Hydro-electric Power

Hydro-electric power is electricity produced by the movement of fresh water from rivers and lakes. Gravity causes water to flow downwards and this downward motion of water contains kinetic energy, that can be converted into mechanical energy, and then from mechanical energy into electrical energy in hydro-electric power stations. ("*Hydro*" comes from the Greek word hydra, meaning water). At a good site hydro-electricity can generate very cost effective electricity.

History and Development

The conversion of kinetic energy into mechanical energy is not a new idea. As far back as 2000 years ago wooden waterwheels were used to convert kinetic energy into mechanical energy. The exact origin of water wheels is not known, but the earliest reference to their use comes from ancient Greece.

However, it was much later, in 1882 in the United States, that the first hydro-electric plant was built. This plant made use of a fast flowing river as its source. Some years later, dams were constructed to create artificial water storage areas at the most convenient locations. These dams also controlled the water flow rate to the power station turbines.

Originally, hydro-electric power stations were of a small size and were set up at waterfalls in the vicinity of towns because it was not possible at that time, to transmit electrical energy over great distances. The main reason why there has been large-scale use of hydro-electric power is because it can now be transmitted inexpensively over hundreds of kilometres to where it is required, making hydro-power economically viable. Transmission over long distances is carried out by means of high voltage, overhead power lines called transmission lines. The electricity can be transmitted as either AC or DC.

Unlike conventional coal-fired power stations, which take hours to start up, hydro-electric power stations can begin generating electricity very quickly. This makes them particularly useful for responding to sudden increases in demand for electricity by customers ("peak demand").

Hydro-stations need only a small staff to operate and maintain them, and as no fuel is needed, fuel prices are not a problem. Also, a hydro-electric power scheme uses a renewable source of energy that does not pollute the environment. However, the construction of dams to enable hydro-electric generation may cause significant environmental damage.

How Hydro-Electric Power Stations Operate

The amount of electrical energy that can be generated from a water source depends primarily on two things: the distance the water has to fall and the quantity of water flowing. Hydro-electric power stations are therefore situated where they can take advantage of the greatest fall of a large quantity of water- at the bottom of a deep and steep-sided valley or gorge, or near the base of a dam (see figure 1).

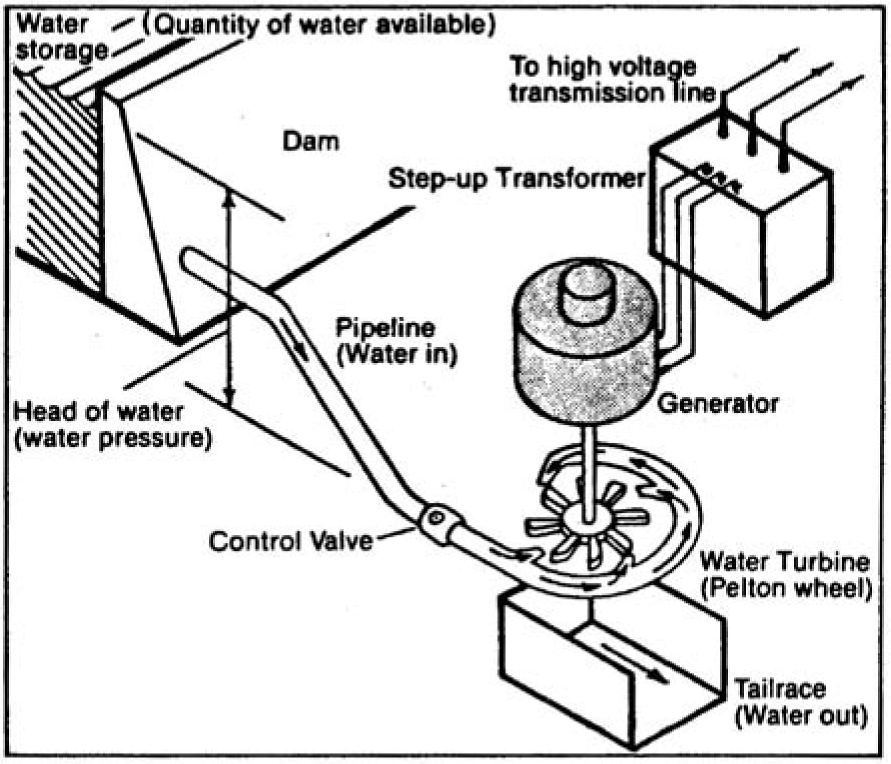

Figure 1 Diagram of hydro-electric scheme
(Copyright Western Power Corporation [1])

Water is collected and stored in the dam above the station for use when it is required. Some dams create big reservoirs to store water by raising the levels of rivers to increase their capacity. Other dams simply arrest the flow of rivers and divert the water down to the power station through pipelines.

While a water turbine is much more sophisticated than the old water wheels, it is similar in operation. In both cases blades are attached to a shaft and when flowing water presses against the blades, the shaft rotates. (The effect is the same as wind pressing against the blades of a windmill.) After the water has given up its energy to the turbine, it is discharged through drainage pipes or channels called the "tailrace" of the power station for irrigation or water supply purposes or, in some parts of the world, even into the ocean.

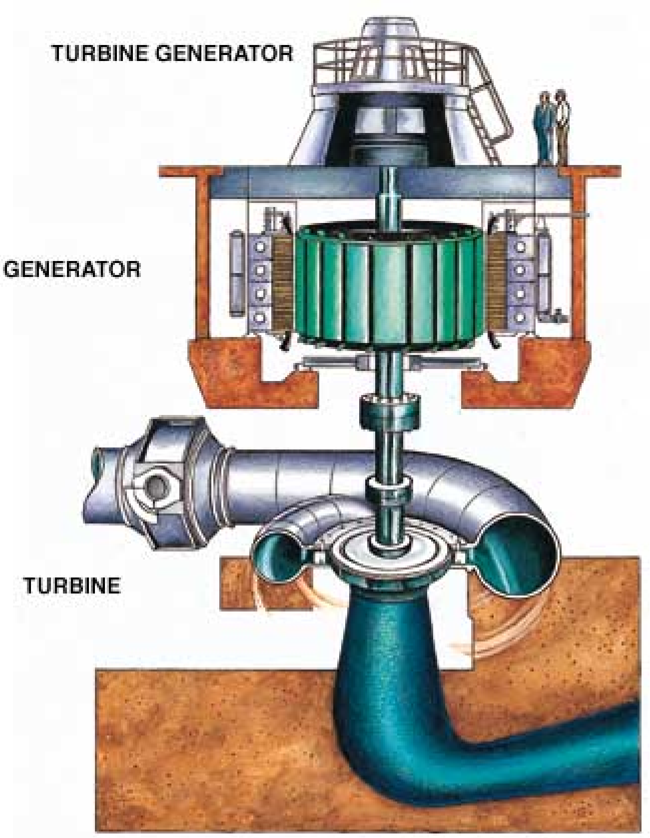

Figure 2 Cut-away drawing of a water-turbine generator
(Image courtesy of the Snowy Mountains Hydro-Electric Scheme)

In a conventional coal-fired (thermal) power station each "generating unit" consists of a boiler, a steam turbine, and the generator itself. A hydro-electric generating unit is simpler and consists of a water turbine to convert the energy of flowing water into mechanical energy, and an electric generator to convert mechanical energy into electrical energy.

The amount of energy available from water depends on both the quantity of water available and its pressure at the turbine. The pressure is referred to the head, and is measured as the height that the surface of the water is above the turbine.

The greater the height (or head) of the water above the turbine, the more energy each cubic metre of water can impart to spin a turbine (which in turn drives a generator). The greater the quantity of water, the greater the number and size of turbines that may be spun, and the greater the power output of the generators.

Type of Water Turbines

Water for a hydro-electric power station's turbines can come from a specially constructed dam set high up in a mountain range, or simply from a river close to ground level. As water sources vary, water turbines have been designed to suit the different locations. The design used is determined largely by head and quantity of water available at a particular site.

The three main types are Pelton wheels, Francis turbines, and Kaplan or propeller type turbines (named after their inventors). All can be mounted vertically or horizontally. The

Kaplan or propeller type turbines can be mounted at almost any angle, but this is usually vertical or horizontal.

The Pelton wheel (see figure 3) is used where a small flow of water is available with a ‘large head’. It resembles the waterwheels used at water mills in the past. The Pelton wheel has small ‘buckets’ all around its rim. Water from the dam is fed through nozzles at very high speed hitting the buckets, pushing the wheel around

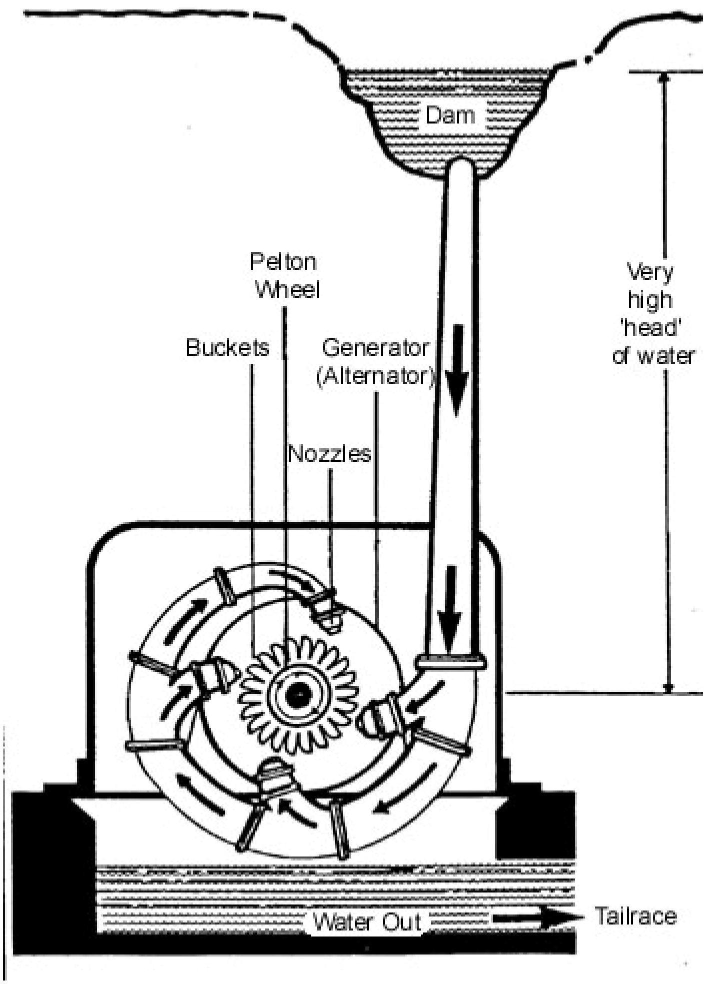

Figure 3 Pelton wheel
(Copyright Western Power Corporation [1])

The Francis turbine (see figure 4) is used where a large flow and a high or medium head of water is involved.

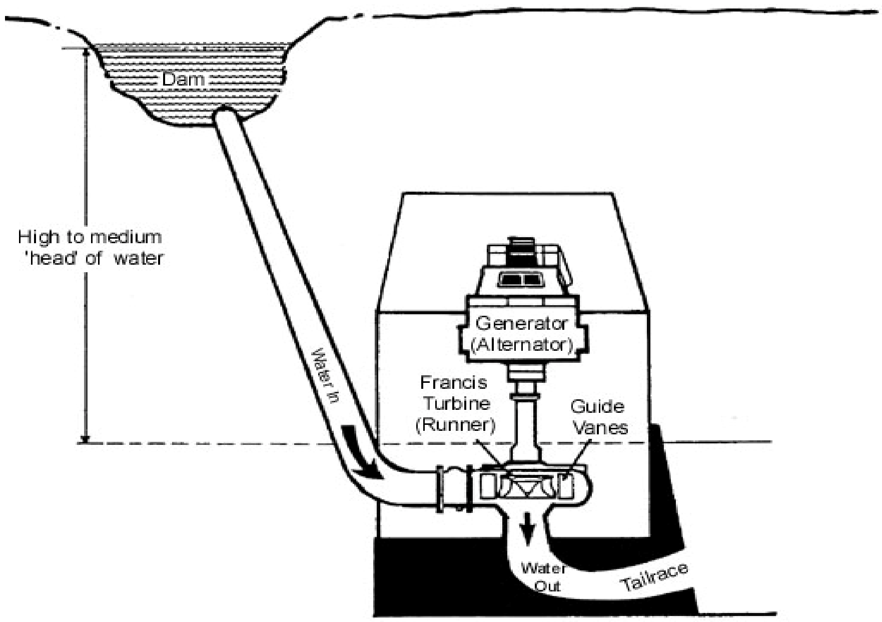

Figure 4 Francis water turbine
(Copyright Western Power Corporation [1])

The Francis turbine is also similar to a waterwheel in that it looks like a spinning wheel with fixed blades in between two rims. This wheel is called a 'runner'. A circle of guide vanes surround the runner and control the amount of water driving it. Water is fed to the runner from all sides by these vanes causing it to spin.

Propeller type turbines are designed to operate where a small head of water is involved. These turbines resemble ship's propellers. However, with some of these (Kaplan turbines, see figure 5) the angle (pitch) of the blades can be altered to suit the water flow.

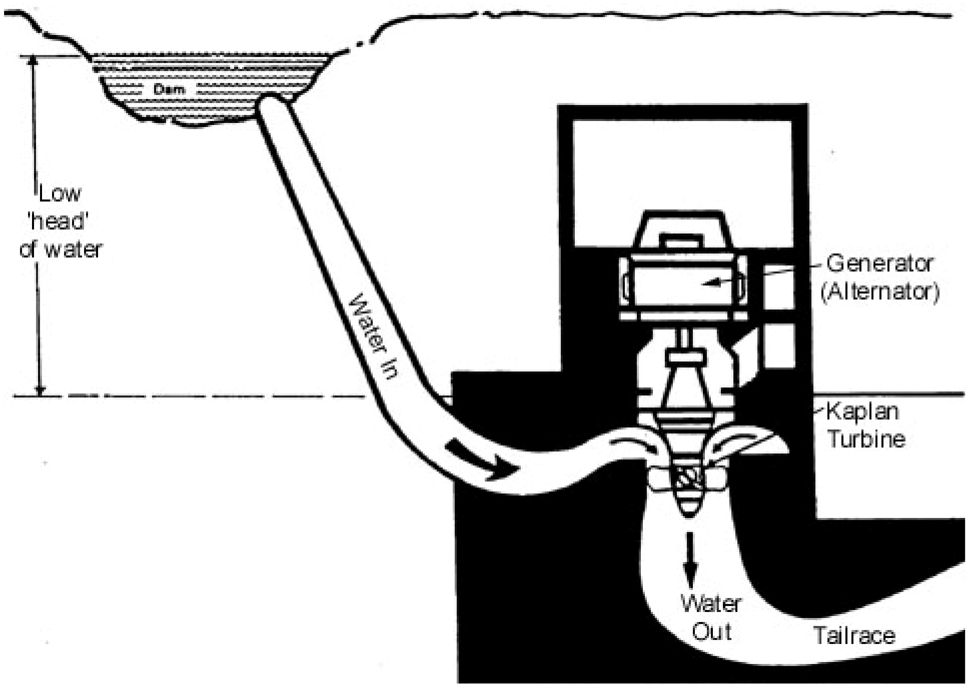

Figure 5 Kaplan and propeller type turbine
(Copyright Western Power Corporation [1])

The variable pitch feature permits the machine to operate efficiently over a range of heads, to allow for the seasonal variation of water levels in a dam.

Large Scale Hydro

Large scale hydro-electric power systems have been installed all over the world, with the largest having a capacity of over
10 000 megawatts (MW) (10 gigawatts (GW)). Each of these large scale systems requires a very large dam, or series of dams, to store the enormous quantities of water required by the system. The Kariba dam in Zambia holds 160 billion m^3 of water!

The Snowy Mountains hydro-electric power scheme is the largest in Australia, with a generation capacity of nearly 3800 MW. The Snowy Scheme consists of seven power stations (2 underground), 145km of tunnels and 16 large dams, with the largest Lake Eucumbene holding nine times the water volume of Sydney Harbour.

Tasmania's Hydro-Electric Corporation generates the second largest amount of hydro power in Australia, utilising the high rainfall and mountainous terrain of Tasmania.

Pumped Storage Hydro-electric Schemes

A large number of new hydro-electric projects are of the pumped storage type. Each station re-uses the water which is passed through it, by storing it in catchment areas below the station and then pumping it back up to the higher catchment dams above the station in a closed circuit arrangement. This pumping is carried out in 'off-peak' times when there is a surplus of power available from coal, oil, or gas-fuelled stations to accomplish the task. In many countries nuclear power is used for off-peak pumping.

When pumping is required, a reversal of roles occurs. The generator becomes an electric motor, receiving electricity from a nearby power station, and operates the turbine as a pump. The turbine receives energy instead of delivering it.

However, in some pumped-storage schemes there are two sets of equipment. One set is for generating and the other is for pumping. The use of pumped storage increased the total amount of power generated by the hydro power station, but this increase is not renewable. The pumps are run by non renewable sources allowing excess electrical energy to be stored as the potential of energy of water raised to the height of the dam. The amount of renewable energy produced by the hydro power station remains the same.