ENERGY, ENVIRONMENT AND SOCIETY

Chapter - 8

Hydropower (Basics and Types)

Assoc. Prof. Manchan Tiwari

Kathmandu Engineering College

Nepal

LEARNING OBJECTIVES OF THE LECTURE

- Basics of hydropower
- Source of energy for hydropower
- Hydropower equation
- Types of hydropower
- Classifications of turbines
- Importance of micro hydro power in context of Nepal

SOURCE OF ENERGY FOR HYDROPOWER

- The source of energy of hydropower is water flowing in a river.
- It is important to know that why the water flows continuously in a river.
- It is due to hydrological cycle of water which feds water in a river continuously.
- Hence the source of energy of hydropower can be termed as hydrological cycle in indirect terms.

HYDROLOGICAL CYCLE

- The water cycle, also known as the hydrological cycle describes the continuous movement of water on, above and below the surface of the Earth.
- The mass of water on earth remains fairly constant over time but the partitioning of the water into the major reservoirs of ice, fresh water, saline water and atmospheric water is variable depending on a wide range of climatic variables.
- The water moves from one reservoir to another, such as from river to ocean, or from ocean to atmosphere, by the physical processes of evaporation, condensation, precipitation, infiltration, runoff, and subsurface flow.
- In doing so, the water goes through different phases: liquid, solid (ice) and gas (vapor).

HYDROPOWER PLANT

- Hydropower plant is an energy system which derives its power from the flowing river system.
- The water is either stored in a reservoir or blocked by weir/dam from where the water is diverted through canal and/or penstock pipe to rotate a turbine in powerhouse.
- The rotating turbine drives generators that produce electricity.
- The amount of water which flows in the river and the height from which it falls (head) is directly proportional to the power capacity of hydropower.
- Basically in a hydropower the potential energy of the water is converted to kinetic energy in the nozzle which is then converted to mechanical energy in turbine.
- The mechanical energy of the turbine is converted to electrical energy by generator.

TYPES OF HYDROPOWER PLANT

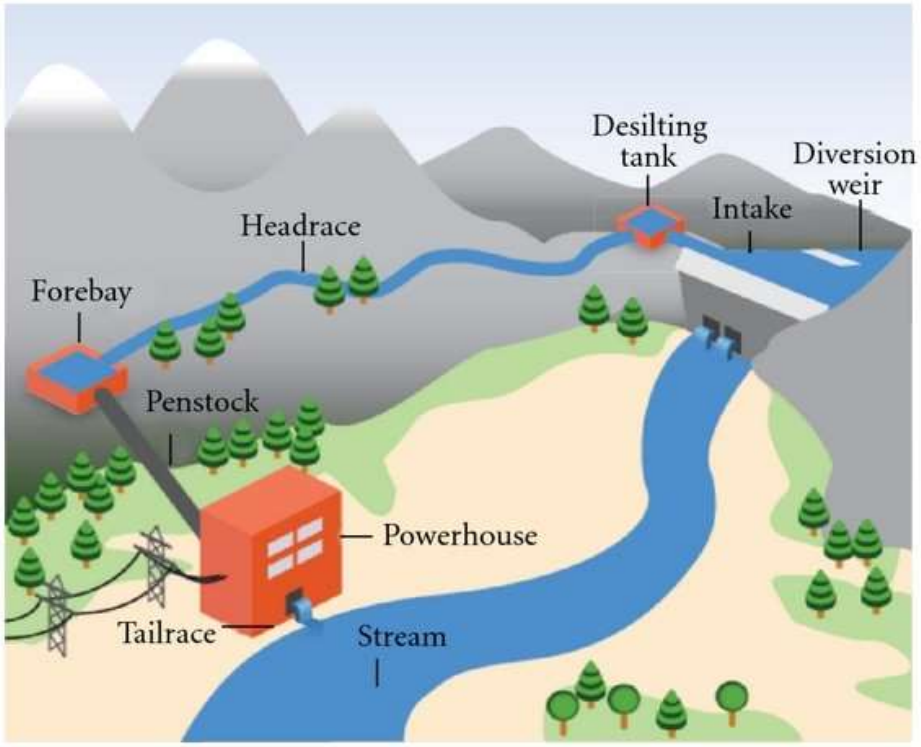
- On the basis of capacity
  - Pico hydro : less than 5 kW
  - Micro hydro: 5 kW to 100 kW
  - Mini hydro: 100 kW to 1000 kW
  - Small hydro: 1000 kW to 10 MW
  - Medium hydro: 0 MW to 300 MW
  - Large hydro: Above 300 MW
- On the basis of working principal

TYPES OF HYDROPOWER PLANT

- On the basis of working principal
  - Run-off river type
  - Reservoir/Pondage type
  - Pump storage type

TYPES OF HYDROPOWER PLANT

- Run-off river type
  - Uses water within the range of natural river flow
  - Seasonal variation of flow results in varying power production
  - No storage of water energy



Run-off river type
(Source: Researchgate, 2022)

TYPES OF HYDROPOWER PLANT

- Reservoir/Pondage type
  - Has a reservoir that enables regulating the river flow
  - Supplies power in response to the demand
  - Head may alter as per reservoir water level

TYPES OF HYDROPOWER PLANT

- Pump storage type
  - Has an upper reservoir and a lower reservoir
  - Generates power during peak demand
  - Pumps up water during low demand
  - Improves load factor

TYPES OF HYDROPOWER PLANT

- The hydropower can be runoff type or storage (reservoir/pondage) type.
- In run off type, the flowing water is directly fed in to hydropower plant where as in storage type the water from river is first brought in to a storage and then fed in to hydropower plant.
- The main disadvantage of run off type is that if the river flow decreases then the power output of the hydropower also decreases and in case of storage type even in the river flow decreases the storage ensures that the flow required for hydropower is met so that there is no considerable change in power output of the plant.
- In some cases the pump storage type is also used.
- In pump storage type the water from turbine exit is again pumped back in to reservoir during the low electricity demand period so as to meet the electricity demand during high/peak demand period.

POWER EQUATION FOR HYDROPOWER

- Micro Hydro Power (MHP) uses mechanical energy of water in streams.
- The energy of water in the streams in present in the form of kinetic and potential energy.
- Kinetic energy of water is due to its velocity of flowing water in river, and potential energy is due to its altitude relative to a provided reference.
- Energy stored in water body at a height (h) above a certain reference can be expressed as
- $E = m\ g\ h$

POWER EQUATION FOR HYDROPOWER

- $E = m\ g\ h$ ---------- (1)
- Where,
  - E = energy of water in Joules
  - m = mass of water in kg
  - g = acceleration due to gravity in m/s^2 and
  - h = elevation of water with respect to the sea level in m

POWER EQUATION FOR HYDROPOWER

- Equation 1 can be rewritten as
- $E = \rho \times V \times g \times h$ [(kg/m3) x (m3) x (m/s2) x m]
  - [where V = volume, ρ = density of water]
- = 1000 x V x g x h [kg x (m/s2) x m]
- = 1000 x V x g x h [N x m]
- = 1000 x V x g x h [J]

POWER EQUATION FOR HYDROPOWER

- So, the power can be calculated as
- $P = E/t$ [J/s]
- $= 1000 \times V \times g \times h/t$ [W]
- $= 1000 \times (V/t) \times g \times h$ [W]
- $= Q \times g \times h$ [kW] [where $Q = V/t$ is the flow rate]

POWER EQUATION FOR HYDROPOWER

- Previous equation represents the theoretical power that may be generated from elevated water. In reality some losses are involved in power generation. Let h be the efficiency of the process of power generation.
- Then the equation may be rewritten as
- $P = 9.8 \times \eta \times Q \times h$
- Where, η = overall efficiency of the plant which depends on efficiency of each individual civil, mechanical, electromechanical, electrical components.
- For micro hydro plants efficiency varies from 0.5 to 0.6.

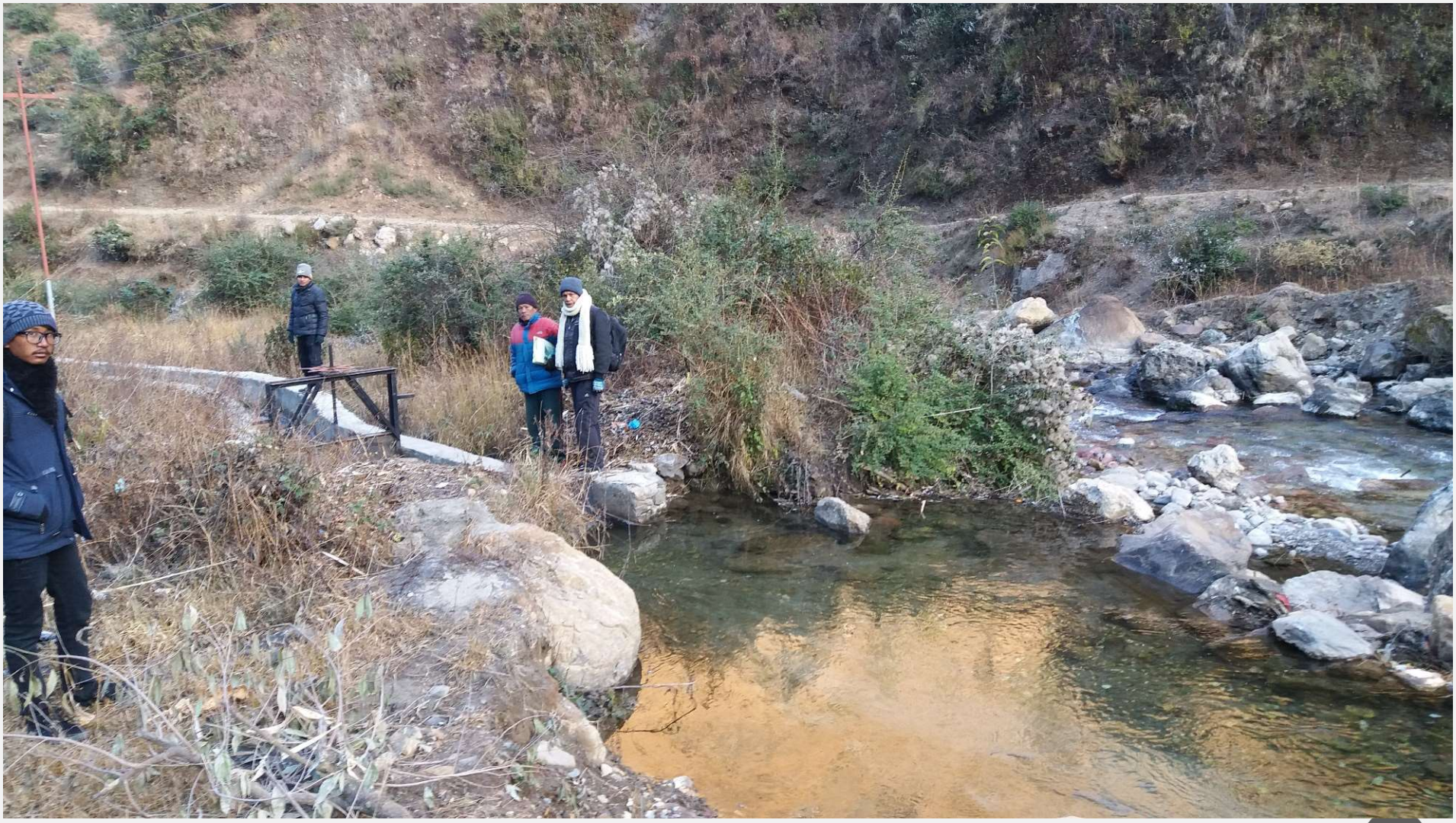
COMPONENTS OF MICRO HYDRO POWER

- Civil components
- Mechanical components
- Electrical components
- Transmission/distribution components
- Protection/control systems

CIVIL COMPONENTS

- **Intake structure**
  - Used to divert water from river to headrace canal
- **Weir**
  - Used to block river flow
- **Headrace Canal**
  - Used to divert flow from river to forebay
- **Gravel trap**
  - Used to separate gravel from diverted flow

CIVIL COMPONENTS



Intake structure

CIVIL COMPONENTS

Intake structure

CIVIL COMPONENTS

Headrace Canal

CIVIL COMPONENTS

Headrace Canal

CIVIL COMPONENTS

Headrace Canal

CIVIL COMPONENTS

Headrace Canal

CIVIL COMPONENTS

Gravel Trap/ Settling Basin

CIVIL COMPONENTS

Gravel Trap/ Settling Basin

CIVIL COMPONENTS

Gravel Trap/ Settling Basin

CIVIL COMPONENTS

- Spillway
  - Used to spill excess water in headrace canal
- Settling basin/desilting basin
  - Used to separate sand particles from diverted flow
- Forebay Tank
  - Used to divert flow from headrace canal to penstock pipe
- Anchor Block and support pier
  - Used to support penstock pipe

CIVIL COMPONENTS

Settling basin/Spillway

CIVIL COMPONENTS

Support Block

CIVIL COMPONENTS

Forebay/Spillway

CIVIL COMPONENTS

Forebay

CIVIL COMPONENTS

- Powerhouse
  - Used to house all major mechanical/electrical components
- Tailrace canal
  - Used to divert flow from turbine to river

CIVIL COMPONENTS

Powerhouse

CIVIL COMPONENTS

Powerhouse

CIVIL COMPONENTS

Powerhouse

MECHANICAL COMPONENTS

- Turbine
  - Used to convert kinetic energy of water to rotational energy
- Penstock
  - To divert flow from forebay to turbine
- Drive System
  - To drive generator using rpm of turbine
- Expansion Joint
  - Joint provided to accommodate linear expansion of penstock pipe in varying climate temperature

MECHANICAL COMPONENTS

Penstock pipe

MECHANICAL COMPONENTS

MECHANICAL COMPONENTS

Mechanical Components

MECHANICAL COMPONENTS

Mechanical Components

MECHANICAL COMPONENTS

MECHANICAL COMPONENTS

- Valves
  - Used to control flow of water from penstock to turbine
- Trash rack
  - To block twigs, leaves, other trash entering the penstock pipe
- Flushing system
  - To flush sand/gravel stored in desilting basin or gravel trap

MECHANICAL COMPONENTS

Trashrack

MECHANICAL COMPONENTS

Flushing Arrangement in Settling Basin

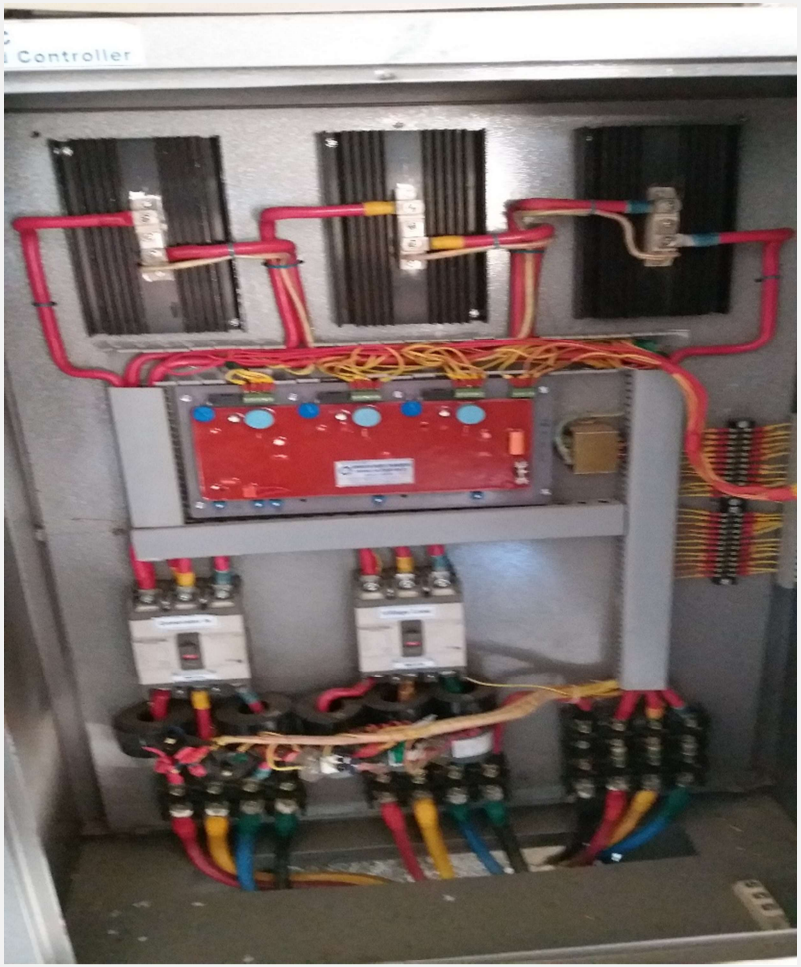
ELECTRICAL COMPONENTS

- Generator
  - Used to convert rotational energy from turbine to electrical power
- Electronic Load Controller
  - Used to maintain frequency of generator by keeping the overall load constant by distributing generator load to ballast and village
- Transformer
  - Use to step up or step-down transmission voltage to minimize loss in transmission/distribution
- Control Panel
  - To control the system
- Power cable
  - To transmit the power

ELECTRICAL COMPONENTS

Generator

ELECTRICAL COMPONENTS



Electronic Load Controller

ELECTRICAL COMPONENTS

Flushing Arrangement in Settling Basin

TRANSMISSION AND DISTRIBUTION COMPONENTS

- Conductor
  - To transmit power from power house to village
- Insulator
  - To provide insulation for conductor
- Stay wires
  - To support poles
- Poles
  - To support conductors

TRANSMISSION COMPONENTS

Transmission line

PROTECTION/CONTROL

- Lighting arrestor
- Earthing
- Fuse/MCB

CLASSIFICATION OF TURBINES

- **According to basic working principle**
  - Impulse and reaction turbine
- **According to head**
  - High head (Pelton)
  - Medium head (Cross flow, Francis)
  - Low head (Kaplan)
- **According to flow directions**
  - Axial Flow
  - Radial Flow
  - Tangential flow
  - Mixed Flow

IMPULSE TURBINE

- Major portion of potential energy of water is converted to kinetic energy before striking the turbine runner.
- The impulsive force imparted by high velocity jet of water on runner bucket produce a mechanical power on the turbine shaft.
- There is no pressure difference between inlet and outlet of the turbine runner

REACTION TURBINE

- In reaction turbine the potential energy of water is mainly converted to pressure energy before striking the turbine blade.
- There exists pressure difference between inlet and outlet of turbine runner.
- The energy transformed due to decrease in pressure energy of pressure difference is known as reaction effect.
- In the reaction type turbines two effects cause the energy transfer from the flow to mechanical energy on turbine shaft.

REACTION TURBINE

- First drop the pressure energy occurs as water flows from inlet to the outlet of the turbine runner.
- This is denoted by reaction part of the energy conversion.
- Secondly change in direction of the velocity vectors of the flow through passage between the runner blades transfer the impulsive force.
- This is denoted by the impulsive part of the energy conversion

FEATURES OF IMPULSE AND REACTION TURBINE

Impulse Turbines	Reaction Turbines
• Tolerate sand	• Water is required to be clean
• Easy to fabricate	• Difficult and expensive to fabricate
• Suitable for medium to high head	• Suitable for low to medium head
• Efficient at wide a range of head and flow	• Poor part flow efficiency
• Jet of water strike the runner bucket	• Runner has to be completely filled with water and used pressure drop across turbine runner
• No cavitation problems	• Cavitation must be avoided
• Low specific speed	• High specific speed

FEATURES OF IMPULSE AND REACTION TURBINE

Impulse Turbines	Reaction Turbines
• Tolerate sand	• Water is required to be clean
• Easy to fabricate	• Difficult and expensive to fabricate
• Suitable for medium to high head	• Suitable for low to medium head
• Efficient at wide a range of head and flow	• Poor part flow efficiency
• Jet of water strike the runner bucket	• Runner has to be completely filled with water and used pressure drop across turbine runner
• No cavitation problems	• Cavitation must be avoided
• Low specific speed	• High specific speed

IMPORTANCE OF MHP IN NEPAL CONTEXT

- Makes use of locally available water resources
- Suitable for Nepal in case of hilly and isolated settlement where there is abundance of water resources and connection opportunity to national grid is limited.
- MHP can supply power source for operating rural cottage industries.
- People in rural area can get involved in income generation activity
- Health improvement, social and educational benefit
- Eco-friendly- less environmental adverse impact

LIMITATIONS

- Site specific: only feasible in sites with availability of head and flow
- Long distance transmission is not suitable
- Power production is based on availability of head and flow, rather than demand which limits the power produced

MHP PHOTOS

MHP PHOTOS

MHP PHOTOS

MHP PHOTOS

MHP PHOTOS

MHP PHOTOS

MHP PHOTOS

REFERENCES

- (2022). Retrieved November 2, 2022, from Researchgate: https://www.researchgate.net/figure/Schematic-diagram-of-a-typical-run-of-river-hydropower-system-4_fig6_258404306
- Boyle, G. (2013). *Renewable Energy Power For A Sustainable Future* (Vol. Third Edition). Oxford: Oxford University Press.
- S. Hasan, S., & Sharma, D. (2009). *Non-Conventional Energy Resources.* Delhi: S. K. Kataria and Sons.
- Sharma, P. D. (2014). IOE Lecture Notes, Solar Energy Resources.
- Singal, R. (2011). *Non-Conventional Energy Resources* (Vol. Third Edition). Delhi: S. K. Kataria and Sons.

THANK YOU