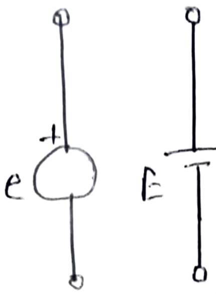
UNIT-I

DC ckt Analysis & Network Theorems

→ Ideal Independent Current & Voltage Source

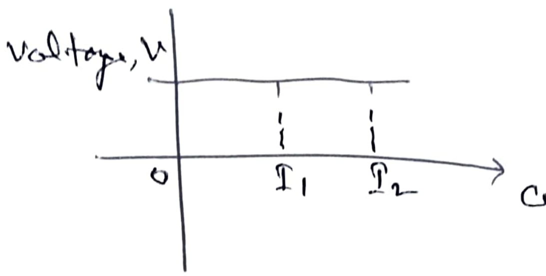
(By Del Toro)

- Ideal Independent Voltage Source - is that in which the value of the voltage is not dependent on the either the magnitude or direction of current flowing through the source.

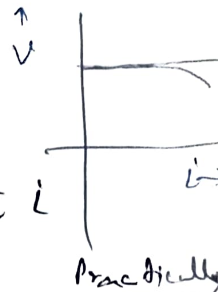


(Ex. Battery)

Symbols Symbol



V-I Chr



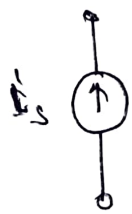
→ Ideal voltage source has zero internal resistance.

By Ohm's law $R = \frac{\Delta V}{\Delta I} = \frac{V_2 - V_1}{I_2 - I_1} = \frac{0}{I_2 - I_1} = 0$

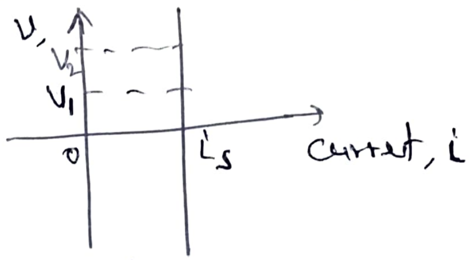
→ so replaced by short ckt.

- Ideal Current Source -

- supplies specified current independently of value & direction of the voltage appearing across its terminals.



(a)



(b)

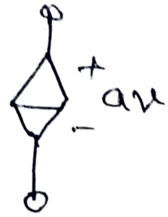
→ Ideal Current Source - internal resistance is infinite

$$R = \frac{\Delta V}{\Delta I} = \frac{V_2 - V_1}{0} = \infty$$

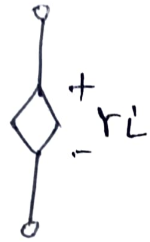
→ So replaced by open ckt.

$g = \frac{1}{r}$

→ Dependent Source –



Voltage dependent Voltage Source



Current dependent Voltage Source

Voltage dept Current Source

Current dept Current Source

→ Active Element :-

- Independent source which can deliver or absorb energy continuously.

  Ex- Ideal Voltage & Current Sources

  Voltage source - Battery, DC Gen, AC Gen; Current Source - Photo-electric cells, Metadyne Gen.

→ Passive Elements :-

- Components which decipate or store energy.

Ex - R, L, C.

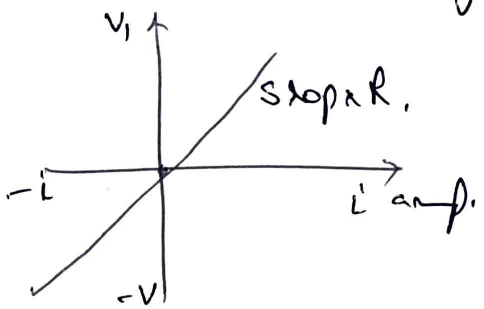
CKT. Parameter

→ **Resistance – (R)** – Property of a substance which opposes the flow of electricity through it.

a) CKT View Point –

By Ohm's law $\boxed{R = \frac{v}{i}}$ Ω. —(1)

– Above Eqn is a linear algebraic expression when the proportionality factor R is independent of current.



– Experiment shows that the resistance of most metallic conductors varies with temp.

$$R_2 = R_1[1 + \alpha_1(T_2 - T_1)]$$

– α_1 – temp coefficient of resistance at T_1 in °C.

b) Energy View point –

power absorbed by resistor –

$$P = vi = (iR)i = i^2R$$

Energy – $W = I^2RT$ Joule

c) Geometrical View Point –

$$R = \frac{\rho l}{A} \ \Omega$$

l → length of conductor (m)

A → Area of cross-section (m^2)

ρ → resistivity of the material (Ω.m)

→ Conductance $\boxed{G = \frac{1}{R}}$ → Physical aspects – colour code

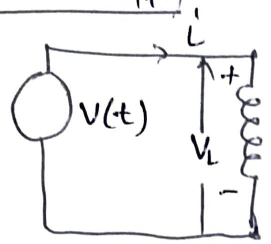
(2.25)

(2) Inductance -

- Inductance can be characterised as the property of a ckt element by which energy is capable of being stored in a magnetic flux field.

Ckt view point -

$$\boxed{v_L = L\frac{di}{dt}} \quad -(1), \; v_L \;\&\; i \text{ are fn. of time.}$$



$$\boxed{L = \frac{v_L}{di/dt}} \quad -(2) \quad \frac{\text{volt-second}}{\text{amp.}} \text{ or Henery}$$

$$\boxed{i(t) = \frac{1}{L}\int_0^t v_L\,dt + i(0)} \quad -(3)$$

Eqn (1) & (3) shows, the current in an inductor can't change abruptly in zero time.

Energy View Point -

$$\boxed{W = \frac{1}{2}Li^2}$$ Energy stored in magnetic form.

Geometrical View Point -

$$L = N\frac{d\phi}{di}$$

$$\text{or } L = \frac{N\phi}{i} \quad \frac{Wb\text{-}t}{A}$$

$N \to$ No. of turns
$\phi \to$ flux
$i \to$ current

③ Capacitance

a) ckt View Point

$q = C V_c$ — ①

$\boxed{i = \frac{dq}{dt} = C\frac{dV_c}{dt}}$ A — ②

$\boxed{C = \frac{i}{\frac{dV_c}{dt}}}$ — ③ $\frac{\text{Amp-sec}}{\text{Volt}}$ / coulomb/volt

farad.

$\boxed{V_c = \frac{1}{C}\int_0^t i\, dt}$

b) Energy View Point it → stores energy in electro static form

$\boxed{W = \frac{1}{2} C V^2}$ J

c) Geometrical

$\boxed{C = \varepsilon \frac{A}{d}}$ F

A → Area of plates

d → distance btw plates

ε → permittivity of dielectric material.

UNIT-II

2. Network Theory

Linear
→ Resistive elements for which V-I ch^R is straight line.

Linear CKt — Electric ckt containing only linear Resistance

Non Linear –
→ Resistive elements for which V-I ch^R is other than a straight line.

Non Linear CKt – so electric ckt containing them (non linear elements) as tungsten element, vaccum tubes and transistor etc

Bilateral CKt – An electric ckt, whose ch^R or properties are same in either direction (as Distribution & Transmission line)

Unilateral CKt – An electric ckt, whose ch^R or properties change with direction of its operation (as diode rectifier)

Passive Network – ~~Network~~ Network containing no source of emf in it.

Active Network – Network containing one or more sources of emf

One Port Network – Rest electric network when a branch is removed from it and left with a pair of terminals.

Two Port Network → when two brances removed, so that network is left with four terminals (or two pairs of terminals), so remainder network is called Two Port Network.

Mesh ~~or loop~~ – Electric network may provide a single closed path.

Junction (Node) – A point in a network where two or more branches meet.

Branch – Any section which joins two nodes, without passing through a third node.

Loop – A closed path in a network formed by a number of connected branches.

→ Mesh is a loop that contains no other loop within it.

→ **KCL →** First Law →

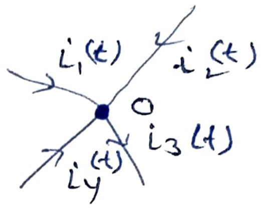
→ The algebraic sum of currents flowing towards a junction in an electric ckt is zero.

→ The sum of currents flowing towards any junction in an electrical ckt is equal to the sum of currents flowing away from junction.

$\boxed{\Sigma I = 0}$ → $i_1(t) + i_2(t) + i_4(t) = i_3(t)$

$I_1 + I_2 - I_3 + I_4 = 0$

or $I_1 + I_2 + I_4 = I_3$



In coming current
= Out going currents

→ **KVL →** Second Law →

→ In any closed circuit or mesh, the algebraic sum of all electromotive forces (e.m.f's) and the voltage drops is equal to zero.

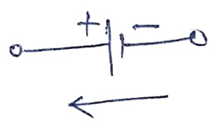
i.e. In any closed circuit or mesh –

Algebraic sum of e.m.f's
+ Algebraic sum of voltage drops
= 0

$\boxed{\Sigma IR + \Sigma E = 0}$

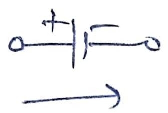
Sign Convention —

Rise in Potential

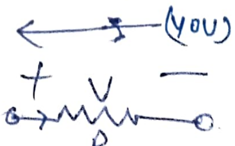


positive
(+)

Fall in Potential



Negative
(−)



(+ve)

(− ve)

→ Mesh Current Method / Loop Current / Mesh analysis

Maxwell's mesh current method consists of following steps—

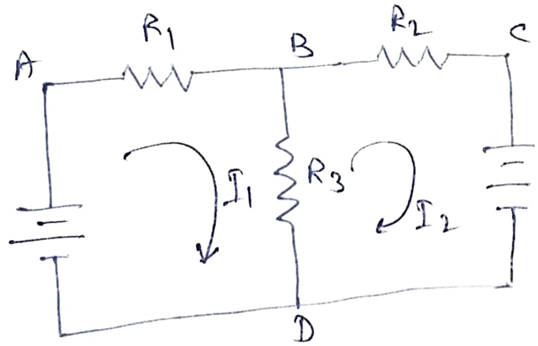
I) Each mesh is assigned a seperate mesh current. For convenience, all mesh currents are assumed to flow in clock wise direction.

II) If two mesh currents are flowing through a circuit element, the actual current in the circuit element is the algebraic sum of two.

III) KVL is applied to write the equation for each mesh in terms of mesh currents.
Writing mesh equation, rise in potential (+)
fall in potential (−).

IV) If the value of any mesh current comes out to be negative, it means that true direction of that mesh current is anticlockwise i.e. opposite to the assumed clockwise direction.

Ex.



→ Numerical Problems.

Nodal Analysis:-

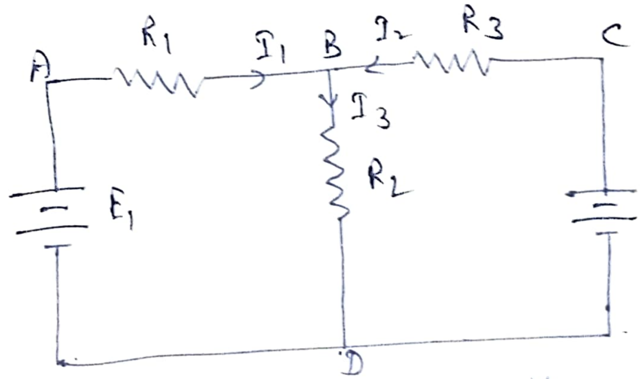
(5) NT

In this method -

- One of the nodes is taken as the reference node (node - is a point in a network where two ~~or~~ more circuit elements meet)
- The potentials of all points in the circuit are measured w.r.t this reference node.
- Apply KCL to write the equations & solve them
- Then each branch current can be determined because voltage across each elements will be known.

* Hence nodal analysis essentially aims at choosing a reference node in the network and then finding the unknown voltages at nodes w.r.t. reference node.

Ex -



Numericals

If we can find V_B, then all currents $I_1, I_2 \& I_3$ can be determined as given below -

In mesh ABDA, the voltage drop across R_1 is $E_1 - V_B$.

$$\therefore I_1 = \frac{E_1 - V_B}{R_1}$$

In mesh BCDB - the voltage drop across R_3 is $E_2 - V_B$.

$$\therefore I_2 = \frac{E_2 - V_B}{R_3}$$

$$\& \quad I_3 = \frac{V_B}{R_2}$$

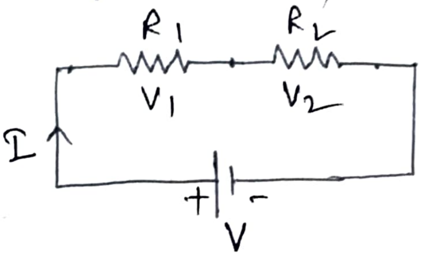
& By KCL at ~~node~~ B point -

$$I_1 + I_2 = I_3$$

Only V_B is

16/9

- Voltage Dividing Rule :-



Equ. or Total Resistance

$$R = R_1 + R_2$$

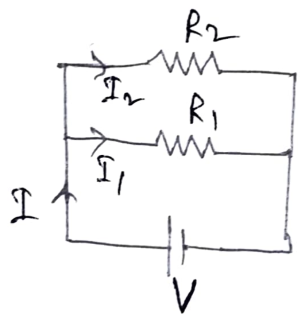
$$I = \frac{V}{R} = \frac{V}{R_1+R_2}$$

$$V_1 = I R_1 = \frac{V}{R_1+R_2} \cdot R_1$$

$$\boxed{V_1 = V \cdot \frac{R_1}{R_1+R_2}}$$

$$V_2 = I R_2 = \frac{V}{R_1+R_2} \cdot R_2 \Rightarrow \boxed{V_2 = V \cdot \frac{R_2}{R_1+R_2}}$$

- Current Dividing Rule :-



Total Resistance

$$R = \frac{R_1 R_2}{R_1+R_2}$$

$$V = I \cdot R = I \cdot \frac{R_1 R_2}{R_1+R_2}$$

$$\Rightarrow \because I_1 = \frac{V}{R_1} = \frac{I \cdot \cancel{R_1} R_2}{\cancel{R_1} \; R_1+R_2} =$$

$$\boxed{I_1 = I \cdot \frac{R_2}{(R_1+R_2)}}$$

$$\Rightarrow \because I_2 = \frac{V}{R_2} = \frac{I \cdot R_1 \cancel{R_2}}{\cancel{R_2} \; R_1+R_2}$$

$$\boxed{I_2 = I \cdot \frac{R_1}{R_1+R_2}}$$

→ Source Transformation :-

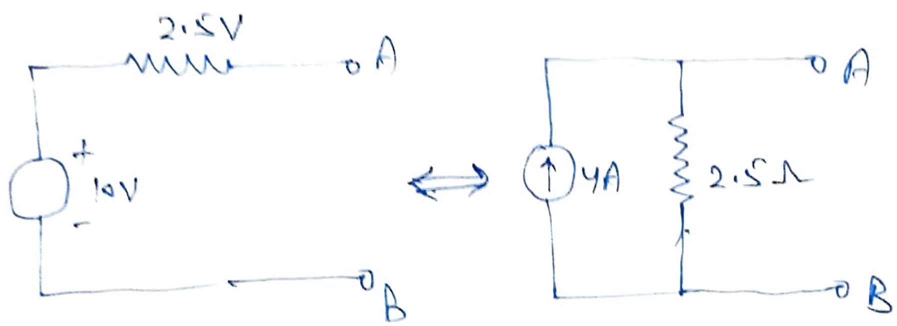
→ Source can either operate as a current source or voltage source.

→ If load impedance is very large in comparison to internal impedance, use Voltage Source.

→ If load impedance is very small in comparison to internal impedance of source, it is better to represent source as a current source.

→ It is possible to convert a voltage source into a current source or vice-versa.

Ex.



Super Position:-

The basic principle of superposition states that, if the effect produced in a system is directly proportional to the cause, then the overall effect produced in the system, due to a number of causes acting jointly, can be determined by superpositing (adding) the effects of each source acting separately.

✓ In a linear network containing more than one sources, the resultant current in any branch is the algebraic sum of the currents that would be produced by each source acting alone (all other sources would be replaced meanwhile by their respective internal resistances).

✓ The superposition theorem is only applicable to linear networks and systems. We can call a device linear, if it is characterised by an equation of the form-

$\boxed{y = mx}$ where m is a constant and not a function of x

The principle of superposition is useful for linearity test of the system.

This is not valid for power relationship.

Sources can be made inoperative by

a) short circuiting the voltage sources and replacing them by their series impedances.

b) open-circuiting the current sources and substituting them by their shunt impedances.

A linear network comprises independent sources, linear dependent sources and linear passive elements like resistors, inductors, capacitor and transformer. Moreover, the components may either be time-varying or time invariant.

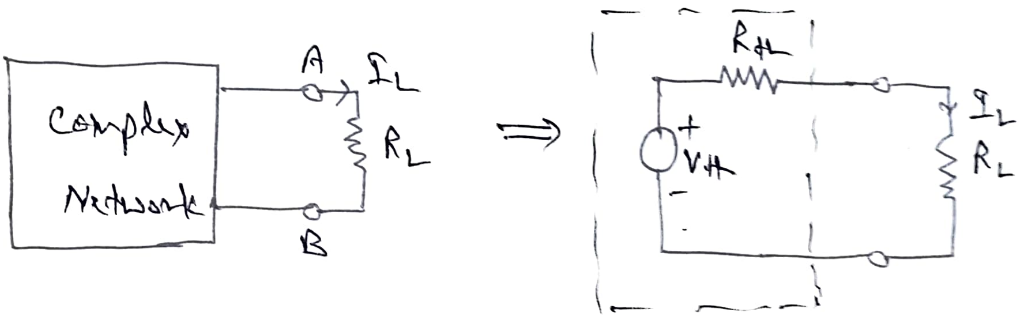
A linear ckt is one whose parameters (eg. resistances) are constt i.e, they do not change with current & voltage

→ **Thevenin Theorem :-**

- This theorem provides a mathematical technique for replacing a two terminal network.
- It states that - Any linear, active, bilateral two terminal network can be replaced by a voltage source V_{th} in series with a resistance R_{Th} (or Z_{th} in ac ckt), where

V_{th} - Thevenin voltage or open ckt voltage across two terminal (load terminal) when load is disconnected.

R_{th} - Thevenin equ resistance of network across two terminal, replacing all sources with their internal resistance. (with load disconnected)



Thevenin Equi ckt of complex network

load current $\boxed{I_L = \dfrac{V_{th}}{R_{th} + R_L}}$

→ Norton Theorem :-

- By using this theorem we can replace a complex network by a current source in parallel with a resistance.
- Any linear, active, bilateral complex network can be replaced by a current source I_N in parallel with a resistance R_N.

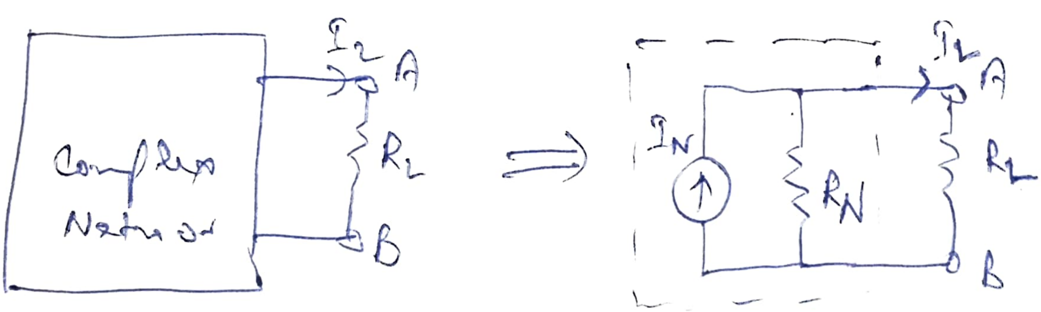
Where I_N = Short ckt current between two terminal $\boxed{I_N = I_{sc}}$

R_N = Equ. Norton resistance of complex network across two terminal, replacing all the sources by their internal resistances.

$$R_N = R_{th}$$

Load Current $\boxed{I_L = I_N \cdot \frac{R_N}{R_N + R_L}}$

$$I_{sc} = I_N = \frac{V_{th}}{R_{th}}$$

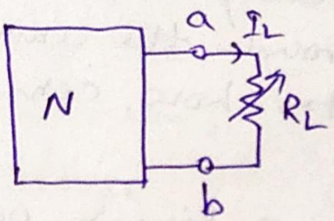


⇒ Max. Power Transfer Theorem :-

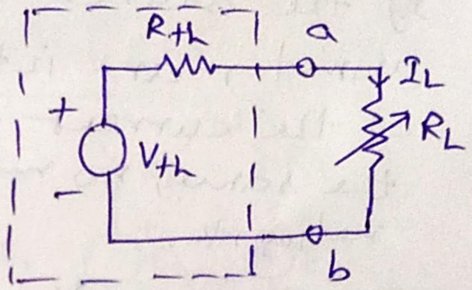
MPT theorem for dc networks is stated as :-

A load resistance connected to a dc network abstracts/draws max. power when load resistance is equal to equivalent resistance of the network as seen from load terminals.

Proof :-



DC Network, N with R_L



Thevenin Eqv. Network

$$I_L = \frac{V_{th}}{R_{th} + R_L} \quad -①$$

Power delivered to load, $P_L = I_L^2 R_L \quad -②$

By ① & ② → $$P_L = \left(\frac{V_{th}}{R_{th}+R_L}\right)^2 . R_L$$

$$P_L = \frac{V_{th}^2 . R_L}{R_{th}^2 + R_L^2 + 2R_{th}R_L} = \frac{V_{th}^2}{\frac{R_{th}^2}{R_L} + R_L + 2R_{th}}$$

for max. power P_L, denominator

$$x = \frac{R_{th}^2}{R_L} + R_L + 2R_{th} \text{ should be min.}$$

$$\frac{dx}{dR_L} = -\frac{R_{th}^2}{R_L^2} + 1 + 0$$

$$0 = -\frac{R_{th}^2}{R_L^2} + 1$$

$\boxed{R_L = R_{th}}$ Proved.

Max. Power, $P_{max} = \frac{V_{th}^2 \cdot R_{th}}{(R_{th}+R_{th})^2} = \frac{V_{th}^2 \cdot \cancel{R_{th}}}{4R_{th}^{\cancel{2}}}$

$$\boxed{P_{max} = \frac{V_{th}^2}{4R_{th}}}$$

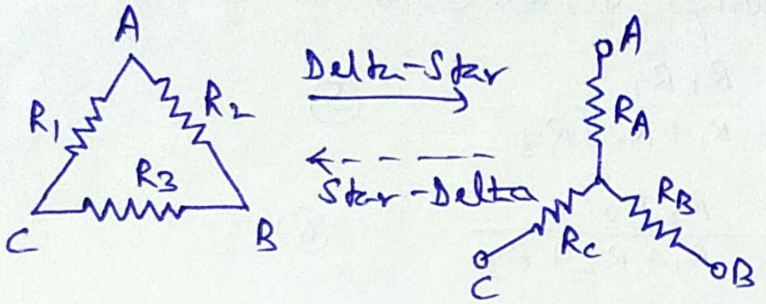
Reciprocity Theorem :-

- According to this theorem -
  If the source voltage and zero-resistance ammeter are interchanged, the magnitude of the current through the ammeter will be the same, no matter how complicated the network.

- In other words, In a linear passive network, supply voltage V and current I are mutually transferable.
  The ratio of V and I is called the transfer resistance (transfer impedance in AC system).

→ Limitation :- It is applicable only to single-source networks and not in multisource networks.

Star Delta Transformation



Delta-Star Tr - The replacement of delta (mesh) by equivalent star system is known as delta-star Tr.

- Two system will be equ. or identical if the resistances measured between any pair of lines is same in both system, when the third line is open.

Hence Resistance between terminal B & C -

$$R_{BC} = R_3 \parallel (R_1+R_2) = \frac{R_3(R_1+R_2)}{R_1+R_2+R_3} \quad \text{in delta system}$$

and $R_{BC} = R_B + R_C$ in star system

- Since both systems are identical, resistances measured between terminals B and C in both system must be equal.

$$\therefore R_B + R_C = \frac{R_3(R_1+R_2)}{R_1+R_2+R_3} \quad \text{— (1)}$$

Similarly

$$R_C + R_A = \frac{R_1(R_2+R_3)}{R_1+R_2+R_3} \quad \text{— (2)}$$

$$R_A + R_B = \frac{R_2(R_1+R_3)}{R_1+R_2+R_3} \quad \text{— (3)}$$

Adding (1), (2), (3) ---

$$2(R_A + R_B + R_C) = \frac{2(R_1R_2 + R_2R_3 + R_3R_1)}{R_1+R_2+R_3} \quad -$$

$$R_A + R_B + R_C = \frac{R_1R_2 + R_2R_3 + R_3R_1}{R_1+R_2+R_3} \quad \text{— (4)}$$

→ Subtracting ①, ②, ③ from ④ –

$$R_A = \frac{R_1 R_2}{R_1 + R_2 + R_3} \quad -⑤$$

$$R_B = \frac{R_2 R_3}{R_1 + R_2 + R_3} \quad -⑥$$

$$R_C = \frac{R_3 R_1}{R_1 + R_2 + R_3} \quad -⑦$$

If $R_1 = R_2 = R_3 = R_D$ then $R_A = R_B = R_C = R_S$

$$R_S = \frac{R_D R_D}{R_D + R_D + R_D} = \frac{R_D}{3}$$

Star-Delta Tr – Multiplying ⑤ & ⑥ and ⑥ & ⑦ and ⑦ & ⑤ and adding them –

$$R_A R_B + R_B R_C + R_C R_A = \frac{R_1 R_2^2 R_3 + R_1 R_3^2 R_2 + R_1^2 R_2 R_3}{(R_1 + R_2 + R_3)^2}$$

$$= \frac{R_1 R_2 R_3 \cancel{(R_2 + R_3 + R_1)}}{(R_1 + R_2 + R_3)^{\cancel{2}}}$$

$$\boxed{R_A R_B + R_B R_C + R_C R_A = \frac{R_1 R_2 R_3}{R_1 + R_2 + R_3}} \quad -⑧$$

Dividing ⑤, ⑥, ⑦ from ⑧ –

$$R_3 = \frac{R_A R_B + R_B R_C + R_C R_A}{R_A} = R_B + R_C + \frac{R_B R_C}{R_A} \quad -⑨$$

$$R_1 = \frac{R_A R_B + R_B R_C + R_C R_A}{R_B} = R_A + R_C + \frac{R_A R_C}{R_B} \quad -⑩$$

$$R_2 = \frac{R_A R_B + R_B R_C + R_C R_A}{R_C} = R_A + R_B + \frac{R_A R_B}{R_C} \quad -⑪$$

Again $R_D = R_S + R_S + \frac{R_S R_S}{R_S} = 3 R_S$