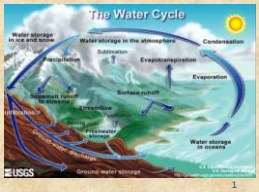
Hydropower Energy

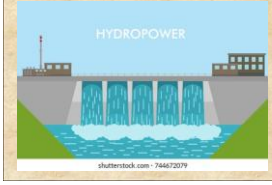


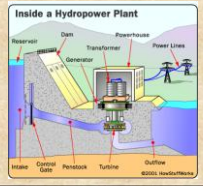
Introduction to the lecture

- Hydropower lecture is divided into 3 parts.
- Part 1 focuses on the basic concept of hydro energy i.e. definition of hydro power, history of hydro power, advantage and disadvantages of hydro power and modern usage of hydro power.
- Part 2 provides an overview on hydro power plant. This part discusses the layout, elements of a hydro power plant, mechanism and types of hydro power plant.

Introduction to the lecture

- This part also discusses the quantification electricity production of a hydro power plant.
- Part 3 focuses on the environmental and social impacts, life cycle assessment of environmental impacts and planning hydro power system by students.





Aim and Learning outcomes

- The aim is to introduce students to understand the hydro power system, generation of electricity and impacts of hydro power system.
- On completion of lecture “Hydropower Energy, students will be able to:
  - Describe the general historical development of hydropower.
  - Classify hydropower based on capacity, storage type, and head.

Aim and Learning outcomes

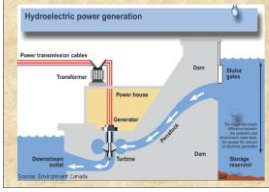
- On completion of lecture “Hydropower Energy, students will be able to:
  - Learn key components of a micro/small-scale hydropower system.
  - Understand the layout of a hydropower plant.
  - Describe working principles of a hydropower system.
  - Know the hydropower energy production, distribution and trends in the world.

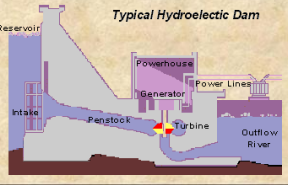
Talk outline

- **Part-I**
- **Introduction – Hydro Energy**
  - **Hydropower History**
  - **Advantage and disadvantage of hydropower**
  - **Modern usage of hydropower**

Talk outline

- **Part-II**
- **How does a hydro power plant work**
  - **Layout of hydropower plant**
  - **Elements of hydro power plant**
  - **Mechanism of hydropower plant**
  - **Types of plant**
  - **How much electricity can be produced**

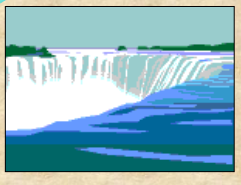


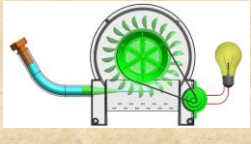


Talk outline

- **Part-III**
  - **Environmental and social impacts**
  - **Lifecycle assessment of environmental impacts**
  - **Planning your own Hydro System**

What is Hydropower





➢Hydroelectric power (often called hydropower) is considered a renewable energy source

A renewable energy source is one that is not depleted (used up) in the production of energy

Through hydropower, the energy in falling water is converted into electricity without "using up" the water.

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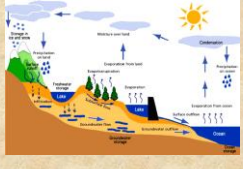

➢ Hydropower energy is ultimately derived from the sun, which drives the water cycle

In the water cycle, rivers are recharged in a continuous cycle

Because of the force of gravity, water flows from high points to low points

There is **kinetic energy** present in the flow of water.

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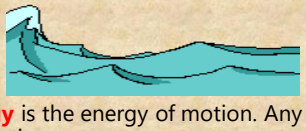

Kinetic energy is the energy of motion. Any moving object has kinetic energy.

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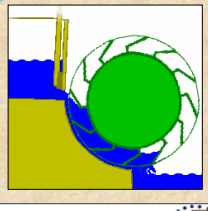
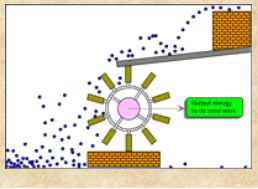




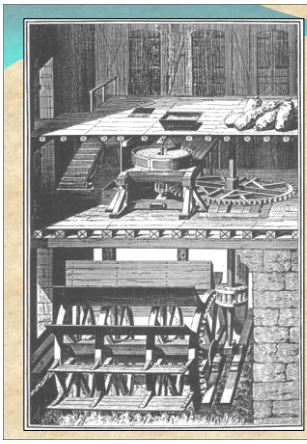
➢Humans first learned to control the kinetic energy in water by using waterwheels

A waterwheel is a revolving wheel fitted with blades

Waterwheels convert the kinetic energy of flowing water to mechanical energy.

Cont'd……

- Mechanical energy is a form of kinetic energy, such as in a machine.
- Mechanical energy has the ability to do work
- Any object that is able to do work has mechanical energy.



- Early waterwheels used mechanical energy to grind grains and to drive machinery such as sawmills

Cont'd……

- After the discovery of electricity
- It was realized that a turbine's mechanical energy could be used to activate a generator and produce electricity
- The first hydroelectric power plant was constructed in 1882 in Appleton, Wisconsin
- It produced 12.5 kilowatts of electricity which was used to light two paper mills and one home.

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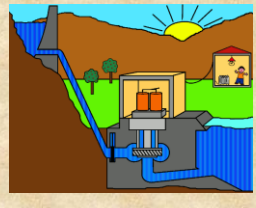
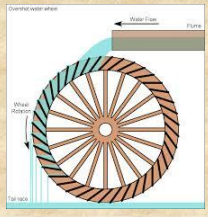


- Hydroelectric power systems convert the kinetic energy in flowing water into electric energy.

History of Hydropower

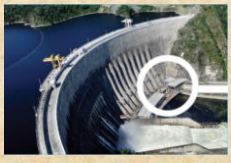
- Hydropower has been used for centuries
- The Greeks used water wheels to grind wheat into flour more than 2,000 years ago
- In the early 1800s, American and European factories used the water wheel to power machines

History of Hydropower



- The water wheel is a simple machine
- The water wheel is located below a source of flowing water
- It captures the water in buckets attached to the wheel and
- The weight of the water causes the wheel to turn
- That energy can then be used to grind grain, drive sawmills, or pump water.

History of Hydropower

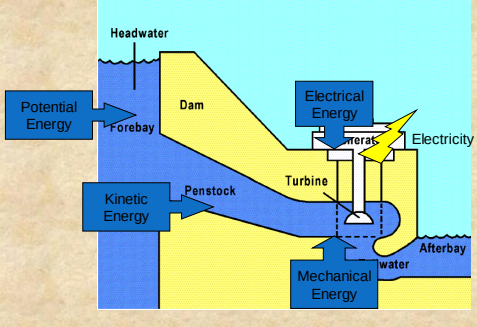


- In the late 19th century, the force of falling water was used to generate electricity
- The first hydroelectric power plant was built on the Fox River in Appleton, WI in 1882
- In the following decades, many more hydroelectric plants were built

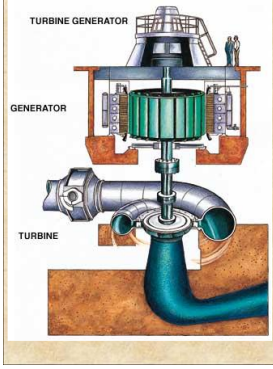
History of Hydropower

- By the late 1940s, the best sites for big dams had been developed
- At that time, plants burning coal or oil could make electricity more cheaply than hydro plants

Hydropower to Electric Power



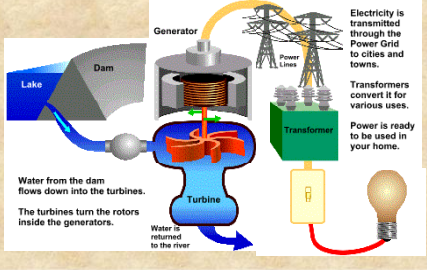
How a Hydroelectric Power System Works



- Flowing water is directed at a turbine (remember turbines are just advanced waterwheels).
- The flowing water causes the turbine to rotate,
- Converting the water's kinetic energy into mechanical energy.

How a Hydroelectric Power System Works

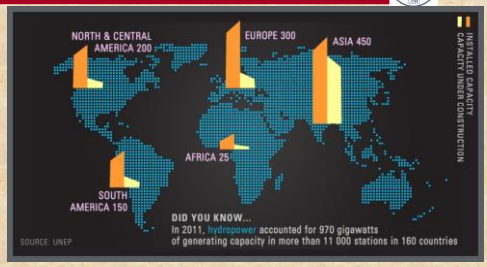
The mechanical energy produced by the turbine is converted into electric energy using a turbine generator. Inside the generator, the turbine spins a magnet inside coils of copper wire. It is a fact of nature that moving a magnet near a conductor causes an electric current.



Hydropower in Context

Global View

world distribution of hydropower



Hydropower is the most important and widely-used renewable source of energy.
Hydropower represents 19% of total electricity production.
China is the largest producer of hydroelectricity, followed by Canada, Brazil, and the United States (Source: Energy Information Administration).

World Trends in Hydropower

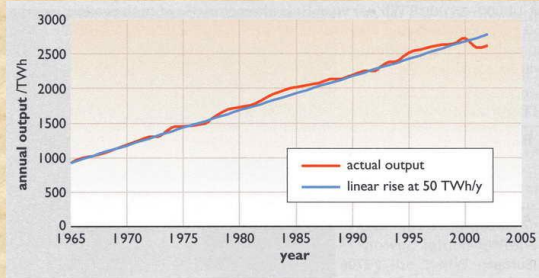


Figure 5.4 World annual hydroelectricity output, 1965–2002 (source: BP, 2003)

Boyle, *Renewable Energy*, 2nd edition, Oxford University Press, 2003

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World hydro production

Producers	TWh	% of World total
Canada	338	12.4
Brazil	306	11.2
United States	306	11.2
People's Rep. of China	284	10.4
Russia	158	5.8
Norway	106	3.9
Japan	104	3.8
India	75	2.8
France	64	2.3
Venezuela	61	2.2
Rest of the World	924	34.0
World	**2 726**	**100.0**

2003 data

Installed Capacity (based on production)	GW
United States	94
Canada	69
Brazil	65
People's Rep. of China	58
Japan	46
Russia	44
Norway	28
India	27
France	25
Venezuela	13
Rest of the World	307
World	**776**

2002 data
Sources: United Nations, IEA.

Country (based on first 10 producers)	% of hydro in total domestic electricity generation
Norway	98.9
Brazil	83.8
Venezuela	66.0
Canada	57.5
Russia	17.2
People's Rep. of China	14.9
India	11.9
France	11.4
Japan	9.9
United States	7.5
Rest of the World*	15.2
World	**16.3**

2003 data

* *Excludes countries with no hydro production.*

IEA.org

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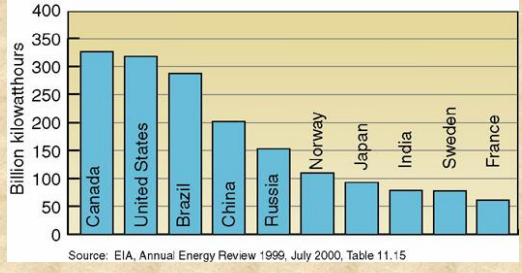
Major Hydropower Producers



Source: EIA, Annual Energy Review 1999, July 2000, Table 11.15

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Advantage to hydroelectric power

- **Advantages to hydroelectric power:**
- Fuel is not burned so there is minimal pollution
- Water to run the power plant is provided free by nature
- Hydropower plays a major role in reducing greenhouse gas emissions
- Relatively low operations and maintenance costs
- The technology is reliable and proven over time
- It is renewable - rainfall renews the water in the reservoir, so the fuel is almost always there

Disadvantage to hydroelectric power

Disadvantages to power plants that use coal, oil, and gas fuel:

- They use up valuable and limited natural resources
- They can produce a lot of pollution
- Companies have to dig up the Earth or drill wells to get the coal, oil, and gas

Hydroelectric power is not perfect, though, and does have some disadvantages:

Hydroelectric power is not perfect, though, and does have some disadvantages:

- High investment costs
- Hydrology dependent (precipitation)
- In some cases, loss or modification of fish habitat
- Fish entrainment or passage restriction
- In some cases, changes in reservoir and stream water quality
- In some cases, displacement of local populations

World's Largest Dams

Name	Country	Year	Max Generation	Annual Production
Three Gorges	China	2009	18,200 MW	
Itaipú	Brazil/Paraguay	1983	12,600 MW	93.4 TW-hrs
Guri	Venezuela	1986	10,200 MW	46 TW-hrs
Grand Coulee	United States	1942/80	6,809 MW	22.6 TW-hrs
Sayano Shushenskaya	Russia	1983	6,400 MW	
Robert-Bourassa	Canada	1981	5,616 MW	
Churchill Falls	Canada	1971	5,429 MW	35 TW-hrs
Iron Gates	Romania/Serbia	1970	2,280 MW	11.3 TW-hrs

Ranked by maximum power.

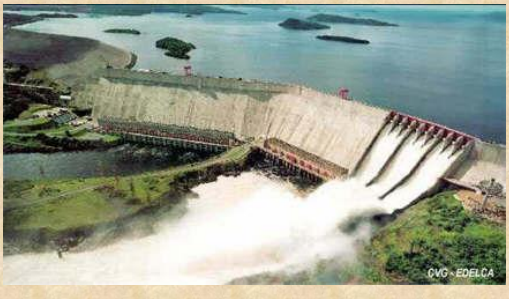
"Hydroelectricity," Wikipedia.org

Three Gorges Dam (China)

Itaipú Dam (Brazil & Paraguay)

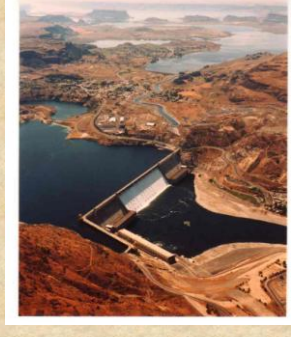
"Itaipu," Wikipedia.org

Guri Dam (Venezuela)



http://www.infodestinations.com/venezuela/espanol/puerto_ordaz/index.shtml

Grand Coulee Dam (US)



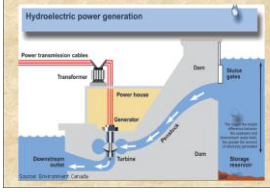
www.swehs.co.uk/docs/coulee.html

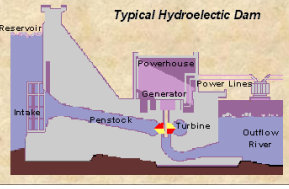
Talk outline

- Part-I
- Introduction – Hydro Energy
  - Hydropower History
  - Advantage and disadvantage of hydropower
  - Modern usage of hydropower


Talk outline

- Part-II
- How does a hydro power plant work
  - Layout of hydropower plant
  - Elements of hydro power plant
  - Mechanism of hydropower plant
  - Types of plant
  - How much electricity can be produced

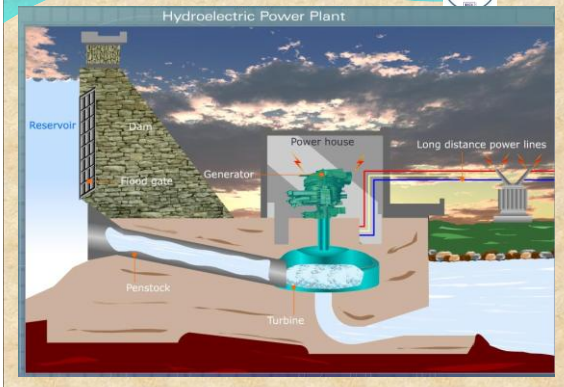




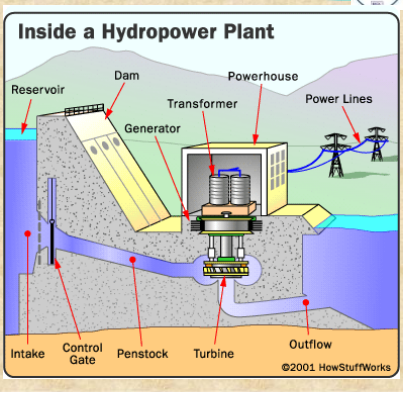
Talk outline

- Part-III
  - Environmental and social impacts
  - Lifecycle assessment of environmental impacts
  - Planning your own Hydro System


Layout of a hydropower plant



Layout of a hydropower plant



Layout of a hydropower plant

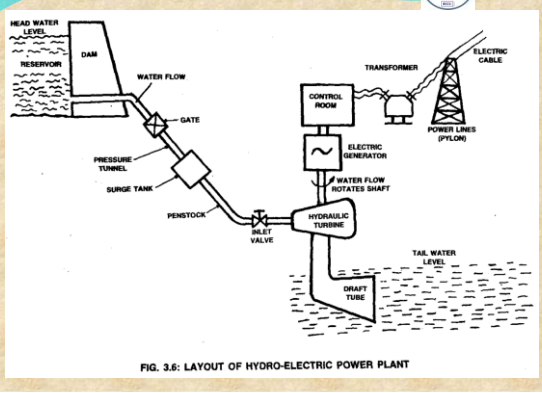
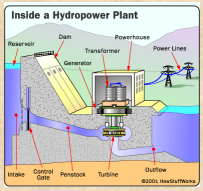
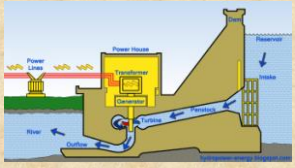


FIG. 3.6: LAYOUT OF HYDRO-ELECTRIC POWER PLANT

Components of a Hydro-Power Plant





The essential features of a hydro power plant are as below:

1. Catchment area.
2. Reservoir.
3. Dam.
4. water way.
5. Power house.
6. Tail water way or outlet.

Components of a Hydro-Power Plant

1.Catchment Area

- The catchment area of a hydro plant is the whole area behind the dam, draining a stream or river across which the dam has been built at a suitable place.

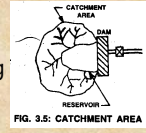
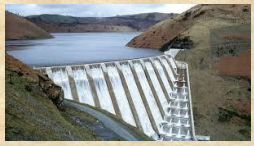


FIG. 3.5: CATCHMENT AREA

Components of a Hydro-Power Plant



2- Water reservoir:

- In a reservoir the water collected from the catchment area is stored behind a dam.
- Catchment area gets its water from rain and streams.
- The level of water surface in the reservoir is called Head water level.
- Note: Continuous availability of water is a basic necessity for a hydro-electric power plant.

Components of a Hydro-Power Plant

3- Dam :

- The purpose of the dam is to store the water and to regulate the out going flow of water.
- The dam helps to store all the incoming water. It also helps to increase the head of the water.
- In order to generate a required quantity of power it is necessary that a sufficient head is available.

- **Dam are classified based on following factors:**

a) Function
b) Shape
c) Construction material
d) Design

e) Based on function the dam may be called as storage dam, diversion dam.

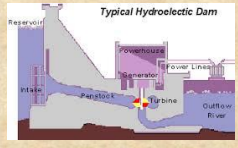
b) Based on the shape the dam may of trapezoidal section & arch type.

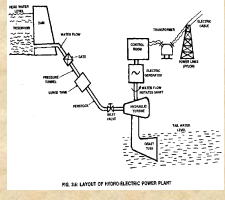
c) The materials used for constructing dams are earth, rock pieces, stone masonry.

d) According to structural design the dam maybe classified as:

i. Gravity dam
ii. Arch dam
iii. Buttress dam

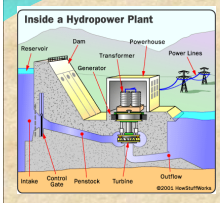
Components of a Hydro-Power Plant

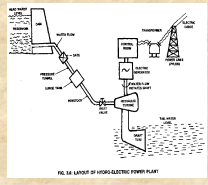




4- Water Ways.

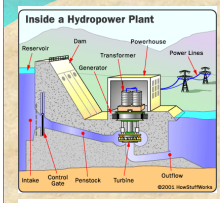
- Water ways are the passages, through which the water is conveyed to the turbines from the dam.
- These may include tunnels, forebay, penstocks and also surge tanks.
- A forebay is an enlarged passage for drawing the water from the reservoir or the river and giving it to the pipe lines or canals.

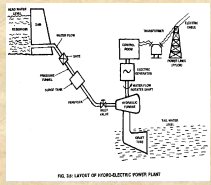




Spillway:

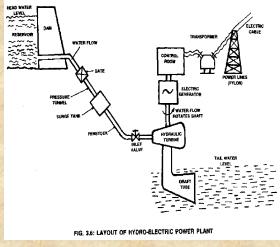
- Excess accumulation of water endangers the stability of dam construction.
- Also in order to avoid the over flow of water out of the dam especially during rainy seasons spillways are provided.
- This prevents the rise of water level in the dam.
- Spillways are passages which allows the excess water to flow to a storage area away from the dam.





Gate:

- A gate is used to regulate or control the flow of water from the dam.
- Pressure tunnel: It is a passage that carries water from the reservoir to the surge tank.

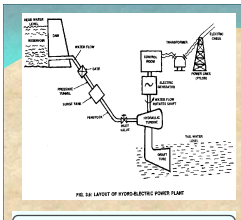


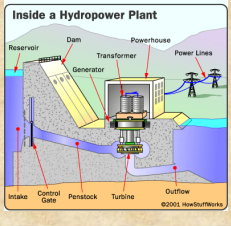
Surge tank:

- A Surge tank is a small reservoir or tank in which the water level rises or falls due to sudden changes in pressure.

Purpose of surge tank:

- To serve as a supply tank to the turbine when the water in the pipe is accelerated during increased load conditions and
- As a storage tank when the water is decelerating during reduced load conditions.
- To reduce the distance between the free water surface in the dam and the turbine, thereby reducing the water-hammer effect on penstock and also protect the upstream tunnel from high pressure rise.





Penstock:

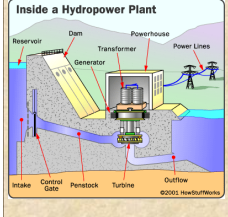
- Penstock is a closed pipe of steel or concrete for supplying water under pressure to the turbine

Inlet valve :

- Water from the penstock flows to the turbine through the inlet valve.
- The valve may be partially closed or open thereby regulating the pressure of water flowing to the turbine.

Hydraulic turbine(Prime mover)

- The hydraulic turbine converts the energy of water into mechanical energy.

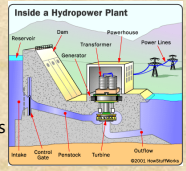


- The mechanical energy(rotation) available on the turbine shaft is coupled to the shaft of an electric generator and electricity is produced.
- The water after performing the work on turbine blades is discharged through the draft tube.
- The prime movers which are in common use are Pelton wheel, Francis turbine and Kaplan turbine.

5- Power House.

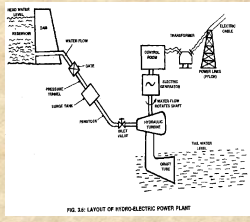
The power house is a building in which the turbines, alternators and the auxiliary plant are housed. Some important items of equipment provided in the power house are as follows:

i. Turbines
ii. Generators
iii. Governors
iv. Relief valve for penstock setting
v. Gate valve
vi. Transformer
vii. Switch board equipment and instruments
viii. Oil circuit breaker
ix. Storage batteries
x. Outgoing connections
xi. Cranes
xii. Shops & offices



Draft tube:

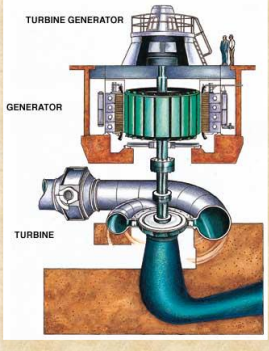
- It is connected to the outlet of the turbine.
- It allows the turbine to be placed above the tail water level.



6- Tail water level or Tail race:

- Tail water level is the water level after the discharge from the turbine. The discharged water is sent to the river, thus the level of the river is the tail water level.

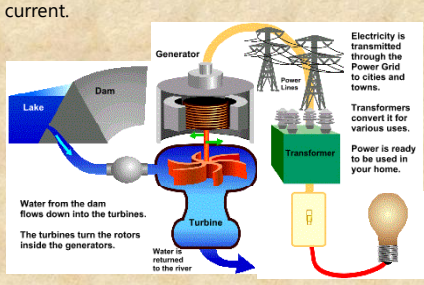
How a Hydroelectric Power System Works



- Flowing water is directed at a turbine (remember turbines are just advanced waterwheels).
- The flowing water causes the turbine to rotate,
- Converting the water's kinetic energy into mechanical energy.

How a Hydroelectric Power System Works

The mechanical energy produced by the turbine is converted into electric energy using a turbine generator. Inside the generator, the turbine spins a magnet inside coils of copper wire. It is a fact of nature that moving a magnet near a conductor causes an electric current.



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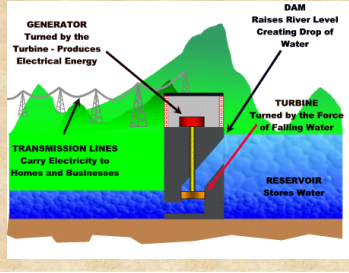


Classification of hydro-Electric power plant

The classification of hydro electric power plant depend on the following factors:

1) Quantity of water:

It is following types.

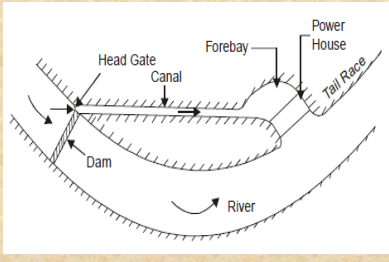
i. Run of river plant.
ii. Storage plant.
iii. Pumped storage.

2) Availability of Head of Water:

a) Low head plant. Operating head < 15m.
b) Medium head plant. Operating head 15 to 50m.
c) High head plants Operating head > 50m.

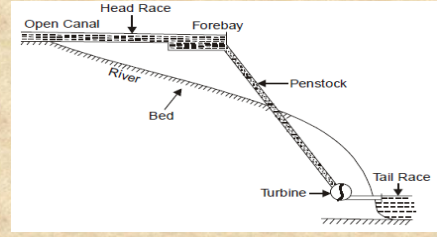
a) Low head plant

- Operating head is less than 15m.
- Vertical shaft Francis turbine or Kaplan turbine.
- Small dam is required.



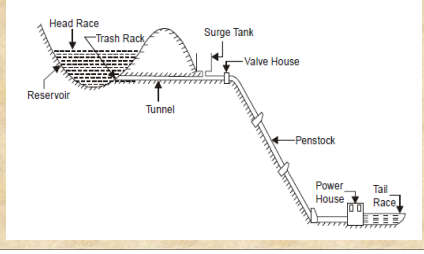
a) Medium head plant

- Operating head is less than 15 to 50m.
- Francis turbines.



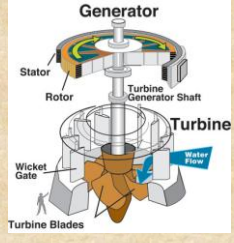
a) High head plant

- Operating head exceed 50m.
- Pelton turbines.
- surge tank is attached to the penstock to reduce water hammer effect on the penstock.

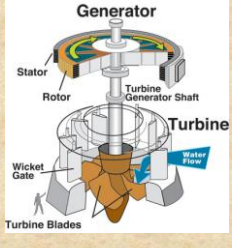


Hydraulic Turbines

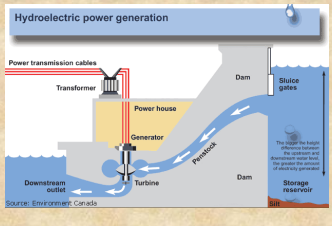
- Turbines are used to convert the energy water of falling water into mechanical energy.
- Water turbine is a rotary engine that takes energy from moving water.
- Flowing water is directed on to the blades, creating a force on the blades



Hydraulic Turbines



- **Types of turbines:**
- **Impulse**
- **Reaction**



Power generation

The amount of electricity that can be generated by a hydropower plant depends on two factors:

- **flow rate** - the quantity of water flowing in a given time; and
- **head** - the height from which the water falls.

The greater the flow and head, the more electricity produced.

Flow Rate = the quantity of water flowing
Head = the height from which water falls

A standard equation for calculating energy production:

$$\text{Power} = \frac{(\text{Head}) \times (\text{Flow}) \times (\text{Efficiency})}{11.8}$$

Power = the electric power in kilowatts or kW

Head = the distance the water falls (measured in feet)

Flow = the amount of water flowing (measured in cubic feet per second or **cfs**)

Efficiency = How well the turbine and generator convert the power of falling water into electric power. This can range from 60% (0.60) for older, poorly maintained hydroplants to 90% (0.90) for newer, well maintained plants.

11.8 = Index that converts units of feet and seconds into kilowatts

As an example, let's see how much power can be generated by the power plant.

The dam is 357 feet high, the **head** (distance the water falls) is 235 feet. The typical **flow rate** is 2200 cfs. Let's say the turbine and generator are 80% efficient.

$$\text{Power} = \frac{(\text{Head}) \times (\text{Flow}) \times (\text{Efficiency})}{11.8}$$

$$\text{Power} = \frac{235\text{ft.} \times 2200\text{ cfs} \times .80}{11.8}$$

$$\text{Power} = \frac{517{,}000 \times .80}{11.8}$$

$$\text{Power} = \frac{413{,}600}{11.8}$$

Power = 35,051 kilowatts (kW)

Planning your own hydro system

- How to measure head and flow

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Planning your own hydro system

Measuring head:
Head can be measured as vertical distance (feet or meters)
Or as pressure (pounds per square inch)

1 vertical feet = 0.433 psi
1 psi = 2.31 vertical feet

Direct distance measurement: