Basic Electrical Engineering (TEE 101)

Lecture 8: Kirchhoff's Voltage Law, and Mesh Analysis

Content

This lecture covers

- **Kirchhoff's Voltage Law**
- **Mesh Analysis**

Kirchhoff's Voltage Law (KVL)

It states as follows : "*The algebraic sum of the products of currents and resistances in each of the conductors in any closed path (or mesh) in a network plus the algebraic sum of the e.m.fs in that path* is *zero*"

In other words, $\sum IR + \sum e.m.f = 0$

It should be noted that algebraic sum is the sum which takes into account the polarities of the voltage drops.

KVL signifies "Law of Conservation of Energy"

The basis of this law is:

- *If we start from a particular junction and go round the mesh till we come back to the starting point, then we must be at the same potential with which we started.*
- *Hence, it means that all the sources of e.m.f. met on the way must necessarily be equal to the voltage drops in the resistances, every voltage being given its proper sign, plus or minus.*

MESH ANALYSIS

*In this method, **Kirchhoff's voltage law** is applied to a network to write mesh equations in terms of* **mesh currents** *instead of branch currents. **(i.e. Mesh Analysis** is used to determine the **Mesh Currents** in each mesh of the network)*

Mesh currents are the closed loop currents assumed to be circulating in the meshes.

The direction of **mesh currents** can be assumed either clockwise or anti clockwise but for convenience the direction shall be kept uniform in all the meshes.

- ***Note: Mesh Currents are the unknown quantities***

PROCEDURE TO SOLVE NETWORK USING MESH ANALYSIS

The steps to solve any electrical network using Mesh Analysis are summarized below:

Identify the number of meshes in the given circuit. ***(Mesh is the elementary loop of the network and also known as essential mesh or independent mesh)***

Assign a circulating current to each mesh (such as: I_1, I_2 etc.)

As each mesh current enters as well as leaves the mesh elements, the mesh currents implicitly satisfy KCL.

It is preferable to assign the same direction to the mesh currents in each mesh.

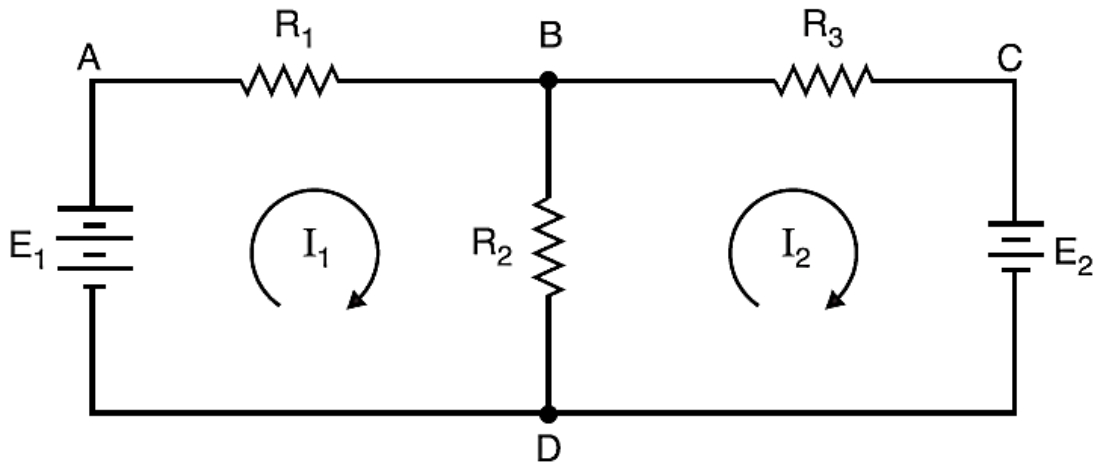
Write KVL equations for each mesh

Solve the Mesh Equations to determine the Mesh Currents.

The number of KVL equations are equal to number of meshes in the network (For ex.: if there are two meshes, then there will be two KVL or Mesh equations)

(Note: It is observed here that no circuit branch can carry more than two mesh currents)

Consider an Electrical Network as shown below:



Identify the number of meshes: There are two meshes in this circuit

Assign the currents to each mesh: Let the currents in meshes is I1 and I2

Assume the direction of flow of these currents: Let these currents are circulating in clockwise direction in respective meshes

Now apply KVL to write the Mesh Equations.

Because there are two meshes, so there will be two mesh equations.

Let us write KVL equations for the two meshes of Figure shown

Apply KVL in Mesh 1, the mesh equation is:

$$E_1 - I_1R_1 - (I_1 - I_2)R_2 = 0$$
$$E_1 = I_1R_1 + (I_1 - I_2)R_2$$
$$E_1 = I_1R_1 + I_1R_2 - I_2R_2$$
$$\boldsymbol{I_1(R_1 + R_2) - I_2R_2 = E_1} \quad \textbf{(1)}$$

Apply KVL in Mesh 2, the mesh equation is:

$$-I_2R_3 - E_2 - (I_2 - I_1)R_2 = 0$$
$$E_2 = -I_2R_3 - (I_2 - I_1)R_2$$
$$E_2 = -I_2R_3 - I_2R_2 + I_1R_2$$
$$\boldsymbol{I_1R_2 - (R_2 + R_3)I_2 = E_2} \quad \textbf{(2)}$$

Now, equations (1) and (2) can be solved algebraically to calculate the mesh currents I_1 and I_2

$$I_1 (R_1 + R_2) - I_2 R_2 = E_1 \qquad (1)$$

$$I_1 R_2 - (R_2 + R_3) I_2 = E_2 \qquad (2)$$

Solving eq. (1) and eq. (2) simultaneously, mesh currents *I*1 and *I*2 can be found out.

Once the mesh currents are known, the branch currents can be readily obtained.

The advantage of this method is that it usually reduces the number of equations to solve a network problem.

Note.

- *Branch currents are the real currents because they actually flow in the branches and can be measured.*
- *However, mesh currents are fictitious quantities and cannot be measured except in those instances where they happen to be identical with branch currents.*
- *Thus in branches DAB and BCD, branch currents are the same as mesh currents and hence, both can be measured.*
- *Hence mesh current is a concept rather than a reality.*

Thank You