IES MASTER

Civil Engineering

Toppers Handwritten Notes

HYDRAULIC MACHINES

BY-AMIT MITTAL SIR

- Theory
- Explanation
- Derivation
- Example
- Shortcuts
- Previous Years Question With Solution

Hydraulic Machines

Weightage

ESE prelims : 6-7 ques.

GATE → 2-3 marks

ESE mains → 20-30 Marks

K. Subramanyam

(1) Overview of Hydroelectric Projects.

(2) Hydraulic Turbines
- → Pelton Wheel
- → Francis Turbine
- → Kaplan Turbine and Propeller Turbine
- → Model ~~An~~ Analysis and specific speed

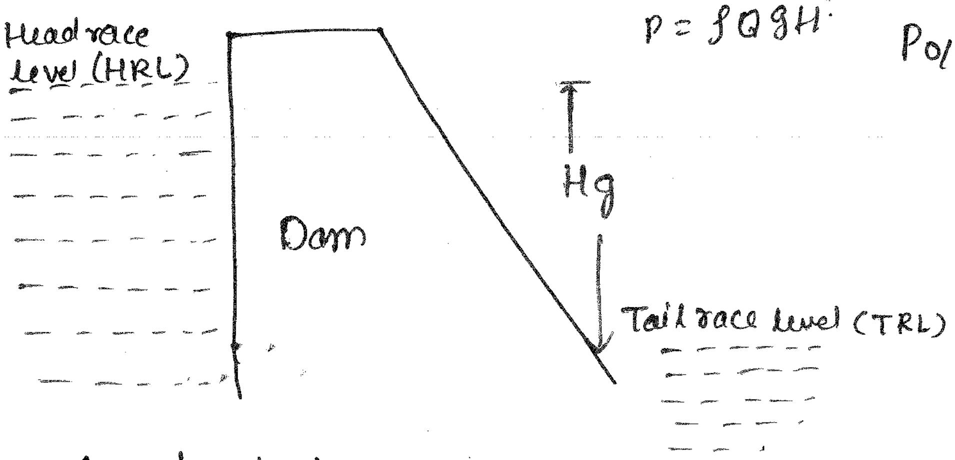
(3) Hydraulic pumps:
- → Centrifugal pumps
- → Reciprocating pumps

Chapter (1) Hydro electric plants (HEPs) overview

HE plants

Potential energy $\xrightarrow{\text{turbine}}$ Mechanical Energy $\xrightarrow{\text{generator}}$ electrical energy

$$mgh \rightarrow \text{input}$$
$$P = \rho Q g H$$
$$\eta = \frac{o/p}{i/p}$$
$$P_{o/p} = \check{\eta} \times \check{\rho}\check{g} Q \check{H}$$
Q → variable



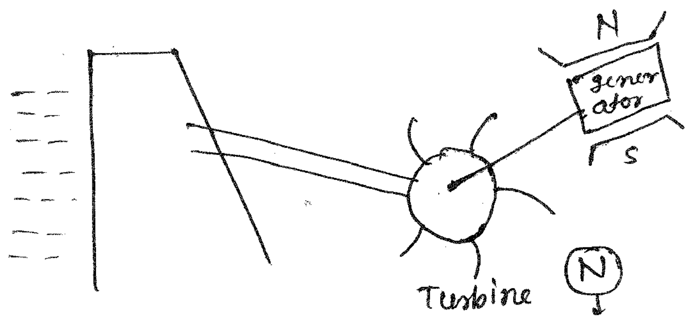
basin → घाटी

Apart from producing electricity:
- → Irrigation
- → Drinking water supply
- → Flood moderation
- → Navigation / Recreation (eco tourism)

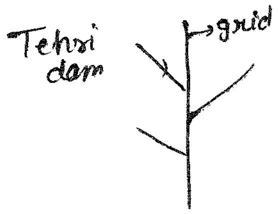
⇓

Multi purpose projects.

Indus Basin / Brahmputra / Ganga → maximum potential



electricity generation (Power plant) ⟶ electricity transmission ⟶ electricity distribution



maintain

Demand	Supply	f (frequency of electricity generation)
100 MW	100 MW	50 Hz
120 MW	100 MW	< 50 Hz
80 MW	100 MW	> 50 Hz

f = ?

$N = \frac{60 \times f}{P}$

f = 50 Hz → India

$N = \frac{60 \times 50}{P}$ P → no of pair of poles (N & S - 2 pairs)

$= \frac{3000}{P}$

Base load: continuous for 24 hours

Thermal power plant ← 3000 MW

Peak load: 4-8 → 3500 MW

Peak load: eg 4-8 hr

Quick starting & closure

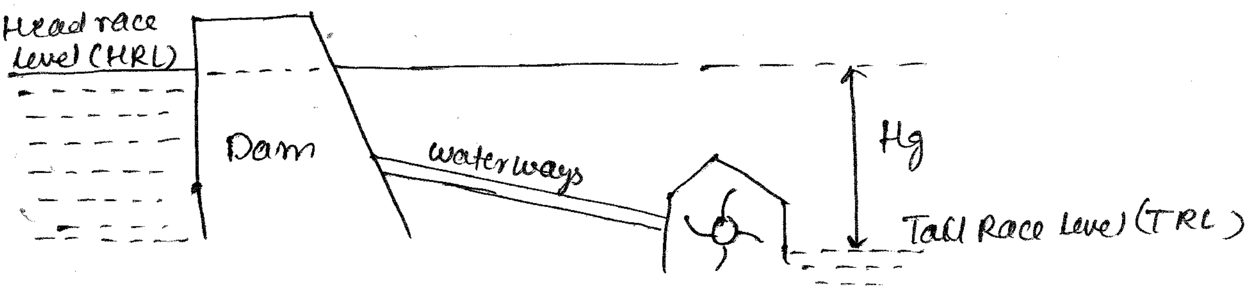
⇓

HEPs → generally for Peak demand

Trip is a kind of failure.

Introduction: ⇒ • In Hydroelectric projects (HEPs) potential energy of water (Hydraulic energy) is utilized to drive the turbine which in turn runs the generator to produce electricity.

• Apart from producing electricity these projects can also be used for irrigation, drinking water supply and flood moderation purpose and hence these projects are generally multi-purpose projects.



Advantage of HEPs

(1) Water is working fluid which is available in abundance.
(2) Running cost is low.
(3) No green house gases emission.
*(4) Quick starting and closure and hence suitable for peak load application.
*(5) These are multipurpose projects.

Limitations of HEPs :⇒ (1) These projects are capital intensive i.e set up cost is high.

(planning से start plant of operation तक)
(2) Long gestation period (around 10 to 15 year)
(3) These projects are located in hilly areas, away from load centre. hence transmission cost is high.
(4) Rehabilitation and resettlement issues. (solatium)
(5) Issue related to E-flow (Ecological flows).

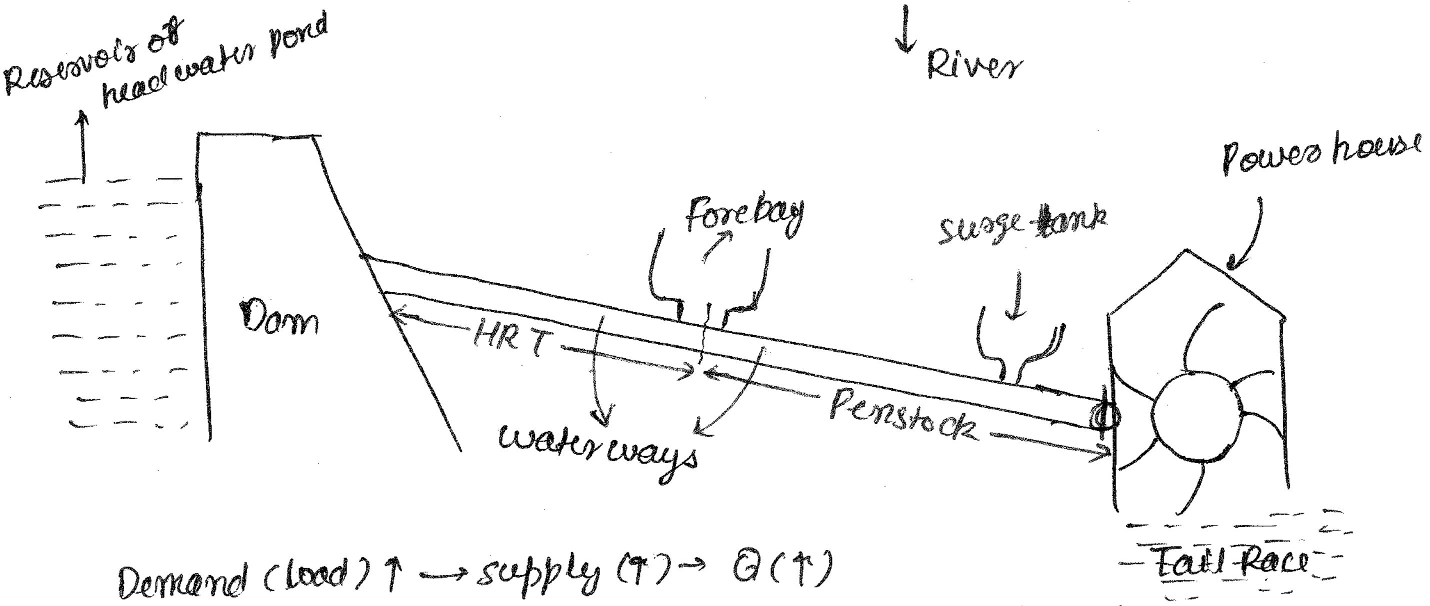
Thermal PP → BHEL

navigation – transportation

load centre → जहां से demand आ रही है

** Component of Hydroelectric plant

Storage reservoir ⟶ Trash Rack (to obstruct debris) ⟶ Intake ⟶ Head Race Tunnel or Power channel (HRT) ⟶ Forebay ⟶ Penstock
↓
Surge tank
↓
Turbine ⟶ Tail Race
↓
River



Demand (load) ↑ ⟶ supply (↑) ⟶ $Q(\uparrow)$

Load (↓) ⟶ supply (↓) ⟶ $Q(\downarrow)$ $P = \rho g Q H$

(1) **Storage Reservoir :⇒** • Water available in catchment area is stored in reservoir so as to meet requirement of power plant throughout the year.

- Reservoir can be natural as well as artificial.
- Natural reservoir are lakes in mountain.
- Artificial reservoir are made by constructing a dam across a river.

(2) Trash rack :⇒ (जाली) • It is used to obstruct debris (मलवा) for going from into the intake.

(3) Waterways :⇒ • Water is a passage through which water is carried from storage reservoir to power house.

• It consist of tunnel or canal (HRT), forebays and penstock.

(4) Forebays :⇒ • The Fore bay is an enlarged portion at the end of a power channel (HRT).

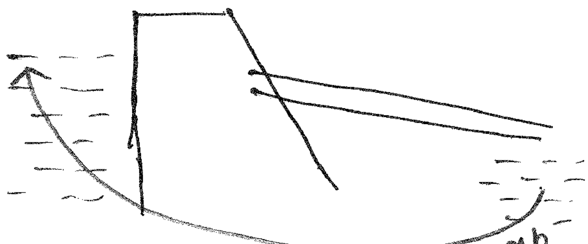
• It is essentially a small pond (storage tank) and serves the purpose of steady and continuous supply of water to the turbines.
• Penstock pipes take off from the fore bay to lead the water to the turbines. The storage volume in the forebay is designed to be adequate to take care of small fluctuations in the supply of water to the turbines due to load rejection and acceptance by the turbines.
• In addition, the fore bays acts as the last settling basin to the sediment particles.
• It is enlarged section installed after HRT.
• It's function is to receive temporarily the water rejected by plant when the load is reduced so as to meet instantaneous increased demand of water due to sudden ↑ in load.
• It also help in absorbing sudden rise in pressure due to sudden closure of valves when load on turbine decreases.

(5) Penstock :⇒ • A penstock is a closed conduit for supplying water under pressure from fore bay to turbine. It is subjected to water hammer pressure due to fluctuation in load.

• For long penstock, water hammer effect is reduced by providing a surge tank.

(6) Surge tank :⇒ • It is small reservoir fitted at some opening in penstock to recieve the rejected flow when value is suddenly closed and thus it helps in reducing the water hammer effect (generally it is close to the turbine).

(7) Tail race :⇒ • It is a waterways for carrying water discharged by the turbine to a suitable point where it can be safely released in the river or can be stored for pumping back into the reservoir.

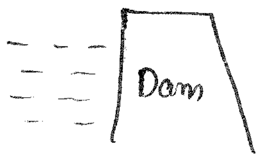


(8) Storage and Pondage :⇒ • Storage and pondage of water is required for regulation of flow of water so as to make it available in requisite quantity to meet the power demand at a given time.

- Storage is impounding of considerable amount of *excess runoff during seasons or surplus flow for use in dry seasons. This is accomplished by constructing a dam across a river.
- Pondage is a regulating body of water in the form of relative small pond or reservoir provided at that plant.
- Pondage is used to regulate the variables water flow to meet power demand. E.g → forebay & surge tank.

Note :⇒ Storage and pondage can be obtained from flow duration curve.

Storage → seasonal variation in flow. eg → dam



Ponding → regulating body of water.

demand ↑ → supply ↑ → Q ↑
demand ↓ → supply ↓ → Q ↓
eg → forebay, surge tank

Classification of Hydroelectric Power plants

(A) Based on Availability of Head

(i) High Head plants: Head > 250m

(ii) medium head plants: Head is from 30m to 250m.

(iii) Low head plants: Head is from 2m to 30m.

Note:⇒ This classification is not based on any scientific criteria.

(B) Based on load capacity

(i) Base load plants :⇒ • Power plants capable of substantially meeting the stipulated load at 95% of times are known as base load plants.

- Cater for the base load of the system.
- ** supply constant power.
- E.g→ thermal power plant, hydropower plant with storage can also work as base load plants.

(ii) Peak load plants:⇒ • A peak load plant * work in conjunction with a base load plant and takes care of the peak-load of the power system.

- A* storage type hydro plant is ideally suited for this purpose, as it can be started at a very short startup time which can vary from a few seconds to the order of 3 to 4 min. depending upon the length of conduit to the nearest storage spot.
- *% Pumped storage hydro plant is an example of using the excess power of the base load to meet the needs of the peak-load.

eg→ 3500 → 3500 MW
3000 MW → Base load
500 MW → Peak load.