Program : **B.Tech**

Subject Name: **Renewable Energy Technology**

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Semester: **6th**

Unit 4 Small Hydro Power Systems

1.1 Renewable Energy in the World and in India

Renewable energy is energy generated from natural resources—such as sunlight, wind, rain, tides, and geothermal heat—which are renewable (naturally replenished). In 2006, about 18 percent of the global final energy consumption came from renewable sources, with 13 percent coming from traditional biomass, such as wood-burning. Hydroelectricity was the next largest renewable source, providing 3 percent of global energy consumption and 15 percent of global electricity generation.

Wind power is growing at the rate of 30 percent annually, with a worldwide installed capacity of 1,21,000 megawatts (MW) in 2008. It is widely used in European countries and the United States. The annual manufacturing output of the photovoltaic industry reached 6,900 MW in 2008, and photovoltaic (PV) power stations are popular in Germany and Spain. Solar thermal power stations operate in the U.S.A and Spain, and the largest of these is the 354 MW SEGS power plant in the Mojave Desert. The world's largest geothermal power installation is The Geysers in California, with a rated capacity of 750 MW. Brazil has one of the largest renewable energy program in the world, involving production of ethanol fuel from sugar cane, and ethanol now provides 18 percent of the country's automotive fuel. Ethanol fuel is also widely available in the USA. While most renewable energy projects and production are large-scale, renewable technologies are also suited to small off-grid applications, sometimes in rural and remote areas, where energy is often crucial for human development. Kenya has the world's highest household solar ownership rate with roughly 30,000 small (20–100 watt) solar power systems sold per year.

Some renewable-energy technologies are criticized for being intermittent or unsightly, yet the renewable-energy market continues to grow. Climate-change concerns, coupled with high oil prices, peak oil, and increasing government support, are driving increasing renewable-energy legislation, incentives and commercialization. New government spending, regulation and policies should help the industry weather the 2009 economic crisis better than many other sectors. With India's power needs projected to reach over 240,000 MW by 2012 – an increase of about 20,000 MW per year – it has become critically important to exploit other energy sources. As much as 18 percent of the additional grid interactive renewable power capacity that was commissioned during the first three years of the Tenth plan came from renewables.

The estimated potential in India for generation of power from wind, small hydro, and biomass is around 80,000 MW. Renewable power capacity is likely to double every five years or so in the future. By 2012 around 20,000 MW, which is 10 percent of the then installed capacity would be contributed by renewables. Sources estimate that about 7.5 billion dollars have so far been invested in the renewable power sector in India. About 90 percent of the investment has come from the private sector.

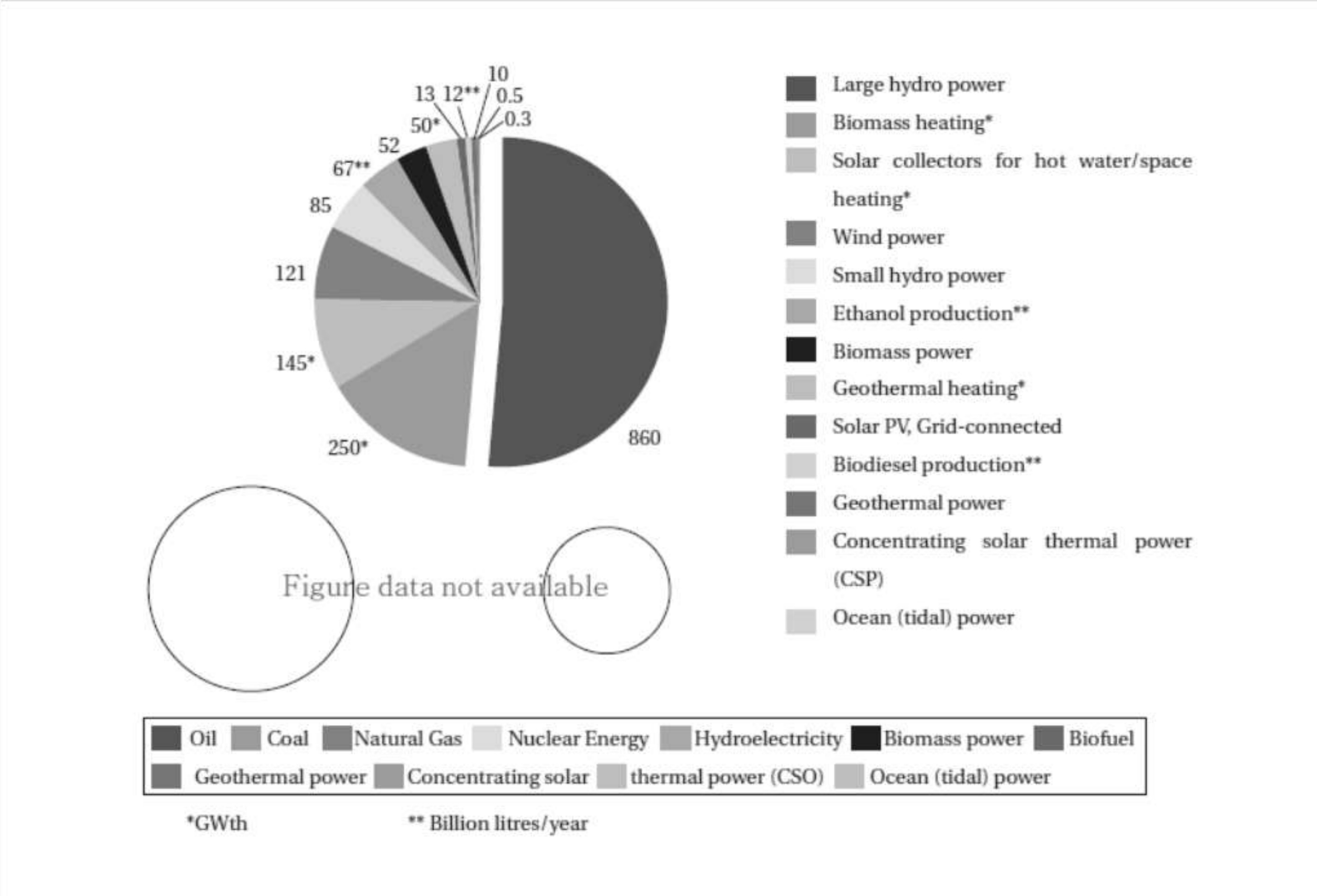


Figure 1.1 Renewable energy, end of 2008 (GW)

1.2 Hydro Power Generates Electricity

Of the renewable energy sources that generate electricity, hydro power is the one used most often. It is one of the oldest sources of energy and was used thousands of years ago, to turn a paddle wheel for the purpose of grinding grain.

How Hydro Power Works

It is important to understand the water cycle to understand hydro power. In the water cycle:

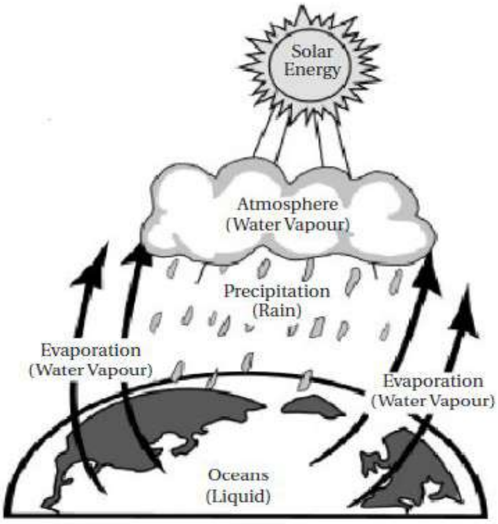
- Solar energy heats water on the surface, causing it to evaporate
- This water vapor condenses into clouds and falls back onto the surface

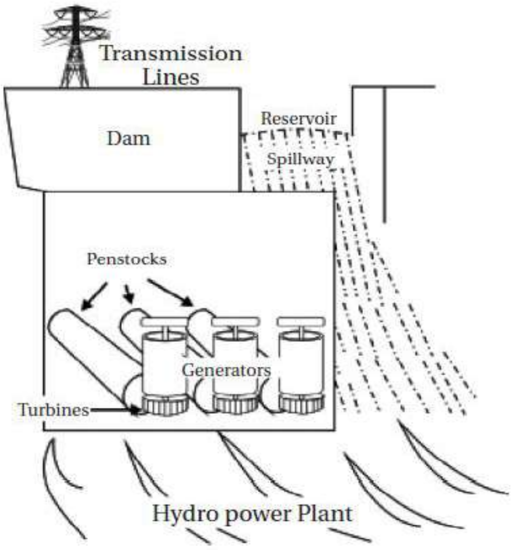
as precipitation

- The water flows through rivers back into the oceans, where it can evaporate and begin the cycle all over again.

Mechanical energy is derived by directing, harnessing, or channeling moving water. The amount of available energy in moving water is determined by its flow or fall. Swiftly flowing water in a big river, like the Narmada or the Ganges, carries a great deal of energy in its flow. The same is the case with water descending rapidly from a very high point. In either instance, the water flows through a pipe, or penstock, then pushes against and turns the blades in a turbine, to spin a generator to produce electricity. In a runoff-

the-river system, the force of the current applies the needed pressure, while in a storage system, water is accumulated in reservoirs created by dams, then released when the demand for electricity is high. Meanwhile, the reservoirs or lakes are used for boating and fishing, and often the rivers beyond the dams provide opportunities for whitewater rafting and kayaking.





1.3 Hydro Power and the Environment

Some people regard hydro power as the ideal fuel for electricity generation because unlike the nonrenewable fuels used to generate electricity, it is almost free, there are no waste products and hydro power
does not pollute the water or the air. However, it is criticized because it does change the environment by affecting natural habitats. For instance, the recent Narmada Valley Project created a mass movement that pressurized the Government of India to lower the height of the dam so that a smaller area would be submerged. However, in this part of our syllabus we are talking of Small Hydro Power projects that have minimum impact on the environment and the people around it.

Over 40 percent of India's population does not have access to electricity and providing electricity for 24 hours in rural areas is a major challenge. For this, the Indian government has envisioned several paths for its energy requirements, from nuclear to renewable Overby Despite greening its energy requirements, the government has taken various paths, from bidding for foreign oil wells through diplomatic maneuvering, to establishing fossil fuel thermal plants.

The National Electricity Policy envisages that the per capita availability of electricity will be increased to over 1,000 KW, by 2012. To achieve this, the government is expecting a total capacity addition of about 78,577 MW at the end of 2012, of which:

- 16,553 MW is expected from hydro
- 58,644 MW from thermal and
- 3,380 MW from nuclear.

Although India has significant potential for generation of power from non-conventional energy sources (1,83,000 MW) such as wind, small hydro, biomass and solar energy, the emphasis is still on thermal energy sources. India has at present a 7.5 percent overall electrical energy shortage and 11 percent shortage during peak hours.

1.4 Options for Hydro power

In the 2005 National Electricity Policy the objectives have been set as follows:

- Provision for access to electricity for all households
- Demand to be met by 2012, with no energy and peaking shortages
- Adequate reserves to be made available and
- Reliable and quality power supplies, at reasonable rates.

The Indian government considers hydro power as a renewable, economic, non-polluting and environmentally benign source of energy. The exploitable hydro-electric potential in terms of installed capacity, is estimated to be about 1,48,700 MW (See Table 1), out of which, a capacity of 30,164 MW (20.3 percent) has been developed so far and 13,616 MW (9.2 percent) of capacity is under construction. In addition, 6,782 MW in terms of installed capacity from small, mini and micro hydro schemes have been assessed. Also, 56 sites for pumped storage schemes with an aggregate installed capacity of 94,000 MW have been identified. The government expects to harness its full potential of hydro power by 2027, with a whopping investment of 5,000 billion rupees.

Table 1: India's Hydro power potential

River Basin	Potential at 60 percent load factor (MW)	Probable capacity (MW)
Indus Basin	19,988	33,832
Brahmaputra Basin	34,920	66,065
Ganga Basin	10,715	20,710
Centrall India Basin	2,740	4,152
System	6,149	9,430
East Flowing River System	9,532	14,511
Total	84,044	1,48,700

1.5 Small Hydro-Power: A Viable Option

Small and mini hydel projects have the potential to provide energy in remote and hilly areas where extension of an electrical transmission grid system is uneconomical. Realizing this fact, the Indian government is encouraging development of small hydro power (SHP) projects in the country. Since 1994 the role of the private sector for setting up of commercial SHP projects has been encouraged. So far, 14 States in India have announced policies for setting up commercial SHP projects through private sector participation. Over 760 sites of about 2,000 MW capacity have already been offered/allotted.

An estimated potential of about 15,000 MW of SHP projects exist in India. 4,233 potential sites with an aggregate capacity of 10,071 MW for projects up to 25 MW capacities have been identified. In the last 10-12 years, the capacity of Small Hydro projects up to 3 MW has increased 4-fold from 63 MW to 240 MW. 420 Small Hydro power projects up to 25 MW station capacity with an aggregate capacity, of an over 1,423 MW have been set up in the country and over 187 projects in this range with an aggregate capacity of 521 MW are under construction.

The Ministry of New and Renewable Energy Source (MNRES) provides various incentives like soft loans for setting up of SHP projects up to 25 MW capacity in the commercial sector, renovation and modernization of SHP projects, setting up of portable micro hydel sets, development/upgradation of water mills, detailed survey and investigation, detailed project report preparation, interest subsidy for commercial projects, capital subsidy for SHP projects in the North-Eastern region, and implementation of UNDP/GEF Hilly Hydro project. India has a reasonably well-established manufacturing base for the full range and type of small hydro equipment. There are currently eight manufacturers within India in the field of small hydro manufacturing,
supplying various types of turbines, generators, control equipment, etc.

Asian Development Bank(ADB) has begun its engagement in producing hydro-power in Uttarakhand in India with 4 SHPs (4-10 MW). However, the Manila based regional development bank believes that India's vast hydro power potential can contribute to the country's energy security in an environmentally sustainable and socially responsible manner. The report of ADB (Hydro power Development in India, 2007) provides an assessment of the hydro power development potential in India and highlights how hydro power can meet the country's goal of providing power for all by 2012. Probably, the World Bank would like to assist in the construction of hydro power structures and the ADB will lay the transmission lines from the projects to the grid. As major rivers transcend international boundaries in South Asia, India has taken up regional (mostly bilateral) co-operation on harnessing the hydro-power potential of international river systems. At present, India has the co-operation of Bhutan, Nepal and Myanmar on hydro-power. commercial SHP projects has been encouraged.

2. Small Hydro Power – Basic Working Principles

2.1 What is Micro Hydro power?

Micro Hydro power (from hydro meaning water and micro meaning small scale) refers to electrical energy that comes from the force of moving water used to power a household or a small village.

The fall and flow of water is part of a continuous natural cycle. The sun draws up moisture from the oceans and rivers and the moisture then condenses into clouds in the atmosphere. This moisture falls as rain or snow, replenishing the oceans and rivers. Gravity moves the water from high ground to low ground. The force of moving water can be extremely powerful, as anyone who has experienced whitewater rafting knows! Micro Hydro power harnesses some of this power to create electricity. Hydro power is a renewable energy source because it is replenished by snow and rainfall. If the rain falls, we won't run out of this energy source.

Small Hydro Power Site

The site that is chosen for SHP is usually rivers or streams. It is called a run-of-the river system. For a SHP site, two types of information are needed. First, the flood flow or the expected maximum water level is needed to size a spillway (if any), to locate turbines and generators above the highest expected water level and to design diversion structures or canals. Second, the statistical distribution of monthly stream flow volumes (flow duration curve) is needed to estimate the reliability of the site to produce a given amount of electrical power and to size a turbine.

2.2 How Does Micro Hydro Power Work?

Hydro power plants capture the energy of falling water to generate electricity. A turbine converts the energy of falling water into mechanical energy. Then an alternator converts the mechanical energy from the turbine into electrical energy. The amount of electricity a hydro power plant produces is a combination of two factors:

1. How far the water falls (Head): Generally, the distance the water falls depends on the steepness of the terrain the water is moving across, or the height of the dam the water is stored behind. The farther the water falls, the more power it has. In fact, the power of falling water is 'directly proportional' to the distance it falls. In other words, water falling twice as far has twice as much energy. It is important to note we are only talking about the vertical distance the water falls – the distance the water travels horizontally are consequential only in calculating the expense of the system and friction losses. 'Head' is usually measured in 'feet'.

2. Volume of water falling (Flow): More water falling through the turbine will produce more power. The amount of water available depends on the volume of water at the source. Power is also 'directly proportional' to river flow or flow volume. A river, with twice the amount of flowing water as another river, can produce twice as much energy. Flow volume is usually measured in 'gallons per minute', or GPM.

For Micro Hydro systems, this translates into two categories of turbines:

For high head and low flow volume sites, impulse turbines are the most efficient choice. The power produced by an impulse turbine comes entirely from the momentum of the water hitting the turbine runners. This water creates a direct push or 'impulse' on the blades, and thus such turbines are called 'impulse turbines'.

For low head and high flow volume sites, a reaction turbine is the best choice. The reaction turbine, as the name implies, is turned by reactive force rather than a direct push or impulse. The turbine blades turn in reaction to the pressure of the water falling on them. Reaction turbines can operate on heads as low as 2 feet, but require much higher flow rates than an impulse turbine.

3. Working of an SHP

3.1 Main parts of an SHP

An SHP plant generates electricity or mechanical power by converting the power available in the flowing water of rivers, canals and streams. The objective of a hydro power scheme is to convert the potential energy of a mass of water flowing in a stream with a certain fall, called 'head', into electric energy at the lower end of the scheme, where the powerhouse is located. The power of the scheme is proportional to the flow and to the head. A well-designed SHP system can blend in with its surroundings and have minimal negative environmental impacts. SHP schemes are mainly run-of-the river, with little or no reservoir impoundment.

Figure 3.1: Small Hydro power model

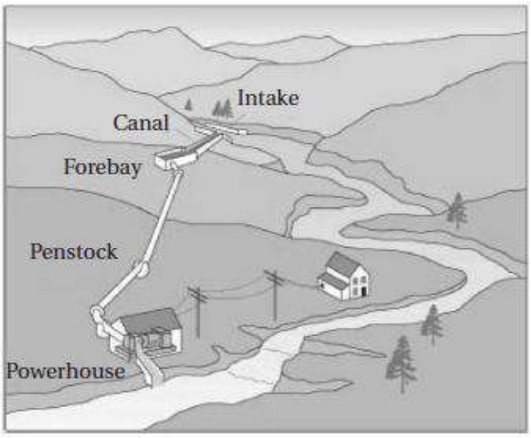


Figure 3.2: Cross-section of an SHP

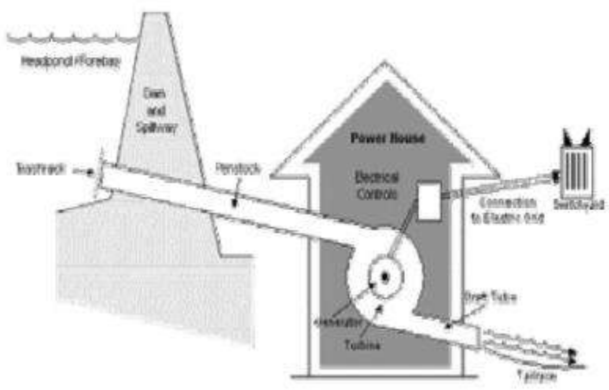


Figure 3.1: Small Hydro power model **Figure 3.2: Cross-section of an SHP**

For run-of-the river systems, a portion of river water is diverted to a water conveyance which delivers the water to a turbine. The moving water rotates the 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.

Small hydro power is not simply a reduced version of a large hydro plant. Specific equipment is necessary to meet fundamental requirements about simplicity.

3.2 Weir and Intake

An SHP must extract water from the river in a reliable and controllable way. A weir can be used to raise the water level and ensure a constant supply to the intake. Sometimes, a weir is not built because the natural features of the river are used. The following are required for an intake:

- The desired flow must be diverted,
- The peak flow of the river must be able to pass the weir and intake without causing damage to them,

- Minimum maintenance and repairs as for as possible,
- It must prevent large quantities of loose material from entering the canal,
- It should have the possibility for more piled up sediments.

3.3 Canal

The canal conducts water from the intake to the forebay tank. The length of the canal depends on the local conditions. In one case, a long canal combined with a short penstock can be cheaper or necessary while in other cases, the combination of a short canal with a long penstock is better suited. The canals are sealed with cement, clay or polythene sheets to reduce friction and prevent leakages. The size and shape of a canal is a compromise between cost and reduced head. The following are incorporated in a canal:

- Settling basin – these are basins which allow particles and sediments, which have come from the river

flow, and which will settle on the basin floor. The deposits are periodically flushed.

- Spillways – these divert excess flow at certain points along the canal. The excess flow can be due to

floods.

3.4 Forebay tank

The forebay tank forms the connection between the canal and the penstock. The main purpose is to allow the particles to settle down, before the water enters the penstock.

3.5 Penstock

In front of the penstock, a trash rack (Figure 3.2) is installed to prevent large particles from entering the penstock. Penstock is a pipe which conveys water under pressure from the forebay tank to the turbine. Usually unplastified polyvinyl chloride (uPVC) is used to make penstock pipes. uPVC can reduce a lot of friction in the pipe, it is cheap, and it can withstand pressure when compared to other materials that can be

used to make penstock pipes. Pipes are generally made and supplied in standard lengths and must be joined together on site. There are several ways to join the pipe; flanged, spigot and socket, mechanical and welded. Expansion joints are used to compensate for maximum possible change in length.

Penstock pipes can be either buried or surface mounted. This depends on the nature of the terrain and environment considerations. Buried pipelines should be 0.75 m below the surface so that vehicles do not damage it. However, one disadvantage can be, that if leaks occur in the pipes, it would be difficult to detect and rectify. When pipes are run above ground, anchors or thrust blocks are needed to counteract the forces which can cause undesired pipeline movement. The pressure rating of the penstock is critical because the pipe wall must be thick enough to withstand the maximum water pressure. This pressure depends on the head; the higher the head the greater will be the pressure.

3.6 Powerhouse and tailrace

Powerhouse is a building that contains the turbine generator and the control units. Although the powerhouse can be a simple structure; its foundation must be solid. The tailrace is a channel that allows the water to flow back to the stream, after it has passed through the turbine. (Figure 3.2)

4. Electrical and Mechanical Equipment in a Small Hydro Power Plant

The Powerhouse:

In a small hydro power scheme, the role of the powerhouse is to protect the electromechanical equipment that converts the potential energy of water into electricity from the weather. The number, type and power of the turbo-generators, their configuration, the scheme head and the geomorphology of the site determine the shape and size of the building. As shown in figures 4.1 and 4.2, the following equipment will be displayed in the powerhouse:

- Inlet gate or valve
- Turbine
- Speed increaser (if needed)
- Generator
- Control system
- Condenser, switchgear
- Protection systems
- DC emergency supply
- Power and current transformers etc.,

Fig. 4.1 is a schematic view of an integral intake indoor powerhouse suitable for low 'head' schemes. The substructure is part of the weir and embodies the power intake with its trash rack, the vertical axis Kaplan turbine coupled to the generator, the draft tube and the tailrace. The control equipment and the outlet transformers are in the generator forebay.

4.1 Turbines

A turbine unit consists of a runner connected to a shaft that converts the potential energy in falling water into mechanical or shaft power. The turbine is connected either directly to the generator or is connected by means of gears or belts and pulleys, depending on the speed required for the generator. The choice of turbines depends mainly on the head and the design flow for the SHP installation. All turbines have power-speed characteristics.

Figure 4.1: Schematic view of a powerhouse - low head

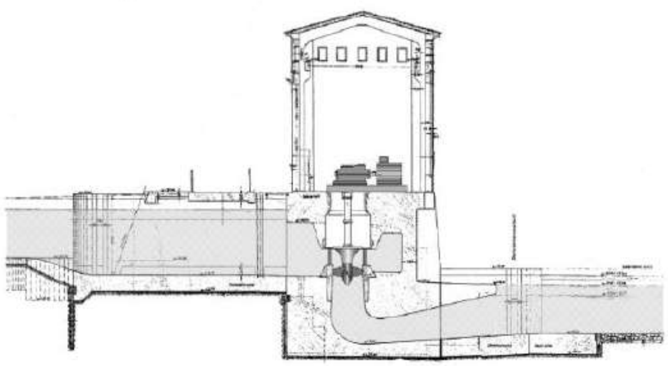
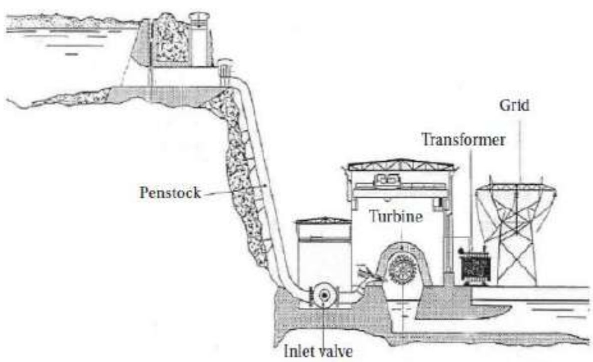


Figure 4.2: Schematic view of a powerhouse - high and medium heads



They perform most efficiently at a speed, head and flow combination. There are two types of turbines impulse and reaction. Table 2 shows which turbine is used for what kind of head.

4.1.1 Impulse turbines (high head, low flow)

Do you remember playing with toy pinwheels as a child? They are a good illustration of the principles behind an impulse turbine. When you blow on the rim of the pinwheel, it spins rapidly. The harder you blow, the faster it turns. The impulse turbine operates on the same principle, except that it uses the kinetic energy from the water as it leaves the nozzle rather than the kinetic energy of air. In a system using an impulse turbine, water is diverted upstream from the turbine into a pipeline. The water travels through this pipeline to a nozzle, which constricts the flow to a narrow jet of water. The energy to rotate an impulse turbine is derived from the kinetic energy of the water flowing through the nozzles. The term 'impulse' means that the force that turns the turbine comes from the impact of the water on the turbine runner. This causes the attached alternator to turn, and thus the mechanical work of the water is changed into electrical power.

Table 2: Groups of water turbines

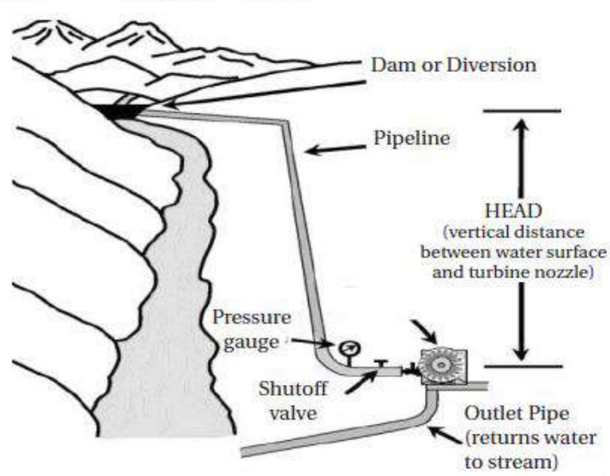
Turbine	High head (more than 100 m)	Medium head (20-100 m)	Low head
(5-20 m)	Ultra low 'head' (less than 5 m)		
Impulse	Pelton		
Turgo	Cross-flow		
Turgo			
Multi-jet pelton	Cross-flow		
Multi-jet pelton	Waterwheel		
Reaction	-	Francis	
Pump-as-turbine	Propeller		
Kaplan	Propeller		
Kaplan			

Most sites with a head of at least 25 feet now use impulse turbines. These turbines are very simple and relatively inexpensive. As the stream flow varies, water flow to the turbine can be easily controlled by changing nozzle sizes or by using adjustable nozzles. Common impulse turbines are the Pelton, Turgo, Cross flow and waterwheel or Chain turbines.

I. *Pelton Turbine*

This has a set of buckets on the periphery of a circular disc. It is turned by jets of water that are discharged from one or more nozzles. The bucket is split into two halves so that the central area does not act as a dead spot incapable of defecting water away from the oncoming jet. (Figure 4.4) The cutaway on the lower lip allows the following bucket to move further before cutting off the jet, propelling the bucket ahead of it and a permitting smoother entrance of the bucket into the jet.

Figure 4.3: Impulse Turbine



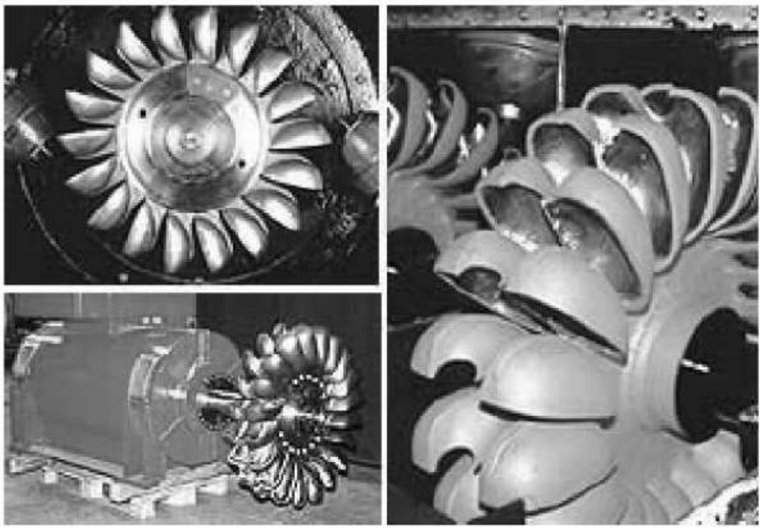


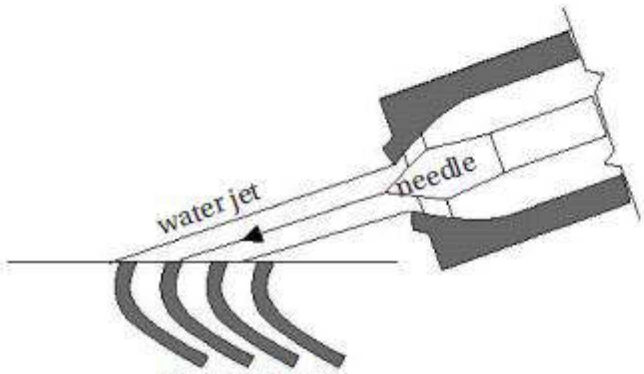
Figure 4.4 Pelton Turbine

The Pelton turbine can be used efficiently if the number of jets are increased. This ensures that the rotational speed is increased, for a given flow.

II. *Turgo Turbine*

These are designed to have higher specific speed. The jets are aimed to strike the plane of the runner on one side and exit on the other. (Figure 4.5) With smaller faster spinning runners, it is more likely and to convert Turgo turbines directly to the generator.

Figure 4.5: Turgo Turbine



III. *Cross-flow Turbine*
This has a drum-shaped runner consisting of two parallel discs connected near their rims by a series of curved blades. (Figure 4.6)

IV. *Waterwheel (Chain Turbine)*
These are traditional means of converting useful energy from flowing and falling water into mechanical power. (Figure: 4.7)

Figure 4.6: Cross-flow Turbine

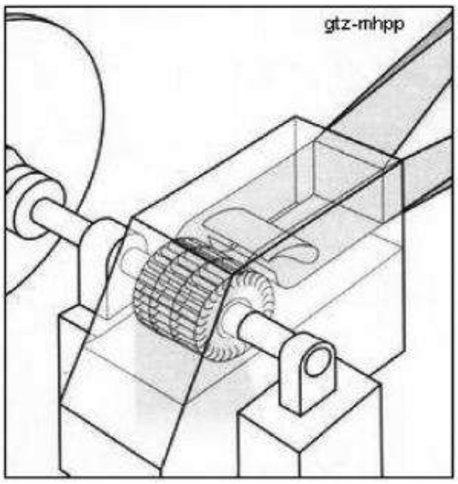
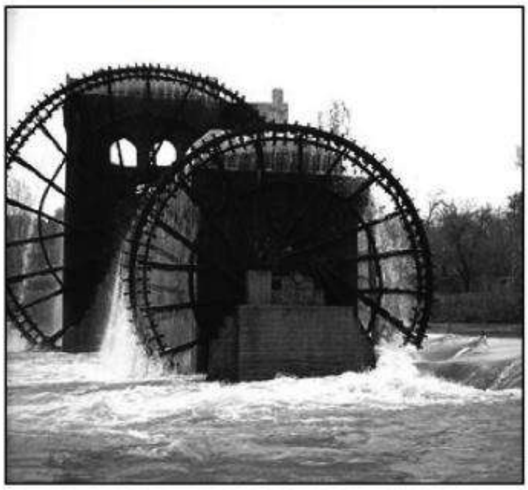
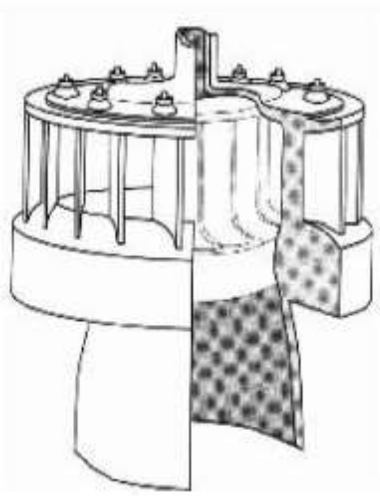


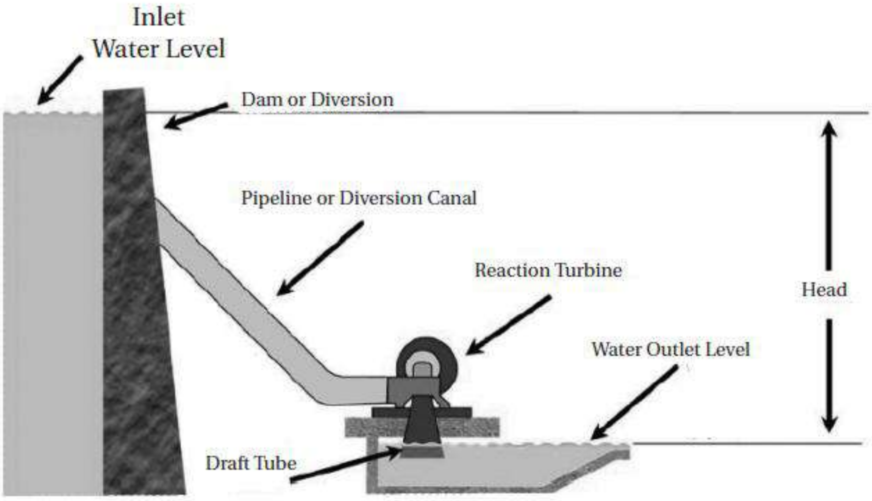
Figure 4.7 : Waterwheel



4.1.2 Reaction turbines (low head, high flow)
The reaction turbine, as the name implies, is turned by reactive force rather than by a direct push or impulse. In reaction turbines, there are no nozzles as such. Instead, the blades that project radially from the periphery of the runner are formed and mounted so that the space between the blades have in cross section, the shape of nozzles. You can use a balloon to demonstrate the kickback or reaction force generated by the nozzle blades. Blow up the balloon and release it. The air will rush out through the opening and the balloon will shoot off in the opposite direction. When the balloon is filled with air, you have potential energy stored in the increased air pressure inside. When you let the air escape, it passes through the small opening. This represents a transformation from potential energy to kinetic energy. The force applied to the air to speed up the balloon is acted upon by a reaction in the opposite direction. This reactive force propels the balloon forward through the air. You may think that the force that makes the balloon move forward comes from the jet of air blowing against the air in the room, but it is not so. It is the reaction of the force of the air as it passes through the opening that causes the balloon to move forward. The reaction turbine has all the advantages of the impulse-type turbine, plus a slower operating speed and greater efficiency. However, the reaction turbine requires a much higher flow rate than the impulse

turbine. A reaction turbine runner, with the outer guide vanes guiding the water flow into the runner blades, which act as nozzles, Figure 4.8. Diagram showing the components of a reaction turbine system with a combination diversion system in figure 4.9





There are four types of Reaction turbines:

I. Francis Turbine

This is either volute cased or an open flume machine. The runner blades are profiled in a complex manner and direct the water so that it exits axially from the center of the runner. In doing so, the water imparts most of its pressure energy to the runner before leaving the turbine via a draft tube.

II. Propeller Turbine

This consists of a propeller fitted inside a continuation of the penstock pipe. The turbine shaft passes out of the pipe at the point where the pipe changes direction. A propeller turbine is known as a fixed blade axial flow turbine because the pitch angle of the rotor cannot be changed.

III. Kaplan Turbine

This is a propeller type turbine with adjustable blades.

Figure 4.10 : Francis Turbine

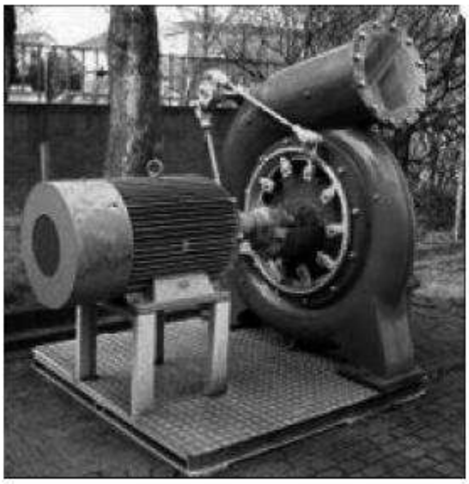
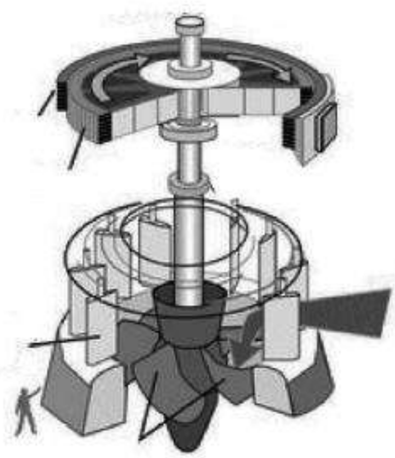


Figure 4.11 : Kaplan Turbine



IV. Reverse Pump Turbine

Centrifugal pumps can be used as turbines by passing water through them in reverse. Research is currently being done to enable the performance of pumps as turbines. The advantage is that it is low cost and spare parts are readily available. Impulse turbines are usually cheaper than reaction turbines because there is no need for specialist pressure casing. Impulse turbines are generally more suitable for SHP applications as compared with reaction turbines because they have:

- Greater tolerance of sand and other particles in water
- Better access to working parts
- Easier to fabricate and maintain
- Better part-flow efficiency

One major disadvantage of impulse turbines is that they are mostly unsuitable for low head sites.

4.3 Drive Systems

The drive system transmits power from the turbine shaft to the generator shaft. It also has the function of changing the rotational speed from one shaft to the other, when the turbine speed is different to the required speed of the generator. The following can be considered for the SHP drive system:

- Direct drive
- Flat belt and pulley
- V or wedge belt and pulleys
- Chain and sprocket
- Gearbox

4.4 Generators

These convert the mechanical (rotational) energy produced by the turbine to electrical energy. The basic principle of generator operation is that voltage is induced in a coil of wire when the coil is moved in a magnetic field. Although most early hydroelectric systems were of the direct current (DC) variety to match early commercial electrical systems, nowadays, only three-phase alternating current (AC) generators are used in normal practice. Depending on the characteristics of the network supplied, the producer can choose between:

- Synchronous generators: They are equipped with a DC electric or permanent magnet excitation system (rotating or static) associated with a voltage regulator to control the output voltage before the generator is connected to the grid. They supply the reactive energy required by the power system when the generator is connected to the grid. Synchronous generators can run isolated from the grid and produce power since excitation is not grid-dependent
- Asynchronous generators: They are simple squirrel-cage induction motors with no possibility of voltage regulation and running at a speed directly related to system frequency. They draw their excitation current from the grid, absorbing reactive energy by their own magnetism. Adding a bank of capacitors can compensate for the absorbed reactive energy. They cannot generate when disconnected from the grid because are incapable of providing their own excitation current. However, they are used in very small stand-alone applications as a cheap solution when the required quality of the electricity supply is not very high.

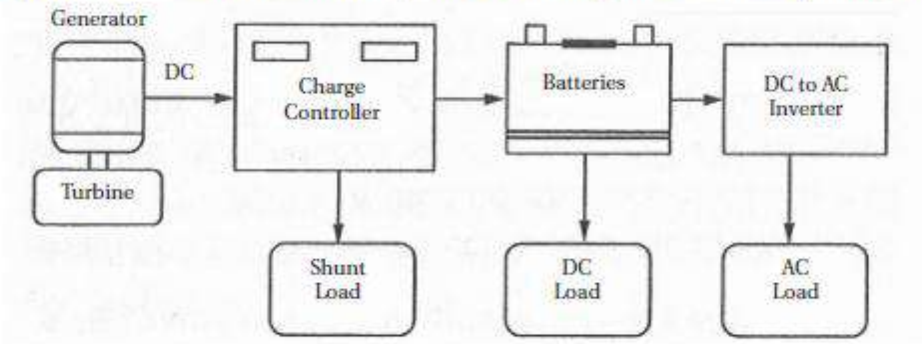
Below 1 MW synchronous generators are more expensive than asynchronous generators and are used in power systems where the output of the generator represents a substantial proportion of the power system load. Asynchronous generators are cheaper and are used in stable grids where their output is an insignificant proportion of the power system load. The efficiency should be 95 percent for a 100 KW machine and can increase to 97 percent towards an output power of 1MW. Efficiencies of synchronous generators are slightly higher. In general, when the power exceeds some MVA, a synchronous generator is installed.

Recently, variable-speed constant-frequency systems (VSG), in which turbine speed is permitted to fluctuate widely, while the voltage and frequency are kept constant and undistorted, have become available. The frequency converter, which is used to connect the generator via a DC link to the grid, can even be “synchronized” to the grid before the generator starts rotating. This approach is often proposed as a means of improving performance and reducing cost. However, no cost reduction can be achieved using propeller turbines, if only the runner regulation is replaced. It is also not possible to improve the energy

production as compared to a double-regulated Kaplan turbine. There are, nevertheless, many cases, where variable speed operation seems to be a suitable solution, e.g. when the head varies significantly.
The operating voltage of the generator increases with power. The standard generation voltages of 400 V or 690 V allow for the use of standard distributor transformers as outlet transformers and the use of the generated current to feed into the plant power system. Generators of some MVA are usually designed for higher operating voltages up to some KV and connected to the grid using a customized transformer. In this case, an independent transformer HT/LT is necessary for the auxiliary power supply of the power plant.
Electrical power can be generated in either AC or DC. AC can be connected directly to household appliances and AC is much more economical for transmitting power to homes. DC can be used in two ways, either directly as DC or converted to AC using an inverter. The main advantage of DC is ease of battery storage. Lead acid deep cycle batteries are usually used in SHP plants.

4.5 Controllers
SHP systems with lead acid batteries require protection from overcharge and over discharge. Overcharge controllers redirect the power to an auxiliary or shunt load when the battery reaches a certain level. (Figure 4.12). This protects the generator from overspeed and overvoltage conditions. Over discharge control involves disconnecting the load from the batteries when the voltage drops below a certain level.

Figure 4.12 : Electrical block diagram of a battery-based small hydro system.



Over the last two decades, electronic load controllers (ELCs) have been developed that have increased the simplicity and reliability of the modern SHP system. An ELC is a solid state electronic device designed to regulate output power of SHP systems. Maintaining a near-constant load on the turbine generates stable voltage and frequency. The controller compensates for variation in the main load by automatically varying the amount of power dissipated in a resistive load, generally known as the ballast or dump load, to keep the total load on the generator and turbine constant. Water heaters are generally used as ballast loads. An ELC constantly senses and regulates the generated frequency. The frequency is directly proportional to the speed of the turbine. The major benefit of ELCs is that they have no moving parts, are reliable and virtually maintenance free.

4.6 Automatic Control
Small hydro schemes are normally unattended and operated through an automatic control system. Not all power plants are alike therefor it is almost impossible to determine the extent of automation that should be included in each system, though some requirements are of general application:
a) The system must include the necessary relays and devices to detect malfunctioning of a serious nature and then act to bring the unit or the entire plant to a safe de-energized condition.
b) Relevant operational data of the plant should be collected and made readily available so that operating decisions can be taken and stored in a database, for later evaluation of plant performance.
c) An intelligent control system should be included to allow for full plant operation in an unattended environment.
d) It should be possible to access the control system from a remote location and override any automatic decisions.

e) The system should be able to communicate with similar units, up and downstream, for optimizing operating procedures.
f) Fault anticipation constitutes an enhancement to the control system. Using an expert system fed with baseline operational data, it is possible to anticipate faults before they occur and take corrective action so that the fault does not occur.

The system must be configured by modules. They are an analogue-to-digital conversion module for measurement of etc., water level, wicket-gate position, blade angles, instantaneous power output, temperatures, etc., a digital-to-analogue converter module to drive hydraulic valves, chart recorders, etc. A counter module to count generated KWh pulses, rain gauge pulses, flow pulses, etc., and a “smart” telemetry module providing the interface for offsite communications via dial-up telephone lines, radio link or other communication technologies. This modular system approach is well suited to the widely varying requirements encountered in hydro power control, and permits both hardware and software to be standardized. Cost reduction can be realized using a standard system and modular software allows for easy maintenance. Automatic control systems can significantly reduce the cost of energy production by reducing maintenance and increasing reliability, while running the turbines more efficiently and producing more energy from the available water.

5. Generating Power

5.1 Developing Head Pressure
In the following section, we will discuss how head is developed at a hydro site and how it is transferred into power. Have you ever swum down to the bottom of a deep swimming pool and felt your ears pop? That’s caused by water pressure which is created by the weight of the water above you. We measure water pressure in pounds per square inch (PSI). That to the weight in pounds of the water on a one-square-inch area. A reaction turbine uses “pressure head” in the same way to produce electricity. If you substitute the diver in the picture for a submerged reaction turbine, you can imagine how the pressure of all that water falling through the turbine blades, creates the force to turn the blades and produce electricity.

This ‘pressure head’ accounts for most of the power output of a reaction turbine. In addition, many reaction turbines also have a water discharge tube called a ‘draft tube’, which can increase the head by producing a vacuum between the turbine runner blades and the level of the exit water. This is called the ‘suction head’ and can increase power output of the turbine by up to 20 percent, if it is set up properly. It is important that it is completely submerged in the tail water with no air leaks, maintaining a closed system and thus, the vacuum suction. With this system, the total head is a combination of the pressure head and the suction head.

Figure 5.1: Water Pressure exerts force on a diver

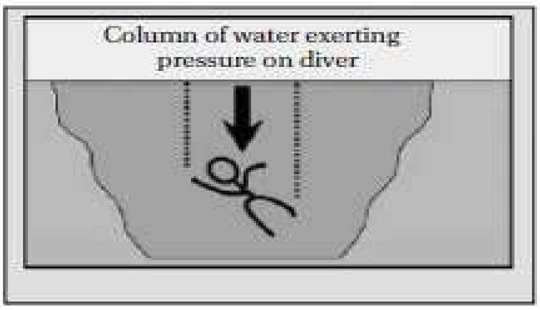
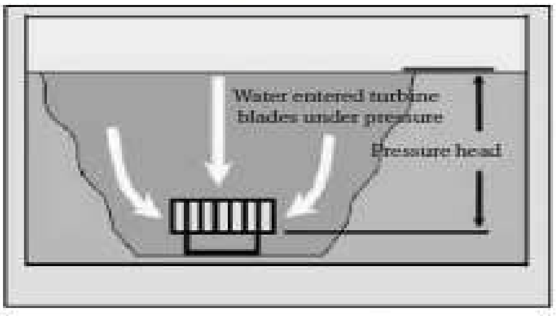


Figure 5.2: Pressure Head for a ReactionTurbine



Another important characteristic of water is that it is essentially a non-compressible liquid. This means it exhibits the unique trait of transferring pressure horizontally when in a confined space (what we define as a closed system). This becomes very important in hydro systems where a pipeline is involved, which is always the case with impulse turbines and is occasionally used with reaction turbines as well. Water that enters a pipe exhibits the same pressure at the bottom as it would if the pipe were perfectly vertical, even if the pipe itself isn't. The best way to demonstrate this is with a picture. If the water is not flowing through the pipeline, the pressure of the water at the lower end of the pipe is the same as the water pressure at an equivalent level directly below the inlet. This is true no matter how long the pipe is. Since water is a non-compressible liquid it transfers the pressure horizontally along the pipe route for any distance without any loss of pressure.

This is called the "static pressure" (or "static head") of the water. If this system were completely frictionless, the pressure would remain the same when the water was flowing as well. However, there is friction between the water and the inner surface of the pipeline, causing the pressure to drop once the water is moving (called "friction loss"). The usable force of the water when it reaches the turbine is called the "dynamic pressure" (or "dynamic head"), and is calculated by subtracting the friction loss caused by the pipeline from the amount of static head. The total length and diameter of the pipe you use becomes important in planning your system because you always want to minimize your friction losses. Impulse turbines are not submerged in the water,
and thus, the water exits the closed system when it exits the pipeline at the turbine nozzle. Hence there is no suction head and in an impulse turbine the total head is equal to the pressure head. What we are beginning to see is that in a hydro system, it's not just important how much head and how much flow you have available in a theoretical sense, it's also important to consider how you can get that water to your turbine location with as little loss as possible.

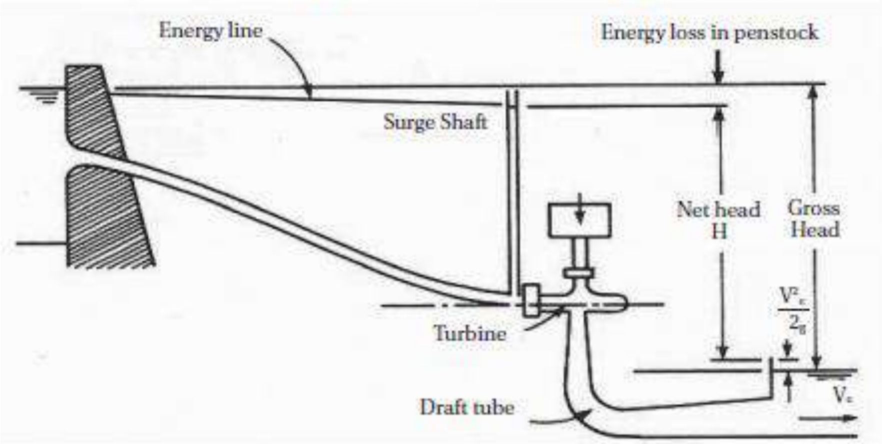
An analogy could be made with driving your car. Your car has a certain potential amount of power it can produce. But the amount of power you use at any given time has a lot to do with the road you are travelling on. A twisting, winding road will not allow you to move as fast as a straight one. A muddy road will not let you move as fast as nice smooth pavement. In the same way, it's not just the amount of power (from head) that you can theoretically get from your water source, it's also the 'road' you build to get your water to the turbine. We call this road a 'diversion system', and just as with a road, water prefers nice straight diversion systems without abrupt turns and smooth walls.

5.2 'Pressure Head' for an Impulse Turbine System

Hydro power is obtained from the potential and kinetic energy of water flowing from a height. The energy contained in the water is converted into electricity by using a turbine coupled to a generator. The hydro power potential of a site is dependent on the discharge and head of water. It is estimated by the following equation

P (power in KW) = Q x H x 9.81 x η, where
Q = discharge (rate of flow) in m^3 /s;
H = Head (height) in meters; and
η= overall power generating system efficiency.

Figure 5.3: Components of a Small Hydropower Unit



A hydro power resource can be measured according to the amount of available power or energy per unit time. The power of a given situation is a function of head and rate of flow. (Figure 5.4) The energy in a SHP starts out as potential energy by its height above the powerhouse. Water under pressure in the penstock can do work when released so there is energy associated with the pressure as well. The transformation of energy is from potential to pressure to kinetic energy. The total energy is the sum of the potential, pressure and kinetic in a run-of-the river system.

Net head is the gross head minus the head losses that occur when water flows from the intake to the turbines through canals and penstock. Water loses energy (head loss) as it flows through a pipe, fundamentally due to:

1. Friction against the wall.

The friction against the pipe wall depends on the wall material roughness and the velocity gradient which by near the wall. The friction in the pipe walls can be reduced by increasing the pipe diameter. However, increasing the diameter increases the cost, so a compromise should be reached between the cost and diameter.

2. Flow turbulence

Water flowing through a pipe system with bends, sudden contractions and enlargement of pipes, racks, valves and other accessories experiences in addition to the friction loss, a loss due to inner viscosity. This loss depends on the velocity and is expressed by an experimental K multiplied with the kinetic energy. Water flown in a pipe bend, experiences an increase of pressure along the outer wall and a decrease of pressure along the inner wall. This pressure imbalance causes a secondary current. Both movements together (the longitudinal flow and the secondary current), produces a spiral flow at a length of around 100 meters is dissipated by viscous friction. The head loss produced depends on the radius of the bend and the diameter of the pipe. The loss of head produced by water flowing through an open valve depends on the type and manufacture of the valve.

6. Economics of using an SHP

6.1 Advantages of an SHP

Some of the key advantages of SHP are:

- Environmental protection through CO_2 emission reduction – CO_2 emission is reduced because electricity production from SHP does not release CO_2 in the process
- Proven and reliable technology
- Improves the diversity of energy supplies – this is the one of many alternatives of producing electricity
- Grid stability

- Reduced land requirements – unlike in wind energy, where a fair bit of land is required to install a wind turbine
- Local and regional development – leads the community to be independent of fossil fuel
- Assists in the maintenance of river basins
- Technology suitable for rural electrification in developing countries
- High energy payback ratio

6.2 Shortcomings of an SHP

Some of the shortcomings are:

- SHP is a site-specific technology and usually the site is far away from the place where the electricity is required
- Run-of-the river plants experience significant fluctuations in output power

6.3 Environmental Impact of an SHP

Firstly, 1GWh of electricity produced by SHP allows to:

- Supply electricity for one year to 250 households in a developed country
- Save 220 tons of petrol
- Save 335 tons of coal
- Avoid the emission of 480 tons of carbon dioxide
- Supply electricity for one year to 450 households in a developing country

Secondly, because SHP is produced from run-of-the river systems, it doesn't disturb aquatic life. A general rule of thumb is to not divert more than 20 percent of the water flow of the river through the turbine and to return any diverted water back to the river just below the turbine.

6.4 SHP Economics and Costs

The capital required for small hydro plants depends on the effective head, the flow rate, geographical and geological features, the equipment (turbines, generators and others) and civil engineering works and continuity of water flow.

Sites with low heads and high flow require a greater capital outlay, as large turbine machinery are needed to handle larger flow of water. If, however, the system can have a dual purpose- such as power generation and flood control, power generation and irrigation, power generating and drinking water production-the payback period can be lowered. The operation and maintenance cost including repairs and insurance can range from 1.5 to 5 percent of investment costs.

OCEAN ENERGY

Ocean thermal energy conversion (OTEC) generates electricity indirectly from solar energy by harnessing the temperature difference between the sun-warmed surface of tropical oceans and the colder deep waters. A significant fraction of solar radiation incident on the ocean is retained by seawater in tropical regions, resulting in average year-round surface temperatures of about 283°C. Deep, cold water, meanwhile, forms at higher latitudes and descends to flow along the sea floor toward the equator. The warm surface layer, which extends to depths of about 100-200m, is separated from the deep cold water by a thermocline. The temperature difference, *T*, between the surface and thousand-meter depth ranges from 10 to 253°C, with larger differences occurring in equatorial and tropical waters, as depicted in Figure 1. *T* establishes the limits of the performance of OTEC power cycles; the rule-of thumb is that a differential of about 203°C is necessary

to sustain viable operation of an OTEC facility. Since OTEC exploits renewable solar energy, recurring costs to generate electrical power are minimal. However, the fixed or capital costs of OTEC systems per kilowatt of generating capacity are very high because large pipelines and heat exchangers are needed to produce relatively modest amounts of electricity. These high fixed costs dominate the economics of OTEC to the extent that it currently cannot compete with conventional power systems, except in limited niche markets. Considerable effort has been expended over the past two decades to develop OTEC by-products, such as fresh water, air conditioning, and mariculture, that could offset the cost penalty of electricity generation.

State of the Technology

OTEC power systems operate as cyclic heat engines. They receive thermal energy through heat transfer from surface sea water warmed by the sun, and transform a portion of this energy to electrical power. The Second Law of Thermodynamics precludes the complete conversion of thermal energy in to electricity. A portion of the heat extracted from the warm sea water must be rejected to a colder thermal sink. The thermal sink employed by OTEC systems is sea water drawn from the ocean depths by means of a submerged pipeline. A steady-state control volume energy analysis yields the result that net electrical power produced by the engine must equal the difference between the rates of heat transfer from the warm surface water and to the cold deep water. The limiting (i.e., maximum) theoretical Carnot energy conversion efficiency of a cyclic heat engine scales with the difference between the temperatures at which these heat transfers occur. For OTEC, this difference is determined by *T* and is very small; hence, OTEC efficiency is low. Although viable OTEC systems are characterized by Carnot efficiencies in the range of 6-8%, state-of-the-art combustion steam power cycles, which tap much higher temperature energy sources, are theoretically capable of converting more than 60% of the extracted thermal energy into electricity.

The low energy conversion efficiency of OTEC means that more than 90% of the thermal energy extracted from the ocean's surface is 'wasted' and must be rejected to the cold, deep sea water. This necessitates large heat exchangers and seawater flow rates to produce relatively small amounts of electricity. Despite its inherent inefficiency, OTEC, unlike conventional fossil energy systems, utilizes a renewable resource and poses minimal threat to the environment. In fact, it has been suggested that widespread adoption of OTEC could yield tangible environmental benefits through avenues such as reduction of greenhouse gas CO_2 emissions; enhanced uptake of atmospheric CO_2 by marine organism populations sustained by the nutrient-rich, deep OTEC sea water; and preservation of corals and hurricane amelioration by limiting temperature rise in the surface ocean through energy extraction and artificial upwelling of deep water.

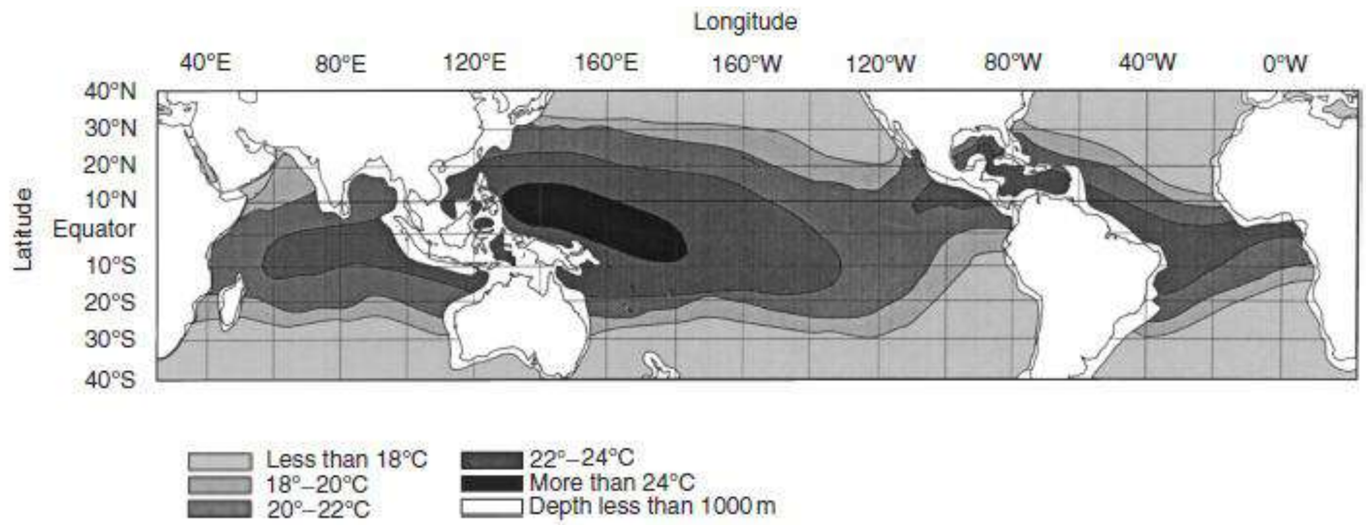


Figure 1 Temperature difference between surface and deep sea water in regions of the world. The darkest areas have the greatest temperature difference and are the best locations for OTEC systems.

Carnot efficiency applies only to an ideal heat engine. In real power generation systems, irreversibility will further degrade performance. Given its low theoretical efficiency, successful implementation of OTEC power generation demands careful engineering to minimize irreversibility. Although OTEC consumes what is essentially a free resource, poor thermodynamic performance will reduce the quantity of electricity available for sale and, hence, negatively affect the economic feasibility of an OTEC facility.

An OTEC heat engine may be configured following designs by J.A. D'Arsonval, the French engineer who first proposed the OTEC concept in 1881, or G. Claude, D'Arsonval's former student. Their designs are known, respectively, as closed cycle and open cycle OTEC.

Closed Cycle OTEC

D'Arsonval's original concept employed a pure working fluid that would evaporate at the temperature of warm sea water. The vapor would subsequently expand and do work before being condensed by the cold sea water. This series of steps would be repeated continuously with the same working fluid, whose flash path and thermodynamic process representation constituted closed loops hence, the name 'closed cycle.' The specific process adopted for closed cycle OTEC is the Rankine, or vapor power, cycle. Figure 2 is a simplified schematic diagram of a closed cycle OTEC system. The principal components are the heat exchangers, turbo generator, and seawater supply system, which, although not shown, accounts for most of the parasitic power consumption and a significant fraction of the capital expense. Also, not included are ancillary devices such as separators to remove residual liquid downstream of the evaporator and subsystems to hold and supply working fluid lost through leaks or contamination.

In this system, heat transfer from warm surface sea water occurs in the evaporator, producing a saturated vapor from the working fluid. Electricity is generated when this gas expands to lower pressure through the turbine. Latent heat is transferred from the vapor to the cold sea water in the condenser and the resulting liquid is pressurized with a pump to repeat the cycle.

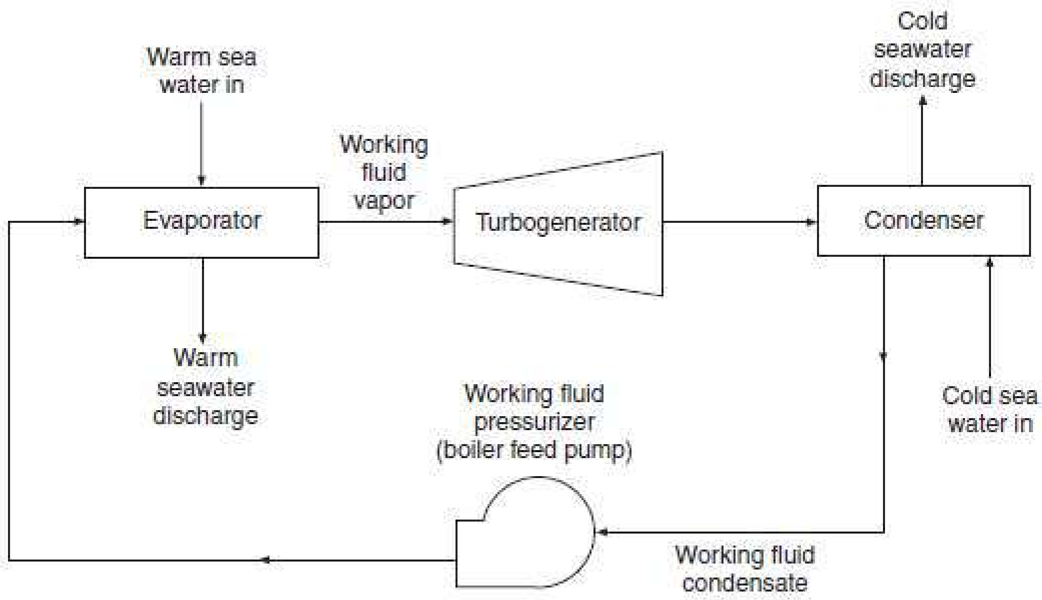


Figure 2: Schematic diagram of a closed-cycle OTEC system.

The working fluid is vaporized by heat transfer from the warm sea water in the evaporator. The vapor expands through the turbo generator and is condensed by heat transfer to cold sea water in the condenser. Closed-cycle OTEC power systems, which operate at elevated pressures, require smaller turbines than open-cycle systems.

The success of the Rankine cycle is a consequence of more energy being recovered when the vapor expands through the turbine than is consumed in re-pressurizing the liquid. In conventional (e.g., combustion) Rankine systems, this yields net electrical power. For OTEC, however, the remaining balance may be reduced substantially by an amount needed to pump large volumes of sea water through the heat exchangers. (One misconception about OTEC is that tremendous energy must be expended to bring cold sea water up from depths approaching 1000 meters. The natural hydrostatic pressure gradient provides for most of the increase in the gravitational potential energy of a fluid particle moving with the gradient from the ocean depths to the surface.) Irreversibility in the turbomachinery and heat exchangers reduce cycle efficiency below the Carnot value. irreversibility in the heat exchangers occur when energy is transferred over a large temperature difference. It is important, therefore, to select a working fluid that will undergo the desired phase changes at temperatures established by the surface and deep-sea water. Insofar as many substances can meet this requirement (because pressures and the pressure ratio across the turbine and pump are design parameters), other factors must be considered in the selection of a working fluid including: cost and availability, compatibility with system materials, toxicity, and environmental hazard.

Leading candidate working fluids for closed cycle
OTEC applications are ammonia and various fluorocarbon refrigerants. Their primary disadvantage is the environmental hazard posed by leakage; ammonia is toxic in moderate concentrations and certain fluorocarbons have been banned by the Montreal Protocol because they deplete stratospheric ozone. The Kalina, or adjustable proportion fluid mixture (APFM), cycle is a variant of the OTEC closed cycle. Whereas simple closed cycle OTEC systems use a pure working fluid, the Kalina cycle proposes to employ a mixture of ammonia and water with varying proportions at different points in the system.

The advantage of a binary mixture is that, at a given pressure, evaporation or condensation occurs over a range of temperatures; a pure fluid, on the other hand, changes phase at constant temperature. This additional degree of freedom allows heat transfer-related irreversibility in the evaporator and condenser to be reduced. Although it improves efficiency, the Kalina cycle needs additional capital equipment and may impose severe demands on the evaporator and condenser. The efficiency improvement will require some combination of higher heat transfer coefficients, more heat transfer surface area, and increased seawater flow rates. Each has an associated cost or power penalty. Additional analysis and testing are required to confirm whether the Kalina cycle and assorted variations are viable alternatives.

Open Cycle OTEC
Claude's concern about the cost and potential biofouling of closed cycle heat exchangers led him to propose using steam generated directly from the warm sea water as the OTEC working fluid. The steps of the Claude, or open, cycle is: (1) Flash evaporation of warm sea water in a partial vacuum; (2) expansion of the steam through a turbine to generate power; (3) condensation of the vapor by direct contact heat transfer to cold sea water; and (4) compression and discharge of the condensate and any residual non-condensable gases. Unless fresh water is a desired by-product, open cycle OTEC eliminates the need for surface heat exchangers. The name 'open cycle' comes from the fact that the working fluid (steam) is discharged after a single pass and has different initial and final thermodynamic states; hence, the flow path and process are 'open.'

The essential features of an open cycle OTEC system are presented in Figure 3. The entire system, from evaporator to condenser, operates at partial vacuum, typically at pressures of 1-3% of atmospheric. Initial evacuation of the system and removal of non-condensable gases during operation are performed by the vacuum compressor, which, along with the sea water and discharge pumps, accounts for the bulk of the open cycle OTEC parasitic power consumption. The low system pressures of open cycle OTEC are necessary to induce boiling of the warm sea water. Flash evaporation is accomplished by exposing the sea water to pressures below the saturation pressure corresponding to its temperature. This is usually accomplished by pumping it into an evacuated chamber through spouts designed to maximize heat and mass transfer surface area. Removal of gases dissolved in the sea water, which will come out of solution in the low-pressure evaporator and compromise operation, may be performed at an intermediate pressure prior to evaporation.
Vapor produced in the flash evaporator is relatively pure steam. The heat of vaporization is extracted from the liquid phase, lowering its temperature and preventing any further boiling. Flash evaporation may be perceived, then, as a transfer of thermal energy from the bulk of the warm sea water of the small fraction

of mass that is vaporized. Less than 0.5% of the mass of warm sea water entering the evaporator is converted into steam.

The pressure drop across the turbine is established by the cold seawater temperature. At 43°C, steam condenses at 813 Pa. The turbine (or turbine diffuser) exit pressure cannot fall below this value. Hence, the maximum turbine pressure drop is only about 3000Pa, corresponding to about a 3:1 pressure ratio. This will be further reduced to account for other pressure drops along the steam path and differences in the temperatures of the steam and seawater streams needed to facilitate heat transfer in the evaporator and condenser. Condensation of the low-pressure steam leaving the turbine may employ a direct contact condenser (DCC), in which cold sea water is sprayed over the vapor, or a conventional surface condenser that physically separates the coolant and the condensate. DCCs are inexpensive and have good heat transfer
characteristics because they lack a solid thermal boundary between the warm and cool fluids. Surface condensers are expensive and more difficult to maintain than DCCs; however, they produce a marketable freshwater by-product. Effluent from the condenser must be discharged to the environment. Liquids are pressurized to ambient levels at the point of release by means of a pump, or, if the elevation of the condenser is suitably high, can be compressed hydrostatically. As noted previously, non-condensable gases, which include any residual water vapor, dissolved gases that have come out of solution, and air that may have leaked into the system, are removed by the vacuum compressor.

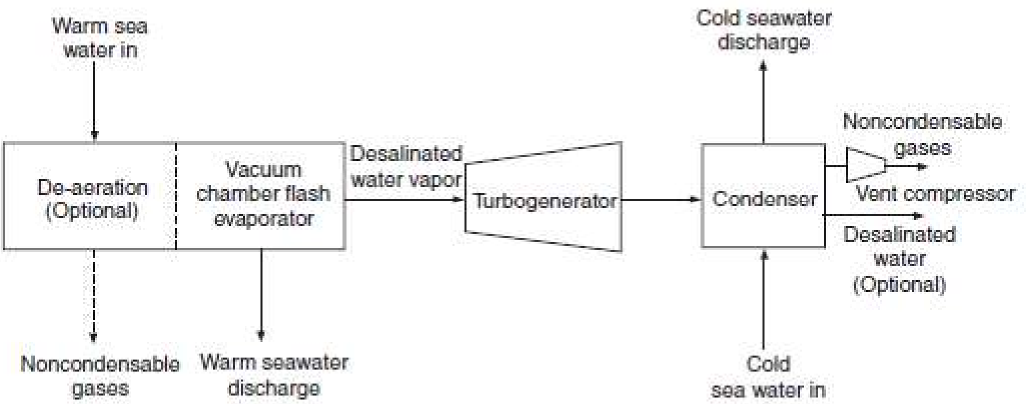


Figure 3: Schematic diagram of an open-cycle OTEC system.

In open-cycle OTEC, warm sea water is used directly as the working fluid. Warm sea water is flash evaporated in a partial vacuum in the evaporator. The vapor expands through the turbine and is condensed with cold sea water. The principal disadvantage of open-cycle OTEC is the low system operating pressures, which necessitate large components to accommodate the high volumetric flow rates of steam.
Open cycle OTEC eliminates expensive heat exchangers at the cost of low system pressures. Partial vacuum operation has the disadvantage of making the system vulnerable to air in-leakage and promotes the evolution of non-condensable gases dissolved in sea water. Power must ultimately be expended to pressurize and remove these gases. Furthermore, because of the low steam density, volumetric flow rates are very high per unit of electricity generated. Large components are needed to accommodate these flow rates. Only the largest conventional steam turbine stages have the potential for integration into open cycle OTEC systems of a few megawatts gross generating capacity.

It is generally acknowledged that higher capacity plants will require a major turbine development effort. The mist lift and foam lift OTEC systems are variants of the OTEC open cycle. Both employ the sea water directly to produce power. Unlike Claude's open cycle, lift cycles generate electricity with a hydraulic turbine. The energy expended by the liquid to drive the turbine is recovered from the warm sea water. In the lift process, warm seawater is flash evaporated to produce a two-phase, liquid vapor mixture either a mist consisting of liquid droplets suspended in a vapor, or a foam, where vapor bubbles are contained in a continuous liquid phase. The mixture rises, doing work against gravity. Here, the thermal energy of the vapor is expended to increase the potential energy of the fluid. The vapor is then condensed with cold sea water and discharged back into the ocean. Flow of the liquid through the hydraulic turbine may occur before or after the lift process. Advocates of the mist and foam lift cycles contend that they are cheaper to implement than closed cycle OTEC because they require no expensive heat exchangers, and are superior to the Claude cycle because they utilize a hydraulic turbine rather than a low-pressure steam turbine.

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 generator 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.

Formation of Waves

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).

Conversion of Wave Energy into Electricity

To harness wave energy and make it create and energy output for us, we must go where the waves are. Successful and profitable use of wave energy on a large scale only occurs in a few regions around the world. The places include the states of Washington, Oregon and California and other areas along North America’s west coast. This also includes the coasts of Scotland Africa and Australia. Wave energy is, essentially, a condensed form of solar power produced by the wind action blowing across ocean water surface, which can then be utilized as an energy source. When the intense sun rays hit the atmosphere, they get it warmed up. The intensity of sun rays hitting the earth’s atmosphere varies considerably in different parts of the world. This disparity of atmospheric temperature around the world causes the atmospheric air to travel from hotter to cooler regions, giving rise to winds.

As the wind glides over the ocean surface, a fraction of the kinetic energy from the wind is shifted to the water beneath, resulting in waves. As a matter of fact, the ocean could be a gigantic energy storehouse collector conveyed by the sun rays to the oceans, with the waves transporting the conveyed kinetic energy across the ocean surface. With that in mind, we can safely conclude that waves are a form of energy and it's the same energy, not water that glides over the surface of the ocean. These waves can travel throughout the expansive oceans without losing a lot of energy. However, when they reach the shoreline, where the depth of water is considerable shallow, their speed reduces, while their size significantly increases. Ultimately, the waves strike the shoreline, discharging huge quantities of kinetic energy.

Wave Energy Converter

The Wave energy hitting the shore is converted into electricity using a wave energy converter (WEC), essentially, a power station. The operating principle of this power station is both simple and ingenious. It's an enclosed chamber with an opening under the sea, which allows strong sea waves to flow into the chamber and back.

The water level in the chamber rises and falls with the rhythm of the wave, and so air is forced forwards and backward via the turbines joined to an upper opening in the chamber. The compressed and decompressed air has enough power to propel the turbines. The turbine is propelled in the same direction by the back and forth airflow through the turbine. The propelling turbine turns a shaft connected to a generator.

The generator produces electricity, which is transported to electrical grids and later supplied to demand centers and distribution lines that connect individual homes and industries. The advantage of this wave energy converter is that even considerably low wave motions can produce sufficient airflow to maintain the movement of the turbine to generate energy.

Tidal Energy

Tidal Energy or Tidal Power as it is also called, is another form of hydro power that utilizes large amounts of energy within the oceans tides to generate electricity. Tidal Energy is an "alternative energy" that can also be classed as a "renewable energy source", as the Earth uses the gravitational forces of both the moon and the sun every day to move vast quantities of water around the oceans and seas producing tides. As the Earth, its Moon and the Sun rotate around each other in space, the gravitational movement of the moon and the sun with respect to the earth, causes millions of gallons of water to flow around the Earth's oceans creating periodic shifts in these moving bodies of water. These vertical shifts of water are called "tides".

Tidal Effects of the Sun and Moon

Alignment of the Moon and Sun on Tides: When the earth and the moons gravity lines up with each other, the influences of these two gravitational forces becomes very strong and causes millions of gallons of water to move or flow towards the shore creating a "high tide" condition. Likewise, when the earth and the moons gravity are at 90o to each other, the influences of these two gravitational forces is weaker and the water flows away from the shore as the mass of water moves to another location on the earth, creating a "low tide" condition. This ebbing and flowing of the tides happens twice during each period of rotation of the earth with stronger weekly and annual lunar cycles superimposed onto these tides. When the moon is in perfect alignment with the earth and the sun, the gravitational pull of the moon and sun together becomes much stronger than normal with the high tides becoming very high and the low tides becoming very low during each tidal cycle. Such tides are known as spring tides (maximum). These spring tides occur during the full or new moon phase.

The other tidal situation arises during neap tides (minimum) when the gravitational pull of the moon and the sun are against each other, thus cancelling their effects. The net result is a smaller pulling action on the sea water creating much smaller differences between the high and low tides thereby producing very weak tides. Neap tides occur during the quarter moon phase. Then spring tides and neap tides produce different amounts of potential energy in the movement of the sea water as their effects differ from the regular high and low sea levels and we can use these tidal changes to produce renewable energy. So, we can say that the tides are turning for alternative energy.

So, we now know that the constant rotational movement of the earth and the moon with regards to each other causes huge amounts of water to move around the earth as the tides go in and out. These tides are predictable and regular resulting in two high tides and two low tides each day with the level of the oceans constantly moving between a high tide and a low tide, and then back to a high tide again. The time taken for a tidal cycle to happen is about 12 hours and 24 minutes (called the "diurnal cycle") between two consecutive high tides allowing Oceanographers and Meteorologist to accurately predict the ebb and flow of the tides around the oceans many years in advance.

The main big advantage of this is that the tides are therefore perfectly predictable and regular unlike wind energy or solar energy, allowing miles of coastline to be used for tidal energy exploitation and the larger the tidal influence, the greater the movement of the tidal water and therefore the more potential energy that can be harvested for power generation. Therefore, Tidal Energy can be considered as a renewable energy source as the oceans energy is replenished by the sun as well as through tidal influences of the moon and suns gravitational forces.

Tidal Energy Generation

Since the position of the earth and the moon with respect to the sun changes throughout the year, we can utilize the potential energy of the water contained in the daily movement of the rising and falling sea levels to generate electricity. The generation of electricity from tides is similar in many ways to hydro-electric generation we looked at in the hydro energy tutorials. The difference this time is that the water flows in and out of the turbines in both directions instead of in just one forward direction.

Tidal energy, just like hydro energy transforms water in motion into a clean energy. The motion of the tidal water, driven by the pull of gravity, contains large amounts of kinetic energy in the form of strong tidal currents called tidal streams. The daily ebbing and flowing, back and forth of the oceans tides along a coastline and into and out of small inlets, bays or coastal basins, is little different to the water flowing down a river or stream. The movement of the sea water is harnessed in a similar way using waterwheels and turbines to that used to generate hydroelectricity. But because the sea water can flow in both directions in a tidal energy system, it can generate power when the water is flowing in and when it is ebbing out. Therefore, tidal generators are designed to produce power when the rotor blades are turning in either direction. However, the cost of reversible electrical generators is more expensive than single direction generators.

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