Electrical Science

Electrical Science Presentation

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Enrollment Numbers:
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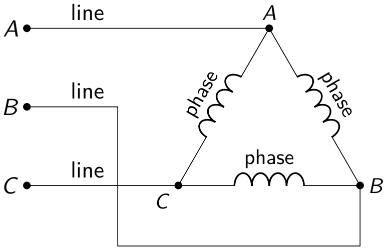
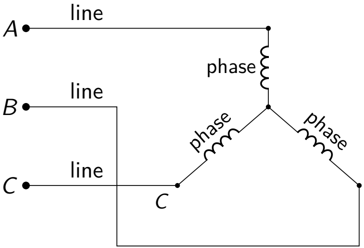
Explain the mathematical expression for voltage and current relationship in star and delta connection.

What are lines and phases?
The individual windings of a delta or star-connected alternator or transformer, and their corresponding load impedance are called “phases”, whereas the conductors that interconnect three-phase supplies and their loads are called “lines”:





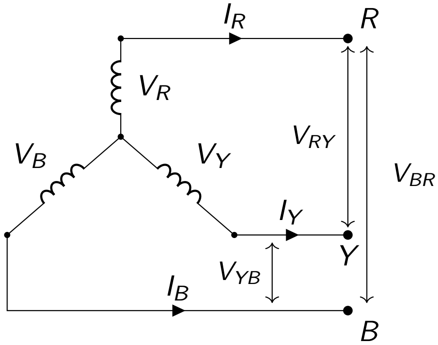
Phase and Line Voltages and Currents

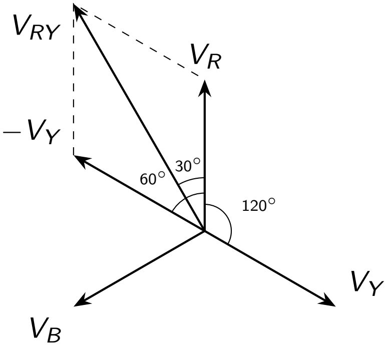
The potential difference appearing across any phase is called a “phase voltage” (E_P), and the current flowing through any phase is called a “phase current” (I_P).

The potential difference appearing between any pair of line conductors is called a “line voltage” (E_L), and the current flowing through a line conductor is called a “line current” (I_L).

In a three-phase, three-wire system, there are three “line conductors”.

Star (Wye) Connected System





Let V_R, V_Y and V_B represent the three phase voltages while V_{RY}, V_{YB} and V_{BR} represent the line voltages. Assume that the system is balanced, so:

$$|V_R| = |V_Y| = |V_B| = |V_{ph}|$$

From the circuit and phasor diagram of star connected load, it can be observed that the line voltage V_{RY} is a vector difference of V_R and V_Y or the vector sum of V_R and $-V_Y$:

$$V_{RY} = V_R + (-V_Y) = V_R - V_Y$$

Applying parallelogram law to obtain the magnitude of this, we get:

$$\begin{aligned} V_{RY} &= \sqrt{(V_R)^2 + (V_Y)^2 + 2V_R V_Y \cos(60^\circ)} \\ &= \sqrt{(V_{ph})^2 + (V_{ph})^2 + 2(V_{ph})^2 \cos(60^\circ)} = \sqrt{3}V_{ph} \end{aligned}$$

Similarly,

$$V_{RY} = V_Y - V_B = \sqrt{3}V_{ph}$$
$$V_{BR} = V_B - V_R = \sqrt{3}V_{ph}$$
$$\therefore V_{RY} = V_{YB} = V_{BR} = V_L = \text{line voltage}$$
$$\therefore V_L = \sqrt{3}V_{ph}$$

Therefore, in a star connected system,

$$\text{Line voltage} = \sqrt{3} \times \text{Phase Voltage}$$

Again, refer the circuit of star connected system, it can be seen that each line is in series with its individual phase winding. Therefore, in a star connection, the line current in each line is equal to the current in the corresponding phase winding.

Let I_R, I_Y and I_B be the currents in R, Y and B lines respectively. Since, the load is balanced, therefore:

$$I_R = I_Y = I_B = I_{ph}$$

Then,

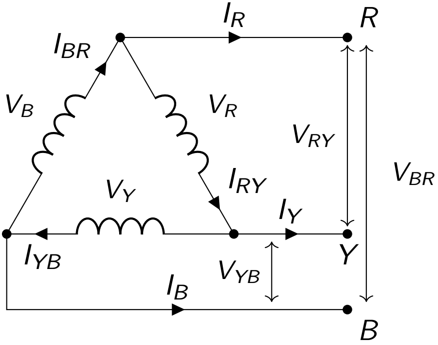
$$I_L = I_{ph}$$
$$\text{Line Current} = \text{Phase Current}$$

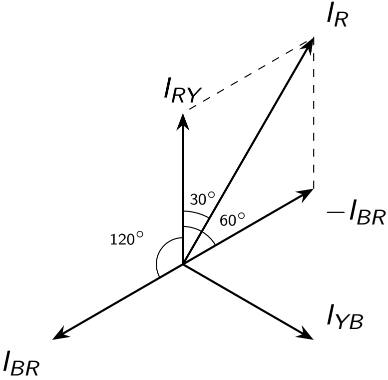
Note: for a balanced star connected system, the vector sum of line current is equal to zero.

$$I_R + I_Y + I_B = I_n = 0$$

Where, I_n is the neutral current.

Delta Connected System





Let I_{RY}, I_{YB} and I_{BR} are the phase current in delta connected system while I_R, I_Y and I_B being the line currents.

By referring the circuit and phasor diagram, it can be seen that current in each line is the vector difference of corresponding phase currents and are given as:

$$I_R = I_{BR} - I_{RY}$$
$$I_Y = I_{RY} - I_{YB}$$
$$I_B = I_{YB} - I_{BR}$$

Now, the magnitude of current I_R can be obtained by parallelogram law of vector addition, as follows:

$$I_R = \sqrt{(I_{BR})^2 + (I_{RY})^2 + 2I_{BR}I_{RY}\cos(60^\circ)}$$

Assume the system is balanced, therefore:

$$|I_{RY}| = |I_{BR}| = |I_{YB}| = |I_{ph}|$$

$$\Rightarrow I_R = \sqrt{(I_{ph})^2 + (I_{ph})^2 + 2(I_{ph})^2\cos 60^\circ} = \sqrt{3}I_{ph}$$

Since the system is balanced, therefore the current through each line will be the same:

$$I_R = I_Y = I_B = I_L = \text{Line Current}$$
$$\therefore I_L = \sqrt{3} \times \; I_{ph}$$
$$\Rightarrow \text{Line Current} = \sqrt{3} \times \; \text{Phase Current}$$

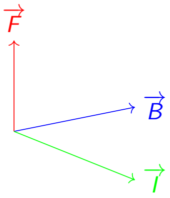
Since, neutral does not exist in a delta connected system, thus the phase voltage and line voltage are same.

$$V_{RY} = V_{YB} = V_{BR} = V_L$$
$$\Rightarrow V_L = V_{ph}$$

Write the working principle of DC motor. Also explain the classification of different DC motors.

Flemming Left Hand Rule:

If we stretch the first finger, second finger and thumb of our left hand to be perpendicular to each other, and first finger represents the direction of the magnetic field, the second finger represents the direction of the current, then the thumb represents the direction of the force experienced by the current carrying conductor.

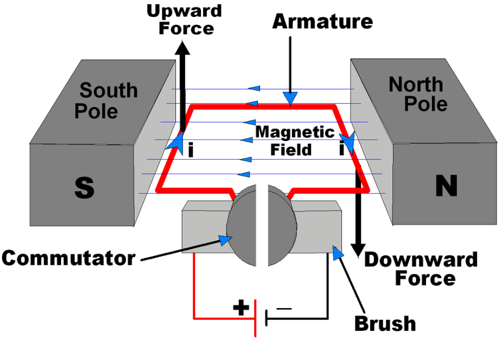


Working Principle

"When a current carrying conductor is placed in a magnetic field, it experiences a mechanical force"

A DC motor operates based on the principle of electromagnetic induction. It consists of a coil (armature) that carries current and is placed in a magnetic field. When current flows through the coil, it generates a magnetic field. The interaction between this magnetic field and the external magnetic field (created by stationary magnets or field windings) results in a torque, causing the motor to rotate. The commutator and brushes help to maintain the direction of current flow, ensuring continuous rotation.

Diagram:



DC Motor Conceptual Diagram

Types of DC Motor

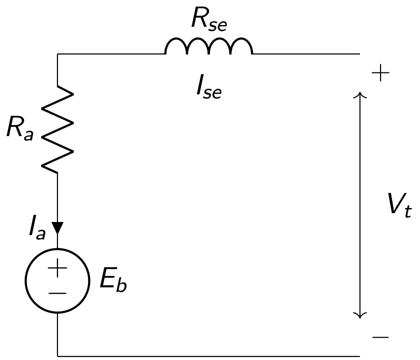
There are three types of motors:

1. Series Motor
2. Shunt Motor
3. Compound Motor
    1. Long Shunt
    2. Short Shunt

Series Motor:

$$I_L = I_{se} = I_a$$
$$E_b + I_a R_a + I_{se} R_{se} - V_t = 0$$
$$E_b + I_a R_a + I_a R_{se} - V_t = 0$$
$$E_b + I_a (R_a + R_{se}) - V_t = 0$$

$$\boxed{V_t = E_b + T_a (R_a + R_{se}) + V_{\text{brush}}}$$



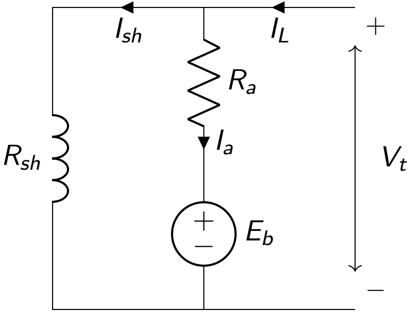
Shunt Motor:

$$I_L = I_{sh} + I_a$$

$$E_b + I_a R_a - V_t = 0$$

$$\boxed{V_t = E_b + I_a R_a}$$

$$\boxed{I_{sh} = \frac{V_t}{R_{sh}} = \frac{E_b + I_a R_a}{R_{sh}}}$$



Compound Motor (Long Shunt):

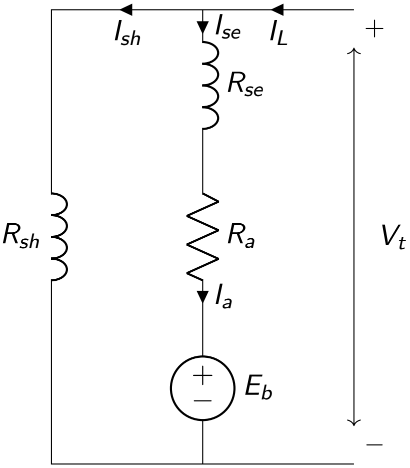
$$I_L = I_{se} + I_{sh}$$

$$I_L = I_a + I_{sh}$$

$$E_b + I_a R_a - I_{se} R_{se} - V_t = 0$$

$$\boxed{V_t = E_b + I_a R_a + I_{se} R_{se}}$$

$$\boxed{I_{sh} = \frac{V_t}{R_{sh}} = \frac{E_b + I_a\left(R_a + R_{se}\right)}{R_{sh}}}$$



Compound Motor (Short Shunt):

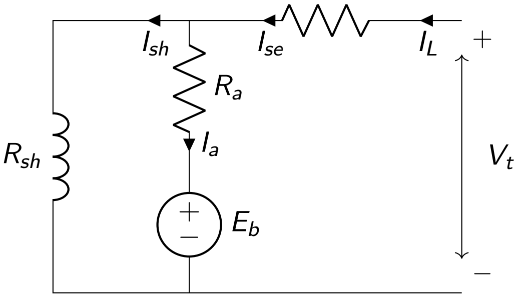
$$I_L = I_{se}$$

$$I_L = I_{se} = I_a + I_{sh}$$

$$E_b + I_a R_a + I_{se} R_{se} - V_t = 0$$

$$\boxed{V_t = E_b + I_a R_a + I_{se} R_{se}}$$

$$\boxed{I_{sh} = \frac{V_t}{R_{sh}} = \frac{E_b + I_a R_a + I_{se} R_{se}}{R_{sh}}}$$



What are measuring instruments? Also classify the different categories of the measuring instrument.

An instrument is a device in which we can determine the magnitude or value of the quantity to be measured. The measuring quantity can be voltage, current, power and energy etc. Generally instruments are classified into two categories:

1. Absolute Instrument
2. Secondary Instrument

Absolute Instruments

These instruments doesn't give direct readings but gives in terms of instrumental constant. These are accurate measuring instruments. These are used in the research laboratories.

Example: Tangent galvanometer, which gives the measured current in terms of tangent of deflected angle, the radius and the number of turns of the galvanometer.

Secondary Instruments

This instrument determines the value of the quantity to be measured directly. Generally these instruments are calibrated by comparing with another standard secondary instrument.

Examples of such instruments are voltmeter, ammeter, watt-meter, etc. Practically secondary instruments are suitable for measurement.

Secondary instruments are divided into three categories:

1. Indicating Instruments
2. Recording Instruments
3. Integrating Instruments

Indicating Instruments

Indicating instruments are those which indicate the instantaneous value of the electrical quantity being measured at the time at which it is being measured. Their indications are given by pointers moving over calibrated scale.

Example - Ammeter, Voltmeter and Watt-meter.

Recording Instruments

Recording instruments are those, which gives a continuous record or the variations of such a quantity over a selected period of time. The moving system of the instrument carries an inked pen which rests lightly on a chart or graph, that is moved at a uniform and low speed, in a direction perpendicular to that of the deflection of the pen. The path traced out by the pen presents a continuous record of the variations in the deflection of the instrument.

Integrating Instruments

Integrating instruments are those which measure the total quantity of electricity or electrical energy supplied over a period of time.

Example - Ampere-hour and watt-hour meters.