9.2.10. Conclusions

A comparative study of the closed (ammonia), open (steam), and hybrid cycles showed the closed-cycle system to be most economical in cost and to require the least parasitic power.

Closed cycle is favoured for the future development in expectation of higher efficiency but does not yet have the advantage of having been put in practice. Compared with the prospects of wind power for large scale development to help meet out energy needs soon, it is this lack of experience that puts oceans thermal difference development at a disadvantage and leads to the emphasis on wind power. In the case of wind power the favoured method has been demonstrated as practicable in several countries over the past half century and has failed only the economic test in the era of cheap fuel whereas the favoured method of ocean thermal energy conversion has not been so demonstrated. It is to be hoped that it soon will be ; there are reports that Japan plans to lead the way in actual development. Research and actual development particularly of materials, fouling problems, and design are in progress in this country.

9.2.11. Prospects of Ocean Thermal Energy Conversion in India

The OTEC project cell established at IIT, Madras has completed the preliminary feasibility study for establishing a, 1 MW OTEC plant in Lakshadeep Island at Minicoy. The OTEC works on the principle of utilizing the temperature difference of sea water at depth and that at the surface. The surface sea water is used to vaporise a low boiling chemical which drives, a turbogenerator. The vaporised chemical is then compressed, it is condensed by using cold sea water from depth. Preliminary oceanographic studies on eastern side of Lakshadeep Island suggest the possibility of the establishment of shore based OTEC plant at the island with a cold water pipe line running down the slope to a depth of 800—1000 m. Both the island have large lagoons on the western side. The lagoons are very shallow with hardly any nutrient in the sea water. The proposed OTEC plant will bring up the water from 1000 m depth which has high nutrient value. After providing cooling effect in the condenser, a part of deep sea water is proposed to be diverted to the lagoons for the development of aqua culture. A hydrographic survey of the proposed site was undertaken by National Hydrographic Office, Dehra Dun. The preliminary assessment of survey indicates the availability of suitable conditions for establishment of OTEC plant.

9.3. Energy from Tides

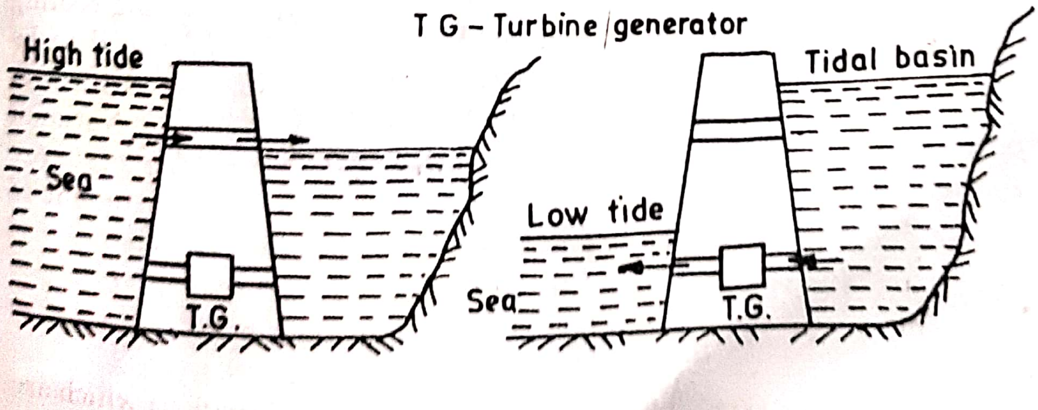
9.3.1. Introduction

Tide is a periodic rise and fall of the water level of sea which are carried by the action of the sun and moon on the water of the earth.

Tide energy can furnish a significant portion of all such energies which are renewable in nature. It has been estimated that about a billion kW of tidal power is dissipated by friction and eddies alone. This is slightly less than the economically exploitable power potential of all the rivers of the World. It is only indication of the magnitude of tidal power available ; all of it is not economically feasible also. The first attempt to utilize energy of the ocean was in the form of tidal "mills" in the eleventh century in Great Britain and latter in France and Spain.

The large scale up and down movement of sea water represents an unlimited source of energy. If some part of this vast energy can be converted into electrical energy it would be an important source of hydro-power. The main feature of the tidal cycle is the difference in water surface elevations at the high tide and at the low tide. If this differential head could be utilized in operating a hydraulic turbine, the tidal energy could be converted into electrical energy by means of an attached generator. In principle, this is not very difficult as water, at the time of high tide, is at a high level and can be let into a basin to be stored at a high level there. The same water can be let back into the sea during the low tide through the turbines, thus producing power. Since the basin water level is high and sea water is low, there is a differential head comparable to the tidal range, that can be utilized for the running of the turbines. Basically it appears to be a simple proposition, the problems involved in it, are many. The Tides, as we see, although free, were inconvenient because they come at varying times from day to day, have varying ranges (heads) and, for large outputs required large capital expenditures. Their early use declined and eventually came to a half with the coming of the age of steam and cheap coal. With the beginning of the energy crisis in the 1970s, the tidal energy, like other renewable energy sources, received renewed attention.

The first tidal power plant was commissioned by General De-Gaulle at La Rance in 1966 which marked a break through. The average tidal range is 8.4 m (± 4.2 m), and the maximum is 13.5 m. Effective



(a) (b)

Fig. 9.3.1. Principle of Tidal power generation.

namely, Sonrai creek and Bhavnagar creek which have the essential requirements for locating probable plants. However, the silt change of the Gulf of Cambay is about 5000 ppm which is thought to be high and needs a closer study for future development. Gulf of Kutch has a maximum spring tide range of 7.5 m. The silt change here (near Navalakhi in the Gulf of Kutch) is much lower (nearly 1000 ppm).

The tidal ranges and power potential of these sites are indicated in the table 9.3.10.1.

Table 9.3.10.1. Tidal Power Potential in India

Sites	*Spring Tidal range in metres*	*Assumed area in Sq. kms.*	*Total maximum potential energy 10^6 kWh/yr.*	*Single Basin Cycle*		*Two basins*			
						Alternatively operating		*Cooperating*	
				MW	*10^6 kW/yr.*	*MW*	*10^6 kWh/yr.*	*MW*	*10^6 kWh/yr.*
Gulf of Kutch Navalakhi	7.5	10	1110	43	376	48	419	16.4	143
Gulf of Cambay	10.8	10	2300	89.4	784	100	880	34.2	300
Sagar	4.85	10	464	18	157	20.1	176	6.9	60
Diamond Harbour	3.9	10	686	26.6	233	29.7	262	10.15	89

There is at present no indication regarding the cost of generation from tidal power. Preliminary studies already carried out by the CPWD and for tidal station in the Gulf of Cambay indicated higher cost of generation from conventional sources. However, the cost of coal and other allied materials is increasing which may open up the possibility of exploitation of this source of power. Adequate data will have to be collected for any realistic assessment of tidal power potential and possible impact on the environment, current patterns, tidal reflections, sedimentation, erosion etc. Detailed feasibility reports based on full technology assessment are called for before venturing into this field.

9.4. Ocean Waves

9.4.1. Introduction

Ocean and sea waves are caused indirectly by solar energy like the wind and OTEC. Wave energy derives from wind energy, which drives in turn from solar energy. As stated earlier, the wind energy is caused by the uneven solar heating and subsequent cooling of the earth's crust and the rotation of the earth. Wave energy at its most active, however, can be much more concentrated than the solar energy. Devices that convert energy from waves can therefore produce much higher power densities that solar devices.

The power in the ocean waves has been part of the human experience for thousands of years. However, the history of attempts to exploit this power for human purposes has been extensive. It was the recent energy crisis that prompted serious attempts at harnessing the waves for the production of electricity. During the decade of the 1970s dozens of patents were filed to do this, though most are complicated and rather fragile in the face of the gigantic power of the ocean storms. Patents have been issued on a variety of devices and many schemes have been described conceptually. Some small-scale prototype devices have been tested. Upto now no major development programme has been carried out through in any country. Small devices are available, however, and are in limited use as power supplies for buoys and navigational aids. From the engineering development point of view, waves energy development is not nearly as far along as wind and tidal energy.

World sites that may be suitable for 'harvesting' of energy from waves include the Molakai and Alenuihaha channels in the Hawalian islands, where 2 to 3 m-high (crest to trough) waves are typical during normal trade wind periods, the Pacific coast of North America, the Arabian sea of India and Pakistan, the North Atlantic coast of Scotland, the coast of New England etc.

9.4.2. Advantages and Disadvantages of Wave Energy

Advantages are : (1) The wave energy has the advantage over wind or solar that the energy has been naturally concentrated by accumulation overtime and space and transported from the point at which it was originally present in the winds.

(2) The degree of power concentration effected by waves is quite substantial whereas the power density in wind may, at a good site, average some hundreds of watts per square meter, wave from being transported across a plane perpendicular to the wave propagation direction at a good site is from 10 to 100 times at large.

(3) It is a free and renewable energy source.

(4) Wave power devices do not use up large land masses unlike solar or wind.

(5) These devices are relatively pollution free and, because they remove energy from the waves, leave the water in a relatively placid (calm) state in their wakes.

The potential energy density per unit area is PE/A,

where $A = \lambda L$, in J/m^2.

$$\therefore \quad \frac{PE}{A} = \frac{1}{4} g \rho a^2 \qquad ...(9.4.3.5)$$

Kinetic Energy. The derivation of the K.E. is rather complex and beyond the scope of the book. From hydrodynamic theory this can be expressed as

$$\text{K.E.} = \frac{1}{4} g \rho a^2 \lambda L \qquad ...(9.4.3.6)$$

and the K.E. density is

$$\frac{\text{K.E.}}{\text{A}} = \frac{1}{4} g \rho a^2 \qquad ...(9.4.3.7)$$

Total energy and power density can be written as

$$\frac{E}{A} = \frac{1}{2} g \rho a^2, \qquad ...(9.4.3.8)$$

$$\frac{P}{A} = \frac{1}{2} g \rho a^2 . f \qquad ...(9.4.3.9)$$

where f is the frequency. (The Power P = energy × frequency).

9.4.4. Wave-Energy Conversion Devices

The mechanical energy in waves takes different forms. There is the energy of forward motion of the wave—the highly noticeable energy that slams into ships and cliffs. Some of the proposed schemes are oriented toward this forward motion kinetic energy. Any geometric arrangement that absorbs energy by converting the forward momentum of the wave into motions of its internal parts, without re-emitting as much energy as it absorbs, can extract this forward motion energy.

Also very promising from the energy extraction point of view is the potential energy of the raised water at the wave crest. The gravity head between crest and trough is not large enough to permit practical power generation by driving a hydro-turbine directly, but the potential energy in the wave is very considerable. The rate at which work is done on a large ship by the ocean as the ship is lifted up by the swell is typically several times the power being delivered by the ship's engine.

It is not difficult to invent a variety of ratchet, valve, or intermittent-pump mechanisms that can convert wave energy to hydraulic, pneumatic, or electrical form. The engineering challenge is to find a cost-effective way to do it on a large scale. Since waves come in a wide range of wave lengths and amplitudes, any effective device will either have to be broad band-that is, non resonant—or it will have to have its resonance frequency continuously adjusted. Many mechanisms have been proposed, and a number are being investigated. For example, waves can be made to compress air in the top of *floating tank*, using one way air valves. Electricity is generated as the air is bled out through a pneumatic or air turbine.

In a different devices, waves passing a pipe standing vertically in the water and equipped with an internal flop valve that allows water to move upward in the pipe but not downward, cause a water column to rise in the pipe, to a height many times the wave height. The water can be released from an elevated part in a controlled manner, to drive a conventional hydro turbine. Another class of mechanism employs the floats with different dynamic response characteristics. The differential motion is used to operate a pump or mechanical engine. For example, a long vertical cylinder extending far below the surface will remain nearly stationary as the waves pass by. A toroidal float surrounding it will rise and fall with the valves, and can be made to push and pull on pump plungers attached to the cylinder.

Some of the main concepts for converting wave energy into mechanical or electrical are described briefly as follows :

Wave-Energy Conversion by Floats

Wave motion is primarily horizontal, but the motion of the water is primarily vertical. Mechanical power is obtained by floats making use of the motion of water. The concept visualizes a large float that is driven up and down by the water within relatively stationary guides. This reciprocating motion is converted to mechanical and then electrical power is generated.

A system based on this principle is shown in Fig. (9.4.4.1), in which a square float moves up and down with the water. It is guided by

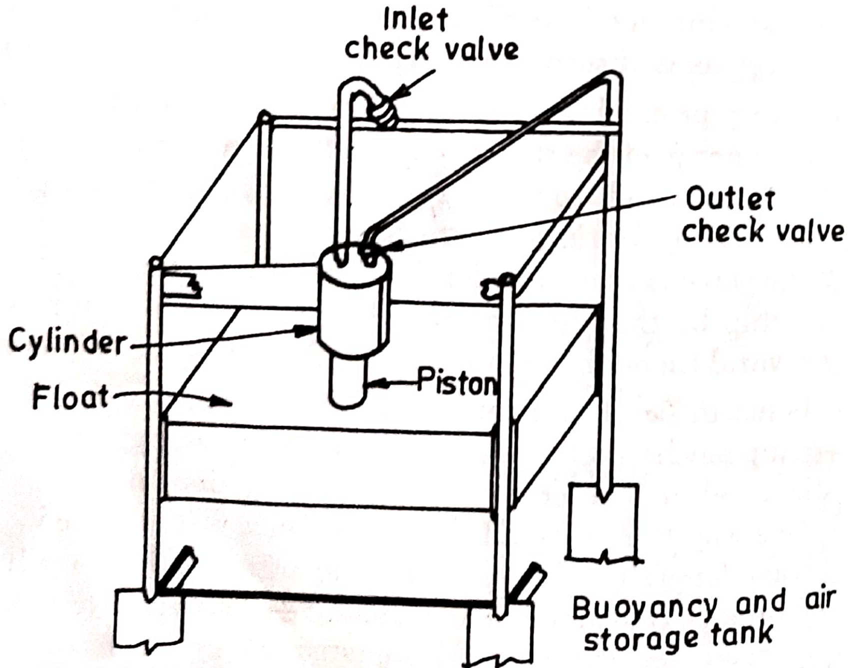


Fig. 9.4.4.1. Schematic of a float wave-power conversion device.

four vertical manifolds that are part of a platform. There are four large under water floatation tanks which stabilizes the platform. Platform is supported by buoyancy forces and no vertical or horizontal displacement occurs due to wave action. Thus the platform is made stationary in space. A piston which is attached to float as shown in figure moves up and down inside a cylinder. The cylinder is attached to platform and is therefore relatively stationary. The piston and cylinder arrangement is used as a reciprocating compressor. The downward motion of the piston draws air into the cylinder *via* an inlet check valve. This air is compressed by upward motion of the piston and is supplied to the four under-water floatation tanks, through an outlet check valve *via* the four manifolds. In this way, the four floatation tanks serve the dual purpose of buoyancy and air storage, and also the four vertical manifolds and float guides. An air turbine is run by the compressed air which is stored in the buoyancy-storage tanks, which in turn drives an electrical generator, producing electricity which is then transmitted to the shore *via* an under water cable.

High-Level Reservoir Wave Machine

The concept of this device is illustrated with reference to Fig. (9.4.4.2), in which a magnification piston is used. The pressurized

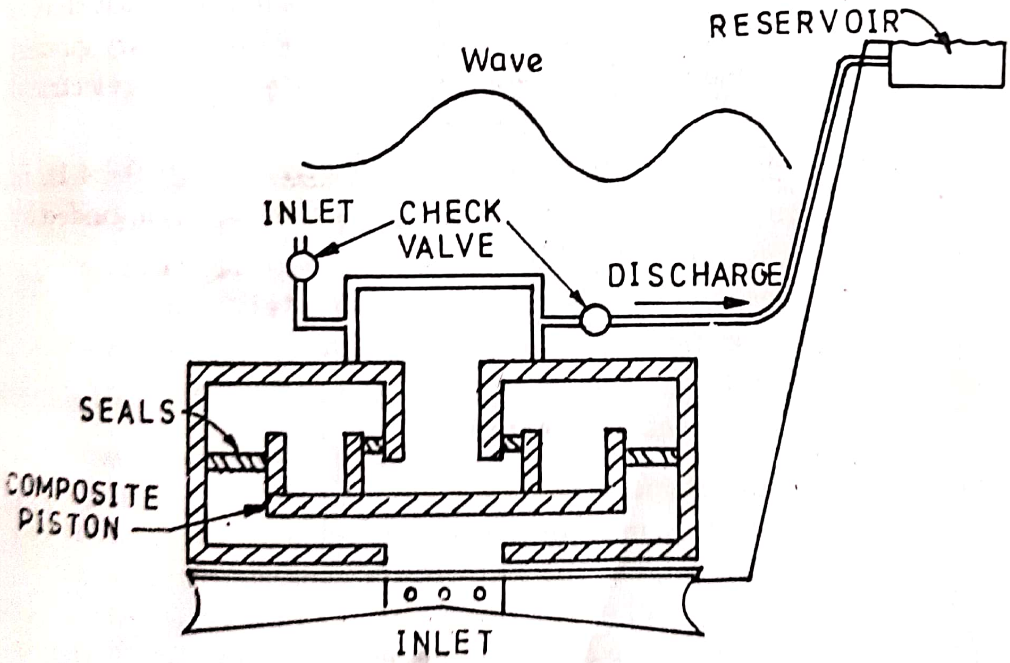


Fig. 9.4.4.2. Schematic of a high-level reservoir wave machine.

water is elevated to a natural reservoir above the wave generator, which would have to be near a shore line, or to an artificial water reservoir. The water in the reservoir is made to flow through a turbine coupled to an electric generator, and then back to sea level. Calculations made shown that a 20 m diameter generator can produce 1 MW power.

The Dolphin-Type Wave-Power Machine

This type of wave-generator, which is designed by Tsu Research laboratories in Japan is shown in Fig. (9.4.4.3). The system consists of following major components :

(i) a dolphin, (ii) a float, (iii) a connecting rod, and (iv) two electrical generators.

This device uses the float which has two motions. The first is a rolling motion about its own fulcrum with the connecting rod. Revolving movements are caused between the float and the connecting rod. The

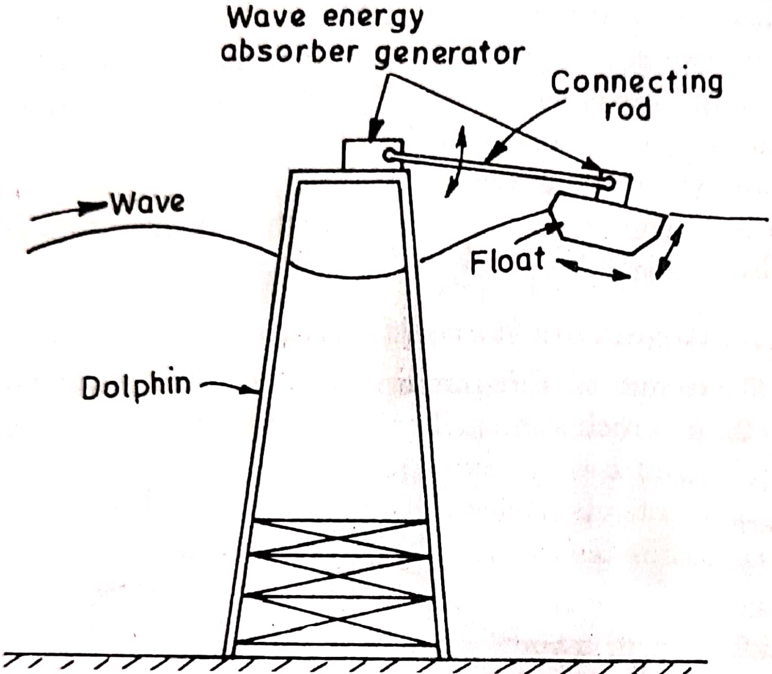


Fig. 9.4.4.3. Schematic of the Dolphin-type wave generator.

other is a nearly vertical or heaving motion about the connecting rod fulcrum. It causes relative revolving movements between the connecting rod and the stationary dolphin. In both the cases, the movements are amplified and converted by gears into continuous rotary motions that drive the two electrical generators.

Other Wave Machines

Hydraulic accumulator wave machines are also used, which instead of compressing air, the water itself is pressurized and stored in a high-pressure accumulator or pumped to a high-level reservoir, from which it flows through a water-turbine electric generator. This is done by transforming large volumes of low-pressure water at wave crest into small volumes of high-pressure water by the use of a composite piston. The piston is composed of a large-diameter main piston and a small-diameter piston at its centre. The main piston moves up and down with the entering of the wave water through the opening. A closed water loop exists above the small piston. The pressure on the main piston is magnified on the small piston during the upstroke. The high-pressure water is conducted through a one-way valve to a hydraulic accumulator at the top of the generator. Two air (or other gas) volumes counter balance and act as cushions in a chamber above the main piston and in a sealed compartment in the hydraulic accumulator. The latter also maintains the high water pressure. Part of the high-pressure water flows through a Pelton wheel or Francis hydraulic turbine that drives an electrical generator and is then discharged to a storage chamber below the turbine.

In another differential motion concept, called the "*nodding duck*" employs large cam-shaped "ducks" mounted on a very long, floating frame. The 'ducks' oscillate or 'nod' relative to the frame, driving hydraulic pumps. This 'nodding duck' scheme though only in the model testing stage, has been investigated more than most of the other concepts, and is currently one of the leading contenders in the British wave energy programme. It is a rather serious criticism it was claimed by a wind-power proponent that the energy pay back time for wave power systems in general and the nodding duck scheme in particular may be excessively long, owing to the large amount of steel and concrete required. This claim was disputed by the inventor of the nodding duct concept.

It is interesting to recall that S.J. Savonius used a rotor of the type generally known as a Savonius rotor and generally used as a windmill to extract energy from the waves of ocean. The rotor was fixed with its axis horizontal and perpendicular to the direction of wave propagation (near the shore, to which it was anchored rigidly, in this case). Water passing the rotor flowed both forward and back at different times and depths ; the asymmetric Savonius rotor can take power from both the forward and back flows. Power outputs of a few kilowatts per square meter were obtained with equipment that was far from perfect.

9.5. Small Scale Hydroelectric

9.5.1. Introduction

Small scale hydroelectric facilities can supply in principle significant amounts of electricity for irrigation or potable water pumping, lighting, or health or educational purposes. The total potential amount of such a resource is very poorly documented but is apt to be large.

Upto 1972, hydro engineers concentrated on developing the larger sites, where the economy of scale enabled the production of energy at a cost low enough to compete thermal power, fueled with low cost oil. However with the prospect of rapidly depleting fossil fuels coupled with steady rise in oil prices, attention has returned to the smaller sites previously regarded as uneconomic. Moreover, the remarkable advancement in the technology of development of turbines suitable for utilising small falls and small discharges efficiently has increased the chances of development of *small* (*mini* and *micro* included) hydel installations to a large extent. Manufacturers have been quick enough to develop packages designs for small units. For very small hydroplants of less than 500 kW capacity, *electronic load controllers* have been developed to replace the governor. These controllers maintain a constant load on the turbine and hence constant flow, surplus power is diverted to a resistor and either wasted or used to heat water.

Many countries now have active small hydro development and rural electrification programmes, due to the several advantages offered by these plants.

The advantage of their operation in hilly and remote areas and the elimination of long transmission system, and lesser gestation periods have lent added attraction. It has little or no adverse environmental impact, effects on stream ecology are minor.

China has concentrated on small hydro, has over 1 lakh sites developed and is now exporting low cost units. These mini hydro schemes which are spreaded all over the country, are supplying about 10% of China's total installed capacity which is in the vicinity of 7,000 MW. Other countries such as Malaysia, Indonesia and Phillipins are actively pursuing small and micro-hydro, developing sites using a minimum of elaborate equipment.

In India, the potential of small hydropower is estimated to be 5,000 MW at present, while further investigations and surveys are expected to indicate a higher potential. *Small hydropower is covered in the renewable energy programme.* The alternate hydro-energy centre at Roorkee works on the development of solar hydro-power systems as well as *Hybrid* hydro systems. If small hydro-power stations are set up all over the country, decentralized availability of power will be become possible.

Sites for low-head installations can be found everywhere in the mountain region, plains or even at the sea level. They may range from micro sets (less than a megawatt) to the largest axial flow turbines (upto 50 MW). Also, low head hydro-power sites can be close to power consumption areas, which is an advantage. In water logged areas like the Sundarbans in Bengal or remote hilly areas such as Ladakh, low head installations are often the only source of energy.

It is in this context that the Bulb-Turbine, the youngest member in the family of hydro-turbines came into picture. Bulb turbine including its generator is enclosed in a shell known as bulb which can be conveniently installed horizontally in a low head stream. It has more or less a straight flow-path. It can work under a head from as low as half a metre to a head of 95 meters. It can generate power from as-low-as

5 kW to as-high-as 50 MW. Bulb turbines can easily be standardised in the step of 100 kW in the micro-range, in the step of 1 MW in the mini range and in the step of 5 MW in the range of small turbines.

The small hydro power potential which remains largely untapped so far because of an impression that :

1. Small hydro electric projects entail higher capital costs on per kW installation basis.

2. Higher managerial and administrative costs.

3. Relatively low utilization.

4. Unstable operation of isolated systems due to low inertia.

5. Certain problems caused by the disbursed nature of projects in site identification, preparation of reports, proper construction planning and management and operation etc.

Yet one can not deny a place for small hydel in the larger energy frame work primarily because :

1. Small or mini hydro power (SHP) is a non-consumptive generator of electrical energy utilizing a renewable resource which is made continually available through the hydrologic cycle of environment.

2. Small hydro power (SHP) is essentially non-polluting and release no heat. Adverse environmental impacts are negligible and for small installation may be totally eliminated.

3. With the development of compact efficient machines the investment per kW installed is not very high. SHP projects do not require large capital investment.

4. Compared to other conventional energy generation schemes, these projects have low gestation period ranging from 8 to 24 months.

5. Operating costs are low and the equipment does not need trained and skilled personnel. With the introduction of microprocessor the SHP station may run virtually unattented. Further freedom from fuel dependence together with long life of SHP plant make installation resistant to inflation.

6. SHP is ideal decentralized energy generation source. It can supply energy to rural feeders thereby cutting distribution losses to a large extent.

7. SHP can be synchronised with grid and has been demonstrated in national demonstration projects in H.P., Haryana and Tamilnadu. SHP synchronisation with utility grid improves voltage profile.

8. With the interconnection and synchronisation with grid, plant utilization factor becomes very high. Thus SHP becomes economically attractive.

9. Due to their small size and local availability of utility grid, SHP stations generally use induction generators. Thus induction generators are not only inexpensive but also the problem of synchronization and interconnection is also vastly simplified.

10. SHP can be a catalyst in remote areas using relative simple technology in mobilizing productive resources and cutting enhanced economic opportunities for local residents.

11. Most of these schemes, in India, can be constructed on existing canals and irrigation system thereby necessitating minor modification and result in minimal disturbances to surrounding environment.

12. SHP can be developed to augment hydro power capacity at existing irrigation dams and power houses. The possibility of retrofits and additional turbines and generators makes the upgrading of present installations attractive. The determinants in the economic feasibility of alternative proposals of power generation may not necessarily depend upon the variables of the highest gain, from any individual scheme, but variables on the basis of the impact on economy of the system as a whole. From the considerations of higher efficiency and lower cost per kW capacity, a larger set may be individually more economical but this individual economic gain might be out weighted by the adverse economy as a consequence of :

(*a*) Low operation efficiency due to partial loading.

(*b*) Sudden loss of unit.

(*c*) Longer gestation period due to sizeable difference between the generation capacity of the unit and the increment rate of load developed in the region served by the plant.

(*d*) Transport difficulties in hilly areas.

(*e*) Transmission losses.

(*f*) Transmission Costs.

(*g*) High cost of fossil fuels when compared to thermal power.

In coming years the small hydel (mini, micro and small) shall be more feasible and economical than other sources like thermal power because cost of fossil fuels.

9.5.2. What is Small Hydel Development ?

There is no formal definition of a small hydro plant but this may generally be taken as power station/plant having output upto 5000 kW. Some associate the concept of small hydro with low head say upto 15 m. This may not generally be true as there is no restriction on head for small hydro development. Stations upto output of 1000 kW are called micro and upto 5000 kW as mini hydroplant. Concepts of small hydro are naturally relative and vary from country to country depending on the size of its existing development. In U.S.A. even 15000 kW is considered small hydro development while in France and some other countries it is upto 3000 kW. The hydro-electric installations having plants of higher unit rating can generally be made by utilising conventional technology of hydro equipment and tailor made designs both for equipment and civil works for power stations. It may be mentioned that source of energy from sea waves, coastal tides and ocean water itself, attempts in development of which also are gaining momentum, are not included in small hydro development. These are distinct types of development requiring all together different type of technology. Conceptually small hydro development can be categorised in two types—*one utilizing small discharges but having high head* and the second utilising *large discharges under comparatively very small head*. These are also distinguished by the nature of the generating plant required in these two types. For high head discharges being small, the physical size of the plant required is small. For the second type, as the discharges handled are high, the physical size of the generating unit and the power station consequently is quite big compared to the general notions of the rating. Also for the latter type proper arrangement for entry of water and its discharge is required to be made.

9.5.3. Nature of Small Hydro Development

Equipment technology is available to utilise discharge as small as 200 litres/sec. (0.2 cumec), head ranging from even 1 metre and producing an output of 1 kW with reasonable cost. Development of potential, relatively small is of course dependent on the pressing need and the resources.

The small hydro development of the first type which is confined mainly to hilly areas is characterised by relatively very simple features of works. The civil work involved comprise a small structure to divert the flow of the hill stream/river, small water conductor system such as a channel, flume or buried conduits, power house building and a small length of transmission line.

There is no need for substantial storage and generally run of river is utilised. The power generally consumed in the local area eliminating requirement of long transmission lines. The grid line would normally be far away and hence the need of local development.

Features of development of the second type which normally belongs to the plains are somewhat different. The head available is rather low and discharges have to be comparatively large to be economically viable. The development thus can take place on small river, irrigation outlet, canal falls etc. The difference usually comes in because of regulating arrangement for inlet and discharge of water and the type

Tail Race Channel

Water after flow through machine is fed to the stream downstream of power house. It may be trapezoidal or rectangular channel constructed in stone masonry or brick masonry depending upon the material available locally.

Materials for Construction

Efforts should be made to use the locally available material. The material generally used are Reinforced concrete, structural steel, stone masonry Brick masonry etc. Research is going on for the development of new materials *e.g.* Ferrocement and steel Fibre Reinforced concrete. These are discussed briefly as follows :

Ferro Cement. Ferrocement a composite material, usually brittle, is reinforced with fibres dispersed throughout the composite. In ferro cement structures, the reinforcement consists of small diameter wiremesh in which the proportion and distribution of the reinforcement are made uniform by spreading out the wire meshes throughout the thickness of element. This dispersion of the fibres in the brittle matrix offer not only convenience and practical means of achieving improvement in many of the engineering properties of the materials such as fracture, tensile and flexural strength, toughness, fatigue resistance and impact resistance but also provides advantages in terms of fabrication of products and components.

The use of ferrocement may be made in gates, penstocks slabs etc.

Steel Fibre Reinforced Concrete

Steel fibre reinforced concrete (SFRC) is a new concrete for which gradients are hydraulic cement, fine and coarse aggregate and discontinuous discrete steel fibres. In recent years, it has been recognised that the additions of small closely spaced and uniformly dispersed discrete steel fibres in concrete would substantially improve its static and dynamic properties. The SFRC has better characteristics as compared to ordinary concrete as regards compressive strength, tensile strength, flexural strength, shear strength, fatigue strength and impact resistance.

SFRC may be used for Forebay, gates and penstocks.

9.5.7. Turbines and Generators for Small Scale Hydro Electric

(1) *Bulb or Tubular Turbine.* This is rather a recent development in which complete turbine and the generator is enclosed inside the conduit which carries water from headrace to tail race. This enclosure is a water tight housing (or bulb), which is supported centrally within a horizontal water channels. The turbine is essentially of Kaplan type or a propeller type. The generator may be directly coupled to the turbine shaft or driven through a set of gears for increasing the speed to reduce

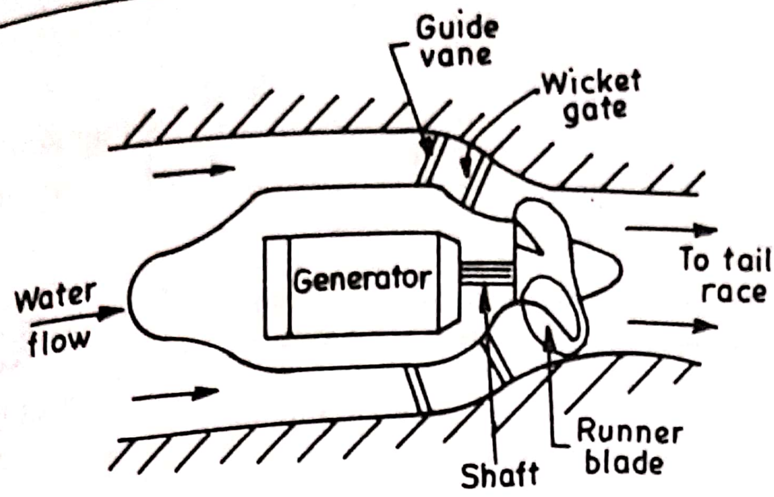


Fig. 9.5.7.1. Bulb Turbine.

the generator size. The generator is usually on the upstream side of the turbine now a days. The turbine, located at the downstream end, is connected to the generator, by way of a sealed shaft. Water flows in the axial direction around the bulb and through guide vanes and wicket gates to the turbine runner with propeller type blades. (Fig. 9.5.7.1).

This development is most suitable for utilisation of comparatively low heads, the range being from 3 to 18 m. The output rating of the bulb type design are available right from 200 MW to 40 MW, though the bigger one may not come under small hydroelectric development.

Arrangement of the bulb unit (See figure) indicates that this is rather complicated. But the design has been almost perfected and there are a large number of units of various sizes in operation all over the world. The efficiencies of the generating set of this type are very high compared to the size and are comparable with those of conventional units as hydraulic losses are kept minimum. The units are available as package units which facilitates erection and dismentling.

(2) *Tube Turbine.* Modification of the Kaplan—type turbine have been developed for water-heads below some 15 m (50 ft). In one such type, called the *tube turbine*, the turbine was a horizontal (or almost horizontal) shaft is located in a tubular channel ; the water flows in an axial direction through the channel with the runner. The water is directed between the propeller blades by fixed guide varies, and the flow is controlled by wicket (or similar) gates.

If the shaft is horizontal the channel slopes downward beyond the turbine so that the attached generator is above the water level in the tail race. (Fig. 9.5.7.2). Alternatively, the turbine shaft may be sloped upward to achieve the same objective. An advantage claimed for the tube turbine is that the water does not change direction and hence lose energy before it enters the turbine.

This type of turbine is a varient of bulb turbine. In this type of management, only the turbine is housed inside the conduit and the

The precision of governing necessary will depend on whether the electrical generator is synchronous or induction type. There are advantages to the induction type of generator. It is less complex and therefore, less expensive. Its frequency is controlled by the frequency of the grid it is feeding into, thereby eliminating the need of an expensive conventional governor. It can not operate independently but can only feed into a network and does so with lagging power factor which may or may not be disadvantage, depending on the nature of the load. Long transmission lines, for example, have a high capacitance and in this case the lagging power factor may be an advantage.

9.5.8. Protection, Control and Management of Equipments :

Small hydro power plant controls are required for unit start, unit shut down, unit synchronising and unit loading and control (speed and voltage), unit electrical and mechanical protection and emergency shut-down, hydraulic control.

A major cost in small hydros is operation and management man power. These costs can be prohibitive in microhydel. Low cost automation is therefore, of importance if mini and micro hydel is to survive unit starting and synchronising can be manual. But emergency shut down must be fool proof to avoid damage. It is considered that even if man power is provided for management, the level of expertise will be of low level. Accordingly, dependable and sample control/remote control of unit is required. Microprocessors are being used.

Control of induction generator grid connected units is easy synchronisation, speed and voltage control are automatically taken care of. Generator are less in cost. Automation costs are very low. Large scale installation of these units on our existing irrigation works like canals etc., can be highly economical.

In isolated areas local grids can be formed and smaller units can be induction generator type and can be controlled from a manned control mini hydro station where synchronous generator are installed.

9.5.9. Advantages and Limitations of Small Scale Hydroelectric

Advantages. (*i*) Smaller hydro projects takes the shortest time for developing a unit, and

(*ii*) Once it is built the running expenditure is almost negligible.

(*iii*) The operation and maintenance of such power station is the simplest.

(*iv*) These energy sources are free from hazards of pollution.

(*v*) Unlike the big hydrodevelopments, these have no environmental problems, no submergence of land, no loss of agricultural land,