INTRODUCTION TO ELECTRICAL ENGNEERING (22ESC142/242)
MODULE-1

Syllabus: **Introduction:** Conventional and non-conventional energy resources; General structure of electrical power systems using single line diagram approach. Power Generation: Hydel, Nuclear, Solar & wind power generation (Block Diagram approach).

DC Circuits: Ohm's Law and its limitations. KCL & KVL, series, parallel, series-parallel circuits. Simple Numerical.

INTRODUCTION
CONVENTIONAL & NON-CONVENTIONAL ENERGY RESOURCE

Conventional Energy Resource

Conventional energy sources are naturally present and have been in use for many years these are also known as non-renewable energy sources, which are present in a limited quantity and take over hundreds of years to form.
Ex: Coal, petroleum, firewood, fossil fuels , straw etc.

Non-Conventional Energy Resource

The Non-Conventional energy sources are the sources of energy which are used as the alternative of conventional energy sources. These are also known as renewable energy sources. Which are available abundance in nature and being regularly generated in short time.
Ex: Solar, wind, tidal, biomass energy etc.

Difference between Conventional and Non-Conventional Energy Resource

Conventional Energy	Non-Conventional Energy
• The sources of energy that have been used all around the world for a long time are called conventional energy sources.	• The energy sources whose evolution has been done the recent years are known as non-conventional energy sources.
• Conventional sources of energy available are limited quantity in nature.	• Non-conventional sources are available in abundance in nature.
• Ex: coal, petroleum, natural gas, firewood, etc.	• Ex: sun, wind, tides, water, biofuels, etc.

• These sources are mainly used at large scale in commercial and industrial applications such in thermal power plants, fuel in vehicles, etc. • Theseare **Non renewable** and are not **pollution free.**	• These sources are used at small scale in domestic and specific commercial and industrial applications such as solar power for houses, offices, etc. • These are **renewable** and **pollution free**

GENERAL STRUCTURE OF ELECTRICAL POWER SYSTEMS

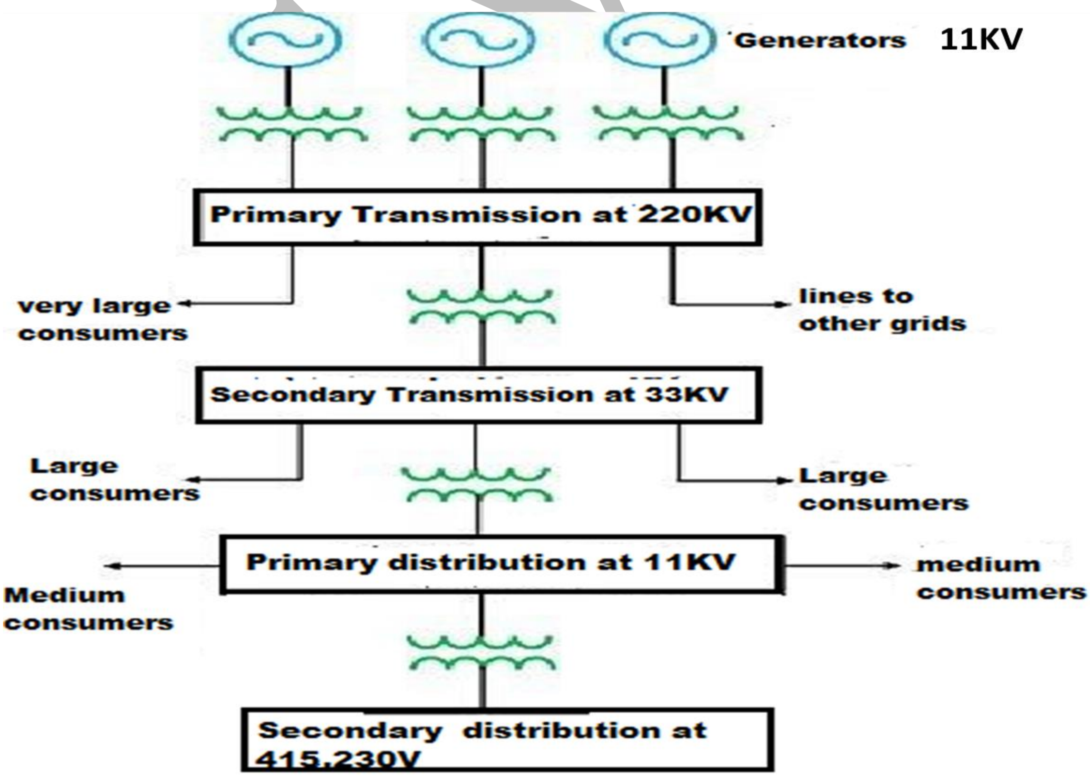
The electrical power supply system consists of 3 divisions:

1. Generation
2. Transmission
3. Distribution

The power is generated in generating station. The transmission system is to deliver power from generating station to centers and to large industrial consumers. The distribution system is to deliver from centers to various consumers.

The single line diagram is as shown below

Single line diagram



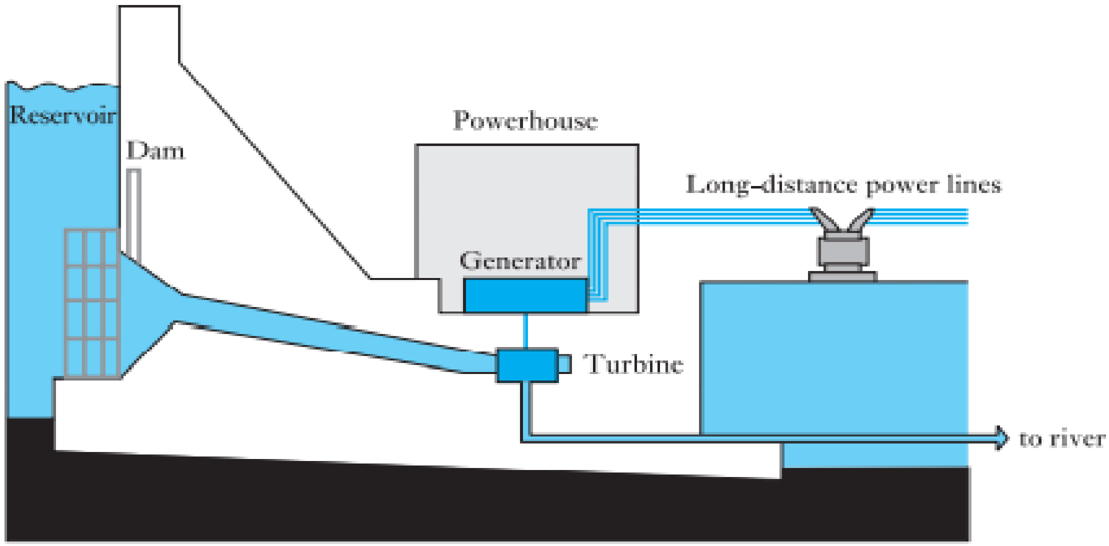
Single line diagram of Electrical power

- The block diagram and single line diagram is as shown in fig.
- The electrical power is generated by alternators in generating stations.
- Usually the generated voltage is 11KV in certain cases 33KV also.
- In order to reduce the copper loss and for economy reasons the voltage is stepped up from 11KV to 220KV using step up transformers.
- The Primary transmission lines transmit the power from generating station to various substations.
- At this substation the voltage is step down from 220KV to 33KV by using step down transformer.
- Then the secondary transmission lines transmit the power to various substations and to large Industries.
- In primary distribution station the voltage is step down to 33KV to 11KV using step down Transformer.
- These substations transmit the power to various areas and to the medium scale industries.
- In each area using step down transformer the voltage is step down to 11KV to 415V
- The most of domestic, commercial and small scale industries are supplied power at low voltage i,e 415V to 3-Phase load and 230V to single phase loads.

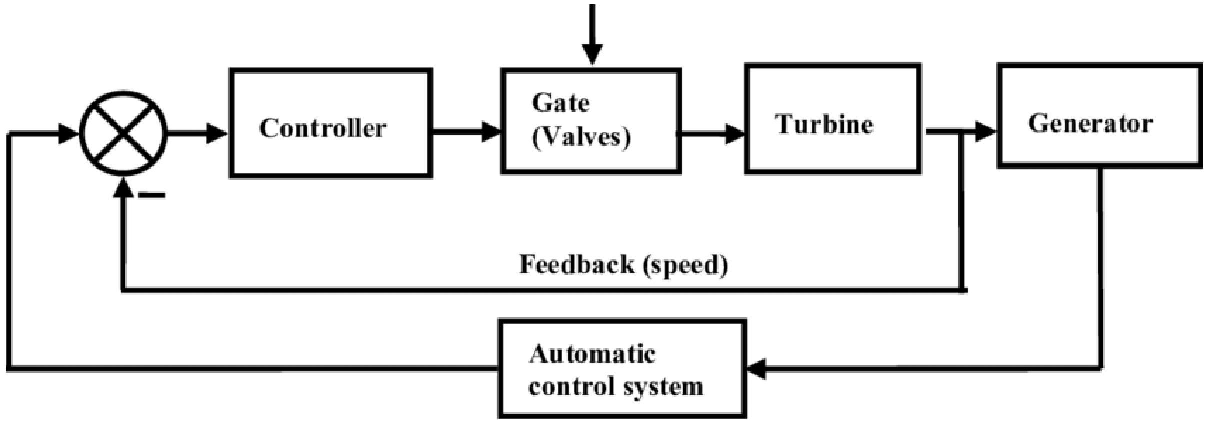
POWER GENERATION

Hydro power generation

Hydro power plants convert the potential energy of falling water into electricity. The block diagram of a hydro power station is as shown below.



General Layout of Hydro power plant



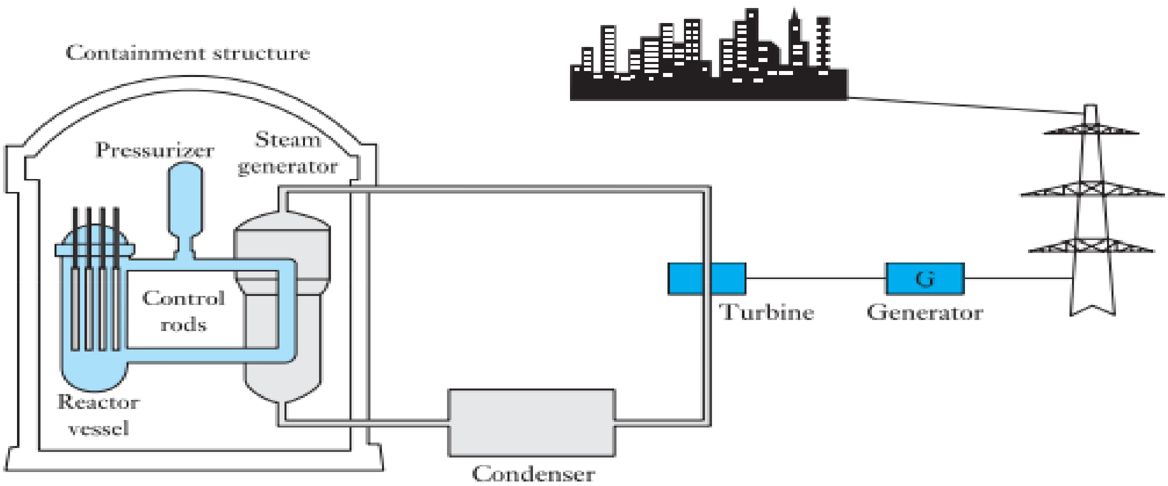
Block diagram of Hydro power plant

In Hydroelectric power stations the water can be store in a man-made lake, or reservoir. When water is released through the gates of reservoir, it spins a turbine which is placed below and water turbine captures the energy of the falling water. This turbine is coupled with the armature of an alternator which converts mechanical energy into electrical energy. The controller controls the flow of water so that the turbine rotates at constant speed.

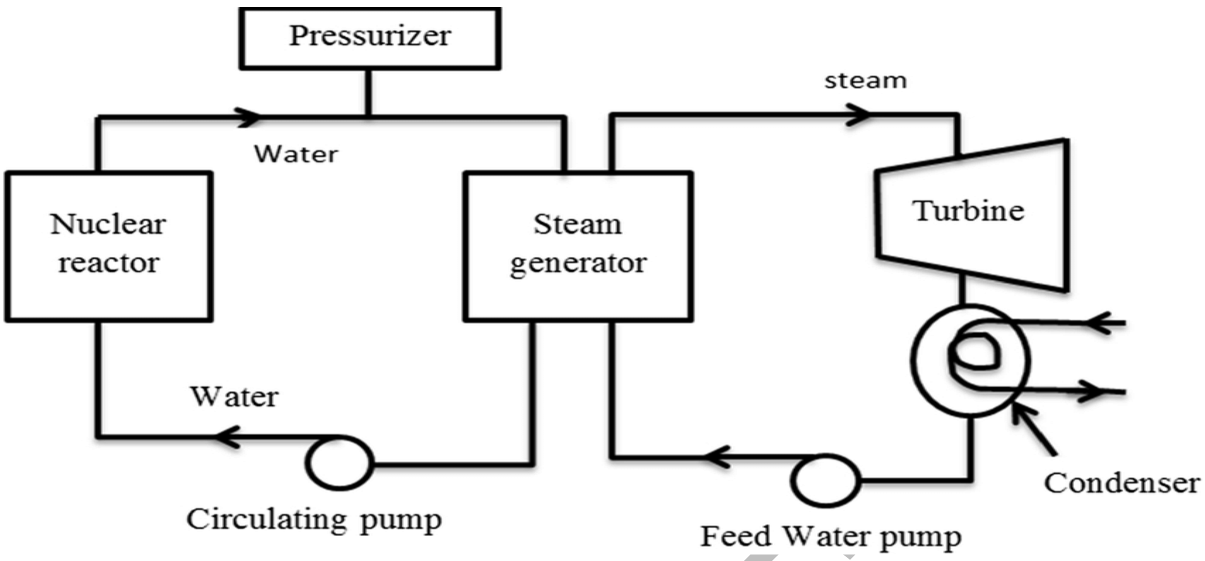
Hydroelectric power stations are becoming very popular because the reserves of fuels (i.e., coal and oil) are depleting day by day. They have the added importance for flood control, storage of water for irrigation and water for drinking purposes.

Nuclear power generation

Nuclear Power plants is a thermal power plant where heat generated by nuclear fission is used to drive the turbine. The block diagram is as shown below.



General Layout of Nuclear power plant

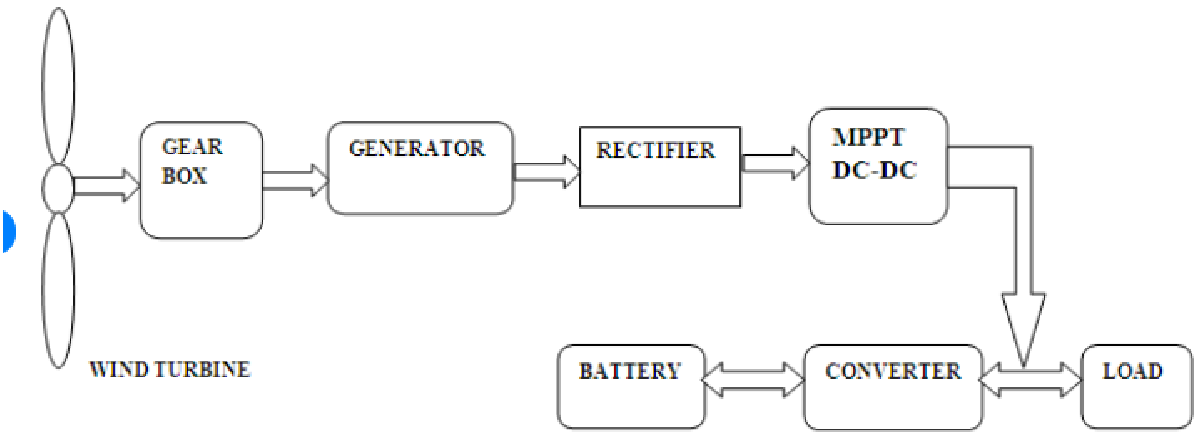


Block diagram of Nuclear power plant

Nuclear fission inside the Nuclear reactor generates heat. The coolant in the circuit gets heated by observing the heat and enters into a steam generator. In this feed water is heated and converted to steam. The steam from the steam generator enters into the turbine and rotates the turbine. This turbine is coupled with the armature of an alternator which converts mechanical energy into electrical energy. After that the steam will moved to the condenser and converted to water which is pumped back to steam generator. The cycle is repeated continuously for generation of power.

Wind power generation

In wind power generation the wind energy is used to generate electricity. The wind energy is converted into mechanical energy by an aero turbine. The block diagram is as shown below.

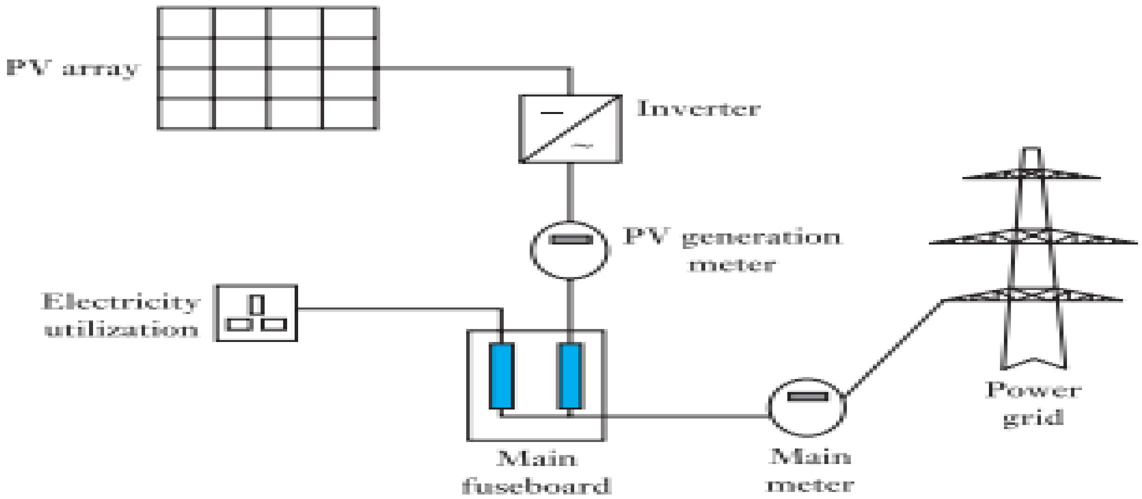


Wind energy system block diagram

The mechanical power is transferred through gears to the generator to increase its speed. Since rotor speeds are low, a gear system is necessary to match the synchronous speed of the generator. Due to fluctuations in wind speed, it not possible to obtain a power supply of a fixed frequency from windmills. To overcome this problem, the output of generator is rectified and converted into AC with the help of inverter.

Solar power generation

In a Solar power plant the electricity is generated using photo voltaic system consists of PV array. The block diagram is as shown below



Solar power is harnessed using Solar Photovoltaic (PV) technology that converts sunlight into electricity by using semiconductors.
When the sun hits the semiconductor within the PV cell, electrons are freed and bus bars collect the running electrons which results in electric current.
When the Solar panels are placed in the sunlight in a calculated manner, they start producing current and voltage in the form of Direct current (DC) but in most of the countries the appliances and equipment runs on Alternative current (AC) so the Solar panels are connected to an Inverter which then converts DC into AC for home use.

Ohm’s Law

German physicist Georg Ohm derived relationship between voltage, current and resistance in an electrical circuit called ohm’s law.

It states that “The potential difference applied across the circuit, is directly proportional current flowing through the circuit provided the temperature remains Constant ".

$$V \propto I$$

$$V = R\,I$$

R - Constant of proportionality called Resistance of a conductor in ohm's (Ω).

V – Potential difference across the circuit or voltage in volts (V).

I - Current in Amps (A).

Limitations of Ohm's law

- It is not applicable to non-metallic conductors like silicon carbide.
- It is not applicable to non-linear devices like diodes.
- It is not applicable to 'arc lamps', because arc produced exhibits non-linear characteristics.

Kirchhoff's Law

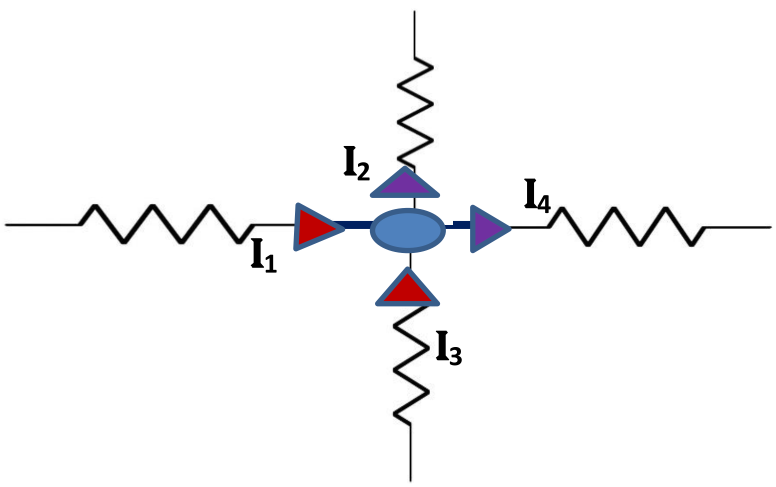
Kirchhoff's circuit laws are deals with the two parameters in the electric circuit - current and potential difference. They were first described in 1845 by German physicist Gustav Kirchhoff. He generalized the work of Georg Ohm.

i) Kirchhoff's Current Law (KCL)

Statement: It states that **"The Algebraic sum of the currents meeting at a junction in an electric circuit is equal to zero."**

$$\Sigma I = 0$$

Example: Consider a junction in an electrical network as shown in the fig.The currents $\mathbf{I_1}$ and $\mathbf{I_3}$ are taken as positive as they are entering the junction. While $\mathbf{I_2}$ and $\mathbf{I_4}$ are negative as leaving the junction.



Applying KCL to the above circuit

$$I_1 - I_2 + I_3 - I_4 = 0$$

$$\text{I,e} \quad I_1 + I_3 = I_2 + I_4$$

"The total current flowing towards a junction is equal to the total current leaving the junction."

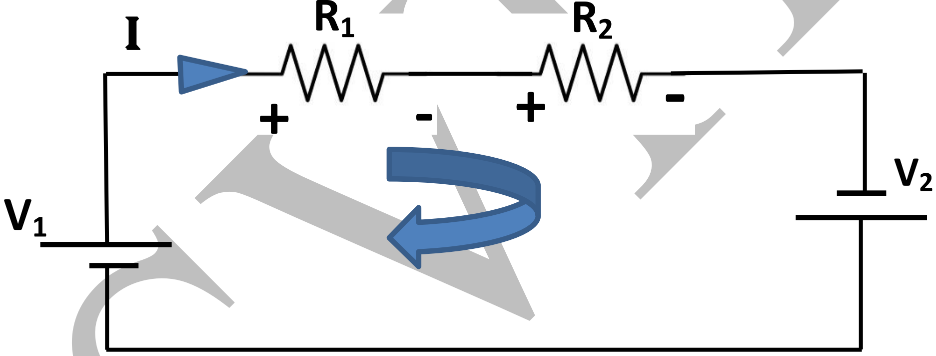
Note: Sign convention: The currents entering the junction taken as **positive** and the currents leaving the junction are taken as **negative**.

ii) Kirchhoff's Voltage law [KVL]

Statement: "**In any closed path, the algebraic sum of the Emf's and the voltage drops across the circuit elements is equal to zero**. "

$$\Sigma \text{ Emf} + \Sigma \text{ IR drops} = 0$$

Example: Consider an electrical network as shown in fig



Applying KVL to the loop

$$- IR_1 - IR_2 + V_2 + V_1 = 0$$

$$V_1 + V_2 = IR_1 + IR_2$$

Note: Sign convention: while tracing the path across

i) If its moving from '+' **to** '-'then it is voltage drop therefore take as **negative.**

ii) If its moving from '-' **to** '+'then it is voltage rise therefore take as **Positive.**

Electrical Power

The rate at which electrical work is done in a circuit is called **Electrical Power**. Electrical power is denoted by P and measured in Watt (W).

$$\mathbf{P=V\ I}$$

$$P = (IR)\ I \quad = I^2 R \qquad\qquad [V = IR]$$

$$P = V\ (\frac{V}{R}) = \frac{V^2}{R} \qquad\qquad [I=V/R]$$

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

Energy

Energy is defined as the amount of electrical work is done in a circuit in a specified time.

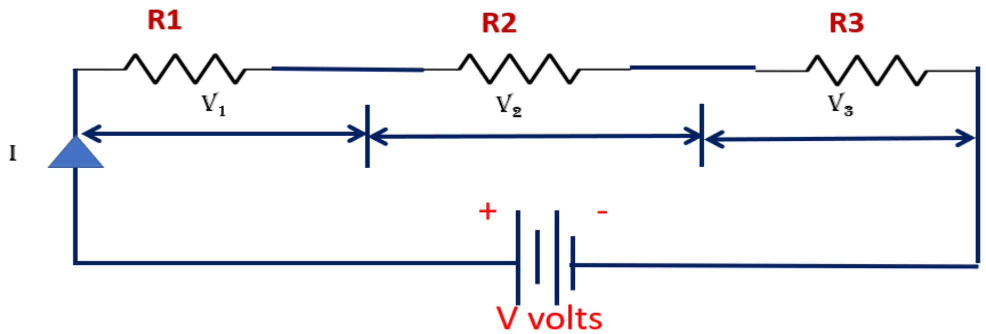
It is denoted as 'E' and measured in Joules (J).

$$\boxed{\mathbf{E=VI\ t = \ I^2 R\ t = \frac{V^2\ t}{R}}\ \text{joules}}$$

Analysis of Series and Parallel Circuits

I. Series Circuit

In a series circuit the finishing end of one resistor is connected to starting end of another resistor.
Consider three resistances connected series.



In series circuit the current flowing through all the resistances is same.
Let **'I'** be the current flowing through all the resistors.

Let **V_1, V_2,** and **V_3** be the voltages drops across the resistances **R1 ,R2** and **R3** respectively

The supply voltage **'V'** is the sum of the voltage drops across the resistances.

I,e $V = V_1 + V_2 + V_3$

According to Ohm's law

$V_1 = IR_1$ $V_2 = IR_2$ $V_3 = IR_3$

Applying Ohm's law to the overall circuit $V = I R_T$

R_T - is the Total or equivalent resistance of the circuit

$$V = V_1 + V_2 + V_3$$
$$I R_T = IR_1 + IR_2 + IR_3$$
$$I R_T = I [R_1 + R_2 + R_3]$$
$$R_T = R_1 + R_2 + R_3$$

Thus the Total or Equivalent Resistance in a series Circuit is equal to the Sum of the resistances connected in series.

Inference

- In Series circuit the same current is flowing through all resistances.
- The supply voltage **'V'** is the sum of the individual voltage drops across the each resistance.
- If **'N'** resistances connected in series then

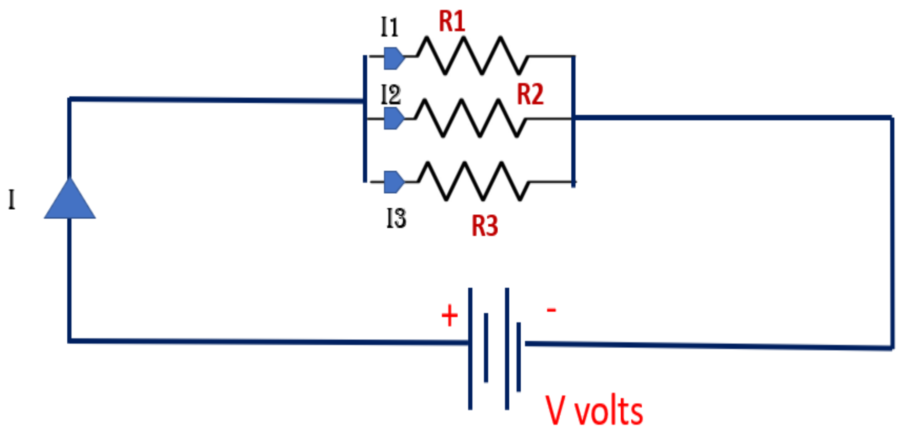
$$R_T = R1 + R2 + R3 + \text{---------------} + R_N$$

and $V = V1 + V2 + \text{-------------} + V_N$

II. Parallel Circuit

In a Parallel circuit the starting end of all the resistor are connected to one point and finishing end of all the resistors are connected to another point.

Consider three resistances connected in parallel.



In parallel circuit the voltage applied across each resistance is equal to the supply voltage.

Let **'I'** be the current drawn from the supply.

Let I_1, I_2, and I_3 be the Current through the resistances **R1** ,**R2** and **R3** respectively.

I,e $$I = I_1 + I_2 + I_3$$

According to Ohm's law

$$I_1 = \frac{V}{R1} \qquad I_2 = \frac{V}{R2} \qquad I_3 = \frac{V}{R3}$$

Applying Ohm's law to the overall circuit $I = \frac{V}{RT}$

R_{eq} - is the Total or equivalent resistance of the circuit

$$I = I_1 + I_2 + I_3$$

$$\frac{V}{R_T} = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}$$

$$\frac{V}{R_T} = V\left[\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right]$$

$$\boxed{\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}}$$

Thus the reciprocal of Total or Equivalent Resistance in a parallel Circuit is equal to the Sum of the reciprocal of individual resistances connected in parallel.

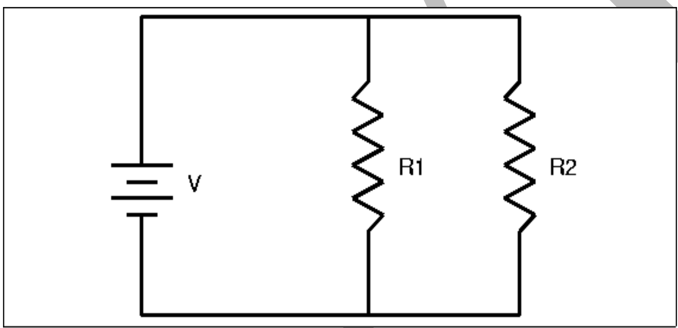
Inference

- In Parallel circuit the voltage across each resistance is equal to supply voltage.
- The total current **'I'** is the sum of the currents drawn by the each resistance.
- If **'N'** resistances connected in parallel then

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \text{-----------} + \frac{1}{R_N}$$

$$\textbf{and} \quad I = I_1 + I_2 + \text{-------------} + I_N$$

Note: When 2 Resistances are connected in parallel then the Total resistance is



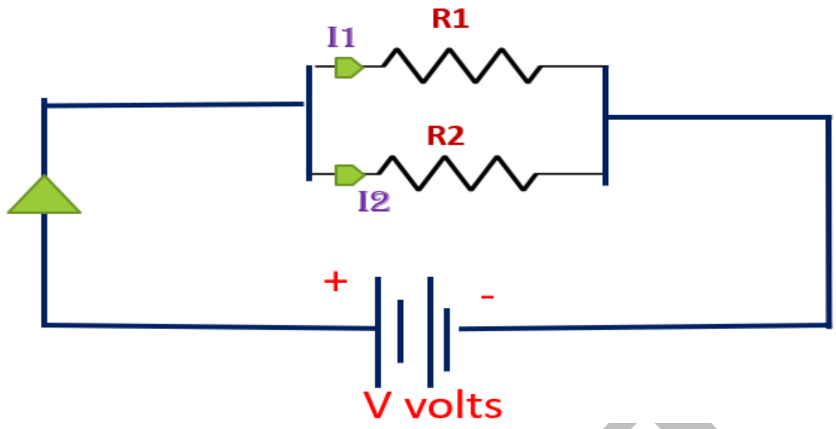
$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2}$$

$$\frac{1}{R_T} = \frac{R_1+R_2}{R_1R_2}$$

$$\boxed{R_T = \frac{R_1+R_2}{R_1R_2}}$$

III. Current Division in Parallel circuit of Resistors

Consider a parallel circuit of two resistors R_1 and R_2 connected across a supply Voltage of **'V'** Volts.



Let I_1 and I_2 be the Current through the resistances R1 and R2 respectively.

I,e $$I = I_1 + I_2 \quad \text{-----------------------------1}$$

According to Ohm's law

$$I_1 = \frac{V}{R1} \quad \text{and} \quad I_2 = \frac{V}{R2}$$

We know that in parallel circuit the voltage across each resistance is equal to supply voltage.

$$\text{I,e} \quad V = V_1 = V_2$$

Where V_1 and V_2 is the voltage across R_1 and R_2

wkt $V_1 = I_1 R_1$ and $V_2 = I_2 R_2$

Therefore $I_1 R_1 = I_2 R_2$

$$\boxed{I_1 = \frac{I_2 R_2}{R1}}$$

Substitute I_1 in equation 1 we get

$$I = I_1 + I_2$$

$$I = \frac{I_2 R_2}{R1} + I_2$$

$$I = I_2 \left[\frac{R_2}{R1} + 1 \right]$$

$$I = I_2 \left[\frac{R_2 + R1}{R1} \right]$$

Therefore $$I_2 = \frac{I\,R1}{R_1 + R2}$$

Similarly $$I_1 = \frac{IR2}{R_1 + R2}$$

List of Formulas

1. By ohm's Law $V = I\,R$, $I = \frac{V}{R}$, and $R = \frac{V}{I}$
2. In series Circuit $R_T = R_1 + R_2 + R_3 + \text{---------------} R_N$
3. In Parallel circuit $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R3}$

   If two resistances are in parallel $R_T = \frac{R_1 R_2}{R_1 + R_2}$
4. The current division in parallel circuit

   Current in a branch $= \frac{\text{Total current x Resistance in an another branch}}{\text{sum of the resistances}}$

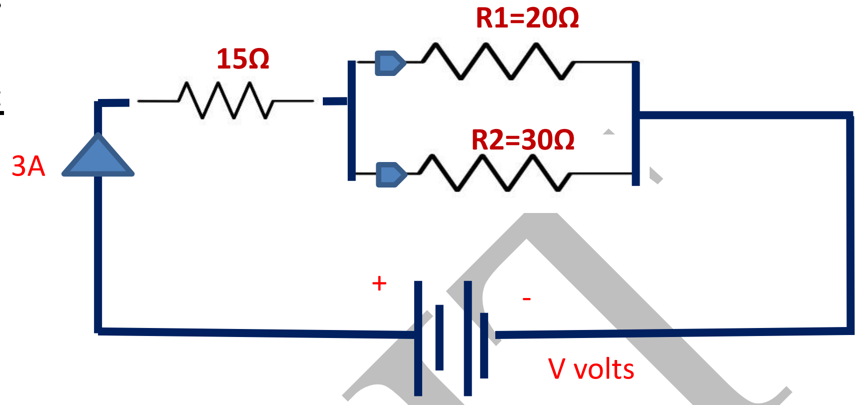
   I,e $I_1 = \frac{I\,R2}{R_1 + R2}$ and $I_2 = \frac{I\,R1}{R_1 + R2}$
5. Kirchhoff's Current Law (KCL) $\Sigma I = 0$

   Total Sum of Incoming Currents = Total sum of outgoing Currents
6. Kirchhoff's Voltage law (KVL) $\Sigma \text{Emf} + \Sigma IR_{\text{drops}} = 0$
7. Electrical Power $P = VI = I^2 R = \frac{V^2 t}{R}$ watts
8. Energy $E = VI\,t = I^2 R\,t = \frac{V^2 t}{R}$ joules

Problems on DC circuits

1. **A circuit consists of two parallel resistors having resistances of 20 Ω and 30 Ω respectively, connected in series with a 15 Ω resistor. If the current through 15 Ω resistor is 3A, find (i) the current in 20 Ω and 30 Ω resistors, (ii) the voltage across the whole circuit, (iii) voltage drop across 15Ω resistor and (iv) the total power and power consumed in all resistors.**

Solution:



$I_{20\Omega}$ =? $I_{30\ \Omega}$ =?

V=? $V_{15\Omega}$ =? P=?

$P_{15\Omega}$ =? $P_{20\Omega}$ =? $P_{30\ \Omega}$ =?

Current through the 15Ω resistor $I_{15\Omega}$ =I =3A the total current of the circuit

i) The current through 20Ω is $I_{20\Omega} = \frac{IR2}{R1+R2}$

$$I_{20\Omega} = \frac{3X30}{30+20}$$

$$\boxed{I_{20\Omega} = 1.8A}$$

The current through 30Ω is $I_{30\Omega} = \frac{I\,R1}{R1+R2}$

$$I_{30\Omega} = \frac{3X20}{30+20}$$

$$\boxed{I_{30\Omega} = 1.2A}$$

ii) Supply Voltage V=?

Wkt $V = I R_T$

$R_T = (20 \| 30) + 15$

$$R_T = \frac{20 \ X\ 30}{20+30} + 15 \qquad \left[R_p = \frac{R_1 R_2}{R_1 + R_2}\right]$$

$R_T = 12+15 = 27\ \Omega$

Therefore

$$V = I R_T = 3 \ X \ 27$$

$$\mathbf{V = 81\ V}$$

iii) Voltage across 15Ω is $\mathbf{V_{15\Omega}}$ = current flowing through the resistance X value of resistance

$$= 3X15$$

$$\mathbf{V_{15\Omega} = 45\ V}$$

iv) Power consumed by the circuit P=?

Power consumed by the 15Ω resistor $P_{15\Omega} = I^2_{15\Omega}\ x\ R$

$= (3^2) x\ 15 =$ **135 watts**

Power consumed by the 20Ω resistor $P_{20\Omega} = I^2_{20\Omega}\ x\ R$

$= (1.8^2) x\ 20 =$ **64.8watts**

Power consumed by the 30Ω resistor $P_{30\Omega} = I^2_{30\Omega}\ x\ R$

$= (1.2^2) x\ 30 =$ **43.2watts**

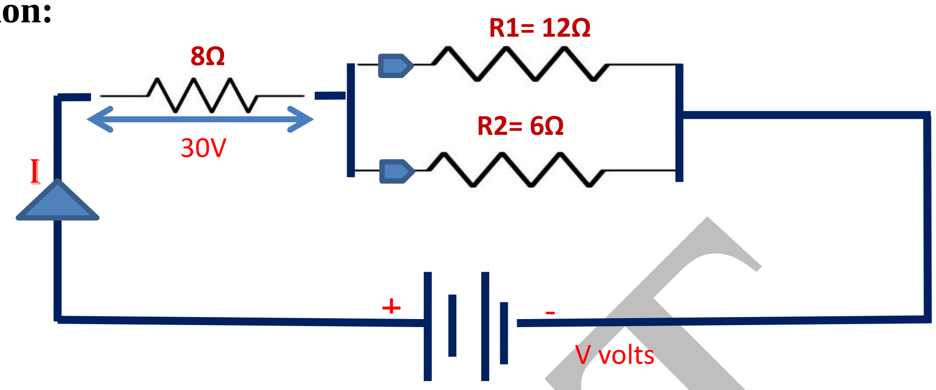
Total Power consumed by the circuit

P= 135+64.8+43.2 or P= VI= 81x3

P= 243 Watts

2. **An 8-ohm resistor is in series with a parallel combination of two resistors 12 ohm and 6 ohms. If the voltage drop across 8ohm is 30V. find (i) the current in 12 Ω and 6 Ω resistors, (ii) the total power and power consumed by each resistor iii) Voltage drop across 6Ω resistor iv) supply voltage .**

Solution:



$I_{12\Omega}$ =? $I_{6\Omega}$ =? P=?

Total or current through 8Ω **I = $V_{8\Omega}$/R** = 30 / 8

I= 3.75 A

i) $I_{12\Omega} = \frac{I\,R2}{R_1+R2} = \frac{3.75X6}{12+6}$ **$I_{12\Omega}$ = 1.25A**

$I_{6\Omega} = \frac{I\,R1}{R_1+R2} = \frac{3.75X\,12}{12+6}$ **$I_{6\Omega}$ = 2.5A**

ii) Power consumed by the circuit P=?

Power consumed by the 8Ω resistor $P_{15\Omega} = I^2_{8\Omega}$ x R

= (3.75^2)x 8 = **112.5 watts**

Power consumed by the 20Ω resistor $P_{20\Omega} = I^2_{20\Omega}$ x R

= $(1.25\,^2)$x 12= **18.75watts**

Power consumed by the 30Ω resistor $P_{30\Omega} = I^2_{30\Omega}$ x R

= 2.5^2x 6 = **37.5watts**

Total Power consumed by the circuit

P= 112.5+18.75+37.5

P= 168.75 Watts

iii) Voltage Drop across 6Ω resistor = $I_{6\Omega}$ X R

= 2.5 X6

$\mathbf{V_{6\Omega} = 15\ V = V_{12\Omega}}$

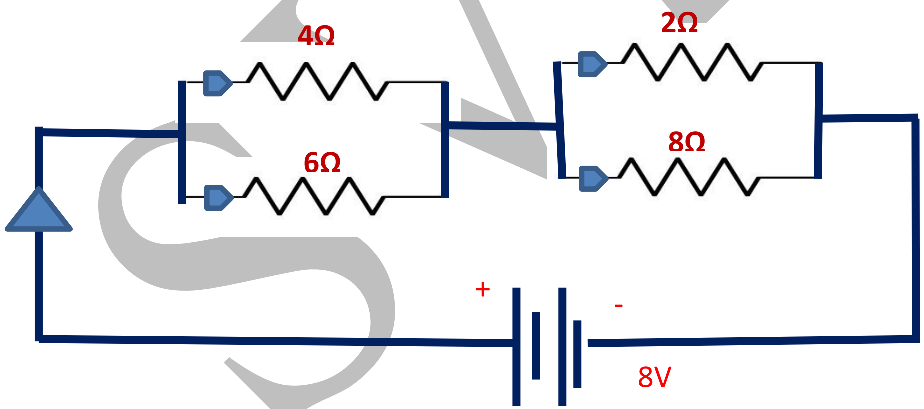
iv) Supply or Total Voltage

V= Voltage drop across 8Ω + Voltage drop across parallel combination

V = 30 +15

V =45 V

3. For the circuit shown below find the current through all the resistances and the power consumed by the circuit



Solution: $I_{4\Omega}$ =? $I_{6\Omega}$ =? $I_{2\Omega}$ =? $I_{8\Omega}$ =? P=?

Wkt $\mathbf{I} = \frac{V}{Req}$

$R_T= (4 \| 6) + (2 \| 8) = \frac{4X6}{4+6} + \frac{2X8}{2+8} = 2.4 + 1.6 = \mathbf{4\ \Omega}$

$\mathbf{R_T = 4\ \Omega}$

$I = \frac{V}{RT} = \frac{\mathbf{8}}{4} = 2\ \mathbf{A}$

Total current **I =2A**

Current in a branch $= \dfrac{\text{Total current x Resistance in an another branch}}{\textit{sum of the resistances}}$

$I_{4\Omega} = \dfrac{2 \times 6}{4+6}$ **=1.2 A**

$I_{6\Omega} = \dfrac{2 \times 4}{4+6}$ **=0.8 A**

$I_{2\Omega} = \dfrac{2 \times 8}{8+2}$ **=1.6 A**

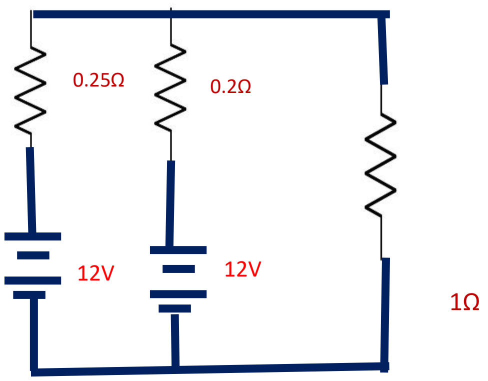
$I_{8\Omega} = \dfrac{2 \times 2}{8+2}$ **=0.4 A**

ii) The power Consumed by the circuit P= VI

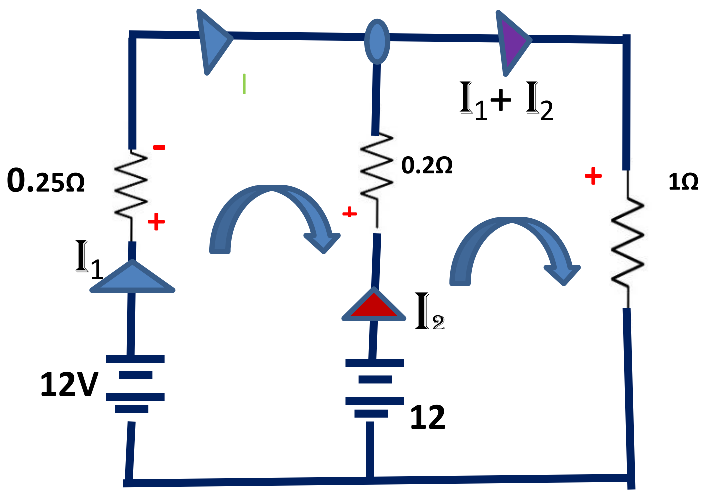
= 8 x2 = **16watts**

P = 16 watts

5. The two 12V batteries with internal resistance of 0.2Ω and 0.25Ω respectively are joined parallel and resistance of 1Ω is placed across the terminals. Find the current supplied by the battery and power consumed by 1Ω resistor.



Solution:



Applying KVL to LOOP 1

$-0.25I_1 + 0.2I_2 - 12 + 12 = 0$

$\mathbf{-0.25I_1 + 0.2I_2 = 0}$ --------------- 1

Applying KVL to LOOP

$-1(I_1 + I_2) + 12 - 0.2\, I_2 = 0$

$-I_1 - I_2 - 0.2\, I_2 = -1$

$\mathbf{- I_1 - 1.2\, I_2 = -12}$**-------------------2**

Solving Equation 1 and 2

$-0.25I_1 + 0.2I_2 = 0$

$-I_1 - 1.2\, I_2 = -12$

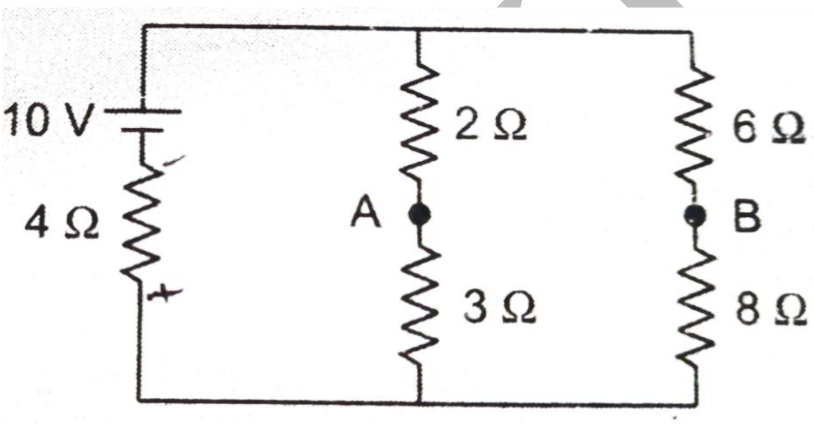
We get $\mathbf{I_1 = 4.8A \quad and\ I_2 = 6A}$

Therefore current supplied from each battery is 4.8A and 6A respectively

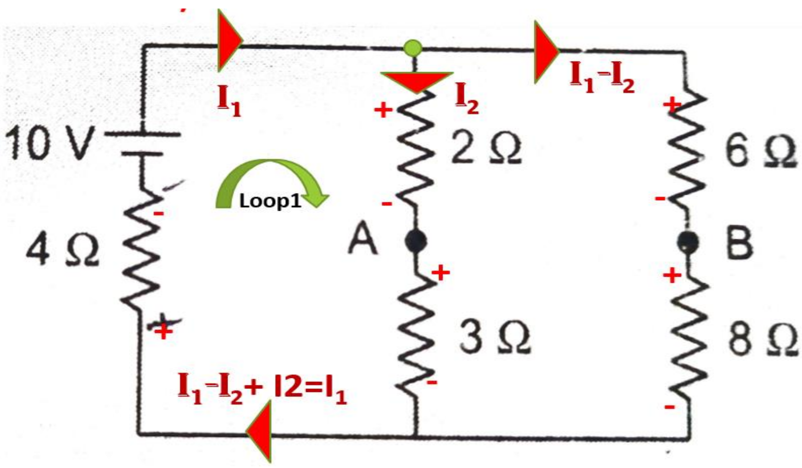
Current through 1Ω resistor is $I_{1\Omega} = I1 + I_2 = 4.8 + 6 =$ **10.8A**

Power consumed by 1Ω resistor is $P_{1\Omega} = I^2_{1\Omega} \times R = 10.8^2 \times 1 =$ **116.64watts**

7. **Find current in the battery ,the current in branch and pd (potential difference) across AB in the network shown.**



<u>Solution:</u>



Applying KVL to LOOP 1

$-2I_2-3I_2 -4I_1+10=0$

$-4I_1-5I_2 = -10$-------1

Applying KVL to LOOP 2

$-6(I1-I2) -8(I1-I2)+3I2 +2I_2=0$

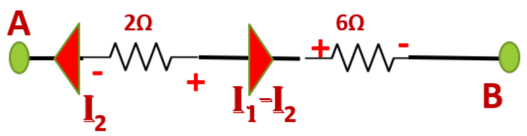
$-6I1+6I2 -8I1+8I2+3I2 +2I_2=0$

$-14I_1+19I_2 = 0$----------2

Solving Equation 1 and 2
$-4I_1-5I_2 = -10$
$-14I_1+19I_2 = 0$

Solving Equation 1 and 2
$I_1 = 1.3A$
$I_2 =0.95A$

To find the pd across AB

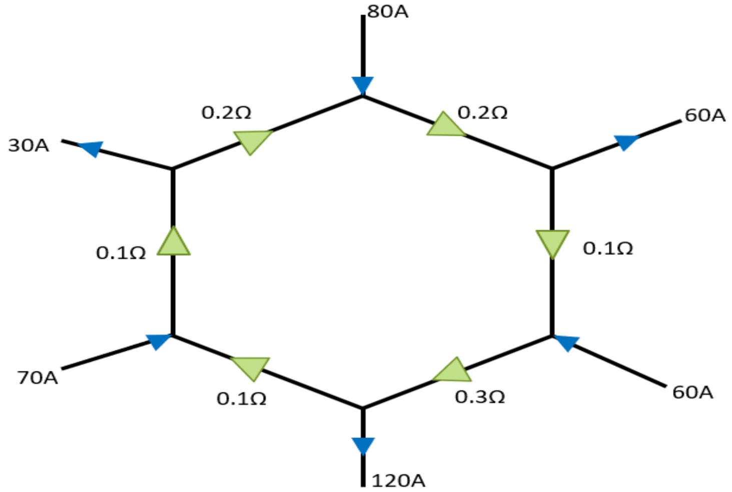


$+2I_2-6(I1-I2) =V_{AB}$

$V_{AB} = 2(0.95) -6(1.3-0.95)$

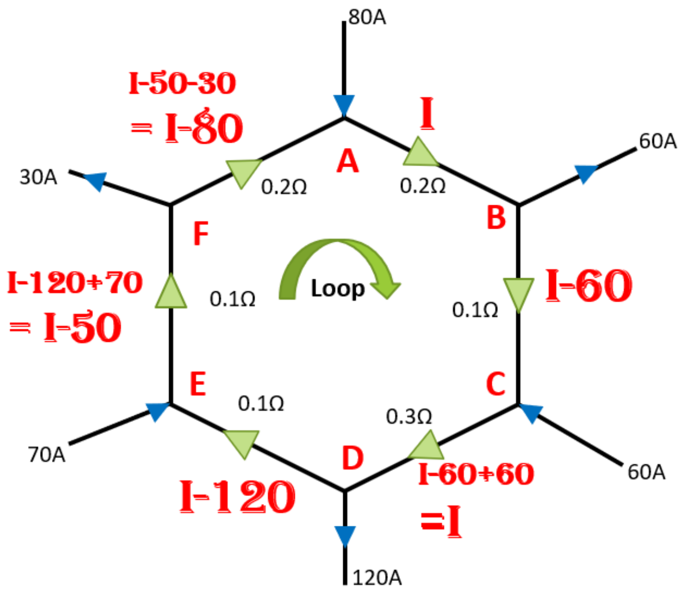
$V_{AB} = -0.2V$

14. Find the values of currents in all the branches of the network shown in figure



Solution:

Let I be the current flowing from A to B



Applying KVL to LOOP ABCDEFA

-0.2I -0.1(I-60) -0.3I -0.1(I-120)

-0.1(I-50) -0.2(I-80) =0

-0.2I - 0.1I + 6 - 0.3I - 0.1I

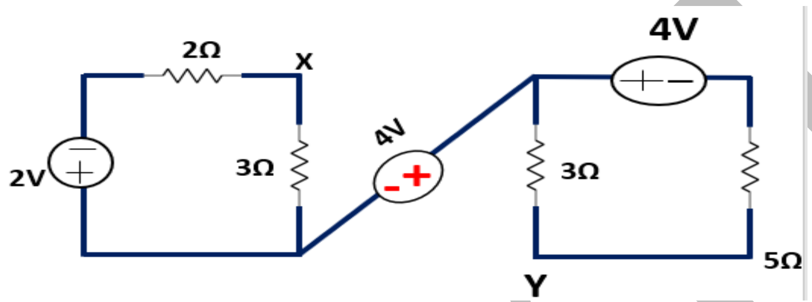
+12- 0.1I +5 - 0.2I +16=0

-1I = -39A

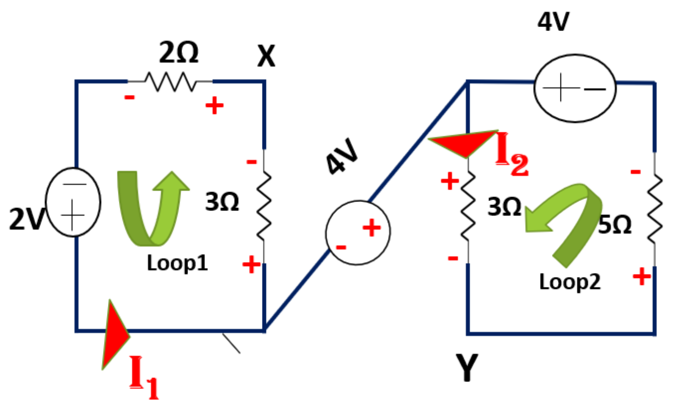
I = 39A

Current in Branch AB is I = 39A
Current in Branch BC is I-60 = 39-60 =-21A
Current in Branch CD is I = 39A
Current in Branch DE is I-120 = 39-120 =-81A
Current in Branch EF is I-50 = 39- 50 =-11A
Current in Branch FA is I-80 = 39- 80 =-41A

15.Obtain the potential difference V_{xy} in the circuit shown



Solution:



Applying KVL to LOOP1

$-3I_1 \ -2I_1+2 \ =0$

$-5I_1=-2$

$I_1= -2\backslash-5 =0.4A$

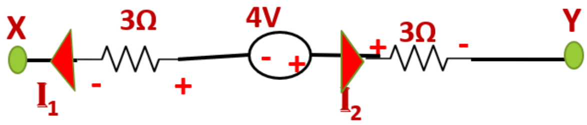
Applying KVL to LOOP2

$-3I_2 \ -5I_2+4 \ =0$

$-8I_2=-4$

$I_2= -4\backslash-8 =0.5A$

To find the pd across XY



$3I_1+4-3I_2 =V_{xy}$

$V_{xy} \ = \ 3(0.4) +4-3(0.5)$

$V_{xy} = 3.7V$