Chapter 02: Decentralized electricity production

Lecture 04

II.7.2 Wind energy

A- Definition

Wind energy is a form of renewable energy derived from the kinetic energy of the wind. It is harnessed using wind turbines, which convert the kinetic energy of moving air into electricity.

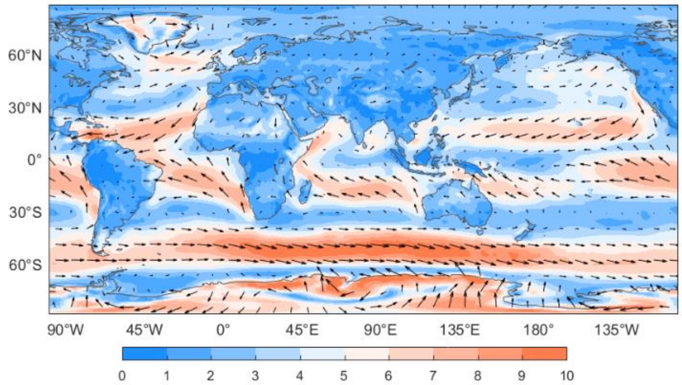

Figure.1 Global average wind direction and speed.

B- Wind speed ranges

- Low-Cut-in Wind Speed:

Range: Typically between **3 to 5** meters per second (m/s).

Purpose: This is the minimum wind speed required for the wind turbine to start generating power.

- Rated Wind Speed:

Range: Generally between **11 to 16 m/s** .

Purpose: This is the wind speed at which the wind turbine operates most efficiently and produces its maximum rated power output.

- High-Cut-out Wind Speed:

Range: Around **25 to 30 m/s** or higher.

Purpose: This is the wind speed at which the wind turbine shuts down or adjusts its blades to prevent damage during high wind conditions.

C- Types of Wind Turbine Generators (WT)

Wind turbines are classified into two general types: horizontal axis and vertical axis. A horizontal axis machine has its blades rotating on an axis parallel to the ground. A vertical axis machine has its blades rotating on an axis perpendicular to the ground.

1- Horizontal Axis Wind Turbines (HAWTs):

- Blades are attached to a central horizontal shaft, resembling airplane propellers.
- Efficient and commonly used for large-scale wind farms.
- Can capture wind energy effectively in a wider range of wind speeds.
- Suitable for both small and large-scale applications.
- Requires a mechanism to orient the turbine to face the wind (yaw mechanism).
- Tower needs to be taller to access higher wind speeds.

Figure.2 HAWT.

2- Vertical Axis Wind Turbines (VAWTs):

- Blades are arranged around a central vertical shaft, forming a helical or eggbeater shape.
- Generally less efficient than HAWTs but can be more tolerant to changing wind directions.
- Suited for decentralized or small-scale applications.
- Can capture wind from any direction without the need for a yaw mechanism.
- Lower tower height can be an advantage in some applications.
- Generally less common in large utility-scale wind farms.

Figure.3 VAWT.

D- Parts of a Wind Turbine

- The nacelle contains the key components of the wind turbine, including the gearbox, and the electrical generator.
- The tower of the wind turbine carries the nacelle and the rotor. Generally, it is an advantage to have a high tower, since wind speeds increase farther away from the ground.
- The rotor blades capture wind energy and transfer its power to the rotor hub.
- The generator converts the mechanical energy of the rotating shaft to electrical energy

- The gearbox increases the rotational speed of the shaft for the generator

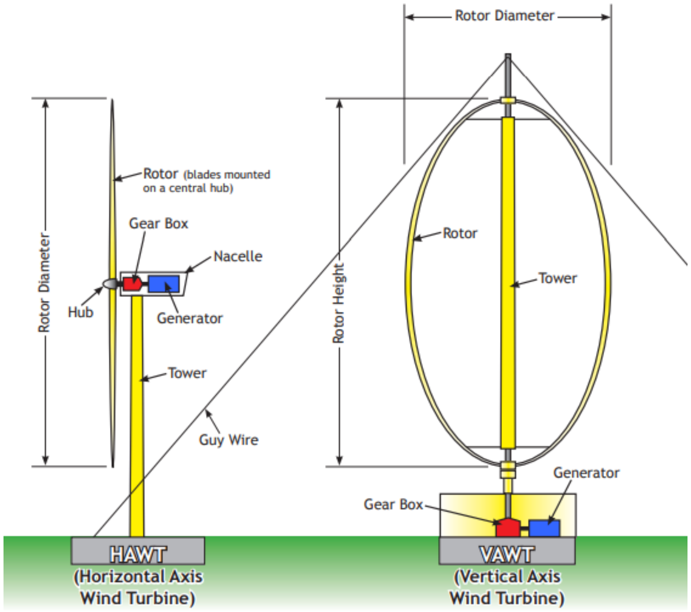

Figure.4 Wind turbine parts.

II.7.3 Hydro power

A- Definition

Hydropower, also known as hydroelectric power, is the generation of electricity through the movement of water. It harnesses the energy of flowing or falling water to produce mechanical power, which is then converted into electrical power.

B- Types of hydroelectric turbines

1- Impulse Turbines

- Working Principle: Impulse turbines operate on the principle of converting the kinetic energy of a high-speed jet of water into mechanical energy. The water strikes the turbine blades, generating rotational movement.
- Design Features: Impulse turbines have a series of buckets or blades mounted around the periphery of a wheel. The water is directed through a nozzle to create a high-speed jet that impinges on the buckets.

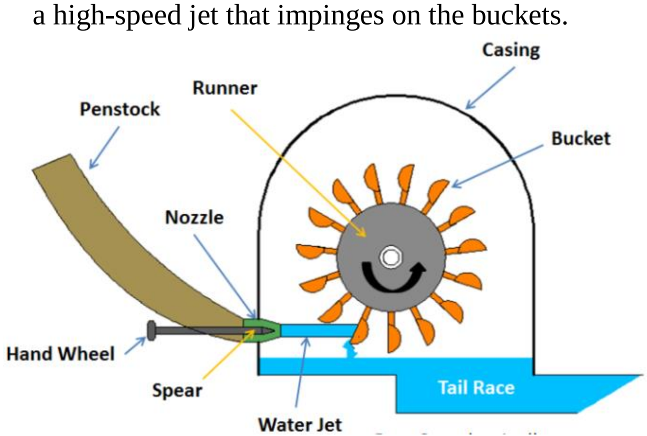

Figure.4 Impulse turbine

- Examples of impulse turbines: (Pelton turbine)
- Suitable Head: **High head** (typically >300 meters).
- Suitable Flow: **Low to medium flow** (0.1 to 10 m^3/s).
- Characteristics: Pelton turbines are well-suited for sites with high vertical drops or steep slopes. They are designed to operate efficiently at high heads and low flow rates.

Figure.4 Pelton turbine

2- Reaction Turbines

- Working Principle: Reaction turbines, on the other hand, operate on the principle of converting the kinetic energy and pressure energy of water simultaneously. The water enters the turbine and flows over the blades, causing both pressure and velocity changes.
- Design Features: Reaction turbines have a set of blades designed to extract energy from the water as it flows through the turbine. The runner blades are shaped in such a way that they react to the pressure and velocity changes of the water.

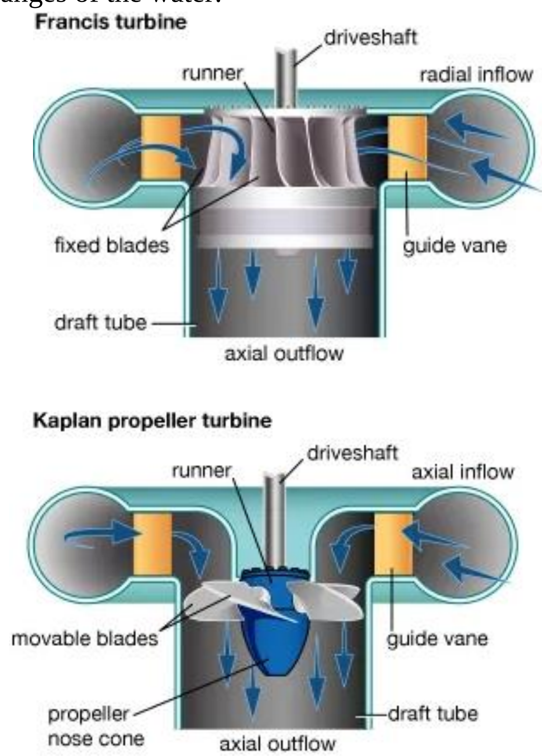

Figure.5 Reaction turbines

- <u>Examples of reaction turbines</u>

1- Francis Turbine:

- Suitable Head: **Medium to high head** (typically 10 to 300 meters).
- Suitable Flow: **Medium to high flow rates** (1 to 100 m³/s).
- Characteristics: Francis turbines are versatile and can handle a wide range of head and flow conditions. They are commonly used in locations where the water head is moderate and the flow rate is significant.

Figure.6 Francis turbine.

2- Kaplan Turbine:

- Suitable Head: **Low to medium head** (typically below 30 meters).
- Suitable Flow: **High flow rates** (10 to 500 m³/s)
- Characteristics: Kaplan turbines are designed for sites with low heads and high flow rates, such as rivers with a relatively flat terrain. Kaplan turbines are often used in locations where a low head is combined with a substantial flow of water.
-

Figure.6 Kaplan turbine.

II.7.2 Geothermal energy

E- Definition

F- Geothermal energy is a form of renewable energy that harnesses heat from within the Earth.

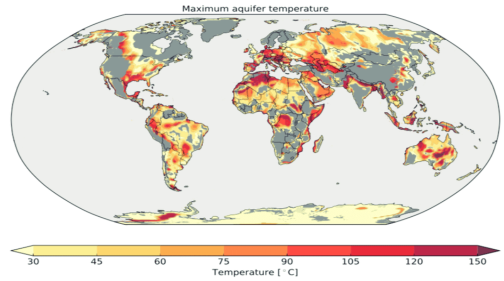

Figure.1 Global geothermal energy.

G- Geothermal power plants:

1- Binary Cycle Power Plants:

These plants transfer heat from geothermal hot water to another liquid with a lower boiling point, which is then used to produce steam to generate electricity.

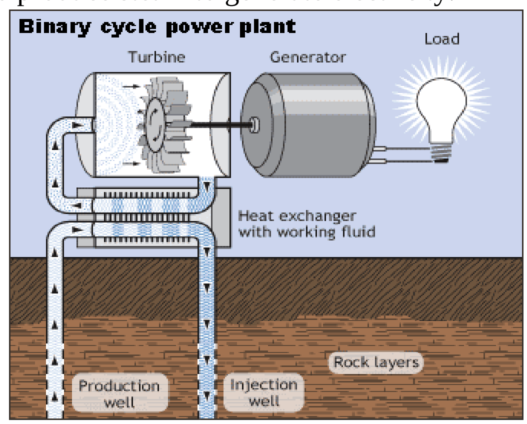

Figure.2 Binary Cycle Power Plants.

2- Flash Steam Power Plants

These plants utilize high-pressure hot water from the geothermal reservoir to produce steam directly for electricity generation.

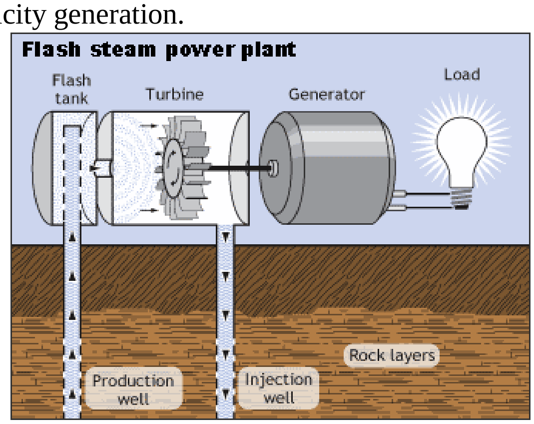

Figure.3 Flash Steam Power Plants

3- Dry Steam Power Plants

These plants use steam directly from the geothermal reservoir to turn turbines and generate electricity.

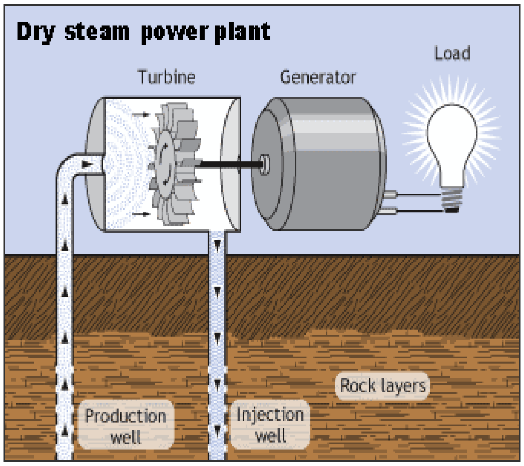

Figure.4 Dry Steam Power Plants