MICRO HYDROPOWER SYSTEM INSTALL GUIDELINES

Acknowledgement

The development of this guideline was funded through the Sustainable Energy Industry Development Project (SEIDP). The World Bank through Scaling Up Renewable Energy for Low-Income Countries (SREP) and the Small Island Developing States (SIDSDOCK) provided funding to the PPA as the Project Implementation Agency for the SEIDP. The guidelines have been developed by Global Sustainable Energy Solutions and reviewed by PPA and SEIAPI Technical Committees.

These guidelines have been developed for The Pacific Power Association (PPA) and the Sustainable Energy Industry Association of the Pacific Islands (SEIAPI).
They represent latest industry BEST PRACTICE on installation of Micro-Hydropower System.

Front Cover Photo Source: Application Solutions

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List of Abbreviations and Acronyms

a.c.	Alternating current
AS/NZS	Australian / New Zealand Standard
cfs	Cubic feet per second
d.c.	Direct current
DN	Diameter Nominal (nominal diameter)
ELV	Extra low voltage
FPS	Feet per second
gpm	Gallon per minute
HD	High density
IEC	International Electrotechnical Commission
kWh	Kilowatt hour
kPa	Kilopascal
LV	Low voltage
lpm	Litres per minute
PSI	Pounds per square inch
PE	Polyethylene
PVC	Polyvinyl chloride
NEC	National Electrical Code
NFPA	National Fire Protection Association
US	United States (of America)
Wh	Watthour

1. Introduction

This guideline provides the minimum knowledge on installation of micro hydropower systems in regional countries. Also, this guideline should be read in conjunction with Micro Hydropower: System Design Guidelines for clarity/confirmation/verification on design aspects.

Before commencing the installation process, you should have selected the appropriate components and consulted your local regulations concerning use of water and undertaking electrical work.

The main components of a typical micro hydropower system as depicted in Figure 1 are:

- **Weir**: is a man-made barrier across the river which is built to keep the water level at that point at a constant level to maintain a continuous flow through the intake.
- **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.
- **Channel or head race**: a channel that connects intake and temporary storage facility such as a forebay tank.
- **Forebay**: allows water to slow down sufficiently for suspended particles to settle out on the bottom.
- **Penstock**: a cavity or pipeline that connects water storage to the power house. Gravity conducts the water through the penstock to the turbine.
- **Turbine**: The water strikes the turbine blades and turns the turbine, which is coupled to a generator by a shaft. There are a few different types of turbines, each distinct in usage based on head and flow rates.
- **Generator**: Converts the mechanical energy in the rotor to electrical energy through electromagnetic induction to produce alternating current (a.c).

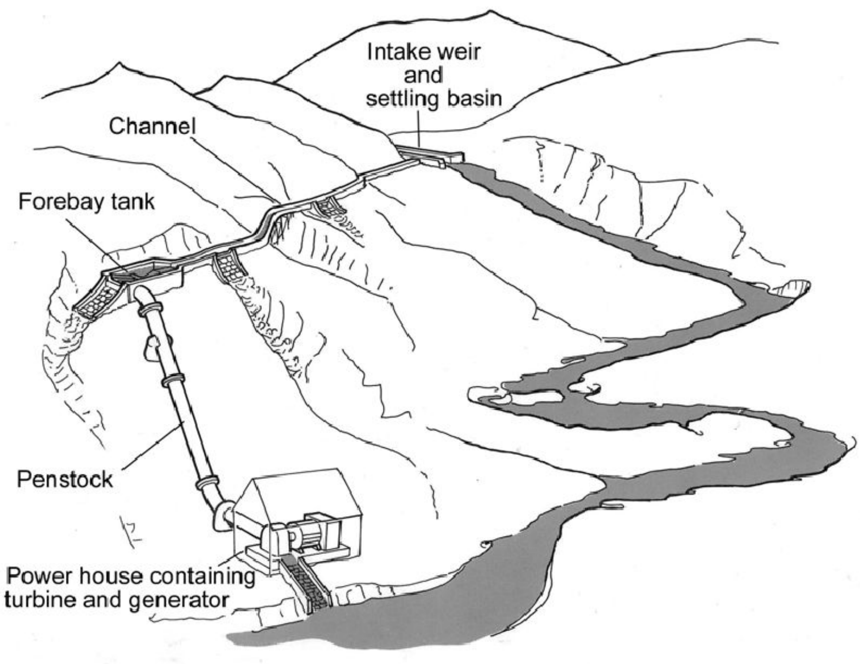


Figure 1 Typical Arrangement of a Micro-hydro System
Source: IntechOpen

The guideline, therefore presents information pertaining to above major components. However, since there is a good portion of civil components, they have been summarized appropriately to be understood well by a person having no civil background. It is recommended that a civil engineer is consulted for all civil works further to the guidelines. Most importantly, this guideline focusses on electrical installation, wiring and protection aspects. There is more elaboration on a.c. coupled systems, since the a.c. based systems are more common in the Pacific compared to d.c. based systems, however fundamental guides on d.c. coupled systems have been presented where necessary.

2. Relevant Standards and Guidelines

System installations should follow any standards that are typically applied in the country or region where the micro hydro installation will occur, in particular, the electrical works. The following are the relevant standards in Australia, New Zealand and the USA. Some Pacific island countries and territories follow these standards though with some modifications to better fit local conditions. These standards are often updated and amended so the latest version should always be applied.
In Australia and New Zealand, the relevant standards include:

- AS/NZS 1768 — Lightning Protection.
- AS/NZS 3000 — Wiring Rules.
- AS/NZS 3008 — Electrical Installations - Selection of Cables.
- AS/NZS 5139 — Electrical installations - Safety of battery systems for use with power conversion equipment).
- AS/NZS 4509 — Stand-alone power systems.
- AS 3011 — Electrical Installations - Secondary batteries installed in buildings.
- AS 2676 — Guide to the installation, maintenance, testing and replacement of secondary batteries in building.
- AS 2638.1-2011 — Gate valves for waterworks purposes – Part 1: Metal seated
- AS 2638.2-2011 — Gate valves for waterworks purposes – Part 2: Resilient seated
- AS/NZS 4087-2011 — Metallic flanges for waterworks purposes
- AS 4795.1-2011 — Butterfly valves for waterworks purposes – Part 1: Wafer and lugged
- AS 4795.2-2011 — Butterfly valves for waterworks purposes – Part 2: Double flanged
- IEC 61116 — Electromechanical equipment guide for small hydroelectric installations
- IEC 62006 — Hydraulic Machines - Acceptance Tests of Small Hydroelectric Installations

In USA the relevant codes and standards include:

- Electrical Codes — National Electrical Code and NFPA 70
- IEC 61116 — Electromechanical equipment guide for small hydroelectric installations
- IEC 62006 — Hydraulic Machines - Acceptance Tests of Small Hydroelectric installations

Additionally, it is recommended that the components used such as micro hydro-turbines, micro hydro-generators or micro-hydro turbine-generator group, comply to the international safety standards as far as possible to avoid injury due to moving parts and other unexpected incidents due to system/ component failure.

3. Voltage Limits and Work Restrictions

Some countries in the Pacific follow the voltage limits as defined in the Australian/New Zealand standard AS/NZS 3000 where:

- Extra Low Voltage (ELV) is <120V d.c. or <50V a.c.
- Low Voltage (LV) is >120V d.c. and <1500V d.c. or >50V a.c. and <1000 a.c.

In following this, some countries impose the following requirements on licensed or registered electricians:

Extra Low Voltage Work:

All ELV wiring should be performed by a 'competent' person, which is defined in various standards: "a person who has acquired through training, qualifications, experience or a combination of these, knowledge and skill enabling that person to correctly perform the task required."

Low Voltage Work:

All LV work: >120V d.c. or >50V a.c. should be performed by a trained electrician or similar (e.g. licensed or registered).
In the NEC standard anything above 60V d.c. is considered dangerous. LV is dangerous and can kill a person if they come into contact with live terminals.

4. General Safe Working Practices

To meet good working practices and safety requirements, the installer must:

- Check for any transit damage to the components prior to installing it, if damaged it must not be installed.
- Install/connect equipment in compliance with the relevant national/regional standards.
- Always read and comply with manufacturer's installation manual and aspects.
- If the a.c micro-hydro unit or the d.c. unit produces LV, all metallic portions of the turbine/generator shall be electrically earthed.
- Protect the supply cable from the generator in conduit as per local wiring rules, ensure wiring, cable insulation, conductors and routing of all wires of the equipment is suitable for the electrical, mechanical, thermal and environmental conditions of use.
- Securely fix the turbine base prior to operation and tighten all electrical connections inside the generator.
- If batteries are to be used in a d.c. system, installation should comply with relevant installation and safety standards in the country/region.
- Always complete turbine/generator testing and commissioning prior to use.
- Train the end owner/user of the turbine/generator in routine care and maintenance of the hydro system.
- Complete all documentation as required in this guideline and in local wiring rules.
- Ensure that all protective enclosures are in position after commissioning and prior to client hand over.
- Do not intentionally run turbine unloaded (for other than short duration open circuit voltage testing).
- Do not run turbine at a head significantly above the name plate rating.
- Comply with signage requirements as listed in relevant national/regional standards or as those accepted as best industry practices.
- In a turbine runaway situation turn off the water supply by closing the water supply valve(s). Check for excessive noise.
- Always check the voltage of conductors prior to touching conductors on equipment that have been recently turned off while testing.
- Do not install stop valves at pipe intakes, unless there is an air vent to prevent negative pressure pipe collapse.
- A stop valve should be fitted at the end of the pipe prior to the turbine. A sign at this turbine stop valve to "turn off slowly" may be a good reminder to reduce water hammer effect.

- Ensure that the installation includes the following as a minimum: voltmeter, ammeter, wattmeter/ energy meter, pressure gauge and overcurrent protection devices.
- If necessary, bury the penstock to protect it against rock falls, tree falls, slips, etc.

5. Site Verification for Micro-hydro Turbine

Prior to installation, it should be verified that the site chosen is appropriate for a micro-hydro turbine, the following points should be considered:

a. Determining the maximum static head as far as possible.
b. Being within a suitable distance for transmission of electrical power to the dwelling/households.
c. Accessibility of the site.

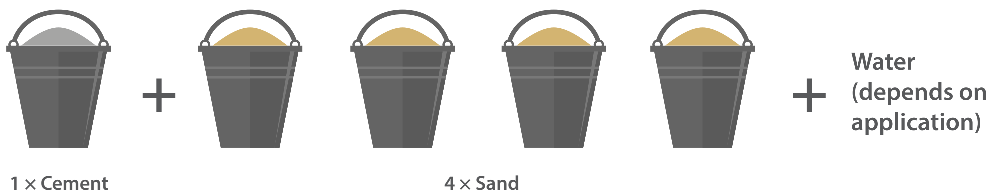
The likely flood level for the site should be re-assessed, in order to either locate the turbine above flood level, or, where the turbine and generator will withstand flooding, make provision for adequate protection from floodwaters and flood-borne debris.

Any local regulations regarding diversion of water from the watercourse should be met.

6. Civil works: Construction and Installation

All civil works should be of adequate construction to withstand flooding, where such works are below flood level. This includes dams, pipes and their anchors, filters and turbine mounting or housing. All civil works shall commence under qualified civil personnel who has prior experience in building of micro hydropower systems successfully.

As a recommendation for brick work / masonry, the following sand and cement ratio is recommended for use in cement mortar. Cement mortar shall be composed of 4 parts by volume of sand with 1 part by volume of cement.



Note, sand shall be evenly graded from fine to coarse, particles measuring max. 4 – 5 mm. sand shall be gritty, hard particles free from dust, clay or organic matter. otherwise to be washed until free of any foreign material.

For civil work design guides, refer to section 6 of Micro-hydropower: System Design Guidelines.

6.1 Weir Construction

Some important considerations on weir construction are:

- That the weir should be able to survive the largest flood likely to occur in the lifetime of the micro-hydro scheme.
- The walls must be suitably high and prevent the flood waters from causing damage to the channel works. For wall height calculations, refer to section 6.1 of Micro-hydropower: System Design Guidelines.
- The walls must be built with appropriate materials that has a long life such as wall built from gabions (wire cages with boulders), or concrete, or rock and mortar to a substantial thickness.

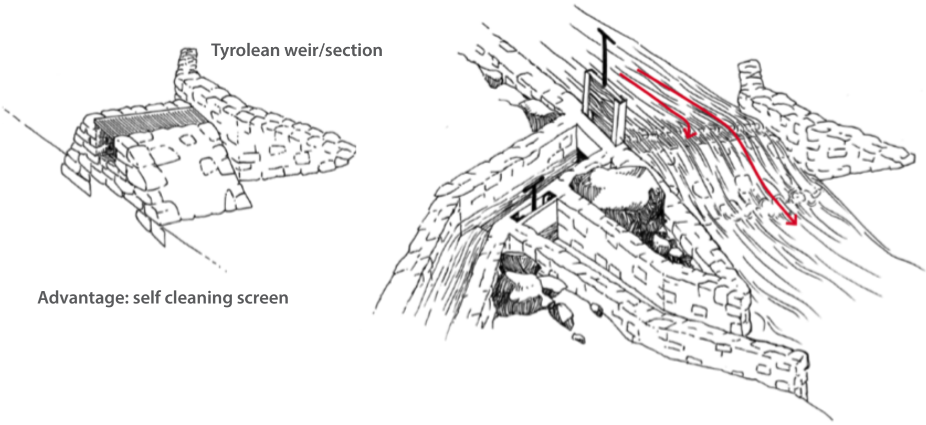


Figure 2: Tyrolean Weir construction [1]
Source: Practical Action

6.2 Channel construction

Some important considerations in channel construction are:

- The side slope and cross-sectional profile should be appropriate for the application and ensure that it is free from sedimentation.
- The channel must be durable and reliable.
- The channel constructed must survive storm run-off, rockfalls crossing its path, or by landslip.
- The channel must not spill when it is carrying excessive water. The channel should accommodate the design flow and have additional capacity.
- If it involves high channel flows, it should be regulated by spillways.

Figure 3 Channel/head race
Source: Environment Science for Social Change (ESSC)

[1] Micro hydro power Scout Guide

6.3 Spillways Construction

The spillway is the channel flow regulator and is often combined with control gates as a means of channel emptying. The spillway construction should consider the following:

- The control gates must be placed at a distance from the stream to allow easy access when the river is in flood.
- It is advisable not to rely on one channel-emptying mechanism, but have two, since a gate can fail to operate when needed if not often used.
- In low cost micro hydro schemes, gates could be eliminated altogether, instead, it can be replaced with less expensive stop-log and rack arrangement

Figure 4 Simple stop-log and rack kind of arrangement
Source: Pond Boss magazine

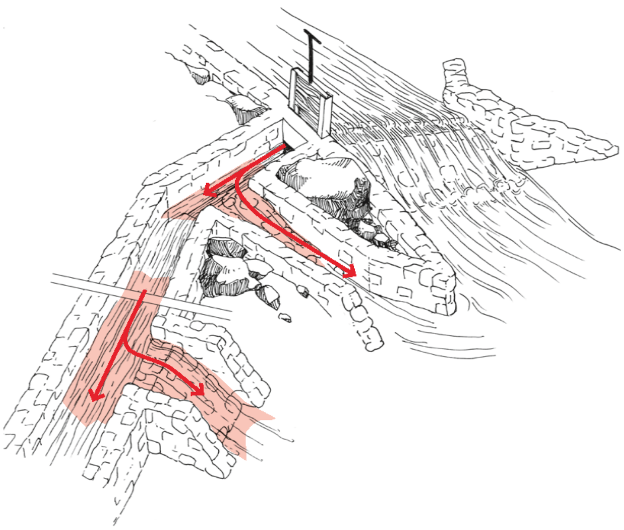


Figure 5 Two Spillways placed at a distance apart[2]
Source: Practical Action

[2] Micro hydro power Scout Guide

6.4 Water intake Installation

- The penstock inlet should be located at a suitable natural pond or small dam or forebay tank and fitted with a filter. The filter should be of such construction as to withstand flood conditions, and should resist blockage to an extent that will prevent reduction of turbine performance. This maybe also called trash rack.
- The size of the trash rack should be such that it allows suitable flow velocity that does not attract bedload and debris as this may result in increased head loss).
- Since boulders can frequently impact the coarse trash rack, it needs to be robust, i.e. thick steel sections should be used. Depending on the length and width of the opening, nature of the sediment load and the required flow, a clear spacing of 50 mm to 200 mm can be used.

6.5 Forebay Tank Construction

When constructing the forebay tank, the following must be ensured:

- The entrance to the penstock must be fully submerged. A rule of thumb is to submerge the penstock mouth by a distance below the water level of more than 4 penstock diameters.
- It is necessary to install an air vent at the point where the penstock is joined to the forebay tank to prevent damage to the penstock in the event that the mouth is blocked.
- A trash rack should also be placed before the penstock mouth to prevent clogging from debris.

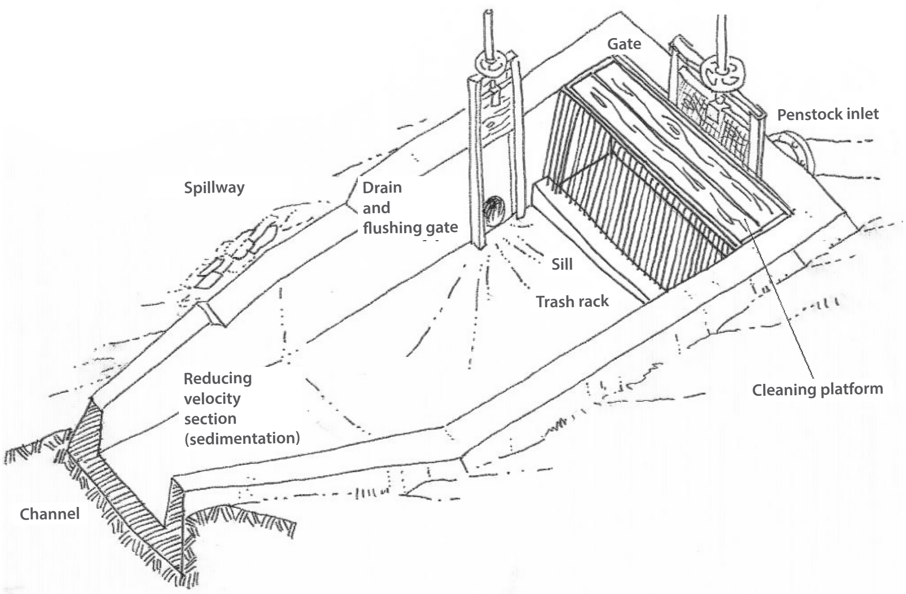


Figure 6 A well designed forebay tank layout
Source: Practical Action

7. Penstock Installation

Prior to installation, the type and size of penstock pipe needs to be verified to ensure minimum wall friction losses and also turbulence losses. Refer to Section 7 of the Micro-Hydropower; System Design Guidelines.

Also, verify that the pipe is of appropriate thickness to withstand the hydraulic pressures experienced in the system in all operational conditions. This includes the static head as well as any transient conditions caused by flow regulation at the turbine, blockages or air pockets. A pressure conversion table is provided in Annex 1 that provides details on expected pressure at different heads.

All pipes should be anchored at regular intervals and at all elbows, to ensure secure fixing under all operating conditions.

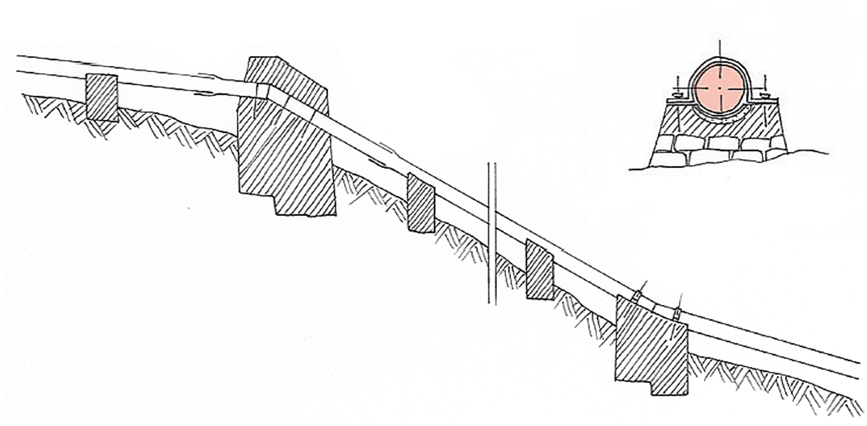


Figure 7 Penstock anchoring
Source: Practical Action

- The penstock should be laid in such a way as to prevent the formation of air pockets which may reduce the performance of the turbine or, where this is not possible, air release valves should be installed at appropriate points.
- Avoid crossings, inaccessible terrain etc.
- Try keeping the penstock in straight alignment as far as possible.
- The penstock should be joined with appropriate jointing methods stated in Section 7.1.

Figure 8 Penstock Installation works in Vanuatu
Source: Pacific Regional Data Repository (PRDR)

7.1 Penstock Jointing

Penstock pipes shall be jointed with appropriate jointing methods. Some recommended methods are: flanged joints; spigot and socket joints; mechanical joints and welded joints.

7.1.1 Flanged joints

- Water pipe flanges should normally only be coupled to identical flanges using studs or bolts with washers on both sides of the joint and nuts.
- Ensure proper bolt and gasket selection.
- Ensure proper alignment of the joint before tightening.
- Do not tighten bolts in rotation: They must be tightened in a crossover pattern to torque the bolts evenly.
- Take into account applied bolt torque and achieved gasket stress

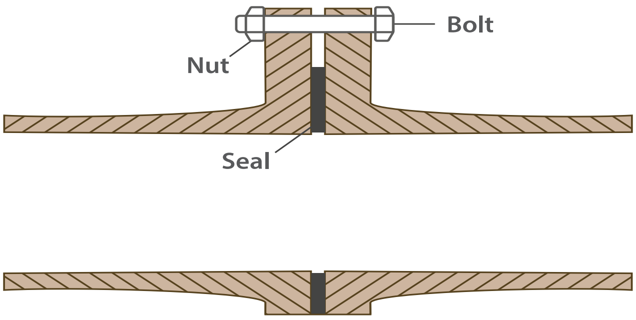


Figure 9 A Flanged joint

7.1.2 Spigot and socket joints

- Ensure using a good seal between each pipe section.
- The seal must be clean before assembly.
- A special lubricant must be used. Avoid the use of grease, use soap as an alternative.
- For pipes over 50mm, always use clamps and ratchet pulley to ‘pull’ the two halves of the joint together.
- Ensure proper alignment of the joint.

Figure 10 Picture showing Spigot and socket jointing
Source: Pelena Energy

7.1.3 Mechanical joints

- This joint may allow slight deflection.
- This joint could be used for jointing pipes of different materials.
- Some joints will require restraining by anchor blocks.

7.1.4 Welded joints

- Used on mild steel penstocks.
- Should be done by a competent welder.
- Ensure corrosion protection of the joints upon welding.

8. Valve Installation

For micro-hydropower applications, the most usual types are gate and butterfly valves. However, other applicable technologies that are designed for micro-hydropower applications could be used upon consultation with Hydro power experts. Always follow manufacturer's guide and the right tools to install these valves in the system.

8.1 Gate valve installation

- Verify that manufacturer documentation matches your specifications.
- Verify the pressure rating of the valve against the application requirement.
- Piping should be supported by hangers placed on either side of the valve and large heavy valves should be independently supported
- Handle valve only with apparatus that will adequately support it, using a safe and proper technique.
- Install the valve using good piping practices.
- Pipe Line and valve must be cleaned of all foreign materials.
- For flanged end valves
- Check and align pipe flanges. Use proper type and size fasteners.
- Use a proper type and size gasket
- Do not attempt to fit two flanges that are not matched. Plain face with plain face or raised face with raised face are the proper procedure. Bolting together flanges of two different materials requires special instructions.
- Do not tighten bolts in rotation: They must be tightened in a crossover pattern to torque the bolts evenly.

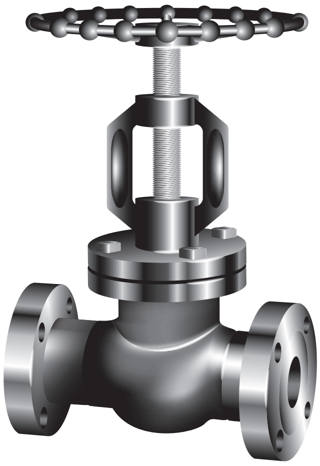


Figure 11 A Gate Valve

8.2 Butterfly valve installation

- Verify the material of the butterfly valve, seat and disc before installation with the specifications required. Ensure that there are no defects caused by storage or transportation.
- Valves can be installed in any orientation however it is best if it can be installed upright especially in bigger sizes to reduce load on the shaft.
- Verify the pressure rating of the valve against the application requirement.
- Complete all welding works before valve installation and be sure the flange has cooled to ambient temperature before installing the butterfly valve.
- Make sure there is no welding residue, waste, rust or other debris in the pipe before installation. Wash with water or a mild detergent if needed.
- Clean the surface of the flange that will come in contact with the butterfly valve to ensure it is free of rust and debris. Wash with water or a mild detergent if needed.
- Make sure there is no warpage of the flange or misalignment of the butterfly valve in relation to the flange. This is the most common cause of butterfly valve problems where it is not aligned with the flange/pipe correctly and the disc catches when trying to open/close. Support the valve where necessary to reduce load from the piping assembly.
- Install spacing bolts taking care not to damage the valve seat and adjust the face to face of the two flanges so there is space when the piping is spread open (enough space to remove the valve or replace it for maintenance).
- Once the pipes are centred, insert the bolts so that the bottom of the valve can rest upon them to prevent the valve from falling through.
- Before tightening the bolts operate the valve to ensure it does not catch on the pipework or the flange.
- Do not tighten bolts in rotation. They must be tightened in a crossover pattern to torque the bolts evenly. so even pressure is applied and a seal is formed between the valve and flanges.
- Once the installation is complete operate the valve several times to ensure it is free from impingement and it has not moved during installation.

Figure 12 A Butterfly Valve

9. Power House Construction

The power house has to be designed and constructed to the requirements of the turbine and its connections to the tail side.

The powerhouse of the micro-hydropower plant is equipped with hydro turbine, hydro power generator, distributor control panel and other auxiliary equipment. The Powerhouse should be easily accessible for operation and maintenance, compact in size, and conform to the economy and relevant standards. The following shall be ensured during construction:

1. Power house should be situated in a location to be safe from immersion through rising floods.
2. Hydropower turbine and generator set installation should be firm. Power house should be dry, properly ventilated and should have a smooth drainage.

During the power house construction, the tail race should be accommodated depending on the type of turbine utilised. Tailrace channel is the drainage channel after the hydro turbine draft tube. For some impulse turbines, tailrace channel function is to drain away the water from the turbine. For some reaction turbines, its tailrace has certain requirements, building must be set strictly in accordance with the requirements of hydropower turbine manufacturer and supplier. See section 10.1 for illustrations on tail race.

10. Hydro Turbine, Hydro Generator or Turbine-Generator Group Installation

Fundamentally, all turbines, generators or turbine-generator group installations shall comply with manufacturer's installation instructions. Additionally, the following points need to be considered.

10.1 Turbine Installation

- Verify that the site selected is located appropriately to provide the most pressure and optimum flow to ensure maximum output with the components selected. Refer to Section 7 of the Micro Hydropower: System Design Guidelines on selection.
- The turbine shall be installed according to the manufacturer's instructions.
- Ensure the site is not subject to flooding.
- The hydro turbine needs to be installed in a shed or enclosure to provide extra protection against the environment and to ensure reduced noise. It is also advisable to have it bolted down onto a floor or fixed structure.
- Prefer use of an intake filter.
- Ensure all air has been expelled before operation by filling with water.
- The turbine should have provision for maintenance.
- Crossflow and Pelton lose tail head in power generation as the water expels to open air with a chamber beneath the turbine. See figure 13 for illustration and compare with figure 14 to identify the difference in tail race requirements for different turbines.

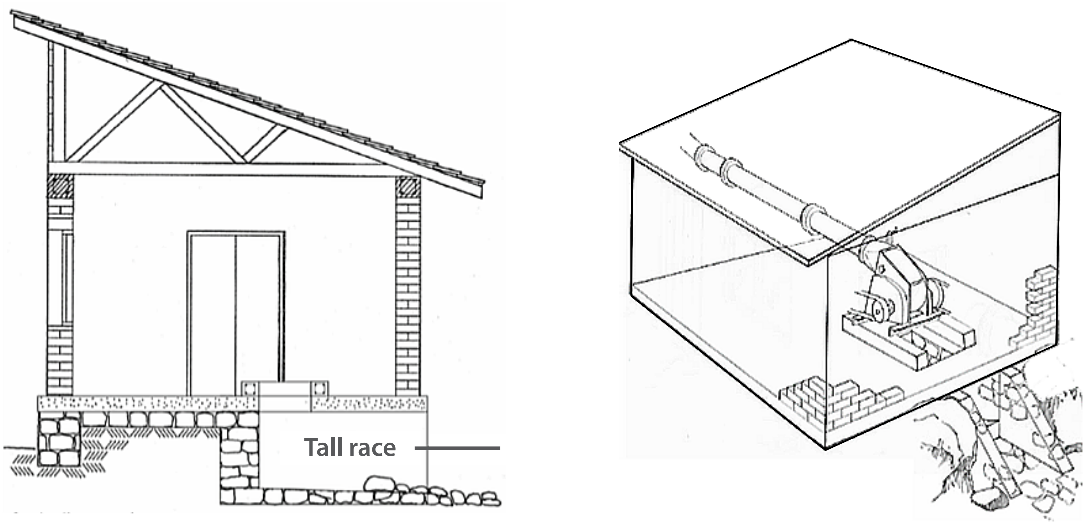


Figure 13 Tail race required for Pelton and cross flow turbines
Source: Practical Action

- Francis turbines and a few other reaction turbines utilize the full head to tail water level. See figure 14 for illustration.

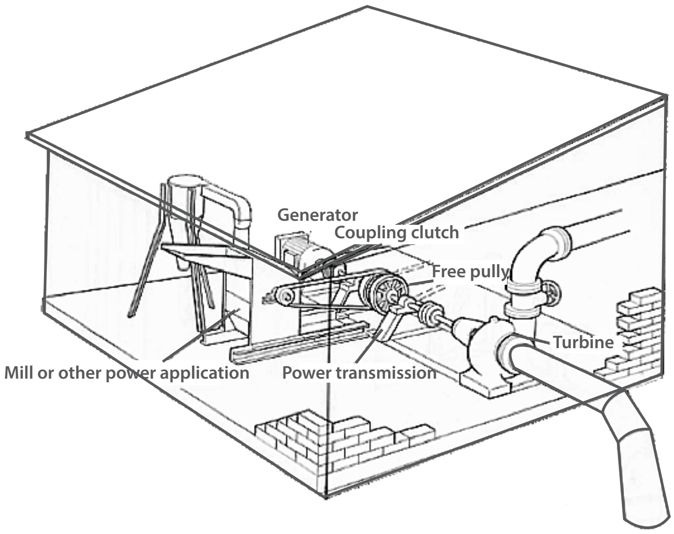


Figure 14 Typical reaction turbine installation
Source: Practical Action

10.2 Hydro Generator set Installation

The hydro generator or turbine/generator unit shall be installed according to the manufacturer's instructions.

Specifically, the following recommendations apply to hydro generating set installation:

a. Hydro generating set installation should allow for an adequate air flow for cooling sufficient to maintain the air temperature around the hydro generating set within manufacturer's specified operating temperatures, during normal operating conditions.
b. The hydro generating set should be easily accessible for maintenance purposes.
c. The hydro generating set accommodation should be constructed in such a way as to ensure stability, reduced noise emission from the body to an acceptable level and appropriate provisions of protection to personnel and equipment in case of failure.

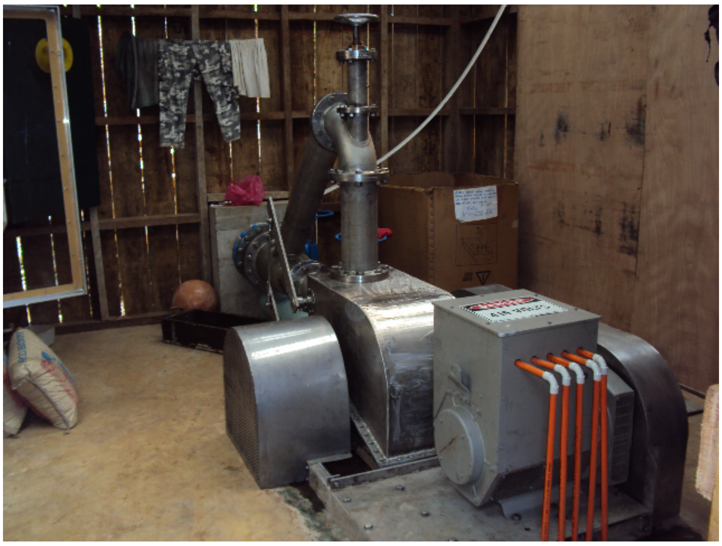


Figure 15 A picture showing a micro hydro range turbine-generator installation
Source: Pelena Energy

10.3 Vibration

All piping, ducting or cable connections between the generator and any fixed point should include flexible sections to withstand the vibration experienced under all operating conditions for the expected life of the hydro generating sets. The mounting of the hydro generating set should include adequate vibration isolation.

11. Drive System Installation

11.1 Direct-coupled drive system

Some of the important points to consider in installation of this system are:

- Both turbine and generator may be bolted to concrete foundation or rigid structure at same height.
- Alignment of shafts must be correct to prevent failure of coupling or bearings.
- Flexible in-line coupling is needed. A flexible coupling exists to transmit power (torque) from one shaft to another, to compensate for minor amounts of misalignment and, in certain cases, to provide protective functions such as vibration dampening, etc.

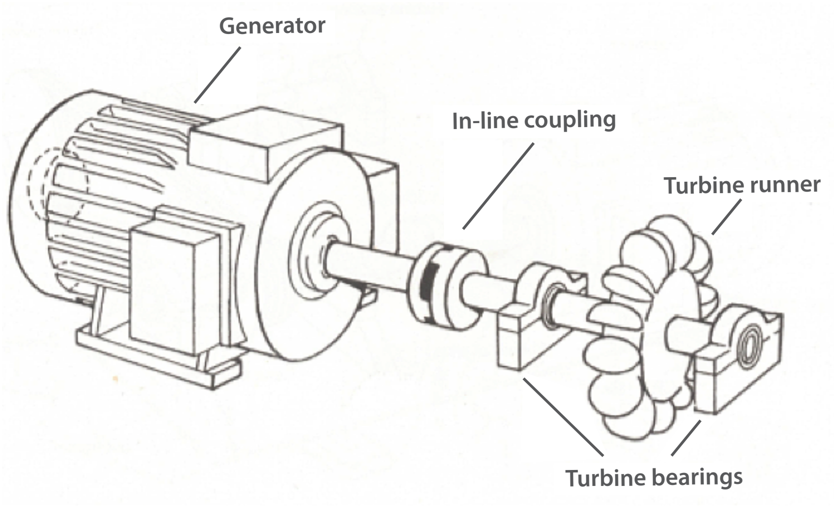


Figure 16 Direct coupled drive system
Source: Practical Action

11.2 Wedge belt drive system

Some of the important points to consider in installation of this system are:

- Generator shall be mounted on side rails to obtain belt tension.
- Turbine and generator may be at different heights.
- Direction of rotation should pull on the lower part of the belts.

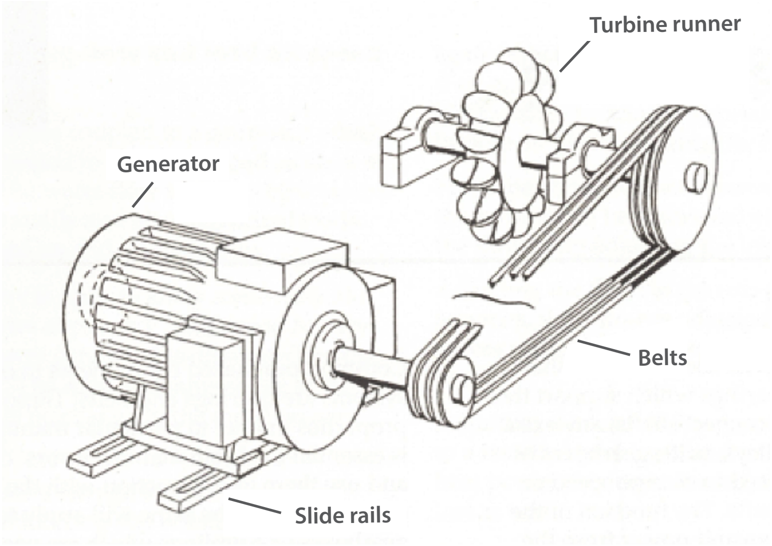


Figure 17 Wedge belt drive system
Source: Practical Action

11.3 Wedge belt drive system with extra bearings

Some of the important points to consider in installation of this system are:

- Turbine may have an extra shaft and bearings for the generator.
- The generator extension shaft must be removable from the bearings to enable belts to be changed
- Flexible in-line coupling required with the generator shaft. A flexible coupling exists to transmit power (torque) from one shaft to another, to compensate for minor amounts of misalignment and, in certain cases, to provide protective functions such as vibration dampening, etc.
- Direction of rotation should pull on the lower part of the belts.

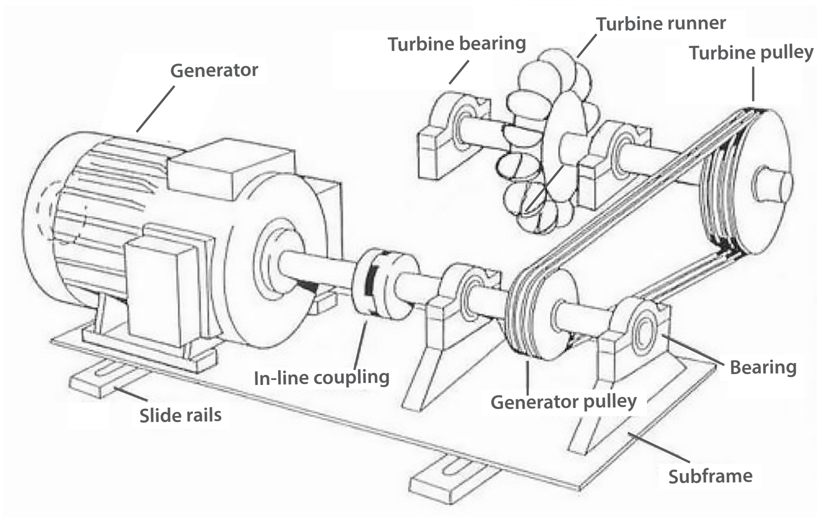


Figure 18 Wedge belt drive system with extra bearings
Source: Practical Action

11.4 Quarter turn belt drive

Some of the important points to consider in installation of this system are:

- Generator shall be mounted on slide rails to obtain belt tension.
- Extra bearings, shafts and couplings may be used.
- Turbine and generator pulleys must be aligned with care.

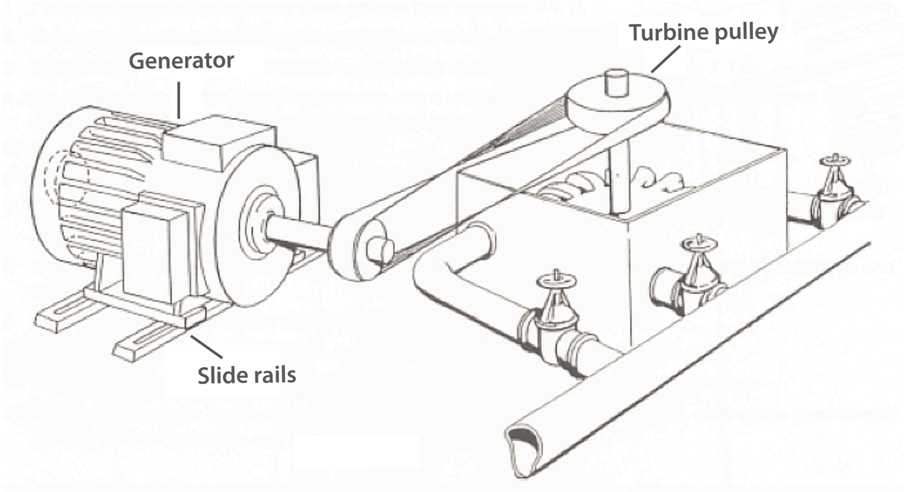


Figure 19 Quarter turn belt drive
Source: Practical Action

11.5 Direct coupled turbine and geared motor used as a generator

Some of the important points to consider in installation of this system are:

- Various types of gears may be used: spur gears, helical gears and bevel gears which are suited to speed increasing drives. Worms and worm wheels are not suitable because they will not run backwards.
- The gearbox provides the speed change between turbine and generator so the ratio should be verified before installation.

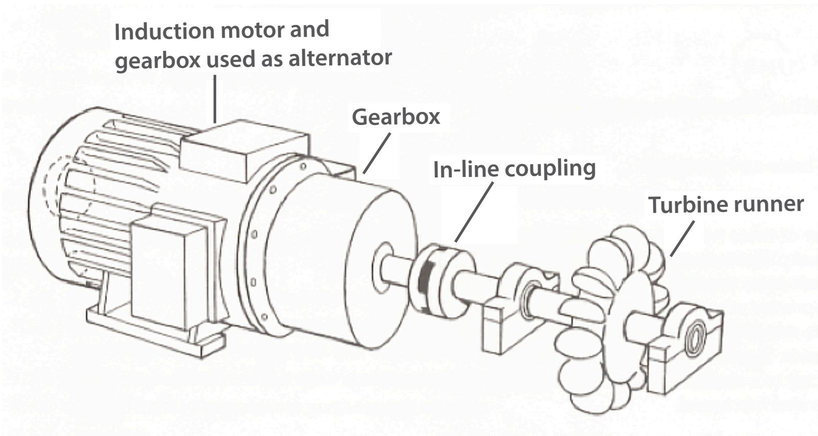


Figure 20 Direct coupled turbine and geared motor used as an alternator
Source: Practical Action

11.6 Turbine rotor mounted on generator shaft

Some of the important points to consider in installation of this system are:

- The turbine and generator speed should match.
- There has to be clearance between turbine and generator to avoid water splash interference.
- The bearings should be able to tolerate the side load of the turbine.
- Alternatively, a geared motor unit may be used as a generator.

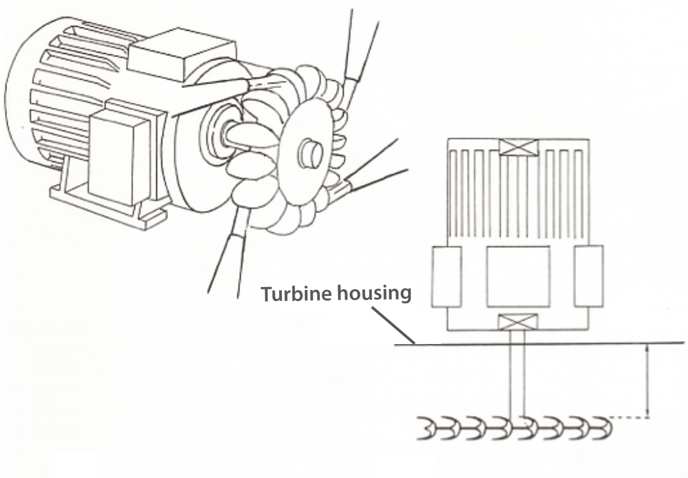


Figure 21 Turbine rotor mounted on generator shaft
Source: Practical Action

12. Wiring, Switchgear and Protection

12.1 Wiring

- All electrical wiring shall be done in accordance with local/regional standards.
- All a.c. and d.c. cables used shall be rated for maximum current, voltage and temperature expected in the system.
- All a.c. and d.c. cables shall satisfy the current carrying capacity, voltage drop and other minimum size requirements for conductors. Additionally, they shall be sized to minimise voltage drop, in the absence of local/regional standards, a maximum value of 5% is recommended from the point of distribution for a.c circuits.
- Cabling from generator shall be installed in accordance with local/regional standards. Generally, it must be protected against any potential mechanical (or moving parts), thermal and environmental damage and also prevent any entry of moisture. This could be achieved through the use of HD conduits being properly secured.
- Wiring systems shall be fixed in position by suitable clips, saddles or clamps or by means that will not damage the wiring system and that will not be affected by the wiring system material or any external influences. Cabling and/or enclosures shall be secured with appropriate fasteners at regular intervals that are resistant to corrosion and ensure durability. Plastic cable ties are not recommended as primary means of support.
- Cables shall be appropriately terminated such as to avoid sudden and direct contact to equipment and personnel and should ensure water ingress protection.
- All cabling shall be protected with an overcurrent protection device that has been sized based on local/regional standards.
- Where aerial wiring is done, the installation shall meet the required minimum clearances, maximum spans, etc. according to the local/regional wiring standards.
- If underground wiring is adopted, cables shall be laid at appropriate depth in HD enclosures and shall fully comply with local/regional standards on underground installation aspects.
- Overall, the wiring shall meet the additional requirements as specified in the equipment manufacturer’s instructions.

Figure 22 Cabling on a Micro hydro Project in Vanuatu
Source: Application Solutions

12.2 Switchgear and Protection

All micro-hydro installations should have some form of switchgear to automatically disconnect supply in case of faults. The purpose of the switchgear is to isolate the power supply when necessary (maintenance) and also to have some control over the electrical power flow. The protection equipment should operate in normal circumstances and should isolate the power supply when a fault occurs.

The protection shall meet the following requirements:

- Follow local/regional wiring standards on protection requirements (AS/NZS 3000/ NEC).
- The protection device shall be appropriately rated for use and carry rated currents without deterioration.
- The protection device shall isolate the circuit in a timely manner before any damages to equipment or personnel.
- The protection device shall be sized appropriately to protect against overloads and short circuit events.
- The protection device shall be rated for the prospective fault currents expected in the system.
- The protection device shall ensure co-ordination/discrimination in operation to ensure the nearest protection device trips first, then the second most and so forth where there are various stages of supply distribution.
- All light and power sockets shall be protected by Residual Current Devices with appropriate rating and tripping current desired in local/regional standards.

Additionally, in **Damp situations:**

- The protection device shall provide additional protection against electric shock in locations where the presence of water or high humidity presents an increased risk; and
- The protection device shall provide adequate protection against damage that might reasonably be expected from the presence of water or high humidity.

Furthermore, the a.c. hydro generator shall be protected against abnormal running conditions such as:

- Overloading
- Overvoltage/undervoltage
- Under-frequency/over-frequency
- Insufficient water flow
- Earth faults and Phase to phase faults (three phase installations)

In large micro hydro systems, further protection against the following is also recommended:

- Loss of excitation
- Unbalanced loading
- Lubrication oil failure
- Failure of turbine
- Rotor displacement
- Excessive vibration
- Always discuss above with the manufacturer.

12.3 Equipment Earthing/Grounding

- Earthing/Grounding of all exposed metal (equipment bonding) should be done as required by local/regional wiring standards. Make sure you establish a good electrical "bond" that can last the lifetime of the system. Equipotential bonding is recommended for associated metallic parts.
- Read the equipment instruction manuals to see what is recommended or if not stated, check local regulations for sizes of earthing conductors and earth electrodes.

13. Controls and Auxiliary Installation

All control and auxiliary components shall be installed according to the manufacturer's instructions ensuring appropriate clearances, ventilation, water ingress protection and protection against mechanical, thermal or environmental damage. All water prone devices shall be IP56 rated.

Figure 23 Control Panel
Source: Pelena Energy

13.1 d.c. coupled systems

Furthermore, where d.c. coupled systems are installed, the battery installation shall comply with relevant local/regional battery standards to ensure safety, ventilation and clearances to avoid risk of fire and accidents. The batteries shall be housed in a properly ventilated room with appropriate mechanical and electrical protection. The battery cables and protection devices shall be sized appropriately to avoid insulation failure. The battery system shall accompany an industry standard charge controller/system controller to ensure charging control and eventually, a longer life. (Refer to the PPA/SEIAPI guideline titled: Off Grid PV Power Systems -System Installation Guidelines for further information)

14. Shutdown Procedure

- A shutdown procedure is required to ensure safe de-energisation of the system.
- The shutdown procedure shall reflect the specific requirements of the individual system.
- The shutdown procedure shall include both electrical and water isolation.

A simple 'shut-down' procedure that maybe used include:

1. Close the inlet valve or the guide vane.
2. Put load switch off.
3. Close the inlet valve and the guide vane completely.
4. Close the intake gate

- All isolating switches/valves/auxiliary equipment referred to in the shutdown procedure shall correspond to individual equipment labels. e.g. 'Main Switch, "Hydro generator Isolator 1", "Valve 1", etc.
- The shutdown procedure shall show a step-by-step procedure on shutting down a system for maintenance or when required.

15. Metering

As a minimum each system should have meters showing:

- generator terminal voltage
- generator output current
- frequency (if a.c.)
- power factor (if a.c.)
- energy produced in kWh
- pressure gauge

16. Signage

- All equipment/components/controls and protection devices shall be labelled and where there is more than one, they shall be numbered in ascending order.
- A sign showing the proper Shutdown Procedure shall be located near the system.
- Caution signs shall be displayed to indicate the extent of electrical hazards present and the risks present due to moving equipment or failure of system, as listed below in figure 24 and 25.

Figure 24 Caution sign to denote risk of electric shock

Figure 25 Caution sign warning against risks of personal injury or damage to equipment

17. Testing and Commissioning

17.1 Testing

All electrical wiring and operation shall be tested before operation. The following mandatory tests shall be conducted on all electrical wiring and associated components:

- Continuity test
- Polarity test
- Insulation resistance test
- Earth/ground continuity test

The generator specifications should contain very complete and clearly phrased factory and field test sections. The tests required should be explicitly listed, or accompany a test certificate.

Field test results that could be present include[2]:

a. Measurement of winding resistance;
b. Phase sequence test;
c. Regulation test
d. Measurement of leakage reactances and potier reactance
e. Measurement of open-circuit characteristic
f. Measurement of short-circuit characteristic
g. Efficiency test;
h. Temperature-rise test;
i. Over speed test;
j. Insulation resistance test (both before and after Dielectric test);
k. Dielectric test;
l. Determination of deviation of voltage wave form from sinusoidal

Depending upon presence of test equipment, upon installation, the essential results shall be verified such as:

- Correct Phase sequence
- Measurement of open-circuit characteristic
- Temperature-rise test
- Insulation resistance test

[2] http://ahec.org.in/publ/Modern_Hydroelectric_Engineering_Practice_Prof_OD_Thapar/Volume_I/Chapter-12_Hydro_Generator_and_Excitation_System_Tests.pdf

17.2 Commissioning

The size and type of components present in a micro-hydropower system will differ from one system to another. The commissioning sheets similar to one attached in Annex 2 should be completed by the installer. This could be fabricated to suit the system at hand and completed accordingly. A completed copy shall be provided to the customer as part of the system documentation and a copy retained by the installer that has been initialled by the customer showing it to be a true copy of the commissioning sheets provided to the customer.

18. Documentation

All complex systems require a user manual for the customer, Micro-hydropower systems are no exception. As a minimum, the documentation for system installation that shall be provided includes:

- List of equipment supplied with each item's model, description and serial number.
- List of action to be taken in the event of common expected faults or emergency.
- Shutdown and isolation procedures for emergencies and for maintenance.
- Commissioning sheet and installation checklist.
- Warranty information.
- A basic connection diagram that includes electrical ratings of the turbine, generator or turbine-generator group, the associated control and auxiliaries and ratings of all overcurrent devices and switches as installed.
- System performance estimate.
- Recommended maintenance procedures and timetable for the installed system.

Annex 1 Pressure Conversion Charts

Pressure Conversion Table

metres	kPa	feet	PSI	metres	kPa	feet	PSI	metres	kPa	feet	PSI	metres	kPa	feet	PSI
5	49.03	16.42	7.11	10	98.1	32.84	14.22	20	196	65.7	28.4	45	441	147.8	64.0
5.1	45.96	16.75	7.25	10.2	100.0	33.50	14.51	20.5	201	67.3	29.2	46	451	151.1	65.4
5.2	46.86	17.08	7.40	10.4	102.0	34.15	14.79	21	206	69.0	29.9	47	461	154.4	66.8
5.3	47.76	17.41	7.54	10.6	104.0	34.81	15.08	21.5	211	70.6	30.6	48	471	157.6	68.3
5.4	48.66	17.73	7.68	10.8	105.9	35.47	15.36	22	216	72.3	31.3	49	481	160.9	69.7
5.5	49.56	18.06	7.82	11	107.9	36.12	15.65	22.5	221	73.9	32.0	50	490	164.2	71.1
5.6	50.46	18.39	7.96	11.2	109.8	36.78	15.93	23	226	75.5	32.7	51	500	167.5	72.5
5.7	51.37	18.72	8.11	11.4	111.8	37.44	16.21	23.5	230	77.2	33.4	52	510	170.8	74.0
5.8	52.27	19.05	8.25	11.6	113.8	38.10	16.50	24	235	78.8	34.1	53	520	174.1	75.4
5.9	53.17	19.38	8.39	11.8	115.7	38.75	16.78	24.5	240	80.5	34.8	54	530	177.3	76.8
6	54.07	19.70	8.53	12	117.7	39.41	17.07	25	245	82.1	35.6	55	539	180.6	78.2
6.1	54.97	20.03	8.68	12.2	119.6	40.07	17.35	25.5	250	83.7	36.3	56	549	183.9	79.6
6.2	55.87	20.36	8.82	12.4	121.6	40.72	17.64	26	255	85.4	37.0	57	559	187.2	81.1
6.3	56.77	20.69	8.96	12.6	123.6	41.38	17.92	26.5	260	87.0	37.7	58	569	190.5	82.5
6.4	57.67	21.02	9.10	12.8	125.5	42.04	18.21	27	265	88.7	38.4	59	579	193.8	83.9
6.5	58.57	21.35	9.24	13	127.5	42.69	18.49	27.5	270	90.3	39.1	60	588	197.0	85.3
6.6	59.48	21.67	9.39	13.2	129.5	43.35	18.77	28	275	92.0	39.8	61	598	200.3	86.8
6.7	60.38	22.00	9.53	13.4	131.4	44.01	19.06	28.5	279	93.6	40.5	62	608	203.6	88.2
6.8	61.28	22.33	9.67	13.6	133.4	44.66	19.34	29	284	95.2	41.2	63	618	206.9	89.6
6.9	62.18	22.66	9.81	13.8	135.3	45.32	19.63	29.5	289	96.9	42.0	64	628	210.2	91.0
7	63.08	22.99	9.96	14	137.3	45.98	19.91	30	294	98.5	42.7	65	637	213.5	92.4
7.1	63.98	23.32	10.10	14.2	139.3	46.63	20.20	30.5	299	100.2	43.4	66	647	216.7	93.9
7.2	64.88	23.65	10.24	14.4	141.2	47.29	20.48	31	304	101.8	44.1	67	657	220.0	95.3
7.3	65.78	23.97	10.38	14.6	143.2	47.95	20.77	31.5	309	103.4	44.8	68	667	223.3	96.7
7.4	66.68	24.30	10.53	14.8	145.1	48.60	21.05	32	314	105.1	45.5	69	677	226.6	98.1
7.5	67.59	24.63	10.67	15	147.1	49.26	21.33	32.5	319	106.7	46.2	70	686	229.9	99.6
7.6	68.49	24.96	10.81	15.2	149.1	49.92	21.62	33	324	108.4	46.9	71	696	233.2	101.0
7.7	69.39	25.29	10.95	15.4	151.0	50.57	21.90	33.5	329	110.0	47.6	72	706	236.5	102.4
7.8	70.29	25.62	11.09	15.6	153.0	51.23	22.19	34	333	111.7	48.4	73	716	239.7	103.8
7.9	71.19	25.94	11.24	15.8	154.9	51.89	22.47	34.5	338	113.3	49.1	74	726	243.0	105.3
8	72.09	26.27	11.38	16	156.9	52.55	22.76	35	343	114.9	49.8	75	736	246.3	106.7
8.1	72.99	26.60	11.52	16.2	158.9	53.20	23.04	35.5	348	116.6	50.5	76	745	249.6	108.1
8.2	73.89	26.93	11.66	16.4	160.8	53.86	23.33	36	353	118.2	51.2	77	755	252.9	109.5
8.3	74.80	27.26	11.81	16.6	162.8	54.52	23.61	36.5	358	119.9	51.9	78	765	256.2	110.9
8.4	75.70	27.59	11.95	16.8	164.8	55.17	23.89	37	363	121.5	52.6	79	775	259.4	112.4
8.5	76.60	27.91	12.09	17	166.7	55.83	24.18	37.5	368	123.2	53.3	80	785	262.7	113.8
8.6	77.50	28.24	12.23	17.2	168.7	56.49	24.46	38	373	124.8	54.0	81	794	266.0	115.2
8.7	78.40	28.57	12.37	17.4	170.6	57.14	24.75	38.5	378	126.4	54.8	82	804	269.3	116.6
8.8	79.30	28.90	12.52	17.6	172.6	57.80	25.03	39	382	128.1	55.5	83	814	272.6	118.1
8.9	80.20	29.23	12.66	17.8	174.6	58.46	25.32	39.5	387	129.7	56.2	84	824	275.9	119.5
9	81.10	29.56	12.80	18	176.5	59.11	25.60	40	392	131.4	56.9	85	834	279.1	120.9
9.1	82.00	29.89	12.94	18.2	178.5	59.77	25.89	40.5	397	133.0	57.6	86	843	282.4	122.3
9.2	82.91	30.21	13.09	18.4	180.4	60.43	26.17	41	402	134.6	58.3	87	853	285.7	123.7
9.3	83.81	30.54	13.23	18.6	182.4	61.08	26.45	41.5	407	136.3	59.0	88	863	289.0	125.2
9.4	84.71	30.87	13.37	18.8	184.4	61.74	26.74	42	412	137.9	59.7	89	873	292.3	126.6
9.5	85.61	31.20	13.51	19	186.3	62.40	27.02	42.5	417	139.6	60.4	90	883	295.6	128.0
9.6	86.51	31.53	13.65	19.2	188.3	63.05	27.31	43	422	141.2	61.2	92	902	302.1	130.9
9.7	87.41	31.86	13.80	19.4	190.3	63.71	27.59	43.5	427	142.9	61.9	94	922	308.7	133.7
9.8	88.31	32.18	13.94	19.6	192.2	64.37	27.88	44	431	144.5	62.6	96	941	315.3	136.5
9.9	89.21	32.51	14.08	19.8	194.2	65.02	28.16	44.5	436	146.1	63.3	98	961	321.8	139.4

Annex 2 Sample Commissioning Checklist

A. Salient Features

Name of plant:		Name of Owner:	
Location:			
Manufacturer:		Supplier/Installer:	
Ownership: Private/community		No of households:	
Gross head: m; Design flow:		m^3/s	Rated output: kW
System: Single-phase/Three-phase		Volt: V; Maximum current: A	
Start of construction of project:		day/month/year	
Commissioning date:		day/month/year	

B. Technical Status

B1 Intake	
Type of intake:	Permanent/Temporary
If permanent, any cracks observed:	Yes/No
Any leakage observed:	Yes/No
Trash rack at intake:	Installed/Not installed
If installed, Clearance: mm	
Any structured cracks observed:	Yes/No
Type of Trash rack:	metal/local (special)
Flow controlling mechanism: Sluice gate/wooden stop logs/bush-boulder/Others (specify)	
Remarks on Intake - Briefly discuss any major defects observed.	
B2 Headrace	
Length of headrace (section 1): m Rectangular/Trapezoidal/Triangular	Type of headrace (section 1): open earth/open Cemented, DPE conduit/others (specify)
Length of head race (section 2): m Rectangular/Trapezoidal/Triangular	Type of head race (section 2): open earth/open cemented/HDPE conduit/others (specify)
Length of headrace (section 3): m Rectangular/Trapezoidal/Triangular	Type of head race (section 2): open earth/open cemented/HDPE conduit/others (specify)
Any leakage observed:	Yes/No
Any cracks observed:	Yes/No
Remarks on Headrace – Briefly discuss any major defects observed	

B3 Forebay	
Type of Forebay:	Stone masonry in concrete/reinforced cement concrete/others (specify)
Trash rack:	Installed/Not installed
If installed, Clearance: mm	Any structured cracks observed: Yes/No
Type of Trash rack: metal/local (specify)	Spillover: incorporated/not incorporated
Flushing arrangement: Works well/defects observed	
Air vent pipe: installed/not installed	
Remarks on Forebay - Briefly discuss any minor/major defects observed:	

B4 Gravel Trap/Settling Basin	
Type:	Stone masonry in concrete/reinforced cement concrete/Others (specify)
Flushing arrangement:	Works well/defects observed
Remarks on Gravel Trap - Briefly discuss any minor/major defects observed	

B5 Penstock Pipes	
Penstock Length (section 1/top): m	Section 1: HDPE /GI/MS/uPVC; Thickness ______mm;OD
Penstock Length (section 2/mid): m	Section 2: HDPE /GI/MS/uPVC; Thickness ______mm;OD
Penstock Length (section 3/bot): m	Section 3: HDPE /GI/MS/uPVC; Thickness ______mm;OD
Any leakage observed in Penstock:	Yes/No
Ground clearance maintained:	Yes/No (minimum 300 mm)
Expansion Joint: Flange connected/Welded	
Any leakages in expansion joint: Yes/No	
No. of joints:	
Maximum expansion measured:	J1=______ J2=_____ J3=____ J4=______
HDPE conduit buried:	Yes/No
No. of Penstock Sections:	____________
Remarks on Penstock pipes - Briefly discuss any major defects observed	

B6 Anchor Blocks/Support Pier	
Any cracks observed in Anchor blocks:	Yes/No
Any cracks observed in support piers:	Yes/No

Remarks on Anchor blocks/support piers - Briefly discuss any minor/major defects observed
B7 Powerhouse
Length:______m, Width:___ m Height: ___m Powerhouse size (internal): Construction: Stone masonry/Concrete/Others (specify) Powerhouse roof: Corrugated GI/Plain GI/Others (specify) Powerhouse floor: Compacted earth/Dry stone slabs/Cemented
Adequate working space for O/M: Yes/No Adequate ventilation: Yes/No Cleanliness: Yes/No Adequate lighting in Power House: Yes/No Free of undue leakages: Yes/No Tailrace safely disposed off: Yes/No Earthing done properly: Yes/No (Earth resistance < 10 ohm:)
Remarks on Powerhouse - Briefly discuss any major defects observed
B8 Tailrace
Construction: Stone masonry in concrete/Earth/Others (specify) Section: Rectangular/Trapezoidal/Triangular Condition of tailrace: good/bad Any cracks observed in structure: Yes/No
Remarks on Tailrace - Briefly discuss any major defects observed

B9 Turbine and Driving System
Type of Turbine: Pelton/Cross flow / Francis / others (Specify) Pressure gauge installed: Yes /No If yes, Size of gauge: kg/cm² Pressure head during plant operation: kg/cm² Pressure head during plant closure: kg/cm² Type of valves installed: Spear valve/Gate valve: Runner mounting: Vertical/Horizontal
Driving System:

Type of Belt: V -Belt/Flat Belt OR Direct coupling/others (Specify)
Size /No: Size No
Alignment: Well aligned/deviation observed

Remarks on Turbine and driving system - Briefly discuss any major defects observed

B10 Generator

Specification:
Type: Synchronous/Induction
Phase: 3 -phase/ 1-phase Voltage: V
Capacity: kW PF
RPM: Full load current: A
Frequency: Hz
Insulation class: Protection class (IP rating):
Manufacturer:
Earthing done properly: Yes/No (Earth resistance < 10 ohm)

Remarks on Generator: Briefly discuss any major defects observed

B11 Load Controller

Load controller type: ELC/ELC-Extension/IGC/Others (Specify)
Capacity: kW
Rating voltage: Volt Current: A
Condition of load controller: operates well/deviation observed.

Remarks on Load Controller: Briefly discuss any defects observed.

B12 Control Panel and Switchgear

Protection provided: Yes No
Over voltage/under voltage: _____ ______
Over frequency/under Frequency: _____ ______
Overload/Short circuit: _____ ______

Are the installed fuses/breakers of adequate size: Yes/No

Size of MCCB/MCB: A Rated breaking capacity of the breaker: kA

Type of Fuse installed: Rating: A

Emergency switch and feeder switch working properly: Yes/No
Lightning arrestors installed at the power house: Yes/No

Earthing of lightning arrestors properly done (R<10 Ohm) Yes/No Ohm

All metal parts in power house well connected to earth Yes/No Ohm

Central earthing connector installed where all metal parts are directly connected to.
Yes/No

Measuring instruments incorporated in the Control panel to measure the following:			
1.	Main voltage	Yes ( )	No ( )
2.	Load currents	Yes ( )	No ( )
3.	Frequency	Yes ( )	No ( )
4.	Power (kW)	Yes ( )	No ( )
5.	Energy (KWh)	Yes ( )	No ( )
6.	Reactive Energy (kVAr)	Yes ( )	No ( )
6.	Indicator lamps	Yes ( )	No ( )
7.	Time totalizer (turbine operating hours)	Yes ( )	No ( )
Remarks on Control Panel and switchgears - Briefly discuss any defects observed			

B13 Cable, Connections and supply	
Type of power cable used in the power house:	Copper/Aluminium
Size of Cable	mm²
Cable jointing and connections properly?	Yes/No
Type of Service cable used for hooking up:	Concentric/Twin /flat/Others
Size of Cable:	mm²
Tapping connection done properly?	Yes/No
Consumer end voltage within limit?	Yes/No (total V drop < 5%)
Receiving end voltage at peak load:	
At start of village: Volts	voltage drop in %:
At mid of village: Volts	voltage drop in %:
At end of village: Volts	voltage drop in %:
B14 Transmission/distribution lines	
Type of transmission/distribution	Overhead/underground
Length of the system:	m;
Voltage transmission line:	kV
Voltage distribution line:	kV
Type of cable:	ACSR/ABC/PVC Mild
Type of Pole:	Steel/Wood/Concrete/Other

• Lightning arrestor installed at each end of line and at every lightning prone areas of the system. • Are earthings provided to each lightning arrestor? • Are all joints along the earth path being brazed/soldered? • Is measured ground resistance < 10 ohm? • Are DB boxes weatherproof and rain protected? • Shall pole stays be used at all poles at angle and at line ends? • Preservative or anti corrosion paint applied on pole foundation? • Safety clearances adequate? General clearances: Ground to Wire: Off road: m Across road: m Along sides of motor road: m Insulator type acceptable?	Yes/No Yes/No Yes/No Yes/No Yes/No Yes/No Yes/No Yes/No Yes/No Yes/No
Remarks on electrical lines: Briefly discuss any defects observed in construction, finishing, cable jointing and terminations, service cable tapping, bedding, clearance and safety of transmission and distribution system.	