Department of Electrical Engineering
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HYDROPOWER PLANTS

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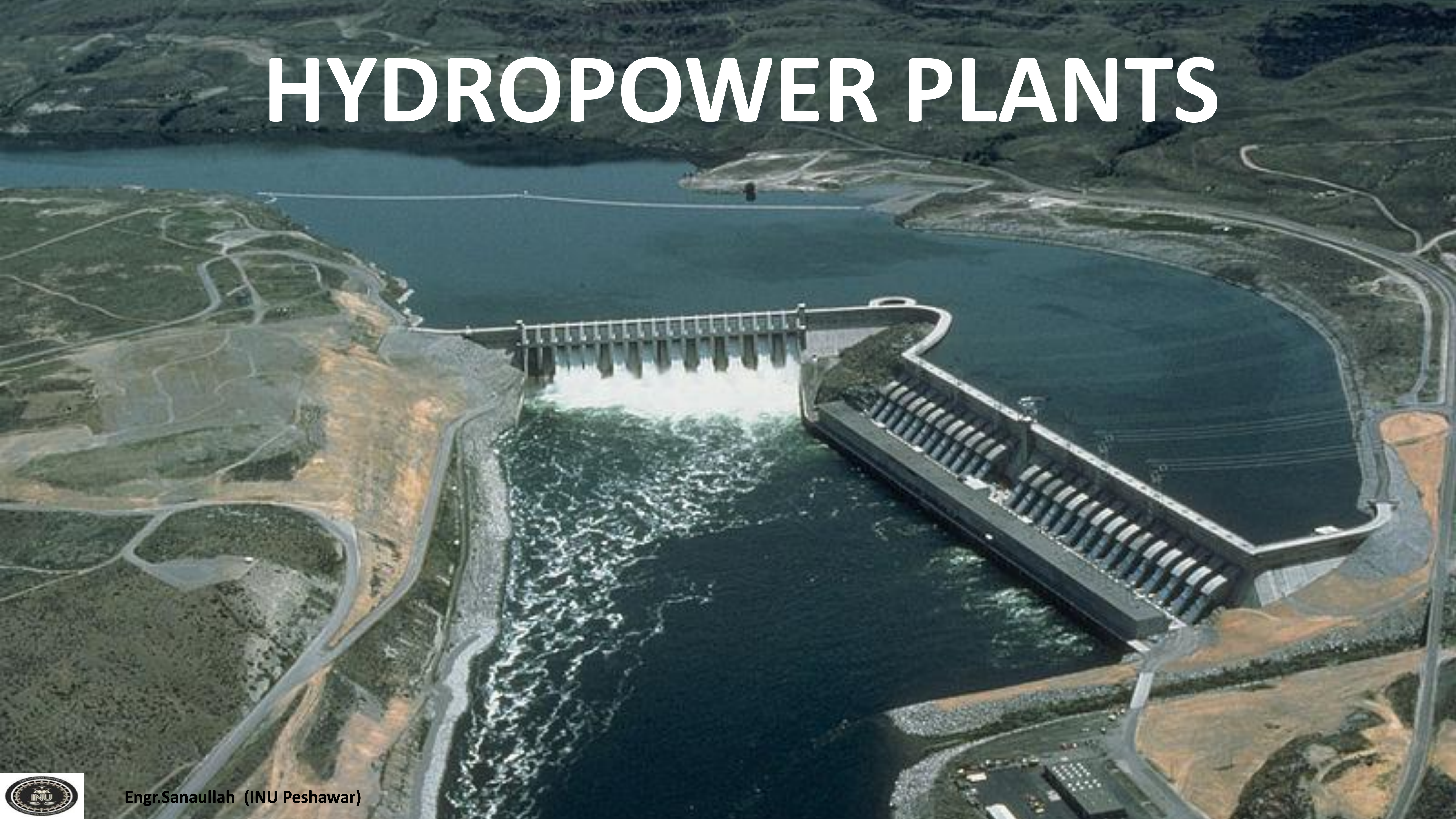


History

- Hydro-power or water power is power derived from the energy of **falling water or running water**.
- First used by Greeks for grinding wheat.
- Earlier waterwheels were used to turn machinery.
- These waterwheels powered textile and industrial mills.
- Hydro power is **conventional** but **renewable** energy source.

History

- In 1753, French engineer Bernard Forest first give idea about the use of hydropower.
- In 1848 James B. Francis, while working as head engineer of Lowell's Locks and Canals company, created first turbine from waterwheel with 90% efficiency.
- By the late 19th century, the electrical generator was developed.

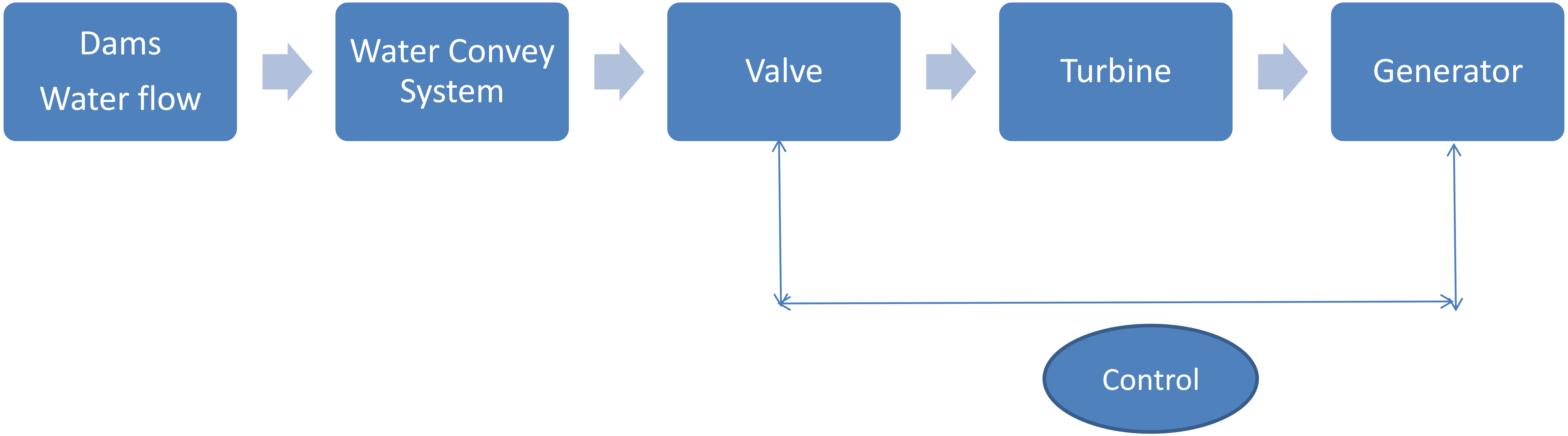
Hydro-Electricity

- **Hydroelectricity** is the term referring to **electricity** generated by **hydropower**; the production of electrical power through the use of the gravitational force of falling or flowing water.
- About 16-18 %of global electricity generation.
- Total installed hydropower capacity is about 630 GW.
- China is the largest hydroelectricity producer.(721 terawatt-hours)

Hydropower Types

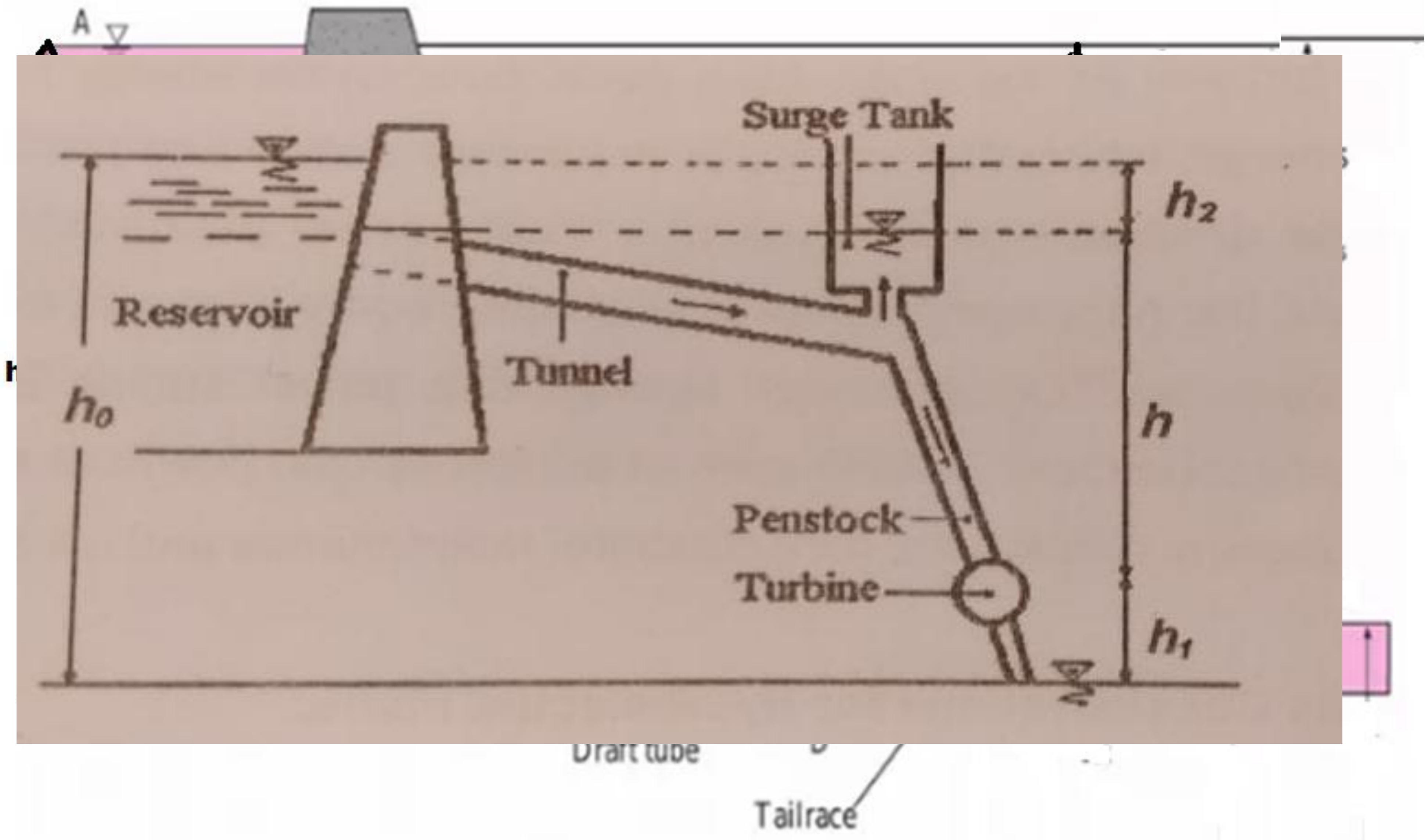
- **Conventional hydroelectric** referring to hydroelectric dams.(**Potential Energy)**
- **Run-of-the-river hydroelectricity** which captures the **(kinetic energy)** in rivers or streams, without the use of dams.
- **Small hydro projects** are **10 megawatts** or less and often have **no artificial reservoirs.**
- **Micro hydro projects** provide a **few kilowatts** to a few **100 kilowatts** to isolated homes, villages, or small industries.
- **Pumped-storage hydroelectricity** stores water **pumped** during periods of **low demand** to be released for generation when demand is high.

Hydroelectric General Layout



Site Considerations for Hydropower Plants

- Two Factor
  - Amount of Water flow per unit time.
  - Vertical Height that water can be made fall (head).
- For Reaction turbines the gross head h_o *is the* vertical distance between the water surface level at the intake and the tailrace. While for impulse turbine it is taken from water intake level to nozzle level.
- Effective head height can be calculated by simply subtracting the head losses along path. Head losses are due to frictions within the system (pipes , penstock , tunnels etc).
    - $H = ho - h2 - h1$
- *H Use d to determine the effective potential energy available .*


Surge Tank
Reservoir
Tunnel
Penstock
Turbine
h_0
h_2
h
h_1
Draft tube
Tailrace

Site Considerations

- Water Sources.
- Hydrology. *(preparation of hydrograph , data flow records rain etc)*
- Catchment area. *(Suitable area for lake)*
- Geographical Condition. *(Fault line)*
- Geological Mapping.
- Seismic activity.
- Strong foundation for dam.

Purpose Classification

- Single Purpose
  - Irrigation

- Multi purpose
  - Water supply
  - Flood control
  - Soil erosion
  - Environmental management
  - **Hydroelectric power generation**
  - Navigation
  - Recreation
  - Irrigation

➢CLASSIFICATION OF HYDROPOWER PLANTS :

Classification of hydropower plants

- **According to Capacity**
  - Large
  - Medium
  - Small
  - Mini
  - Micro
  - Pico
- **According to head**
  - High
  - Medium
  - Low
- **According to purpose**
  - Single purpose
  - Multi purpose
- **According to facility types**
  - Run-of-River
  - Reservoirs
  - In-stream
  - Pumped storage
- **According to hydrological relation**
  - Single
  - Cascade
- **According to transmission system**
  - Isolated
  - Connected to grid

CLASSIFICATION ACCORDING TO CAPACITY:

- LARGE: >100 MW
- MEDIUM: 25 – 100 MW
- SMALL: 1-25 MW
- MINI: 100 KW - 1MW
- MICRO: 5 – 100 KW
- PICO: < 5 KW

➢ small hydro power definitions in different countries:-

COUNTRY NAME	SHP (MW)
Italy	≤ 3
Dominican Republic, Guatemala, Macedonia	≤ 5
Marocco	≤ 8
Afghanistan, Burundi, Iran, Malaysia, Mali, Nepal, Norway, Sri Lanka, Tunisia, Kenya, Uganda, Zambia, Madagascar, Armenia, Austria, Croatia, Montenegro, Nigeria, Turkey, Serbia, Slovenia, Switzerland, Azerbaijan, Cambodia, Philippines, Indonesia, Senegal	≤ 10
Georgia	≤ 13
Bangladesh, Laos, Lesotho, Thailand	≤ 15
El Salvador, Peru	≤ 20
Bhutan, India, Mozambique	≤ 25
Argentina, Brazil, Mexico, Benin, United States	≤ 30
Canada, China, Pakistan, New Zealand	≤ 50

CLASSIFICATION ACCORDING TO HEAD

➢**LOW HEAD**:

- Low head hydro power applications use river current or tidal flows of **30 meters** or **less** to produce energy.
- These applications **do not need to dam** or retain water to create hydraulic head, the head is only a few meters.
- Using the current of a river or the naturally occurring tidal flow to create electricity may provide a renewable energy source that will have a minimal impact on the environment.

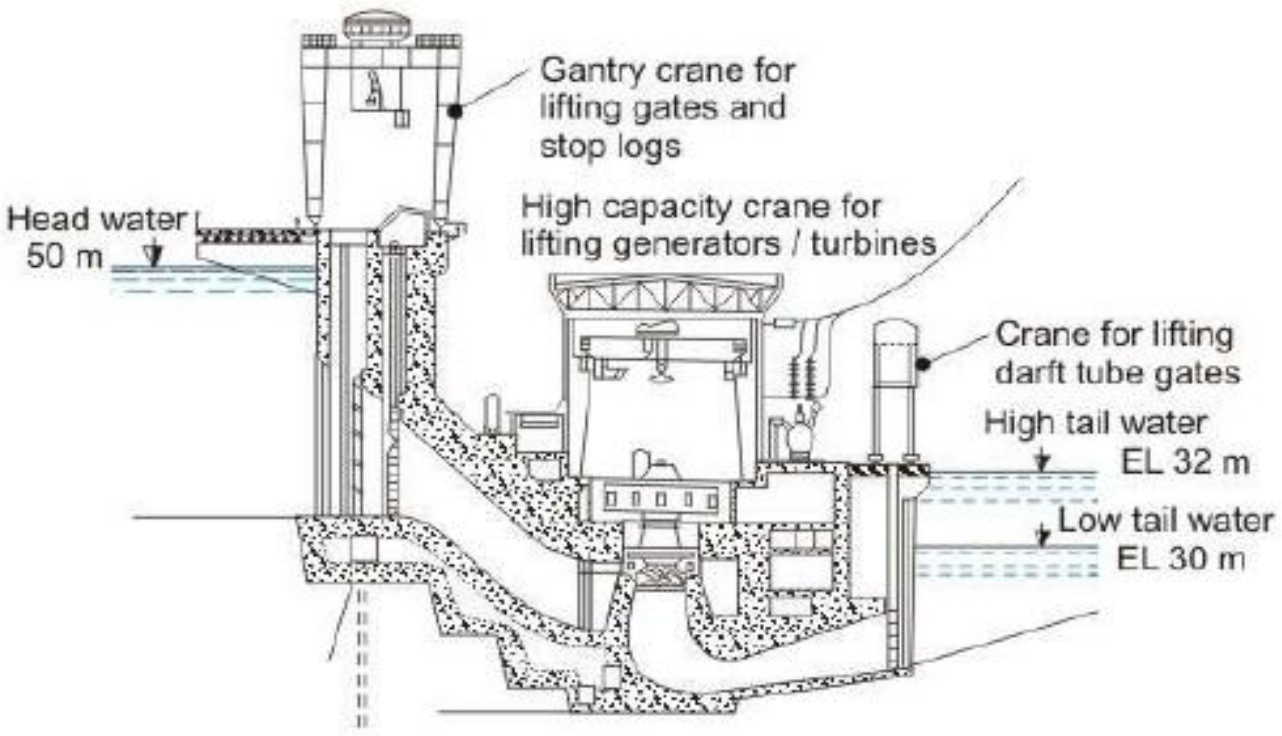


Figure-sectional view of low head hydropower plant

CLASSIFICATION ACCORDING TO HEAD

- **MEDIUM HEAD**:
  - A power station operating under heads from **30m to 300m**.

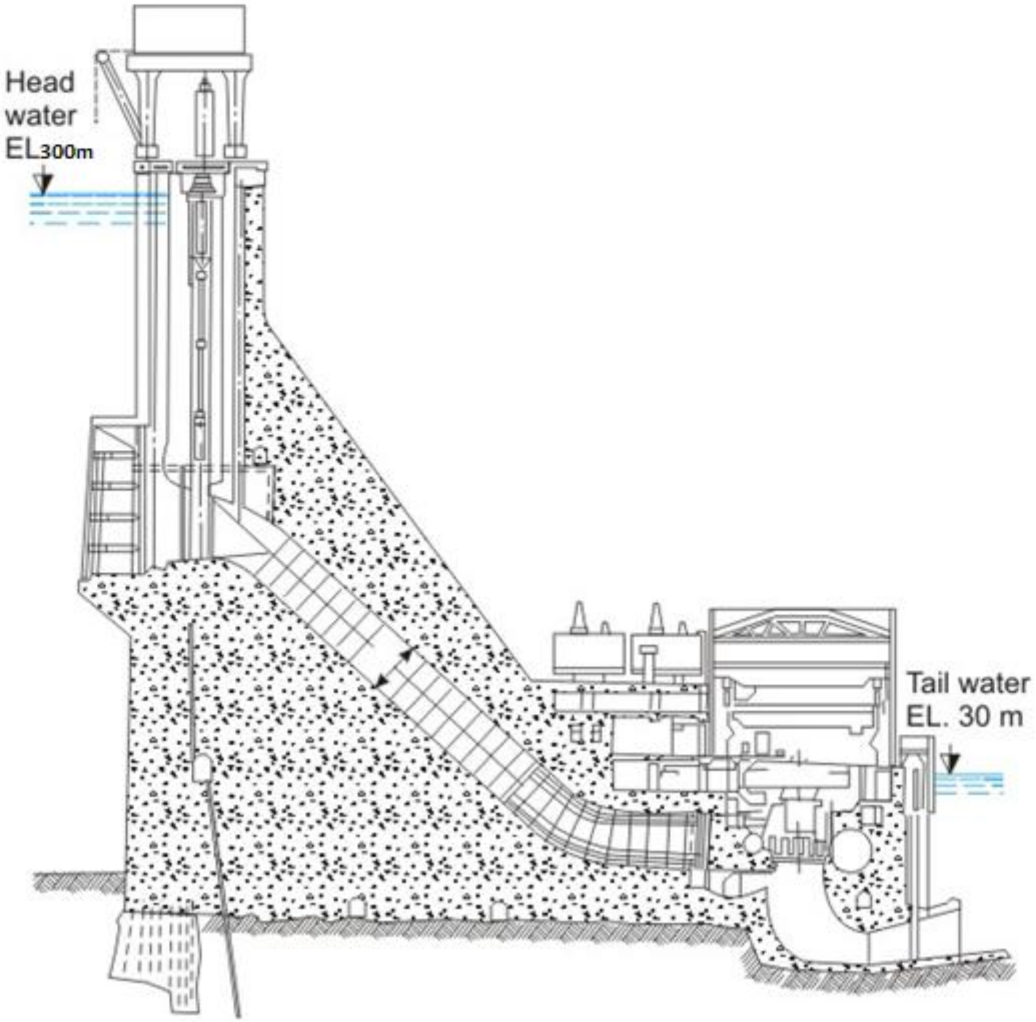


Figure- sectional view of medium head hydropower plant

CLASSIFICATION ACCORDING TO HEAD

➢**HIGH HEAD**:

- A power station operating under heads above about 300m.
- A head of 200m/250m is considered as the limit between medium and high head power stations.

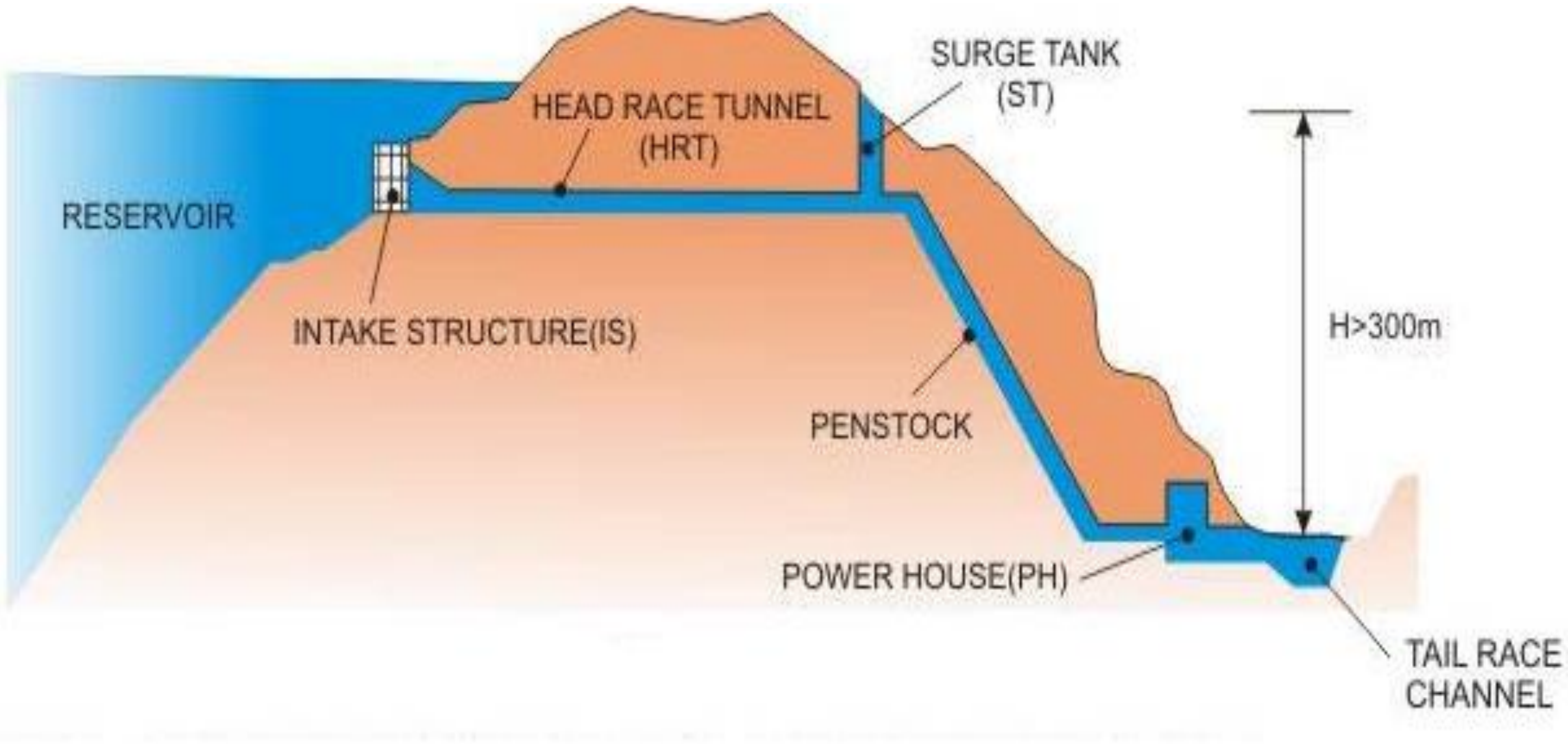
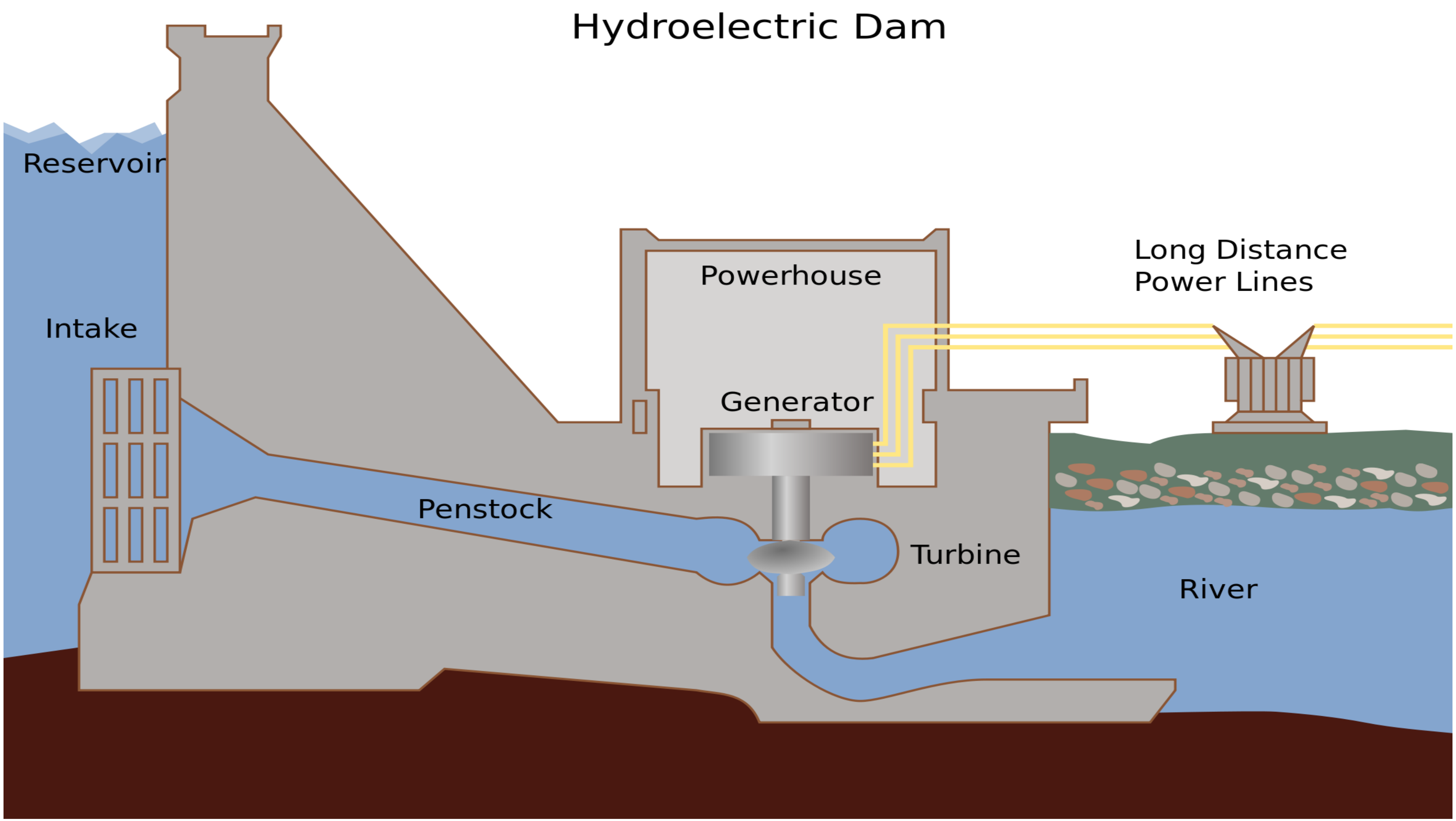


Figure- high head hydropower plant


Hydroelectric Dam
Reservoir
Intake
Penstock
Powerhouse
Generator
Turbine
Long Distance
Power Lines
River

CLASSIFICATION ACCORDING TO HDROLOGICAL RELATION

- **SINGLE STAGE-** When the run off from a single hydropower plant is diverted back into river or for any other purpose other than power generation, the setup is known as Single Stage.

- **CASCADE SYSTEM-** When two or more hydropower plants are used in series such that the runoff discharge of one hydro power plant is used as the is a intake discharge of the second hydro power plant such a system is known as CASCADE hydropower plant.

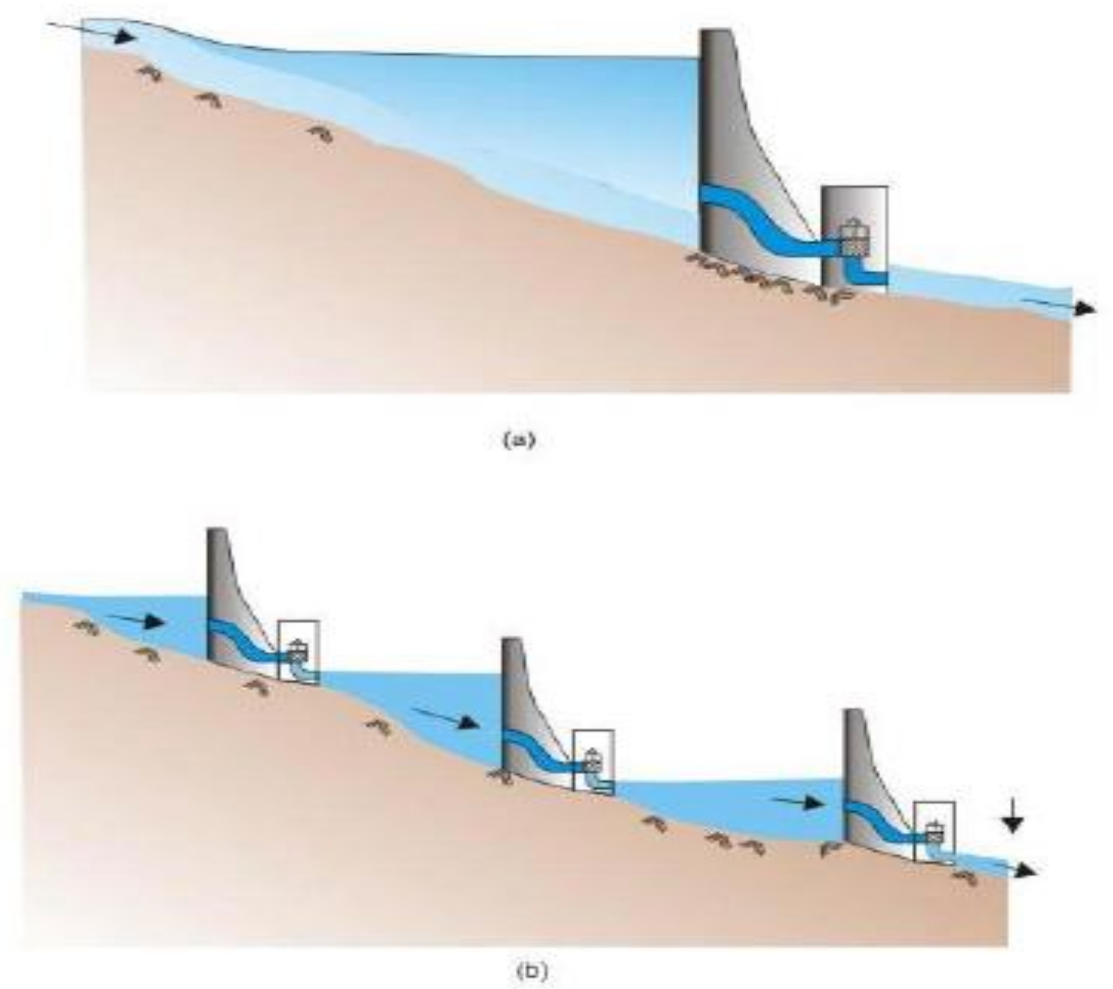


Figure-(a) single stage hydropower development scheme
(b) cascade or multistage hydropower system

CLASSIFICATION ACCORDING TO PURPOSE:

SINGLE PURPOSE: When the whole soul purpose of a project is to produce electricity or irrigation then such a project is known as a Single Purpose Hydro Power Project.

MULTIPURPOSE : When the water used in hydropower project is to be used for other purposes like irrigation, flood control or fisheries then such a project is known as Multi Purpose Hydro Power Project.

CLASSIFICATION ACCORDING TO FACILITY TYPE

➢RUN-OF-RIVER TYPE

- These are hydro power plants that utilize the stream flow as it comes , without any storage being provided.

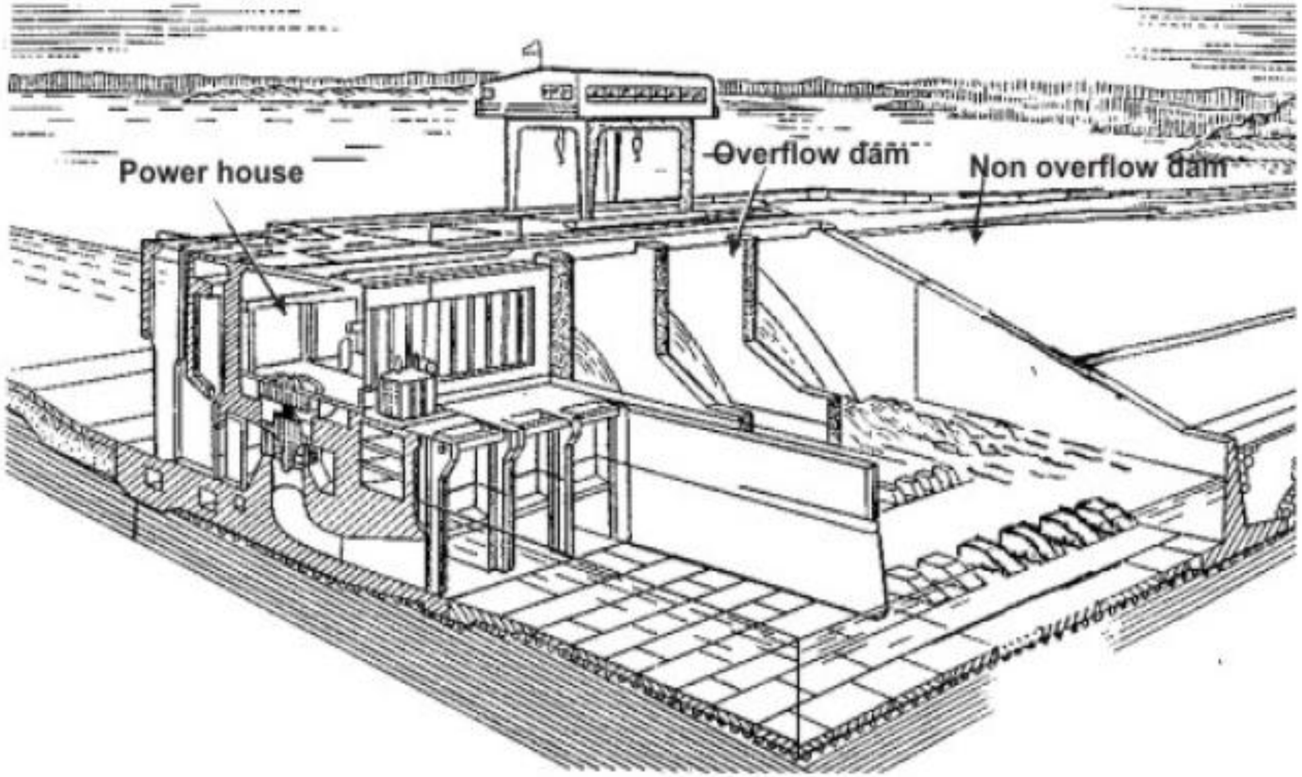
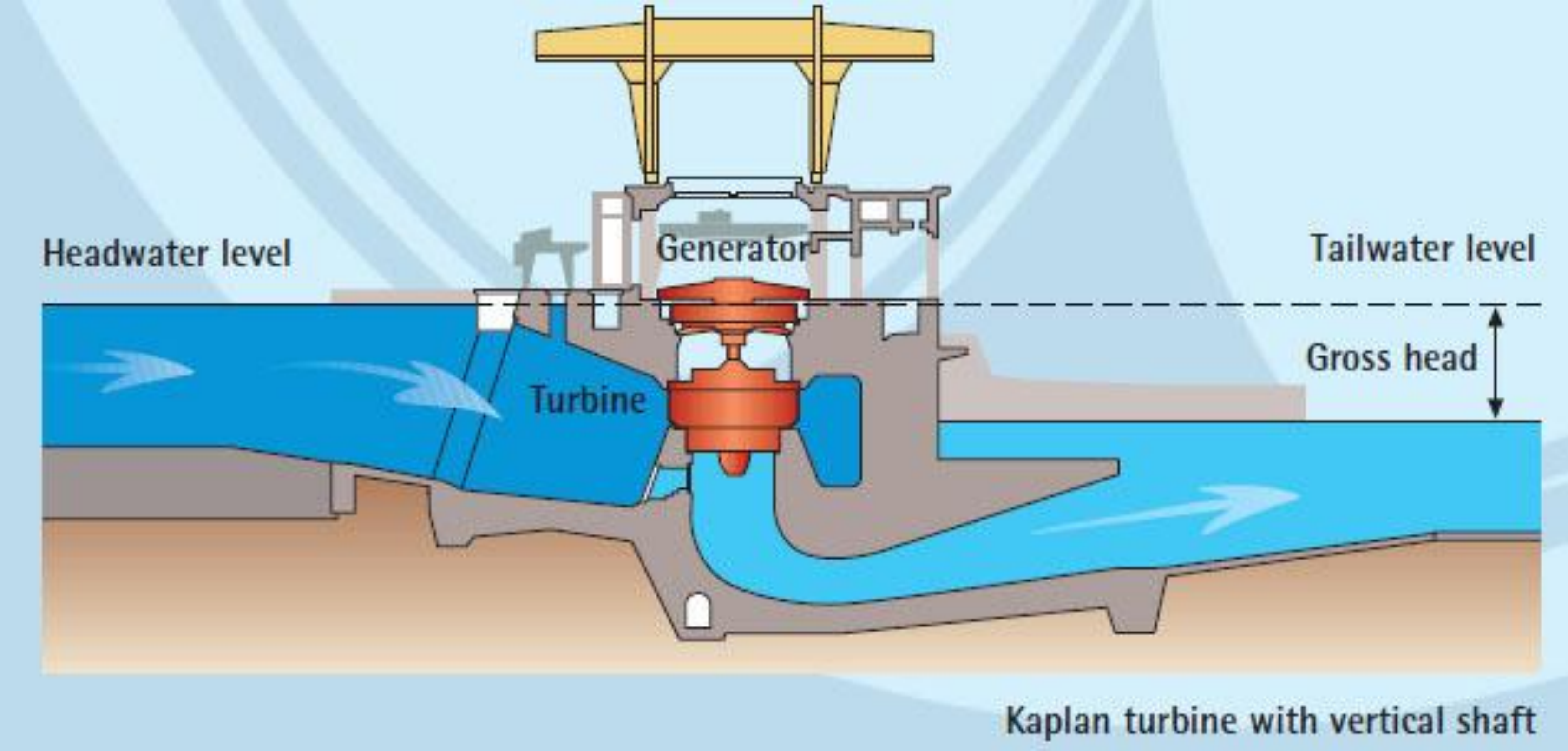


Figure-Run-of-River hydropower plant

Run on River

Little or no water storage is provided. Run-of-the-river power plants may either have no storage at all, or a limited amount of storage, in which case the storage reservoir is referred to as **pondage**



CLASSIFICATION ACCORDING TO FACILITY TYPE

➢STORAGE (RESERVOIR) TYPE

➢Hydropower plants with storage are supplied with water from large storage reservoir that have been developed by constructing dams across rivers.

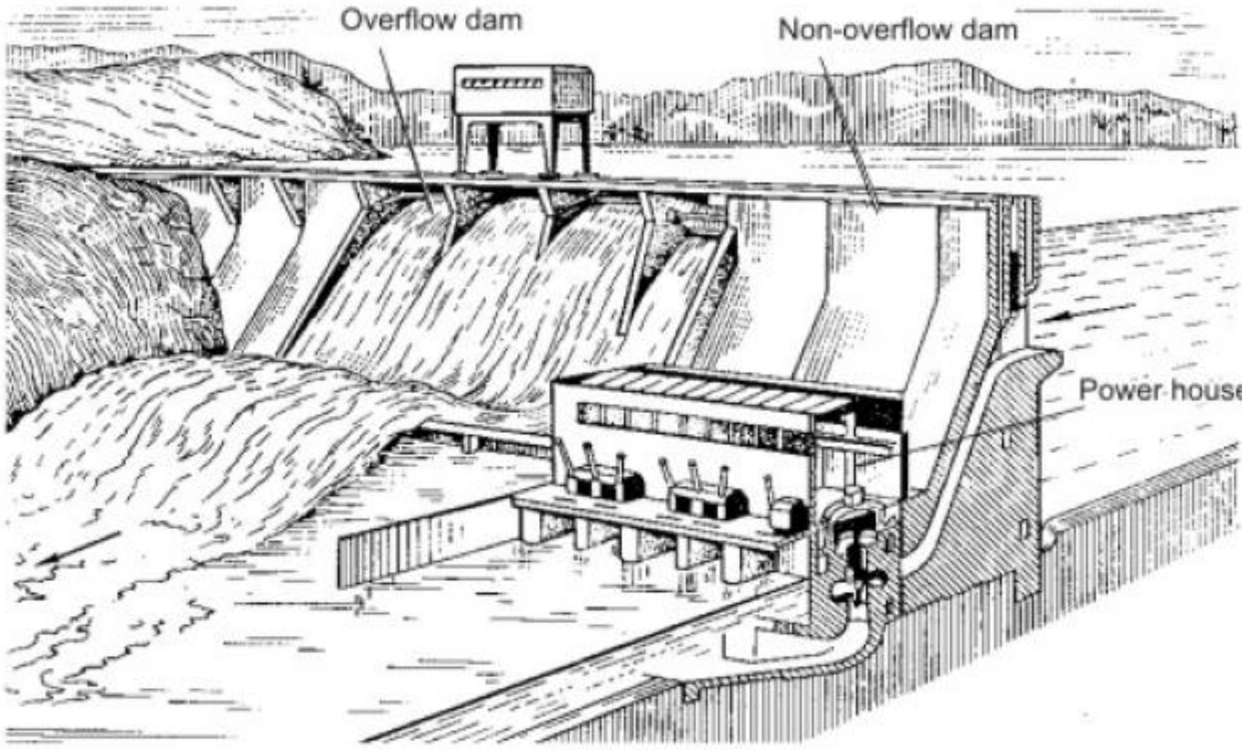


Figure-pumped storage hydropower plant

CLASSIFICATION ACCORDING TO FACILITY TYPE

➢PUMPED STORAGE TYPE

- Pumped storage type hydropower plants are those which utilize the flow of water from a reservoir at higher potential to one at lower potential.
- During off-peak hours, the reversible units are supplied with the excess electricity available in the power grid which then pumps part of the water of the tail-water pond back into the head-water pond.

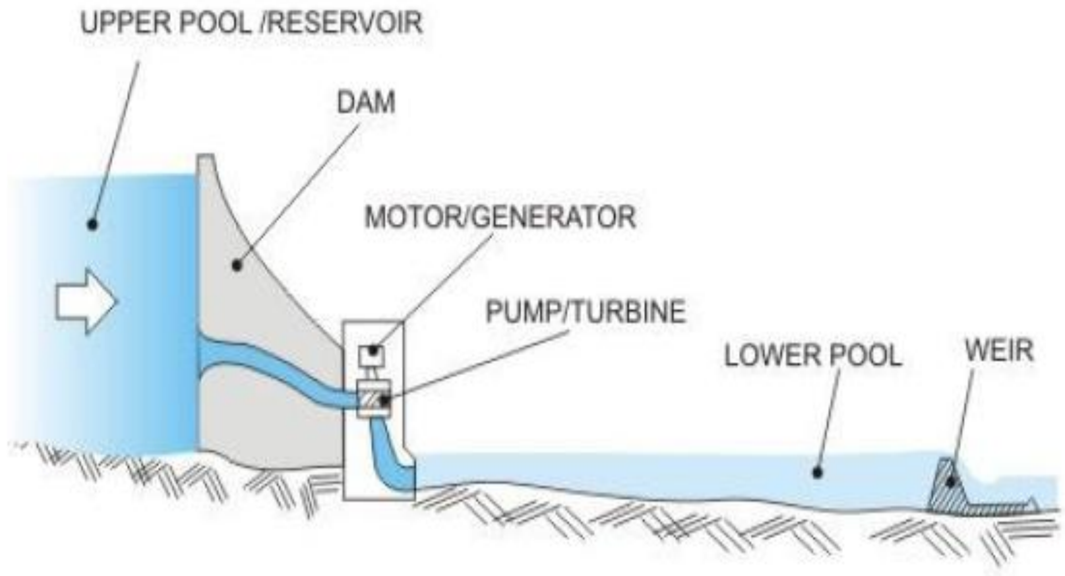
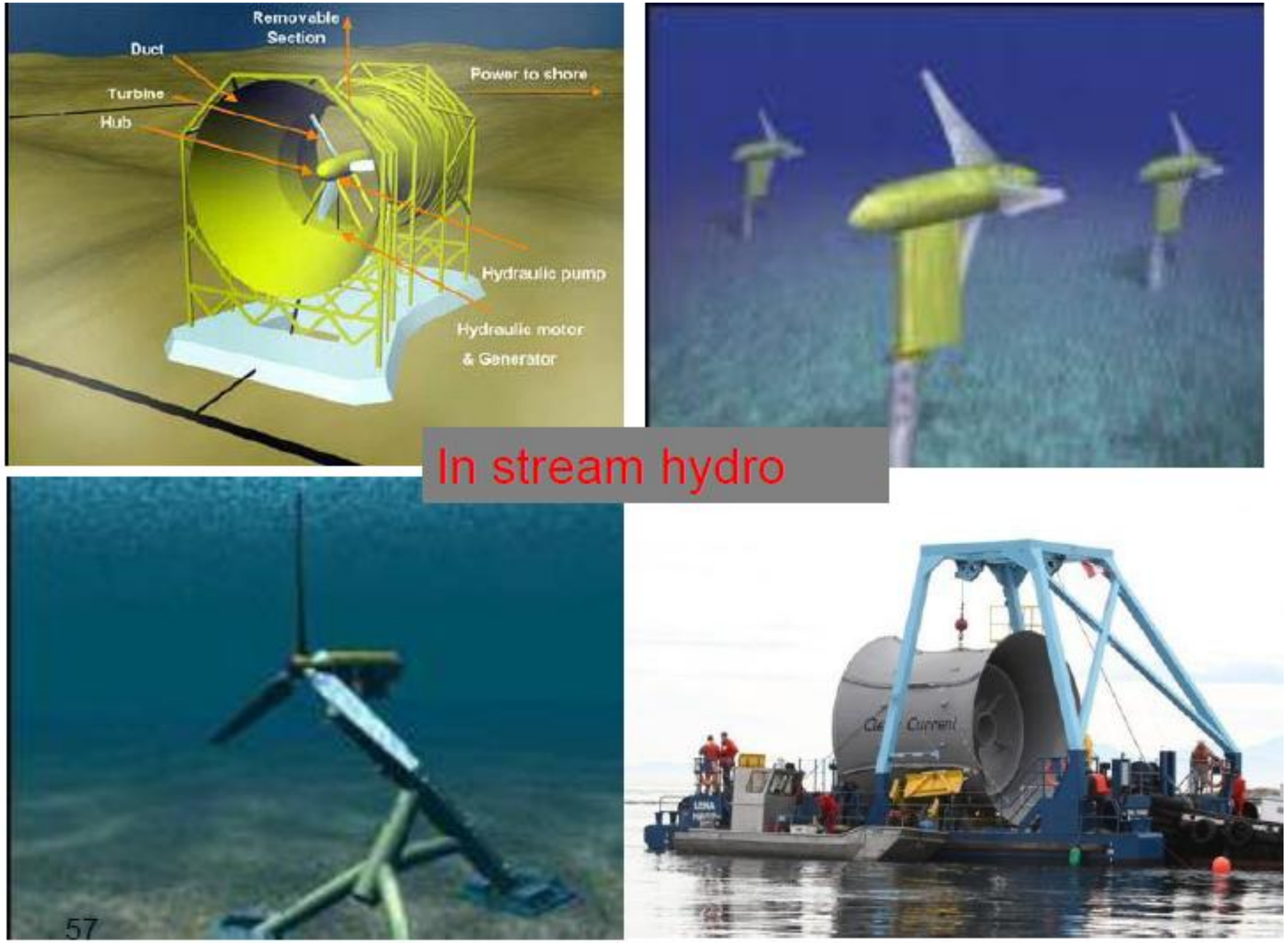


Figure-pumped storage hydropower plant

CLASSIFICATION ACCORDING TO FACILITY

➢IN-STREAM

When the velocity of water i.e kinetic energy flowing in the stream is used for conversion into electrical power, then the system is known as In-stream.



Photograph of In-stream hydro power system

CLASSIFICATION ACCORDING TO TRANSMISSION SYSTEM:

- **ISOLATED:** Whenever a hydropower plant is set up in a remote area in order to meet the local demands then such a hydropower plant is known as Isolated System.

- **CONNECTED TO GRID:** Whenever the hydropower plant is set up to meet the demands of areas which are at a fair distance from the plant, then the transmission of power takes through the grid system. Such a setup is referred to as Connected to grid.

FACTS ABOUT HYDROPOWER PROJECTS

- **The two largest hydropower projects in the world are the 14 GW itaipu project in brazil and the three gorges project in china with 22.4 GW.**

- **The three gorges dam, china has the world's largest capacity (22,500 MW).**

Photograph of Itaipu Dam (Paraná River) located on the border between Brazil and Paraguay

Photograph of Three Gorges Dam (Yangtze River, china)

Largest Production Dams(Electricity)

Rank	Station	Country	Location	Capacity (MW)
1	Three Gorges Dam	China	30°49′15″N 111°00′08″E	20,300
2	Itaipu Dam	Brazil Paraguay	25°24′31″S 54°35′21″W	14,000
3	Xiluodu Dam	China	28°15′35″N 103°38′58″E	13,860[17]
4	Guri Dam	Venezuela	07°45′59″N 62°59′57″W	10,200
5	Tucurui Dam	Brazil	03°49′53″S 49°38′36″W	8,370
6	Grand Coulee Dam	United States	47°57′23″N 118°58′56″W	6,809

Name[1]	Country	Year	Structure Height [m]	Structure Volume[2] [10^6 m^3]	Reservoir Volume [10^9 m^3]
Syncrude Tailings Dam Mildred MLSB[3]	Canada	1995	88	540[4]/720	0.35
Tarbela Dam	Pakistan	1976	143	106[5][6]/152[7]	13.7
Syncrude Tailings Dam Mildred SWSS[8]	Canada	2010	40-50	119[4]	0.25[4]
Fort Peck Dam[9]	United States	1940	76.4	96	23
Atatürk Dam[10]	Turkey	1990	166	84.5	48.7
Flevoland Dyke	Netherlands	1968	13	78[4]	0 [11]
Oahe Dam[9]	United States	1963	75	70.3	29
Gardiner Dam[12]	Canada	1967	64	65.4	9.4
Mangla Dam	Pakistan	1967	138	65.4	7.25
Oroville Dam	United States	1968	230	59.6	4.36
San Luis Dam (B F Sisk Dam)	United States	1967	93	59.6	2.52
Nurek Dam	Tajikistan	1980	300	54	10.5
Samara Dam (Kuybyshev Reservoir)	Russia	1955	52	54[4]	57.3
Garrison Dam (Lake Sakakawea)[9]	United States	1954	64	50.8	29
Cochiti Dam	United States	1975	76.5	50.2	0.73
Aswan Dam[13]	Egypt	1970	111	44.3	169
W. A. C. Bennett Dam (Williston Lake)	Canada	1968	186	43.7	7.4
ASARCO Mission Mine Tailings Dam	United States	1973	30[14]	40.1	0 [15]
Fort Randall Dam (Lake Francis Case)[9]	United States	1953	50.3	38.2	6.7
Afsluitdijk	Netherlands	1932	13	36.5[4]	5.5
San Roque Dam	Philippines	2003	200/210	35[4]	0.835

Types of dams by STRUCTURE

- Arch dams
  – Concrete made arch shape the force of water is distributed into the foundations and sides
- Gravity dams
  – Massive size made from concrete and stones.
- Arch-gravity dams

- Embankment dams
  - Made form various materials like sand, soil, clay or rock etc. the force of water on side is shifted downwards.
- Rock-fill dams
  - The Embankments are covered with rocks.
- Earth-fill dams
  - Earth dam is entirely constructed of one type of material usually near by the dam site, **Terbela dam is the world largest Earth fill dam.**
- Concrete-face rock-fill dams
  - Concrete + rock fill.
- Barrages
  - Special kind having Gates to control the flow of water.

Calculating Available Power

A simple formula for approximating electric power production at a hydroelectric station is

$$P = \rho h r g k$$

where

P is Power in watts,

ρ is the density of water (~1000 kg/m^3),

h is height in meters,

r is flow rate in cubic meters per second,

g is acceleration due to gravity of 9.8 m/s^2,

K is a coefficient of efficiency ranging from 0 to 1. Efficiency is often higher (that is, closer to 1) with larger and more modern turbines.

Example : A reservoir with a capacity of 6 x 10"m with available head of 200m for the production of power, If the overall efficiency of the system is 70%, determine the energy in KWH that can be made available.

Given that:

Reservoir capacity is the volume available V= 6 × 10 ^10 m^3
Available head of water H = 200m
Overall efficiency 70% or 0.7

E= pnVgh

1000x 0.7 x6x10^10 x 9.81x 200

8.24 x 10J (W-s) or 2.28 x 10^10 kWh

Example : Water for a small hydroelectric station is to be made available from a pondage with a volume of 5 x 10'm located at a height up hill to provide water at a head of 100m at a hydraulic efficiency of 85% If the electrical efficiency is 94% and the water supply is available for 8 hours daily, determine the capacity of the generator to be installed at the power station.

Given that:

Available volume at pondage: V = 5 x 10^5 m^3

Available head: h = 100m

Hydraulic efficiency: 85% 0.85

Electrical e efficiency: 0.94

Therefore: Overall efficiency: 0.85 x 0.94= 0.80

Using: E= npghV = 0.8 x 1000 x 9.81 x 100 x 5x 10^5

E = 3.92 x 10^ 11 W-s

Advantages

Advantages

(i) It requires no fuel as water is used for the generation of electrical energy.

(ii) It is quite neat and clean as no smoke or ash is produced.

(iii) It requires very small running charges because water is the source of energy which is available free of cost.

(iv) It is comparatively simple in construction and requires less maintenance.

(v) It does not require a long starting time like a steam power station. In fact, such plants can be put into service instantly.

(vi) It is robust and has a longer life.

(vii) Such plants serve many purposes. In addition to the generation of electrical energy, they also help in irrigation and controlling floods.

(viii) Although such plants require the attention of highly skilled persons at the time of construction, yet for operation, a few experienced persons may do the job well.

Disadvantages

Disadvantages

(*i*) It involves high capital cost due to construction of dam.

(*ii*) There is uncertainty about the availability of huge amount of water due to dependence on weather conditions.

(*iii*) Skilled and experienced hands are required to build the plant.

(*iv*) It requires high cost of transmission lines as the plant is located in hilly areas which are quite away from the consumers.

end