1 Chapter

Non-Conventional and Conventional Sources of Energy

1.0 NON-CONVENTIONAL

The contemporary non-conventional sources of energy like wind, tidal, solar etc. were the conventional sources until James Watt invented the steam engine in the eighteenth century. In fact, the New World was explored by man using wind-powered ships only. The non-conventional sources are available free of cost, are pollution-free and inexhaustible. Man has used these sources for many centuries in propelling ships, driving windmills for grinding corn and pumping water, etc. Because of the poor technologies then existing, the cost of harnessing energy from these sources was quite high. Also because of uncertainty of period of availability and the difficulty of transporting this form of energy, to the place of its use are some of the factors which came in the way of its adoption or development. The use of fossil fuels and nuclear energy replaced totally the non-conventional methods because of inherent advantages of transportation and certainty of availability; however these have polluted the atmosphere to a great extent. In fact, it is feared that nuclear energy may prove to be quite hazardous in case it is not properly controlled.

In 1973 the Arab nations placed an embargo on petroleum. People began to realise that the fossil fuels are not going to last longer and that remaining reserves should be conserved for the petro-chemical industry. But unfortunately, both nuclear and coal energy pose serious environmental problems. The combustion of coal may upset the planet's heat balance. The production of carbon dioxide and sulphur dioxide may adversely affect the ability of the planet to produce food for its people. Coal is also a valuable petro-chemical and from long term point of view it is undesirable to burn coal for generation of electricity. The major difficulty with nuclear energy is waste disposal and accidental leakage (*e.g.* leakage at Chernobyl nuclear power plant).

As a result of these problems, it was decided by almost all the countries to develop and harness the non-conventional sources of energy, even though they are relatively costlier as compared to fossil-fuel sources. It is hoped that with advancement in technology and more research in the field of development of non-conventional sources of energy, these sources may prove to be cost-effective as well. The future of wind, solar, tidal and other energy sources is bright and these will play an important role in the world energy scenario.

The following sections have been devoted to the study of some of the important non-conventional sources of energy.

1.1 TIDAL POWER

1.1.1 Introduction

Tidal or lunar energy as it is sometimes called, has been known to mankind since time immemorial. Various devices, particularly the mills were operated using tidal power. In the past water supply of London was pumped to a water tower by a mill operated by the tidal power (which consisted of a large paddle wheel, mounted on a raft and fastened between two of the piers of old London Bridge). The tidal power has been used to irrigate fields in Germany and to saw firewood in Canada.

Tides are caused by the combined gravitational forces of Sun and Moon on the waters of the revolving Earth. When the gravitational forces due to the Sun and the Moon add together, tides of maximum range, called spring tides, are obtained. On the other hand, when the two forces oppose each other, tides of minimum range, called neap tides, are obtained. In one year there are approximately 705 full tidal cycles.

1.1.2 Basic Schemes

It has been suggested, that for harnessing tidal power effectively the most practicable method is the basin system. Here a portion of the sea is enclosed behind a dam or dams and water is allowed to run through turbines, as the tide subsides.

The power available from a given head of water varies as the square of the head and since the head varies with the tidal range, the power available at different sites from tidal energy shows very wide variation. Various tidal basin systems have, therefore, been evolved, in order to overcome this wide variation in availability of tidal power.

Single Basin System

The simplest scheme for developing tidal power is the single basin arrangement, in which a single basin of constant area is provided with sluices (gates), large enough to admit the tide, so that the loss of head is small. The level of water in the basin is the same as that of the tide outside. When the tides are high, water is stored in the basin and sluice gates are closed. When the tides are falling, sluices are opened to allow water to go through the turbine to generate power. A head of water is obviously required for the turbine to generate water. This continues to generate power till the level of the falling tides coincides with the level of the next rising tide.

The major disadvantage of this single basin scheme is that it gives intermittent supply of power, varying considerably over the period of operation. It is for this reason that the tidal power has not been developed on a large scale. Also with this scheme, only about 50 per cent of tidal energy is available.

Two Basin System

An improvement over the single basin system is the two-basin system. In this system, a constant and continuous output is maintained by suitable adjustment of the turbine valves to suit the head under which these turbines are operating.

A two-basin system regulates power output of an individual tide but it cannot take care of the great difference in outputs between spring and neap tides. This system, therefore, provides a partial solution to the problem, of getting a steady output of power from a tidal scheme.

This disadvantage can be overcome by the joint operation of tidal power and pumped storage plant. During the period when the tidal power plant is producing more energy than required, the pumped storage plant utilizes the surplus power for pumping water to the upper reservoir. When the output of the tidal power plant is low, the pumped storage plant generates electric power and feeds it to the system. This arrangement, even though technically feasible, is much more expensive, as it calls for higher installed capacity for meeting a particular load.

This basic principle of joint operation of tidal power with steam plant, is also possible when it is connected to a grid. In this case, whenever tidal power is available, the output of the steam plant will be reduced by that extent which leads to saving in fuel and reduced wear and tear of steam plant. This operation requires the capacity of steam power plant to be equal to that of tidal power plant and makes the overall cost of power obtained from such a combined scheme very high. In the system shown in Fig. 1.1, the two basins close to each other, operate alternatively. One basin generates power when the tide is rising (basin getting filled up) and the other basin generates power while the tide is falling (basin getting emptied). The two basins may have a common power house or may have separate power house for each basin. In both the cases, the power can be generated continuously. The system could be thought of as a combination of two single basin systems, in which one is generating power during tiding cycle, and the other is generating power during emptying.

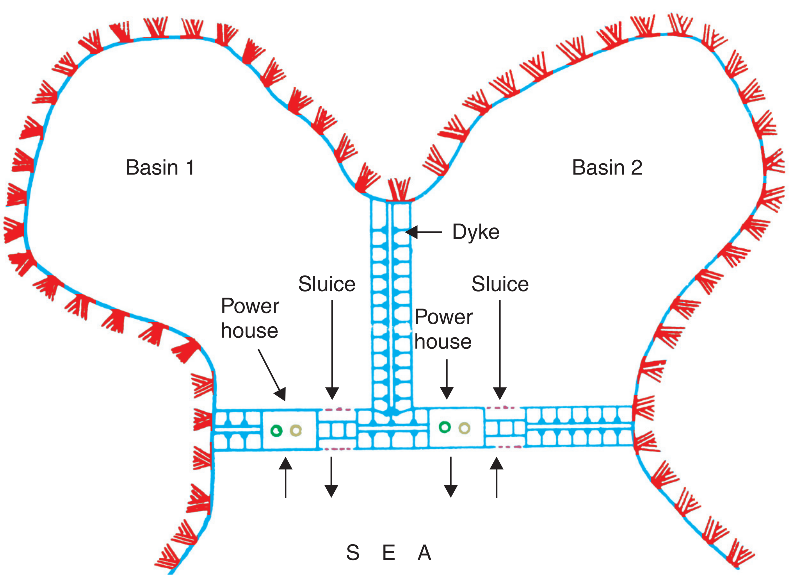

Fig. 1.1 Double Basin System

Cooperating double basin system. This scheme consists of two basins, at different elevation connected through turbine. The sluices in the high and low level basin communicate with sea water directly as shown in Fig. 1.2. The high level basin sluices are called the inlet sluices and the low level as outlet sluices. The basic operation of the scheme is as follows.

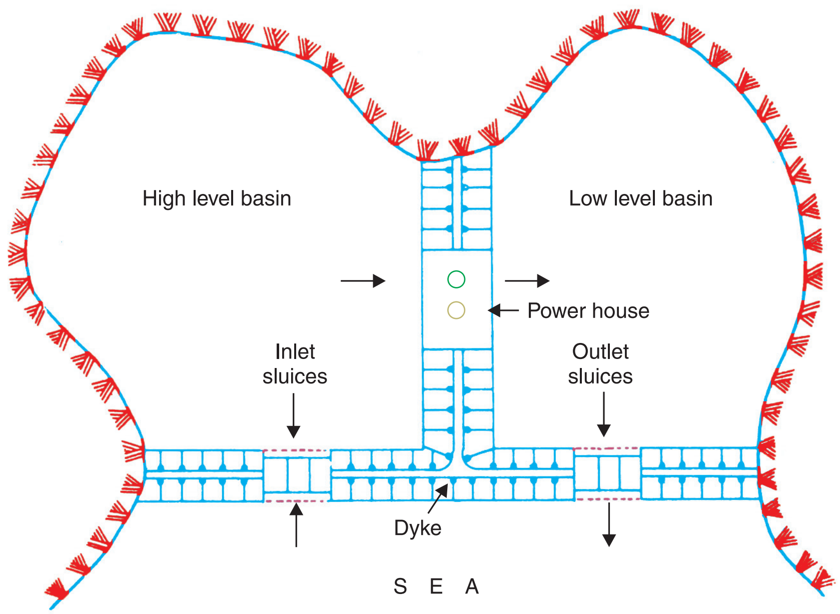

Fig. 1.2 Cooperating Double Basin System

Let us assume that the upper basin is filled with water. The water is allowed to flow to the lower basin through the turbine. Therefore, the level in the upper basin falls and that in the lower basin rises. At an instant when the rising level in the basin is equal to the level of the falling tide, the outlet gates are opened. When the tide reaches its lower most level, the outlet gates are closed. After a while the tide rises. When its level becomes equal to the low level of the upper basin, the inlet gates are opened. As a result, the level of the upper basin starts rising. At the same time, the turbines are fed from the upper basin transferring water to the lower basin, thus raising level of water there. When the tide reaches its peak value, the inlet gates are called again. Thus the cycle is repeated.

1.1.3 Turbines for Tidal Power

Tidal power plants operate using a rapidly varying head of water and, therefore, their turbines must have high efficiency at varying head. The Kaplan type of water turbine operates quite favourably under these conditions. The propeller type of turbine is also suitable because the angle of the blades can be altered to obtain maximum efficiency while water is falling.

A compact reversible horizontal turbine has been developed by French Engineer which acts with equal efficiency both as a pump and as a turbine. The bulb-type turbine (Fig. 1.3) consists of a steel shell completely enclosing the generator which is coupled to the turbine runner. The turbine is mounted in a tube within the structure of the barrage, the whole machine being submerged at all times.

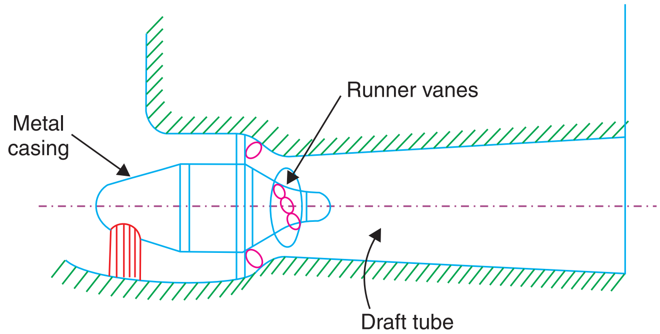

Fig. 1.3 Bulb-Type Turbine

When the power demand on the system is low during the rising tides, the unit operates as a pump to transfer water from sea to the basin. When the load on this system is high, the unit will work as a generator, and deliver the stored energy which is a valuable additional input to the system.

There are two tidal power plants in France now in operation; an experimental one with a capacity of 9 MW at Saint Malo and a 240 MW Plant with a 700 m long dam at the mouth of the Rance River. A large number of tidal power projects have been planned but subsequently abandoned because of the high cost involved and obstruction in navigation.

Even though many problems have to be overcome in tidal power development, this form of power has certain definite advantages. Output of a tidal power station is independent of the seasonal changes and can be predicted well in advance, as it depends on the cosmic phenomenon. It is possible to predict the amount of power and the time at which it will be available throughout the year. This power can, therefore, be utilized at the proper position of the load curve.

More than fifty sites have been identified in the world for possible generation of tidal power. As more and more technological advancement take place, even more sites could be identified for tidal power development. Some of the important sites are:

(*i*) La Rance (France), (*ii*) Severn Barrage (UK), (*iii*) White sea (USSR), (*iv*) Passamaquoddy (USA), (*v*) Gulf of Cambey (India) and (*vi*) Gulf of Kutch (India).

The maximum tidal range in the Gulf of Cambey is about 10.8 m and is quite attractive for a tidal plant. However, the silt charge of the Gulf of Cambey is relatively high and needs a closer study for further development.

The Gulf of Kutch has a maximum spring tide of 7.5 m and the silt charge is relatively low.

1.2 WIND POWER

1.2.1 Introduction

The wind wheel, like the water wheel, has been used by man for a long time for grinding corn and pumping water. Ancient seamen used wind power to sail their ships. With the development of the fossil fuelled and hydro-electric plants, there was decline in the use of wind power due to the less cost involved in the new methods. Another difficulty with wind power was the problem of energy storage. The energy could not be made available, on demands, due to uncertainties of wind. Due to these two reasons, no further attempt was made to develop wind power for large scale power generation.

In recent years, however, as a result of energy crisis in the world, it has been decided to investigate all possible means of developing power, as alternatives to fuel fired plants. The wind could supply a significant portion of the world's energy demand. An estimate by an American Professor indicates the potentialities of wind power. According to him about 350,000 wind mills each rated for about 1250 KW to 2200 KW could develop power of the order of 190,000 MW. With the advancement in the knowledge of aero-dynamics it has been possible to build larger and more efficient wind power plants. A typical example is the 1250 KW installation at Grandpa's Knol in U.S.A. Whereas some success has been achieved in developing small and medium size plants, the prospects of large scale generation *i.e.*, 1 MW or above are not, as yet very encouraging.

1.2.2 Characteristics of Wind Power

Wind as a source of energy is plentiful, inexhaustible and pollution free but it has the disadvantage that the degree and period of its availability are uncertain. Also, movement of large volumes of air is required, to produce even a moderate amount of power. As a result, the wind power must be used as and when it is available, in contrast to conventional methods where energy can be drawn upon when required. Wind power, therefore, is regarded as a means of saving fuel, by injection of power into an electrical grid, or run wind power plant in conjunction with a pumped storage plant.

The power that can be theoretically obtained from the wind, is proportional to the cube of its velocity and thus high wind velocities are most important. The power developed using this law, in atmospheric condition where the density of air is 1.2014 kg/cu metre, is given as

$$\text{Power developed} = 13.14 \times 10^{-6} A V^3 \text{ KW}$$

where A is the swept area in sq. metre and V the wind velocity in Km/hr. The energy developed is affected by :

The Altitude of the Site

The velocity of the wind increases with the altitude. In general, the higher the wind wheel is placed above ground, the greater will be wind power available.

Velocity Duration Curve

The variation of velocity of wind over the period affects the power output, *e.g.*, let the velocity over the first hour be 30 kmph and the next hour be 20 kmph. The energy developed is proportional to $30^3 + 20^3 = 35{,}000$. On the other hand, if we assume average velocity during these two hours of 25 kmph, the power developed is proportional to $2 \times 25^3 = 33250$. Thus, the relation between the actual energy available, and that available from a steady wind of average velocity, varies considerably and depends on the shape of the velocity-duration curve for the period of generation.

The wind speeds, between which a wind wheel generator operates, are limited. A certain minimum wind velocity is required to overcome frictional and other losses of the machine and, on the other hand, it would be uneconomical to design a plant for very high velocity wind which would occur only for a small period over the year. Therefore, the machine must be designed for a rated wind velocity, for which the output is maximum. Typical wind velocities for some sites may range between 30 kmph to 45 kmph.

The rated wind velocity, for which a plant is designed substantially affects the specific output (K whr generated per annum per KW installed capacity) and also the cost of construction. If the rated velocity is low, the specific output is high as full output will be generated for a relatively longer duration of the year, whereas if the rated velocity is high, the converse will be true. But with low rated wind velocity, a larger diameter wheel will be required for a given KW rating, which in turn increases the cost of the plant. Economic development of wind power, therefore, requires selection of sites where high specific outputs are compatible with reasonable cost of construction of plant. It is, therefore, necessary to obtain wind velocity duration curve for a particular site and to know the output of the machine for varying wind velocities. The maximum efficiency of the wind power plant is found not to exceed 40%.

1.2.3 Design of Wind Wheels

Several types of wind wheels have been used but the advantage of propeller rotating about a horizontal shaft, in a plane perpendicular to the direction of the wind make it the most likely type to realise economic generation on a large scale. A propeller consisting of two or three blades (with an aerofoil section) and capable of running at the high speeds is likely to be the most efficient. Present technology has been able to build systems with 60 m long blades, on towers as high as 305 m. A large tower system, to support many small rotor-generator units, can also be built.

Wind pressure rotates the wind vanes or propellers attached to a shaft. The revolving shaft rotates the rotor of a generator, through a mechanism of gears couplings etc. Thus, electricity is generated.

The wind power plants can be operated in combination with steam or hydro power station, which will lead to saving in fuel and increase in firm capacity, respectively of these plants.

Wind energy can prove to be a potential source of energy for solving the energy problem. It can certainly go a long way to supply pollution-free energy to millions of people, living in the villages all over the world.

The economic viability of windmills is better in situations where conventional transmission costs are extremely high (because of inaccessibility and small load) or where continuous availability of supply is not essential so that only a limited amount of storage on standby power need be provided.

1.3 GEOTHERMAL POWER

1.3.1 Introduction

Many geothermal power plants are operating throughout the world. Although larger geothermal power plants are in operation in America today, it is to the credit of the Italians that the first impressive breakthrough in geothermal power exploitation was achieved. The oldest geothermal power station is near Larderello in Italy, which has an installed capacity of 380 MW. In New Zealand geothermal power accounts for 40% of the total installed capacity, whereas in Italy it accounts for 6%.

It is a common knowledge that the earth's interior is made of a hot fluid called 'magma'. The outer crust of the earth has an average thickness of 32 Km and below that, is the magma. The average increase in temperature with depth of the earth is 1°C for every 35 to 40 metre depth. At a depth of 3 to 4 Kms, water boils up and at a depth of about 15 Kms, the temperature is, in the range of 1000°C to 1200°C. If the magma finds its way through the weak spots of the earth's crust, it results into a volcano. At times, due to certain reasons the surface water penetrates into the crust, where it turns into steam, due to intense heat, and comes out in the form of springs or geysers. Moreover, the molten magma also contains water, which it releases in the form of steam, which could be utilized for electric power generation.

1.3.2 Principle of Operation

Various types of cycles have been suggested for geothermal power generation. Only two important ones, which are being used in practice, are discussed here.

Indirect Condensing Cycle

While developing Larderello power plant, it was thought, that geothermal steam may corrode the turbines. Therefore, an indirect system was adopted, which involved the use of a heat exchanger by means of which clean steam was raised from contaminated natural steam (Fig. 1.4). In spite of the fact that about 15% to 20% of the steam power potential had to be sacrificed in the heat exchanger, the cycle was considered economical, because of the recovery of minerals and non-condensible gases from the new steam.

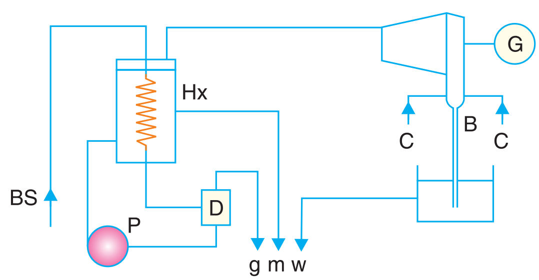

Fig. 1.4 Indirect Condensing Cycle

With the advancement in metallurgy technology and the declining economic attractions of mineral extraction, through this process, this cycle has been rendered obsolete.

Direct Non-Condensing Cycle

This is the simplest, cheapest and most widely used geothermal cycle. Bore steam, either direct from dry bores, or after separation (using centrifugal separator) from wet bores, is simply passed through a turbine and exhausted to atmosphere (Fig.1.5).