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Hydro-Electric Power Plant
Topic No. 3

Hydro-Electric Power Plant

Marks: 18   Hours: 08

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1. Definition of Hydro-Electric Power Plant:

A generating station which utilizes the potential energy of water at a high level for the generation of electrical energy is known as a hydro-electric power station.

एक असे निर्मिती केंद्र जे पाण्याच्या स्थिर उर्जेचे रुपांतर वीज निर्मिती साही करते त्यास जलविद्युत वीज निर्मिती केंद्र असे म्हणतात.

2. Basic Principal of Hydro-Electric Power Plant.

\[
\text{PE} \leftrightarrow \text{KE} \leftrightarrow \text{ME} \leftrightarrow \text{EE}
\]

(Potential Energy ↔ Kinetic Energy ↔ Mechanical Energy ↔ Electrical Energy)

We know that, water is stored in dam by using rain water. This stored water contains Potential energy, due to height or head of dam. When this water is flow towards turbine, at that time the Kinetic Energy is Converted into Mechanical Energy. The turbine or prime mover is mechanically coupled with generator. Whenever turbine starts to rotate with the help of high pressure water, automatically generator starts to rotate & it produced an electrical energy.
3. List of Hydro-Electric Power Plants in Maharashtra & India with their installed Capacities:

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>State</th>
<th>Place</th>
<th>No. of Units</th>
<th>Total Installed Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Maharashtra</td>
<td>Koynanagar</td>
<td>Stage I 4 x 70&lt;br&gt;Stage II 4 x 80&lt;br&gt;Stage III 4 x 80&lt;br&gt;Stage IV 4 x 250&lt;br&gt;KDPH 2 x 18</td>
<td>1956 MW</td>
</tr>
<tr>
<td>2</td>
<td>Maharashtra</td>
<td>Tillari</td>
<td>1 x 66</td>
<td>66 MW</td>
</tr>
<tr>
<td>3</td>
<td>Maharashtra</td>
<td>Raadhanagari</td>
<td>4 x 1.2</td>
<td>4.8 MW</td>
</tr>
<tr>
<td>4</td>
<td>Maharashtra</td>
<td>Warna</td>
<td>2 x 8</td>
<td>16 MW</td>
</tr>
<tr>
<td>5</td>
<td>Maharashtra</td>
<td>Panshet</td>
<td>1 x 8</td>
<td>8 MW</td>
</tr>
<tr>
<td>6</td>
<td>Maharashtra</td>
<td>Dudhganga</td>
<td>2 x 12</td>
<td>24 MW</td>
</tr>
<tr>
<td>7</td>
<td>Maharashtra</td>
<td>Ujani</td>
<td>1 x 12</td>
<td>12 MW</td>
</tr>
<tr>
<td>8</td>
<td>Maharashtra</td>
<td>Pawana</td>
<td>1 x 10</td>
<td>10 MW</td>
</tr>
<tr>
<td>9</td>
<td>Maharashtra</td>
<td>Veer</td>
<td>2 x 4.5</td>
<td>9 MW</td>
</tr>
<tr>
<td>10</td>
<td>Andhra Pradesh</td>
<td>Upper Sileru</td>
<td>2 x 60</td>
<td>720 MW</td>
</tr>
<tr>
<td>11</td>
<td>Andhra Pradesh</td>
<td>Lower Sileru</td>
<td>6 x 100</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Andhra Pradesh</td>
<td>Shri Sailam</td>
<td>4 x 110&lt;br&gt;7 x 110</td>
<td>1210 MW</td>
</tr>
<tr>
<td>13</td>
<td>Kerala</td>
<td>Sabarigiri</td>
<td>6 x 50</td>
<td>300 MW</td>
</tr>
<tr>
<td>14</td>
<td>Tamilnadu</td>
<td>Kundha 4 Stages&lt;br&gt;Chennai</td>
<td>2 x 90&lt;br&gt;1 x 245&lt;br&gt;1 x 119</td>
<td>535 MW</td>
</tr>
<tr>
<td>15</td>
<td>Karnataka</td>
<td>Mysore Sharavthi</td>
<td>1 x 178.2&lt;br&gt;1 x 534.6&lt;br&gt;1 x 178.2</td>
<td>891 MW</td>
</tr>
<tr>
<td>16</td>
<td>Punjab</td>
<td>Bhakra-Nangal</td>
<td>5 x 90&lt;br&gt;2 x 24&lt;br&gt;2 x 29&lt;br&gt;1 x 24&lt;br&gt;4 x 120</td>
<td>1084 MW</td>
</tr>
</tbody>
</table>

Mr. N. S. Patil
4. Selection of Site for Hydro-Electric Power Plant:

1. Quantity of Water Required: पुरेसे पाणी
As we know that, the hydro-electric power plant totally runs on water, so that ample quantity of water is continuously available throughout the year.

2. Hilly Area Required:
For storage of ample quantity of water, both side of dam hilly area or strong mountains required for storage of water.

3. Civil Work:
It should have strong foundation or the cost of foundation should be as low as possible.

4. Large Catchment Area:
Large catchment area required, so that the water in it should never fall below the minimum level.

5. Transportation Facility:
For Workers & Civil Material required better transportation facility.

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6. Near to Load Center:
To reduce cost of Transmission & Distribution the plant should be located near to load center.

7. Availability of Material:
At the time of erecting the dam & power house a huge amount of civil material is easily available without any shortage.

8. Area free from earthquake:
Ample quantity of water storage in dam of hydro-electric power plant because of earthquake chances to flood occurs; to avoid this area should be free from earthquake.

9. Accommodation Facility:
For operational & maintenance staff better facility of accommodation is provided at reasonable rate.

10. Future Expansion:
For increasing per MW Capacity of plant the space is available for future expansion.
5. Definition of the terms & their significance in capacity of power plant: Hydrology, Surface runoff, evaporation & precipitation.

![](Image)

**Fig: Hydrological Cycle**

**a. Hydrology:**

It is the system which is related with water is known as hydrology. The hydrology related with head of water, flow of quantity of water, mass of water. The above data is useful for to utilize to decide the installed capacity of hydro-electric power plant.

**b. Surface Run-off:**

It is the portion of precipitation which makes its way towards streams, lakes or oceans. Run-off can be possible only when the rate of precipitation exceeds the rate at which water infiltrates into soil. Also the losses due to evaporation have been deducted.
Where, \( R = P - E \)
\[ R = \text{Run-off (वाहणारे पाणी)} \]

\[ P = \text{Precipitation पर्जन्य} \]
\[ E = \text{Evaporation वाष्पीभवन} \]

c. **Evaporation:**

It is the transfer of water from liquid to vapour state. द्रव पाण्याचे स्वप्नात वाफिल होणे.

d. **Precipitation:**

It includes all types of water falls from atmosphere to earth surface. It is of two types: यामध्ये पाणी पडूनचे सर्व प्रकार पृष्ठीवर पृष्ठभाग वातावरण येते.

1. Liquid Precipitation (Rainfall)
2. Solid Precipitation (Snow, Hail)

e. **Significance of this on capacity of power plant:**

1. The quantity of water is available to store in dam.
2. To know the head (height) of water.
3. To know the quantity of water available for per sec. or per hour.
4. It helps to determine the power in kW.
5. To know the installed capacity of the power plant.
6. Schematic arrangement of Hydro-Electric Power Plant:

Fig: Hydro-Electric Power Plant
7 Function of Different Components used in Hydro-Electric Power Plant:

Fig: Shows all Parts of Hydro-Electric Power Plant (use only for understanding)

1. Catchment Area: धरणाचे पाणलोट क्षेत्र

In hydro-electric power plant collect the rain water through surrounding hilly area, the surrounding all water collect & stored area to those place is known as catchment area.

जल विद्युत निर्मिती केंद्र हे पूर्णपणे पावसाच्या पाण्याच्या अवलंबून असते त्यामुळे पाणलोट क्षेत्र जेवढे मोठे तेवढ्या जास्त मुंबलक प्रमाणात आपण पाणी साठवू शकतो.
2. **Reservoir:** *(Shown in above figure)*

The function of reservoir is to store the water near dam; this water is useful to drive the water turbines. The reservoir is useful to provide a head of stored water.

याचा उपयोग धरणाजवळ मुबलक प्रमाणात पाणी साठ करण्यासाठी होतो. या मुळे साठवलेल्या पाण्याला दाब तयार होते. या दाबाचा उपयोग करून आपण पाणी वीज निर्मिती केंद्रांकडे सोडतो.

3. **Track Rack:**

![Track Rack](image)

*Fig: Track Rack*

It is used in hydro-electric power plant to filter the water before it flows towards turbine. The unwanted impurities (e.g. fish, plastics etc.) present in the stored water are avoided to flow towards turbine.

धरण मध्ये साठवलेले पाणी हे शुद्ध नसते, हे पाणी असेच जर टरबाइन कडे सोडले असता ते नादुस्त किवा ब्लोक होय शकते त्यामुळे पाणी शुद्ध करण्यासाठी हे उपकरण वापरतात.

4. **Head-Race Level:** *(Shown in Schematic arrangement of HPP)*

The water surface in the reservoir up to the dam is known as head-race level. जमिनीपासून ते उपलब्ध असलेले पाण्याची पातळी म्हणजे हेड रेस लेवल होय.

5. **Dam:**

The dam is used in hydro-electric power plant to store the water. Whenever the dam stored the water, it provides suitable head to this stored water. This stored water is useful throughout the year to run the hydro-electric power plant. Dam is made up of cement, concrete & sand materials. If higher rainfall occurs then door of dams are opened to flow of water.
6. **Spill Way:**

The excess water from dam is discharged through spillway at a permissible level.

7. **Penstock:**
It is the device which is used in hydro-electric power plant for the purpose of flow of water. The water flow of from dam towards turbine with the help of penstock. It converts the potential energy of water into kinetic energy. The penstocks are made up of cast iron or concrete material. The penstock is hollow in nature & of large diameter.

Fig: Penstock arrangement in HPP

8. **Tunnel (Water ways):** बोगदा

The passage of flow water from dam is called Tunnel or intake. Water ways may be in the form of canal or tunnel or penstock. OR It is used to carry the water from water reservoir to surge tank.
9. Surge tank:

![Surge Tank Diagram](electricallive.com)

**Fig: Surge Tank**

It is a device which is connected in between dam & power house. It is of vertical type, at the time of starting of hydro-electric power plant, near power house valve is closed. Then water flows from dam towards turbine & filled the surge tank, after that valve is open either manually or automatically, water flow towards turbine when valves are open & turbine or prime mover starts to rotate. This sequence is follow to avoid or to prevent the turbines against water hammer effect.

**Water hammer effect:**

When load on power plant or alternator decreases then Governor (valve) reduces discharge of water. Due to sudden reduction in water discharge causes increase in pressure of the water in the penstock. Due to high pressure penstock may damage. This effect is known as ‘Water hammer effect’

**OR**

**When load on power plant or alternator decreases then:**

- Governor (valve) reduces discharge of water.
- Due to sudden reduction in water discharge causes increase in pressure in the penstock.
- Due to high pressure penstock may damage.
- This effect is known as ‘Water hammer effect.

**Effect is reduced:**

With the help of surge tank water hammer effect is eliminated OR At that time surge tank helps by storing this rejected water immediately. In this way it avoids Water hammer effect.

Instead of surge tank some hydro-electric power plants used Forebay. The Forebay are useful as the surge due to change in load occurs. Forebay is an
enlarged body of water at the intake (dam) to store more quantity of water. It is nothing but regulating reservoir. Forebay is stores the rejected water as the load on the turbine decreases & supplies water immediately when load on turbine increases i.e. it is nothing but surge tank for small capacity hydro power station.

11. Valve house:

![Fig: Valve used to ON/OFF water flow](image)

It is installed near power house, its function is to start or stop the flow of water towards turbine.

व्हाल्ड्ह हा पेन स्टोक वर बसवला जातो. याचा उपयोग पाणी चालू किंवा बंद करण्यासाठी केला जातो. व्हाल्ड्ह हा स्वयंचलित किंवा स्वतः हाताने चालू किंवा बंद करता येतो.

12. Power House: वीज निर्मिती करणारे घर:

It is the main heart of hydro-electric power plant. Form the electrical engineers point of view. In Power house main function is to produce electrical power. For that purpose the turbine or prime mover is mechanically coupled with generator. The mechanical energy is converted into electrical energy through
generator or whenever turbine starts to rotate at higher speed the generator produces electrical power output.

यामध्ये टरबाईन आणि विघ्न उर्जा निर्माण करणाऱे जनित्र एकमेकास जोडले जाते. उज्यावेची आपण टरबाईन वर्ती जास्त दाबाने पाणी सोडलेला जाईल तेथे टरबाईन व विघ्न उर्जा निर्माण करणाऱे जनित्र फिरण्यासाठी होतात व आपणास विद्युत उर्जा मिळते.

13. Prime Mover or Turbine:

![Fig: Prime Mover (Turbine) # Generator of HPP](image)

Its main function is to take water from dam at high pressure & start to rotate. The prime mover or turbine converts kinetic energy of water into mechanical energy. In hydro-electric power plant depends upon head or height pelton wheel, Francis, Kaplan & Propeller types of turbines are used.
14. Draft tube:

![Draft Tube Diagram]

Fig: Draft Tube

It is used in hydro-electric power plant near the turbine. Its main function is to press the water & its pressure increases. Depends upon the type of turbine draft tube are required.

15. Generator:

![Turbine Generator Diagram]

Fig: Turbine # Generator
It is used to convert the mechanical energy into electrical energy. For that purpose the turbine & generator are mechanically coupled.

विद्युत जनित्र येथे महत्त्वाचे काम म्हणजे विद्युत उत्सर्जन निर्मिती करणे होय.

**Cavitations Effect:**

When load on power plant or alternator increases then Governor (valve) increases discharge of water.

- Due to sudden increase in water discharge causes/creates vacuum in the penstock. (Negative pressure).
- That is causes cavity, so penstock will not supply water properly.
- This effect is known as ‘Cavity effect’.

**Effect is reduced:**

With the help of surge tank cavitations effect is eliminated OR At that time surge tank helps by supply the required water immediately. In this way it avoids Cavity effect.

16. **Tailrace: (Shown in schematic arrangement of HPP)**

After generation the remaining water discharges to river or lake through tail race. From ground level to the turbine some height is maintained to discharge the water. टेल रेस चा उपयोग टरबाईल मधूल बाहेर जाणारे पाणी नदीस सोडण्याकरिता होते.
8. Classification of Hydro-Electric Power Plant:

1. Classification According to Quantity of Water Available:
   a. Run of River Plants Without Pondage.
   b. Run of River Plants with Pondage.
   c. Reservoir Plants.

a. Run of River Plants Without Pondage:
   In this type of hydro-electric power plant, the available water from river or lake is not stored in pond. Whenever the water available from river or lake it is directly used to run water turbine. The capacity of such plants depends upon the rate of flow of water. Such type of plant may run during rainy season.

b. Run of River Plants with Pondage.
   The above mentioned runs of river plant without pondage have some limitations. To overcome this drawback, in this type of hydro-electric plant the available water from river or lake is stored in pond. Due to this storage water in pond, it is useful to run the plant during off-peak & peak period. The capacity of such type of hydro-electric plant is depends upon the size of pond.
c. Reservoir Plants.

This type of hydro-electric plant is totally different form the above mentioned two plants. In this type of hydro-electric power plant, reservoir is provided. This reservoir is useful to store an ample quantity of water during rainy season, & this is useful throughout the year. Such type of power plant has better capacity. This type of hydro-electric power plant may be used as base load plant. Majority of the hydro-electric power plants are of this type.

पाणी साठवून ठेवणेसाठी यात मोठ्या क्षेत्रफळ असलेले जलशय्या असते.
2. Classification According to Available Water Head.

a. Low Head Plants (Below 30m) 

b. Medium Head Plants (30 to 300 m) 

c. High Head Plants (above 300m) 

a. Low Head Plants:

![Fig: Low Head HPP](image)

The low head plants have water head below 30m. A low head power plant store water by construction of dam across river or lake. The power house is installed near the base of dam on the downstream side. The barrages with regulating gates are provided to flow of excess water in river or lake. In low head hydro-electric power plant Kaplan turbines can be used.

जो धरणात पाणी साठ होते त्याची उंची 30 मीटर पेक्षा कमी असते. नदी किंवा तलावाचे पाणी आडवून धरण बांधले जाते. व धरणाच्या खाळील बाजूस वीज निर्मिती करणारे घर असते. या प्रकारच्या प्लांट मध्ये कपलान प्रकारचे टरबाईन वापरले जाते.
b. Medium Head Plants:

![Diagram of Medium Head HPP]

**Fig: Medium Head HPP**

If the available water head is between 30 and 100 m, the plant is called a medium-head plant. Water is led to the turbines from the Forebay by the penstocks, which may be steel pipes. Forebay also stores the rejected water as the load on the turbine decreases. Francis turbines are normally used.

**OR**

If the available water head is between 30 and 100 m, the plant is called a medium head plant. Water is led to the turbines from the Forebay by the penstocks, which may be steel pipes. Forebay also stores the rejected water as the load on the turbine decreases. Francis turbines are normally used.

या प्रकारच्या धरणात पाण्याची ऊंची 30 मीटर पेक्षा कमी व 300 मीटर पेक्षा जास्त असते. या प्लांट ची वीज निर्मिती क्षमता देखील थोडी जास्त असते. यामध्ये पाणी साठववेसाठी फोर वे देखील असतो. या प्रकार च्या प्लांट मध्ये फ्रांसीस प्रकारचे टरबाईन वापरले जाते.
c. High Head Power Plant:

If the available head is more than 300 m, the plant is called high-head plant. The civil works include a surge tank, the function of which is to meet the sudden changes in the requirement of water caused by the fluctuations in the system load.

OR

If the available head is more than 300 m, the plant is called high-head plant. The civil works include a surge tank, the function of which is to meet the sudden changes in the requirement of water caused by the fluctuations in the system load.

---

या प्रकारच्या धरणात पाण्याची ऊंची ३०० मीटर पेक्षा जास्त असते. वर जलविद्युत केंद्र कसे चालतो हे दिलेले आहे.

उपरोक्त प्रकारे विद्युत निर्मिती केंद्र एका दिवसात म्हणजेच २४ तास चालू असते त्यास बैस लोड असे म्हणतात. आणि जे विद्युत निर्मिती केंद्र ठरविक वेळी म्हणजे सकाळी किवा सायंकाळी चालू असते त्यास पिक लोड असे म्हणतात. पुढील पानावर याची आकृती व माहिती दिलेली आहे.
3. Classification of plants According to Nature of Load:

a. Base-Load Plants:

b. Peak-Load Plants:

c. Pumped Storage Hydro-Electric Power Plant for Peak Load.

![Diagram of base and peak load](image)

**Fig: Base & Peak Load**

**a. Base-Load Plants:**

The unvarying load which occurs almost the whole day on the station is known as base load. Refer the load curve as shown in figure. It is clear that 20 MW of load to be supplied by the station at all times of day & night i.e. throughout 24 hours. Therefore 20 MW is the base load of the station. The base load on the station is almost constant in nature. The base load plants have largest capacity & load factor.

**b. Peak-Load Plant:**

The various peak demands of load over & above the base load on the station are known as peak load. Refer the load curve as shown in above figure, it is clear that there are peak demands of load excluding peak load. These peak demands of the station generally from a small part of the total load & may occur through the day. Run-off River plants with pondage can be used as peak load.
Q. Compare Base Load & Peak Load Power Plant:

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Points</th>
<th>Base load plant</th>
<th>Peak load plant</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Definition</td>
<td>The power plant which supplies base load of load curve is known as base load plant</td>
<td>The power plant which supplies peak load of load curve is known as peak load plant</td>
</tr>
<tr>
<td>2</td>
<td>Generating capacity</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>3</td>
<td>Firm capacity</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>4</td>
<td>Working Hours</td>
<td>24 hours</td>
<td>Only during peak load hours</td>
</tr>
<tr>
<td>5</td>
<td>Cost of generation/unit</td>
<td>Generally low cost of generation per unit are selected as base load plant</td>
<td>Generally high cost of generation per unit are selected as peak load plant</td>
</tr>
<tr>
<td>6</td>
<td>Starting time</td>
<td>Both quick &amp; more starting time power plant can be selected as a base load plant</td>
<td>Quick starting time power plant are selected as a peak load plant</td>
</tr>
<tr>
<td>7</td>
<td>Load factor</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>8</td>
<td>Utilization factor</td>
<td>More</td>
<td>Less</td>
</tr>
<tr>
<td>9</td>
<td>Examples</td>
<td>Large capacity hydro, thermal, nuclear power station</td>
<td>Small capacity storage hydro, pumped storage hydro, gas, diesel power station.</td>
</tr>
</tbody>
</table>

Q. Distinguish between run-off river plant with pondage & pumped storage power plant:

<table>
<thead>
<tr>
<th>S.No</th>
<th>Points</th>
<th>Run off river plant with pondage</th>
<th>Pumped storage power plant</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>No. of reservoir</td>
<td>One water reservoir at headrace</td>
<td>One water reservoir at headrace and one water reservoir at tailrace</td>
</tr>
<tr>
<td>2</td>
<td>Alternator</td>
<td>Converts mechanical power into electrical power</td>
<td>Converts mechanical power into electrical power and also works as a motor i.e converts electrical power into mechanical power</td>
</tr>
<tr>
<td>3</td>
<td>Turbine</td>
<td>Converts mechanical power</td>
<td>Converts mechanical power and work as a pump</td>
</tr>
<tr>
<td>4</td>
<td>Capital cost</td>
<td>Per mega watt cost is less as only one dam is required</td>
<td>Per mega watt cost is more as two dam are required</td>
</tr>
<tr>
<td>5</td>
<td>Plant capacity</td>
<td>More</td>
<td>Less</td>
</tr>
<tr>
<td>6</td>
<td>Surge tank</td>
<td>Need of surge tank</td>
<td>No need of surge tank</td>
</tr>
<tr>
<td>7</td>
<td>Application</td>
<td>Used as a base load</td>
<td>Used as a peak load</td>
</tr>
</tbody>
</table>
c. **Pumped Storage Hydro-Electric Power Plant:** (पंप्ट जलवियुत केंद्र)

The schematic arrangement of Pumped Storage Hydro-Electric Power Plant is as shown in figure. This type of power plant is useful where availability of water for power generation is insufficient. Generally, there are two ponds. One is in head race level & other is in tail race level. The stored water from head race pond is useful for electrical power generation. When the water flows towards turbine, it starts to rotate. The discharge water from turbine is stored in tail race pond. During off peak period the stored water from tail race pond is pumped to head race pond again, with the help of motors. This cycle is continuously repeated, that’s why it is known as Pumped storage hydro-electric power plant.

**Applications of Pumped storage plants:** To supply peak load.

---

**Fig: Pumped Storage Hydro-Electric Power Plant**

The schematic arrangement of Pumped Storage Hydro-Electric Power Plant is as shown in figure. This type of power plant is useful where availability of water for power generation is insufficient. Generally, there are two ponds. One is in head race level & other is in tail race level. The stored water from head race pond is useful for electrical power generation. When the water flows towards turbine, it starts to rotate. The discharge water from turbine is stored in tail race pond. During off peak period the stored water from tail race pond is pumped to head race pond again, with the help of motors. This cycle is continuously repeated, that’s why it is known as Pumped storage hydro-electric power plant.

**Applications of Pumped storage plants:** To supply peak load.
9. Types of Turbine: टरबाइन चे वेगवेगळे प्रकार:

The turbines used in hydro-electric power plant are acts as a prime mover of generator, can be classified into two types:

- **According to the type of flow of water:**
  - **Axis along the shaft of the machine:** The machines having flow of water along the axis are called as axial flow turbines.
  - **Axis along the radius:** The machines in which the water flows along the radius are called as radial flow turbines.
  - **Axis along the tangential directions:** The turbines using this type of flow are called tangential flow turbines.

- **According to the action on fluid:**
  - **Impulse Turbine:**
    Such types of turbines are used at high heads. In an impulse turbine the entire pressure of water is converted into kinetic energy in a nozzle & the
velocity of the jet drives the wheel. The example of this type of turbine is Pelton Wheel.

ii. Reaction Turbine

Reaction turbines are used for low & medium heads. In a reaction turbine water enters the runner partly with pressure energy & partly with velocity head. The reaction turbines are classified into two types: Francis & Kaplan turbines.

Example of Impulse & Reaction Turbine:

Fig. A: Pelton Wheel Turbine

Fig B: Francis Turbine

Fig C: Kaplan Turbine
a. Pelton Wheel:

![Pelton Wheel Diagram](image)

**Fig: Pelton Wheel Turbine**

- Pelton wheel is an impulse type of turbine.
- This type of turbine is used at high head (90 to 1100 m).
- Its specific speed is 10 to 40 rpm.
- It consists of a rotor equipped with elliptical buckets along the whole periphery.
- The Pelton wheel turbine consists of runner, buckets, nozzle, needle valve & Shaft.
- The buckets are made up of stainless steel, cast iron & bronze material.
- In this type of turbine 1 or 2 jets are used to force the water through buckets.
- The nozzles are used to increase the pressure of water flow towards turbine.
- The shaft is useful to mechanical coupling with generator.
- The direction of flow of water is tangential.
b. Francis Turbine:

![Fig: Francis Turbine](image)

- Francis turbine is a Reaction type of turbine.
- The Francis turbines are mostly used for medium head of water (14 to 300 m).
- The specific speed of Francis turbine is 95 to 440 rpm.
- The Francis turbine consists of outer & inner ring, blades, wheel etc.
- The outer ring consists of stationary guide blades, which are fixed to the casing.
- The inner ring consists of rotating blades.
- The water flows in Francis turbine is in radial direction.
- Sometimes draft tube is used for discharge of water directly into tail race.
- The Francis turbine is of both horizontal & vertical type.
- The horizontal turbines are used for higher speeds.
- The vertical turbines are used for higher capacity.
- The diameter & weight of Francis turbine is less.
- The blades of this type of turbine are moved in both directions, according to the flow of water.
- At higher speed it is very efficient type of turbine.
c. Kaplan Turbine:

The Kaplan turbine is a reaction type of turbine.

- The Kaplan turbine is used for low head up to 3 to 30 m.
- The specific speed of Kaplan turbine is 550 to 830 rpm.
- The Kaplan turbine consists of runner, blades, casing, guide blades, guide wheel, draft tube & shaft.
- The Kaplan turbine consists of 3 to 6 blades.
- In Kaplan turbine the water strikes in axial direction.
- The guide vans are used to control speed of water.
- This type of turbine has higher efficiency at all load.
- It is used for low head, but to run this turbine large quantity of water required.
- The draft tube is useful to discharge the water to tail race level.
- The shaft is useful for mechanical coupling between turbine & generator.
d. Specification of different types of turbines:

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Type of Turbine</th>
<th>Class</th>
<th>Head in Meters</th>
<th>Specific Speed (RPM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Pelton Wheel</td>
<td>Impulse</td>
<td>90 to 1100 m</td>
<td>10 – 40</td>
</tr>
<tr>
<td>2</td>
<td>Francis</td>
<td>Reaction</td>
<td>14 to 300 m</td>
<td>95 – 440</td>
</tr>
<tr>
<td>3</td>
<td>Kaplan</td>
<td>Reaction</td>
<td>3 to 30 m</td>
<td>550 - 830</td>
</tr>
</tbody>
</table>

Q. Compare pelton wheel and Kaplan turbine on the basis of type of flow of water, Suitable for type of head and flow, construction and control of water.

<table>
<thead>
<tr>
<th>S.No</th>
<th>Points</th>
<th>Pelton wheel turbine</th>
<th>Kaplan turbine</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Flow of water</td>
<td>Direction of flow of water is tangential</td>
<td>Direction of flow of water is axial</td>
</tr>
<tr>
<td>2</td>
<td>Suitable for type of head and flow</td>
<td>It is suitable for high head power plant</td>
<td>It is suitable for low head power plant</td>
</tr>
<tr>
<td>3</td>
<td>Construction</td>
<td>The runner rotates in air and no-casing is required OR turbine consist of a) Runner b) Buckets c) nozzle d) Needle valve and e) shaft OR Runners of made of cost steel and Blades made of stainless steel, cast-iron, bronze etc</td>
<td>The runner rotates in fully immersed water and casing is required OR turbine consist of a) Runner b) Blade c) Casing d) Guide blades e) Guide wheel f) draft tube and g) Shaft OR Runners of made of cost steel and buckets made of stainless steel, cast-iron, bronze etc</td>
</tr>
<tr>
<td>4</td>
<td>Control of water</td>
<td>Discharged of water controlled by nozzle opening</td>
<td>By opening wicket gate or guide vans</td>
</tr>
</tbody>
</table>

Q. Comparism between Francis & Kaplan Turbine:

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Points</th>
<th>Francis Turbine</th>
<th>Kaplan Turbine</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Type</td>
<td>Radially in ward or mixed flow Turbine</td>
<td>partially axial flow</td>
</tr>
<tr>
<td>2</td>
<td>Disposition of shafts</td>
<td>vertical or horizontal direction</td>
<td>only in vertical direction</td>
</tr>
<tr>
<td>3</td>
<td>Number of vanes</td>
<td>16 to 24</td>
<td>3 to 8</td>
</tr>
<tr>
<td>4</td>
<td>Adjustment of runner vanes</td>
<td>not adjustable</td>
<td>adjustable</td>
</tr>
<tr>
<td>5</td>
<td>Head</td>
<td>medium head</td>
<td>very low head</td>
</tr>
<tr>
<td>6</td>
<td>Flow Rate</td>
<td>medium flow rate</td>
<td>very large flow rate</td>
</tr>
<tr>
<td>7</td>
<td>Specific Speed</td>
<td>50 to 250</td>
<td>250 to 850</td>
</tr>
<tr>
<td>8</td>
<td>Type of generator</td>
<td>regular generator</td>
<td>heavy duty generator</td>
</tr>
</tbody>
</table>
10. Generators used in Hydro-Electric Power Plant:

- It is 3-ph hydro generator (alternator).
- It is robust in construction.
- A separate excitation is given to separate alternator pole by DC generator (Exciter) which is mounted on same shaft. It excites the field winding of alternator.
- To excite the main exciter there is pilot exciter which is of permanent magnet.
- The excitation voltage DC 110/220/300V.
- Generated voltage is 3.3KV, 6.6Kv, 11KV, 17.5KV and 20 KV.
- Number of poles of hydro generator (alternator). is more and is various from 6 to 120 and machines are salient pole type.
- Hydro generator (alternator). Is large diameter and small is length.
- In case of generator (alternator). Coupled with impulse turbine are horizontal shaft and its speed is 100-1000 rpm.
- In case of hydro generator couple with reaction turbine is vertical shaft and its speed is low 20-500 rpm.
- Hydro-generator is low speed machine compare to the steam turbine driven generator.
- Cooling System: The machines are air cooled, cooling is necessary to improve the performance of generator.
- Protection : Protection against run away (high speed) speeds are provided, Over voltage under voltage protection, Over load protection Over & under frequency protection, Over temperature protection are main protections provided to generator.
11. Advantages & Disadvantages of Hydro-Electric Power Plant:

Advantages:

1. There is no fuel cost as water is available in nature.
2. There is no fuel transportation cost.
3. There is no necessity of fuel & ash handling equipment.
4. There is no air pollution.
5. It is very neat & clean plant.
6. Operating & maintenance cost are very low.
7. H.P.P can be put into service immediately.
8. There are no standby losses.
9. Efficiency of plant is highest and does not change with age.
10. Power generation can be controlled quickly & rapidly without any difficult.
11. This plant is suitable for supplying power to variable load.
12. By controlling discharge of water precisely, constant speed & frequency can be maintained.
13. The life of plant is longest.
14. Generation cost per unit (KWH) is lowest.
15. In addition to generation of electric energy H.P.P. is also useful for supply of drinking water, supply of water for irrigation and control the flood.

Disadvantages:

1. High capital cost due to construction of dam.
2. It depends on nature as it require huge amount of water which is store during rainy season.
3. Firm power (Output) is totally depends on monsoon.
4. It takes long time for complete erecting of power plant.
5. It requires large area (catchment) area for storage of water.
6. As sites are away from load centre, so cost of transmission and losses in it are more.
7. There is limitation to select the site of HPP because of their requirements.
12. MSBTE Questions:

Q. "Hydro electric power stations are not perennial power station" Justify the statement.

**Answer:** The water utilized by the hydro power plants comes mostly from storage dams/reservoirs which get filled up during the monsoon rainy season. Such reservoirs are utilized for supplying water to various purposes to:

- Water drinking storage.
- Agriculture/irrigation purpose and third purpose is generation of electricity

Since rainfall depends on nature which is fluctuating/uneven so water available in reservoirs should be properly used. i.e. for purpose of:

- Water drinking storage.
- Agriculture/irrigation purpose and not for generation of electricity because first two purposes are important.

Hence "Hydro electric power stations are not perennial power station"

Q. **Surge tank is compulsory in the case of high head hydropower plant. Give the reason.**

**Answer:** In the case of high head hydropower plant the distance between main reservoir and turbine valve house is more hence it is compulsory to have a surge tank to avoid damage of penstock due water hammer effect also to avoid cavity effect in penstock. Surge tank is compulsory.

**OR**
Surge Tank: A surge tank is the small reservoir or tank. It is open at the top. It is installed near valve house.

- It avoids cavity effect when load on turbine increases.
- It avoids water hammer effect when load on turbine reduces.

Q. What is meant by lake tapping? State the name of power station with which it is connected in Maharashtra State.

Answer: Lake Tapping is a method of blasting an intake into a body of water from below the natural water surface without first lowering that surface or installing a protective cofferdam around the tap hole. Lake taps are done by first excavating a tunnel almost to the water/rock contact and then blasting out the final protective rock plug at one time to allow water to suddenly inflow into the tunnel from the lake. This procedure can be done ‘dry’ or ‘wet’ In the dry method the tunnel is empty of water before the final plug blast while in the wet method it is partially filled with water.

Or

Answer: Lake Tapping is a method of blasting an intake into a body of water from below the natural water surface without first lowering that surface or installing a protective cofferdam around the tap hole. Lake taps are done by first excavating a tunnel almost to the water/rock contact and then blasting out the final protective rock plug at one time to allow water to suddenly inflow into the tunnel from the lake.

The name of power station with which it is connected to Maharashtra State:
Koyna Hydro-Electric Power Plant (Dist. Satara)
## 13. Important Technical Words & its Meaning:

<table>
<thead>
<tr>
<th><strong>Hydro:</strong></th>
<th>जलविद्युत</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hydro electric power station:</strong></td>
<td>जलविद्युत पॉवर स्टेशन</td>
</tr>
<tr>
<td><strong>Generation:</strong></td>
<td>निर्मिति</td>
</tr>
<tr>
<td><strong>Height or Head:</strong></td>
<td>उंची</td>
</tr>
<tr>
<td><strong>Potential Energy:</strong></td>
<td>स्थिर ऊर्जा</td>
</tr>
<tr>
<td><strong>Kinetic Energy:</strong></td>
<td>गतीज ऊर्जा</td>
</tr>
<tr>
<td><strong>Mechanical Energy:</strong></td>
<td>यांत्रिक ऊर्जा</td>
</tr>
<tr>
<td><strong>Electrical Energy:</strong></td>
<td>विद्युत ऊर्जा</td>
</tr>
<tr>
<td><strong>Stored Water:</strong></td>
<td>पाणी साठवून</td>
</tr>
<tr>
<td><strong>Rotating:</strong></td>
<td>फिरवत</td>
</tr>
<tr>
<td><strong>Ample Quantity:</strong></td>
<td>जरूरीपेक्षा जास्त प्रमाण</td>
</tr>
<tr>
<td><strong>Hilly Area:</strong></td>
<td>हौंगराड वेळ</td>
</tr>
<tr>
<td><strong>Pond:</strong></td>
<td>तलाव</td>
</tr>
<tr>
<td><strong>Capacity:</strong></td>
<td>क्षमता</td>
</tr>
<tr>
<td><strong>Rate of flow of Water:</strong></td>
<td>पाणी प्रवाह</td>
</tr>
<tr>
<td><strong>Limitation:</strong></td>
<td>मर्यादा</td>
</tr>
<tr>
<td><strong>Rainy Season:</strong></td>
<td>पावसाव्यात</td>
</tr>
<tr>
<td><strong>Low height or head:</strong></td>
<td>कमी उंचीचे</td>
</tr>
<tr>
<td><strong>Medium Height:</strong></td>
<td>मध्यम उंची</td>
</tr>
<tr>
<td><strong>High Height:</strong></td>
<td>उच्च उंची</td>
</tr>
<tr>
<td><strong>Barrage:</strong></td>
<td>मोठे धरण</td>
</tr>
<tr>
<td><strong>Reservoir:</strong></td>
<td>जलाशय</td>
</tr>
<tr>
<td><strong>Firm Capacity:</strong></td>
<td>फर्म क्षमता</td>
</tr>
<tr>
<td><strong>Utilization:</strong></td>
<td>वापर</td>
</tr>
<tr>
<td><strong>Capital Cost:</strong></td>
<td>भांडवली खर्च</td>
</tr>
<tr>
<td><strong>Flow of Water:</strong></td>
<td>पाणी प्रवाह</td>
</tr>
<tr>
<td><strong>Fluid:</strong></td>
<td>द्रवपदार्थ</td>
</tr>
<tr>
<td><strong>Perennial:</strong></td>
<td>बारमाही</td>
</tr>
</tbody>
</table>