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Unit: 04

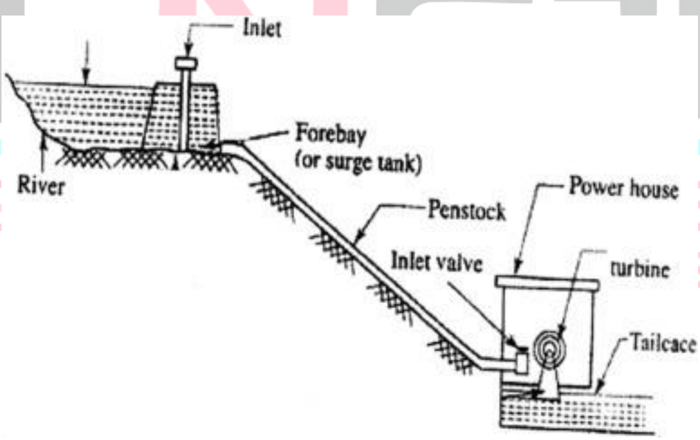
Mini, Micro and small hydro system:

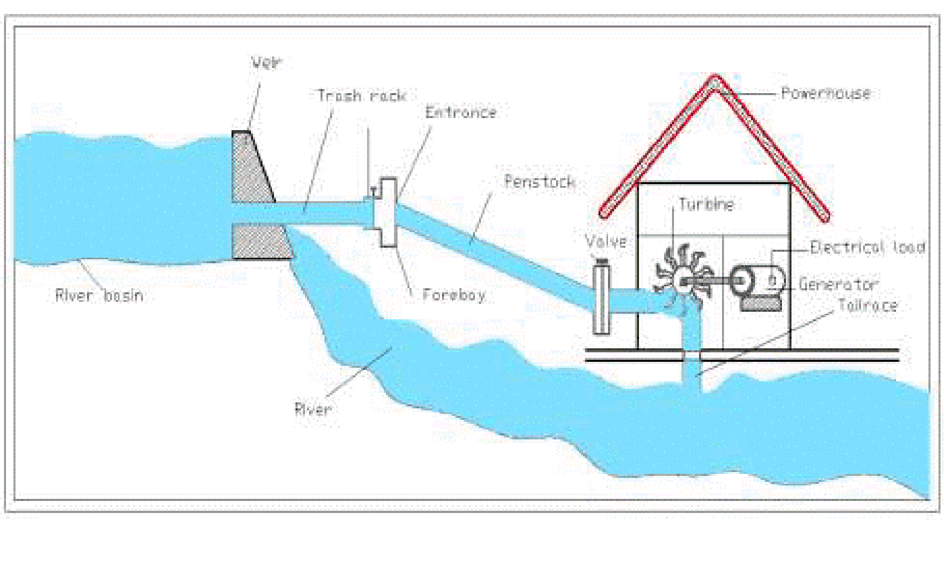
Introduction Hydropower projects below 25 MW are categorized as small hydro projects which are further classified as micro/Pico (with capacities up to 100 kW), mini (capacity 101 kW- 2 MW) and small (capacity 2 MW- 25 MW). Technology characteristics

A small hydro project (SHP) generates electricity of up to 25 MW from the energy of moving water which is used to run a turbine. The mechanical energy from the movement of the turbine is then converted to electrical energy using magnetic fields. Water flowing through a stream enters the forebay through a canal or an intake ditch where intake screens remove debris from the water. After this, the water flows through the penstock to the turbine and the generator unit, where electricity is generated. The electricity is then transmitted to the point of use via the transmission system.

Country specific applicability and potential Bhutan has great potential to meet its energy requirements by generating power through micro/mini hydro projects. Several provisions of various national policies address the development of incentivize such projects. For instance, the Electricity Act 2001 aims to promote small projects by exempting license requirement for projects with capacities less than 500 kW.

Further, the development of micro-hydro (among other renewable energy) and institutional strengthening and capacity building is a priority activity under the renewable energy program of the Tenth Five Year Plan.





How Hydropower Works?

Hydropower systems use the energy in flowing water to produce electricity or mechanical energy. Although there are several ways to harness the moving water to produce energy, run-of-the-river systems, which do not require large storage reservoirs, are often used for micro hydro, and sometimes for small-scale hydro, projects. For run-of-the-river hydro projects, a portion of a river's water is diverted to a channel, pipeline, or pressurized pipeline (penstock) that delivers it to a waterwheel or turbine. The moving water rotates the wheel or turbine, which spins a shaft. The motion of the shaft can be used for mechanical processes, such as pumping water, or it can be used to power an alternator or generator to generate electricity. This fact sheet will focus on how to develop a run-of-the-river project.

System Components

Small run-of-the-river hydropower systems consist of these basic components:

• Water conveyance—channel, pipeline, or pressurized pipeline (penstock) that delivers the water.

• Turbine or waterwheel—transforms the energy of flowing water into rotational energy.

• Alternator or generator—transforms the rotational energy into electricity.

• Regulator—controls the generator.

• Wiring—delivers the electricity.

Many systems also use an inverter to convert the low-voltage direct current (DC) electricity produced by the system into 120 or 240 volts of alternating current (AC) electricity (alternatively you can buy household appliances that run on DC electricity). Some systems also use batteries to store the electricity generated by the system, although because hydro resources tend to be more seasonal in nature than wind or solar resources, batteries may not always be practical for hydropower systems. If you do use batteries, they should be located as close to the turbine as possible, because it is difficult to transmit low voltage power over long distances.

Channels, storage, and filters:

Before water enters the turbine or waterwheel, it is first funneled through a series of components that control its flow and filter out debris. These components are the headrace, forebay, and water conveyance (channel, pipeline, or penstock). The headrace is a waterway running parallel to the water source. A headrace is sometimes necessary for hydropower systems when insufficient head is provided. They often are constructed of cement or masonry. The headrace leads to the forebay, which also is made of concrete or masonry. It functions as a settling pond for large debris which would otherwise flow into the system and damage the turbine. Water from the forebay is fed through the trashrack, a grill that removes additional debris. The filtered water then enters through the controlled gates of the spillway into the water conveyance, which funnels water directly to the turbine or waterwheel. These channels, pipelines, or penstocks can be constructed from plastic pipe, cement, steel and even wood. They often are held in place above-ground by support piers and anchors. Dams or diversion structures are rarely used in micro hydro projects. They are an added expense and require professional assistance from a civil engineer. In addition, dams increase the potential for environmental and maintenance problems.

Turbines and waterwheels:

The waterwheel is the oldest hydropower system component. Waterwheels are still available, but they aren't very practical for generating electricity because of their slow speed and bulky structure. Turbines are more commonly used today to power small hydropower systems. The moving water strikes the turbine blades, much like a waterwheel, to spin a shaft. But turbines are more compact in relation to their energy output than waterwheels. They also have fewer gears and require less material for construction. There are two general classes of turbines: impulse and reaction.

Impulse:

Impulse turbines, which have the least complex design, are most commonly used for high head micro hydro systems. They rely on the velocity of water to move the turbine 5 Dams or diversion structures are rarely used in micro hydro projects. Environmental Issues Large-scale dam hydropower projects are often criticized for their impacts on wildlife habitat, fish migration, and water flow and quality. However, small, run-of the-river projects are free from many of the environmental problems associated with their large-scale relatives because they use the natural flow of the river, and thus produce relatively little change in the stream channel and flow. The dams built for some run-of-the-river projects are very small and impound little water—and many projects do not require a dam at all.

Thus, effects such as oxygen depletion, increased temperature, decreased flow, and rejection of upstream migration aids like fish ladders are not problems for many run-of-the-river projects. wheel, which is called the runner. The most common types of impulse turbines include the Pelton wheel and the Turgo wheel. The Pelton wheel uses the concept of jet force to create energy. Water is funneled into a pressurized pipeline with a narrow nozzle at one end. The water sprays out of the nozzle in a jet, striking the double cupped buckets attached to the wheel. The impact of the jet spray on the curved buckets creates a force that rotates the wheel at high efficiency rates of 70 to 90 percent.

Pelton wheel turbines are available in various sizes and operate best under low-flow and high-head conditions. The Turgo impulse wheel is an upgraded version of the Pelton. It uses the same jet spray concept, but the Turgo jet, which is half the size of the Pelton, is angled so that the spray hits three buckets at once. As a result, the Turgo wheel moves twice as fast. It's also less bulky, needs few or no gears, and has a good reputation for trouble-free operations. The Turgo can operate under low-flow conditions but requires a medium or high head.

Reaction:

Reaction turbines, which are highly efficient, depend on pressure rather than velocity to produce energy. All blades of the reaction turbine maintain constant contact with the water. These turbines are often used in large-scale hydropower sites. Because of their complexity and high cost, they aren't usually used for micro hydro projects. An exception is the propeller turbine, which comes in many different designs and works much like a boat's propeller. Propeller turbines have three to six usually fixed blades set at different angles aligned on the runner. The bulb, tubular, and Kaplan tubular are variations of the propeller turbine. The Kaplan turbine, which is a highly adaptable propeller system, can be used for micro hydro sites. Pumps as substitutes for turbines Conventional pumps can be used as substitutes for hydraulic turbines.

When the action of a pump is reversed, it operates like a turbine. Since pumps are mass produced, you'll find them more readily available and less expensive than turbines. 6 Pelton wheels, like this one, can be purchased with one or more nozzles. Multi nozzle systems allow a greater amount of water to impact the runner, which can increase wheel output.

The submersible Jack Rabbit turbine was originally designed to power scientific instruments during marine oil exploration expeditions. Jack Rabbit Marine, NREL/PIX 09976 7 Grid-connected systems render additional electricity storage capacity, such as a battery bank, unnecessary. However, for adequate pump performance, your micro hydro site must have fairly constant head and flow. Pumps are also less efficient and more prone to damage.

Hydrology:

Water is an essential resource that is required by all life on Earth. Studying the movement, availability, and quality of water are the jobs of a hydrologist. More specifically hydrologists study the chemical properties, biological interactions, and the physical processes that govern the water cycle.

The water cycle or hydrologic cycle is a process by which water is continuously cycled around the earth. This happens through different pathways and at different rates but the central concepts remain the same. Water evaporates from the ocean, condenses as clouds, moves over land, and precipitates. From there it can enter ground water, evaporate again, or enter a stream or lake. It will eventually find its way back to the ocean either by falling as precipitation, flowing with a river, or by moving ever so slowly with ground water. The hydrologic cycle is also a process that transfers heat energy. Heat is transported pole ward by water being evaporated and then condensing which releases heat. Without the water cycle the climate would be much more frigid and areas away from the equator would be much less habitable.

Studying these different aspects allow hydrologists to do many things such as calculate water budgets. This process involves tracking where all the water goes in a watershed and creating an equation with inputs and outputs to understand water surplus and deficit. Once completed this budget may be used by city planners to calculate drinking water availability, farmers to calculate irrigation needs and availability, industries to calculate if they can produce certain items, and mining companies to determine if excavation is cost-effective. Studying floods is another thing that hydrologists do. This can involve creating flood plain maps, modelling stream flow, and predicting what may happen under certain scenarios. Hydrologists also study pollution by looking at the sources, transportation mechanisms, and the ultimate fate of the pollutant. This involves looking at both point source pollution where the source is known and nonpoint source pollution where the source is not known. Groundwater and surface water are investigated to see how the pollutant travels and how it reacts in nature. The observed data are used to determine where it will end up and if it is harmful to the aquatic environment. Much of what hydrologists do involves field work, lab work, and modelling work. This creates a more complete picture of the hydrologic cycle and aids policy makers in making their decisions involving water.

The practical applications of hydrology are the following:

i. Peak flow and future conditions of flow, at any point in the drainage valley can be correctly estimated for any basin or area.

ii. Spillway capacity can be accurately designed by estimating design flood.

iii. Design of river training work is facilitated.

iv. Dependable yields from the stream for generation of hydroelectric power can be calculated.

v. Water supply to township and sewerage schemes can be properly designed.

vi. Water resources account of a river basin can be prepared.

vii. Reservoir capacity can be determined accurately.

viii. Operation of reservoirs can be done in an efficient manner.

Ocean and thermal power plant:

Ocean thermal energy plant uses the ocean thermal gradient between cooler deep and warmer shallow or surface seawaters to run a heat engine and produce useful work, usually in the form of electricity. OTEC can operate with a very high capacity factor and so can operate in base load mode.

The denser cold water masses, formed by ocean surface water interaction with cold atmosphere in quite specific areas of the North Atlantic and the Southern Ocean, sink into the deep sea basins and spread in entire deep ocean by the thermohaline circulation. Upwelling of cold water from the deep ocean is replenished by the downwelling of cold surface sea water.

Among ocean energy sources, OTEC is one of the continuously available renewable energy resources that could contribute to base-load power supply.[1] The resource potential for OTEC is considered to be much larger than for other ocean energy forms.[2] Up to 88,000 TWh/yr of power could be generated from OTEC without affecting the ocean's thermal structure.[3]

Systems may be either closed-cycle or open-cycle. Closed-cycle OTEC uses working fluids that are typically thought of as refrigerants such as ammonia or R-134a. These fluids have low boiling points, and are therefore suitable for powering the system's generator to generate electricity. The most commonly used heat cycle for OTEC to date is the Rankine cycle, using a low-pressure turbine. Open-cycle engines use vapor from the seawater itself as the working fluid.

OTEC can also supply quantities of cold water as a by-product. This can be used for air conditioning and refrigeration and the nutrient-rich deep ocean water can feed biological technologies. Another by-product is fresh water distilled from the sea.[4]

OTEC theory was first developed in the 1880s and the first bench size demonstration model was constructed in 1926. Currently the world's only operating OTEC plant is in Japan, overseen by Saga University.

Thermodynamic efficiency:

(OTEC – Ocean thermal energy conversion)

A heat engine gives greater efficiency when run with a large temperature difference. In the oceans the temperature difference between surface and deep water is greatest in the tropics, although still a modest 20 to 25 °C. It is therefore in the tropics that OTEC offers the greatest possibilities. OTEC has the potential to offer global amounts of energy that are 10 to 100 times greater than other ocean energy options such as wave power. OTEC plants can operate continuously providing a base load supply for an electrical power generation system.

The main technical challenge of OTEC is to generate significant amounts of power efficiently from small temperature differences. It is still considered an emerging technology. Early OTEC systems were 1 to 3 percent thermally efficient, well below the theoretical maximum 6 and 7 percent for this temperature difference. Modern designs allow performance approaching the theoretical maximum Carnot efficiency.

Principle of ocean wave energy:

Wave energy, also known as ocean energy or sea wave energy, is energy harnessed from ocean or sea waves. The rigorous vertical motion of surface ocean waves contains a lot of kinetic (motion) energy that is captured by wave energy technologies to do useful tasks, for example, generation of electricity, desalinization of water and pumping of water into reservoirs.

Wave energy or wave power is essentially power drawn from waves. When wind blows across the sea surface, it transfers the energy to the waves. They are powerful source of energy. The energy output is measured by wave speed, wave height, wavelength and water density. The stronger the waves, the more capable it is to produce power. The captured energy can then be used for electricity generation, powering plants or pumping of water. It is not easy to harness power from wave generator plants and this is the reason that they are very few wave generators plants around the world.

When you look out at a beach and see waves crashing against the shore, you are witnessing wave energy. It's not being harnessed or used for the benefit of anyone in that state, but it is there producing power. And some enterprising individuals would say it is just waiting to be used to make our lives better and our energy consumption cleaner and cheaper. Wave energy is often mixed with tidal power, which is quite different.

But how are those waves formed? When wind blows across the surface of the water strongly enough it creates waves. This occurs most often and most powerfully on the ocean because of the lack of land to resist the power of the wind.

The kinds of waves that are formed, depend on from where they are being influenced. Long, steady waves that flow endlessly against the beach are likely formed from storms and extreme weather conditions far away. The power of storms and their influence on the surface of the water is so powerful that it can cause waves on the shores of another hemisphere. For example, when Japan was hit with a massive tsunami in 2011, it created powerful waves on the coast of Hawaii and even as far as the beaches of the state of Washington.

When you see high, choppy waves that rise and fall very quickly, you are likely seeing waves that were created by a nearby weather system. These waves are usually newly formed occurrences. The power from these waves can then be harnessed through wave energy converter (WEC).

Advantages of Wave Energy

It's highly predictable

The wave arrival pattern is highly predictable. They arrive day and night and harbour more energy than other renewable sources like wind and solar. Wind energy and solar energy, on the other hand, are highly unpredictable. Wind speeds die down unexpectedly, which affects the generation of electricity. Solar energy depends upon exposure from the sun, which means cloud coverage and night hours significantly reduce this exposure leading to less efficiency.

It's a renewable form of energy

Renewable means it's an endless resource. It does not need man's intervention to continue existing. No one has dared to suggest that the oceans and seas will disappear some day. Humans will continue harnessing it to the very end. This aspect makes wave energy a reliable and efficient energy resource.

Wave energy is eco-friendly

Wave energy is a completely clean energy source, which means, it does not emit dangerous greenhouse gasses to the atmosphere. Fossil fuels, for instance, oil, coal and natural gas contribute mightily to environmental pollution because they release dangerous greenhouse gasses including carbon dioxide, nitrous oxide, methane, and ozone to the atmosphere.

Creation of green jobs

Communities living in remote areas and declining industries like the ship building industry bear the biggest brunt of unemployment and economic unsustainability due to lack of electricity. The wave energy sector has the potential to create numerous green opportunities to remote and urban population alike because remote areas that are not able to be reached by conventional electricity supply are well catered by wave power.

Exponential growth of remote areas

The wave energy harnessed can to channelled to remote locations, and this means springing up of industries and businesses. These remote areas will witness strong economic growth moving forward.

Security of energy supply

Setting up a strong wave energy infrastructure can enormously help a country from overdependence on fossil fuels. The fossil fuel market is largely volatile and could hurt a country's economy if shortage occurs. Wave energy is the sure-fire way to bridge this volatility gap since it's cheap, reliable and efficient.

Land remains undamaged

Wave energy plants can be situated offshore alleviating any risk that comes along with these plants situated onshore like soil pollution. Also, the land remains in its natural state unlike fossil fuel extraction, which requires high levels of excavation that leaves land heavily damaged.

Disadvantages of Wave Energy

High upfront capital costs

Construction of wave energy plants requires huge capital outlay. Energy plant maintenance, connection to power grid, wave resources, expected drop in energy costs once the infrastructure is up and running and shelf life of the technology are just some of the variables driving up the cost of wave energy. Determination of actual cost is also difficult since wave energy is in its early stage of development.

Variability in wave magnitude can damage equipment

The wave magnitude is so unpredictable in the seas. Sometimes it comes with a vengeance and could cause heavy wear and tear to the wave energy generation turbines. Damage to this equipment can be costly in terms of repair. It would also mean stalling of electricity supply.

Damage to sea life ecosystem

Offshore wave energy projects are a lot more sophisticated than onshore ones. The projects include platforms, cables, turbines, interconnections, dredging and much more. From ecological standpoint, shallow waters are fertile breeding and resting grounds for most marine life. So, activities from construction and operation of the wave energy plant greatly affect marine ecosystem. Accidental leaks or spills emanating from hydraulic fluids in the plants could potentially pollute the water resulting in marine life deaths.

Disadvantage of location

The downside to wave energy is the location. Individuals or towns in proximity to oceans and seas will enjoy the fruits of wave energy. Because the source of wave energy is restricted to oceans and seas, it can't be relied upon to serve the entire population of a country. This means that towns, cities, and countries not close to such water bodies don't get to enjoy the fruits of wave energy.

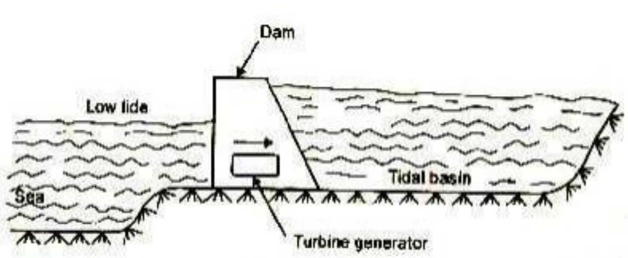
Environmental concerns

Although wave energy is a clean energy source, the sound produced by the plant generators could prove unbearable to some local residents. The plants also interfere with the natural aesthetic look of the ocean. However, the noise of the waves, in most occasions, equalizes the noise produced by the generators.

When the advantages and disadvantages of wave energy are put side by side, the advantages far outweigh the disadvantages, especially, in this day and age where everyone is focusing on renewable forms of energy. Fossils fuels have proved to be detrimental to human health and environment, so expect most government to scale up on wave energy production.

<u>Tidal energy conversion:</u>

Tide or wave is periodic rise and fall of water ea water by the moon. Tides contain large amour on. When the water is above the mean sea level, he mean level it is called ebb tide.



(b) Low tide

Working

The arrangement of this system is shown in figure. The ocean tides rise and fall and water can be stored during the rise period and it can be discharged during fall. A dam is constructed separating the tidal basin from the sea and a difference in water level is obtained between the basin and sea.

During high tide period, water flows from the sea into the tidal basin through the water turbine. The height of tide is above that of tidal basin. Hence the turbine unit operates and generates power, as it is directly coupled to a generator.

During low tide period, water flows from tidal basin to sea, as the water level in the basin is more than that of the tide in the sea. During this period also, the flowing water rotates the turbine and generator power.

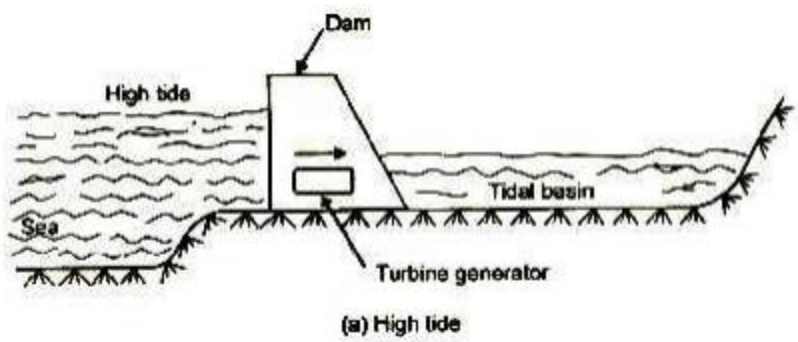


Figure: High tide

The generation of power stops only when the sea level and the tidal basin level are equal. For the generation of power economically using this source of energy requires some minimum tide height and suitable site. Kislaya power plant of 250 MW capacity in Russia and Rance power plant in France are the only examples of this type of power plant.

Advantages of tidal power plants.

1. It is free from pollution as it does not use any fuel.

2. It is superior to hydro-power plant as it is totally independent of rain.

3. It improves the possibility of fish farming in the tidal basins and it can provide recreation to visitors and holiday makers.

Disadvantages

1. Tidal power plants can be developed only if natural sites are available on the bay.

2. As the sites are available on the bays which are always far away from load centres, the power generated has to be transmitted to long distances. This increases the transmission cost and transmission losses.