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Small Hydro Plants

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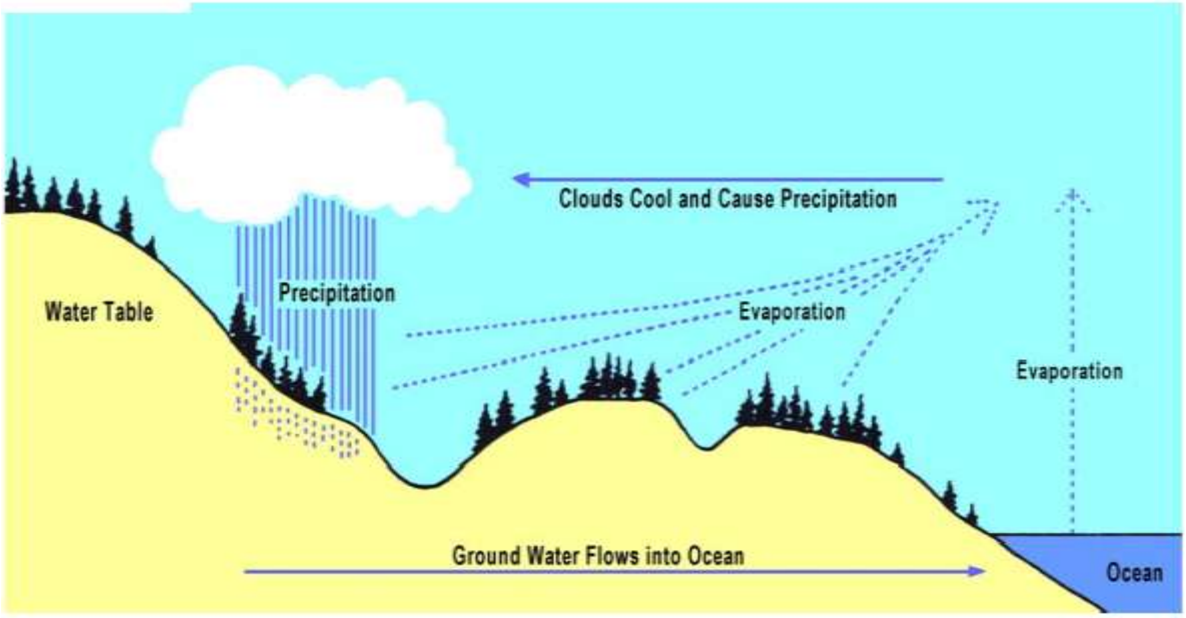
HYDROPOWER-SOURCE OF ENERGY
Why hydropower is called renewable source of energy?

Because it uses and not consumes the water for generation of electricity and leaves this vital resource available for other uses.



Hydroelectric power comes from water at work, water in motion. It can be seen as a form of solar energy, as the sun powers the hydrologic cycle which gives the earth its water. In the hydrologic cycle, atmospheric water reaches the earth's surface as precipitation. Some of this water evaporates, but much of it either percolates into the soil or becomes surface runoff. Water from rain and melting snow eventually reaches ponds, lakes, reservoirs, or oceans where evaporation is constantly occurring.

Moisture percolating into the soil may become ground water (subsurface water), some of which also enters water bodies through springs or underground streams. Ground water may move upward through soil during dry periods and may return to the atmosphere by evaporation.

Water vapour passes into the atmosphere by evaporation then circulates, condenses into clouds, and some returns to earth as precipitation. Thus, the water cycle is complete. Nature ensures that water is a renewable resource.

I. INTRODUCTION

Small hydro is the development of hydroelectric power on a scale serving a small community or industrial plant. The definition of a small hydro project varies but a generating capacity of up to 10 **megawatts** (MW) is generally accepted as the upper limit of what can be termed small hydro. This may be stretched to 25 MW and 30 MW in Canada and United States**. In India, Luni-III and Luni-II constitute SHP for a grid system generates bundled electricity of 10 MW each in Kangra district, Himachal Pradesh**. Cumulative installed capacity of small hydropower is expected to reach 140 GW in 2015 and 201 GW in 2020.

SHP may be connected to conventional electrical distribution network, or a source of low cost renewable energy.SHP may be built in isolated areas that would be uneconomic to serve from a network or in areas where there is no national electrical distribution network. Nowadays, small hydro is one of the most valuable answers to the

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questions of how to offer to isolated rural communities the benefits of electrification and the progress associated with it, as well as to improve the quality of life. Since SHP is usually had minimal reservoirs and civil construction work, they are seen as having a low environmental impact compared to large hydro. This decreased environmental impact depends strongly on the balance between stream flow and power production.

It will be enhanced the main advantages to develop small hydro comparing with other electricity sources:

1. It saves consumption of fossil, fuel and firewood.
2. It is self-sufficient without the need of fuel importation.
3. It does not contribute for environment damages by resettlement; as it occurs with large dams and reservoirs.
4. It can be a good private capital investment in developing or developed countries.
5. It offers a decentralized electrification at a low running cost and with long life.

A small scale project can also induce tourist activities and can benefit both rural and small urban areas with a friendly water scenario.

1.1 DEFINITION OF SMALL HYDRO POWER IN DIFFERENT COUNTRIES

Country	Capacity of Plant
UK	≤5 MW
USA	≤5 MW
Sweden	≤15 MW
Colombia	≤20 MW
Australia	≤20 MW
Canada	≤ 20 MW
India	**≤25 MW**
China	≤25 MW
PHILLIPINES	≤50 MW
New Zealand	≤50 MW

1.2 CLASSIFICATION OF SMALL HYDRO ON THE BASIS OF SIZE

Type	Station Capacity
Micro Hydro	Up to 100KW
Mini Hydro	101 KW to 2000 KW
Small Hydro	2001 KW to 25000KW

1.3 CLASSIFICATION OF SMALL HYDRO ON THE BASIS OF HEAD

Ultra Low Head	Below 3 meters
Low Head	Less Than 40 meters
Medium/High Head	Above 40 meters

1.4 POWER EQUATION OF HYDRO

Water is fed from stream/canal to the turbine by a closed pipe (penstock) through diversion works. The turbine in turn rotates the generator for electricity generation.
The basic equation for calculation of power is a relation between head and flow rate and is given as

$$P = \rho g H Q \eta \quad [1.1]$$

Where P= Electric power output of the scheme in watt.
ρ= density of water (1000 kg/m^3).
g = gravitational acceleration (9.81 m/s^2).
H=Net Head (height difference between the water levels at the intake and the tailrace minus all head losses in headrace and penstock) in meters.
Q = Design flow rate or discharge in m^3/s.
η= Overall efficiency of the turbine, generator and gear box (may be ta

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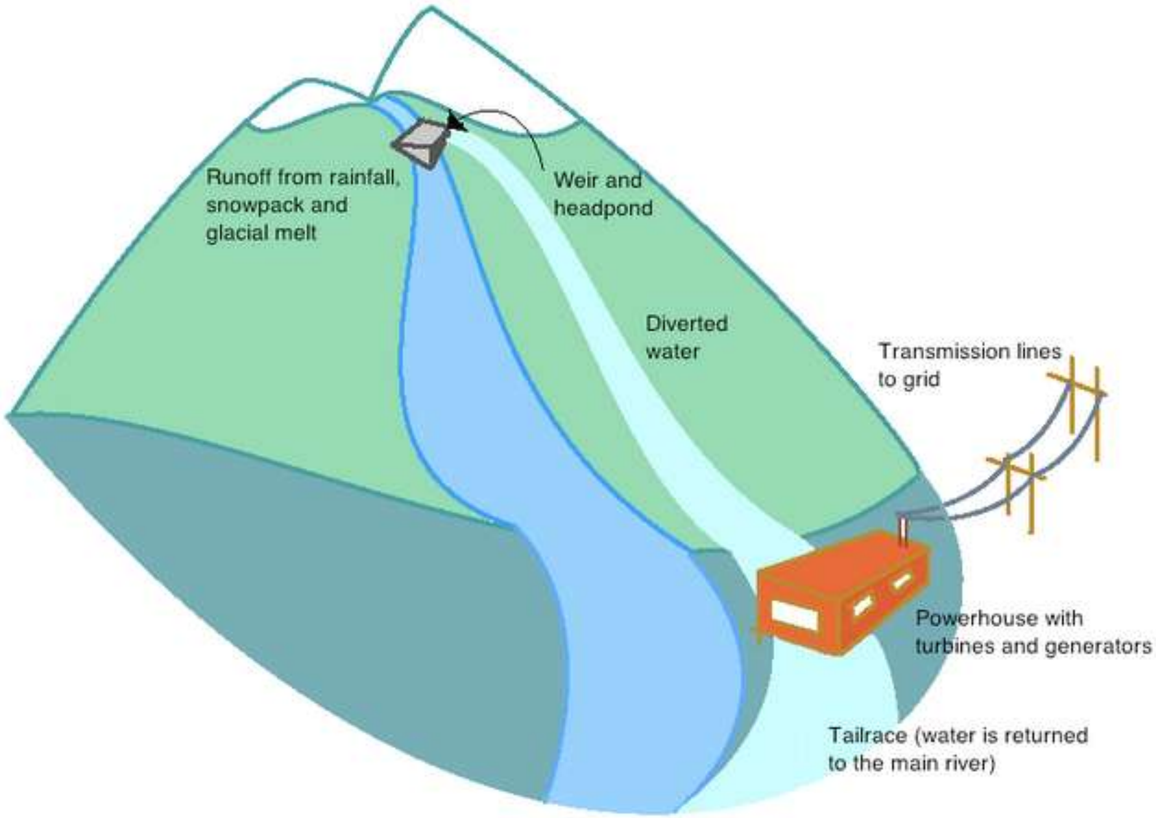
SITE LAYOUT



A diagram showing how a small hydro or run of river facility draws power from a mountain stream.

II. HYDRAULIC DESIGN OF SMALL POWER PLANTS

2.1 Run of River Scheme

Small hydro, often called run of river (ROR), harness the energy in flowing water to generate electricity. In ROR system, running water is diverted from a river and guided down a channel or penstock, which leads to a generating house. Here, the force of the moving water spins a turbine, which then drives a generator. Used water is fed back into the main river further downstream. The difference between run of river and large, conventional storage hydro is the absence of a dam and reservoir. Run of river relies on coursing rivers to generate electricity, as opposed to stored water. Most small hydro facilities do use a dam, or weir, to ensure enough water enters the penstock. **Pondage** is also used at some facilities to store small amounts of water. Plants with pondage tend to be more reliable, as they assuage the effects of daily and seasonal flow frequencies.

2.2 System Components required for small hydro power projects

System can be divided in three major parts as civil works, Electro-Mechanical components and Distribution system. Civil work may include construction work required for weir, intake, desilting tank, forebay, conveyance line or headrace, penstock, tailrace, power house and substations. Electro-Mechanical components include turbines, generators and governor or control system and transmission or distribution system.

1. Weir

The function of a weir is to obstruct water flow and raise the water level significantly and sometimes to allow water storage.

Types

1. Trench weir.
2. Rock fill weirs.
3. Vertical drop weirs.
4. Concrete weir with sloping glacis.
5. Coanda weir.

6. Inflated weir/rubber dam.

2. Intake

It diverts water from a river or a pond and delivers it to a canal, penstock or storage basin.

I. Assured water supply.
II. Suitable quality of water.
III. Control over supply of water.
IV. Safety against flood.

3. Desilting Tank

The water drawn from the river and fed to the turbine will usually carry a suspension of small particles. This sediment will be composed of hard abrasive materials such as sand which can cause expensive damage and rapid wear to turbine runners. To remove To remove this material the water flow must be slowed down in desilting tank so that the silt particles will settle on the basin floor. The deposit formed is then periodically flushed away.

4. Headrace

It conveys the water from the intake to the forebay. A typical headrace is made of pipes of good quality materials.

Types

- Open channel

1. Rectangular.
2. Trapezoidal.
3. Triangular.

- Closed conduit

1. Reinforced concrete pipe.
2. PVC pipes.
3. Steel pipes.

5. Forebay

It is like a pond at the top of the penstock, which serves as a final settling time basin for suspended matters in the water. It also provides submergence for the penstock inlet and accommodates overflow and trash rack arrangements.

Components of forebay

1. Basin
2. Spillway

Spill way is a kind of canal provided besides the dam.
Spill way is used to arrange the excess of accumulation of water because excess accumulation of water may damage hydro plants.

3. Gate or valve.
4. Outlet.
5. Trash rack.

In front of the penstock, a trash rack needs to be installed to prevent large particles to enter the penstock.

6. Air vent.

1 to 2% of penstock area.

6. Penstock

Penstock is a pipe that conveys water under pressure from the forebay to the turbine.

Types

1. Steel pipe.
2. PVC.
3. Reinforced concrete pipe and prestressed concrete pipe.
4. Glass fibre reinforced plastic pipe.
5. Wood staves.
6. Glass fibre reinforced concrete.

7. Power house

The power house provides shelter to the electromechanically equipment (turbines, generators, controls and panels).It may have sufficient space for dismantling the equipments for maintenance and repair.

8. Turbine

These are used to convert kinetic energy of flowing water into mechanical energy and transfer this energy to generators.

9. Generator

These converts mechanical energy input from turbines to electrical energy output.

10. Control systems

These are required to monitor and regulate the power produced from the generators in power house.

11. SubStations

It consists of switchgear and transformers to transform the voltage from the small hydro generator to the high voltage transmission lines.

12. Tailrace

Tailrace is a channel for slowing and redirecting water back into stream.

2.3 SAFETY DEVICES

1. Surge Tank

When there is a sudden close or decrease in pressure due to control valve then there is a back flow of water. This creates a high pressure zone in

the penstock due to which it may burst. This effect is known as **water hammering** effect.
To avoid this tank is attached to the penstock which stores water in it. This tank is called surge tank.

III. ELECTRO-MECHANICAL EQUIPMENTS

1. Turbine
2. Gear
3. Generator with AVR
4. Gates and valves
5. Control panels
6. Switch boards
7. Transformers

3.1 Equipment Standard for SHP Projects

Equipment	Standard
Turbines and generator (Rotating electrical machines)	IEC 60034-1:1983 IEC 61366-1:1998 IEC 61116-1992 IS:4722-2001 IS 12800 (part 3) 1991
Field acceptance test for Hydraulic performance of turbine.	IEC 60041:1991
Governing system for hydraulic turbines	IEC 60308
Transformers	IS 3156-1992 IS 2705-1992 IS 2026-1983
Inlet valves for hydro power stations and systems	IS 7326-1902

3.2 Small hydraulic turbines

The choice of standardised turbines for small hydro schemes depends upon the main system characteristics: net head, unit discharge and unit power. Hydraulic turbines convert hydropower energy into rotating mechanical energy. The main different types of turbines depend upon the way the water acts in the runner:
1. A free jet at atmospheric pressure - impulse turbines;
2. A pressurised flow - reaction turbines.

3.2.1 REACTION: Francis, fixed pitch propeller, Kaplan

1. for low to medium head applications.
2. submerged turbine uses water pressure and kinetic energy.

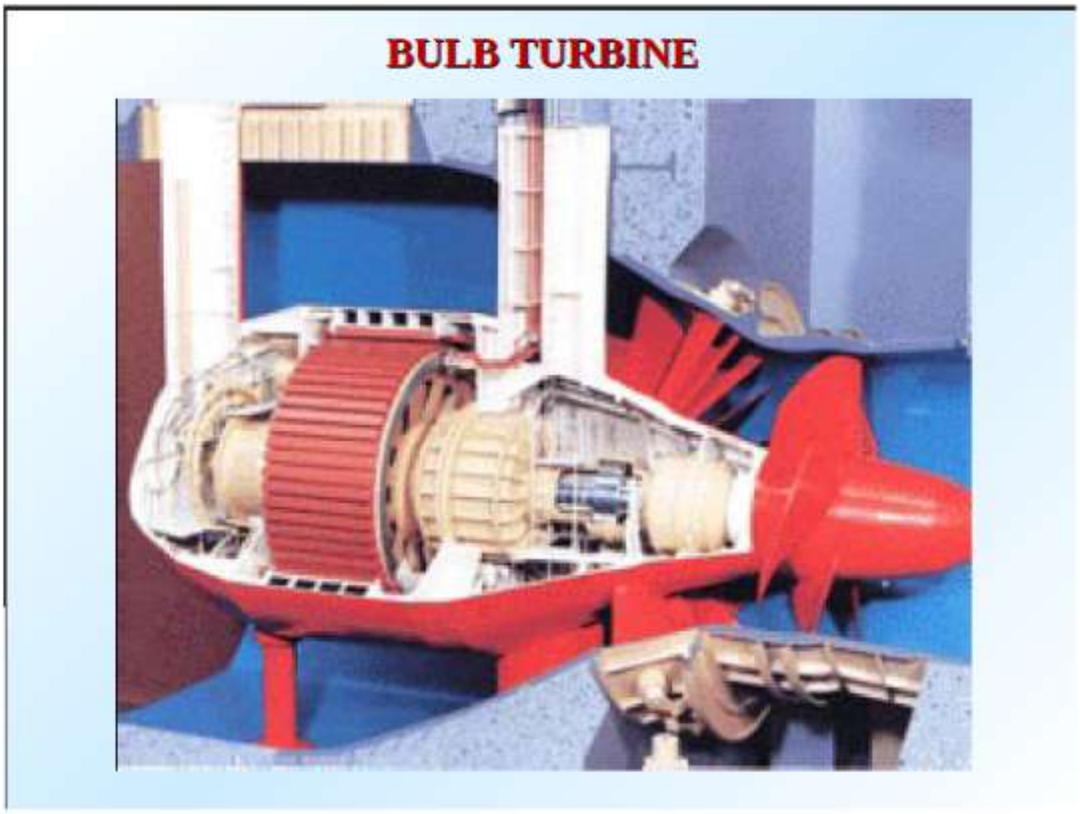
The main advantages of these turbines are
1. It needs lesser installation space (e.g. the runners are smaller than pelton runner).
2. It provides a great net head and a better protection against downstream in high flood levels (can run submerged).
3. It can have greater runner speed.
4. It can attain higher efficiencies for higher power values.

3.2.2 IMPULSE: Pelton, Turgo, Cross flow

1. for high speed applications.
2. Uses kinetic energy of a high speed jet of water.

The main advantages of these turbines are
1. They can be easily adapted to power variation with almost constant efficiency.
2. The penstock overpressure and the runner over speed control are easier.
3. The turbine enables an easier maintenance.
4. Due to the jet, manufactures of these turbines impose a better solid particles control inducing consequently a lower abrasion effect.

HYDRAULIC TURBINES		H (m)	Q (m^3/s)	P(KW)	N_S(r.p.m)
Reaction	Bulb	2-10	3-40	100-2500	200-450
	Kaplan and Propeller-axial Flow	2-20	3-50	50-5000	250-700
	Francis with High specific Speed-diagonal Flow	10-40	0.7-10	100-5000	100-250
	Francis with Low specific Speed-radial Flow	40-200	1-20	500-15000	30-100
IMPULSE	Pelton	60-1000	0.2-5	200-15000	<30
	Turgo	30-200		100-6000	
	Cross flow	2-50	0.01-0.12	2-15	



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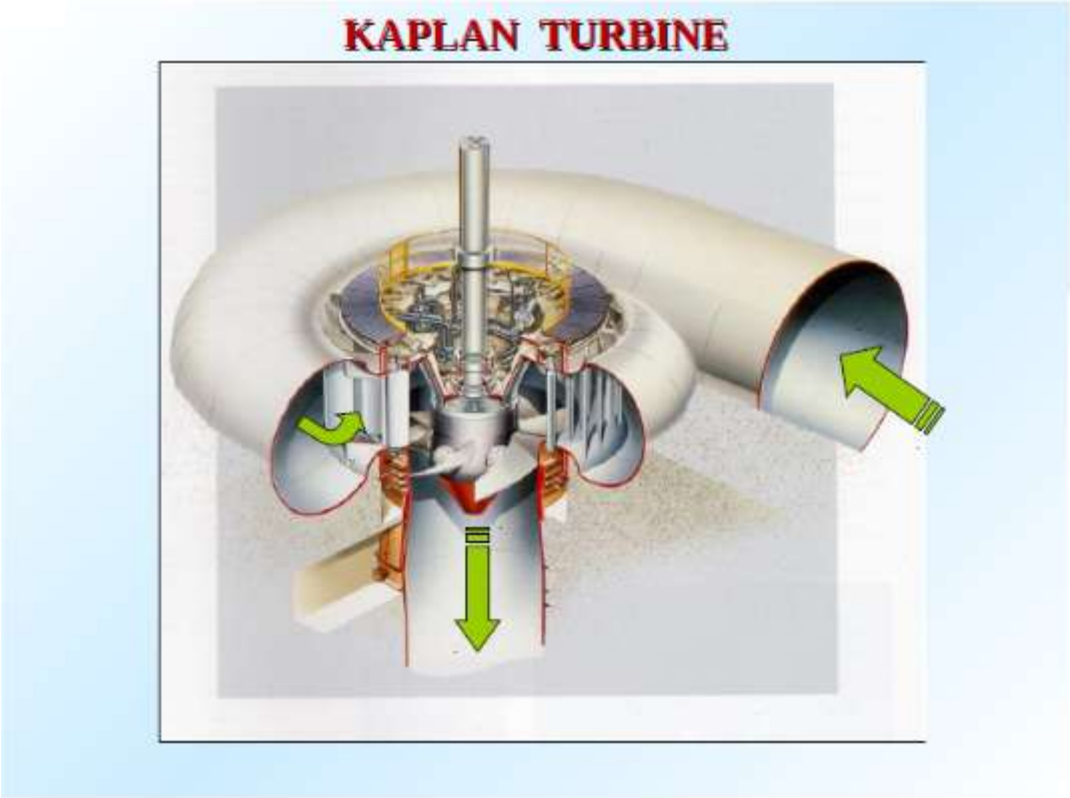

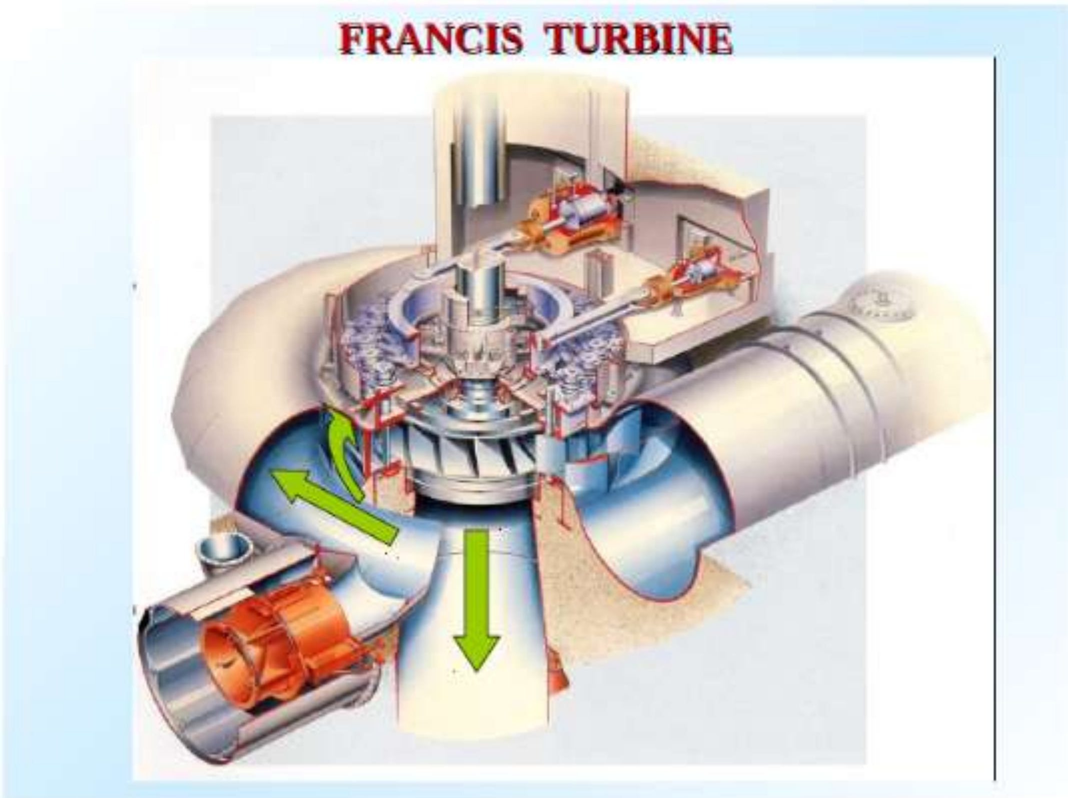

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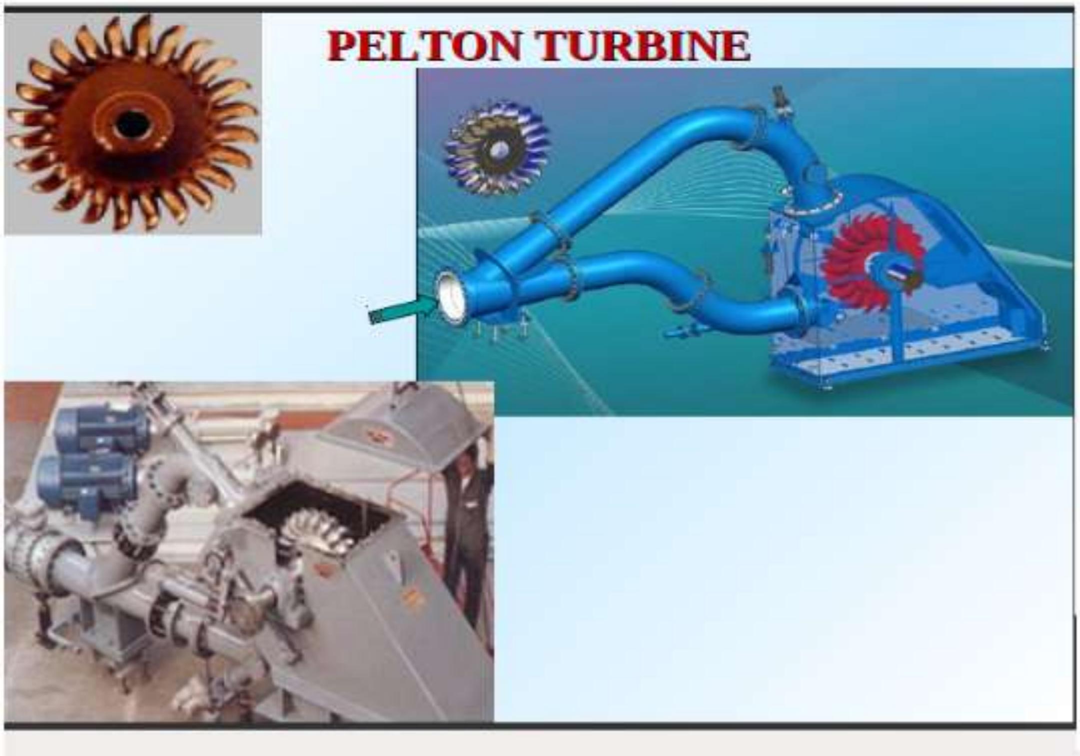
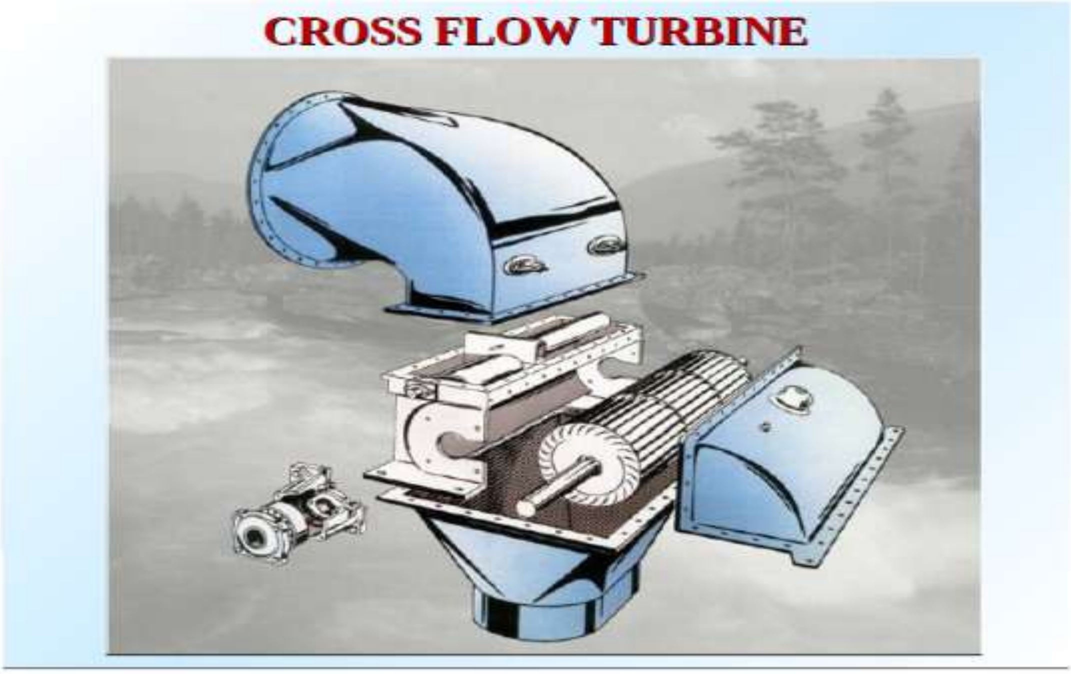




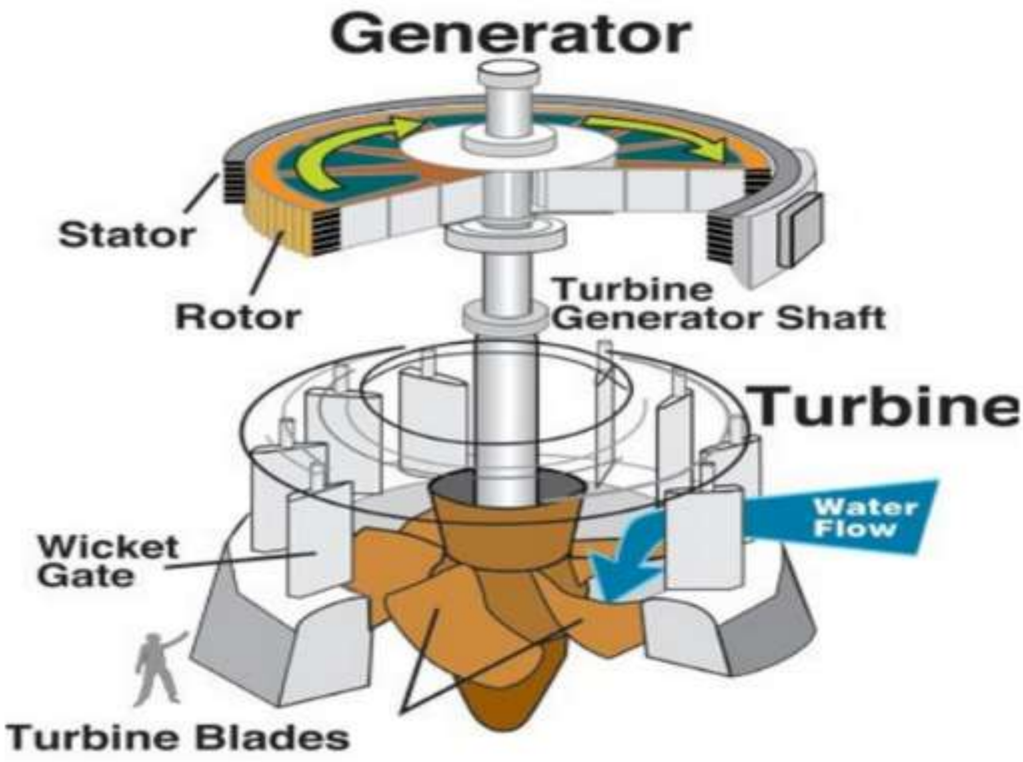
Himalayan Schemes	
Head	**Turbine**
>200 m	Pelton (single-jet or multiple jet)
100-200 m	Turgo, Pelton multiple jet
50-100 m	Cross flow, Francis

3.3 Gearbox
The gear is a device installed between the turbine and generator increasing the rotation speed of the generator in order to reduce its cost.

3.4 Generators
The generator is a rotating machine with its shaft coupled to the turbine, providing the conversion from mechanical to electrical power.
There are two main types of generators used for this purpose, the synchronous and the asynchronous.

3.4.1 Synchronous Generator
1. Can function in isolation from other generators.
2. for stand alone and isolated grid application.
3. Higher efficiency.
4. Higher cost.

3.4.2 Asynchronous (induction) Generator
1. Must be tied to other generators
2. Use to feed electricity on to large grid.
3. Grid dependent.
4. Lower cost.
5. Lower efficiency.
6. Simpler control.



The water strikes and turns the large blades of a turbine, which is attached to generator above it by way of a shaft.
Wicket gate is a key component in hydro electric turbines that control the flow of water from input types (Penstock) to the turbine propeller/blades.

Inside the Generator
1. Shaft
2. Exciter
3. Rotor
4. Stator

As the turbine turns, the exciter sends an electric current to rotor. The rotor is a series of large electromagnets that spins inside a tightly wound coil of copper wire called the stator. The magnetic field between the coil and the magnets creates an electric current.

3.5 Electrical installations
3.5.1 Main Transformer

The transformer is a static unit with the purpose of stepping up the generation voltage to the grid connection voltage level. The voltage ratio is defined by

$$\frac{N_1}{N_2} = \frac{V_1}{V_2} = \frac{I_2}{I_1}$$
[3.1]

N_1, N_2 = primary and secondary winding number of turns.
V_1, V_2 = primary and secondary voltages.
I_1, I_2 = primary and secondary currents (inverse ratio).
The transformers are immersed oil type but dry types/resin impregnated are also used for lower powers.
The high voltage winding of the power station main transformer is fitted with tap changer to allow for expanded adjustment range to the grid voltage.

3.5.2 Switchgear

The mini hydro power stations normally use the medium voltage switchgear, switches and circuit breakers, housed in metal cubicles, these being standard market products satisfying the European electrical regulations (CEI).

The circuit breaker operate in SF_6/vaccum also with standard ranges of breaking capacity and open/close times.

3.5.3 Control Equipment

The typical power station is equipped with electrical control/supply boards, housing the manual and automatic control and auxiliary equipment.

Switches and push buttons support the manual control, with the operator being informed about the state of the plant by the indicating instruments.

The automatic controls are based on a programmable logic controller (PLC), which receives on-line information through transducers and digital input signals and take the necessary control actions for water utilization, flow or level control. The PLC output is processed via suitable relays.

The PLC is also used for data processing and transmission via telephone modem or radio signalling.

3.5.4 Switch yard

1. Switchyard structure.
2. Bus bar system.
3. VCB/SF_6 circuit breakers.
4. Isolators.
5. CTs.
6. PTs.
7. LA.
8. Line side isolators.
9. Surge counters.
10. Outgoing lines.

IV. CONCLUSION

When the estimated potential and initiatives taken by state governments and private sector there is a big scope for the development of small hydro power projects in country. A small hydropower system has advantages that it can be used directly for both as a mechanical and electrical power generation. **For example, water mills or gharats had widely been used in country for various purposes such as rice hulling, flour making, agro processing, mechanical shaft power utilised in sawmills and electricity generation etc.**

Small hydropower systems can be proved as sustainable source of electricity in states, specially in hilly areas where the potential is available.

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