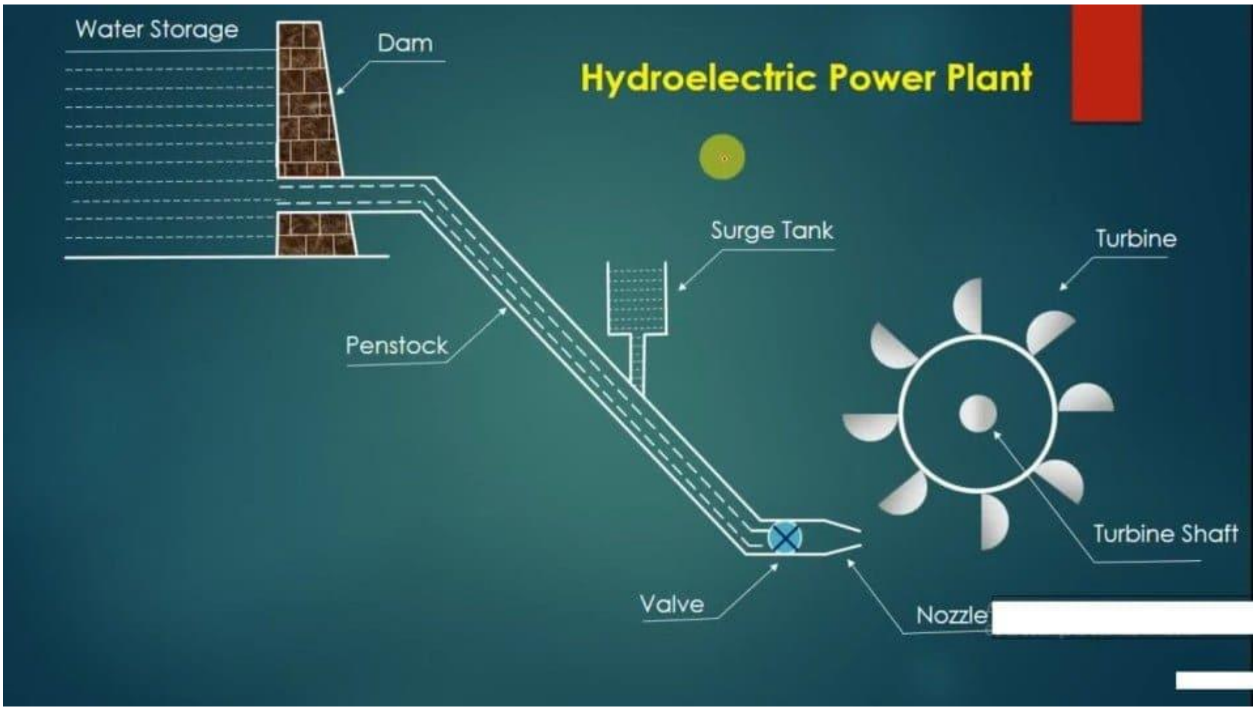
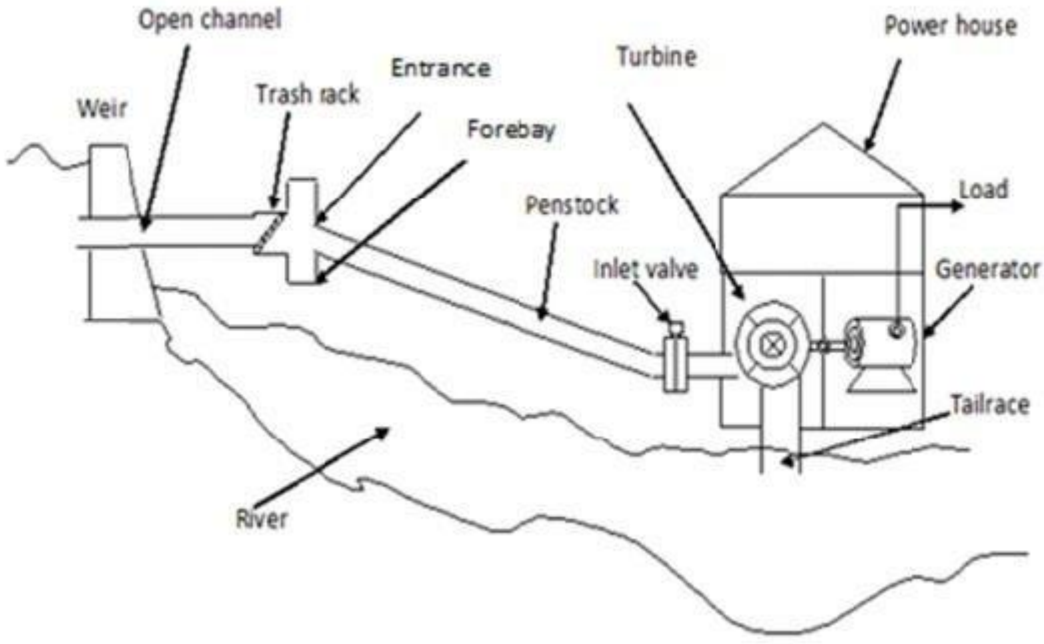
Micro hydro power plant



Micro hydro is a type of small scale hydroelectric power plant that makes advantage of naturally-flowing streams to produce 5 kW – 100 kW of electricity.

This process produces no direct emission. Micro hydro can bring electricity to remote communities, ranging from a single home, to few hundred kilometer for selling into national grid. Water can be harnessed from small scale to large scale.



The main components of micro hydro power plant are explained here.

1. The water in the river diverted by the weir through an opening in the river side (the 'intake') into a channel.
2. A settling basin is built into the channel to remove sand and silt from the water and this channel preserves the elevation of the diverted water.
3. The channel directs the water in to a small reservoir/tank known as the '**forebay**' from there it is directed to the turbines through a closed pipe known as the 'penstock'.
4. The **penstock** essentially directs the water to the turbine at a lower level.
5. The turning shaft of the turbine can be used to rotate a mechanical device such as a grinding mill, wood lathe etc. directly, or to operate an electricity generator.
6. The machines which are energized by the turbine are called the 'load'.
7. When electricity is generated, the 'power house' where the generator is located transfers the electricity to a step-up 'transformer' which is then transmitted to the grid sub-station or to the village/area where this electricity is to be used.

Working Principle

1. Water from a stream or river is diverted to the **intake**.
2. It flows through the **penstock**, gaining **kinetic and potential energy** due to height difference (head).
3. The **turbine** rotates when water strikes its blades.
4. The **generator** converts this rotation into **electric power**.

5. The electricity is then supplied to local users or stored in batteries.

6. **Types (Based on Head and Flow)**

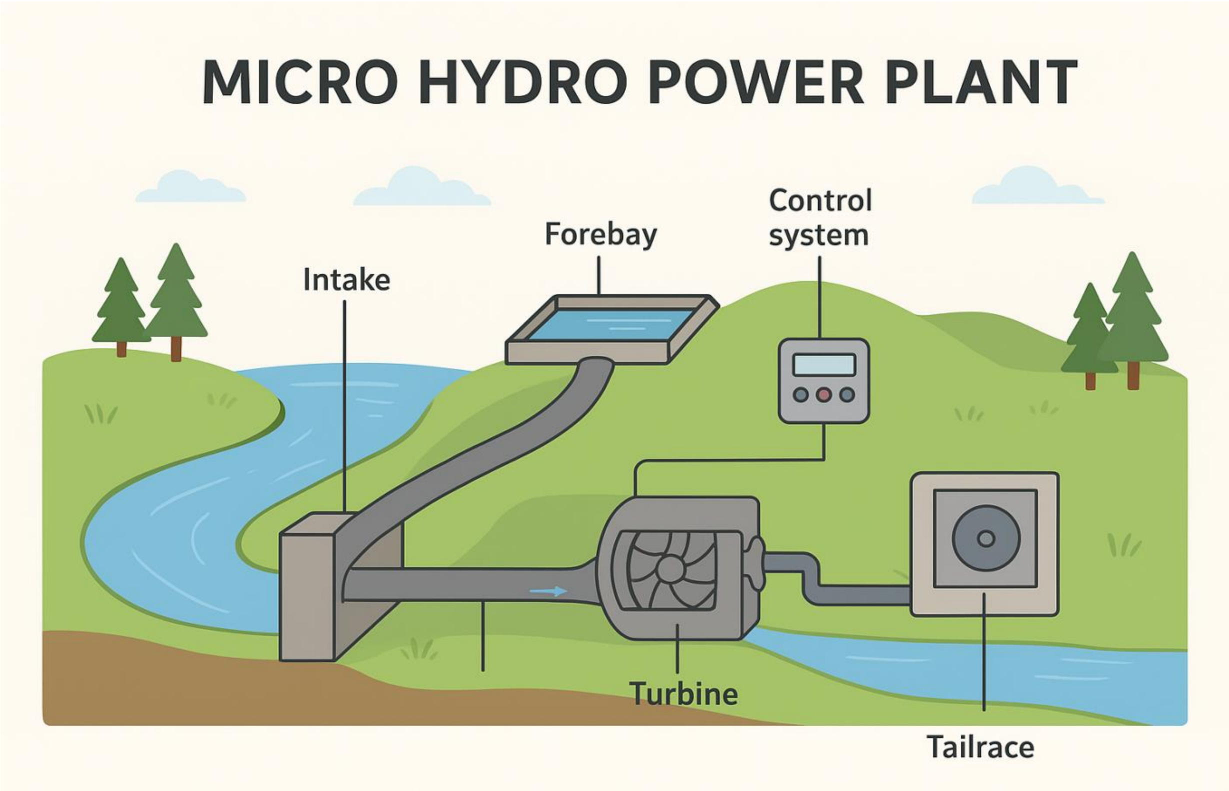
Type	Head Range	Common Turbine
High head	> 50 m	Pelton wheel
Medium head	10–50 m	Francis turbine
Low head	< 10 m	Kaplan or Crossflow turbine

Advantages

- Renewable and environmentally friendly
- Low operating cost
- Reliable for remote communities
- Long lifespan (20–30 years)
- Can operate independently (off-grid)

Disadvantages

- Dependent on water availability (seasonal variation)
- High initial installation cost
- Requires regular maintenance (cleaning intake and filters)
- Site-specific (needs suitable head and flow)



Different types of micro- hydro turbines

Pelton Turbine for Micro Hydro Power Plant

A **Pelton turbine** is the **most commonly used turbine** for **micro hydro power plants** located in **hilly or mountainous areas** where the **water head is high** and **flow rate is low**.
It works on the **impulse principle**, converting the **kinetic energy** of water jets into **mechanical energy**.

In a micro hydro system:

1. Water from a high-level source is carried through a **penstock** (pipe).
2. The **nozzle** converts water pressure into a **high-speed jet**.
3. The **jet strikes the buckets** of the Pelton wheel tangentially.
4. The **runner rotates**, driving the **generator** to produce electricity.
5. The used water exits through the **tailrace** back into the stream.

Main Components in Micro Setup

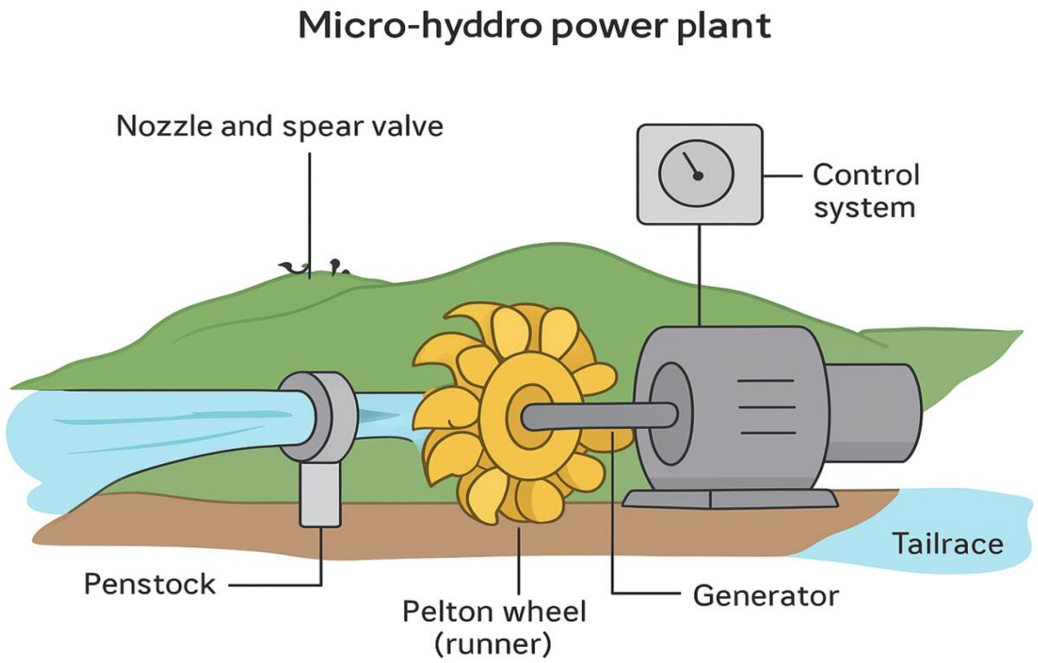
Component	Description
Nozzle with spear valve	Controls and directs the jet of water onto the buckets.
Pelton wheel (runner)	Has multiple double-cupped buckets that receive the water jet.
Casing	Encloses the turbine to prevent water splashing and directs discharge to tailrace.
Shaft & Bearings	Transfer mechanical energy to generator and support rotation.
Generator	Converts mechanical energy into electrical energy (usually synchronous or permanent magnet type).
Control system	Regulates voltage, frequency, and water flow for stable output.

Typical Operating Conditions for Micro Hydro Pelton

Parameter	Range
Head	50 m – 300 m
Discharge	10–200 liters/sec
Output power	5 kW – 100 kW
Efficiency	75–90%

Advantages in Micro Hydro Systems

- High efficiency even at small scales
- Easy to maintain and operate
- Long life span of buckets and nozzle
- Works well in hilly or mountainous terrain
- Handles variations in water flow efficiently



Francis Turbine for Micro Hydro Power Plant

A **Francis turbine** is a **reaction-type mixed-flow turbine** commonly used in **micro and small hydro power plants** where the **head is medium (10–50 m)** and **flow is moderate**.
It efficiently converts both **pressure** and **kinetic energy** of water into **mechanical energy**.

Working Principle

- Water from the **penstock** enters the **spiral casing**.
- It passes through **guide vanes** (or wicket gates), which control the flow and direct water to the **runner blades**.
- As water flows through the runner, it exerts pressure and velocity on the blades, causing the **runner to rotate**.
- The **rotating shaft** drives a **generator** to produce electricity.
- Finally, the water exits through the **draft tube** to the **tailrace**.

Main Components

Component	Function
Spiral Casing (Volute)	Distributes water evenly around the runner.
Guide Vanes / Wicket Gates	Control flow rate and direction of water entering the runner.
Runner	Has curved blades that convert water energy into mechanical energy.
Draft Tube	Recovers pressure and discharges water into the tailrace.
Generator	Converts mechanical energy into electrical energy.
Control System	Regulates turbine operation and electrical output.

Typical Operating Conditions (Micro Hydro)

Parameter	Range
Head	10 – 50 meters
Discharge	Medium
Power output	5 kW – 200 kW
Efficiency	80 – 90%

Advantages

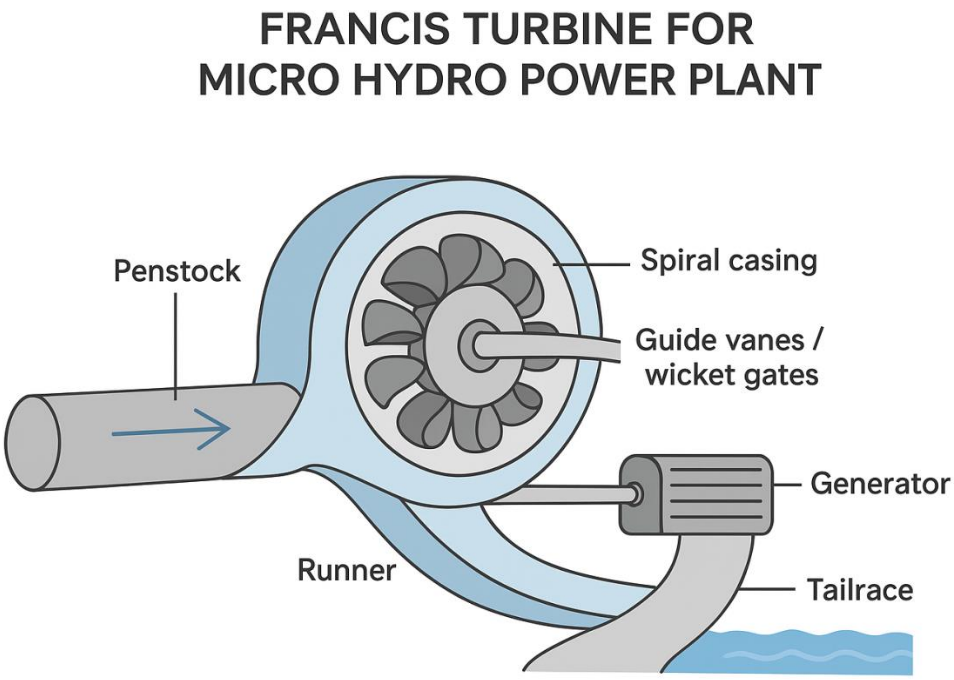
- Works efficiently for medium heads
- Compact design and smooth operation
- Handles flow variations well
- Suitable for continuous operation
- Durable and long-lasting

Disadvantages

- More complex design than Pelton
- Difficult to maintain in remote areas
- Needs precise installation for efficiency

Applications

- **Medium-head micro hydro sites** (hilly rivers, dam outlets)
- **Rural electrification projects**
- **Run-of-river schemes**



Low head Kaplan turbine

A **low head Kaplan turbine** is a **reaction-type axial flow turbine** specially designed to generate power from **low-head (2–10 meters)** water sources with **high discharge**.
It is widely used in **micro and mini hydro power plants** where the available water head is small, such as in rivers, canals, and irrigation systems.

Working Principle

1. Water from the **penstock or canal** enters the **spiral casing**.
2. The **guide vanes** (wicket gates) control and direct the water flow toward the **runner blades**.
3. The **runner blades** are **adjustable**, allowing efficient operation under varying flow conditions.
4. The **axial flow of water** causes the runner to rotate, driving the **generator**.
5. The **draft tube** recovers kinetic energy and directs the water to the **tailrace**.

6. Main Components

Component	Function
Spiral Casing (Volute)	Distributes water uniformly around the runner.
Guide Vanes / Wicket Gates	Control and guide the flow direction.

Component	Function
Runner (Adjustable Blades)	Converts energy of flowing water into mechanical energy.
Draft Tube	Converts remaining kinetic energy into pressure and directs flow to tailrace.
Generator	Converts mechanical energy to electrical energy.
Control System	Adjusts guide vane and blade angles automatically for efficiency.

Operating Conditions

Parameter	Range
Head	2 – 10 meters
Flow rate	High
Power output	5 kW – 500 kW
Efficiency	85 – 90%

Advantages

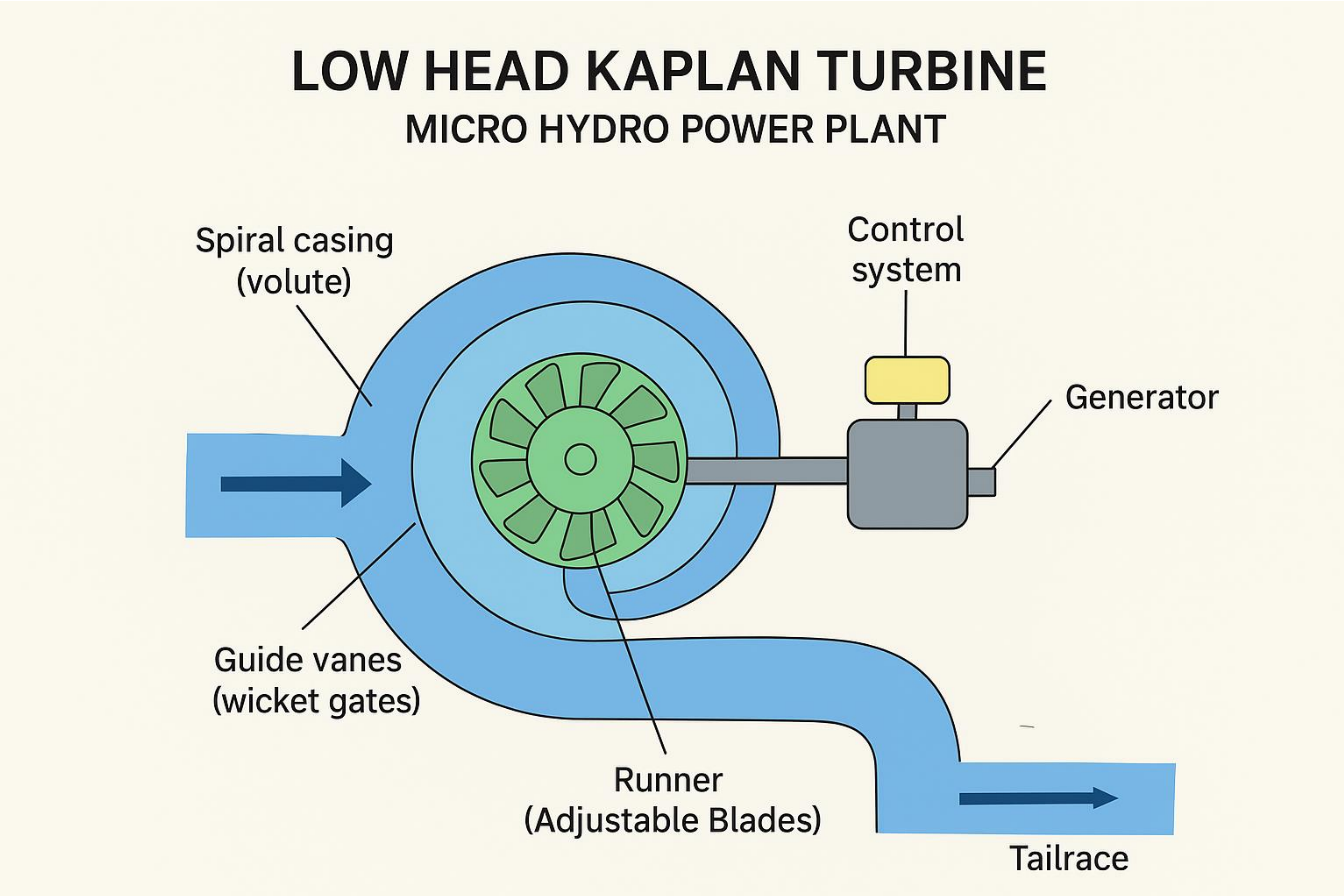
- High efficiency for low-head applications
- Handles large water flow volumes
- Adjustable blades allow flexible operation
- Compact and reliable
- Ideal for run-of-river and canal systems

Disadvantages

- More expensive and complex than fixed-blade turbines
- Requires frequent maintenance of blade mechanism
- Not suitable for high-head sites

Applications

- **Micro hydro projects** on rivers or irrigation canals
- **Low-head dams** and **run-of-river plants**
- **Rural and agricultural power generation**



Micro- or small-hydro power plants in india.

A 100 kW (2×50 kW) micro-hydro plant in **Jakhna** village electrifies three local villages and about 260 households.

Ramgarh micro/mini plants — e.g., Ramgarh 100 kW schemes (state reports and case studies list several 50–100 kW units). Uttarakhand has dozens of installed MHPs (tens of MW when aggregated

Jammu & Kashmir / Ladakh

- **Biaras (Drass), Kargil** — **1.5 MW (2×0.75 MW)** small hydro commissioned under Ladakh renewable initiatives (example of a larger 'small' project in high Himalaya).

Seed table — 25 documented micro / mini hydro stations (site • capacity • state • source)

1. **Jakhna MHP** — 100 kW — Uttarakhand. Bentham Open
2. **Ponglefo SHP (Salomi, Kiphire)** — 1,000 kW (1 MW) — Nagaland. The Times of India
3. **Wanakbori (Kaplan listed in supplier PDF)** — 1000 kW (supplier entry) — Gujarat. jyoti.com
4. **Ganganahal MHS** — 1,000 kW (supplier entry) — Karnataka. jyoti.com

5. **Shageon (Turgo)** — 36 kW (supplier entry) — (listed in installations PDF). jyoti.com
6. **Kattepura** — listed (supplier entry) — capacity entries in supplier list; useful for micro/mini catalogs. jyoti.com
7. **Numerous Karnataka commissioned SHP (state list)** — multiple mini projects 10–12 kW up to several MW — Karnataka (KREDL commissioned list). kredl.karnataka.gov.in+1
8. **Multiple MNRE "small hydro" ongoing / R&D projects list (examples of small hydro demonstrations and pilot MHPs)** — various capacities (dataset/overview). Ministry of New and Renewable Energy+1
9. **Darjeeling early small hydro (historic reference)** — 130 kW historic plant (Darjeeling). India WRIS
10. **Various canal/civil low-head plants (Punjab canal projects; Kotla Branch examples)** — capacities typically 100 kW–1 MW (canal scheme entries). NRedcap+1
11. **Selected Uttarakhand mini/micro plants (policy & state lists)** — many 50–200 kW community projects (UREDA / Uttarakhand policy). CDN BBSR+1
12. **Nagaland / North East small SHPs (other NE SHPs listed in news & state pages)** — 250–1000 kW range examples. The Times of India
13. **Hemavathi RBC (Karnataka commissioned SHP)** — listed in Karnataka commissioned projects PDF. kredl.karnataka.gov.in
14. **Tallur (Jyothi / supplier list entry)** — small/mini hydro entry in KREDL / supplier lists. jyoti.com+1
15. **Kukke Stage-2 (Karnataka file listing)** — SHP entry in state list (capacity listed in state PDF). kredl.karnataka.gov.in
16. **Many MNRE-supported ultra-low head / hydrokinetic pilot projects (IIT Roorkee centre of excellence examples)** — R&D pilots & demonstration MHP units. Ministry of New and Renewable Energy
17. **Projects in Himachal Pradesh (HIMURJA / state list entries)** — multiple community micro units (50–500 kW) — Himachal.
18. **Ladakh / J&K small hydro (examples: Drass / Kargil area projects)** — small/mini SHPs in extreme-altitude areas.
19. **Supplier / industry install lists (bulk of smaller MHP names & capacities: useful catalogue entries across India)** — cross-state entries. jyoti.com
20. **IREDA hydro energy sector page (listing small hydro support & projects)** — national level reference to many small/mini sites. IREDA
21. **NREDCAP executed mini hydel projects listing (state project list entries)** — detailed project execution lists for many small projects. NRedcap
22. **State policy lists showing village MHPs (Uttarakhand micro & mini policy: dozens of named village schemes)** — multiple 50–100 kW projects named in DPRs. CDN BBSR
23. **Various news entries covering newly commissioned small/mini hydels across NE & Himalayan states (recent commissioning notices)** — e.g., 2025 reports. The Times of India
24. **India WRIS / hydropower wiki (catalogues & historical lists across states)** — historic and modern small hydro site references. India WRIS
25. **Compilations in research / case-study PDFs (life-cycle, feasibility, case studies listing specific MHPs like Jakhna)** — useful for technical data (head, Q, turbine). Bentham Open+1

Safe practices of Hydro power plants

- **Regular Training:** All employees must be trained in plant operations, emergency procedures, and use of personal protective equipment (PPE).
- **Permit to Work System:** Follow the "permit to work" procedure before starting maintenance or repair work.
- **Signage and Labels:** Proper warning signs should be displayed near high-voltage areas, turbines, spillways, and restricted zones.
- **Emergency Preparedness:** Conduct regular mock drills for fire, flood, or equipment failure scenarios.
- **First Aid and Safety Kits:** Must be available at multiple accessible locations.
- **Proper Grounding:** Ensure all equipment is properly earthed to prevent electric shock.
- **Insulated Tools and PPE:** Use rubber gloves, safety shoes, and insulated tools while handling electrical components.
- **Dry Working Conditions:** Avoid working with electrical equipment in wet or damp areas.

- **Turbine Safety:** Do not approach rotating parts while in operation; ensure interlocks and guards are in place.

- **Pressure Systems:** Regularly inspect pipelines, valves, and pressure vessels for leaks or weaknesses.

- **Dam Integrity Checks:** Regular inspection of dam structure for cracks, seepage, or erosion.

- **Spillway Maintenance:** Ensure spillways are clear of debris for safe water discharge.

- **Slope and Landslide Monitoring:** Especially important in hilly terrain.

- **No Smoking Zones:** Especially near oil storage and generator areas.
- **Fire Suppression Systems:** Maintain automatic fire extinguishers and water spray systems.
- **Cable Fire Protection:** Use fire-resistant cable coatings or ducts.
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Major hydroelectric power plants in India

Himachal Pradesh

- **Bhakra Nangal Project** – on **Sutlej River**, Bilaspur district (shared with Punjab).
   Type: Storage-type, large hydro (1325 MW)
- **Karcham Wangtoo Project** – on **Sutlej River** (1000 MW).
- **Chamera I, II, III Projects** – on **Ravi River**, Chamba district (total ~1200 MW).
- **Nathpa Jhakri Hydroelectric Plant** – on **Sutlej River** (1500 MW) – one of India's largest hydro plants.

Uttarakhand

- **Tehri Dam Project** – on **Bhagirathi River** (2400 MW) – one of the tallest dams in Asia.
- **Dhauliganga Hydroelectric Project** – on **Dhauliganga River** (280 MW).
- **Maneri Bhali I & II** – on **Bhagirathi River** (304 MW).

Jammu & Kashmir

- **Salal Hydroelectric Project** – on **Chenab River** (690 MW).
- **Baglihar Hydroelectric Project** – on **Chenab River** (900 MW).
- **Dulhasti Project** – on **Chenab River** (390 MW).

Arunachal Pradesh

- **Subansiri Lower Project** – on **Subansiri River** (2000 MW, under construction).
- **Ranganadi Hydroelectric Project** – on **Ranganadi River** (405 MW).

Sikkim

- **Teesta Stage III** – on **Teesta River** (1200 MW).

- **Teesta Stage V** – on **Teesta River** (510 MW).

Assam

- **Kopili Hydroelectric Project** – on **Kopili River** (275 MW).

Jharkhand

- **Subarnarekha Hydroelectric Project** – on **Subarnarekha River** (130 MW).

Odisha

- **Hirakud Dam Project** – on **Mahanadi River** (307.5 MW).
- **Balimela Hydroelectric Project** – on **Sileru River** (360 MW).

West Bengal

- **Teesta Canal Fall Hydel Project** – on **Teesta River** (67.5 MW).

Maharashtra

- **Koyna Hydroelectric Project** – on **Koyna River** (1960 MW) – **largest in Maharashtra**.
- **Bhimashankar Project** – on **Bhima River** (12 MW, small).

Gujarat

- **Ukai Dam** – on **Tapi River** (305 MW).
- **Sardar Sarovar Dam** – on **Narmada River** (1450 MW).

Karnataka

- **Sharavathi Hydroelectric Project** – on **Sharavathi River** (1035 MW).
- **Almatti Dam Project** – on **Krishna River** (290 MW).
- **Varahi Hydroelectric Project** – on **Varahi River** (460 MW).

Kerala

- **Idukki Hydroelectric Project** – on **Periyar River** (780 MW).

- **Sabarigiri Hydroelectric Project** – on **Pamba River** (340 MW).

Tamil Nadu

- **Kundah Hydroelectric Project** – on **Bhavani River** (585 MW).
- **Mettur Dam (Stanley Reservoir)** – on **Cauvery River** (240 MW).

Andhra Pradesh / Telangana

- **Nagarjuna Sagar Dam** – on **Krishna River** (816 MW).
- **Srisailam Dam** – on **Krishna River** (1670 MW).

Classification of Turbines

According to type of energy at Inlet

a) Impulse Turbine - Pelton Wheel(Requires High Head and Low Rate of Flow)

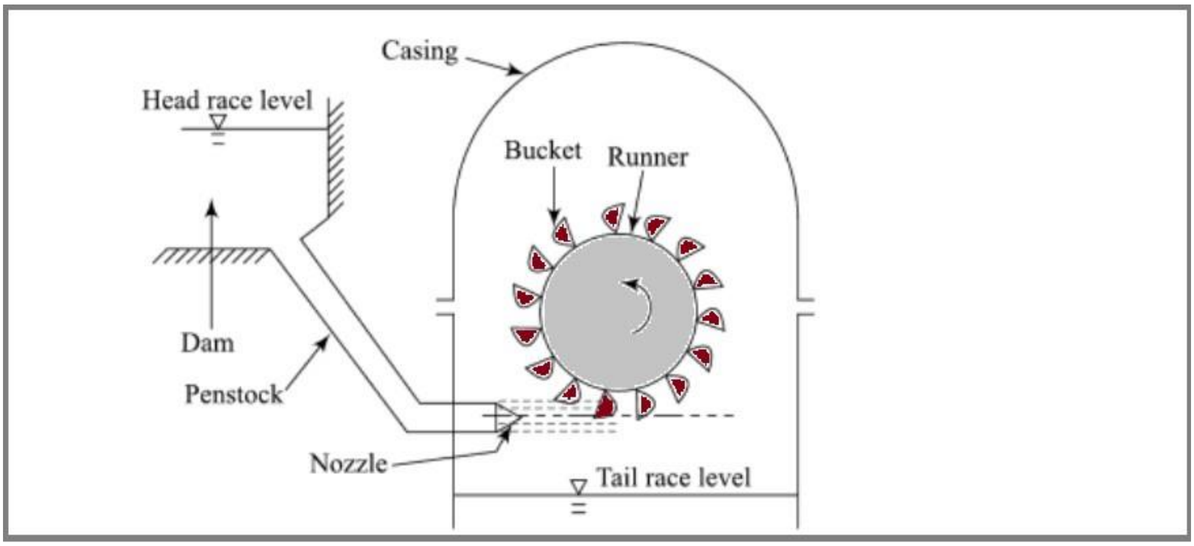
b) Reaction Turbine - Fancis, Kaplan(Requires Low Head and High Rate of Flow)

Pelton turbine

A Pelton turbine, also known as a Pelton wheel turbine, is an impulse turbine uniquely designed to convert the kinetic energy of water into mechanical energy.

The Pelton wheel turbine is developed by Lester Allan Pelton, who is an American Engineer.

The Pelton turbine operates efficiently in high-head,



Components of a Pelton Turbine

- **Nozzles:**

  These are stationary devices at the end of a penstock that convert the pressure head of the water into a high-velocity jet.

- **Runner and Buckets:**

A wheel, called the runner, is mounted on a shaft and has a series of double hemispherical buckets around its circumference. A central splitter in the bucket splits the water jet into two halves.

- **Casing:**

  A protective casing surrounds the runner to prevent splashing and guide the water to the tailrace after it has passed through the buckets.

- **Shaft:**
  The runner is mounted on a shaft that connects to a generator to produce electricity.

Working principle

1. Water is supplied from a high-head source (e.g., a dam) through a long pipe called a penstock.
2. The water flows through nozzles at the end of the penstock, which accelerates it into a high-speed jet.
3. This high-velocity jet strikes the buckets on the periphery of the runner.
4. The impact of the jet on the curved buckets transfers kinetic energy, causing the runner and the connected shaft to rotate.
5. As the water strikes the bucket, its direction is reversed, and it falls into the tailrace below the turbine.
6. A governing mechanism controls the water flow through the nozzles to match power demand and maintain a constant speed.
7. The rotation of the shaft drives a generator, which converts the mechanical energy into electrical energy.

Advantages:

The following adavnatages of Pelton Turbine are:

- The Pelton Turbine simple in design and also the construction is not complex.
- The water which is clean cannot cause very rapid wear in high heads.
- The overhaul and inspection are much easier than another turbine.
- The water hammer effect is not there.

- The overall efficiency is quite high as compared to reaction turbines.
- There is no requirement for the draft tube here.
- It can work on relatively less Q(discharge) of flow rate.
- In the Hydraulic Turbine, it is the most efficient turbine.
- The parts assemble of the Pelton turbine is very easy. No complexity here.
- The water striking and leaving the runner at atmospheric pressure only.
- This is a tangential flow turbine. It can move in axial flow or radial flow direction.

Disadvantages:

The following application of Pelton Wheel Turbine is:

- The Pelton Turbine wheel turbine is used in Hydro Power Plant where Less discharge and High Heads are required.
- This is used to get more velocity of the fluid for maximum power and efficiency [Because the turbine and wheel are designed in such a way that the water jet velocity is twice the rotating bucket velocity].
- It is also used to drive the generator and who is attached to the turbine shaft here the Mechanical energy gets converted into Electrical Energy.

Francis Turbine - Construction, Working Principle

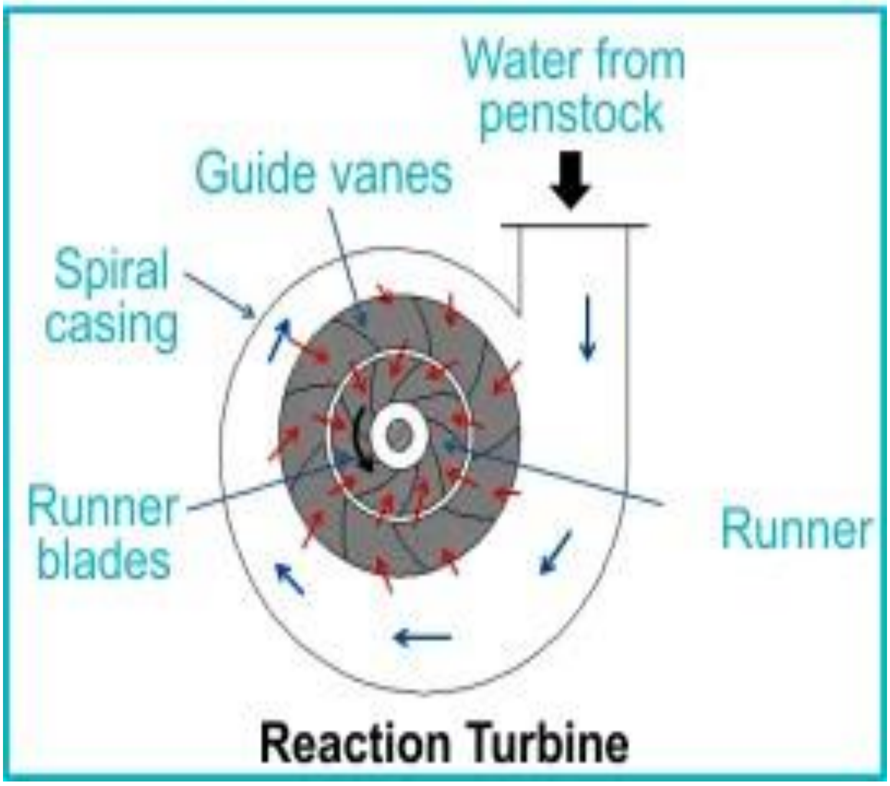
A Francis Turbine is a type of reaction turbine that works on both pressure energy and kinetic energy of water.

This turbine is often referred to as a mixed-flow reaction turbine because water enters radially and exits axially.

Francis Turbine is the most widely used turbine in hydropower plants around the world due to its high efficiency, reliability, and suitability for medium heads ranging between 40 meters and 600 meters.

The concept of merging impulse and reaction turbines was conceived by James B. Francis, an American civil engineer who designed the turbine with water entering and exiting the turbine axially.

Francis Turbine Main Parts



Spiral Casing

The spiral casing serves as the inlet for water into the turbine, allowing high-pressure water from the reservoir or dam to pass through. To ensure efficient striking of the turbine blades, the water's circular movement is controlled by gradually reducing the casing's diameter, maintaining uniform pressure and momentum for striking the runner blades effectively.

Stay Vanes

Stationary stay vanes and guide vanes work in tandem to guide the water flow toward the runner blades. Stay vanes prevent radial flow-induced swirling, improving the turbine's efficiency.

Guide Vanes

The adjustable guide vanes play a vital role in controlling the angle of water striking the turbine blades, optimizing efficiency. They also regulate the flow rate of water into the runner blades, allowing the turbine's power output to be adjusted based on the load.

Runner Blades

The design of the runner blades directly impacts the turbine's performance and efficiency. In a Francis turbine, the runner blades are divided into two parts: the lower half is shaped like small buckets, utilising impulse action for rotation, and the upper part utilising the reaction force of water flow. The combination of these forces facilitates the rotation of the runner.

Draft Tube

The draft tube is employed to address the pressure difference at the exit of the runner. As the pressure is generally lower than atmospheric pressure, the tube gradually increases in the area to discharge water from the turbine's exit to the tail race. This ensures smooth water flow and prevents direct discharge into the tail race.

Working Principle

The Francis Turbine working principle is based on the reaction principle, where water pressure energy and kinetic energy are converted into mechanical energy as water flows through the turbine.

1. Water Entry - High-pressure water from the penstock enters the spiral casing.
2. Flow Regulation - Guide vanes control the flow direction and quantity of water.
3. Energy Transfer - Water strikes the runner blades, transferring both pressure and kinetic energy.
4. Rotation of Runner - The force of water causes the runner to rotate, which rotates the shaft.
5. Exit through Draft Tube - Water exits axially through the draft tube, recovering pressure energy and reducing velocity losses.
6. Power Generation - The rotating shaft is connected to a generator that converts mechanical energy into electrical energy.

Advantages of Francis Turbine

The Francis Turbine efficiency is one of its strongest features. Some of the key advantages include:

- **High Efficiency -** Can achieve efficiencies up to 95%.
- **Versatile Head Range -** Works in medium-head power plants (40–600 m).
- **Stable Operation -** Provides smooth operation under varying loads.
- **Compact Design -** Requires less space compared to other turbines.
- **Mixed Flow -** Utilizes both radial and axial flow for maximum energy conversion.
- **Low Maintenance -** Rugged construction reduces maintenance needs.
- **Economic Feasibility -** Widely used in large hydroelectric projects.

Disadvantages of Francis Turbine

Despite its advantages, the Francis Turbine also has limitations:

- **Not Suitable for Very High Heads -** Works best in medium-head plants, unlike Pelton wheels.
- **Complex Construction -** They are difficult to manufacture compared to other turbines.
- **Cavitation Issues -** Can face cavitation under certain conditions, reducing lifespan.
- **Installation Cost -** Higher initial cost than smaller turbines.
- **Skilled Maintenance -** Requires technical expertise for efficient maintenance.

Application of Francis Turbine

The Francis Turbine applications are vast, particularly in hydroelectric power generation:

- **Hydropower Plants -** Primary use in medium-head hydroelectric stations.
- **Irrigation Projects -** Used where water regulation is necessary.
- **Industrial Use -** Power generation in industries requiring a continuous energy supply.
- **Pumped Storage Plants -** Used for both power generation and water pumping.

KAPLAN TURBINE

A Kaplan turbine is specifically a reaction turbine or a type of propeller hydro turbine used in hydroelectric plants.

In this turbine, the water flows both in & exist from the turbine in an axial direction. This turbine works at a high water flow rate & low head with the highest efficiency.

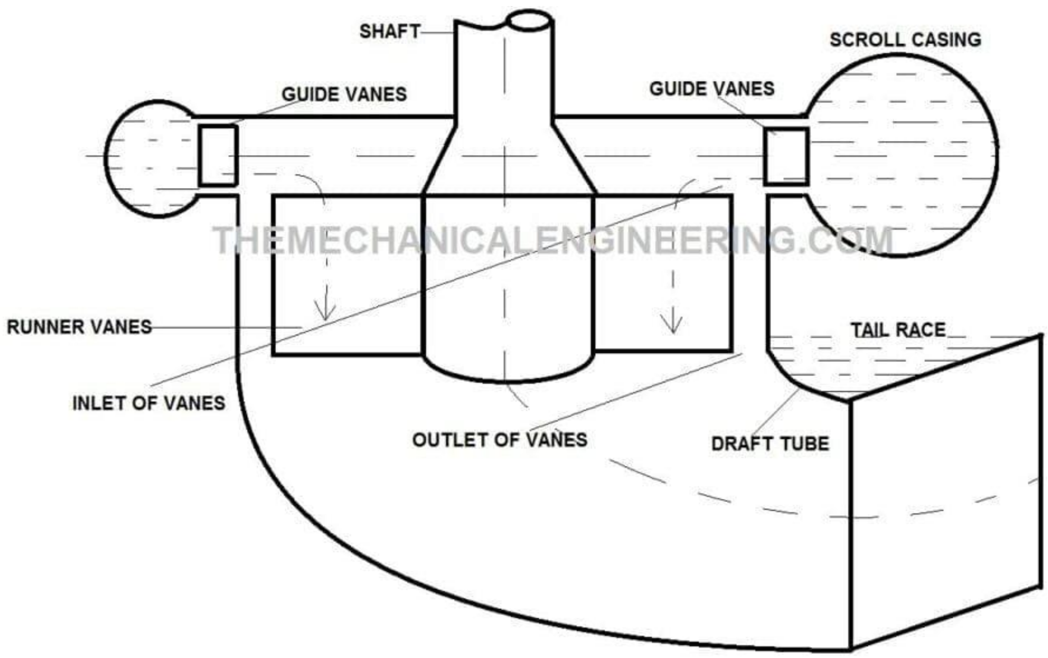
The main feature of the Kaplan turbine is that the blades in the turbine will change their location when required to maintain maximum efficiency in different water supply conditions.

When water flows through this turbine then it loses its pressure, so this is known as a reaction turbine.

The working principle of a Kaplan Turbine **mainly depends on the axial flow reaction principle because, in axial flow types turbines, the water supplies throughout the runner along the direction which is parallel to the rotation axis of the runner.**

In the turbine, the water at the inlet possesses both pressure & kinetic energy for effective blades rotation within a hydro-power station.

Construction



These turbines are designed with several rotor blades which are connected to the central shaft of the turbine directly.

Runner Blades

The runner blades are essential components in this turbine which looks similar to a propeller.

As compared to other axial flow turbines, these turbines don't have plane blades but they are twisted so that the water flows at the inlet to exit. Once the water hits these blades, then they start rotating which further turns the shaft.

Hub

The shaft of this turbine is vertical and the shaft's lower end is made larger which is known as a hub. The blades of the turbine are located on the hub to control the revolution of blades.

Shaft

In the turbine, one end of the shaft is simply connected to the runner of the turbine, whereas the other end is connected to the generator coil. When the runner turns because of the rotation of the blades, then the shaft also rotates, further, this rotation can be transmitted to the generator coil.

Once the generator coil turns then it generates electricity. The turbine shaft should include heat-resistant properties because it rotates at a high speed which ranges from 1800rpm to 3600 rpm. The material used in the turbine shaft is structural steel.

Guide Vane

The guide vane in the turbine is a regulating component that turns ON & OFF based on the power requirement.

Guide vanes turn at a precise angle to control the flow of water. If the requirement of power is more, then it opens more so that it allows a large amount of water to hit the rotor blades.

When the requirements of power decrease, then it opens less so that it allows less amount of water to hit the blades. The turbine efficiency can be increased through guide vanes otherwise it cannot function efficiently.

Runner

The runner or impeller in the turbine plays an essential role. It is a rotating component that helps in generating electricity.

Mechanism of Blade Control

The blade of the turbine has a movable axis at the connection point. The blade control mechanism controls the attack angle as the water hits the blade, caused by the movable blade connection.

Scroll Casing or Volute Casing

The whole turbine can be surrounded by a scroll casing so that it decreases the cross-sectional area. Initially, the water supplies from the penstock to the volute casing; then, it supplies into the area of the guide vane.

Draft Tube

The accessible force at the exit of the turbine's runner is usually smaller as compared to the atmospheric force. Thus, the exit water cannot be released directly to the tailrace. A tube can slowly enhance the area & this is used in discharging water from the Kaplan turbine to the tailrace.

Kaplan Turbine Working

The water flowing from the pen-stock will enter into the scroll casing of the turbine where scroll casing is made in such a way without losing the flow pressure.

The guide vanes in the turbine will push the water into the runner blades. The vanes are changeable according to the necessity of the flow rate of water.

The water supply takes a 90-degree twist so that the water direction is axial toward runner blades.

When the water hits runner blades then it starts rotating because of the reaction force of the water supply. These blades have twisted through their length to include optimum angle of attack always for all cross-sections of blades to attain greater efficiency. The water enters from the runner blades to the draft tube wherever its kinetic energy & force energy is reduced.

Once kinetic energy is changed into pressure energy then water pressure can be increased. The turbine rotation can be used to turn the generator's shaft for the generation of electricity.

Advantages

The **advantages of the Kaplan turbine** include the following.

- Kaplan turbine works at low head.
- It includes fewer blades.
- It occupies less space.

- It includes flexible runner vanes.
- Simple construction.
- Its efficiency is very high as compared to other turbines.
- Its size is not large.
- Applicable for high discharge-based applications.

Disadvantages

The **disadvantages of the Kaplan turbine** include the following.

- Cavitation can be occurred because of the pressure drop within the draft tube.
- Requires high flow rate.
- Manufacturing and installation cost is high.
- The material used for runner blades is stainless steel which may decrease the cavitation problem to some level.

Applications

The **applications of the Kaplan turbine** include the following.

- These turbines are used for the production of electrical power.
- These turbines work very efficiently at high flow rates & low heads.
- These turbines are used where the head is low & discharge is high.

Difference between Pelton, Francis and Kaplan turbine

Turbine Type	**Pelton Turbine**	**Francis Turbine**	**Kaplan Turbine**
Operating Principle	**Impulse Turbine - Water jets**	**Reaction Turbine - Water**	**Reaction Turbine - Water**
	strike buckets	**guided by fixed and moving**	**guided by adjustable guide**
	to generate impulse.	**vanes.**	**vanes.**
Head Range	**High Head Applications**	**Medium Head Applications**	**Low to Medium Head**
	(usually above 300 meters)	**(typically between 10 to 300**	**Applications (typically**
		meters)	**below 30 meters)**
Efficiency	**High**	**Medium to High**	**High**
Flow Control	**Not easily adjustable**	**Fixed guide vanes,**	**Adjustable guide vanes**

		adjustable	
		runner blades.	
Application	Suitable for high head	Widely used for medium head	Ideal for low to medium head
	and low flow rates.	and moderate flow rates.	and high flow rates.
Size	Typically larger in size	Moderate size	Smaller size
Blade Design	Buckets with a splitter	Radial vanes and curved	Adjustable blades with twist
	arrangement for efficient	blades for efficient	along their length to
	energy conversion.	energy conversion.	maintain optimal angles.
Advantages	High efficiency in high head	Versatile and suitable for	Efficient at low head and
	conditions, suitable for remote	a wide range of head and flow	high flow rates, compact and
	locations with limited water	conditions, good efficiency	easy to install, adaptable
	resources.	across varying loads.	to varying water conditions.
Disadvantages	Limited application in low	Higher complexity and	Sensitive to water quality,
	head scenarios, higher capital	maintenance requirements	potential cavitation issues,
	cost compared to some other	compared to Pelton turbines,	and not as effective in high
	turbine types.	may not operate efficiently	head conditions.
		at very low head conditions.	

Connected Load

Connected Load is the **sum of the rated power (in watts or kW)** of all electrical appliances, machines, or equipment that are connected to a power supply system **whether they are ON or OFF**.

Definition

Connected load is the total of all nameplate ratings of electrical equipment connected to the system.

It represents the **maximum possible load** the consumer *could* draw if every appliance operates simultaneously.

Here is a **simple and clear explanation** of **Connected Load**, suitable for class notes and exams.

Formula

Connected Load=∑(Rated Power of all connected equipment)\text{Connected Load} = \sum (\text{Rated Power of all connected equipment})Connected Load=∑(Rated Power of all connected equipment)

Units: **W, kW, or MW**

Example

A household has:

- 4 LED lights × 10 W = 40 W
- 2 Fans × 60 W = 120 W
- 1 TV × 150 W = 150 W
- 1 Refrigerator × 200 W = 200 W

Connected Load = 40 + 120 + 150 + 200
= **510 W ≈ 0.51 kW**

Even if all of them are not running at the same time, they are included in connected load.

Firm Power

Firm Power is the **amount of power that a generating station or utility guarantees to supply continuously under all normal operating conditions**.

It is the **minimum assured power** available from a plant or an interconnected system **at any time**, regardless of variations in load, weather, or breakdowns.

Examples

1. A thermal power plant commits **100 MW firm power** to the grid—this must be supplied at all times.
2. In a hydro-thermal system, hydro plant may guarantee **30 MW firm power**, even in dry season.
3. Solar or wind plants usually **cannot** supply firm power without storage.

Why Firm Power is Important?

- Helps maintain **grid stability**
- Ensures **reliable supply** to industries and households
- Allows proper **planning of reserves and generation**
- Critical for **contracts** between electricity producers and consumers

Cold Reserve

Cold Reserve is the **standby generating capacity** in a power system that is **kept shut down (not running)** but can be **brought into operation when required**, usually within several **hours**.

It is used during:

- Unexpected rise in load
- Failure of a generating unit
- Planned maintenance of other stations

Example

- A 50 MW thermal unit kept completely shut down, but ready to start in **4–6 hours** during peak demand or a major generator outage → this is **Cold Reserve**.

Hot Reserve

Hot Reserve is the generating capacity that is **kept running at operating temperature** but **not connected to the load**.
It can be **brought into service quickly**, usually within **a few minutes**, when extra power is needed.

It acts as a **standby unit** to improve system reliability.

Key Features

- The unit is **running but not supplying power**.
- Can take load within **minutes**.
- Faster response than cold reserve.
- Used during:
  - Sudden increase in load
  - Failure of a running generator
  - Short-term emergencies
- Higher operating cost than cold reserve (because it stays warm and consumes auxiliaries).

Spinning Reserve

Spinning Reserve is the extra generating capacity that is already running (spinning) and connected to the grid, but not fully loaded.

It can supply power immediately (within seconds) to handle sudden load increases or generator failures.

Key Features

- Generator is **ON, synchronized to the grid**, and rotating at rated speed.
- Not carrying full load → some capacity kept in reserve.
- Can respond **instantly** (few seconds).
- Provides **highest reliability** among all reserves.
- Most expensive reserve due to continuous operation and fuel consumption.

Why Spinning Reserve is Needed?

- Sudden increase in load
- Tripping of a generator
- Stabilizing system frequency
- Emergency power support

Example

A 100 MW generator running at **70 MW**, leaving **30 MW** available instantly → this **30 MW** is the spinning reserve.

Comparison Table (Quick Memory Chart)

Feature	Spinning Reserve	Hot Reserve	Cold Reserve
Condition	Running + synchronized	Running (not synchronized)	Shut down
Response	Seconds	Minutes	Hours

Cost	High	Medium	Low
Reliability	Very High	High	Moderate
Use	Immediate backup	Quick backup	Long-term standby

Base Load Plant

A **Base Load Plant** is a power station that is designed to supply the **continuous, constant portion of the load** on a power system throughout the day and year.

It operates **24 hours a day** and carries the **minimum (base) demand** of the system.

Characteristics of a Base Load Plant

- Operates **continuously** at or near full load
- **High load factor**
- **Low running (operating) cost**
- **High capital cost**, but economical in long-term operation
- **Slow to start**, but very reliable
- Supplies the part of load that **does not change** with time

Types of Base Load Plants

1. **Thermal Power Plants (Coal-fired)**
2. **Nuclear Power Plants**
3. **Large Hydro Plants (when water is available)**
4. **Combined Cycle Gas Turbine Plants** (in some regions)

Peak Load Plants

Peak Load Plants are power stations that operate **only during periods of high demand** (peak hours).
They supply the **extra load** above the base load in the power system.

Peak load generally occurs in:

- Morning hours
- Evening hours
- Seasonal peaks (summer/winter)

These plants **do not run continuously**.

Characteristics of Peak Load Plants

- **Quick start-up and shutdown**
- **High running cost**
- Operate only for **a few hours**
- Lower efficiency compared to base load plants
- Low capital cost (usually)
- Handle load fluctuations quickly

Types of Peak Load Plants

1. **Gas Turbine Power Plants**
   - Start in minutes
   - Used widely for peak demand
2. **Diesel Engine Power Plants**
   - Rapid start
   - Suitable for small loads
3. **Pumped Storage Hydro Plants**
   - Extremely fast response
   - Used for very sharp peaks
4. **Battery Energy Storage Systems (Modern)**
   - Instant response

Peak Load vs Base Load Plants

Feature	Peak Load Plant	Base Load Plant
Operating time	Few hours	24 hours
Running cost	High	Low
Capital cost	Low/Moderate	High
Start-up time	Very fast	Slow
Examples	Gas turbine, diesel, pumped hydro	Coal, nuclear, CCGT
Load factor	Low	High

Load Curve

A **Load Curve** is a graph that shows how the **power demand (load)** on a power system varies with **time**.

- **X-axis:** Time (hours, days, months)
- **Y-axis:** Load (kW, MW)

It helps engineers understand how demand changes throughout the day or year.

Types of Load Curves

1. Daily Load Curve

- Shows variation of load during **24 hours**.
- Used for short-term planning (generation scheduling).

2. Monthly Load Curve

- Shows average daily load for each day of a month.

3. Yearly Load Curve

- Shows load pattern for the whole year.

4. Load Duration Curve (LDC)

- A rearranged load curve in **descending order** of demand.
- Useful for planning base load and peak load plants.

Uses of Load Curves

- Determines **maximum demand**
- Helps calculate:
  - **Load factor**
  - **Plant capacity factor**
  - **Utilization factor**
- Helps in deciding:
  - Size and number of generating units
  - Base load and peak load plant requirements
- Helps in tariff planning

Load Duration Curve (LDC)

A **Load Duration Curve** is a graph obtained by **rearranging the load curve (load vs time)** in **descending order of load**, without regard to the time sequence.

It shows **how long (hours)** a particular load level is demanded in a system.

How It Is Made

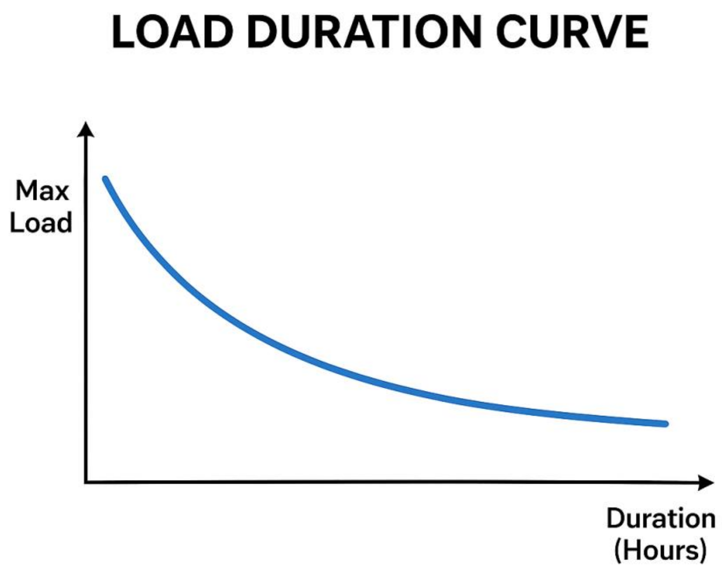
1. Take the **daily/weekly/yearly load curve**.
2. Arrange the load values from **highest to lowest**.
3. Plot:
   - **X-axis:** Duration (hours)
   - **Y-axis:** Load (kW or MW)

Importance of Load Duration Curve

- Helps in **deciding capacity of base load and peak load plants**
- Used for **economic scheduling** of power plants
- Helps determine:
  - **Load factor**
  - **Capacity factor**
  - **Energy generated** (area under curve)
- Very important for **generation planning**

Difference: Load Curve vs Load Duration Curve

Load Curve	Load Duration Curve
Load vs time	Load vs hours
Time order is preserved	Time order is rearranged (descending load)
Used for daily scheduling	Used for plant planning & economics
Shows peak and valley directly	Shows duration for which load stays high



Integrated Duration Curve (IDC)

The **Integrated Duration Curve** is the graph obtained by plotting the **cumulative (integrated) energy** corresponding to the Load Duration Curve (LDC).

It shows **total energy consumed** as load decreases from maximum to minimum.

In simple words:

IDC = Integral (area) of Load Duration Curve plotted cumulatively

How It Is Constructed

1. Start with the **Load Duration Curve (LDC)**.
2. Calculate the **area under the curve** from the left (highest load) to any point.
3. Plot **cumulative energy (kWh or MWh)** on the Y-axis.
4. X-axis remains **time (hours)**.

Purpose of Integrated Duration Curve

- Shows **total energy generated/consumed** over time
- Used to determine:
  - **Energy supplied by base load plants**
  - **Energy supplied by peak load plants**
  - **Plant scheduling and energy planning**
- Helps utilities estimate:
  - Optimal mix of **base load**, **intermediate**, and **peak load** plants
  - Required **fuel and water resources**
  - Long-term **capacity planning**

Simple Example (conceptual)

If the LDC shows:

- 10 MW for 4 hours
- 8 MW for 6 hours
- 5 MW for 8 hours

IDC cumulative energy values will be:

- After 4 hours → 10 × 4 = **40 MWh**
- After 10 hours → 40 + (8 × 6) = **88 MWh**
- After 18 hours → 88 + (5 × 8) = **128 MWh**

Plotting these cumulative values gives the **Integrated Duration Curve**.

Cost of generation

Average Demand

Average Demand is the **average load** on a power system over a specified period of time.

It represents the **mean value of the load** and is used to calculate energy consumption and load factor.

Average Demand=Time Period (hours)/Total Energy (kWh)

Where:

- **Total Energy** = Area under the load curve
- **Time period** = Number of hours (day, month, or year)

Example

If a system consumes 24,000 kWh in one day (24 hours):

Average Demand=24000/24=1000 kW

Maximum Demand

Maximum Demand is the **greatest (highest) load** on a power station or consumer during a specific period of time.

It indicates the **peak power requirement** of the system.

Definition

Maximum Demand:
The highest value of load (kW or MW) recorded on the power system during a given period such as a day, month, or year.

Example

A consumer's load varies during the day.
The highest value observed = **850 kW**.

So,

Maximum Demand=850 kW

Difference Between Maximum Demand and Average Demand

Factor	Maximum Demand	Average Demand
Meaning	Highest load	Mean load
Value	Always greater	Always lower

Importance	Plant rating	Load factor
Unit	kW/MW	kW/MW

Demand Factor

Demand Factor is the ratio of the **maximum demand** of a system (or consumer) to the **connected load**.

It shows how much of the connected load is actually used at the peak time.

Formula

Demand Factor=Maximum Demand/Connected Load

Example

Connected load = 100 kW
Maximum demand = 60 kW

Demand Factor=60/100=0.6

So the consumer uses **60% of the connected load** at peak.

Plant Capacity Factor (PCF)

Plant Capacity Factor is the ratio of the **actual energy generated** by a power plant in a given period to the **maximum possible energy** it could have produced if it ran at full capacity for the entire period.

Formula

Plant Capacity Factor=Actual Energy Generated/(Plant Capacity×Time)

Where:

- **Actual Energy Generated** → in kWh or MWh
- **Plant Capacity** → rated power in kW or MW
- **Time** → hours in the period (e.g., 24 hrs/day, 8760 hrs/year)

Example

A power plant of **100 MW** operates for a year and generates **500 million kWh**.

Maximum possible annual energy:

$100 \times 8760 = 876{,}000$ MWh

Capacity Factor:

$PCF = 500{,}000/876{,}000 = 0.57 = 57\%$

Plant Use Factor

Plant Use Factor indicates how efficiently a power plant is used **during the actual hours it is in operation**.

It is the ratio of:

Plant Use Factor=Actual Energy Generated/(Plant Capacity×Hours Plant Actually Operate)

Difference from Capacity Factor

Plant Capacity Factor	Plant Use Factor
Uses **total hours** in the period	Uses **operating hours only**
Indicates overall yearly efficiency	Indicates efficiency during running condition
Always lower	Usually higher

Example

A 100 MW plant ran for **3000 hours** in a year and generated **240 million kWh**.

Use Factor$=240{,}000/(100 \times 3000)=0.8=80\%$

So, when the plant was running, it operated at **80% of its rated load**.

Diversity Factor

Diversity Factor is the ratio of the **sum of individual maximum demands** of all consumers to the **maximum demand of the whole system**.

It shows that not all consumers reach their maximum demand at the same time.

Formula

Diversity Factor=Sum of Individual Maximum Demands/Maximum Demand of the System

Example

Suppose three consumers have:

- Max demand of consumer 1 = 50 kW
- Max demand of consumer 2 = 40 kW
- Max demand of consumer 3 = 30 kW
- Max demand of the system = 90 kW

Then,

DF=50+40+30/90=120/90=1.33

Load Factor

Load Factor is the ratio of the **average load** to the **maximum load (maximum demand)** over a given period.

It indicates how efficiently the power system or consumer is using the maximum demand.

Formula

Load Factor=Average Load/Maximum Demand

OR

Load Factor=Total Energy (kWh)/(Maximum Demand×Time (hours))

Example

A consumer has:

- Maximum demand = 100 kW
- Daily energy consumption = 1800 kWh

Average load:

Average Load=1800/24=75 kW

Load Factor:

LF=75/100=0.75=75%

Plant Load Factor (PLF)

Plant Load Factor is the ratio of the **actual energy generated** by a power plant to the **maximum possible energy** that could have been generated if the plant operated at its **rated capacity** for the entire period.

It indicates **how effectively the plant capacity is utilized**.

Formula

PLF=Actual Energy Generated/(Rated Capacity×Time)

Where:

- **Actual Energy Generated** → in kWh or MWh
- **Rated Capacity** → plant's maximum output (kW or MW)
- **Time** → total hours in the period

Example

A plant of **200 MW** operates for 1 year and generates **900 million kWh**.

Maximum possible energy:

$200 \times 8760 = 1{,}752{,}000$ MWh

PLF:

PLF=900,0001,752,000=0.514=51.4%

Difference Between Plant Load Factor and Plant Capacity Factor

Plant Load Factor	Plant Capacity Factor
Uses **maximum demand actually on plant**	Uses **rated capacity**
Indicates utilization based on actual load imposed	Indicates theoretical maximum capability
Always ≤ Capacity Factor	Always ≥ Load Factor

NUMERICAL 1: Load Factor, Average Demand

A consumer uses **4800 kWh** of energy in a day.
Its **maximum demand** is **300 kW**.

Find:

1. Average demand
2. Load factor

NUMERICAL 2: Plant Load Factor (PLF)

A power plant rated **150 MW** generates **700 million kWh** annually.

Find PLF.

NUMERICAL 4: Plant Use Factor

A 100 MW plant runs for **3000 hours** in a year and generates **210 million kWh**.

Find Use Factor.

NUMERICAL 5: Maximum Demand and Demand Factor

A consumer has a connected load of **500 kW** and demand factor of **0.65**.

Find maximum demand.

NUMERICAL 6: Diversity Factor

Three consumers have maximum demands:

- 40 kW
- 50 kW
- 30 kW

The maximum demand on the station is **95 kW**.

NUMERICAL 7: Average Load from Load Factor

A system has:

- Maximum demand = 1000 kW
- Load Factor = 0.7

Find average load.

ASSIGNMENT

1.A power plant has a **rated capacity of 250 MW**.
During one year, it generates **900 million kWh** of electrical energy.

Find the Plant Load Factor (PLF).

ANS-41.1%

2. Three consumers have maximum demands:

- 20 kW
- 15 kW
- 25 kW

The maximum demand on the station is **45 kW**.

Find Diversity Factor.

ANS-1.33

CHOICE OF SIZE AND NUMBER OF GENERATOR UNITS

When designing a power station, engineers must decide:

✔ **How many generator units to install**

✔ **What should be the size (capacity) of each unit**

This decision affects **cost**, **reliability**, **efficiency**, and **future expansion** of the plant.

FACTORS AFFECTING THE CHOICE

1 Load Demand Pattern

- If the demand varies widely → use **different sizes of units**.
- Base load met by **larger units**.
- Peak load handled by **smaller units**.

2.Economy of Scale

- Larger units give:
    - Lower cost per MW
    - Better efficiency
    - Less fuel consumption
      → Therefore, larger units are **economically preferred**.

But **too large** units increase risk of large outage.

3. Reliability of Supply

- If the plant has **many small units**, failure of one unit does not affect supply much.
- If the plant has **one large unit**, failure causes a large power loss.

So usually:

❗ **"NOT one huge unit, but multiple medium/large units."**

4. Maintenance Requirements

- Units must be shut down periodically for overhaul.
- Having multiple units allows:
  - Easy scheduling
  - No full shutdown of plant

5. Future Expansion

- If future increase in demand is expected:
  - Install few large units now
  - Keep space for additional units later

Type of Power Plant

✔ Thermal + Nuclear

- Usually use **large units (200 MW to 1000 MW)**
- Because fuel cost depends on efficiency → larger units preferred.

✔ Hydro

- Size depends on **water availability** and **head**.

GUIDELINES FOR UNIT SELECTION

Total capacity usually divided into 2–6 units.

Common choices:

- 2 units of 250 MW
- 4 units of 120 MW
- 3 units of 200 MW

✔ Combination example:

- Large units for **base load**
- Small units for **peak load**

ADVANTAGES OF USING MULTIPLE UNITS

✔ High reliability

✔ Easy maintenance

✔ **Flexibility in operation**

✔ **Ability to meet varying load**

✔ **Partial load operation better controlled**

COMBINED OPERATION OF POWER STATIONS – CAUSES / ADVANTAGES

Combined operation means **operating different types of power stations together** in an interconnected system (thermal, hydro, nuclear, gas, diesel, etc.) to supply electrical load more efficiently.

This approach is used because it gives many benefits.

MAIN CAUSES / REASONS FOR COMBINED OPERATION

1 Better Use of Base Load and Peak Load Plants

- Base load supplied by **cheap, efficient plants** (thermal, nuclear).
- Peak load supplied by **quick-start plants** (hydro, gas).

This gives **minimum cost per kWh**.

Higher Reliability of Supply

If one plant fails, others take over.
This avoids **blackouts** and increases **system security**.

Economy in Operation

Combined operation reduces:

- Running cost
- Fuel consumption
- Operating cost
- Reserve requirement

Overall cost of electricity becomes **cheaper**.

Better Load Factor of Plants

Different stations share the load → every plant operates closer to its **best efficiency**.

Load factor of the system improves significantly.

Reduced Need for Large Standby Units

In a combined system, every station need not have its own reserve.
A **common spinning reserve** is enough.

This reduces capital cost.

Optimum Use of Natural Resources

- Water used efficiently in hydro stations
- Fuel saved in thermal stations
- Gas/diesel used only during peaks

Prevents resource wastage.

Improved System Stability & Frequency Control

Interconnected operation allows:

- Stable frequency
- Balanced load sharing
- Better voltage control