UNIT-4 (SUB - KOE 074)

RENEWABLE ENERGY RESOURCES

ONE - SHOT

© MULTIATOHS

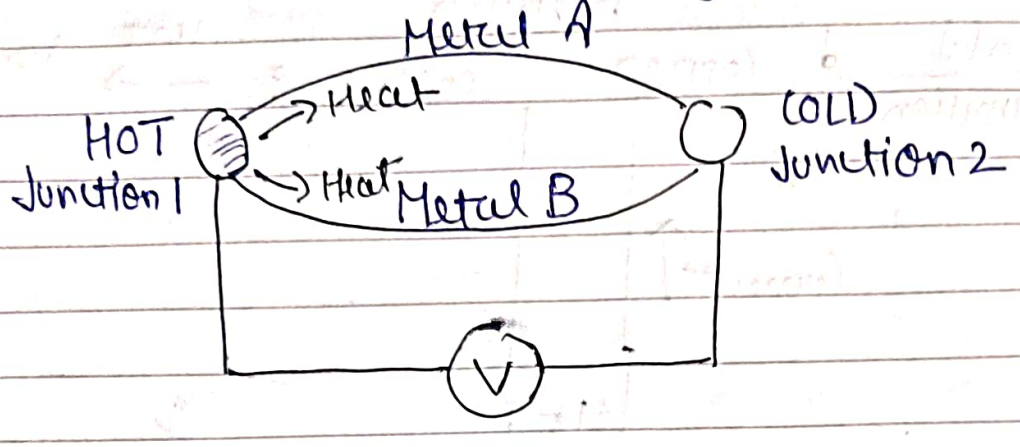
=> Topics :-

- Types of Effect
- ThermoElectric Generator
- Thermionic Generator
- Wind & caused of wind
- Wind Energy Conversion System
- Types of WECS
- limitation of WECs

⇒ SEEBECK EFFECT:-

⇒ The Seebeck effect is all about turning heat into electricity using the temperature difference between two points.

⇒ When two different types of metals or semiconductor are connected at two different points, and these points are kept at difference temperature, an electric current is generated.



$$E = \alpha_S \Delta T$$

ΔT = Difference between hot and cold Jnctn

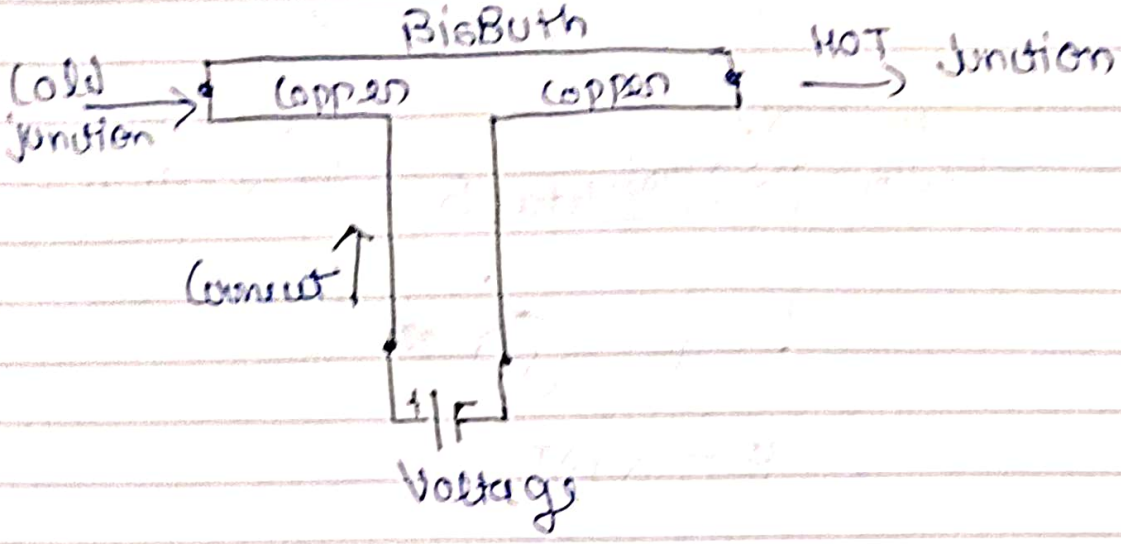
α_S = Seebeck coefficient

⇒ PELTIER EFFECT

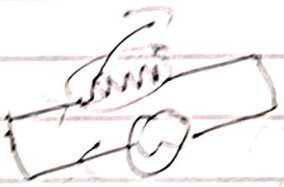
- The Peltier effect cooling or heating by simply passing an electric current

→ It is opposite of the Seebeck effect. Instead of generating electricity from heat, the peltier effect uses electricity to create a temperature difference.

→ When an electric current passed through a circuit made of two different materials (metals or semiconductors), heat is either absorbed or released at the junction where the two materials meet

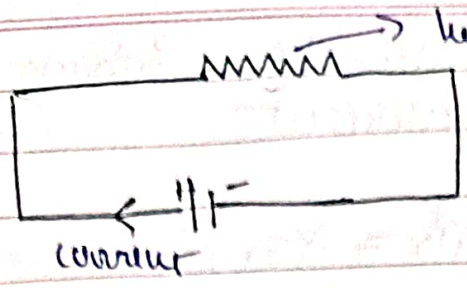


JOULE EFFECT :-



When electricity flow through a conductor (like a wire), the electrons collide with the atoms in the material.

→ These collision generate heat



$Q = I^2Rt$

The heat generated can be calculated using

$$\boxed{Q = I^2Rt}$$

THOMSON EFFECT :-

① It state that any current carrying conductor with a temperature difference between two points will either absorb or emit heat, depending upon the material.

Mathematically :-

$$\sigma = I \frac{dq_T/dx}{dT/dx}.$$

where σ = Thomson coefficient

$\frac{dq_T/dx}{dT/dx}$ = Heat interchange per unit time/length / Temperature gradient

I = current

⇒ Relationships between the Seebeck coefficient and Peltier coefficient

$$\alpha_p = \alpha_s \cdot T$$

or

$$\alpha_{p1,2} = \alpha_{1,2} T$$

⇒ Relationships between the Seebeck coefficient and Thomson coefficient

$$\sigma = T \frac{d\alpha_s}{dT}$$

or

$$\sigma_{1,2} = T \frac{d\alpha_{s1,2}}{dT}$$

THERMOELECTRICAL GENERATOR

⊙ A Thermoelectric Generator is a device that convert heat energy into electricity using the Seebeck effect

Principle:-

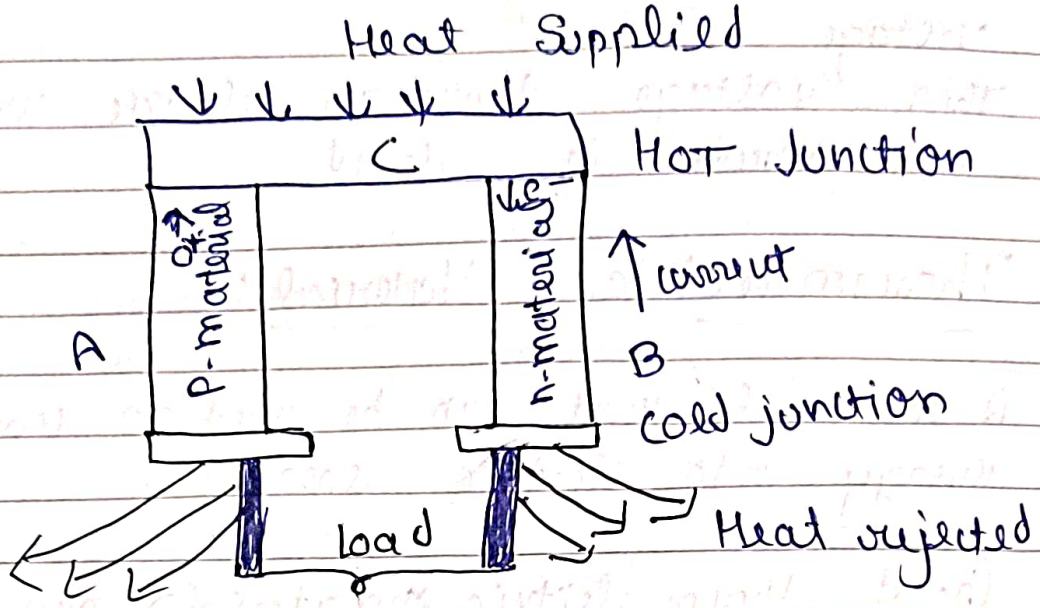
→ The Seebeck effect is the principle behind TEGs

→ The heat at the hot side gives energy

to electrons (or charge carriers), making them flow toward the cooler side.

- The movement of electrons generate a voltage, which can power devices

Construction



-> It consist of two different semiconductors (usually one n-type and one p-type material)

-> A potentiometer to measure the induced voltage.

Working :—

-> The temperature difference between the hot and cold sides create a temperature gradient.

-> Electrons in the n-type material and holes in the p-type material get energized by the heat

- Energized electrons in the n-type material move toward the cold side.
- Energized holes in the p-type material move in the opposite direction toward the cold side.
- The movement of electrons and holes creates a voltage difference.
- This voltage drives an electric current when the circuit is closed.

⇒ Thermoelectric Material :-

→ A material that can be used to convert thermal energy into electric energy.

→ Good thermoelectric materials possess :-

1. large Seabeck coefficient
2. High electrical conductivity
3. low thermal conductivity

Example :- lead telluride (PbTe)
Silicon germanium (SiGe)
Bismuth antimony (BiSb)

Advantages :-

1. No moving parts
2. Durable and long-lasting
3. Environmentaly friendly
4. Compact and lightweight
5. Scalable
6. Operates in extreme conditions

Disadvantages

1 low Efficiency
2 Expensive materials
3 limited power output
4 Dependence on temperature difference
5 Heat dissipation issues

Applications :-

1. Waste heat recovery
2. Space exploration
3. Remote power supply
4. Consumer electronics
5. Automobiles
6. Military and defenses

THERMIONIC GENERATOR

-> A Thermionic Generator is a device that convert heat directly into electricity using the flow of electrons between two electrodes

=> Principle :-

- A thermionic converter (or generator) converts heat energy directly into electrical energy by utilizing thermionic emission effect

=> When a metal or material is heated to a very high temperature, it emits electrons. This happens because the heat gives the electrons enough energy to escape the value or surface of the material.

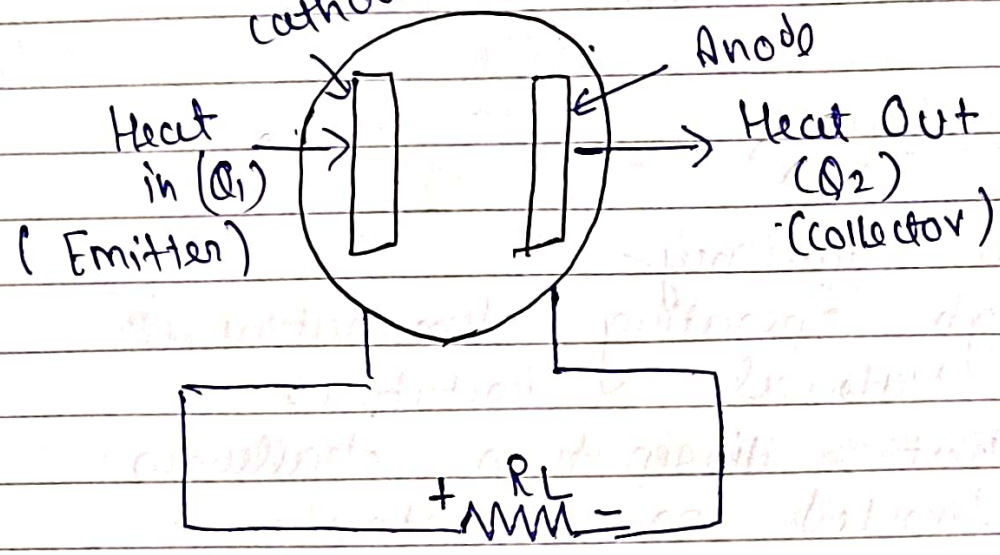
=> Work function :-

-> It is defined as the energy required to extract an electron from the metal.

-> The value of work function varies with the nature of metal and surface conditions

Construction

- The emitter and collector are placed parallel to each other with a small gap.
- A vaccum chamber or low-pressure gas surrounds the emitter and collector to reduce resistance.
- Heat is supplied to the emitter, and the collector is connected to a cooling system.
- The electrical circuit is connected across the emitter and collector to extract the generated electricity.



Working :-

- Heat is applied to the emitter (hot electrode), causing it to emit electrons.
- These electrons travel through a vaccum or low-pressure gas toward the collector (cold electrode)

- The collector absorb the electrons, creating a potential difference (voltage) between the two electrode.

- This voltage drives a current through an external circuit, generating electricity.

Advantage :-

1. Direct Energy conversion
2. Durable and reliable
3. Compact design
4. High temperature Operation
5. Environment Friendly

Disadvantage :-

1. low efficiency
2. High operating temperature
3. Material limitations
4. Heat dissipation challenges
5. Limited power output

Application of Thermionic Generator

1 Space Technology
2 Nuclear power plant
3 Waste heat recovery
4 Remote power systems

Feature	Thermionic Generator	Thermoelectric Generator
Working Principle	Uses thermionic emission	Uses the Seebeck Effect
Temperature Requirement	Requires very high temperature (above 1000°C)	Work with moderate temperature (200°C or more)
Efficiency	Higher Efficiency (10-20%)	lower Efficiency (5-8%)
Material Used	Metal like tungsten and coatings like cesium	Semiconductor like bismuth telluride.
Complexity	Requires a vaccum chamber or low-pressure gas system	Simple, solid-state design with no-special condition used
Cost	Expensive	cheaper
Application	Spacecraft, nuclear power plant, Industrial.	Waste heat recovery, automobile, wearable devices
Durability	less Durable	Extreme Durable
Power output	High Power Output	low Power Output

Q What is the basic difference between thermoelectric and thermionic conversion system & also explain its working (thermoelectric generator) {AKTU 2021-2022}

Sol Done Already (Previous Section)

Q Start Thermo-electrical conversion towards field. Discuss in detail about performance and limitations of thermoelectric power generator. {AKTU 2022-2023}

Sol This technology has promising application across various fields due to its ability to harness wasted heat and provide sustainable power in various settings

-> Industrial Waste Heat Recovery
-> Automative Industry
-> Space Exploration
-> Wearable devices and Consumer Electronics
-> Remote and Off-Grid Power Supply
-> Military and Defense

Performance of Thermoelectric Power Generation (TEGs) :-

1. Efficiency :- TEG's convert heat to electricity, but their efficiency is relatively low, usually between 5-8%.

2. Power Output :- TEG's generally produces small (low power), suitable for small applications like sensors

3. Materials :- The performance is determined by the choice of thermoelectric material like bismuth telluride

4. Temperature Gradient :- A large temperature differences (ideally 500-600°C) between the hot and cold sides of the TEG is needed for better performance

5. Durability :- TEG's are long-lasting

6. Cost :- The cost of materials and system integration can be high.

WIND

① Wind is moving air in the atmosphere.
① It happens because air moves from high-pressure areas to low-pressure areas.
① Wind helps in shaping weather, carrying moisture and even generating electricity.

Causes Of Wind

1. Uneven Heating by the Sun :-
→ The sun heats the Earth unevenly (land and water heat at different rates).
→ This causes temperature differences.

2. Pressure Differences :-
→ Warm air rises, creating a low-pressure area
→ Cool air sinks, creating a high-pressure area
→ Air moves between these areas, forming wind.

3. Earth's Rotation :-
→ The Earth's rotation makes wind change direction
→ Wind curve right —— Northern hemisphere
→ Wind curve left —— Southern hemisphere.

4. Seasons :-
→ Seasonal changes like monsoons, create big wind Pattern due to temperature differences

Q. Explain the factor take for site selection in the wind farm. What are the advantage of wind energy conversion system ?
[AKTU 2023-24]

Sol Factors for Wind Farm Site Selection :-

⊙ Open Area :- choose an open area because wind flow faster and more freely without obstacles like buildings or trees.

⊙ Average wind Speed :- Select the location by checking average wind speed data for consistent performance.

⊙ Year-Round Wind :- Ensure the site has minimum winds speed available throughout the year for steady energy generation

⊙ Stable Ground :- The ground should be stable with strong soil to support heavy wind turbines and towers

⊙ Near Consumers :- Place the wind farm close to power consumer to reduce energy transmission losses

⊙ Away from cities :- Keep the site at least 5km away from cities to minimize noise pollution affecting people

⊙ Low land cost :- Select land with low cost to make the project economically viable.

⊙ Approach Roads :- Ensure there are roads leading to the site for easy transportation of material and maintenance equipment

⊙ Height of Towers :- If trees are present, use taller towers to capture higher wind speed above tree height

Advantages :-

① Renewable Energy Source.
② Low Operating costs.
③ Reduces Greenhouse Gas Emissions.
④ Scalable Technology
⑤ Energy Independence
⑥ Job creation
⑦ Dual land use
⑧ long lifespan

Disadvantage :-

① Intermittent Nature
② High hitial cost
③ Noise pollution
④ Impact on Wildlife
⑤ Space Requirement
⑥ Transmission loss

Application :-

- Electricity Generation
- Remote Power Supply
- Water Pumping
- Desalination
- Battery charging
- Industrial application

Principle of Power Generation in Wind Mills :-

① The basic principle of wind energy is to convert the kinetic energy of wind into rotational motion to operate an electric generator

Q What is the principle of Energy Conversion (wind)? What methods are used to overcome the fluctuating power generation of windmills? [AKTU 2021-2022]

Sol Principle of Wind Energy Conversion

1. The principle of wind Energy conversion is based on aerodynamic and energy transformation.

→ Kinetic Energy of wind:- Wind contains kinetic energy due to its motion

→ Mechanical Energy :- The wind's kinetic energy rotates the turbines blades, converting it into mechanical energy

→ Electrical Energy :- The mechanical energy is then converted into electrical energy using a generator

The conversion follow Betz's law, which state that no wind turbine can capture more than 59.3% of the wind

Method to overcome Fluctuating Power Generation

1. Wind Energy is variable because wind speed and direction are not constant. To address this following methods are used :-

→ Batteries :- Store excess power during high winds for use during low wind periods

→ Pumped Hydro Storage :- Pump water to higher elevation using excess energy, generate electricity when the water flows back down

→ Fly Wheels :- Store kinetic energy to stabilize short-term power fluctuations

→ Grid Integration :- Connect wind farms to the grid to balance fluctuation by pooling energy from multiple sources

→ Advanced Control System :- Use real-time monitoring and algorithm to optimize turbine performance and power output.

→ Backup Generators :- Use conventional power sources (like gas or diesel) as backups during low wind periods

→ The various mechanical controls provided with the wind machine are as follows :-

⊙ Yaw Control :- Adjusts turbine orientation to face the wind.

→ This ensures that the turbines captures maximum wind energy

⊙ Pitch Control :- Changes blade angles to regulate wind capture and prevent damage in high winds

→ light wind → higher angle, high wind → lower angle

⊙ Braking Systems :-

. Stops or slows down the turbine in case of extreme weather conditions or maintenance needs

⊙ Overspeed Protection :- Prevents the turbine from rotating too fast and getting damaged.
→ By adjusting the pitch of the blade.

⊙ Gearbox Protection :- The gearbox in wind turbines helps convert the slow rotational speed of the blades into a higher speed suitable for the generator

---

⇒ Types Of Wind Energy Conversion System

⇒ There are two main types of Wind Energy conversion systems (WECS) based on the design of the turbine.

1. Horizontal Axis Wind Turbines (HAWT)
→ The axis of rotation is horizontal, meaning the blades spin around a horizontal shaft
→ HAWT are the most widely used type of wind turbine around the world.
→ They are highly efficient and perform best in areas with high and consistent wind speeds.
→ Used in large-scale wind farms both onshore and offshore.

Component of the HAWT

① Rotor Blades
→ Large, aerodynamic blade that catch the wind
→ convert wind's kinetic energy into mechanical energy by causing the rotor to spin

② Hub
→ Central part where the blades are attached
→ Connects the beads to the main shaft and allow the rotor to rotate

③ Naculle
→ Enclosed casing at the top of the tower containing mechanical and electrical components
→ Houses the gearbox, generator, yaw mechanism, and brake system, to convert M.E to E.E

④ Gearbox
→ Converts mechanical energy from the rotating rotor into electrical energy.

⑤ Tower
→ The tall structure that support the naculle and rotor.
→ Elevates the turbines to a height where winds speed are stronger and more consistent.

⑤ Yaw Mechanism :-

→ Allows the nacelle and rotor to rotate to face the wind direction
→ Ensures the turbine to a height where wind speeds are stronger and more consistent.
→ Ensures the turbine is always aligned with the wind for maximum energy capture

⑥ Control System :-

→ Monitors and adjusts the turbine's performance
→ Manage setting like blade pitch and rotor speed to optimize energy generation

⑦ Break System :-

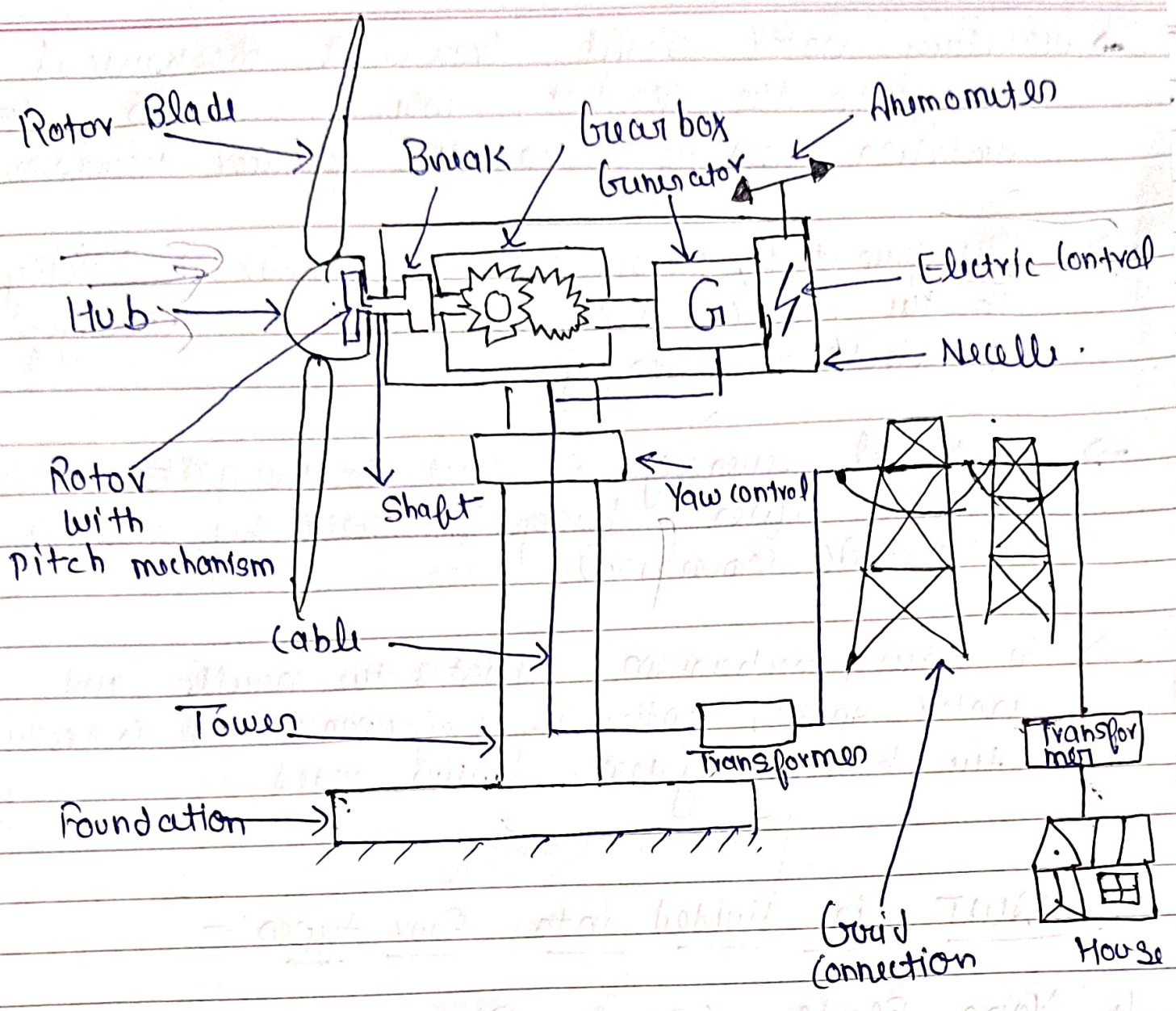
→ It is used to slow or stop the rotor when needed
→ Stops the turbine during high winds or maintenance.

⑧ Electrical System :-

→ Included component like transformer and inverter

⑨ Anemometer :-

→ Device that measures winds speed and direction



⇒ Working :-

⊙ Winds blows across the rotor blades, which are aerodynamically designed to efficiently capture the wind and convert its kinetic energy into mechanical energy.

⊙ The hub connects the blades to the main rotor shaft, causing the entire rotor to spin as the blades, rotate

→ rotating rotor shaft transmits mechanical energy to the gearbox, which increases the rotation speed to match the generator requirements

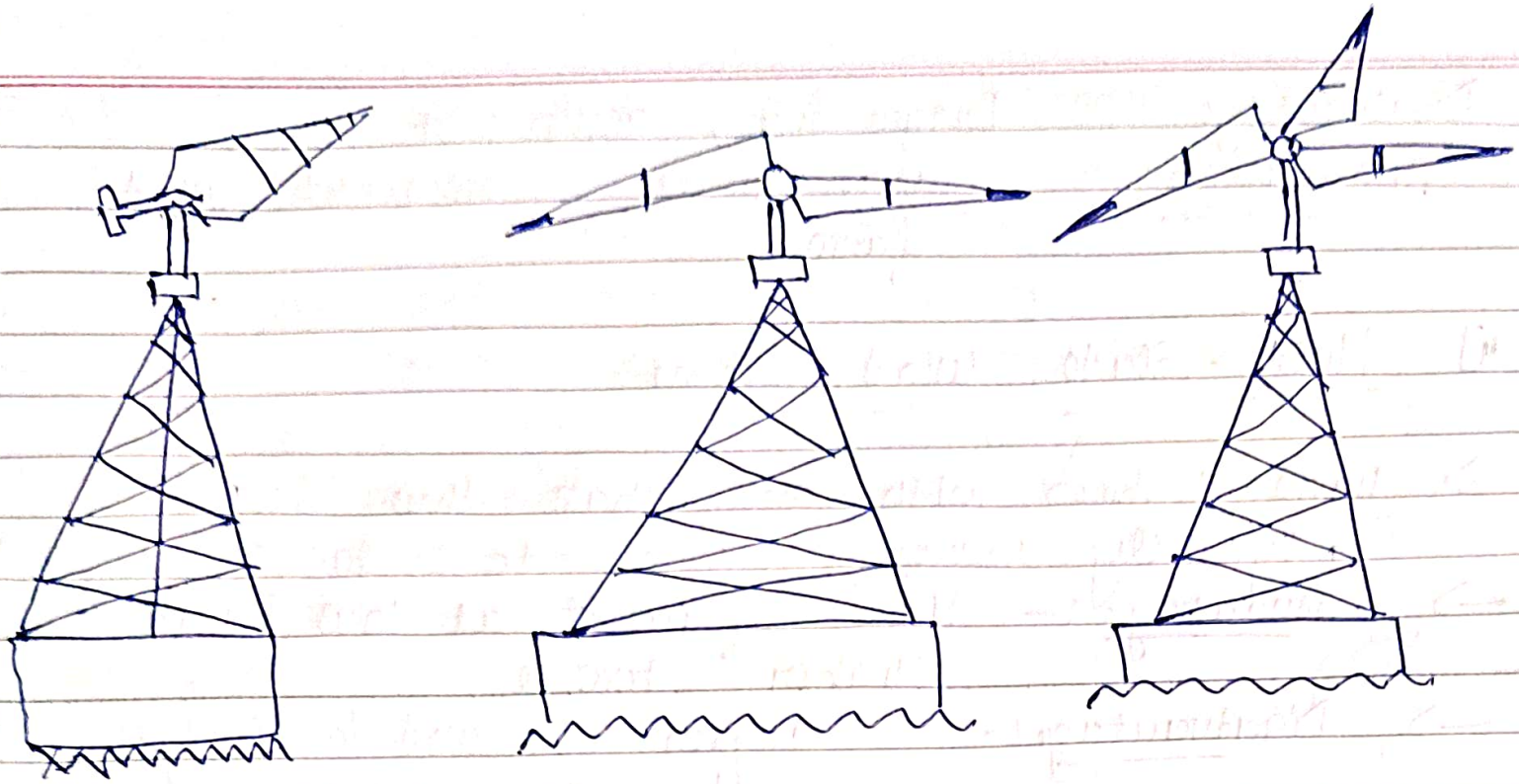
→ The generator, connected to the gearbox or directly to the rotor, converts mechanical energy to electrical energy

→ Electrical energy is sent to the grid or stored after being processed by inverters (DC to AC conversion).

→ The Yaw mechanism adjusts the nacelle and rotor speed, optimizing performance and controlling the brake system when needed

⇒ HAWT is divided into Four types!-

1. Mono Blade (Single Blade Wind Turbine)
→ A wind Turbine with only one blade attached to the rotor
→ Adv!- Simple Design, cost-Effective.
→ Disadvantage!- Stability issues, less Efficiency
→ Applications!- Used in small, experimental turbines
→ Power ⟶ 15KW to 50KW



Mono-blade Twin-blade Three-blade

ii] Twin-Blade :-

→ A wind turbine with two blades attached to the rotor

→ Power — 1 to 3MW

→ Advantage :- Compact Design, More Efficiency. Lowest cost,

→ Disadvantage :- less Stability, Noise and Vibration

→ Applications — Smaller wind turbines

iii] Three-Blade :-

→ A wind turbine with three blades attached to the rotor

→ Power — 15KW → 3MW units

→ Advantage :- Balanced and Stable, High Efficiency, less Vibration Widely used

Disadvantage!- Larger size, Higher cost

Application!- large-scale commercial wind farms

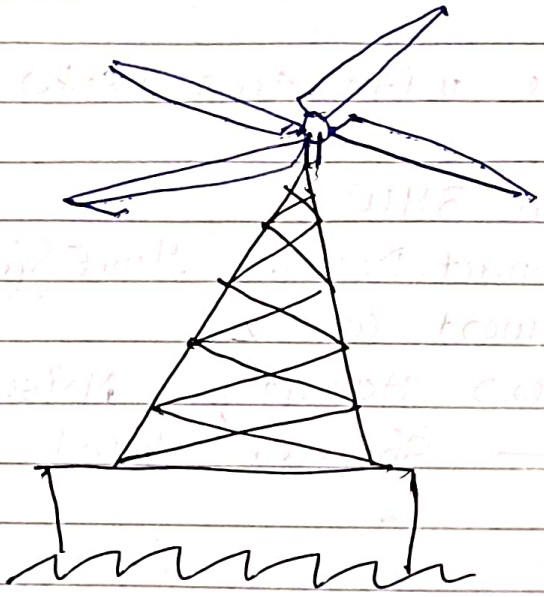
4] Multi-Blade Wind Turbine

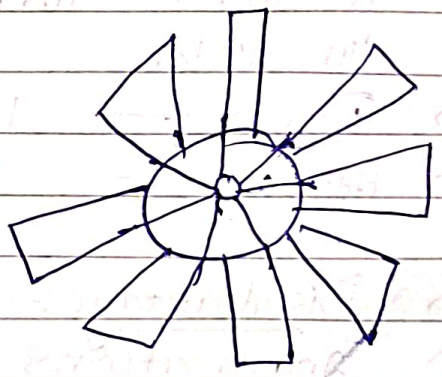
-> Wind turbines with more than three blades, typically ranging from 4 to 12 blades

-> Advantage!- More efficient at low winds
Higher torque.

-> Disadvantage!- Higher cost and complexity
Increased weight
More Mechanical wear

-> Application!- Small scale or older turbines





Multi blade

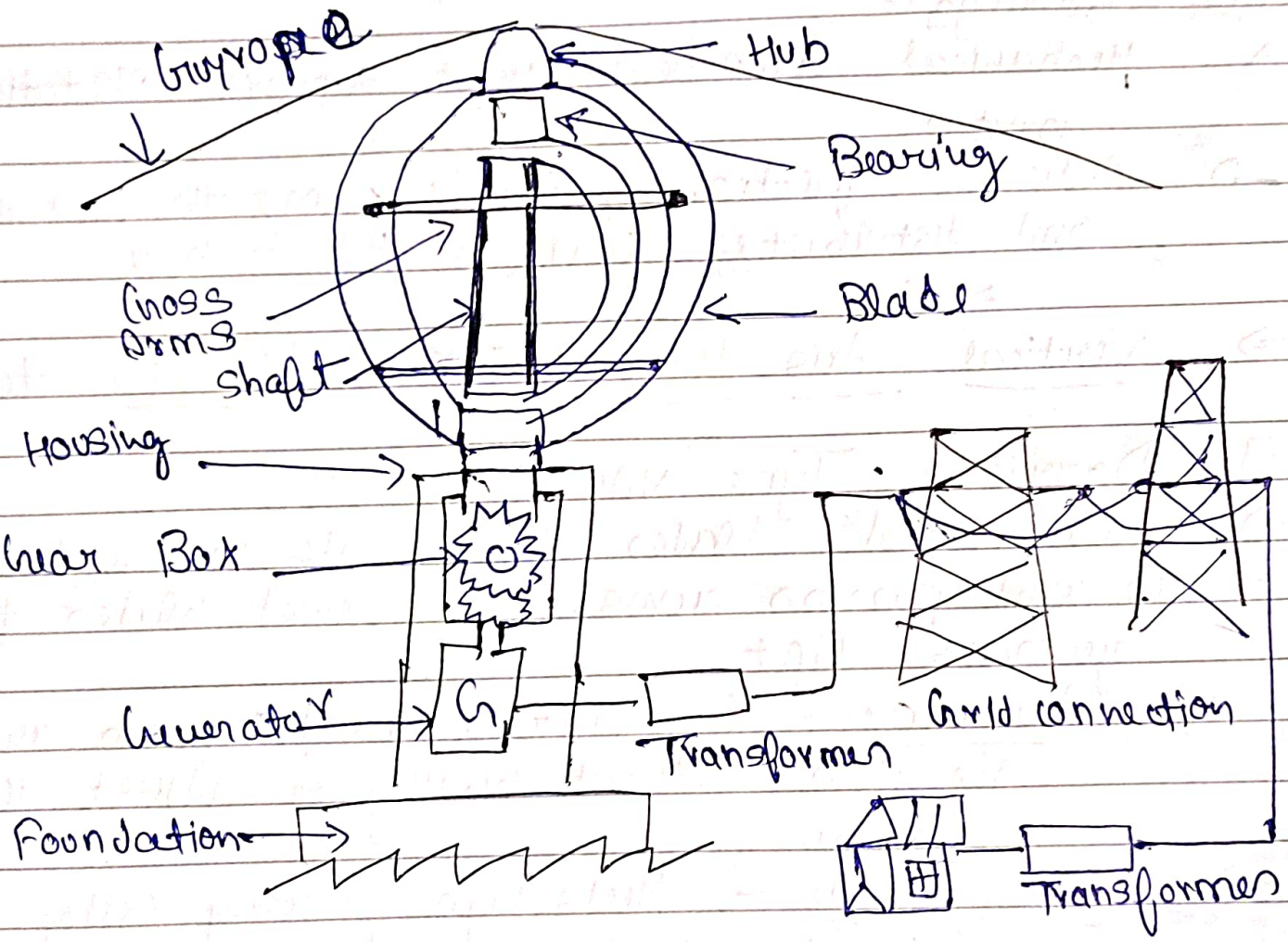
2] Vertical Axis Wind Turbines (VAWT)

-> The axis of rotation is vertical, so the blades spin around a vertical shaft.

-> VAWT do not require a yaw mechanism to face the wind, making them simpler to design and maintain

-> VAWT are generally less efficient than HAWT's

=> Components :-



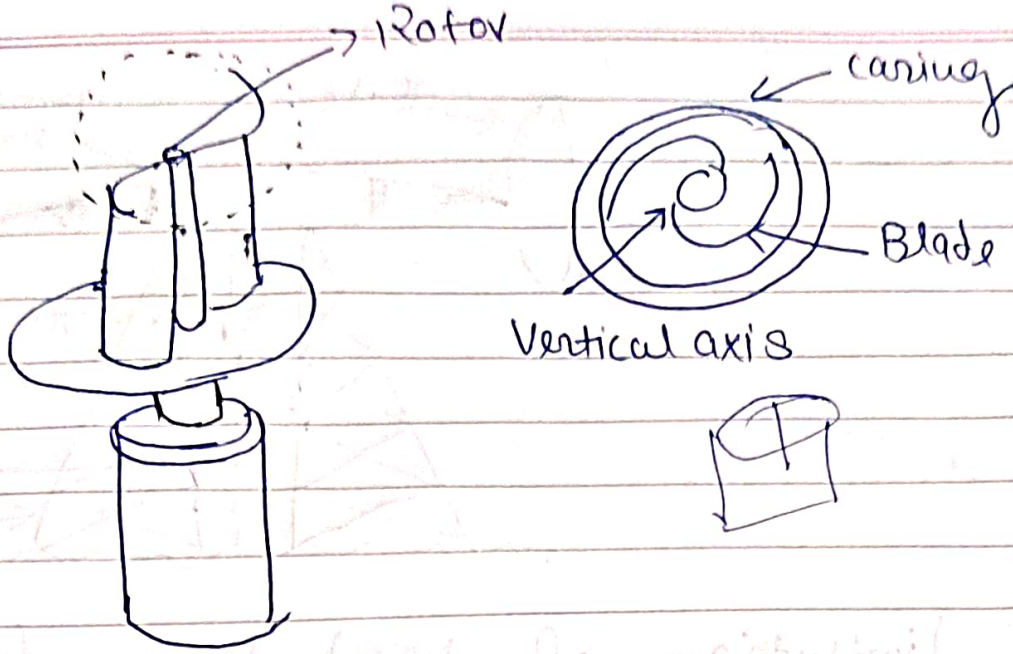
⑥ Cross Arms :-
→ Structural component that hold the rotor blades
→ provide stability, support blades, and distribute fore from the rotor blades

⑦ Gyroscope :-
→ A device that measures or maintains orientation
→ Helps stablize the turbine, assist with yaw control and detect shift in rotation

⑧ Bearings :-
→ Mechanical component that support rotating parts.
→ Reduce friction, enable smooth rotation and distribute loads in the turbine

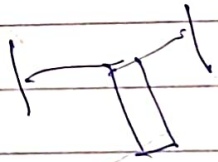
⇒ Vertical Axis Wind Turbines (VAWT) types

1] Darrieus Type VAWT :-
→ Has curved blades shaped like an eggbeater
→ The wind passes across the curved blades to generate lift
→ Advantage :- Can capture wind from any direction without needing to adjust the turbine.
→ Disadvantage :- Needs high starting speeds, less efficient at low winds

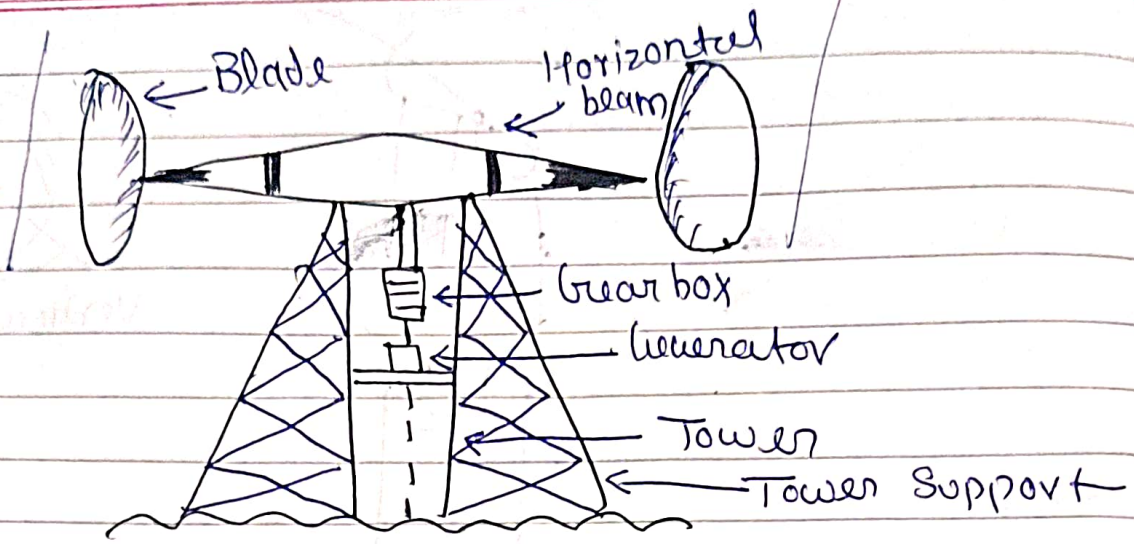


Savonius Wind turbine

2] Savonius Type VAWT
→ uses scooped blades to catch wind, similar to a waterwheel
→ The scooped blades create drag to generate power
→ Advantage!- Simple design, works well in low wind conditions and self-starting
→ Disadvantage!- less Efficient



3] H- Darrieus Type
→ A hybrid of the Darrieus with straight blades, resembling the letter 'H'.
→ Uses vertical straight blades that can better withstand high winds.
→ Advantage!- Improved stability
→ Disadvantage!- require high starting speed



Limitation of Wind Energy Conversion

1. Intermittent Nature
2. High Initial cost
3. Land and Space Requirement
4. Noise Pollution
5. Visual Impact
6. Impact on wildlife
7. Transmission losses
8. Dependency on wind speed
9. Grid Integration issues

UNIT-4 COMPLETED

LIKE SHARE & SUBSCRIBE

COMMENTS @MULTIATOMS

&

@MULTIATOMS