

# Subject Name Solutions

4311101 – Summer 2023

Semester 1 Study Material

*Detailed Solutions and Explanations*

## Question 1(a) [3 marks]

Define the following term (1) Resistance (2) Electrical energy (3) Electrical Power

### Solution

Term	Definition
<b>Resistance</b>	The property of a material that opposes the flow of electric current, measured in ohms ( $\Omega$ )
<b>Electrical Energy</b>	The ability to do work by electrical means, measured in joules (J) or kilowatt-hours (kWh)
<b>Electrical Power</b>	The rate at which electrical energy is transferred or converted, measured in watts (W)

### Mnemonic

“RIP” - Resistance Impedes Path, Energy Is Potential, Power Is Performance

## Question 1(b) [4 marks]

State and Explain Ohm’s Law & write limitations of it.

### Solution

**Ohm’s Law:** The current flowing through a conductor is directly proportional to the voltage across the conductor and inversely proportional to its resistance.

Mathematically:  $V = IR$ , where:

- $V$  = Voltage (volts)
- $I$  = Current (amperes)
- $R$  = Resistance (ohms)

flowchart LR

$V[\text{Voltage}] \{-\{-\} I[\text{Current}]\}$

$R[\text{Resistance}] \{-\{-\} \text{Limits}\{-\}\{-\} I\}$

**Limitations of Ohm’s Law:**

- Not applicable to non-linear devices (semiconductors, gas discharge tubes)
- Doesn’t hold at high temperatures
- Not valid for unilateral elements (diodes)
- Fails for time-varying currents

### Mnemonic

“VIRO” - Voltage Is Resistance times Output current

## Question 1(c) [7 marks]

Explain series and parallel connection of batteries.

## Solution

### Series Connection of Batteries:

flowchart LR

```
B1[Battery 1] --> B2[Battery 2] --> B3[Battery 3] --> L[Load]
L --> B1
```

### Characteristics of Series Connection:

- **Total Voltage** = Sum of individual voltages ( $V = V_1 + V_2 + \dots + V_n$ )
- **Current** = Same through all batteries
- **Applications**: Higher voltage requirements
- **Internal Resistance**: Increases ( $R_s = r_1 + r_2 + \dots + r_n$ )

### Parallel Connection of Batteries:

flowchart LR

```
B1[Battery 1] --> L[Load]
B2[Battery 2] --> L
B3[Battery 3] --> L
L --> B1
L --> B2
L --> B3
```

### Characteristics of Parallel Connection:

- **Voltage** = Same as individual battery (if identical)
- **Total Current** = Sum of individual currents ( $I = I_1 + I_2 + \dots + I_n$ )
- **Applications**: Higher current capacity required
- **Internal Resistance**: Decreases ( $1/R_p = 1/r_1 + 1/r_2 + \dots + 1/r_n$ )

## Mnemonic

“VSCP” - Voltage Sums in Series, Current Parallels

## Question 1(c) OR [7 marks]

Explain series and parallel connection of Resistors.

## Solution

### Series Connection of Resistors:

flowchart LR

```
S[Source] --> R1[R1] --> R2[R2] --> R3[R3] --> S
```

### Characteristics of Series Connection:

- **Equivalent Resistance** = Sum of individual resistances ( $R_s = R_1 + R_2 + \dots + R_n$ )
- **Current** = Same through all resistors
- **Voltage** = Divided across resistors proportional to resistance values
- **Power** divided as per voltage distribution

### Parallel Connection of Resistors:

flowchart LR

```
S[Source] --> R1[R1]
S --> R2[R2]
S --> R3[R3]
R1 --> S
R2 --> S
R3 --> S
```

### Characteristics of Parallel Connection:

- **Equivalent Resistance**:  $1/R_p = 1/R_1 + 1/R_2 + \dots + 1/R_n$
- **Voltage** = Same across all resistors
- **Current** = Divided inverse-proportionally to resistance values
- **Total Current** = Sum of individual currents

### Mnemonic

“RISE-VICE” - Resistance Increases in Series, Voltage Is Constant in Every parallel

### Question 2(a) [3 marks]

Define: (1) Amplitude (2) Frequency (3) Time period

#### Solution

Term	Definition
<b>Amplitude</b>	Maximum displacement of a waveform from its mean position, measured in volts or amperes
<b>Frequency</b>	Number of complete cycles occurring in one second, measured in hertz (Hz)
<b>Time Period</b>	Time taken to complete one cycle of waveform, measured in seconds (s)

### Mnemonic

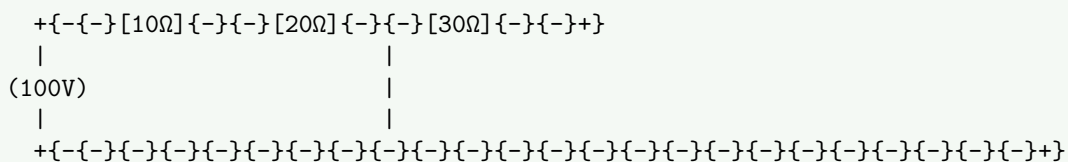
“AFT” - Amplitude is the Full height, Time period is the Total cycle

### Question 2(b) [4 marks]

10Ω, 20Ω and 30Ω resistors are connected in series and 100V supply is given to them. Find (1) Equivalent resistance (2) Circuit current (3) Voltage drop across each Resistor (4) Power loss in each resistor.

#### Solution

Diagram:



Solution:

Parameter	Calculation	Result
Equivalent Resistance	$R = 10\Omega + 20\Omega + 30\Omega$	60Ω
Circuit Current	$I = 100V/60\Omega$	1.67A
Voltage across 10Ω	$V_1 = 1.67A \times 10$	16.7V
Voltage across 20Ω	$V_2 = 1.67A \times 20$	33.3V
Voltage across 30Ω	$V_3 = 1.67A \times 30$	50.0V
Power in 10Ω	$P_1 = 1.67^2 \times 10$	27.8W
Power in 20Ω	$P_2 = 1.67^2 \times 20$	55.6W
Power in 30Ω	$P_3 = 1.67^2 \times 30$	83.4W

### Mnemonic

“REQVP” - Resistances Equivalent Causes Voltage and Power division

### Question 2(c) [7 marks]

Explain A.C Through pure Resistor with wave form & vector diagram.

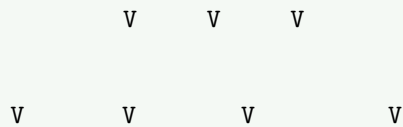
### Solution

In a pure resistive circuit with AC supply:

#### Key Characteristics:

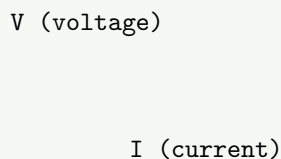
- Current and voltage are **in phase** with each other
- Circuit follows Ohm's Law:  $V = IR$
- Power is always positive ( $P = VI$ )
- No reactive power consumed
- Power factor = 1 ( $\cos = 1$ )

#### Waveform:



{-}{-}{-} Voltage waveform  
{-}{-}{-} Current waveform (identical phase)}

#### Vector Diagram:



### Mnemonic

“PARVIP” - Pure AC Resistor has Voltage In Phase with current

### Question 2(a) OR [3 marks]

Define: (1) cycle (2) Form factor (3) Peak factor

### Solution

Term	Definition
<b>Cycle</b>	One complete repetition of a periodic waveform from start point to same point again
<b>Form Factor</b>	Ratio of RMS value to average value of AC waveform (For sine wave = 1.11)
<b>Peak Factor</b>	Ratio of maximum value to RMS value of AC waveform (For sine wave = 1.414)

### Mnemonic

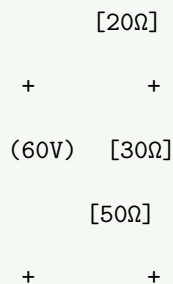
“CFP” - Cycle Finishes a Pattern, Form Factor =  $V_{rms}/V_{avg}$ , Peak Factor =  $V_{max}/V_{rms}$

### Question 2(b) OR [4 marks]

20Ω, 30Ω and 50Ω resistors are connected in parallel and 60V supply is given to them. Find (1) Current in each Resistor. (2) Total current (3) Equivalent resistance (4) Power loss in each resistor.

#### Solution

##### Diagram:



##### Solution:

Parameter	Calculation	Result
Current in 20Ω	$I_1 = 60V/20$	3A
Current in 30Ω	$I_2 = 60V/30$	2A
Current in 50Ω	$I_3 = 60V/50$	1.2A
Total Current	$I = 3A + 2A + 1.2A$	6.2A
Equivalent Resistance	$1/Req = 1/20 + 1/30 + 1/50$	9.68Ω
Power in 20Ω	$P_1 = 60V \times 3A$	180W
Power in 30Ω	$P_2 = 60V \times 2A$	120W
Power in 50Ω	$P_3 = 60V \times 1.2A$	72W

#### Mnemonic

“VICTIM” - Voltage Is Constant, Total current Is the Measure (in parallel)

### Question 2(c) OR [7 marks]

Explain A.C Through pure capacitor with wave form & vector diagram.

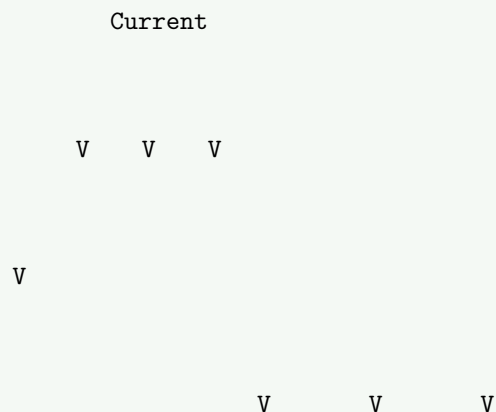
#### Solution

In a pure capacitive circuit with AC supply:

##### Key Characteristics:

- Current **leads** voltage by 90°
- Capacitive reactance  $X_c = 1/(2\pi fC)$
- Only reactive power (no active power)
- Power factor = 0 (lagging)
- Average power over complete cycle = 0

##### Waveform:



## Voltage

**Vector Diagram:**

I (current)

V V (voltage)

### Mnemonic

“CLEAR-90” - Capacitive Load has Electrical Angle Reaching  $90^\circ$  (*current leads voltage*)

### Question 3(a) [3 marks]

Define RMS value and average value related to alternating waveform write formula of it.

#### Solution

Term	Definition	Formula
<b>RMS Value</b>	Root Mean Square value - equivalent DC value producing the same heating effect	$V_{rms} = 0.707 \times V_{max \text{ for sine wave}}$
<b>Average Value</b>	Mean value of all instantaneous values over half cycle	$V_{avg} = 0.637 \times V_{max \text{ for sine wave}}$

### Mnemonic

“RAM” - RMS Averages the Mean square (RMS = 0.707, AVG = 0.637)

### Question 3(b) [4 marks]

If A.C. current is represented by equation  $i = 25 \sin(314t)$ . Calculate (1) R.m.s. value (2) Average value (3) Frequency (4) Time period

#### Solution

**Given equation:**  $i = 25 \sin(314t)$

Parameter	Calculation	Result
Maximum value	$I_{max} = 25 \text{ A}$	25 A
RMS value	$I_{rms} = I_{max} / \sqrt{2} = 25 / 1.414$	17.68 A
Average value	$I_{avg} = 2I_{max} / \pi = 2 \times 25 / 3.14$	15.92 A
Angular frequency	$\omega = 314 \text{ rad/s}$	314 rad/s
Frequency	$f = \omega / 2\pi = 314 / 6.28$	50 Hz
Time period	$T = 1/f = 1/50$	0.02 s

### Mnemonic

“SMART” - Sine’s Maximum divided by root 2 equals RMS Then 2/  $\pi$  for Average

### Question 3(c) [7 marks]

Explain star connection of resistors and Derive equation shows relationship between voltage and current in star connection.

#### Solution

##### Star (Y) Connection:

##### Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph TD
    N((N)) --- R1[R1] --- L1((L1))
    N --- R2[R2] --- L2((L2))
    N --- R3[R3] --- L3((L3))
    N --- Neutral((Neutral))
{Highlighting}
{Shaded}
```

##### Characteristics of Star Connection:

- Three resistors connected at common point (neutral)
- Line voltage ( $V_L$ ) =  $\sqrt{3} \times \text{Phase voltage}(V_{ph})$
- Line current ( $I_L$ ) = Phase current ( $I_{ph}$ )
- For balanced load:  $I_L = I_{ph}$
- Total power =  $3 \times \text{Phase power}$

##### Mathematical Relationship:

- Phase voltage:  $V_{ph} = V_L / \sqrt{3}$
- Phase current:  $I_{ph} = I_L$
- For balanced resistive load:  $I_{ph} = V_{ph} / R$
- Therefore:  $I_L = V_L / (\sqrt{3} R)$

#### Mnemonic

“SLIP-3” - Star Line current Is Phase current, Line voltage is Phase voltage times root-3

### Question 3(a) OR [3 marks]

Explain generation of alternating E.M.F.

#### Solution

##### Generation of Alternating EMF:

##### Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    subgraph "Rotating Coil in Magnetic Field"
        N[N] --- M((Magnet)) --- S[S]
    end
    M --- R[Rotating Coil]
    R --- EMF[EMF Output]
{Highlighting}
{Shaded}
```

##### Process:

- Coil rotates in uniform magnetic field
- Flux linkage changes with angle of rotation
- Rate of change of flux induces EMF
- EMF follows sinusoidal pattern:  $e = E_{max} \sin(\omega t)$
- Frequency depends on rotation speed

### Mnemonic

“FRAME” - Flux Rotation Alternates Magnetic EMF

### Question 3(b) OR [4 marks]

An alternating EMF is expressed by  $e = 100 \sin 50t$ . Find out (1) Max value of EMF (2) Frequency (3) Time period (4) Angular Frequency

#### Solution

Given equation:  $e = 100 \sin 50t$

Parameter	Calculation	Result
Maximum EMF	$E_{\max} = 100 \text{ V}$	100 V
Angular Frequency	$\omega = 50 = 314 \text{ rad/s}$	314 rad/s
Frequency	$f = 50 \text{ Hz (directly from equation)}$	50 Hz
Time Period	$T = 1/f = 1/50$	0.02 s

### Mnemonic

“FAST” - Frequency And period are reciprocals, Sin’s Top value is maximum

### Question 3(c) OR [7 marks]

Explain star connection and Derive equation shows relationship between voltage and current in delta connection.

#### Solution

Delta ( $\Delta$ ) Connection:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    L1((L1)) --- R1[R1] --- L2((L2))
    L2 --- R2[R2] --- L3((L3))
    L3 --- R3[R3] --- L1
{Highlighting}
{Shaded}
```

**Characteristics of Delta Connection:**

- Three resistors connected in closed loop
- Line voltage ( $V_L$ ) = Phase voltage ( $V_{ph}$ )
- Line current ( $I_L$ ) =  $\sqrt{3} \times \text{Phase current}(I_{ph})$
- For balanced load:  $V_{ph} = V_L$
- Total power =  $3 \times \text{Phase power}$

**Mathematical Relationship:**

- Phase voltage:  $V_{ph} = V_L$
- Phase current:  $I_{ph} = V_{ph}/R$
- Line current:  $I_L = \sqrt{3} \times I_{ph}$
- Therefore:  $I_L = \sqrt{3} \times V_L/R$

### Mnemonic

“DELVIr3” - Delta Equal Line Voltage, Its line current equals phase current times root-3



### Question 4(a) [3 marks]

Define (1) M.M.F. (2) Reluctance (3) flux

#### Solution

Term	Definition
<b>M.M.F. (Magnetomotive Force)</b>	The force that produces magnetic flux in a magnetic circuit, measured in ampere-turns (AT)
<b>Reluctance</b>	The magnetic equivalent of resistance, opposition to magnetic flux, measured in AT/Wb
<b>Flux</b>	The total magnetic field passing through a surface, measured in webers (Wb)

#### Mnemonic

“MFR” - MMF Flows against Reluctance like current flows against resistance

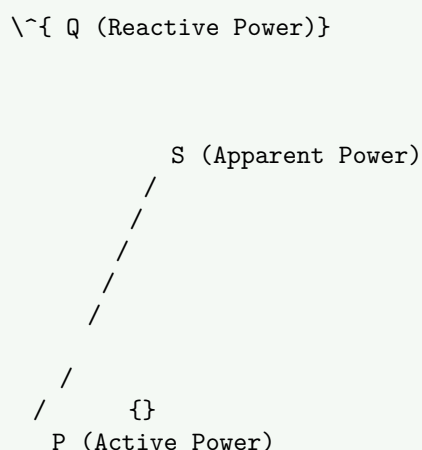
### Question 4(b) [4 marks]

Explain Apparent, Active and Reactive power in A.C circuits.

#### Solution

Power Type	Symbol & Unit	Definition
<b>Apparent Power</b>	S (VA)	Vector sum of active and reactive power
<b>Active Power</b>	P (W)	Actual work-producing power consumed by the load
<b>Reactive Power</b>	Q (VAR)	Power that oscillates between source and load

#### Power Triangle:



#### Relationships:

- $S = \sqrt{P^2 + Q^2}$
- $P = S \times \cos$
- $Q = S \times \sin$
- Power factor =  $\cos$   
=  $P/S$

### Mnemonic

“SPARQ” - S is Power Apparent, Real is P, Q is reactive

### Question 4(c) [7 marks]

Compare electric and magnetic circuit.

#### Solution

Parameter	Electric Circuit	Magnetic Circuit
Force	EMF (V)	MMF (AT)
Opposition	Resistance ( $\Omega$ )	Reluctance (AT/Wb)
Flow	Current (A)	Flux (Wb)
Ohm's Law	$V = IR$	$MMF = \Phi \times S$
Medium	Conductor	Ferromagnetic material
Energy	Stored in electric field	Stored in magnetic field
Leakage	Negligible	Significant
Path	Conductors	Usually closed loop
Material Property	Conductivity	Permeability
Current Flow	Electron flow	No particle flow

### Mnemonic

“VIRO-MSΦS” - Voltage Is to Resistance as MMF is to Reluctance, Our flows Similar

### Question 4(a) OR [3 marks]

State and explain Fleming's left hand rule.

#### Solution

**Fleming's Left Hand Rule:** Used to find the direction of the force experienced by a current-carrying conductor placed in a magnetic field.

#### Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph TD
    subgraph "Fleming's Left Hand Rule"
        T[Thumb: Force] --{-}{-}{-} F[Forefinger: Field] --{-}{-}{-} M[Middle finger: Current]
    end
{Highlighting}
{Shaded}
```

#### Application:

- Thumb  $\rightarrow$  Direction of Force ( $F$ )
- Forefinger  $\rightarrow$  Direction of magnetic Field ( $B$ )
- Middle finger  $\rightarrow$  Direction of Current ( $I$ )
- Only works when fingers are perpendicular to each other

### Mnemonic

“FBI-Left” - Force, B-field, and I-current directions are shown by the Left hand

### Question 4(b) OR [4 marks]

Draw power triangle and explain each component of it.

### Solution

#### Power Triangle:

#### Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    O {--}{--} P[Active Power P]
    O {--}{--} S[Hypotenuse: Apparent Power S]
    P {--}{--} Q[Reactive Power Q]
    P {-.}{-} A[Power Factor Angle ]
{Highlighting}
{Shaded}
```

#### Components:

Component	Symbol	Unit	Meaning
Active Power	P	Watt (W)	Real power doing useful work
Reactive Power	Q	VAR	Power oscillating between source and load
Apparent Power	S	VA	Vector sum of P and Q
Power Factor	cos	-	Ratio of active to apparent power (P/S)

#### Relationships:

- $S^2 = P^2 + Q^2$
- $P = S \times \cos$
- $Q = S \times \sin$

### Mnemonic

“SPQR” - S is Pythagoras of P and Q, Ratio of P/S is power factor

### Question 4(c) OR [7 marks]

Differentiate statically and dynamically induced E.M.F.

### Solution

Parameter	Statically Induced EMF	Dynamically Induced EMF
<b>Definition</b>	EMF induced due to change in current in the primary coil	EMF induced due to relative motion between conductor and magnetic field
<b>Mechanism</b>	Change in linkage flux	Cutting of magnetic flux
<b>Movement</b>	No physical movement required	Requires relative motion
<b>Examples</b>	Transformer, inductor	Generator, motor
<b>Faraday's Law</b>	$e = -N(d\Phi/dt)$	$e = Blv$
<b>Application</b>	Power transfer without motion	Power generation through motion
<b>Energy Conversion</b>	Electrical to magnetic and back	Mechanical to electrical or vice versa

### Mnemonic

“STIM-DMOV” - STatically Induced needs Magnetic flux change, Dynamically needs MOVement

### Question 5(a) [3 marks]

Define (1) solar cell (2) solar panel (3) solar array

#### Solution

Term	Definition
<b>Solar Cell</b>	Basic photovoltaic unit that converts sunlight directly into electricity through semiconductor material
<b>Solar Panel</b>	Collection of solar cells connected in series/parallel in a frame
<b>Solar Array</b>	Multiple solar panels connected together to form a larger electricity-generating unit

#### Mnemonic

“CPA” - Cell Produces electricity, Panel Arrays cells, Array is collection of panels

### Question 5(b) [4 marks]

Differentiate HAWT and VAWT.

#### Solution

Parameter	Horizontal Axis Wind Turbine (HAWT)	Vertical Axis Wind Turbine (VAWT)
<b>Axis Orientation</b>	Parallel to ground	Perpendicular to ground
<b>Efficiency</b>	Higher (35-45%)	Lower (15-30%)
<b>Wind Direction</b>	Needs to face the wind	Works with wind from any direction
<b>Generator Location</b>	At the top of tower	Can be placed at ground level
<b>Space Required</b>	More	Less
<b>Noise</b>	Higher	Lower
<b>Examples</b>	Propeller-type, widely used commercially	Darrieus, Savonius designs

#### Mnemonic

“HAVE” - Horizontal Aligns with wind, Vertical Enjoys omnidirectional wind

### Question 5(c) [7 marks]

Draw and explain the Block diagram of solar power system.

#### Solution

##### Solar Power System Block Diagram:

flowchart LR

S[Solar Panel] --> C[Charge Controller]

C --> B[Battery Bank]

B --> I[Inverter]

I --> L[AC Load]

B --> D[DC Load]

##### Components:

1. **Solar Panels:** Convert sunlight to DC electricity
2. **Charge Controller:** Regulates battery charging, prevents overcharging
3. **Battery Bank:** Stores energy for use when sunlight isn't available

4. **Inverter:** Converts DC to AC power for household appliances
  5. **Loads:** AC loads (appliances) and DC loads (LED lights, etc.)
- Optional Components:**
- **Monitoring System:** Tracks power generation/consumption
  - **Grid Connection:** Allows selling excess electricity

#### Mnemonic

“SCBIL” - Solar Collects, Battery Inverts for Loads

### Question 5(a) OR [3 marks]

Explain the need of green energy for our planet.

#### Solution

##### Need for Green Energy:

1. **Sustainability:** Renewable sources won't deplete unlike fossil fuels
2. **Pollution Reduction:** Minimizes air and water pollution from burning fossil fuels
3. **Climate Change:** Reduces greenhouse gas emissions that cause global warming
4. **Energy Security:** Decreases dependence on imported fuels
5. **Economic Benefits:** Creates jobs and reduces health costs related to pollution

#### Mnemonic

“SPECS” - Sustainable, Pollution-free, Economic, Climate-friendly, Secure

### Question 5(b) OR [4 marks]

Classify green energy and explain any one in detail.

#### Solution

##### Classification of Green Energy Sources:

```
mindmap
  root((Green Energy))
    Solar
    Wind
    Hydro
    Biomass
    Geothermal
    Tidal
```

##### Solar Energy in Detail:

- **Working Principle:** Photovoltaic effect converts sunlight to electricity
- **Components:** Solar cells, panels, inverters, batteries
- **Applications:** Residential power, industrial use, transportation
- **Advantages:** No pollution, abundant source, low maintenance
- **Limitations:** Weather dependent, requires storage, initial cost

#### Mnemonic

“SWHBGT” - Sun Wind Hydro Biomass Geothermal Tidal are green energy types

### Question 5(c) OR [7 marks]

Explain block diagram of wind power system and explain the operation of wind power system.

## Solution

### Wind Power System Block Diagram:

flowchart LR

```
W[Wind Turbine] --> G[Generator]
G --> C[Controller]
C --> B[Battery Storage]
C --> I[Inverter]
I --> L[Load]
I --> GR[Grid Connection]
```

### Operation:

1. **Wind Turbine:** Converts wind's kinetic energy to mechanical energy
2. **Generator:** Transforms mechanical rotation to electrical energy
3. **Controller:** Regulates power output and protects from high winds
4. **Battery:** Stores excess energy (for off-grid systems)
5. **Inverter:** Converts DC to AC for consumption
6. **Grid Connection:** Feeds excess power to grid or draws when needed

### Types of Wind Turbines:

- Horizontal Axis (HAWT): Main commercial type
- Vertical Axis (VAWT): Better for urban settings

### Wind Speed Requirements:

- Cut-in speed: 3-5 m/s
- Rated output: 12-15 m/s
- Cut-out speed: 25 m/s (for safety)

## Mnemonic

“WGCIBIL” - Wind Generates, Controller Balances, Inverter Loads