Unit 2
DC Circuits

ELECTRIC CURRENT

Definition
Electric current is the flow of electric charge (usually electrons) through a conductor like a wire. It is measured in amperes (A). When a potential difference (voltage) is applied across a conductor, free electrons move, forming a current. The direction of electric current is taken as the flow of positive charge (conventional current), although in metals, it is actually due to electrons.
Formula:

$$\boxed{I = \frac{Q}{t}}$$

Where,

I = current (amperes)
Q = charge (coulombs)
t = time (seconds)

ELECTRIC POWER

Definition
Electric power is the rate at which electrical energy is consumed or converted into another form (heat, light, motion). It is measured in watts (W). It tells us how fast energy is being used or produced by an electrical device.
Formula:

$$\boxed{\mathrm{P} = \mathrm{VI} = I^2R = \frac{\mathrm{V}^2}{R}}$$

Where,

P = power (watts)
V = voltage (volts)
I = current (amperes)
R = resistance (ohms)

OHM'S LAW

Definition
Ohm's Law is one of the fundamental principles in electrical engineering. It states that the current (I) flowing through a conductor between two points is directly proportional to the voltage (V) across the two points, provided the temperature and physical conditions of the conductor remain constant. The constant of proportionality is called resistance (R).
Mathematically:

$$\boxed{V = I \times R}$$

Where,

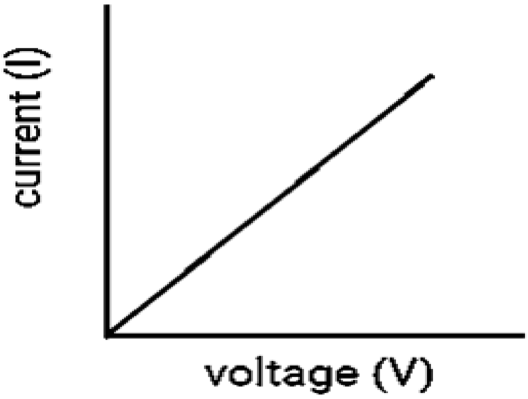
V = Voltage in volts (V)
I = Current in amperes (A)
R = Resistance in ohms (Ω)

Explanation

- The law gives the linear relationship between voltage and current.
- If resistance increases, current decreases for the same voltage.
- Commonly used in analysis and design of electrical circuits.

Graphical Representation

A straight-line graph between Voltage (V) and Current (I), with the slope equal to resistance (R).



CLASSIFICATION OF NETWORK ELEMENTS

Definition: Network elements are individual components used in an electric circuit. These elements can be classified as:

- **Active elements**: Elements that supply energy (e.g., voltage source, current source).
- **Passive elements**: Elements that consume energy (e.g., resistor, inductor, capacitor).
- **Linear elements**: Elements having linear voltage-current relationship (e.g., resistors).
- **Non-linear elements**: Elements with non-linear behaviour (e.g., diodes).
- **Unilateral elements**: Elements where current flows in one direction (e.g., diode).
- **Bilateral elements**: Elements that allow current in both directions (e.g., resistor).

SOURCE CONVERSION

Definition

Source conversion (also called source transformation) is the process of converting a voltage source in series with a resistance into an equivalent current source in parallel with the same resistance, and vice versa, without changing the overall behaviour of the circuit at the terminals.

This technique helps simplify complex networks by allowing easier application of circuit analysis techniques such as Thevenin's and Norton's theorems, Mesh Analysis, and Node Voltage Method.

Types of Source Conversions

There are two basic types of conversions:

1. Voltage Source to Current Source
2. Current Source to Voltage Source

1. Voltage Source to Current Source Conversion

A voltage source (V) in series with resistance (R) can be converted to a current source (I) in parallel with resistance (R).

Conversion Formula:

$$\boxed{I = \frac{\mathrm{V}}{\mathrm{R}}}$$

- The value of the current source = Voltage ÷ Resistance
- The resistance remains the same, just shifts from series to parallel.

Diagram:

$$\begin{array}{cc} V & I \\ ----|>|----R---- & ----->|----R---- \\ Voltage\ Source & Current\ Source \\ (Series\ R) & (Parallel\ R) \end{array}$$

2. Current Source to Voltage Source Conversion

A current source (I) in parallel with resistance (R) can be converted into a voltage source (V) in series with resistance (R).

Conversion Formula:

$$\boxed{V = I \times R}$$

- The value of the voltage source = Current × Resistance
- Resistance remains the same, just shifts from parallel to series.

Diagram:

$$\begin{array}{cc} I & V \\ ----->|----R---- & ----|>|----R---- \\ Current\ Source & Voltage\ Source \\ (Parallel\ R) & (Series\ R) \end{array}$$

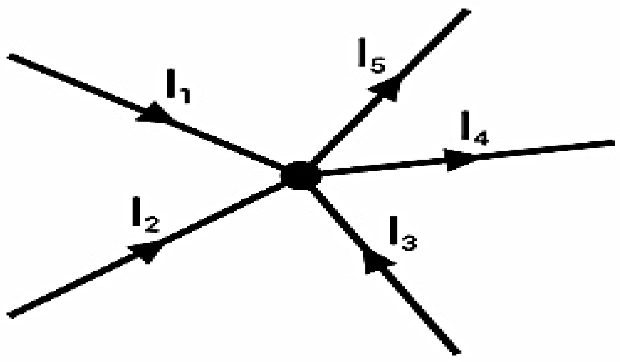
KIRCHHOFF'S LAWS (KVL AND KCL)

(a) Kirchhoff's Current Law (KCL)

Definition: KCL states that the total algebraic sum of currents entering a junction (or node) in an electrical circuit is always equal to zero. This is based on the principle of conservation of electric charge.

Mathematically:

$$\boxed{\sum I(incoming) = \sum I(outgoing)}$$



$$I_1 + I_2 + I_3 = I_4 + I_5$$

Explanation:

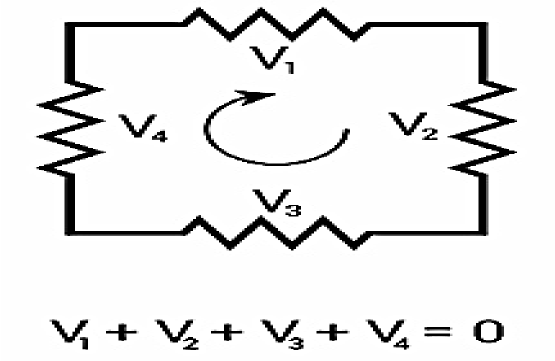
- At any junction, current does not accumulate.
- The sum of currents entering equals the sum of currents leaving.

(b) Kirchhoff's Voltage Law (KVL)

Definition: KVL states that the algebraic sum of all the voltages around any closed loop or mesh in a circuit is equal to zero. It is based on the principle of conservation of energy.

Mathematically:

$$\boxed{\sum V = 0\ (for\ any\ closed\ loop)}$$



Explanation:

- Voltage drops and gains are added algebraically.
- Essential for mesh analysis in circuits.

NODE VOLTAGE AND MESH ANALYSIS

Nodal Analysis

Definition: Nodal analysis is a method to determine the voltage at each node in a circuit using KCL.

Steps:

1. Choose a reference node.
2. Apply KCL to other nodes.
3. Solve equations to find node voltages.

Mesh Analysis

Definition: Mesh analysis is a method used to find the current flowing in each mesh (independent loop) of a planar circuit using KVL.

Steps:

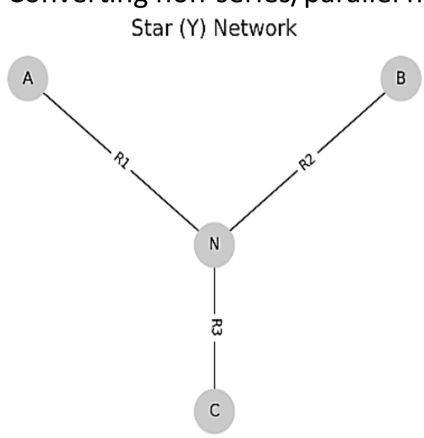
1. Identify meshes.
2. Assign mesh currents.
3. Apply KVL in each mesh.
4. Solve the simultaneous equations.

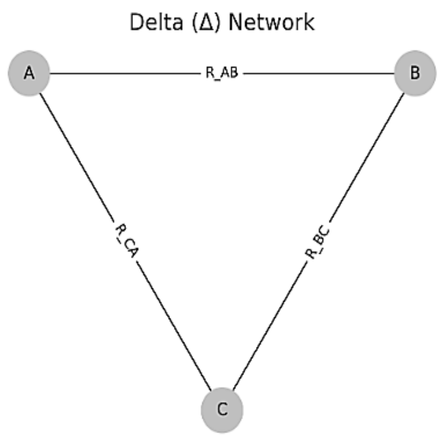
STAR-DELTA AND DELTA-STAR TRANSFORMATIONS

Definition: These transformations are used to simplify complex resistor networks. A star (Y) network is a configuration with three resistors connected to a common node, while a delta (Δ) network is a triangle-like configuration.

Use:

- Simplifying resistive networks in 3-phase circuits.
- Converting non-series/parallel networks into solvable forms.





Conversion Formulas:

1. *Star (Y) to Delta (Δ) Conversion:*
   Given: R_1, R_2, R_3 in star
   Convert to: R_{AB}, R_{BC}, R_{CA} in delta

$$R_{AB} = \frac{R_1R_2 + R_2R_3 + R_3R_1}{R_3}$$
$$R_{BC} = \frac{R_1R_2 + R_2R_3 + R_3R_1}{R_1}$$
$$R_{CA} = \frac{R_1R_2 + R_2R_3 + R_3R_1}{R_2}$$

2. *Delta (Δ) to Star (Y) Conversion:*
   Given: R_{AB}, R_{BC}, R_{CA}
   Convert to:

$$R_1 = \frac{R_{AB} \cdot R_{CA}}{R_{AB} + R_{BC} + R_{CA}}$$
$$R_2 = \frac{R_{AB} \cdot R_{BC}}{R_{AB} + R_{BC} + R_{CA}}$$
$$R_3 = \frac{R_{BC} \cdot R_{CA}}{R_{AB} + R_{BC} + R_{CA}}$$

SUPERPOSITION THEOREM

Definition

Superposition theorem states that in any linear bilateral network with multiple independent sources, the response (current or voltage) in any element of the circuit is the algebraic sum of the responses caused by each independent source acting alone, with all other independent sources turned off (replaced by their internal resistance).

For Independent Sources

- Voltage Source → Replace with a short circuit (0V)
- Current Source → Replace with an open circuit (0A)

Applications

- Analysing circuits with multiple sources.
- Useful for complex DC and AC networks.

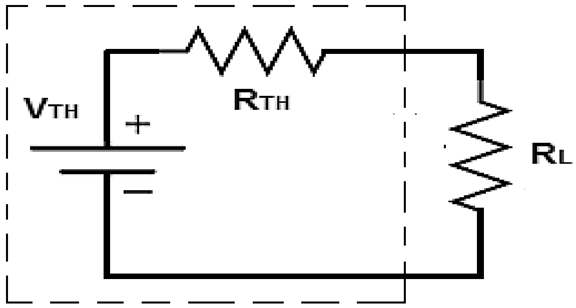
THEVENIN'S THEOREM

Definition

Thevenin's Theorem states that any linear electrical network containing voltage sources and resistances can be replaced at terminals A-B by an equivalent voltage source V_{th} in series with a resistance R_{th}.

Steps to Apply

1. Remove the load resistor.
2. Find open-circuit voltage (Vth).
3. Find equivalent resistance (Rth).
4. Draw the Thevenin's equivalent circuit.



Formula:
V_{th} = Open-circuit voltage
R_{th} = Equivalent resistance across terminals