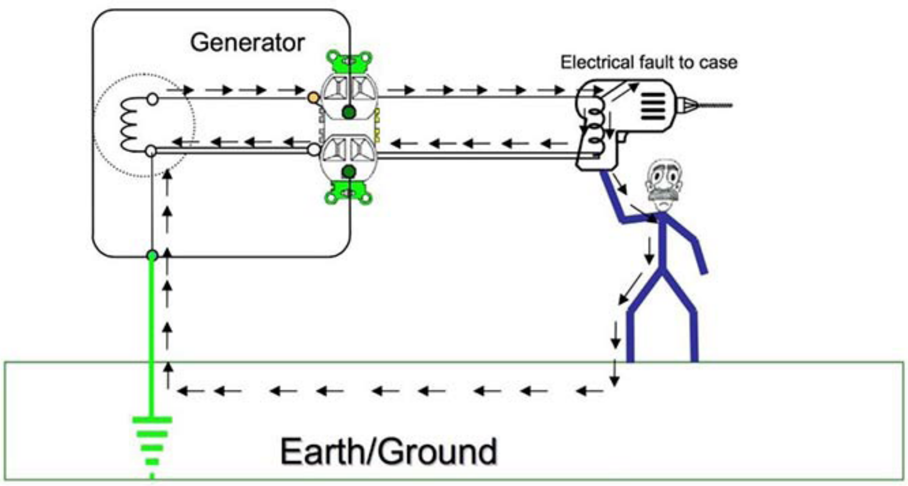
Some of the devices are very sensitive to the voltage and frequency they receive. While in grid tied systems, this is not an issue – standalone systems require voltage regulation as the turbine speed may keep changing. In olden times – speed governors were used to adjust the valves and control water flow to regulate the voltage and frequency. In more recent times a device called Electronic Load Controller (ELC) is used to regulate the voltage and frequency. When the load is reduced, the ELC diverts the power to dump loads (see above topic).. This means that the ELC allows the turbine to operate at maximum capacity all the time even with less loads. The idea is to keep the load steady by connecting and disconnecting dump loads as required by the ELC. This in turn keeps the turbine operating at a steady torque and rpm.

FIGURE 37: Typical hydro Electronic Load Control unit[37]

2.16 Earth and Grounding components

It is required to ground all hydro systems as properly grounded system will help protect you from unintentional shocks and possible deaths (even during any surge and lightening). It can help prevent fires in the system post-installation. In other words, properly grounding your hydro installation protects you. All loads such as dump loads need to have proper grounding as well.

FIGURE 38: How to ground[38]



37 Source: Dhava Mani Technologies, https://1.bp.blogspot.com/-xzLAukzxFa0/V5yP24mX13I/AAAAAAAAAQA/-JbVKYtTI3kHFxXi04uWK8cV7seCBIlEACKgB/s1600/2dumpe-ditmetal.png

38 Source: Portable Power Zone, "The Grounding Process", https://portablepowerzone.com/portable-grounding-generator-steps/

FIGURE 39: Grounding components[39]

39 Source: Watch YouTube video, "Earth (electricity) Wikipedia Audio article", Wikipedia tts, 15 June 2019, https://www.youtube.com/watch?v=S1OS9cox8vI

3

Component Requirements

It is critically important to have components that are of good quality and meet the minimum requirements of SEAPI Guidelines to have a safe and durable hydropower system. Each component is provided with manufacturer's specification or features. The Specification provides specific details on any components or appliance. The following are some of the requirements for each component.

3.1 Forebay Upstream Inlet

The forebay or the upstream inlet may require a small weir or dam made of stones normally to create a buffer of water to flow down the penstock. The forebay helps to collect and feed water directly to the penstock. Stopping some water upstream increases its head which means more efficient electricity production. You may install a penstock directly into a stream at times without obstructing the water flow. Gauze filters are common in Pico-hydro turbine to stop pebbles, twigs, leaves and other matter from entering the penstock. Pico – hydro penstocks have a smaller diameter and can be easily clogged.

Other requirements:

- Ensure the head (vertical height from turbine location to upstream water source) is the same or more than that stated on the turbine.
- Ensure slopes are stable for sediment forebay check dams.
- Ensure the area is easily accessible.

FIGURE 40: Forebay weir with filter and penstock connector[40]

3.2 Penstock

Penstock or delivery pipes need to be flexible Polyethylene or PVC pressure pipes. The water in these pipes can reach very high pressures and therefore the pressure rating on the pipes and valves is very important. Also try to choose a large diameter of pipe as possible to avoid pressure losses. In the Pacific region, most pipes are rated using a PN number which simply gives the working pressure of the pipes. Depending on the head the pressure changes. The table below can be used to know which PN number or pressure class of pipe is suitable for what head of water:

FIGURE 41: Pressure pipes for different heads[41]

Pressure class	PN	Bar	Metres head	MPa	kPa	Psi
A	3	3	30	0.3	300	45
B	6	6	60	0.6	600	90
C	9	9	90	0.9	900	135
D	12	12	120	1.2	1,200	180
E	15	15	150	1.5	1,500	225
F	18	18	180	1.8	1,800	270
No Class defined	10	10	100	1	1,000	150
No Class defined	16	16	160	1.6	1,600	240
No Class defined	20	20	200	2	2,000	300
No Class defined	25	25	250	2.5	2,500	375

40 Source: Pinterest, "Micro hydro intake", https://www.pinterest.com/pin/563020390916765709/

41 Source: Quora.com, "What do PN and PE stand for in a PN6 HDPE pipe", https://www.quora.com/What-do-PN-and-PE-stand-for-in-a-PN6-HDPE-HDPE-pipe

Try to always use pressure pipes or storm water pipes for Penstocks. Other pipes such as electrical conduits have a thinner wall and can get damaged easily. As a rule of thumb, you can ask for PN 9 or PN 12 pipes for making penstocks. These are commonly used.

3.3 Turbine and generator

For Pico-hydro systems, low head turbines that operate on low flowrate is required. Low head means they can run with a small height of water. Low head is classed as 20m or below. Some turbines called current turbines or bulb turbines can be mounted directly in rivers to use the swift current in rivers. These do not require penstocks. Recently Very Low Head (VLH) turbines have been built. VLH is below 4.2 m head. Very low head does not mean low power – the flow may be high, and the power produced can be very high as well. For any turbine ensure that you match the head and flow of your stream to the turbine specifications.

Generators normally come together with the turbines. We have already discussed generators earlier. A key requirement of the generator will be water proofing. Some generators may require an additional power room or powerhouse as they are not fully waterproof. This would mean extra costs in building a powerhouse.

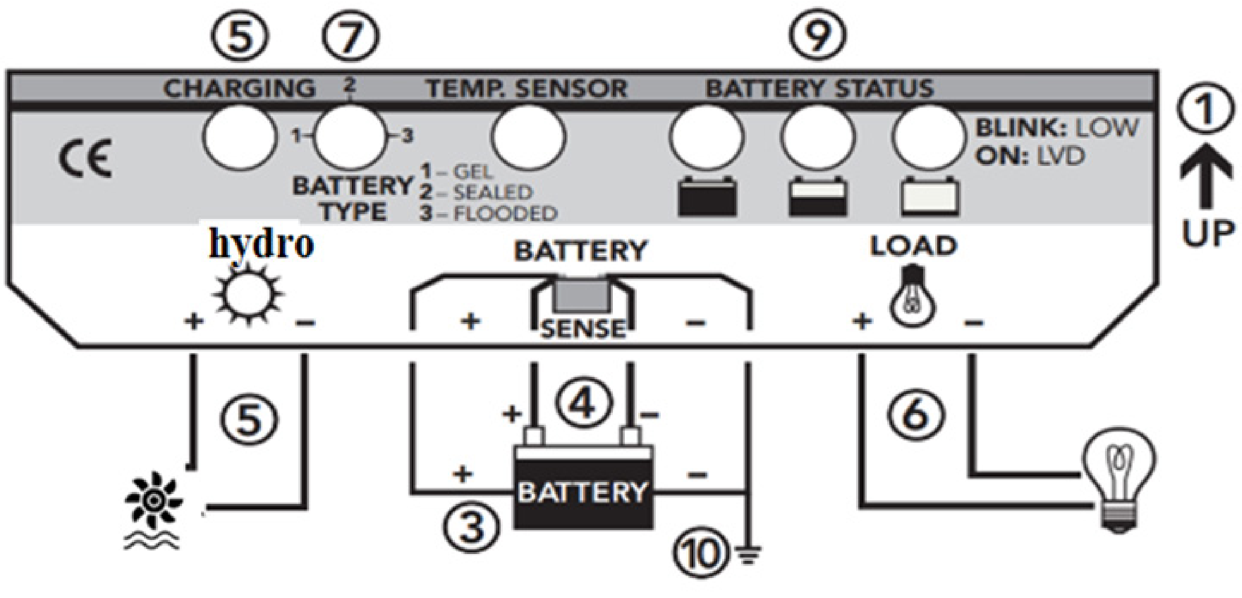
3.4 Charge Controller

While the term charge controller is also used in Solar PV systems, the charge controllers used in hydro power systems deal with much higher currents as compared to solar charge controllers. You must NEVER use an ordinary solar controller in a Pico-Hydro system. While solar charge controllers and hydro charge controllers are almost similar – they both deal with different magnitude of current. Larger charge controllers which can easily handle upwards of 50A of current need to be used.

The charge controller should:

- Have an adequate current capacity for both charging (amperes from hydro turbine) and for operating the loads (load current).
- Accommodate hydro input voltage and battery voltage.
- Have the peak DC power required for cumulative load.
- Be flexible to work with different battery types (flooded or sealed lead-acid battery).
- Be reliable - simple controllers are more reliable than complicated ones (avoid complex extra "features" such as LCD screens, micro-processor programmed control, etc.).

FIGURE 42: General schematic of a Charge controller[42]



42 Morning Star, June 2021, https://www.keoghsmarine.com.au/morningstar-prostar-solar-charge-controller-30a-12-or-24v-pwm-4-stage-charging-led-charge-indicators-sr-ps-30

3.5 Batteries

Batteries only store electricity and does NOT generate electricity:

- **Unit cell is 2V.**
  - 2V means nominal voltage. Voltage range is around 1.85V to 2.40V.
  - 12V battery has 6-unit cells in series connected.
  - 6V battery has 3-unit cells in series connected.
- **Material.**
  - Electrodes: Lead and Lead oxide.
  - Electrolyte: Diluted Sulfuric Acid.
- **Parallel connection sums capacity (Ah).**
- **Series connection sums voltage (V).**
- **Total energy storage remains the same (Wh).**
- **Do not mix different types, models, and age of batteries.**

The batteries are often the main component that fails in a pico- hydropower system.

FIGURE 43: Battery Specification[43]

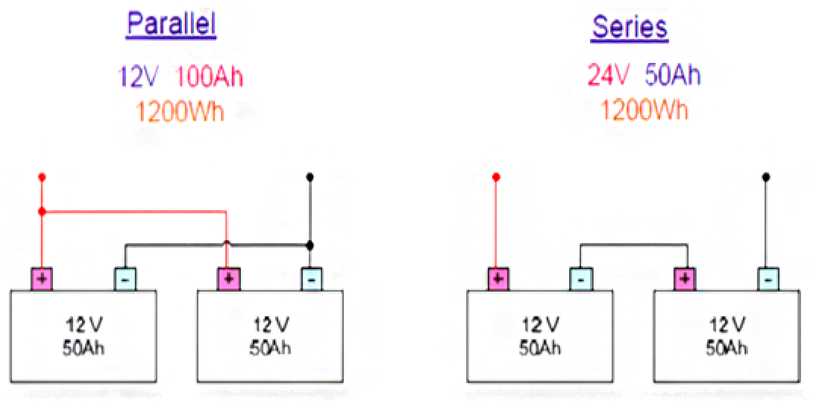
SPECIFICATIONS

Nominal Voltage		12 Volts	
Amp Hour Capacity		115 (C20)	90(C5)
Reserve Capacity Minutes		170 @ 25 Amperes	
Physical Characteristics	Length	13.13"	334 mm
	Width	6.75"	171 mm
	Height	9.38"	238 mm
	Wet Weight	58 Lbs	26.4 Kgs
Terminal Options		BCI Type M	

ELECTRICAL SPECIFICATIONS

Amp Hour Capacity	20 Hour Rate	5.75 A	115 Ah
	10 Hour Rate	10.30 A	103 Ah
	5 Hour Rate	18.00 A	90 Ah
	2 Hour Rate	33.50 A	67 Ah
Internal Resistance	80 F	27 C	7.6 mOhm
Capacity affected by Temperature (20 Ah Rate)	104 F	40 C	102%
	80 F	27 C	100%
	32 F	0 C	65%

FIGURE 44: Typical Battery Connection[44]



3.5.1 Some key points

- Parallel connection sums capacity (Ah).
- Series connection sums voltage (V).
- Total energy storage remains the same (Wh).
- DO NOT parallel more than 4 batteries, as this causes unequal battery charging and discharging, which can cause pre-mature battery failures).
- DO NOT mix different types, models, and age of batteries, as this can cause premature battery failures.
- Batteries must be mounted in a well-ventilated place and protected from sun and rain. Never place batteries inside the house. This is because batteries gradually vent small quantities of hydrogen gas which in an unventilated area could build up and explode. In addition, there is the potential to emit toxic hydrogen sulfide (smells like rotten eggs) in fault conditions.
- Battery charging equipment should be hard wired, do not use temporary connection.
- Battery terminals should be shrouded to prevent inadvertent short circuits.
- Ensure sufficient clearance between battery terminals and metal walls.

Use insulated tools during any battery work.

43 Source: Waveinverter, co.nz, https://waveinverter.co.nz/wp-content/uploads/2017/12/products-CR325-1.png

44 Adapted from "System Components, Batteries", Arizona State University (VOCTEC), http://voctec.asu.edu

3.6 Inverter

Table 1 shows some key features and specification of an inverter. Usually, inverters are single phase and 3 phase. In this study we will only focus on single phase 220-240V, 50Hz output and 12V input.

TABLE 3: Specification and feature of an Inverter

Specifications & Features	
Continuous Power Rating (300 Watts at 25ºC)	Total Harmonic Distortion (< 4%)
Peak Power Rating (600 Watts at 25ºC)	Low Voltage Disconnect (LVD) (11.5V or 10.5V)
DC Input Voltage (10.0V – 15.5V)	Low Voltage Reconnect (12.6V or 11.6 V)
Waveform (Pure sine wave)	LVD Warning Threshold (11.8V or 10.8V)
AC Output Voltage (220V or 115V +/- 10%)	LVD Delay Period (4 minutes)
AC Output Frequency (50 or 60 Hz +/- 10%)	High Voltage Disconnect (15.5V)
Peak Efficiency (92%)	High Voltage Reconnect (14.5 V)

FIGURE 45: Specification of an Inverter[45]

Item	PS-600JAR
Continuous power	600W
Surge power	1200W
Input voltage range	9.5-16V DC (rated power 12VDC)/ 19-30VDC (rated power 24VDC)
Output voltage	□ 115V / □ 120V / □ 220V / □ 230V / □ 240V ±10% (Be subjected to the rating)
Output frequency	□ 50Hz □ 60Hz
DC input	□ 12V □ 24V
Output wave form	Pure sine wave (THD≤3%)
Efficiency	90 %
USB output	5 VDC Max 2.4A
Input over-voltage shutdown	16VDC±0.5V
Input under-voltage shutdown	9.5VDC±0.5V
Input under-voltage alarm	9.8VDC±0.3V
Over temperature protection	65±5℃
Over-load protection	700W±100W
No Load currents	0.8A
Dimension (L×W×H)	213x140x74mm
Weight	1.67Kg
Working temperature	0~40℃
temperature	-10~45℃
Intelligent cooling	The cooling fan on the product will not run when start up the inverter, it will start running only when the case temperature reaches about 40℃

45 Source: Manual ZZ, Giandel PS-600JAR Power Inverter User Manual, https://manualzz.com/doc/52962368/giandel-ps-600jar-power-inverter-user-manual#:~:text=Item%20PS%2D600JAR%20Continuous%20power,wave%20(THD%E2%89%A43%25)

ACTIVITY 3

Your instructor will provide you two batteries. connect them in series and parallel. Measure the total voltage for each setup. DO NOT measure the current. Ensure to wear insulated gloves.

Battery (x2)

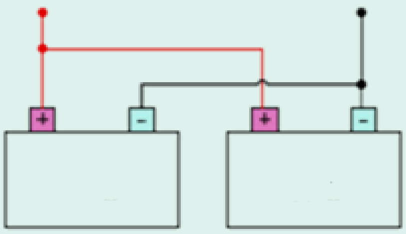
Cables

Multimeter

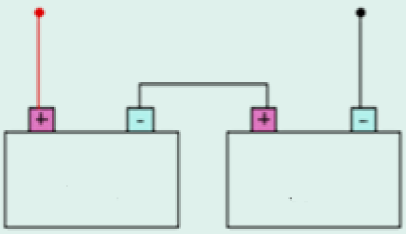
Answer

- Provide the learner with two 12V batteries.
- Provide the learner with Multimeter to measure voltage.
- The learner should connect the batteries as shown.

Parallel
12V 70Ah
840Wh



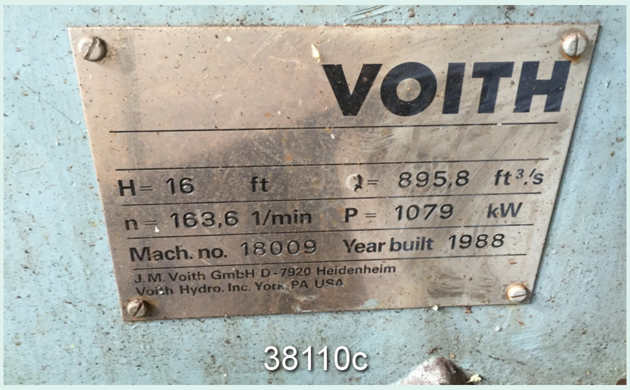
Series
24V 35Ah
840Wh



ACTIVITY 4

1- Provide the learner with all components discussed above (Hydro turbine, Controller, Battery, Inverter and 12 DC light with fixture. Ask learner to identify the name plate data (Specification & Features) on each component. The learner is expected to read/identify all information written on the components as per notes above.

2- For the name plate below what is the power output and required head of the turbine.



Answer: 1079kW and 16 ft.

An example of nameplate data for an inverter

Item	PS-600JAR
Continuous power	600W
Surge power	1200W
Input voltage range	9.5-16V DC (rated power 12VDC)/ 19-30VDC (rated power 24VDC)
Output voltage	☐ 115V / ☐ 120V / ☐ 220V / ☐ 230V / ☐ 240V ±10% (Be subjected to the rating)
Output frequency	☐ 50Hz ☐ 60Hz
DC input	☐ 12V ☐ 24V
Output wave form	Pure sine wave (THD≤3%)
Efficiency	90 %
USB output	5 VDC Max 2.4A
Input over-voltage shutdown	16VDC±0.5V
Input under-voltage shutdown	9.5VDC±0.5V
Input under-voltage alarm	9.8VDC±0.3V
Over temperature protection	65±5℃
Over-load protection	700W±100W
No Load currents	0.8A
Dimension (L×W×H)	213x140x74mm
Weight	1.67Kg
Working temperature	0~40℃
temperature	-10~45℃
Intelligent cooling	The cooling fan on the product will not run when start up the inverter, it will start running only when the case temperature reaches about 40℃

4

Types of Pico-Hydro Systems

There are four types of hydropower system. These are On-grid hydropower system; Standalone hydro (AC) power system; Standalone hydro (DC) power system and Hybrid hydropower system.

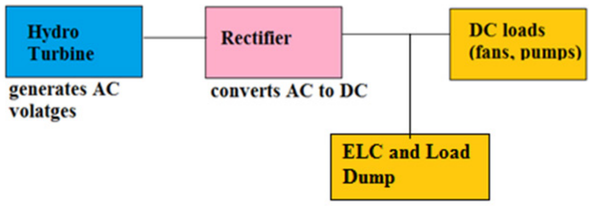
4.1 Standalone Pico Hydro (DC) power system

Stand-alone systems are not connected to the electricity grid and typically are installed in remote areas where there is limited connection to the grid, or areas of low electricity demand.

Unlike their grid-connected counterparts, these systems must have batteries to provide supply at times when the water levels are low. The available power is DC 12V typically, but other voltages such as 24V, 48V etc., are also used depending on size of systems. The biggest advantage of using batteries is the control of the turbine, and so generator speed is not so critical and the power coming out can be smoothed by rectifier and a battery. Additionally, solar based 12V lights and appliances can be easily used so there's no need of getting separate AC lights. Without a battery voltage regulation becomes a problem and shutdowns for maintenance can be a hassle.

4.1.1 Standalone Pico hydro (DC) power system without battery

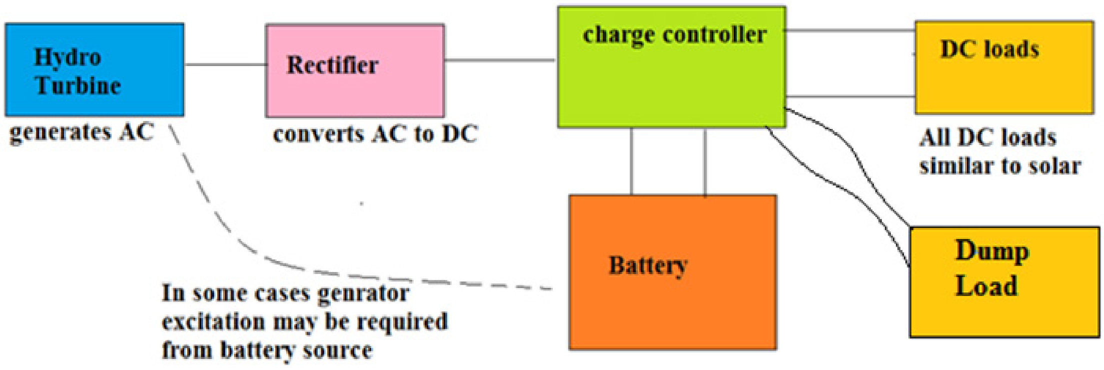
FIGURE 46: Typical DC system without battery[46]



- This specially designed system only works during peak water flow, as long as there is enough power being generated by the hydro system to supply the loads.
- DO NOT try to power loads directly from the hydro turbine as it can cause damage to the load. For direct load connection you may require the connection of an ELC together with dump loads. The dump loads ensure excess energy is converted to heat or other forms.

4.1.2 Standalone pico-hydro (DC) power system with battery

FIGURE 47: Typical standalone DC power system with battery[47]



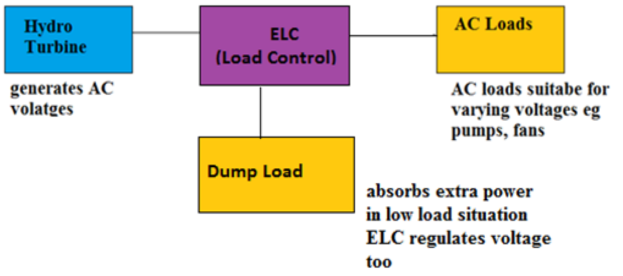
- Can have other DC loads like DC fans, mobile phone charging via USB port, etc.
- Mostly used for smaller home in rural areas that only require lighting and phone charging features and not heavy AC electrical appliances.
- Most DC generators have built in rectifiers.
- Some hydro charge.

46 Source: VOCTEC
47 Source: VOCTEC

4.1.3 Standalone pico-hydro AC power system – AC Direct system

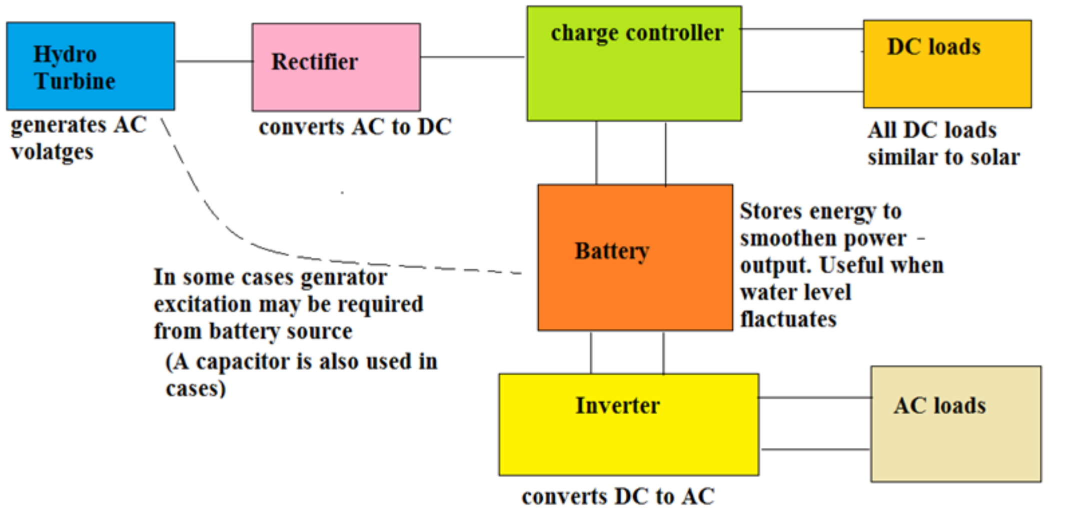
In standalone AC systems, the generator outputs AC voltage and is directly connected to AC loads. All generators develop AC voltage – however depending on the head and flow of water, the voltage output may not be smooth and can vary. This is the simplest system. In Pico-hydro, valve regulation may be manual only and hence the changing voltages may present hazards to equipment's. For this reason, this system requires an Electronic Load Control together with dump loads. A good constant flow of water through the turbine is required to assist in generating a constant amount of power and to work within the load controller parameters.

FIGURE 48: Standalone AC system[48]



4.1.4 Standalone hydro (DC+AC) power system with battery

FIGURE 49: Standalone hydro (DC+AC) power system with battery[49]



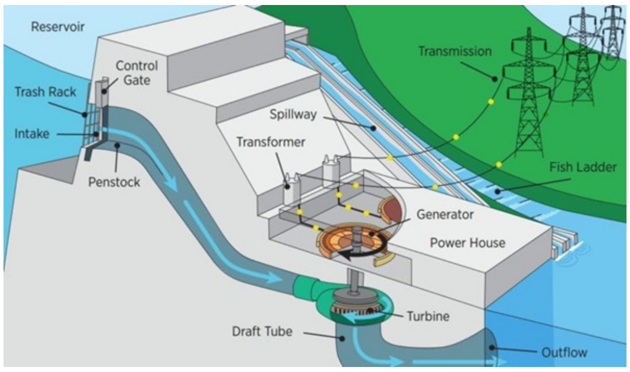
- Smooth power output even when water level is low.
- Same system as "DC load only", but has additional inverter to allow powering of AC loads also.
- DO NOT interchange AC and DC loads. DC loads MUST be powered by DC supply ONLY. **NEVER POWER DC LOADS WITH AC SUPPLY. There is GREAT RISK of equipment damage, serious injury or even death.**
- Mostly used for medium sized homes which has lighting, phone charging and small AC appliance needs.

48 Source: VOCTEC
49 Source: VOCTEC

4.2 On-grid Pico hydropower system

These types of systems are most common in areas where the grid infrastructure is suitable. Houses with grid-connect hydro systems use hydro power first before sourcing electricity from the grid, hence causing saving on the electricity bill. When the turbines are not producing electricity, electricity is provided from the electricity grid. This type of system is not used in rural communities, where either grid electricity is not available or to avoid complexity and instead keep a simple standalone system.

FIGURE 50: On-grid or grid connect setup[50]



ACTIVITY 5

Draw any 3 major types of hydropower systems and label each component.

Answer: The learner is expected to draw on-grid, standalone DC, Standalone AC+DC and Hybrid. Some of them may draw standalone system with batteries and without batteries. Emphasise that this is not a major type (Refer to diagrams in notes above). This falls under standalone DC or AC system.

Discuss in class which system you will prefer and why?

Answer: The learner most likely will prefer either Standalone DC or standalone AC/DC system. The most likely reasons will be the access or availability to use various AC and DC appliances. Expect many different answers.

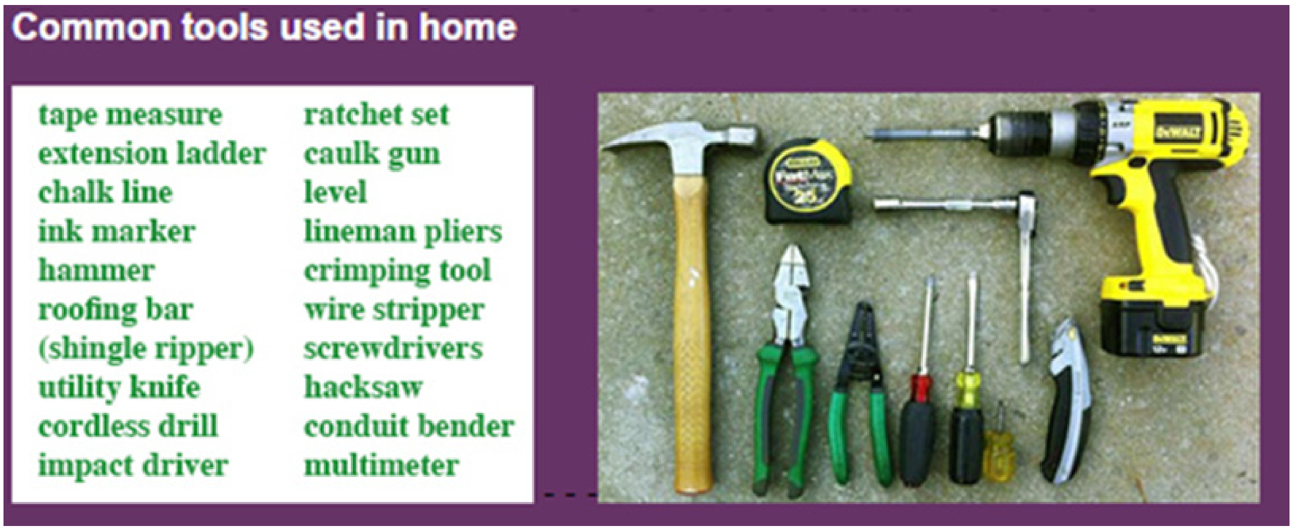
50 Source: National Hydropower Association, www.hydro.org

5

Tools used in Hydro Turbine System

These are common tools that are required in the installation of Hydro turbine system.

FIGURE 51: Common tools[51]



5.1 Specific Tools and its functions

Pictures of Tools	Names of these tools	Uses and functions of these tools
 52	Current of flow meters	Used to measure flow of water in streams and rivers.
 53	Socket spanner	Used to tighten flange bolts etc.
 54	Pipe Wrench	For plumbing works on penstock and valves and even turbine inlet nozzle.

51 Quora, "What type of tools and fasteners are required to install a solar panel", https://www.quora.com/What-type-of-tools-and-fasteners-are-required-to-install-a-solar-panel#!n=12

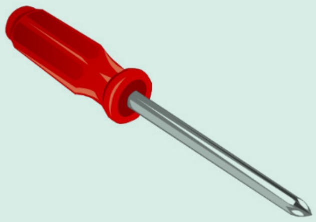
52 Source: RainmanWeather, Flowatch Flowmeter Station, https://www.rainmanweather.com/Flowatch-Flowmeter-Station, accessed 21 June 2021.

53 Source: MITRE10, https://www.mitre10.co.nz/shop/stanley-socket-set-36-piece/p/161418

54 Source: Monotaro.sg, https://www.monotaro.sg/p/57858342.html

 [55]	Pressure gauge	To measure pressure and head.
 [56]	Spade	Digging and setting up sediment weir or laying of penstock pipes.
 [57]	Clamp meter	Clamp meters measure any of these: AC current, AC and DC voltage, resistance, making them perfect for electrical work. Good for higher and easy current measurement.
 [58]	Multimeter	A typical Multimeter can measure voltage, current, and resistance. Has higher resolution. Current can only be measure if meter connected in series (without special adapters).
 [59]	Thread Sealant tape	Useful to apply to threaded connectors to seal off water.
 [60]	PVC glue or PVC cement	While not really a tool – it sis useful in creating joints in PVC pipes.

55 Source: Barista Warehouse.com.au, https://baristawarehouse.com.au/products/3m-water-filter-head-pressure-gauge-for-nephead, accessed 21 June 2021.
56 Source: Cashbuild, "Flat spade", https://www.cashbuild.co.za/shop/spade/4460-flat-spade.html
57 Source: Jim Dunlop Solar
58 Morning Star, June 2021, https://www.keoghsmarine.com.au/morningstar-prostar-solar-charge-controller-30a-12-or-24v-pwm-4-stage-charging-led-charge-indicators-sr-ps-30
59 Source: The Tool Shed, "Toolshed Thread Seal Tape", https://www.thetoolshed.co.nz/product/15623-toolshed-thread-seal-tape-12mm-x-10m?categoryId=2176
60 Source: Magpow, "PVC glue", http://www.magicglue.net/UploadFile/prol20108519304880607.jpg

 61	Clear flexible hose	Useful to measure head at locations.
 62	Wood Saw	Cutting timber for creating turbine mounting or housing structure.
 63	Hack Saw	Cutting up plastic pipes and connectors.
 64	Slotted or Flat screwdriver	Open screws.
 65	Philips Screwdriver	Open screws.
 66	Retractable 100m tape	For measurements of locations – even head measurement can be approximated.

61 Source: Green Chapter, "Air Tube", https://green-chapter-shop.myshopify.com/collections/gush/products/air-tube-per-meter

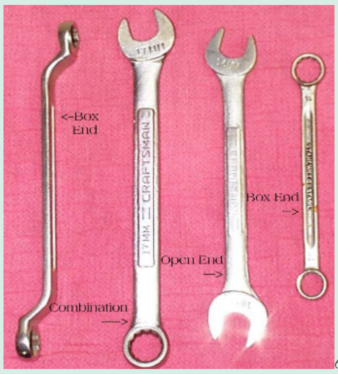
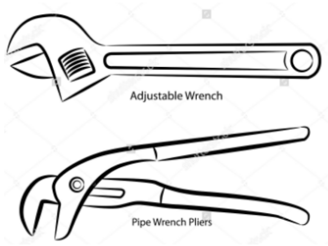
62 Source: ofwoodworking "Hand saw", https://i.pinimg.com/originals/b6/6b/1f/b66b1feee175c25ebebe05cfd855c520.jp

63 Frakem Blog, "Hacksaw", https://www.frakem.com/blog/wp-content/uploads/2016/06/hacksaw.jpg

64 Source: Galco, www.galco.com

65 Source: Conceptdraw.com, "Manufacturing and Maintenance", https://www.conceptdraw.com/examples/diagram-of-screwdriver-and-its-specific-use-in-maintenance

66 Source: Amazon.com, "Retractable 100m tape", https://www.amazon.com/EMI-Body-Tape-Measure-Pieces/dp/B00ELV1QMK?th=1

 [67]	Offset Box wrench, Combination wrench, Open end wrench and Normal box wrench	These are tool used to provide grip and mechanical advantage in applying torque to turn objects—usually rotary fasteners, such as nuts and bolts—or keep them from turning.
 [68]	Adjustable wrench Pipe wrench pliers	These are tool used to provide grip and mechanical advantage in applying torque to turn objects—usually rotary fasteners, such as nuts and bolts—or keep them from turning.
 [69]	Lineman Pliers	Linesman pliers are a type of pliers used by electricians and other tradesmen primarily for gripping, twisting, bending and cutting wire and cable.
 [70]	Needle Nose Pliers	are both cutting and holding pliers used electricians, and other tradesmen to bend, re-position and snip wire.

These are different types of screw heads that hydro instillation technicians may can come across. Each head has a specific screwdriver.

67 Mechanical Engineering, https://mechanical-engg.com/gallery/image/2209-wrench-typesjpg/
68 Source: Pinterest.com, "Different types of wrenches", https://www.pinterest.com/pin/147352219031480866/
69 Source: AmPro, https://ampro.fr/en/shop/pliers/wire-cutting-pliers/71-2-high-leverage-diagonal-pliers/
70 Source: DORNO, Rubber Grip Long-Nose Pliers, https://www.olo-7.top/products.aspx?cname=rubber+needle+nose+pliers&cid=40

FIGURE 52: Different screws with different heads[71]

Handling and carrying tools are also very vital in hydro turbine system. The following methods can be used to carry tools.

FIGURE 53: Ways to carry tools[72]

FIGURE 54: A-frame ladder[73]

5.1.1 Ladders for house wiring

- **Step Ladder (A-frame) -** Step ladders are versatile free-standing ladders. Step ladders are designed to be used in the fully 'open' position. Step ladders are not designed to be used to gain access to ceilings. Step ladders should never be used in the folded position leaned up against a wall or other structure.

71 Source: Mechanical Booster, "Screwdriver types", https://www.mechanicalbooster.com/wp-content/uploads/2018/05/screwdriver-types.jpg?ezimgfmt=ng:webp/ngcb20

72 Source: Pinterest.com, https://www.pinterest.com/bambulancemania/work-apparal/

73 Source: Total Tools, https://www.totaltools.com.au/2-4-4-0m-extension-ladder

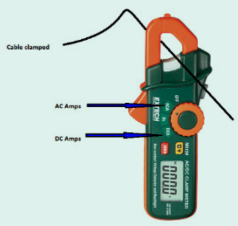
FIGURE 55: Platform Ladder[74]

- **Platform ladder –** is similar to A-frame step ladder however it provides safe working environment. It provides a better platform to step and work on. It also has some sort of rail or barrier which provides bit of fall protection.

ACTIVITY 6

Your trainer will supply you with an inverter and battery. This activity is for you to learn how an inverter can be used to power dc devices. Use an inverter and battery to light a bulb or run a fan. Use the meter to measure current in a cable.

Clamp meter



Battery

Charge Controller

Inverter

Light Bulb

Answer

- Provide learners with a battery, charge controller, inverter and AC light bulb.
- Ensure inverter power is off. The learner should then connect the inverter to the battery.
- The learner should then connect the AC lead from the light to the inverter power socket.
- Then turn on the inverter. The light should come on if connections are done correctly.

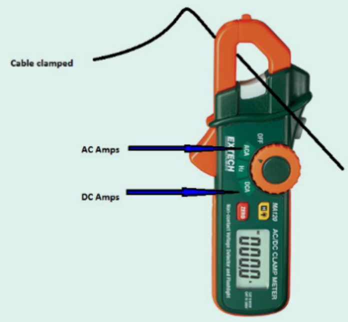
74 Source: Bunnings.com, "Bailey Ladders", https://www.bunnings.com.au/bailey-0-9m-150kg-fibreglass-platform-ladder_p0860918

SAFETY: Ensure that AC bulb is connected with lead wire and male-socket plug wired by an electrician.

Typical diagram for connection

- Now get a clamp meter and change measuring knob to symbol ACA to measure power for AC light or Fan. Open the jaw of the clamp meter as shown below. Read the value on the screen. This is the current used by light bulb. Figure below shows the measurement position and how clamp should be connected.
- Now remove the clamp and change the knob to DCA to measure current flowing from Battery to Inverter.

Position of measuring knob currently on ACA



ALTERNATIVELY – YOU CAN ONLY CONNECT BATTERY + INVERTER + AC LIGHT BULB and measure the current consumed by AC light bulb.

6

Installing Hydro turbine systems

6.1 Preparing for installation

Before you start installation, you must plan the installation and gather all the required material before proceeding. Clearly decide the type of system and connection that will be done and also foresee any safety issues that may arise. Be equipped with the required PPE before you start hydro installations.

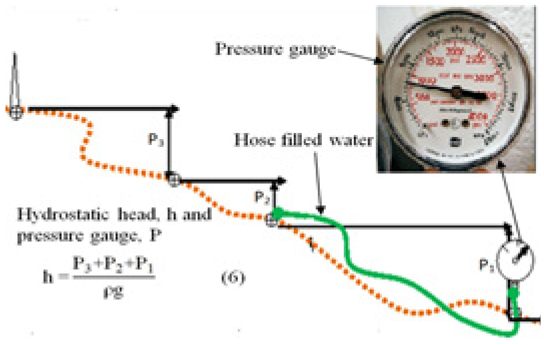
6.2 Preparing the Forebay and penstock

Firstly, the stream location needs to be selected to match the head and flow on your turbine. Measure the head. Here are the steps to measure the head:

Step 1: Take a flexible pipe to the upstream water location. The other end of the pipe must be at the possible turbine location. Fix a pressure gauge at the end where the turbine will be located.

Step 2: Fill the hose pipe with water until it cannot be filled anymore. Read the gauge. This can be approximated as the head pressure.

FIGURE 56: Measuring head[75]



Step 3: We will avoid any formula. You can read the head using this table below.

Height of Water Column		Pressure			
(m)	(ft)	(kPa)	(bar)	(atm)	(psi)
1	3.28	9.81	0.098	0.097	1.42
2	6.56	19.6	0.196	0.194	2.85
3	9.84	29.4	0.294	0.290	4.27
4	13.1	39.2	0.392	0.387	5.69
5	16.4	49.1	0.491	0.484	7.11
6	19.7	58.9	0.589	0.581	8.54
7	23.0	68.7	0.687	0.678	10.0
8	26.2	78.5	0.785	0.775	11.4
9	29.5	88.3	0.883	0.871	12.8
10	32.8	98.1	0.981	0.968	14.2
12	39.4	118	1.18	1.16	17.1
14	45.9	137	1.37	1.36	19.9
16	52.5	157	1.57	1.55	22.8
18	59.0	177	1.77	1.74	25.6
20	65.6	196	1.96	1.94	28.5

Once you find a location upstream which is what your turbine requires on the nameplate, you can start building a sediment weir and place your filter to create the Forebay.

75 Adapted from Water Utility Journal, "Measurement methods for hydropower resources: a review, 2018, http://www.ewra.net/wuj/pdf/WUJ_2018_18_03.pdf

6.3 Forebay

Clear the location and create a small weir or dam using the sediment and rocks or wood. This will increase the head and also allow bulk of water to be filtered and directed towards the turbine. If you have the resources, the forebay dam can be made from concrete as well.

FIGURE 57: Concrete Forebay[76]

Following the forebay dam, the gauze filter must be installed so that the water gets filtered.

FIGURE 58: Intake full screen filter[77]

FIGURE 59: Filter installed with penstock outlet at bottom[78]

6.4 Penstock

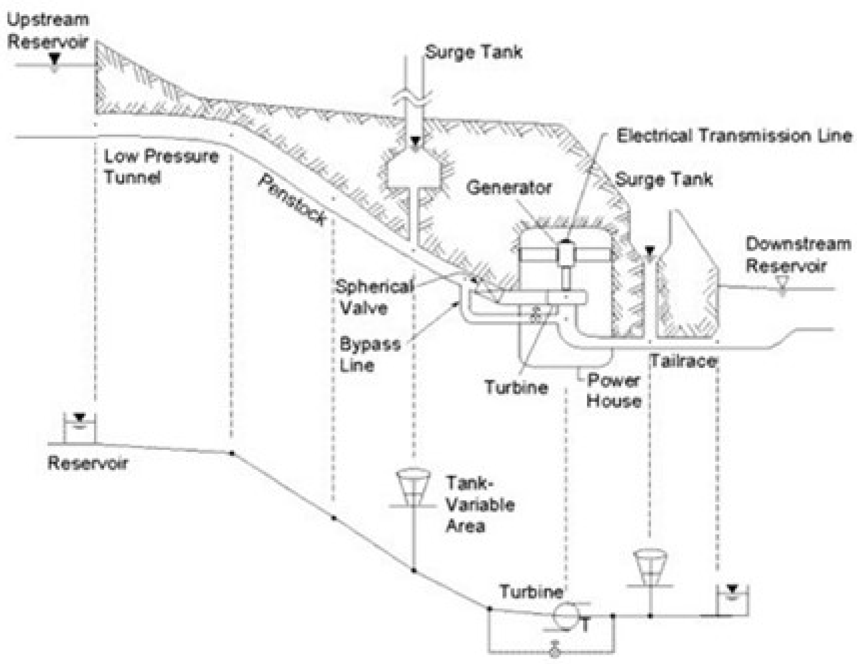
The penstock carries water from the forebay to the turbine location. Connect the penstock at the turbine end first and close the turbine inlet valve. Run the pipe up to the forebay filter and connect the pipe to the forebay. Do not open the valve unless all the installations have been done. The following valve configuration can be used. The upstream valve is optional for changing penstock lines.

76 Source: WISIONS of sustainability, SEPs Energy Projects, https://www.wisions.net/img/pictures/SLP006_2.png

77 Source: Power Spout, www.powerspout.com

78 Source: Waterpower &Dam Construction, "Pico-Hydro", https://www.waterpowermagazine.com/uploads/newsarticle/6798305/images/496422/large/l%20pico%20hydro.jpg

FIGURE 60: Penstock valve arrangements[79]

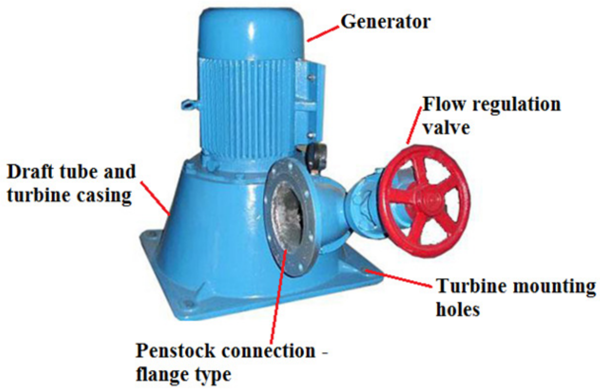


6.5 Turbine and Generator

FIGURE 61: Penstock pipe Turbine and generator[80]

Most Pico-hydro kits come with the turbine and generator connected together. It is often easy to connect the right sized penstock directly to the turbine casing. Most turbines depending on their type will require a mounting.

FIGURE 62: A sample Pico hydro turbine[81]



In the figure above, the penstock connects to the inlet flange. There are different types of connectors for different designs of turbines. Some types of Pico hydro turbines need a clearance below them for water to exit without disturbances.

79 Source: Bentley Communities, https://communities.bentley.com/products/hydraulics___hydrology/f/haestad-hydraulics-and-_hydrology-forum/171943/modeling-water-hammer-protection-with-a-synchronous-bypass-valve

80 Source: https://throughtheluminarylens.wordpress.com/

81 Source: https://www.micro-hydro-power.com

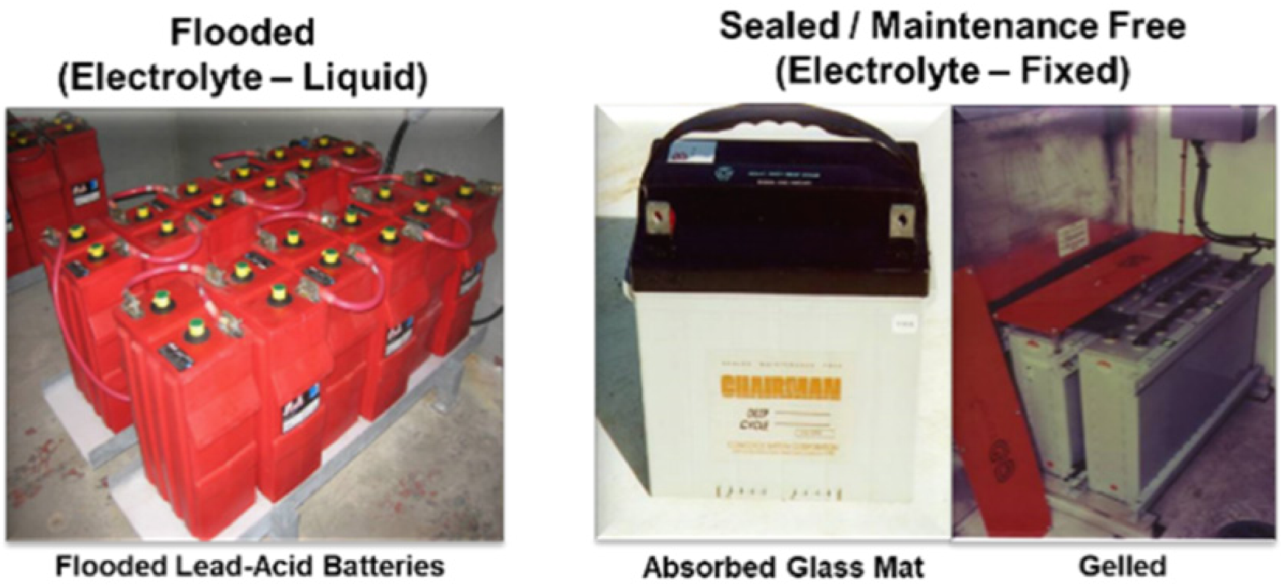
FIGURE 63: A Pico hydro turbine mounted on timber frames[82]

Ensure that if the wires connected from the generator to the house, are more than 30m, you must account for voltage drops. It is best to reduce the distances of cabling where possible.

6.6 Battery

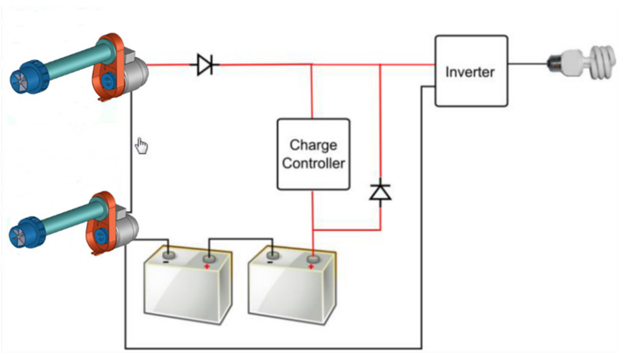
Batteries are used to store energy for use later especially when the water level in the stream fluctuates. Batteries can also provide a way to smoothen the power output of the hydro turbine generator. They are commonly constructed using lead and lead oxide electrodes and contains diluted sulfuric acid inside. Other types of batteries are also available, such as lithium ion and nickel-cadmium.

FIGURE 64: Battery types[28]



In case batteries are used in the hydropower systems, you will need to include a charge controller which can cater for the current from the generator. Unlike wind and solar, hydro power is steady and in case of purely AC on grid systems or even off grid systems – batteries are not needed. However, these are more complex systems where a voltage regulator is needed to maintain a steady voltage between 230-240 VAC.

FIGURE 65: Typical off grid Pico Hydro connection[83]



82 Source: Baylor University, adapted from Wikipedia, "Pico Hydro", https://en.wikipedia.org/wiki/Pico_hydro

83 Source: http://www.unido.or.jp/

7

Safety Requirements of Hydro Turbine Systems

Safety is of utmost importance in a Hydro turbine installation or maintenance exercise. There are numerous health hazards that can be present in Hydro Turbine Systems. While the mechanical generation system present moderate risks, the greater risk comes from the electrical systems.

Here are some general safety rules that you must abide by during hydro turbine installation or repair. As trained technicians you must have been told about safety rules in electrical or mechanical systems and you must follow all safety rules that apply. You must note that your safety is the most important thing, and you must not attempt to do any work where you know your safety is compromised.

7.1 Safety Rules to follow

FIGURE 66: Common Personal Protective Equipment (PPE)[84]

1. Always notify owners of the household and turn the power off, before making any new or additional connections or adjustments. Never attempt to work on a circuit which is still active with power. The amount of current that will flow is determined by voltage and resistance in the circuit. If current greater than 20mA passes through a body, it can cause serious damage. Always check the voltage between any conductor and any other wires, and to ground. Use insulated tools and avoid short circuits that may cause sparks.

FIGURE 67: Safety sign[85]

84 Source: "Personal protection equipment", http://www.mnltap.umn.edu/

85 Source: AviationPros, https://www.aviationpros.com/tools-equipment/safety-equipment/article/11148860/ground-handling- safety-signs

2. Always ensure you conduct installation or repair on circuits for which you have training. Do not attempt to modify hydro turbine systems unless you understand the system properly.

FIGURE 68: A technician at work[86]

3. Always wear PPE (personnel protective equipment) such as insulted gloves, eye goggles and safety footwear. Never touch live exposed wires even with insulated gloves.

4. Never attempt to repair faulty batteries on your own. Batteries contain dangerous chemicals which can cause serious harm. When working with batteries and filling the electrolyte an impermeable apron, glove and goggle must be used. An eye wash of clean water must also be available.

FIGURE 69: Safety sign[87]

5. Never store batteries near a fire or inside living rooms – as batteries can give of toxic gases even if we do not see this. In particular, lead acid batteries give of small quantities of hydrogen which in high enough concentrations can be explosive. Lead acid batteries can also give off Sulphur dioxide or toxic hydrogen sulfide if over charged or battery is damaged or in poor condition. Hydrogen sulfide is notable from smell of rotten eggs and is toxic.

FIGURE 70: Safety sign[88]

6. Never store batteries in confined spaces or near fuels as they can cause a fire from sparks. Always place batteries in well ventilated areas.

FIGURE 71: Safety sign[89]

7. Always work in pairs, especially if carrying out routine checks on hydro turbine penstock and forebay. The streams powering hydro turbines have fast flowing water and are deep in many places. There is always a risk of drowning. The slopes on which penstocks are mounted are often steep and slippery and you must ensure care when climbing slopes especially while carrying equipment.

86 Source: Safety workblog.com, https://safetyworkblog.com/assets/understanding-the-2015-edition-of-nfpa-70e-the-arc-flash- hazard.jpg
87 Source: MSDS online, https://www.msdsonline.com/2014/07/22/sulfuric-acid-safety-tips-sulfuric-acid-msds-information/
88 Source: National Safety Signs, https://nationalsafetysigns.com.au/wp-content/uploads/2020/02/D10332-Toxic-Fumes-sign.png
89 Source: Wriggles Worth Enterprises, "Lithium-ion batteries", https://www.wrigglesworthenterprises.com/post/lithium-ion-batteries

FIGURE 72: Drowning risk exists in most streams[90]

8. Note that a hydro turbine starts generating electricity as soon as the turbine rotates. Ensure not to touch the wires at any time or attempt to accidentally connect wires while rotating the turbine shaft.

FIGURE 73: Safety sign[91]

9. Hydro turbines are often placed in streams and near streams where flash flooding can take place in rainy seasons. Avoid making repairs in rainy weather and keep a look out for flash floods.

FIGURE 74: Safety sign[92]

10. Practice safety while lifting heavy products and ensure you use every tool as per instruction. Hydro turbine components can be heavy and improper lifting can cause injuries.

FIGURE 75: Ensure you lift from your knees and not your back[93]

90 Source: Shutterstock, https://image.shutterstock.com/image-photo/stock-vector-beware-of-drowning-sign-isolated-on-white-background-triangle-warning-symbol-simple-flat--vector-450w-1488476456.jpg

91 Source: Seton.co (Signs, Labels & Solutions for a Safer Workplace), https://www.seton.co.uk/danger-death-hazard-warning-signs- with-upgrades.html#HZ150A3DSDH

92 WataugaDemocrat.com, "Floodway warning", https://www.wataugademocrat.com/flood-warning-sign/image_caa15320-900a-5e5a- b5aa-c93b53efcdd9.html

93 Source: https://www.espinosafamilychiropractic.com/

ACTIVITY 7

Part A:

Ask the learners to get into groups and imagine they have to a hydro turbine with 12V batteries including a 20A charge controller, 2 x Dc lights and 1 x 100W inverter with one single AC light bulb as a load. (We will not really build this system).

The learners are required to first discuss all the safety precautions that they need to take while making this installation. Let them discuss orally or even write it down. Also ask them how they will go about installing the system. After this help them install a DC and AC Standalone system using the VOTEC Kit.

Answer: The safety rules are given in the notes above (rules 1 – 10)

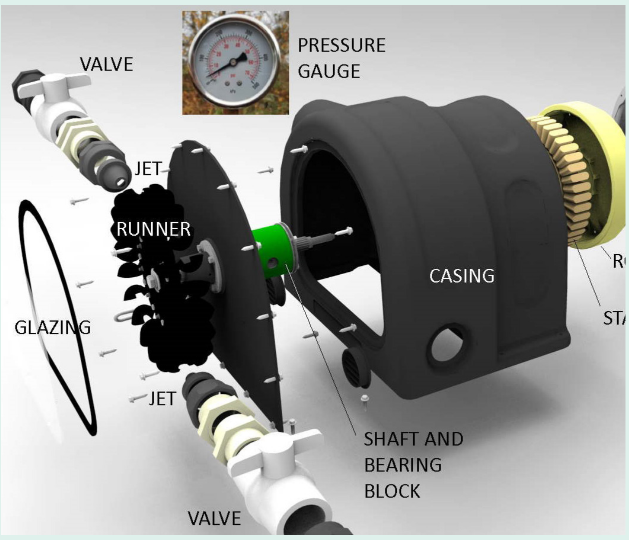
1. Always turn the power off before making and additional connections or adjustments. Never attempt to work on a circuit which is still active with power. The amount of current that will flow is determined by voltage and resistance in the circuit. If current greater than 20mA passes through a body, it can cause serious damage. Always check the voltage between any conductor and any other wires, and to ground. Use insulated tools and avoid short circuits that may cause sparks.
2. Always ensure you conduct installation or repair on circuits for which you have training. Do not attempt to modify hydro turbine systems unless you understand the system properly.
3. Always wear PPE (personnel protective equipment) such as insulted gloves, eye goggles and safety footwear. Never touch live exposed wires even with insulated gloves.
4. Never attempt to repair faulty batteries on your own. Batteries contain dangerous chemicals which can cause serious harm.
5. Never store batteries near a fire or inside living rooms – some batteries give of toxic gases even if we do not see this.
6. Never store batteries in confined spaces or near fuels as they can cause a fire from sparks. Always place batteries in well ventilated areas.
7. Always work in pairs, especially if carrying out routine checks on hydro turbine penstock and forebay. The streams powering hydro turbines have fast flowing water and are deep in many places. There is always a risk of drowning. The slopes on which penstocks are mounted are often steep and slippery and you must ensure care when climbing slopes especially while carrying equipment.
8. Note that a hydro turbine starts generating electricity as soon as the turbine rotates. Ensure not to touch the wires at any time or attempt to accidentally connect wires while rotating the turbine shaft.
9. Hydro turbines are often placed in streams and near streams where flash flooding can take place in rainy seasons. Avoid making repairs in rainy weather and keep a look out for flash floods.
10. Practice safety while lifting heavy products and ensure you use every tool as per instruction. Hydro turbine components can be heavy and improper lifting can cause injuries.

Part B: Installation

You must have the following items to start this activity.

- 1 Jet and 1 valve (2" BSP standard - NPT optional)
- A mid-range oil filled pressure gauge
- Manual grease fitting as standard
- 2m of 4mm2 tinned PV wire for +/-/earth
- 2 x MC4 cable connectors
- 4 x Tek screw fixing kit
- 4 spare jet inserts
- Rotor packing set kit included if we consider them likely to be required

The following is the exploded view of the PS PLT Turbine which you will be assembling in a mock installation.



Exploded view of the PS PLT turbine setup

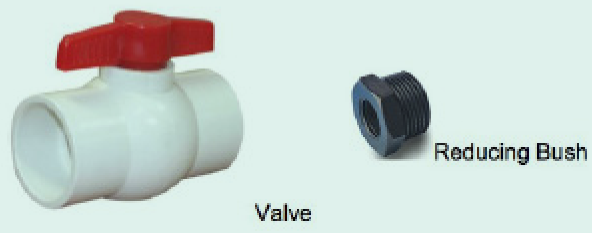
Before you begin the installation, please note the following safety precautions:

- Some turbines produce lethal voltages, especially when over speeding, so you must avoid contact with any wiring whether direct or indirect.
- Before connecting your turbine to any charge controller or inverter you must check the open circuit voltage, or you risk destroying the electronic device.
- The installation shall be carried out under supervision of installers with recognized and approved qualifications, and experience relating to general electrical installations and micro-generators.
- DC voltage from turbines is volatile and can reach three times higher than the rated operating voltage under some conditions. Controllers and inverters contain capacitors that can store and deliver lethal voltages through wiring.
- Loose connections can cause electric arcs to occur that could ignite flammable materials. Tighten all electrical connections inside the turbine very securely during installation.
- PLT turbines have quick release toggle latches. The toggle latches are intended for commissioning and jet optimization. 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.

Piping Connections

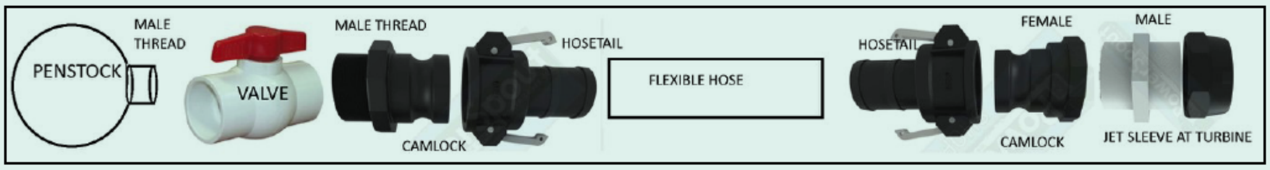
1. Connecting the valve end

The valve is used to regulate the flow of water to the turbine runner. Mount the pressure gauge immediately before the valve as shown. You will need a reducing bush to connect the piping to the valve.



2. Connecting the penstock flow to valve line

A camlock is provided to allow quick release fitting of a flexible 50mm pipe from the penstock to the turbine port. The connection schematic is given below. The diagram below shows the sequence of connections between the penstock (supply pipe) and turbine. You can use one of our pipe saddles to provide a male thread on the penstock and mount the valve on that, followed by the camlock-hose-camlock sequence, leading to the jet sleeve on the turbine.



3. Connecting the Jet to the turbine

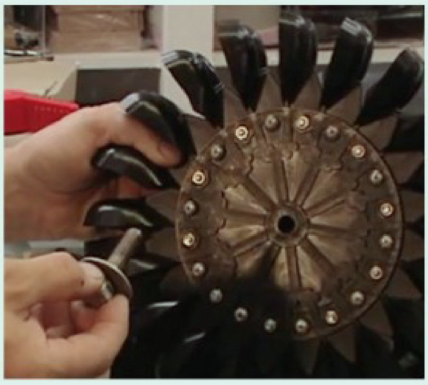
Use the following diagram as a sequence of connection at the jet sleeve end. This end connects to the turbine intake. Grease threads liberally. Tighten the valve or camlock onto jet sleeve outer end with a wrench, but not too tight as to displace the O-ring seal. Jet cap should only be hand-tightened, to retain jet insert on the inner end. But take care it does not fall off and get washed away.

4. Sizing the Jet nozzle holes

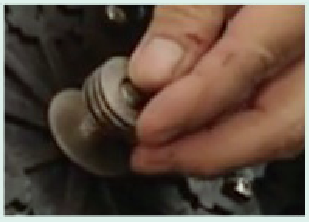
This is a trial-and-error method where we can cut open the nozzle opening of the jet inserts until a suitable flow is reached. There are four spare jet inserts, but we will use only 1. Be careful when using the cutter.

5. Setting up the turbine rotor

The wet side rotor, or "runner" is fitted to the "wet end" of the shaft. Take care that the runner is the right way around to spin clockwise as shown. Fit the spring washer and one large "flange washer" washer to the M12 bolt and insert it. Fit second large "flange washer" and some smaller "shim washers" as supplied at the back. Tighten the bolt to 50 Nm torque or "very tight". The runner may be damaged if it slips.



The shim washers set the correct position of the runner relative to the jets.

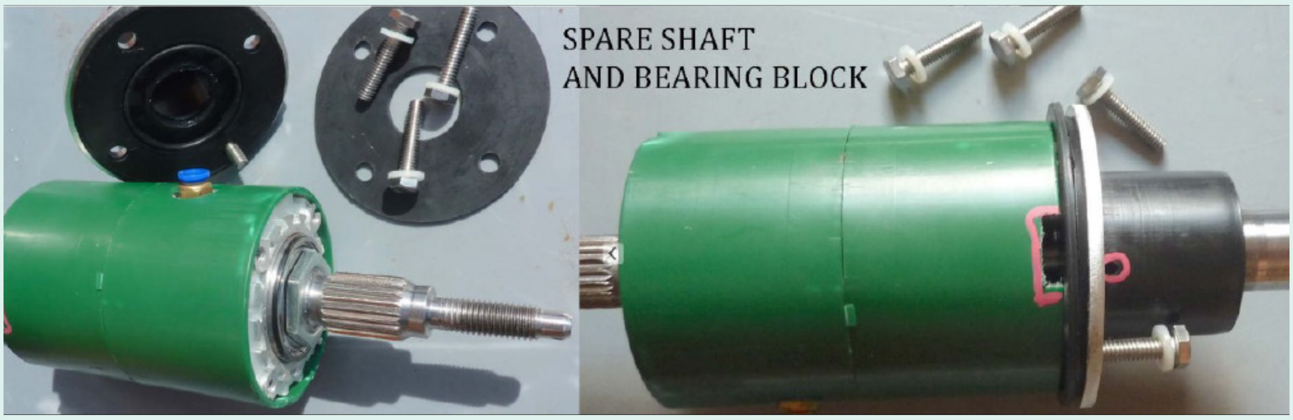


6. Alignment of runner

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.

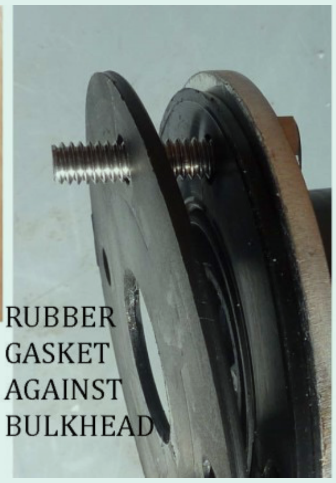
7. Setting up the shaft and bearing assembly

You need to remove and refit the shaft and bearing block assembly in order to change the bearings. Lets see how to fit in the bearing block.

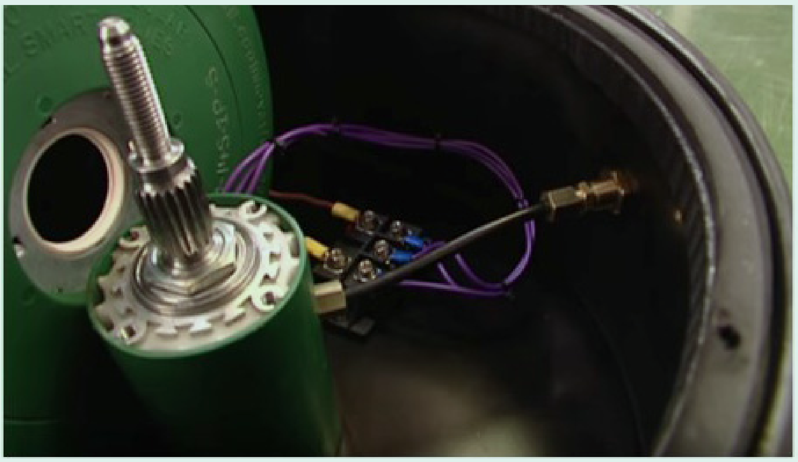


Coming from the "dry side", push the shaft through the bulkhead hole. Make sure that the drainage notch (outlined with pink pen above) is on the underside. Fit the rubber gasket and the top hat assembly (liberally greasing the gasket and seal) over the protruding end of the shaft.

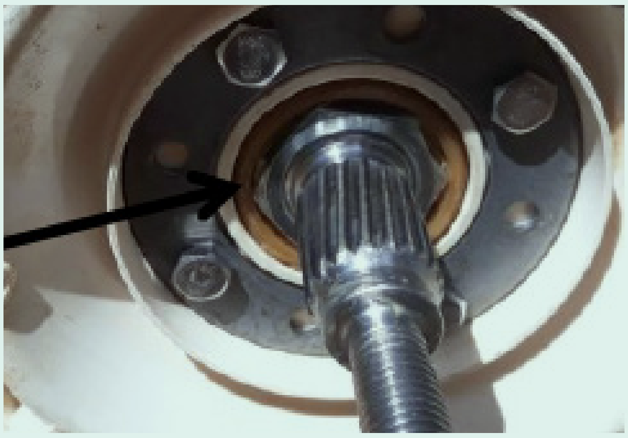
TOP HAT ASSEMBLY



Rotate the top hat until the drain hole is also at the bottom. Use a screwdriver to align holes in all the parts, and then fit the first 1/4-inch screw. Fit the other three screws and tighten evenly with a 7/16" or 11mm socket wrench. Tighten to 5Nm (4 ftlb). Do not over-tighten as this may damage the rubber and cause leakage. Connect the grease hose to the bearing block. Greasing is important for long life of the bearings.



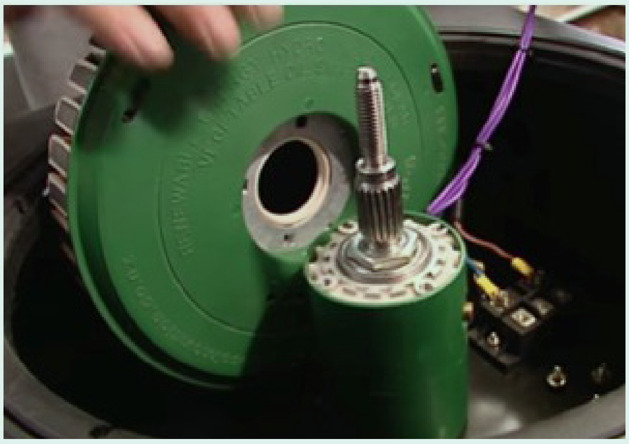
Sealed bearings do need to be re-greased at times, because hydro turbines run 24/7 and see very high cycle rates. The PowerSpout is provided with a re-greasing nipple so this can be easily done. Do this with the shaft spinning (driven either by water power or using a cordless drill with a 19mm socket attachment).

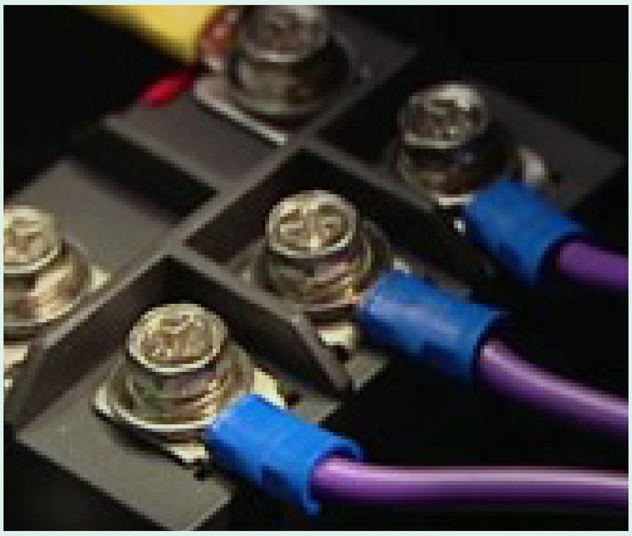


Pump into the bearing block about 40 ml of grease when first commissioning (see image above). This is normally about 40-60 pumps of a domestic type of grease gun. Grease the bearings with the magnetic rotor removed. Once you see grease on the dust shield you can stop. (Perform any checks of output voltage before doing this. as the grease will affect the maximum off-load speed.)

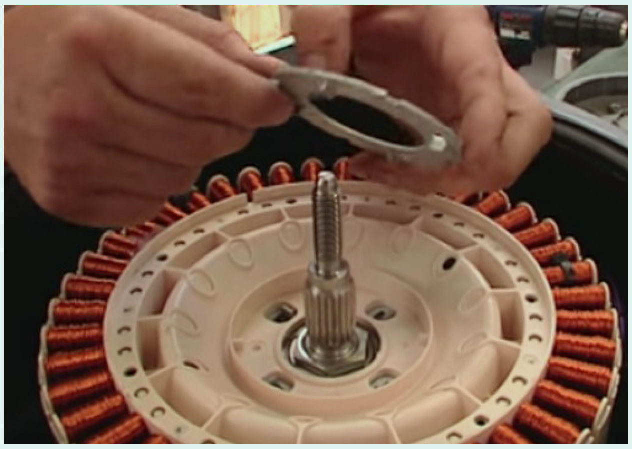
8. Setting up the Generator

Before mounting the stator to the PLT turbine, you must connect the three wires to the rectifier that is mounted on the bulkhead behind it. (Also connect the grease hose to the bearing block.)



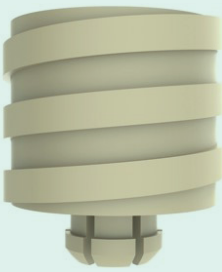


Place the stator on the "dry end" of the bearing block. Place the large galvanized washer on top (with its tabs downward). Rotate the stator on the bearing block, to gently wind the wires around the block loosely, so that there is not enough slack to possibly contact the moving rotor. Snuggly tighten the four machine screws that hold it down, using an 11mm socket spanner (7/16" wrench).



9. Inserting the Extractor knob and Rotor

The extractor knob is a separate part that must be popped into the hole in the magnetic rotor (by pressing hard) prior to assembly. Its function is to make it easy to slide the rotor on and off the shaft despite the strong magnetic forces that pull it toward the stator.



Grease the mating splines. Place the rotor on the "dry end" of the shaft and rotate it gently (whilst holding the runner at the wet end) until the spline engages and it locks on.

Rotate the knob clockwise to install the rotor. Keep going until it stops. Finger tight is fine.

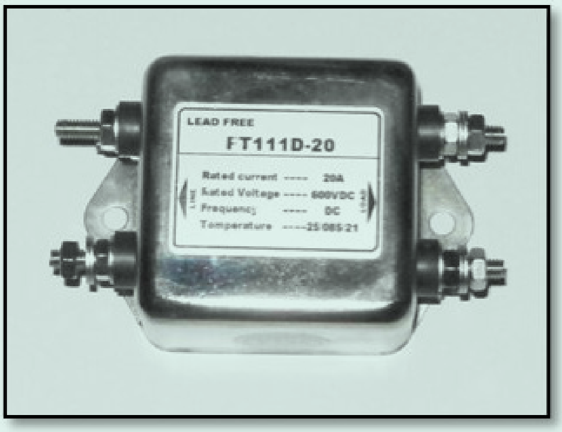
To remove the rotor simply reverse this process, turning the knob to the left, or (instead) hold the knob tight and spin the rotor to the right to pull it free of the stator. Spin the assembled magnet rotor to check that it moves freely. It is normal for it to make a soft whine and slow down in a couple of seconds to a halt.

10. Connecting the 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.

RECTIFIER

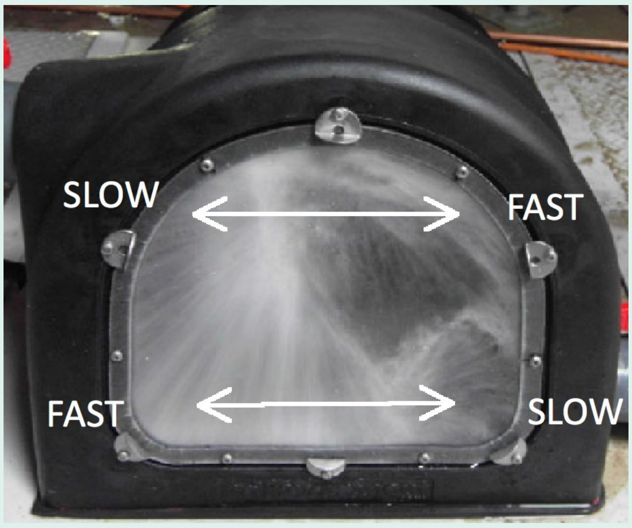
EMC FILTER



Warning:
Do not operate the turbine connected to any MPPT controller or Grid-tie inverter without first checking and adjusting the open circuit voltage (Voc)! If the voltage is too high, then your controller or inverter will be destroyed.

11. Running the turbine and connecting its output

When the valves are fully open, check and record the operating water pressure and the output current. If using flexible manifold pipes, then adjust the pipe supports to fine-tune the jet alignment (to maximize the speed/power). Normally the output will equal or slightly exceed the value on the identification plate. But you may need to optimize the RPM first. Check the appearance of the spray pattern striking the clear plastic glazing to see if the water coming off the pelton runner is thrown to left or right. This will tell you whether the RPM is too slow or too fast. The photo below shows the direction the spray will be thrown for each case. To slow is where the water is thrown back toward the jet. Too fast is where the water is thrown away from the jet.

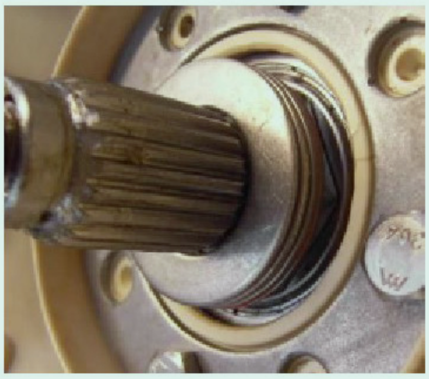


The output can be estimated using the following table. Ensure to connect the turbine output to a charge controller and battery before connecting to your devices to avoid power surges.

Head range	Operating rpm	Runaway rpm	Comment
0-25 m	0-800 rpm	0-1600 rpm	Can be allowed to run unloaded without execessive wear or noise.
25-60 m	800-1250	1600-2500	Safe to run unloaded but will reduce life of parts.
60-130 m	1250-1900	2500-3800	Do not run unloaded, apart from testing Voc.
above 130 m	above 1900	above 3800	Consult with PowerSpout.

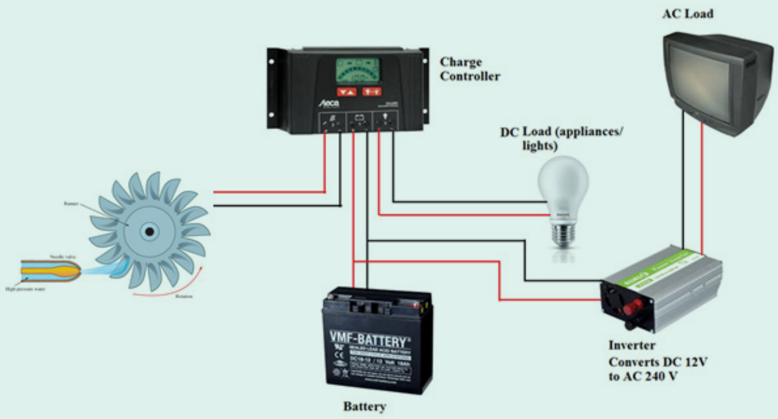
12. Adjusting the Turbine RPM

This is a trial-and-error process, but the spray pattern observations above will help you to make the correct adjustments. Moving the magnet rotor outward, away from the stator will increase RPM (if it is too slow) whereas moving it further onto the stator will reduce RPM.



Start by grasping the extractor knob and turning it anticlockwise relative to the magnet rotor. Keep a note of the number of turns. Optimization 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. Do not over-tighten the plastic nut. Each washer (supplied) is 1.75 mm thick, and each turn of the knob is 1.6mm. The red washer (if supplied) is fitted first.

13. Connect the battery to and inverter using AC circuit breakers at all times



8

Identifying and resolving common faults in Pico hydro systems

While Pico – hydro systems are of both AC and DC types, we will mainly focus on DC type simple systems which connect to inverters for AC conversion.

8.1 Charge Controller Faults

In a hydro turbine system, the charge controller is the brains of the entire system, and it is the first place you can look to for faults. Here are some common faults on charge controllers.

Fault 1: Charge controller does not show full state off-charge.

Reason: Accidental overuse (less rain, special TV program).

Remedy: Reduce load usage time by half for a day to allow batteries to charge properly.

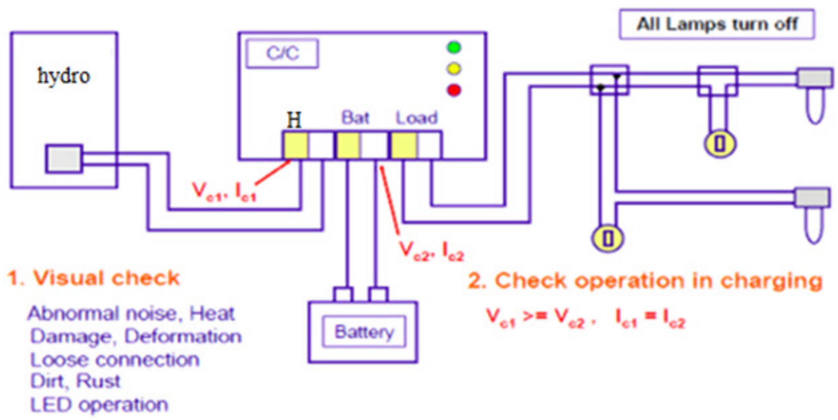
Fault 2: Charge controller cuts-off load and lights.

Reason: Daily overuse (battery is empty):

Remedy: Reduce load usage time by half till C/C shows full state (at least for a week) to allow batteries to charge properly.

The above mentioned are the two most common faults you will see in charge controllers. Most hydro charge controllers will also cut – off power to loads in case of accidental short circuit. The charge controller needs to be reset after the short circuit is removed. Most charge controllers give battery voltage and hydro output voltage too which you can use to troubleshoot. Some controllers, flashes lights or give error codes. Keep your charge controller manuals on hand when trouble shooting error messages.

FIGURE 76: Charge controller connection[94]



Fault 3: No current is flowing to battery, or it signals battery is fully charged even though battery has just begun charging or it keeps charging battery even when full.

Reasons: Blown fuse, loose connection of wires or malfunction of internal controller circuit.

Remedy: Tighten loose connections, replace blown fuse rectify LVD and HVD settings.

Most of the faults are abrupt and can cause the system to shut down while some faults can be found during routine checks. The following figure shows how the different hydro components are expected to give problems in certain time after installations.

8.2 Pico Hydro Turbine Faults

Hydro turbine faults can be found especially when there are power losses or when you make measurements. Display of hydro turbine voltage can also be seen on some charge controllers.

Fault 4: Low or no power output from hydro turbine.

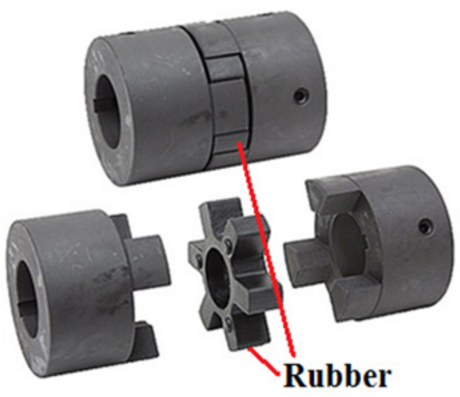
Reason: No or low water supply – blocked penstock. Broken shaft or seized bearings. Electrical shorting of wires.

Remedy:

- Check the continuity of wires to find and replace shorted or faulty wire.
- Check bearing and replace.
- Check penstock and forebay and clear blockage to allow water flow.
- Check the in-line coupling for wear on the rubber or cracks – replace as needed.

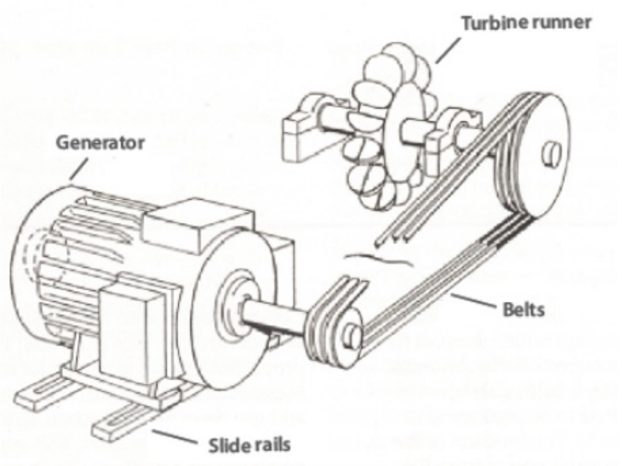
94 Source: JICA

FIGURE 77: Check the coupling for wear or damage[95]



- For belt drive systems check for loose or broken V belts. Replace or tighten as required.

FIGURE 78: Wedge belt drive system[96]



- Check the grease on bearings – grease as needed to prevent seized bearings. Replace if greasing does not help as the bearing may have been damaged.

FIGURE 79: Greasing a bearing on shaft[97]

Other common reasons of power loss:

- Damaged or leaking penstock cannot supply the water with force to the turbine.

FIGURE 80: Damaged and leaking penstock[98]

- The valves may be closed or damaged and are obstructing water flow.

95 Source: "High quality bearing supplies", https://www.thebigbearingstore.com/
96 Source: Practical Action
97 Source: Priest Electric.com https://www.priestelectric.com/
98 Source: Nepal Energy Forum, http://www.nepalenergyforum.com/

FIGURE 81: Commonly used butterfly valve[99]

- Damaged buckets could significantly reduce power from the turbine. Replace damaged buckets.

FIGURE 82: Damaged Pelton turbine blades[100]

8.3 Battery Common Faults

Fault 5: Battery is easily charged or cannot be charged properly of the cells have unequal voltages.

Reasons: Sulfation, dried up battery solution, stratification (when electrolytes in the solution concentrate at the bottom), loose terminal connections, high battery temperature or leakage of electricity due to acid on surface between battery terminals.

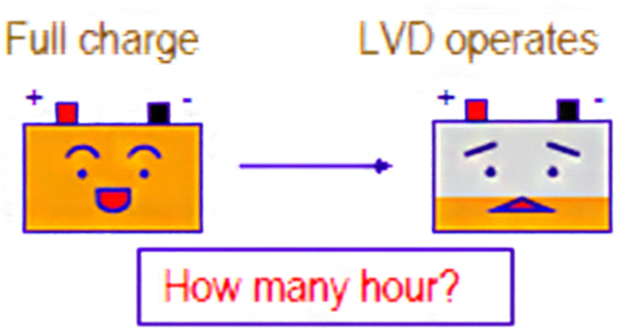
Remedy:

- Loose connection at the terminals.
- Clean terminals with steel brush and apply grease (e.g., Vaseline or lithium grease).
- Level of battery electrolyte, top up when necessary.
- Use appropriate terminal lugs/clamps only.
- Remove corrosion at the terminals.
- Slightly shake battery (not > 10 degrees from the floor line at side) to avoid stratification.
- The installation condition, relocate if necessary.

8.3.1 Checking battery Amp Hour Capacity

Here are some additional checks you can do on your battery. After fully charging battery, use a constant load to draw electricity, disconnect the load at LVD (low volt disconnect).

FIGURE 83: How long does the battery take to reach LVD?[101]



Compare the rated amp-hour capacity with measured amp-hour capacity. If measured amp-hour is less than 80% of the rated capacity, the battery has almost reached the end of its usefulness.

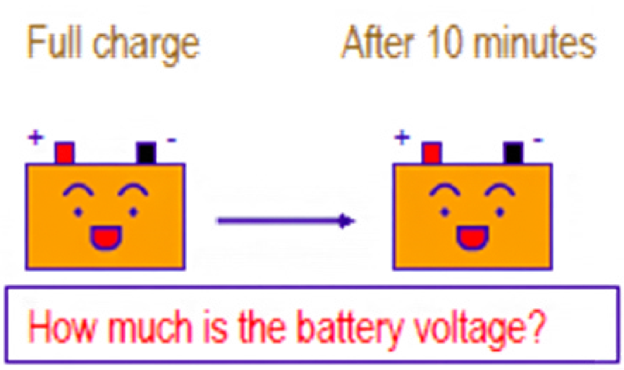
8.3.2 Checking battery voltage

After fully charging battery, stop the charging after minimum 10 minutes but typically 2 hours, measure the battery voltage. If the voltage is lower than 12.5V, the battery has almost reached the end of its usefulness.

It is important to replace severely malfunctioning batteries to avoid damaging other batteries.

99 Source: Indiamart.com, "Flanged butterfly valve", https://5.imimg.com/data5/LB/GT/MY-45145264/double-flanged-butterfly-valve- 500x500.jpg
100 Source: Dependable Turbines. Ltd, http://www.dtlhydro.com/z
101 Source: JICA

FIGURE 84: How well does the battery hold charge[102]



8.4 General Balance of System (BOS) Faults

Faults

- BOS (cables, switches, lights, etc.).
- No light even when battery is fully charged.
- Under-voltage at load end.
- No power at load end.

Reasons:

- Open or short circuit or grounding.
- Inappropriate/undersize cables (large voltage drop).
- Burn-out DC light tube/inverter.
- Loose connection at the terminals.
- High resistance on the switch contact.

Remedy:

- Check voltage level at load end and voltage drop.
- Tighten loose connections at the terminals.
- Check size of cable if the installed cable is the appropriate size, replace as necessary.
- Check continuity of cables, when open circuit, trace the line and connect the open circuit.
- Check and rectify possible short circuit and grounding in the line, re-insulate short-circuited/grounded line.
- Check operation of switch and voltage drop between input and output.

ACTIVITY 8

For this activity a faulty wire will be connected between the battery and charge controller for the learners to detect and correct using continuity tests.

Use the AC/DC hydropower system setup in the last activity. Once the learners see it is working – replace one good wire with the faulty wire. You may demonstrate the fault finding and correction activity using the following instructions

102 Source: JICA

9

Hydro turbine Maintenance checklist

9.1 Planning Maintenance

Routine maintenance is the best way to increase the life of your hydro turbine system and its components. Routine maintenance is normally done as a check which has a list of items of each component that needs to be ticked off. The checklist ensures that the components are inspected, cleaned, evaluated, and serviced on time so they last longer. Here are some tips on how to do routine maintenance.

9.2 Forebay

- Regularly check the forebay depth and clear silt or debris buildup.
- Check water level and clean access to forebay.
- Check forebay gauze filter or mesh for damage or clogging.
- Check the penstock connection for leakage or damage.

FIGURE 85: **Stop-Log rack arrangement as a weir or dam to support forebay**[103]

9.3 Penstock and valves

- Check the penstock filters for any damage.
- Checked for any dirt, debris or obstruction in penstock.
- Regularly open and clean the Y filter to remove silt and dirt.
- Check for corrosion on valves and seal damage on valves.
- Check for any leaks or damage to penstock pipe.
- Check flange bolts are tight and check also for corrosion on bolts.

FIGURE 86: **Check for corrosion in valves**[104]

9.4 Hydro Turbine Maintenance

Hydro turbines are normally designed to last in a rugged environment and should not require much attention. However just like all mechanical devices they still need to be cared for in order to last longer and perform better.

- Check the turbine casing for any damages or lose mounting bolts.
- Check that the bearings are not damaged and greased up.
- Check the inline coupling or belt for wear.
- Check the electrical terminals for any loose connections.
- Check for any dirt or debris stuck in the turbine – especially after floods.
- Check the buckets or blades of the turbine for damage and wear.
- Check the shaft for damage or alignment.

103 Source: Pond Boss Magazine

104 Source: Dreamtime," Corroded valve", https://thumbs.dreamstime.com/z/corroded-valve-maintenance-industrial-plant-46320348.jpg

FIGURE 87: Turbine inspection[105]

9.5 Battery Maintenance

Batteries are the most common to fail if not looked after properly. Battery maintenance involves various tasks depending on the type of battery and manufacturer requirements, including:

- Inspecting and cleaning battery racks, cases trays and terminations.
- Inspecting battery disconnects, overcurrent devices and wiring systems.
- Measuring voltage.
- Battery load testing applies very high discharge rates for a few seconds, while measuring the decrease in battery voltage. This is used to indicate weak or failed cells by significantly greater voltage drop.
- Battery capacity testing involves discharging the battery at nominal discharge rates to a prescribed depth-of-discharge. This evaluates available energy storage capacity for the system.
- Replace the poor batteries from a series string. The performance of a series string battery bank will be dominated by the poor performing battery.
- Discourage Frequent Over-discharges of the System - Overuse and over-discharging reduce battery lifetime due to high depth of discharge (DOD).
- Measuring specific gravity and adding water (for flooded lead-acid batteries only!).
- Periodic battery maintenance should include checks of all terminals for corrosion and proper tightening.
- Use a steel brush to clean oxides at connections. Wear insulation gloves at all times.

FIGURE 88: Battery Care[106]

105 Source: Climate Links, https://www.climatelinks.org/

106 Source: Jim Dunlop Solar

SAFETY TIP: Use safety goggles and rubber gloves when servicing batteries. Wear old clothes because you can get acid on them (if flooded batteries).

Keep an open box of baking soda and a plastic pan of water nearby while servicing your batteries in case of a spill, you can dump the baking soda in the water, stir it, and use the mixture to quickly neutralize any spilled acid.

Low voltage isnt a shock hazard, but high current is. A wrench dropped across terminals can quickly burn your hand and possibly explode the battery. Be careful!

9.5.1 Measure battery state of charge (SoC)

The state of charge SoC is a measure of battery health and battery potential. There are two ways to measure this – by open circuit voltage and by measuring the specific gravity (SG) of the electrolyte.

9.5.2 Voltage Method

Battery specific gravity (flooded battery type only) and open-circuit voltage are measured during maintenance to evaluate battery health and estimate state-of-charge. Open-circuit voltage should be measured after the battery has rested for a few hours. The table below gives the state of charge:

FIGURE 89: State of Charge[107]

State-of-Charge	Specific Gravity	Open-Circuit Voltage (V)
100%	1.265	12.6
75%	1.225	12.4
50%	1.190	12.2
25%	1.155	12.0
0	1.120	11.8

For typical lead-acid battery at 25°C

9.5.3 Hydrometer method (for flooded batteries only)

Hydrometers measure electrolyte specific gravity (SG) by extracting electrolytes from the battery cell into a chamber. Archimedes hydrometers use a float and buoyancy principles to measure SG. Refractive index hydrometers use a prism and optics to measure by the angle that light refracts SGs through a droplet of electrolyte. After reading the SG the above table can be used to estimate the SoC.

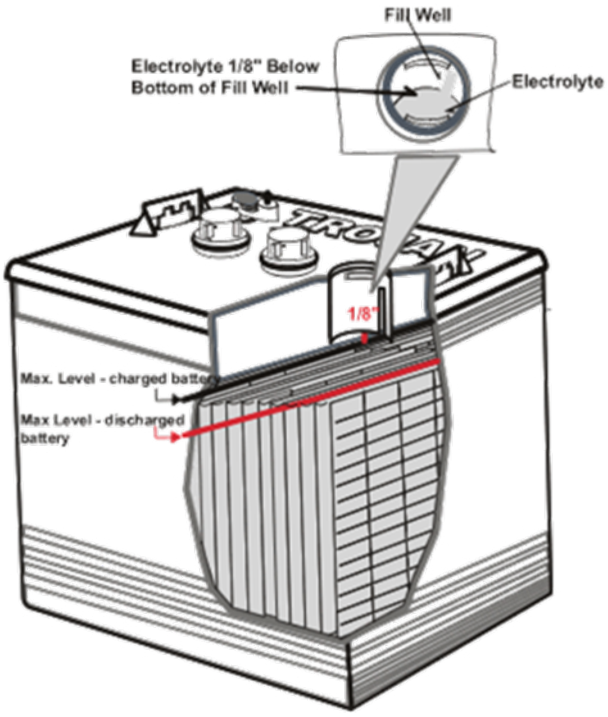
FIGURE 90: Hydrometer usage[108]

9.5.4 Adding Distilled Water to Battery (flooded battery only)

- Open vent flooded batteries loose water due to electrolysis and gassing during charging.
- Water loss increases with temperature, charge rates and age of battery.
- Use distilled water to prevent contamination of the battery and do not overfill.

107 Source, Pinterest.com, https://www.pinterest.com/bambulancemania/work-apparal/
108 Source: Jim Dunlop Solar

FIGURE 91: Battery Structure[109]



You may use a battery maintenance checklist given below to carry out routine checks on batteries.

Batteries (may be part of a backup system)	
Check electrical connection	Weekly
Check for corrosion and clean terminals	Weekly
Check water level and top up for lead acid batteries	Weekly
Ensure that batteries are fully charged on a regular basis	Weekly
Replace the battery bank	Typically, every 3-5 years (lead-acid) and 5-10 years (sealed gel) if well maintained
Manage hazardous materials storage and disposal: recycle spent batteries, manage electrolytes spills for lead-acid batteries	As needed

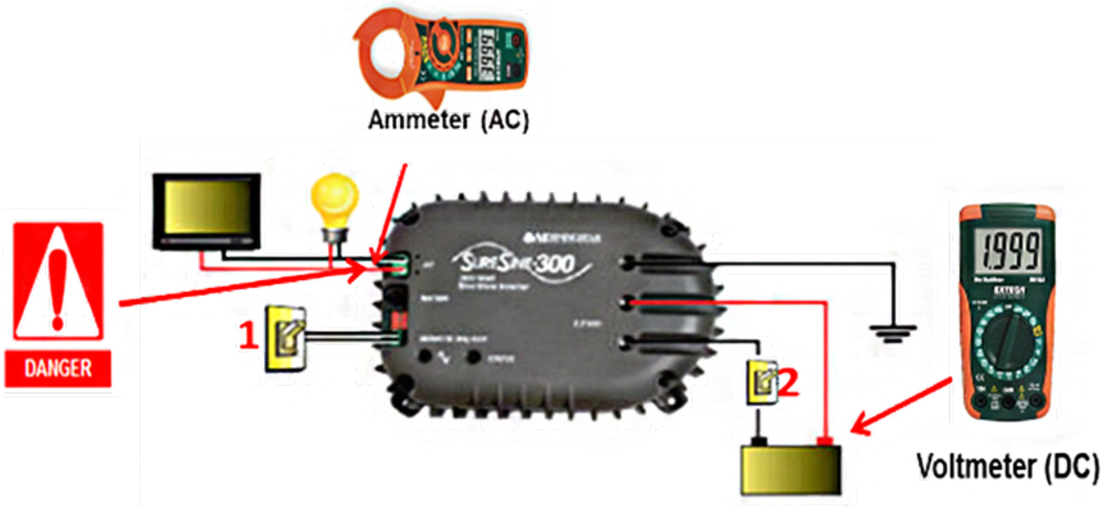
9.6 Inverter Maintenance

- Verify if the inverter is receiving DC voltage from the battery using voltage meter set to DC voltage measurement.
- Verify if the inverter is producing AC voltage to the AC load using voltage meter set to AC voltage measurement.

SAFETY TIP: Inverter generates dangerously high AC voltage of 220-240V. Wear the electrical insulation gloves and follow safety procedures.

109 Source: Jim Dunlop Solar

FIGURE 92: Inverter wiring[110]



Do NOT remove any wiring, do the monitoring in the following sequence:

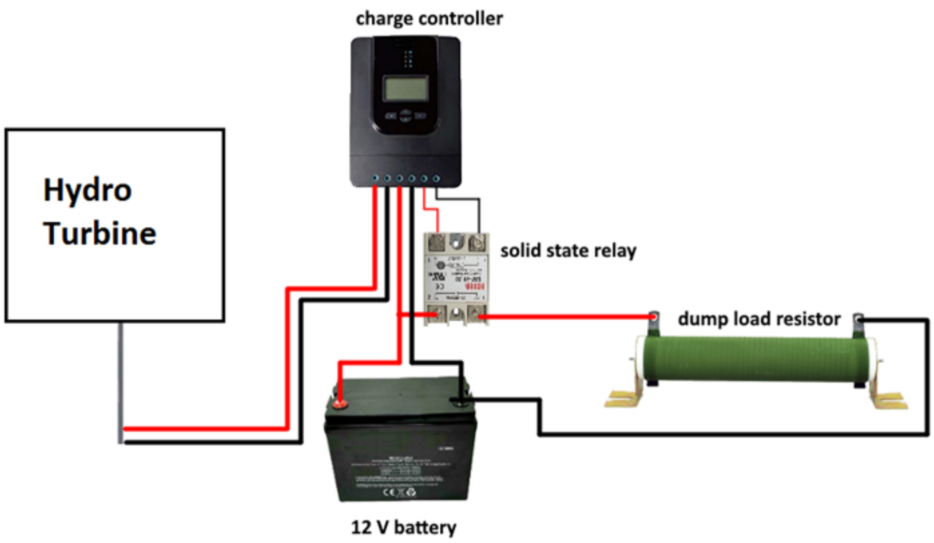
- Turn off the disconnect switches 1 and 2 (see image).
- Use clamp-on ammeter (AC) on the AC side.
- Connect the voltmeter (NOT ammeter) to the battery terminals (remember: Ammeter short circuits the battery and the fuse blows!).
- Turn on the disconnect switches 1 and 2.
- Observe if voltage and current flowing to the load. If yes, the inverter works.

9.7 Charge controller Maintenance

Charge controllers are normally robust and should not give a lot of trouble unless they are overloaded.

- Check loose connections.
- Check display voltages and check for error messages.
- Check fuse is not blown.
- Check mountings of controller.
- Check that diversion load is not worn out or damaged.

FIGURE 93: Hydro Charge Controllers with dump or diversion load resistor[111]



110 Adapted from "Operations &Maintenance of Stand-Alone PV Systems, Arizona State University, VOCTEC, http://voctec.asu.edu

111 Adapted from Resystech.com, "Sizing your Charge Controller and Inverter", https://resystech.com/sizing-your-charge-controller--power-inverter.html

9.8 Creating and using checklists

You can easily overlook a few things during your routine check. It is useful to keep a weekly or monthly checklists in a logbook where you can check each component of your client's hydro turbine system easily without overlooking anything. A checklist is a very useful record for this routine maintenance. It also provides evidence to your clients that you have done the inspections. A **sample monthly master checklist** is given below, and you can always add more to it or remove some that do not apply.

TABLE 4: **Check List**

Check list items	OK	Comment
Turbine installation site Check		
Check for corrosion of damage of casing or pipes.		
Check for vegetation growth to site – clean if needed. Keep access to forebay and turbine location clear.		
Check valves are all working fine.		
Check Y filter and clean if needed.		
Check turbine mounting and battery housing shelter.		
Check that turbine outlet is clear and not blocked by dirt or debris or silt.		
Secure the site with padlock or fencing if required – check for damage o fencing.		
Check for corrosion on electrical terminals on generator.		
Check for bearing wear and grease if needed.		
Check coupling rubber wear.		
Check for V belt wear.		
General Visual Inspection		
Inspect the inverter/electrical pad to make sure it does not show excessive cracking or signs of wear. The inverter should be bolted to the pad at all mounting points per the manufacturer installation requirements. Depending on the size, location, and accessibility of the system to unqualified personnel, the inverters, combiner boxes, and disconnect switches should require tools or have locks to prevent unauthorized access to the equipment.		
Look for warning placards including arc flash or PPE requirements for accessing equipment. Be sure to comply with all warning placards. If no placards are present, or if some placards are missing, make a note of it and install the missing placards during the maintenance visit.		
Inspect Hydro turbines for defects that can appear in the form of burn marks, discoloration, delamination, or corrosion.		
Check for missing bolts or parts.		
Ensure that the turbine wiring is secure and contained in electrical conduits.		
Inspect racking system for defects including rust, corrosion, sagging, and missing or broken clips or bolts.		
Check nozzles for blockages.		

Inspect conduits for proper support, bushings, and expansion joints, where needed.		
Check structural integrity of turbine housing and mount.		
In ground-mounted systems, look for signs of corrosion near the supports.		
Open combiner boxes and check for torque marks on the connections. Torque marks are made when lugs have been tightened to the proper torque value. Ideally, they are applied during initial installation, but if not, the technician can mark the lug after torqueing during a maintenance visit. A proper torque mark is made with a specialized torque marking pen. The mark is a straight line through the lug and the housing. Over time, if the line separates between the lug and the housing, it shows that the lug has moved and needs to be re-torqued. Look for debris inside the boxes and any evidence of damaging water intrusion. Look for discoloration on the terminals, boards, and fuse holders.		
Open the cabinet door to the disconnect(s) and look for signs of corrosion or damage.		
Check to make sure the cabinet penetrations are properly sealed and there is no evidence of water ingress. Check for torque marks on the terminals.		
Perform a visual inspection of the interior and exterior of the inverter. Look for signs of water, rodent, or dust intrusion into the inverter. Check for torque marks on the field terminations.		
If a weather station is present, ensure that the sensors are in the correct location and at the correct tilt and azimuth.		
Inverter Check		
Record and validate all voltages and production values from the human-machine interface (HMI) display.		
Record last logged system error.		
Clean filters.		
Clean the inside of the cabinet.		
Test fans for proper operation.		
Check fuses.		
Check torque on terminations.		
Check gasket seal.		
Confirm warning labels are in place.		
Look for discoloration from excessive heat buildup.		
Check integrity of lightning arrestors.		
Check continuity of system ground and equipment grounding.		
Check mechanical connection of the inverter to the wall or ground.		
Check internal disconnect operation.		
Verify that current software is installed.		
Contact installer and/or manufacturer about any issues found.		
Document findings for all work performed.		

Check insulated gate bi-polar transistors and inverter boards for discoloration.		
Use inspection mirror if necessary.		
Check input dc and output ac capacitors for signs of damage from overheating.		
Record all voltage and current readings from the front display turbine.		
Check appearance/cleanliness of the cabinet, ventilation system, and insulated surfaces.		
Check for corrosion/overheating on terminals and cables.		
Torque terminals, connectors, and bolts as needed.		
Record ambient weather conditions, including the temperature and whether the day is rainy or dry.		
Check the appearance of both the ac and dc surge suppressors for damage or burn marks.		
Check the operation of all safety devices (emergency stop devices, door switches, ground fault detector interrupter).		
Inspect (clean or replace) air filter elements.		
Correct any detected deficiencies.		
Complete maintenance schedule card.		
Complete written inspection report.		
If manufacturer-trained personnel are available on-site, install and perform any recommended engineering field modifications, including software upgrades.		
Battery Check		
Check for signs of any electrolyte in the safety trays (if provided) or on the floor, indicating a possible battery leak or overfilling.		
Check condition of battery containers.		
Check battery voltage level - record voltage levels.		
Check condition of battery terminals - ensure no corrosion, remove corrosion if any.		
Check battery electrolyte levels (not required for gel sealed batteries).		
Wires and connection check.		
Check for any breaks in wires and uncoated wires - report any breaks in wires.		
Ensure that all connections are properly shrouded or covered.		
Check for loose or hanging wires.		
Check for burnt out of uninsulated wires in close proximity.		

ACTIVITY 9

Print out the hydro turbine sample monthly master checklist and give it to each team of learners. Also provide them with insulated gloves, multi meter, clamp meter, eye goggles, and other relevant tools and PPE. They must try to wear safety shoes for the activities.

Ensure everyone puts on the PPE and takes their checklist around the hydro turbine system which they had installed in the previous activity. Since there are many activities, you may ask them to do the ones which are faster to do as an activity. You must continue to observe them and make sure they tick off and comment on the checks they are doing. The final checklist must be collected and checked orally to give feedback on some checks. It is important they use this checklist to learn how to do routine maintenance. During the checking – allow for questions and answers.

Discussion and Questions

10

Annex

10. 1 Annex A: Hydro Preliminary Studies

There are several stages of preliminary studies i.e., a pre-feasibility study, a feasibility study, or a design study. The pre-feasibility study is usually done to consider several alternatives with the use of approximate data. The feasibility study reduces the number of choices down to one or two options with cost estimates, timelines to complete a project and collection of more accurate data. A feasibility study usually submitted to donors, development partners, decision makers, etc for consideration. If a proposed project is approved, a design study is undertaken in which specifications, orders and tender documents are developed for project implementation. Usually in small projects, the feasibility and design aspects can be merged but a pre-feasibility study is essential.

In pre-feasibility studies, head is determined using large-scale maps for high head sites (>60m), pressure gauge and tube for medium-head sites and hand-held levels for low-head sites (<15m). On the other hand, for flow determination, it requires basic hydrological models or simple flow measurement spot checks.

It is essential that the best possible site is established. This site needs to be conveniently located near the demand with a good combination of head and flow rate so that the output is maximized.

When potential sites have been identified, it is essential to obtain contour maps and records of rainfall and water flows in streams and rivers (also regarded as hydrological records) which can be available with meteorological/energy/environment departments. If unavailable, site-specific hydrological study is needed. This is most important and most difficult part of hydro designing process as surface water flow varies through the year in a complex manner.

10.1.1 Topographic and Geological Survey

The main purpose of the topographic and geological survey is to assess the best locations for proposed civil works (i.e., surface movements – loose rocks, landslip, etc.) and estimate construction and maintenance costs. For large projects, this is typically done by qualified civil personnel before confirming a site.

10.1.2 Hydrological Survey

Comparison of Catchment Areas

A thorough check of a contoured large-scale map to compare catchment areas for a suitable hydro scheme is critical. Furthermore, to distinguish between potential sites, it is vital to consider a suitable site that obtains the maximum head, has a good intake location, gives a shorter and convenient penstock (free from steep slopes) to reduce infrastructure and maintenance cost, and makes geological sense that is not prone to landslip or storm runoffs.

Finding the Average Daily Flow (ADF)

Average daily flows are determined from the yearly flow that can be extracted from existing records of rainfalls from nearby rain gauges.

1. **Calculate the Storm Run-off:**

Runoff (mm/yr) = Rainfall (mm/yr) – Evaporation(mm/yr) – Surface absorption (mm/yr)

2. **Calculate for the Annual Volume Flow:**

Volume flow per year (m3/yr) = Runoff (mm/yr) × Catchment areas(m2) × 10-3

3. **Calculate the Average Daily Flow (ADF):**

$$ADF = \frac{\text{Volume flow per year}}{\text{Number of seconds in a year}}$$

<u>**For example:**</u>

The average rainfall recorded at a site is 2930 mm/year. It is estimated that there are 30% evaporation losses and around 10% absorption losses. The catchment area has been estimated to cover an area of 4.88 x 106 m2.

Runoff (mm/yr) = Rainfall (mm/yr) – Evaporation(mm/yr) – Surface absorption (mm/yr) = 2930 – 0.3(2930) – 0.1(2930) = 2930 – 879 – 293 = 1758 mm/yr

Volume flow per year (m3/yr) = Runoff (mm/yr) x Catchment areas(m2) x 10-3
= 1758 x 4.88 x 106 x 10-3 = 8.57 x 106 m3/yr

ADF = Volume flow per year / Number of seconds in a year = 8.57 x 106 m3 / (365 x 24 x 60 x 60) = 0.27 m3/s

In absence of rainfall data, you will need to set up at least 1-2 rain gauge in the region of interest, measure and correlate the onsite flow rate measurements with regional/national data. You can also consult a hydrologist for further advice.

10.1.3 Head Measurements

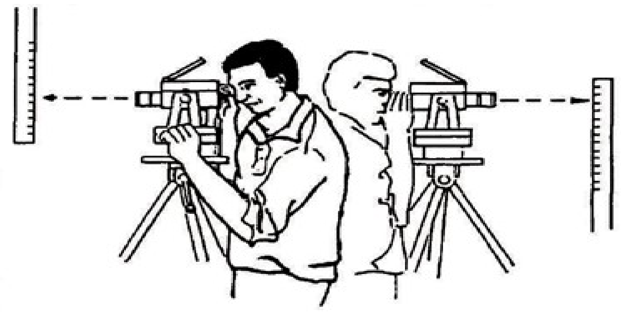
It is recommended to take several separate measurements of head at each site where possible to determine the gross head. A further important factor to note is that the gross head is not strictly constant but varies with the river flow.

Some of the methods commonly used for head measurements are listed below:

- Dumpy levels and theodolites

Dumpy levels are used with level staffs to measure head in a series of stages as shown in Figure 19. A dumpy level is a device which allows the operator to take a sight on a level staff held by a colleague, knowing that the line of sight is exactly horizontal. A clear un-obstructed view is needed, so wooded sites can be frustrating with this method.

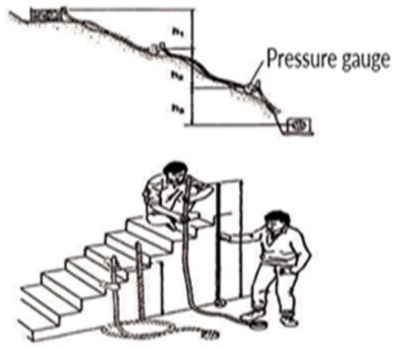
FIGURE 94: The use of dumpy levels for measuring vertical height[112]



- Sighting Meters

Hand-held sighting meters measure angle of inclination of a slope (inclinometers or Abney levels). They are normally used by an experienced person for accuracy.

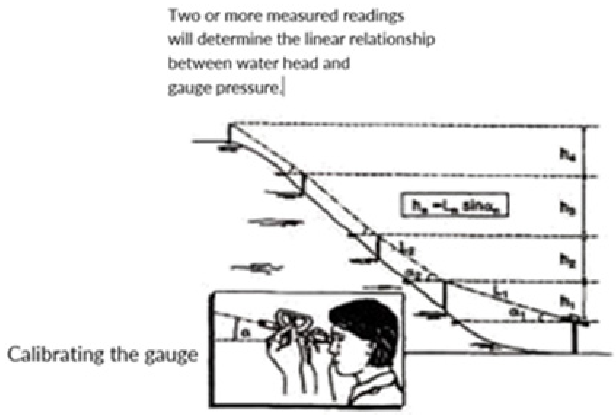
FIGURE 95: Sighting Meter for Measuring Vertical Angles[113]



- Water-filled Tube and Pressure Gauge

A transparent pipe is filled with water to measure the length of the penstock, while a pressure gauge is attached to the lower end of the pipe to measure the head. While measurement is done, there must not be any bubble in the pipe to avoid inaccurate reading.

Figure 96: Water-filled tube and pressure gauge[114]



For example:

A pressure of 20 psi is attained with the water filled tube method. First convert psi to kPa or Pa:

Density of Water – 1000 kg/m3

Remember 1 bar = 14.6 PSI, 1 bar = 100.7 kPa and 1 bar = 100,667 Pa.

Therefore, 20/14.6 = 1.37 bar.

1.37 bar = 1.37 x 100,667 Pa = 137,900Pa

Using the formula Pressure = density of water x Gravity x Height of Fluid (or Head)

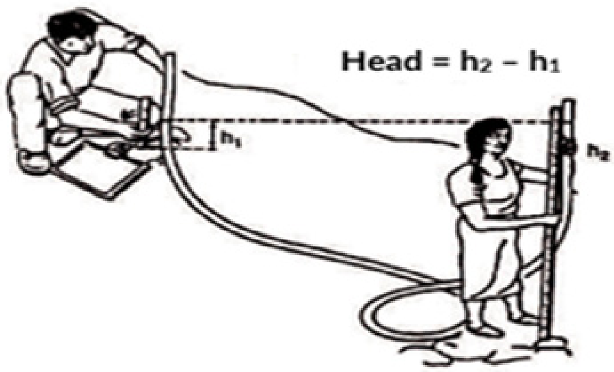
Head = Pressure / density of water x Gravity = 137,900 / (1000 x 9.81) = 14.06 meters

112 Source: Practical Action, https://answers.practicalaction.org/our-resources/item/micro-hydro-pre-feasibility-study-a-technical-guideline/
113 Source: Practical Action, https://answers.practicalaction.org/our-resources/item/micro-hydro-pre-feasibility-study-a-technical-guideline/
114 Source: Practical Action, https://answers.practicalaction.org/our-resources/item/micro-hydro-pre-feasibility-study-a-technical-guideline/

- Water-Filled Tube and Rod

Recommended for low-head sites, this method is similar to the water filled tube and pressure gauge, however, a rod is used to measure the height difference or head (instead of a pressure gauge) from the water level to the ground surface where the turbine/generator will be located. This method can be done by an ordinary, villager or farmer.

FIGURE 97: **Water-filled Tube and Rod**[115]



- Spirit Level and Plank

Quite similar to the principle of water-filled tube and rod method. The difference is that the horizontal sighting is attained not by water levels, but a carpenter's leveler placed on a straight plank of wood.

FIGURE 98: **Spirit Level and Plank Method**[116]

- Maps

Use of large-scale contour maps to read contour difference are very useful for approximate head values although they may not always be available and fully reliable. For example, if the point is halfway between 8- and 10-meter contour lines, then it is 9 meters.

- Altimeters

This method can be useful for high-head pre-feasibility studies and done by surveying altimeters must be handled by experienced personnel to minimize errors.

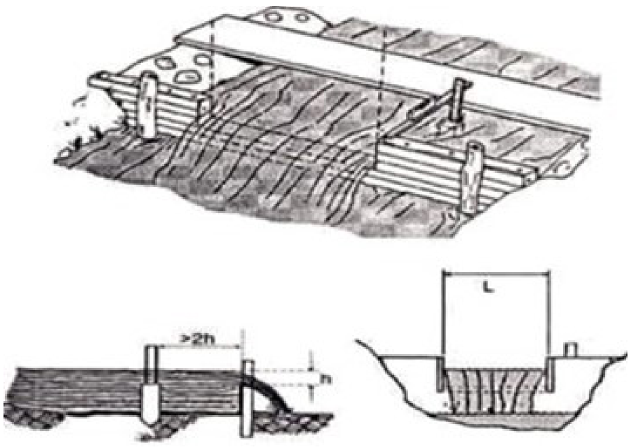
10.1.4 On-site Flow Measurement

Hydrology study is used to predict the variation in the flow during the year and long -term measuring is needed to be set up onsite. Some of the common flow measuring techniques include:

- The Weir Method

A weir (low wall structure) is constructed with a rectangular notch through which all the stream water flows. The flow rate can be determined from a single reading of the difference in height between the upstream water level and the bottom of notch. The crest of the weir must be kept sharp, and sediment must be prevented from accumulating behind the weir. This could be achieved by using sheet metal made of brass or stainless steel.

FIGURE 99: **The Weir Method**[117]



Q = 1.8 (L – 0.2h) h1.5

Where:

Q = flow rate (m3/s)

L = the notch width (m)

h = the head difference (m)

115 Source: Practical Action, https://answers.practicalaction.org/our-resources/item/micro-hydro-pre-feasibility-study-a-technical-guideline/

116 Source: Practical Action, https://answers.practicalaction.org/our-resources/item/micro-hydro-pre-feasibility-study-a-technical-guideline/

117 Source: Practical Action, https://answers.practicalaction.org/our-resources/item/micro-hydro-pre-feasibility-study-a-technical-guideline/

For example:

Suppose a notched weir has width of 2.2m, and the upstream water level is 34cm above the weir crest, then the flow rate works out to be:

Q = 1.8 (L – 0.2h) h1.5

Q = 1.8 (2.2 – 0.2 × 0.34) 0.341.5

Q = 0.761 m3/s (or 761 l/s)

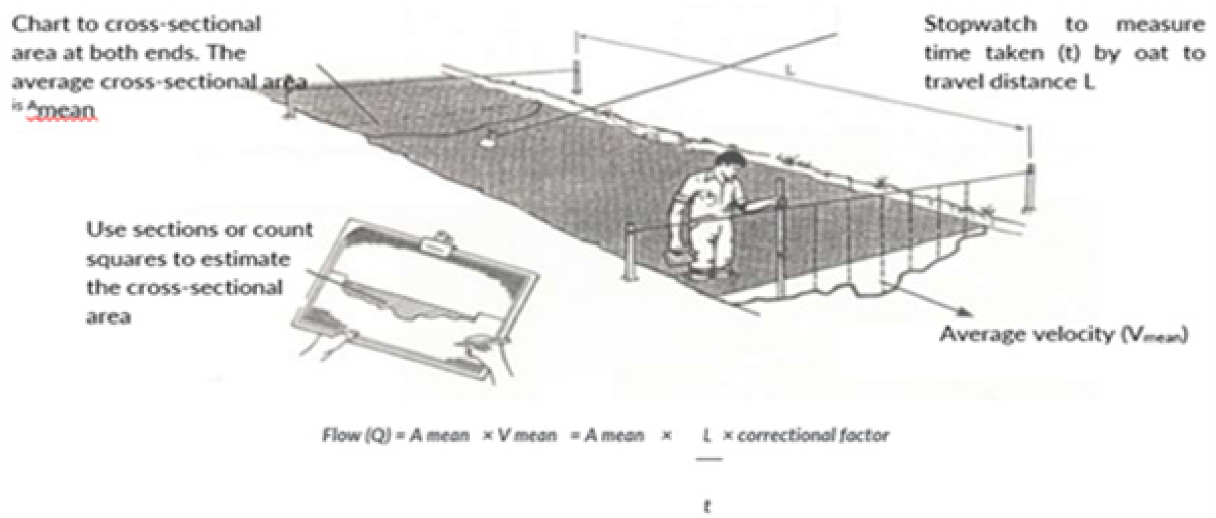
- Bucket Method

Applicable for small streams, the bucket method is a simple way of measuring flow in very small streams. The entire flow is diverted into a bucket or barrel and the time for the container to fill is recorded. The flow rate is obtained simply by dividing the volume of the container by the filling time. Flows of up to 20 l/s can be measured using a 200-litre barrel.

- Float Method

This principle is for the cross-sectional profile of a stream bed (or area of the stream bed used) and an average cross section established for a known length of the stream. A series of floats or pieces of wood are then timed over a measured length of the stream. Results are averaged and a flow velocity is obtained. This velocity must then be reduced slightly by a correction factor to obtain the mean velocity. By multiplying the average cross-sectional area by the averaged and corrected flow velocity, the volume flow rate Q can be estimated.

FIGURE 100: Channel Cross Section with Subsections[118]



Approximate correction factors to convert surface velocity to mean velocity are:

Concrete channel, rectangular, smooth	0.85
Large slow clear stream (>10m2)	0.75
Small slow clear stream (<10m2)	0.65
Shallow (<0.5m) turbulent stream	0.45
Very shallow (<0.2m) turbulent stream	0.25

Unless a smooth regular channel is considered, obtaining an accurate figure for the cross-sectional area of the stream will be very difficult.

- Current Meter

For this method, the stream channel cross section is divided into numerous vertical subsections. In each subsection similar to Figure 100, the area is obtained by measuring the width and depth of the subsection, and the water velocity is determined using a current meter. The discharge in each subsection is computed by multiplying the subsection area by the measured velocity. The total discharge is then computed by summing the discharge of each subsection.

118 Source: Practical Action, https://answers.practicalaction.org/our-resources/item/micro-hydro-pre-feasibility-study-a-technical-guideline/

10.2 Annex B: How to Do Basic Measurements Using a Clamp-Meter

This section shows how to do basic measurements using a clamp meter. Note that some meter brands might not have all the features shown.

10.2.1 Measuring DC Voltage using probes

FIGURE 101: DC Voltage measurement schematic[119]

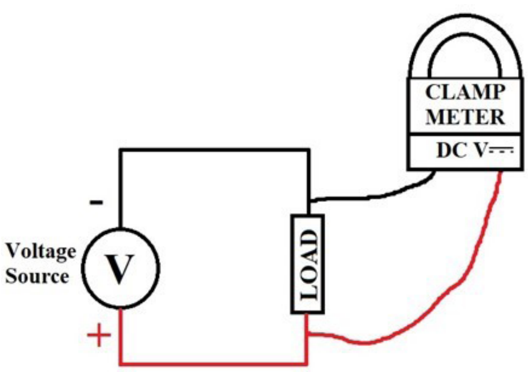


FIGURE 102: DC Voltage measurement on clamp-meter[120]

Steps:

1. Set Clamp-meter dial to DC Voltage mode (DCV or V=).
2. Ensure probes are connected to "V" and "Com" ports of the clamp meter.
3. Touch the end of probes across the load in the circuit to measure its voltage. Voltage measurements are done in parallel to the load. Clamp-meter screen with show measured voltage.

10.2.2. Measuring AC Voltage using probes

FIGURE 103: AC Voltage measurement schematic[121]

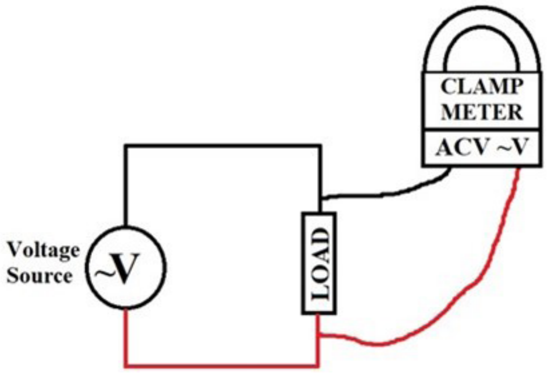


FIGURE 104: AC Voltage measurement on clamp-meter[122]

Steps:

1. Set Clamp-meter dial to AC Voltage mode (ACV or ~V).
2. Ensure probes are connected to "V" and "Com" ports of the clamp meter.
3. Touch the end of probes across the load in the circuit to measure its voltage. Voltage measurements are done in parallel to the load. Clamp-meter screen with show measured voltage.

119 Mohammed Tazil, GGGI
120 Mohammed Tazil, GGGI
121 Mohammed Tazil, GGGI
122 Mohammed Tazil, GGGI

10.2.3 Continuity testing using probes

FIGURE 105: Continuity testing schematic[123]

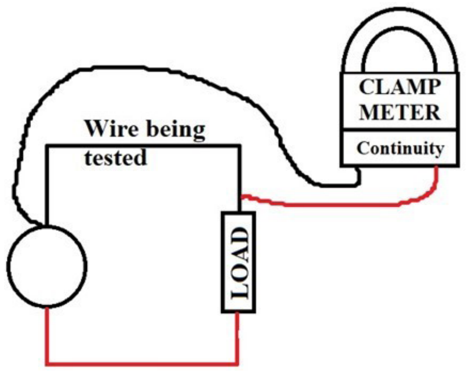


FIGURE 106: Continuity testing on clamp-meter[124]

Steps:

1. Turn OFF power supply in the circuit when doing this test.
2. Set Clamp-meter dial to Continuity mode ")))". If this mode is not available, you can also use resistance (Ω) mode.
3. Ensure probes are connected to "V" and "Com" ports of the clamp-meter.
4. Touch the end of probes across the wire in the circuit to test its continuity. The clamp-meter will "beep" or show "0" if the wire is continuous. If the wire is not continuous or open, the clamp meter will "not beep" or show "1".

10.2.4. Measuring DC current using clamp

FIGURE 107: DC current measurement schematic[125]

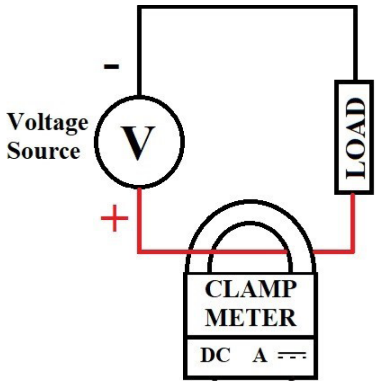


FIGURE 108: DC current measurement on clamp-meter[126]

Steps:

1. Set Clamp-meter dial to DC current mode (DCA or A=)
2. Open the clamp and put the wire inside the clamp.
3. The clamp-meter screen will show the measured current in the wire. The clamp-meter probes are not used in this test.

123 Mohammed Tazil, GGGI
124 Mohammed Tazil, GGGI
125 Mohammed Tazil, GGGI
126 Mohammed Tazil, GGGI

10.2.5 Measuring AC current using clamp

FIGURE 109: AC current measurement schematic[127]

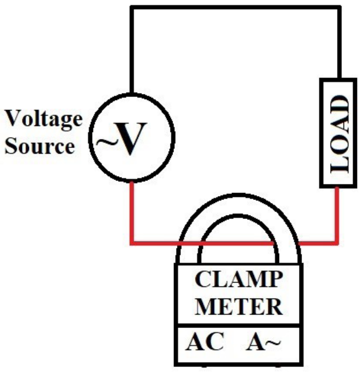


FIGURE 110: AC Current measurement on clamp-meter[128]

Steps:

1. Set Clamp-meter dial to AC current mode (ACA or A~).
2. Open the clamp and put the wire inside the clamp.
3. The clamp-meter screen will show the measured current in the wire. The clamp-meter probes are not used in this test.

127 Mohammed Tazil, GGGI

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10.3 Annex C: How to do Basic Measurements using a Multi-Meter

This section shows how to do basic measurements using a multi-meter. Note that some meter brands might not have all the features shown.

10.3.1 Measuring DC Voltage using probes

FIGURE 111: DC Voltage measurement schematic[129]

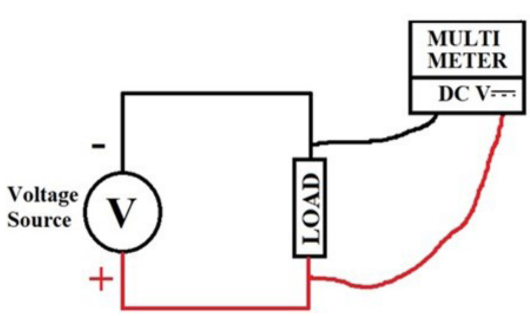

FIGURE 112: DC Voltage measurement on multi-meter[130]

Steps:

1. Set multi-meter dial to DC Voltage mode (DCV or V=).
2. Ensure probes are connected to “V” and “Com” ports of the clamp meter.
3. Touch the end of probes across the load in the circuit to measure its voltage. Voltage measurements are done in parallel to the load. Multi-meter screen with show measured voltage.

10.3.2. Measuring AC Voltage using probes

FIGURE 113: AC Voltage measurement schematic[131]

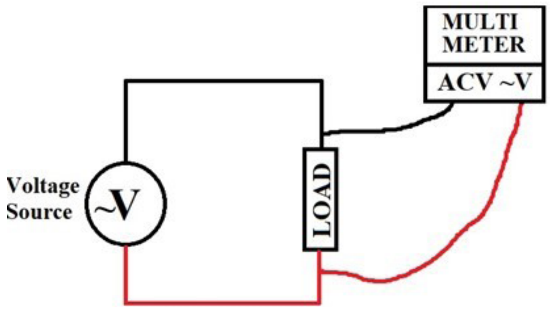

FIGURE 114: AC Voltage measurement on multi-meter[132]

Steps:

1. Set multi-meter dial to AC Voltage mode (ACV or ~V).
2. Ensure probes are connected to “V” and “Com” ports of the multi-meter.
3. Touch the end of probes across the load in the circuit to measure its voltage. Voltage measurements are done in parallel to the load. Multi-meter screen with show measured voltage.

129 Mohammed Tazil, GGGI
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132 Mohammed Tazil, GGGI

10.3.3 Continuity testing using probes

FIGURE 115: Continuity testing schematic[133]

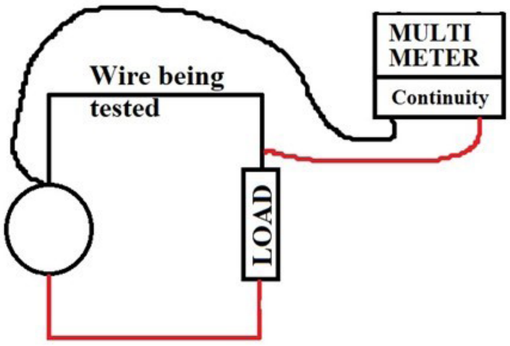

FIGURE 116: Continuity testing on multi-meter[134]

Steps:

1. Turn OFF power supply in the circuit when doing this test.
2. Set multi-meter dial to Continuity mode ")))". If this mode is not available, you can also use resistance (Ω) mode.
3. Ensure probes are connected to "V" and "Com" ports of the multi-meter.
4. Touch the end of probes across the wire in the circuit to test its continuity. The multi-meter will "beep" or show "0" if the wire is continuous. If the wire is not continuous or open, the multi-meter will "not beep" or show "1".

10.3.4. Measuring DC current using probes

FIGURE 117: DC current measurement schematic[135]

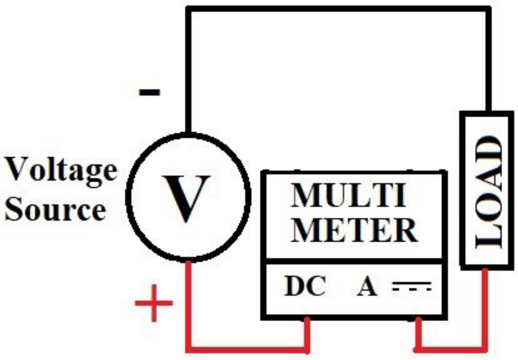

FIGURE 118: DC current measurement on multi-meter[136]

Steps:

1. Turn OFF the circuit
2. Set multi-meter dial to DC current mode (DCA or A= or mA=)
3. Connect the red probe to the "A=" or "mA=" port of the multi-meter and black probe to "Com" port of the multi-meter. Ensure that the measured current does not exceed the maximum rated current of the meter. If the current is very small, then you can use the "mA=" port and "mA=" meter mode to measure smaller currents more accurately.
4. Connect the multi-meter in series to the circuit. This means that the circuit must be broken to connect the meter in series.
5. Turn ON the circuit
6. The multi-meter screen will show the measured current in the wire.

133 Mohammed Tazil, GGGI
134 Mohammed Tazil, GGGI
135 Mohammed Tazil, GGGI
136 Mohammed Tazil, GGGI

10.3.5 Measuring AC current using probes

FIGURE 119: AC current measurement schematic[137]

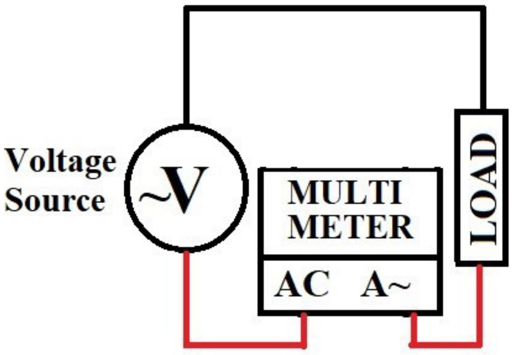

FIGURE 120: AC current measurement on multi-meter[138]

Steps:

1. Turn OFF the circuit
2. Set multi-meter dial to AC current mode (ACA or A~ or mA~)
3. Connect the red probe to the "A~" or "mA~" port of the multi-meter and black probe to "Com" port of the multi-meter. Ensure that the measured current does not exceed the maximum rated current of the meter. If the current is very small, then you can use the "mA~" port and "mA~" meter mode to measure smaller currents more accurately.
4. Connect the multi-meter in series to the circuit. This means that the circuit must be broken to connect the meter in series.
5. Turn ON the circuit
6. The multi-meter screen will show the measured current in the wire.

137 Mohammed Tazil, GGGI

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