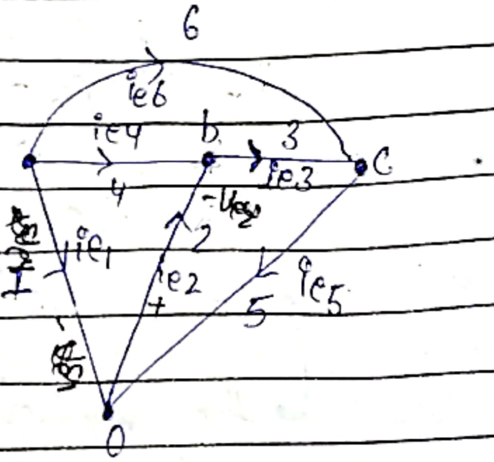
- loop matrix or Tieset matrix → directed matrix
- Cut set matrix.
- incident matrix ⟶ KVL
  KCL

- graph ─┬→ Directed
  └→ undirected.

→ node & Branch



⊙ incident matrix:- [A]

write KCL equation at node a, b, C and o.

at node A: $ie_1 + ie_4 + ie_6 = 0$ ⟵ ①

B: $ie_3 - ie_4 - ie_2 = 0$ ⟵ ②

C: $ie_5 - ie_6 - ie_3 = 0$ ⟵ ③

O: $ie_2 - ie_1 - ie_5$ → no new equation
i.e.
it can be derive from above 3 fundamental equation:-

→ now in topological form.

$$
\begin{array}{c|c}
 & \begin{matrix} 1 & 2 & 3 & 4 & 5 & 6 \end{matrix} \\
\begin{matrix} a \\ b \\ c \\ o \end{matrix} &
\begin{bmatrix}
1 & 0 & 0 & 1 & 0 & 1 \\
0 & -1 & 1 & -1 & 0 & 0 \\
0 & 0 & -1 & 0 & 1 & -1 \\
-1 & +1 & 0 & 0 & -1 & 0
\end{bmatrix}
\end{array}
\begin{bmatrix} ie_1 \\ ie_2 \\ ie_3 \\ ie_4 \\ ie_5 \\ ie_6 \end{bmatrix}
=
\begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}
$$

$$[A][ie] = [0]$$

- last row will be found using above 3 row hence it is useless writing
  it also sum of all four row will be allways zero.

So if you remove forth row then

$$\boxed{[A][i_e] = [0]}$$

reduced incident matrix.

→ the matrix obtained from [A] by eleminating one of the row is called R. incidence matrix.

⇓

Suppression of reference node.

$$[A]_{n \times b} \quad [i_e]_{b \times 1} = [0]_{b \times 1}.$$

n = no. of nodes.
b = no. of branch.

and for r.i.m → kam ka yahi hai.

$$[A]_{(n-1)(b)}$$

KVL ⊙ try to express the element voltage in term of node voltages (v_{ao}, v_{bo}, v_{co}).

$$v_{e1} = v_{ao}$$
$$v_{e2} = v_{ob} = -v_{bo}$$
$$v_{e3} = v_{bo} - v_{co}$$
$$v_{e4} = v_{ao} - v_{bo}$$
$$v_{e5} = v_{co}$$
$$v_{e6} = v_{ao} - v_{co}$$

$$\begin{bmatrix} V_{e1} \\ V_{e2} \\ V_{e3} \\ V_{e4} \\ V_{e5} \\ V_{e6} \end{bmatrix} = \begin{array}{ccc} v_{ao} & v_{bo} & v_{co} \\ \end{array} \begin{bmatrix} 1 & 0 & 0 \\ 0 & -1 & 0 \\ 0 & 1 & -1 \\ 1 & -1 & 0 \\ 0 & 0 & 1 \\ 1 & 0 & -1 \end{bmatrix} \begin{bmatrix} V_{ao} \\ V_{bo} \\ V_{co} \end{bmatrix}$$

$$\downarrow$$

$$[V_{ei}] = \underset{b\times(n-1)}{[A]^T} [V_n]$$

↑ node voltage. {o-reference hai}

⊙ reduced ordered. (A) matrix

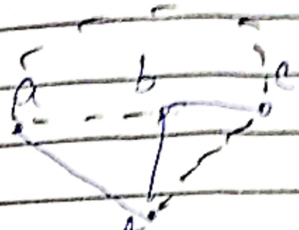
$$[A]\,[i_e] = [0] \longrightarrow KCL$$

$$[A]^T [V_n] = [V_e] \longrightarrow KVL$$

loop x Branch.

⇒ Tie-set matrix / loop-incidence matrix or circuit matrix (Ba)

graph → tree of graph.



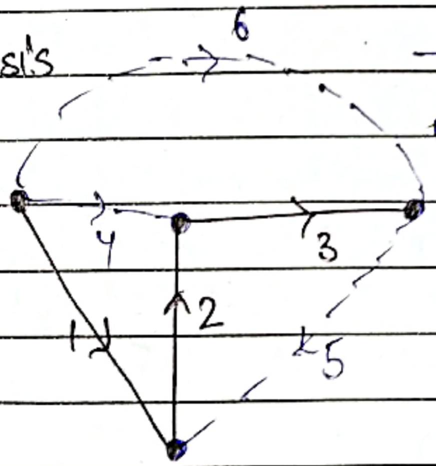
(i) → tree is subset of the graph. Such that → all nodes will be present.
→ no loops can be formed. i.e no closed path.
→ all nodes will be connected.

(ii) twig ⇒ branch of tree
$t \Rightarrow (n-1)$

(iii) - - - links → left out branch or co-tree.

(iv) branch of co-tree

loop analysis



→ at a time a loop only one link can be present

$L4: e_4 - e_2 - e_1 = 0$

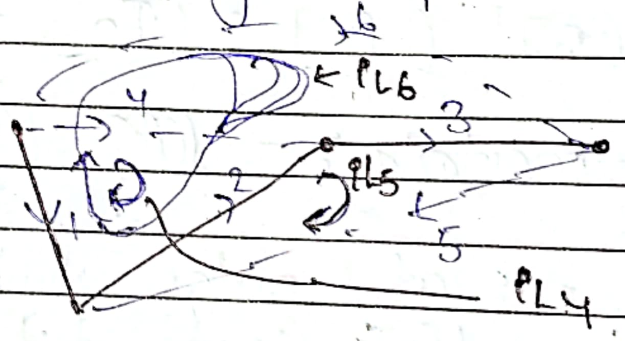
$L5: e_5 + e_2 + e_3 = 0$

$L6: e_6 - e_3 - e_2 - e_1 = 0$

$$\begin{array}{c} \\ L4 \\ L5 \\ L6 \end{array}\begin{array}{c} \begin{array}{cccccc} 1 & 2 & 3 & 4 & 5 & 6 \end{array} \\ \begin{bmatrix} -1 & -1 & 0 & +1 & 0 & 0 \\ 0 & +1 & +1 & 0 & +1 & 0 \\ -1 & -1 & -1 & 0 & 0 & +1 \end{bmatrix} \end{array} \begin{bmatrix} v_{e1} \\ v_{e2} \\ v_{e3} \\ v_{e4} \\ v_{e5} \\ v_{e6} \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}$$

$$\underbrace{[B]}_{l_n \times b}[V_e] = [0] \longleftarrow KVL$$

→ KCL. Expressing elements current in term of loop current.



$i_{e1} = -i_{L4} - i_{L6}$

$i_{e2} = \cancel{i_{L5} + i_{e6}}\ i_{L5} - i_{L4} - i_{L6}$

$i_{e3} = i_{L5} - i_{L6}$

$i_{e4} = i_{L4}$

$i_{e5} = i_{L5}$

$i_{e6} = i_{L6}$

$$\begin{bmatrix} i_{e_1} \\ i_{e_2} \\ i_{e_3} \\ i_{e_4} \\ i_{e_5} \\ i_{e_6} \end{bmatrix} = \begin{array}{c} \begin{array}{ccc} i_{L_4} & i_{L_5} & i_{L_6} \end{array} \\ \begin{bmatrix} -1 & 0 & -1 \\ -1 & 1 & -1 \\ 0 & 1 & -1 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \end{array} \begin{bmatrix} i_{L_4} \\ i_{L_5} \\ i_{L_6} \end{bmatrix}$$

$B \times 1$ $\quad [B]$ $B \times$ no. of loop. $\quad$ no. of loop $\times 1$

↓

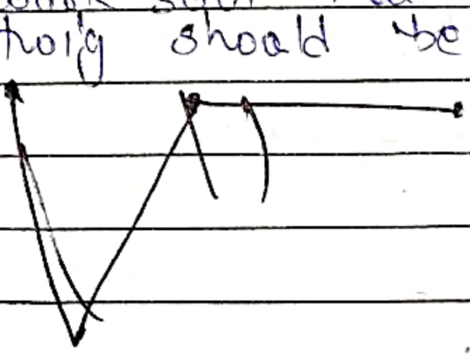
it is trans of B of KVL

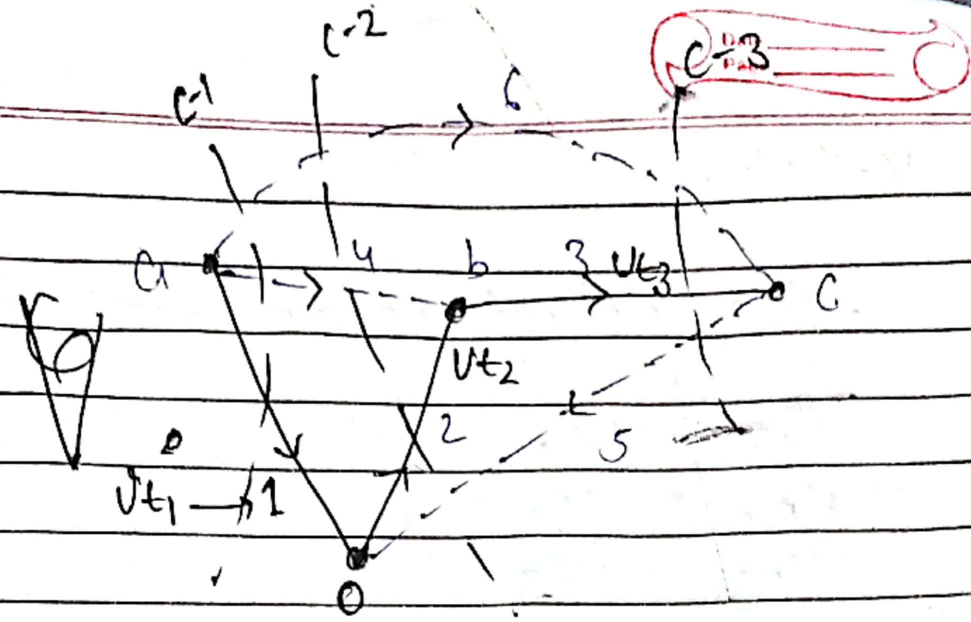
$$[B][V_e] = [0] \text{ — KVL}$$
$$[B]^T [i_L] = [I_e] \text{ — KVL}$$

— Cutsett matrix :- $[Q]$

- KCL not at nodes but at some line (cut-set).

fundament cut-set ⇒ those line which break the networks such that one side one node and one twig should be present and no limit on link.





CS-1 $\quad i_{e_1} + i_{e_4} + i_{e_6} = 0$

CS-2 $\quad i_{e_2} + i_{e_4} + i_{e_6} = 0$

CS-3 $\quad i_{e_3} - i_{e_5} + i_{e_6} = 0$

$$\begin{array}{c} \\ CS-1 \\ CS-2 \\ CS-3 \end{array}\begin{array}{c} \begin{array}{cccccc} 1 & 2 & 3 & 4 & 5 & 6 \end{array} \\ \begin{bmatrix} 1 & 0 & 0 & 1 & 0 & 1 \\ 0 & 1 & 0 & 1 & 0 & 1 \\ 0 & 0 & 1 & 0 & -1 & 1 \end{bmatrix} \end{array} \begin{bmatrix} i_{e_1} \\ \vdots \\ i_{e_6} \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}$$

$$[Q]_{t \times n} [i_e]_{n \times 1} = [0]_{t \times 1}$$

$t = n-1$

K-V-L.

relate element voltage with twig voltage.

$v_{e_1} = v_{t_1}$

$v_{e_2} = v_{t_2}$

$v_{e_3} = v_{t_3}$

$v_{e_4} = v_{t_1} - (-v_{t_2}) = v_{t_1} + v_{t_2}$

$v_{e_5} = -v_{t_2} - v_{t_3}$

$v_{e_6} = v_{t_1} + v_{t_2} + v_{t_3}$

$$\begin{bmatrix} v_{e_1} \\ v_{e_2} \\ v_{e_3} \\ v_{e_4} \\ v_{e_5} \\ v_{e_6} \end{bmatrix} = \begin{array}{ccc} t_1 & t_2 & t_3 \\ \hline \end{array}\begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \\ 1 & 1 & 0 \\ 0 & -1 & -1 \\ 1 & 1 & 1 \end{bmatrix} \begin{bmatrix} v_{t_1} \\ v_{t_2} \\ v_{t_3} \end{bmatrix}$$

$$[v_e]_{B\times 1} = [Q]^T_{n\times t} \cdot [v_t]_{t\times 1}$$