.

Turbines are of two types:

(1) Reaction turbines, where the turbine is totally embedded in the fluid and powered from the pressure drop across the device

(2) Impulse turbines, where the flow hits the turbine as a jet in an open environment, with the power deriving from the kinetic energy of the flow.

Power From Water

Hydropower equation

MHP uses mechanical energy of water in streams. The energy of water in the streams manifests in form of kinetic and potential energy. Kinetic energy of water is due to its velocity of movement through the river course. And potential energy is due to its position above the sea level. Everyone is aware of the energy that flowing-water possesses. But one may not be aware of the energy of water calmly stored in lakes or ponds above the sea level. The energy stored in water elevated from the sea level may be expressed mathematically as follows

$$E = mgh \qquad [1]$$

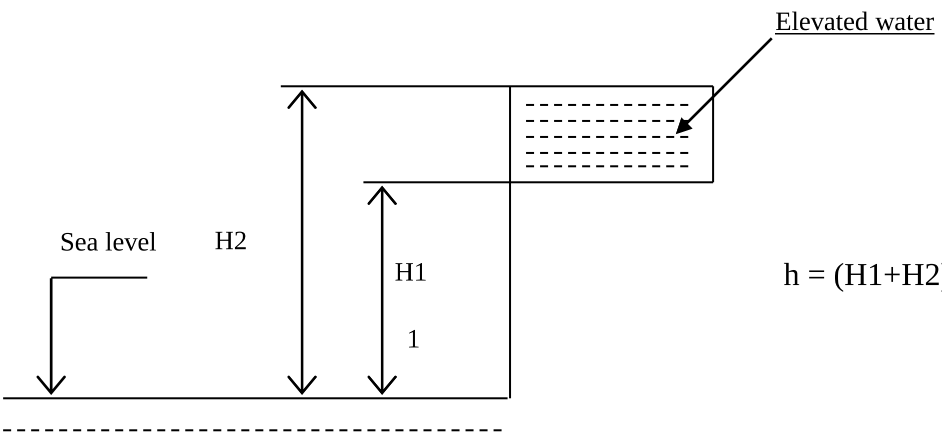
Where, E - energy of water in Joules;

m - mass of water in kg;

g - acceleration due to gravity in m/s^2; and

h – elevation of water with respect to the sea level in m.

This energy may be tapped by allowing the elevated water to flow back to the sea. The power that can be tapped from this water depends upon the rate of flow of water. Obviously the higher the power of the flow the less is the duration of its availability. The total amount of energy that may be tapped from elevated water is the same for any rate of flow and consequently the power tapped.



h = (H1+H2)/2

Illustration of energy of elevated water

Equation [1] may be rewritten as

$E = \rho \times V \times g \times h$ [(kg/m^3) x (m^3) x (m/s^2) x m]

$= 1000 \times V \times g \times h$ [kg x (m/s^2) x m]

$= 1000 \times V \times g \times h$ [N x m]

$= 1000 \times V \times g \times h$ [J]

The corresponding power may be calculated as

$P = E/t$ [J/s] $= E/t$ [W]

$= 1000 \times V \times g \times h/t$ [W]

$= 1000 \times (V/t) \times g \times h$ [W]

$= Q \times g \times h$ [kW]

$$P = 9.81\ Qh \text{ [kW]} \qquad [2]$$

Equation [2] represents the theoretical power that may be generated from elevated water. In reality some losses are involved in power generation. Let η be the efficiency of the process of power generation. Then equation [2] may be rewritten as

$$P = 9.8 \times \rho \times \eta \times Q \times h \qquad [3]$$

This equation is known as hydropower equation. η represents in equation [3] accounts for losses in water conveyance, such as canal, penstock, trashracks losses etc., turbine and generator. For micro-hydropower plants the value η varies from 0.5 to 0.6.

For MHP the rate of flow of water Q, which will be called further discharge, is relatively small. Therefore, the normally adapted unit of Q is litres per second, in short 1ps. When Q is expressed in 1ps the value of P obtained from equation [3] is in watts denoted by W in hydropower practice h in equation [3] is called head, which represents the difference of elevation of water before and after utilization of hydropower by the MHP. For rough estimation of MHP potential the equation [3] may be rewritten as

$$P = 5\ Q\ \ h \qquad [4]$$

Where, Q is expressed in 1ps

h is expressed in m

P is expressed in W.

Power generation

Surface flow, which is called a river/stream, is generated because of the rainfall or more broadly precipitation. The area, which feeds a particular river, is called its catchment. The collection of precipitation in the river courses is a natural process of concentration of hydropower. If the flow is concentrated by nature the head is concentrated artificially. Head concentration by dam is seldom used in MHP, whereas head concentration by diversion is common in MHP. Sometimes head is concentrated by diversion of flow of one river into another. Ghandruk MHP generates power in this way.

Stream flow is not uniform not only within the year but also from year to year. Power generation to be dependable it should be designed for dependable flow. In conventional hydropower practice the discharge, which is likely to be available 95% of the time is taken as design discharge. For MHP such norm is yet to be fixed.

In monsoon fed Nepalese rivers the minimum flow occurs in May - June, whereas monsoon and snow fed rivers in February - March. Building reservoirs to store water during the high flow period and use it during the low flow period can augment the dependable flow. Such reservoirs are beyond the scope of MHP.

In daily span the river discharge is more or less uniform whereas the power consumption is not uniform.

When the stream flow is not enough to generate the peak power requirement. The excess stream flow during off-peak hours may be stored in daily pondage basin to use it during the peak hours.

Nepal has large hydropower potential owing to the high precipitation it receives and its hilly terrain. Theoretical hydroelectric potential of Nepal is estimated at 83,000

MW. The economic potential is around 42,000 MW. Nepal's MHP potential is unknown. Very rough estimates show that it should be over 50 MW. Therefore there is still lot of scope for developing micro-hydropower plants.

Hydropower Classification

In Nepal the classification of hydroelectric plats according to their capacity is as follows:

Table 1.1 Type of hydroelectric plats

Type	Size
Micro-hydropower	Up to 100 kW
Mini-hydropower	Above 100 kW but not exceeding 1,000 kW (1MW)
Small-hydropower	Above 1 MW but not exceeding 10 MW
Medium-hydropower	Above 10 MW but not exceeding 300 MW
Large-hydropower	Above 300 MW

Classification of MHP

Table 1.2 Classification of MHP

Type	Size
Very small MHP	Up to 8 kW
Small MHP	8 – 20 kW
Medium MHP	20 – 50 kW
Large MHP	50 – 100 kW

government, through the ADB/N, started providing loan for MHP under the priority sector interest rates. After this arrangement the ADB/N played a key role in promotion of MHP. The above governmental efforts together with efforts from non-government agencies have helped to achieve a remarkable development of MHP in Nepal.

Systems Components of Mini and Micro Hydropower

Layout of MHP (Civil Components)

The typical layout of MHP is illustrated in Fig. 1.3.1. The major components of MHP are diversion intake, desanding basin, canal, forebay, spillway, penstock, powerhouse, tailrace and transmission/distribution system.

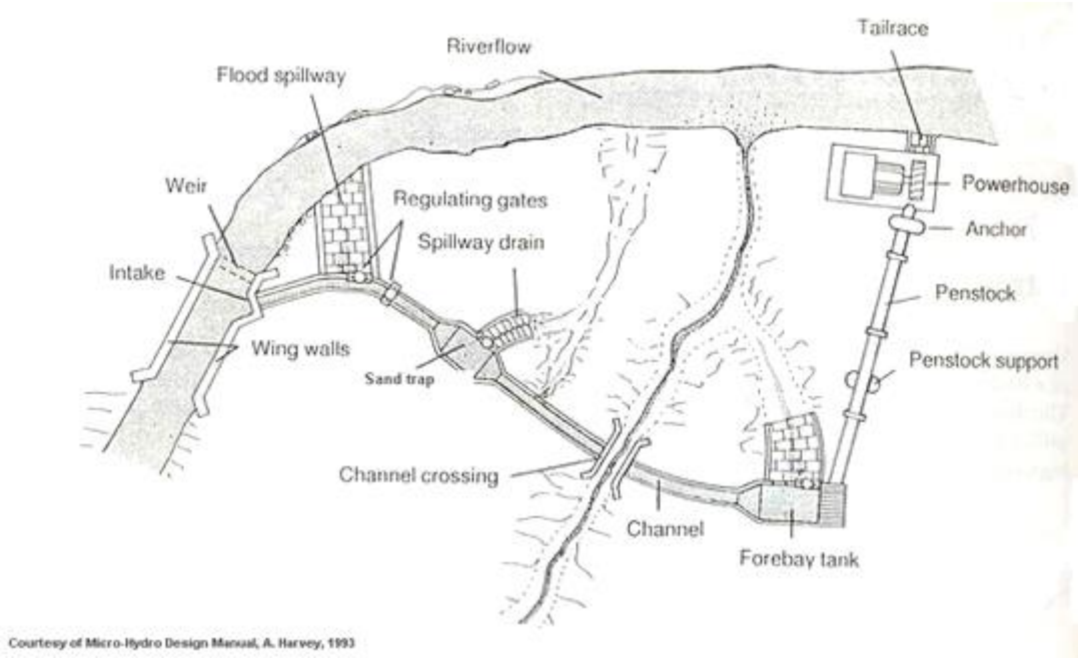


Fig. 1.3.1 Components of Micro-hydro power scheme

Diversion structure is a structure designed to raise the water level in the stream in order to enable water to be diverted off the river. In MHP, as a rule, only temporary structures are built for this purpose. These structures are in most cases simply consists of boulder/mud piling resembling the diversion practiced in traditional watermills. In some cases gabion weirs are also used for diverting water.

Intake is the point from where water flows off the river channel. Therefore intake is the beginning of the conveyance of water diverted for MHP. Intake is normally provided with a gate to control the quantity of diverted water.

Canal is the structure designed to deliver diverted water to the forebay of the MHP. In MHP sometimes pipes substitute canals. In hydropower the conveyance for delivery of water from river to the forebay is called headrace. Therefore headrace can be pipes and canal. In MHP canals are, by and large, lined in order to avoid erosion of turbine by the silt. Most headrace pipes used in MHP are HDPE pipes. The length of headrace can be from a few metres to over a kilometer. For example the length of headrace in Ghandruk MHP is 1,800 m and in Khamje MHP is 8m. The headrace discharge in MHP is seldom goes beyond 200 1ps. Theoretically low head plants can have much larger discharge. But such plants should not be encouraged in the MHP practice, as these will require sophisticated civil works.

Desanding basin

Nepalese rivers carry relatively high amount of sediments owing to high erosion activities taking place in the hills and mountains. The sediment density of Koshi is highest in the world next to Huangho River in China. The sediment density fluctuates within the year. The sediment density is highest during the high flow period. Sediments in river water have the following negative impacts for the MHP:

- Sediments get deposited in the canal and forebay, which reduces carrying capacity of the canal. The design canal capacity can be maintained only through frequent clearing, which is very expensive.
- Sediment among others consists of hard silica compounds. These compounds erode the penstock and turbine. This at the one hand increases the operating costs and at the other decreases efficiency of the MHP.

The purpose of desanding basin is to trap sediments so that these do not enter the canal. The desanding basin is, as a rule, built at the head of the canal and it is regarded as a part of the headworks. The desanding basin is wide and long pool designed to settle the sediments carried by the diverted water through reduction in the speed of water. Most desanding basins are designed to settle particles above 0.2 – 0.3 mm. Desanding basin is provided with a sediment flush in order to reduce the cost associated with its cleaning. During the rainy season daily flushing of the desanding basin may be required.

Forebay

A forebay is located at the end of headrace. A forebay is a wide and deep pool from which the penstock draws water. The purpose of the forebay is to avoid air trapping by the water entering the penstock, as the entry of air through the penstock may cause cavitation, which is a type of erosion created by the explosion of trapped air bubbles under the high pressure, of both penstock and turbine.

A small overflow is to be maintained from the forebay in order to avoid fluctuation of its level and consequently the possible entry of air to the penstock. The volume of overflow from the forebay increases to the level of design discharge in case of generator shut down. Such overflow may continue for long time if the canal intake is not closed. Sediments get settled down in the forebay, as the speed of water is much slower in the forebay compared to that in the headrace. Therefore a sediment flush system is provided in the forebay. A spillway is to be provided from the forebay for safe passage of sediment flush and overflow water to the river. At the outlet of the forebay, which is inlet of the penstock a trash rack is provided to prevent the floating debris from entering the penstock.

Penstock

Penstock is a pipe for delivering water from the forebay to the turbine. Penstock is made of steel or HDPE, and rarely of timber. Recently PVC penstock has also been introduced. If HDPE penstock is prevalent at lower heads, steel penstock is prevalent at higher heads. The MHP head varies from a few metres to over hundred metres. Ghandruk MHP, has a head of 220 m, which is the highest in Nepal among MHP. If low heads are common for add-on MHP high heads are common for stand-alone MHP.

The conversion of potential energy of water into kinetic energy takes place in the penstock. The typical velocity of water in the penstock is around 3 m/sec. In order to reduce the head loss in penstock it is desirable to make the penstock as short as possible. For this purpose penstock is located in a steep slope, which is very often over 45°.

Powerhouse

Conversion of mechanical energy of water into electrical energy takes place in the powerhouse. The major components of powerhouse are electrical generator, turbine, electronic load controller and control panel.

Electrical generator is a device, which converts mechanical energy input to its shaft into the electrical energy. Conventional hydropower plants use synchronous generators. MHP use both synchronous and asynchronous generators. Up to about 20 kW capacity asynchronous generators are cheaper than synchronous generators. Sturdiness is another advantage of asynchronous generators. The generation voltage in MHP is 400/230V.

Mechanical Components:

Turbine: is a device, which converts kinetic energy of water flow into kinetic energy of turbine shaft, which drives the generator shaft. The turbine types widely used in MHP in Nepal are pelton and cross flow (see Fig. 1.3.2 and 1.3.3). If cross-flow turbines are used at lower heads the pelton turbines are used at higher heads.

Drive systems: The drive system comprises of the generator shaft, turbine shaft, bearings, couplings, pulleys, belts and other components used to change the speed or orientation of the drive. The function of the drive system is to transmit power from the turbine to the generator shaft in a required direction and at a required speed. Drive systems are required if the RPM of the turbine and generator are different. As far as possible preference should be given to direct coupling as this minimized both losses due to the drive systems as well as the space required.

Expansion joints: Due to heating and cooling effects, the exposed sections of the penstock pipes are subjected to thermal gradient, which causes the pipes to expand or contract. This results in additional stress on the penstock pipe as it is rigidly fixed on both ends due to the anchor blocks. In order to allow for pipe movement due to the temperature effects, expansion joints are essential. An expansion joint should be located downstream the fore bay and one each downstream the fore bay and one each downstream of every anchor block along the exposed pipe alignment. For buried pipe length (both mild steel and HDPE), expansion joints are not essential as the temperature differences are not significant.

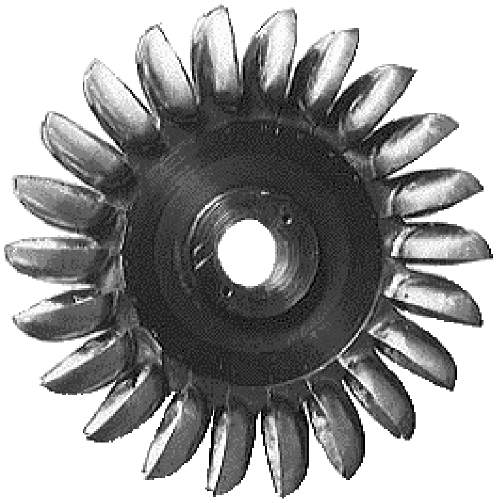


Fig. 1.3.2 Pelton Runner

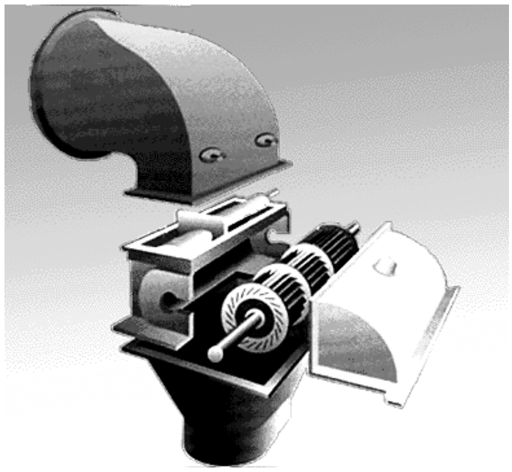


Fig. 1.3.3 Crossflow Turbine

Trashrack: It is essential that the quantity of debris which enters a hydro power scheme be minimized. A trash rack intercepts the entire flow and removes any large debris, whether it is floating, suspended or swept along the bottom. A trashrack is made up of one or more panels, each generally fabricated of a series of an evenly spaced parallel metal bars. Frequently, trashrack is located in the intake structure to prevent debris from entering, and another is placed just before the inlet to the penstock to remove smaller debris as well as other debris which may have entered the water downstream of the intake. Sometimes a trashrack is also located at the entrance to the power conduit or along a lengthy canal.

Valves: Valves are used to stop or regulate the flow of water in penstock pipes or nozzles. For micro hydro power applications, they control the flow through the penstock, usually at the base of the penstock as turbine isolation valve to permit uncoupling of the turbine and penstock and occasionally used at the inlet of the penstock. Generally, Gate valves and Butterfly valves are used in the micro hydro schemes. Gate valves are often more readily available, but butterfly valves are increasing in popularity because these type of valve can be operated with little force due to its design.