Lecture 25: Hydro Power Plants

Course: MECH-422 – Power Plants

Instructor: Kashif Liaqat

Term: Fall 2021

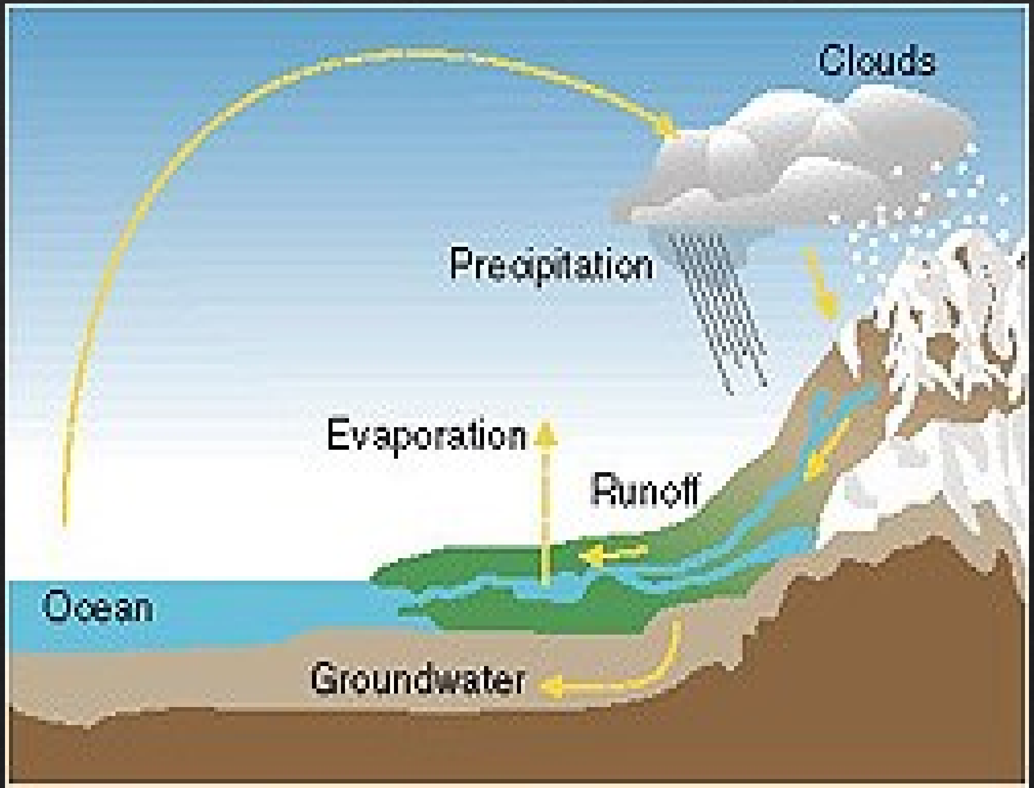
BUITEMS – DEPARTMENT OF MECHANICAL ENGINEERING

HydroPower

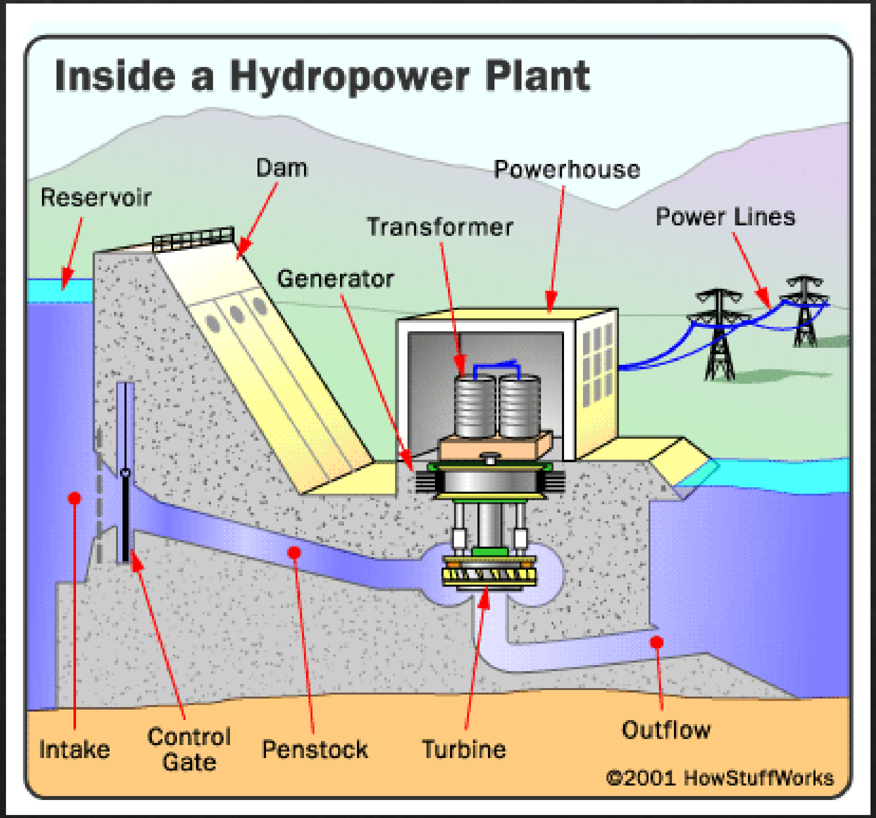
- Hydro means "water". So, hydropower is "water power" and hydroelectric power is electricity generated using water power.
- Potential energy (or the "stored" energy in a reservoir) becomes kinetic (or moving energy).
- This is changed to mechanical energy in a power plant, which is then turned into electrical energy.
- Hydroelectric power is a renewable resource.

How Hydropower Works!

- Hydrologic cycle



Components Of The Plant



Components Of The Plant

a) **The reservoir:**

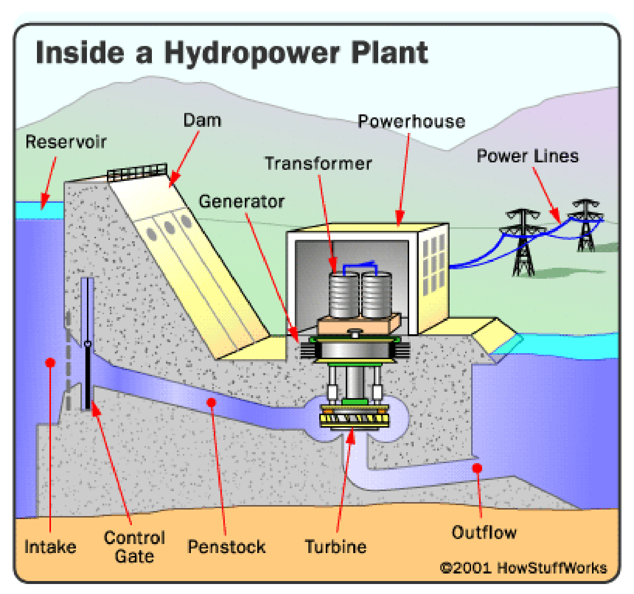
Water from a natural water body like a river is stored in the reservoir. This reservoir is built at a level higher than the turbine.

b) The dam:

The flow of water stored in the reservoir is obstructed by huge walls of the dam.

This prevents the water from flowing and helps us harness the energy present in it.

The dam consists of gates present at its bottom, which can be lifted to allow the flow of water through them.



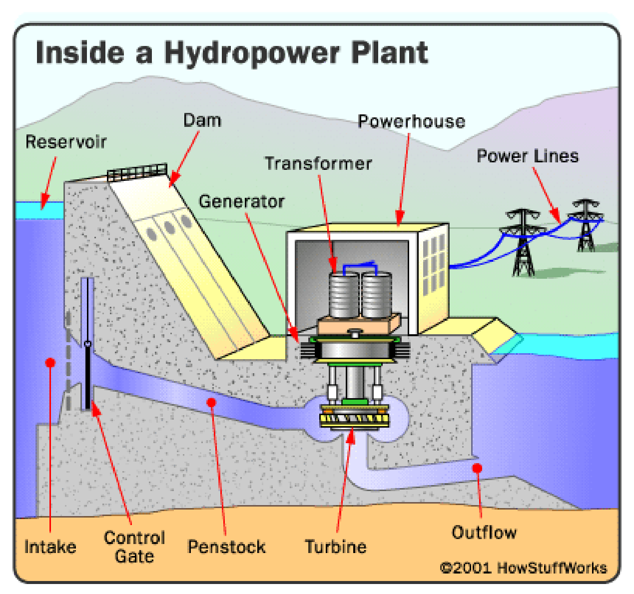
Components Of The Plant

c) The penstock:

This connects the reservoir with the turbine propeller and runs in a downward inclined manner. When the gates of the dam are lifted, the force of gravity makes the water flow down the penstock and reach the blades of the turbine. As the water flows through the penstock, the potential energy of water stored in the dam is converted into kinetic energy.

d) The turbine:

The kinetic energy of the running water turns the blades of the turbine. The turbine can be either a Pelton Wheel Model or a Centrifugal type. The turbine has a shaft connected to the generator.



15.7 CLASSIFICATION OF HYDRO-PLANT

The hydroelectric power plants can be classified as follows:

1. *According to the availability of water head,*

(a) High-head plant > 100 m.

(b) Low-head plant < 30 m.

(c) Medium-head plant 30 – 100 m.

2. *According to the nature of load,*

(a) Base load plant

(b) Peak load plant peak

(c) Storage-type plants

3. *Run-off river power plants*

(a) With pondage

(b) Without pondage

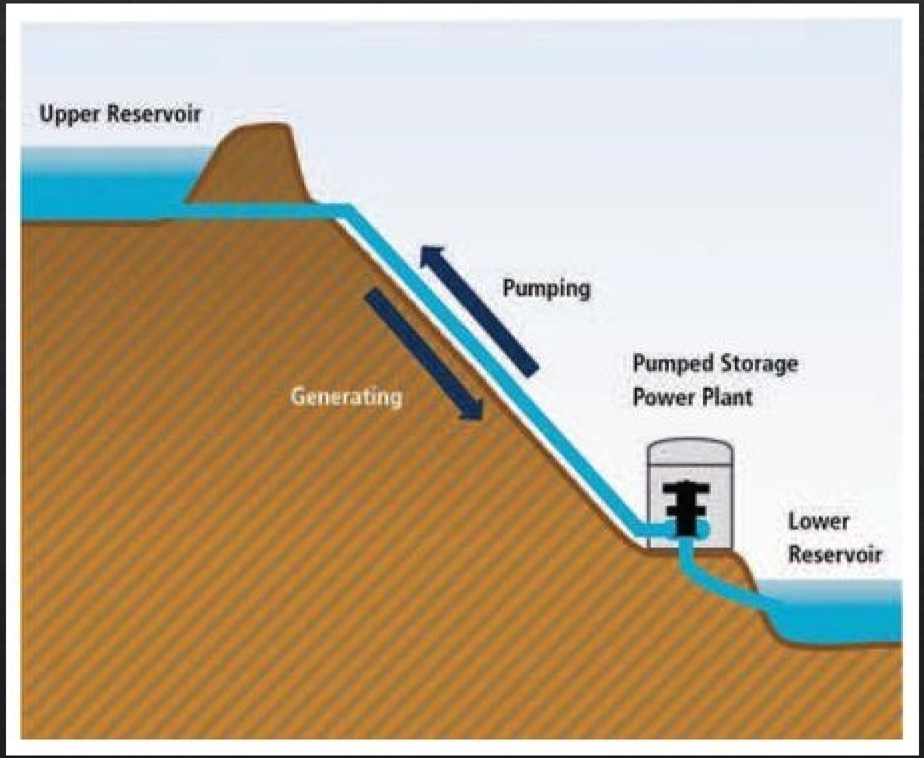
4. *Pumped storage power plants*
5. *Mini- and micro-hydel plants*

Dam Hydro

Run-off river

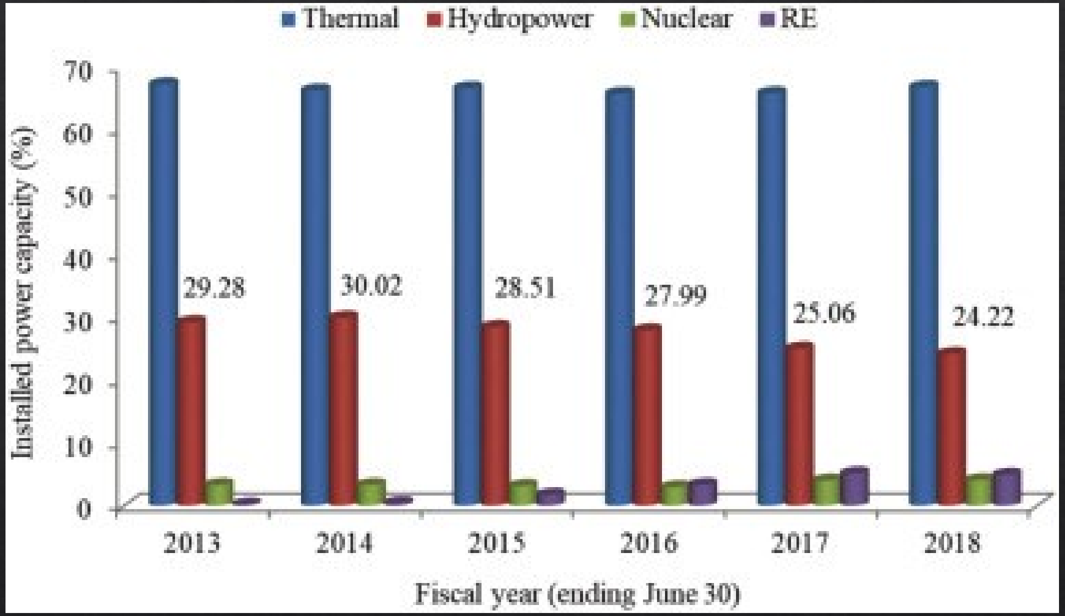
Pump Storage Hydropower Plant

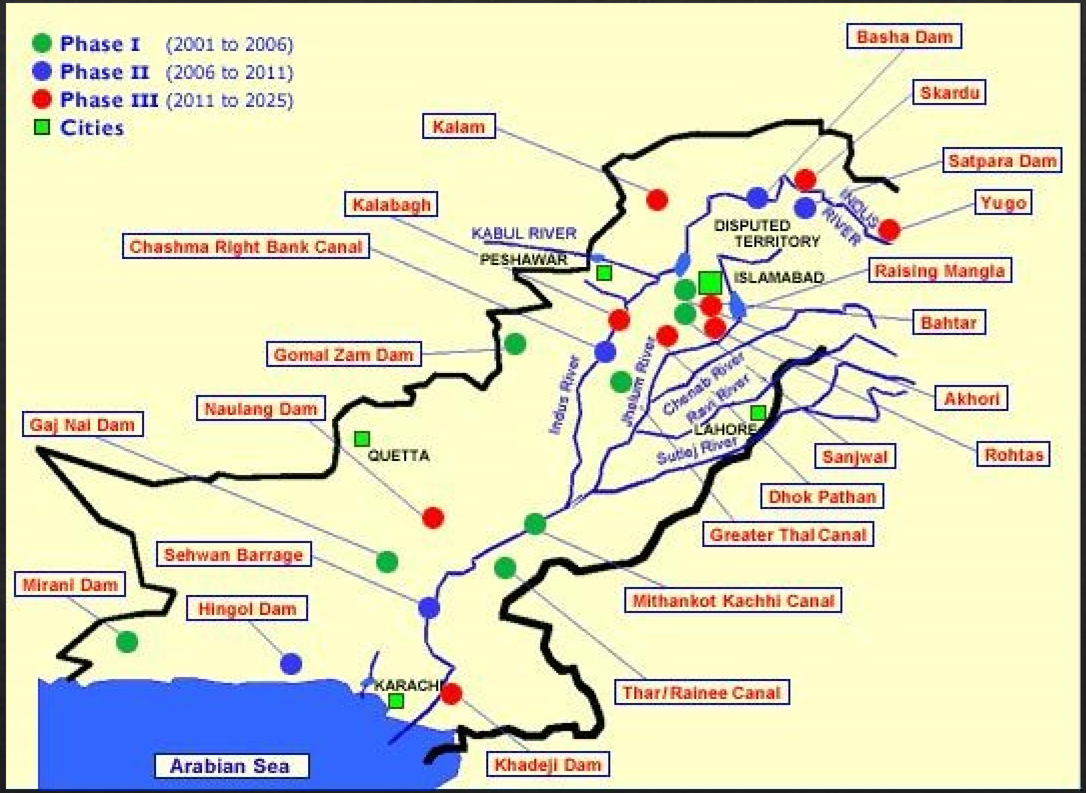
- Pumped storage plants are not energy sources, instead they are storage devices
- Water is pumped from a lower reservoir into an upper reservoir, usually during off-peak hours, while flow is reversed to generate electricity during the daily peak load period or at other times of need
- Although the losses of the pumping process make such a plant a net energy consumer, the plant provides large-scale energy storage system benefits
- Pumped storage is the largest capacity form of grid energy storage now readily available worldwide



Pakistan

- Pakistan is endowed with considerable water resources. According to Pakistan's Water and Power Development Authority (WAPDA), there is 60,000 MW of hydropower potential in the country, of which only 7,320 MW has been developed – 2017

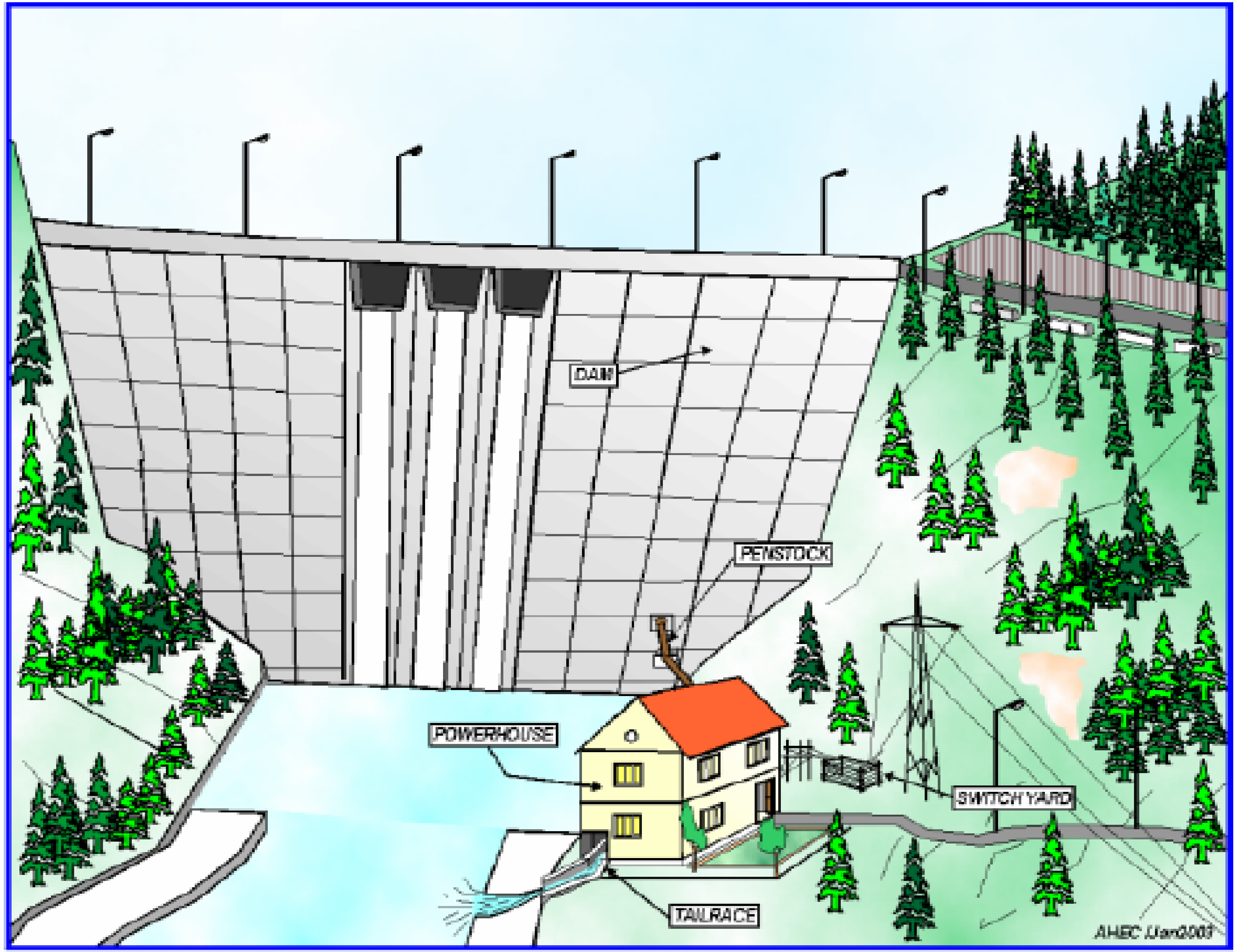




Phase I (2001 to 2006)
Phase II (2006 to 2011)
Phase III (2011 to 2025)
Cities
Basha Dam
Skardu
Kalam
Satpara Dam
Yugo
Kalabagh
Chashma Right Bank Canal
KABUL RIVER
PESHAWAR
DISPUTED TERRITORY
INDUS RIVER
ISLAMABAD
Raising Mangla
Bahtar
Gomal Zam Dam
Naulang Dam
Gaj Nai Dam
QUETTA
Indus River
Jhelum River
Chenab River
Ravi River
LAHORE
Sutlej River
Akhori
Rohtas
Sanjwal
Dhok Pathan
Greater Thal Canal
Sehwan Barrage
Mirani Dam
Hingol Dam
Mithankot Kachhi Canal
KARACHI
Thar/Rainee Canal
Arabian Sea
Khadeji Dam

Tarbela Dam

- Three Gorges Dam of China, a marvel of modern engineering, has the world's largest instantaneous generating capacity of 22,500 MW. It is the biggest hydro dam in the world.



Typical Arrangement of Dam toe Small Hydro Power Station https://www.youtube.com/watch?v=q8HmRLCgDAI

General Formulas

- Density=mass/volume
- W=m x g
- Density of water =1000Kg/m^3
- hydraulic efficiency x electrical efficiency= overall efficiency

Available Hydro Power

- The power that can be extracted from a waterfall depends upon its height and rate of flow.
- The available hydro power can be calculated by the following equation:
    - $P=9.8qh$
- P=available water power[kW]
- q=water rate of flow [m^3/s]
- h= head of water [m]

Example

- A large hydropower station has a head of 324m and an average flow of 1370m^3/s. The reservoir of water covers an area of 6400Km^2. Calculate
  - the available hydraulic power

Solution

- The available hydropower can be found using the equation
- P=9.8qh
- P=9.8 x 1370 x 324=4350MW

Advantages

- Renewable
- Clean
- Cheap

Environmental Impact and Drawbacks

- Large hydroelectric dams have a number of negative impacts on the local environment and human society. Dams disrupt river ecosystems and migrations, killing aquatic life that gets caught in turbine blades. Dams also create artificial reservoirs, which floods farmland and forests, and displaces wildlife and people. Hydroelectric projects are also susceptible to fluctuations in river flows and rainfall. Ghana, which depends on energy from the Volta River Dam, has suffered severe energy shortages in recent years because of lack of rainfall.

- Disappropriating and resettlement represents a mammoth political and management challenge. Related costs can increase project costs by as much as 10% if planned poorly.

HYDROPLANT	COUNTRY	POPULATION DISPLACED
Danjiangkou	China	383000
Aswan	Egypt	120000
Volta	Ghana	78000
Narmada Sardar Sarovar	India	70000
Three Gorges	China	2000000

Generating Technologies

- Types of Hydro Turbines:
  - Impulse turbines
    - Pelton Wheel
    - Cross Flow Turbines
  - Reaction turbines
    - Propeller Turbines : Bulb turbine, Straflo, Tube Turbine, Kaplan Turbine
    - Francis Turbines
    - Kinetic Turbines

Impulse Turbines

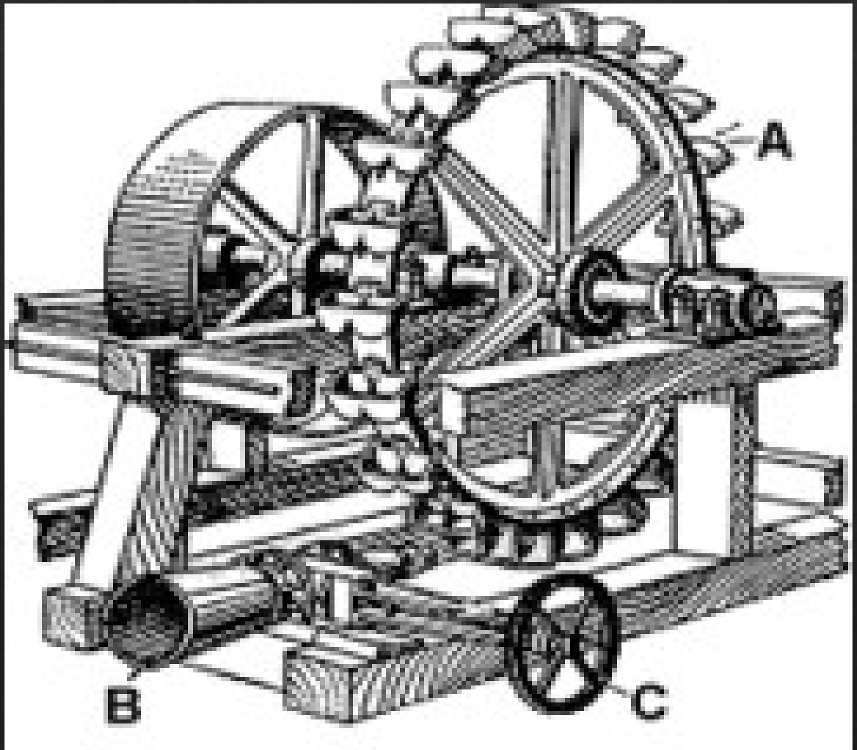
- Uses the velocity of the water to move the runner and discharges to atmospheric pressure.
- The water stream hits each bucket on the runner.
- No suction downside, water flows out through turbine housing after hitting.
- High head, low flow applications.
- Types : Pelton wheel, Cross Flow

Pelton Wheels

- Nozzles direct forceful streams of water against a series of spoon-shaped buckets mounted around the edge of a wheel.
- Each bucket reverses the flow of water and this impulse spins the turbine.

Pelton Wheels (continued…)

- Suited for high head, low flow sites.
- The largest units can be up to 200 MW.
- Can operate with heads as small as 15 meters and as high as 1,800 meters.



Pelton Wheel, p. 1593.

Reaction Turbines

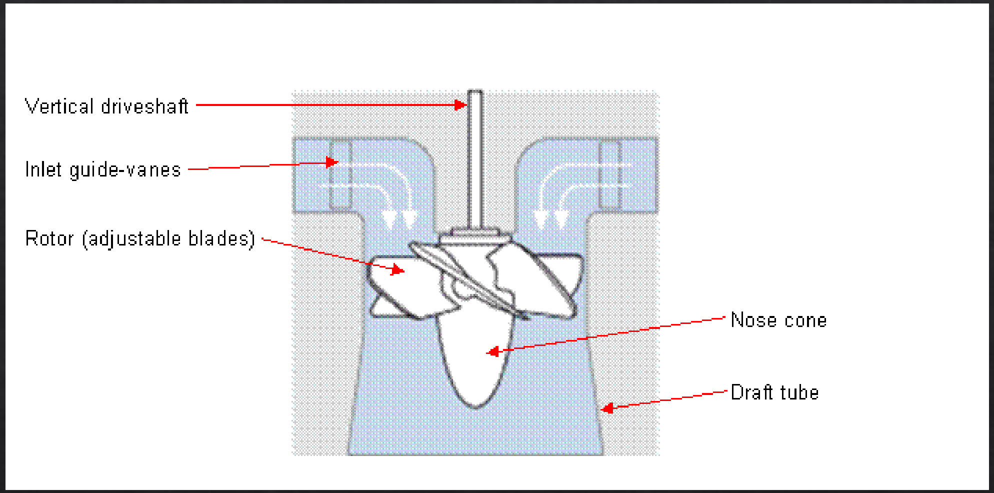
- Combined action of pressure and moving water.
- Runner placed directly in the water stream flowing over the blades rather than striking each individually.
- lower head and higher flows than compared with the impulse turbines.

Propeller Hydropower Turbine

- Runner with three to six blades.
- Water contacts all of the blades constantly.
- Through the pipe, the pressure is constant
- Pitch of the blades - fixed or adjustable
- Scroll case, wicket gates, and a draft tube
- Types: Bulb turbine, Straflo, Tube turbine, Kaplan

Kaplan Turbine

- The inlet is a scroll-shaped tube that wraps around the turbine's wicket gate.
- Water is directed tangentially, through the wicket gate, and spirals on to a propeller shaped runner, causing it to spin.
- The outlet is a specially shaped draft tube that helps decelerate the water and recover kinetic energy.



Francis Turbines

- The inlet is spiral shaped.
- Guide vanes direct the water tangentially to the runner.
- This radial flow acts on the runner vanes, causing the runner to spin.
- The guide vanes (or wicket gate) may be adjustable to allow efficient turbine operation for a range of water flow conditions.

Kinetic Energy Turbines

- Also called free-flow turbines.
- Kinetic energy of flowing water used rather than potential from the head.
- Operate in rivers, man-made channels, tidal waters, or ocean currents.
- Do not require the diversion of water.
- Kinetic systems do not require large civil works.
- Can use existing structures such as bridges, tailraces and channels.

Table 7.2. Comparison of different types of turbines.

Parameters	Pelton turbine	Frances turbine	Kaplan turbine
Turbine type	Impulse turbine	Combination of impulse and reaction turbine	Purely reaction turbine
Flow type	Axial flow turbine	Mixed flow turbine	Axial flow turbine
Number of vanes and buckets	Wheel with 20–40 buckets	Impeller with 16–24 vanes	Impeller with 4–8 vanes
Head requires	Very high head (above 300–400 m)	Medium head (about 100–300 m)	Low head (below 100 m)
Flow rate	Low flow rate	Medium flow rate	Very large flow rate
Specific speed	Low specific speed	Medium specific speed (about 50–250 rpm)	High specific speed (about 250–1000 rpm)
Adjustment of runner vanes	Fixed buckets at the periphery of the wheel	Runner vanes are fixed with the shaft so it can't be adjusted	Runner vanes are adjustable
Force on the blade	$F_{blade} = F_{impulse}$	$F_{blade} = F_{lift} + F_{impulse}$	$F_{blade} = F_{lift}$
Overall efficiency	About 85%–95%	Above 90%	About 90%–93%

End of Lecture!