Behaviour of the system ~~analysis~~

POWER SYSTEM ANALYSIS.

→ Analysis on transmission + gen level (balanced)
→ Transmission system ~~fn~~ is ~~bat~~ fairly balance
↳ whereas distribution system is unbalanced (consumer depended)

→ 3ϕ analysis possible

→ When 1ϕ analysis is possible, system is balanced & 1ϕ can also give analysis of other 2ϕ is possible with 120° rotation.

→ Positive sequence → balanced system
↓
120° anti-clockwise rotation.

Three steps

Network modelling (Electrical modelling)
↳ Short/Medium → lumped system.

Mathematical modelling
↓
form equations (Algebraic) + (Diff)

Solution.
↓
solving the equations

condition

→ Power system has 2 states

- steady (parameters don't change with time) → single frequency
- Dynamic (system parameters change with time)

Analysis

- Phasor analysis
- Steady state analysis
  - But in AC, the magnitude of voltage cannot remain constant.
  - $V_m \sin \omega t = V_m \sin(\omega t + T)$
  - So, when single freq. is maintained, without harmonics & distortion, the AC system is in steady state.
    - Power flow analysis
    - Economic dispatch
    - generation & voltage control
- Dynamic state analysis
  - Here, eq^n are differential in math modelling
    - PS stability analysis

★ EN → linear system → superposition is applicable

→ Algebraic eqn

- linear → order is 1 → have non iterative solution. (one-step)
- non-linear → trigo func, or order > 1

Differential eqn

- linear
- non-linear

★ Source —Power Delivery→ Sink (load side)

Source ↓ Power source ↓ generator (everything is a load for generator)

Sink (load side) ↓ 99% is inductive load

Q) What happens when freq changes?

→ The R, L, C parameters (reactive part) will change

The voltage at each bus should be 1 pu & freq is 50Hz. (within ± 5%) voltage (± 1%) ↙ (→ goal of PS engineer

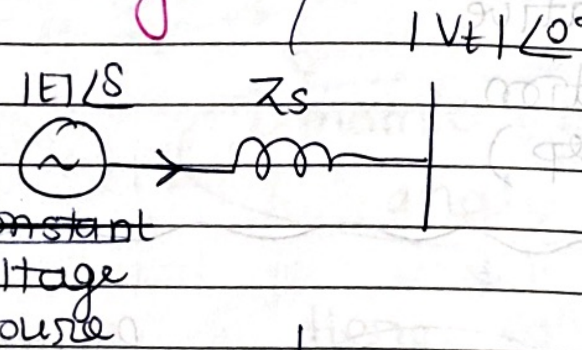
★ PSA is always done in per unit

1) when freq. changes, τ ~~de~~ of the machine depends ~~of~~ on freq (induction machine) so it can cause harm.
∴ balancing the freq is important.
↳ so that load performance isn't affected.

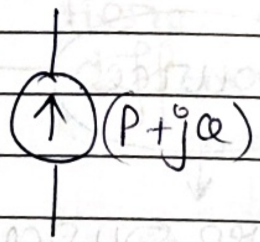
★ Electrical modelling:

1) Generator →

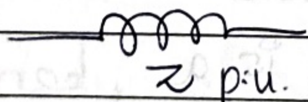
sync. impedance



→ during PA → (modelled as a power source)



2) Transformer →



(modelled as a series impedance)

because Z doesn't change in p.u.

3) Transmission line (π-model)

- med (nominal)
- long (equivalent)

☆ Always modelled as a
π-model because
nodes are less.

(~~sh~~ short line) → series impedance

4) **load** →

ZIP model (combined)
- a) Constant impedance (Z) → $S = \frac{V^2}{Z} \rightarrow S \propto V^2$
- b) constant current (I) → $S = VI^* \rightarrow S \propto V$
  (practically not possible)
- c) constant power (P) → S

→ Synchronous machine → terminal voltage $|V_t|$ control
↓ change real power and freq.
↓ controlling the PM
terminal voltage control ↓ by controlling excitation

OR

generation

Q) Why is generator modelled as power V source?

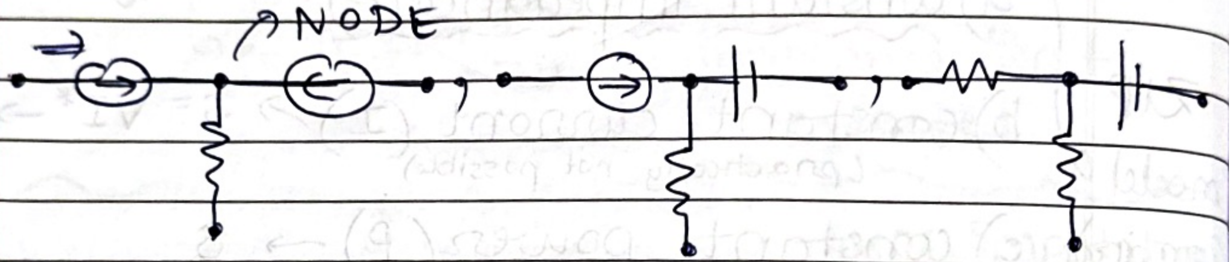
→ $|V_t|$ can remain constant irrespective of the load by changing the excitation

↳ so if $|V_t|$ is constant
↓
impedance (Z_s) doesn't matter that's why
↓
modelled as a

POWER SOURCE

GRAPH THEORY

→ Network's graphical representation
↳ shows the structure of the electrical network

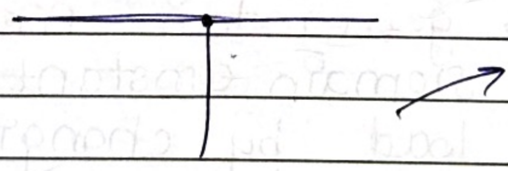
Network →


→ Two components in a network → 1) active
2) passive

→ Node → where components are connected

→ Node = representated as a dot (•)

Component = representated as a branch/(−) edge



→ KCL & KVL is applicable in the network irrespective of the component connected.

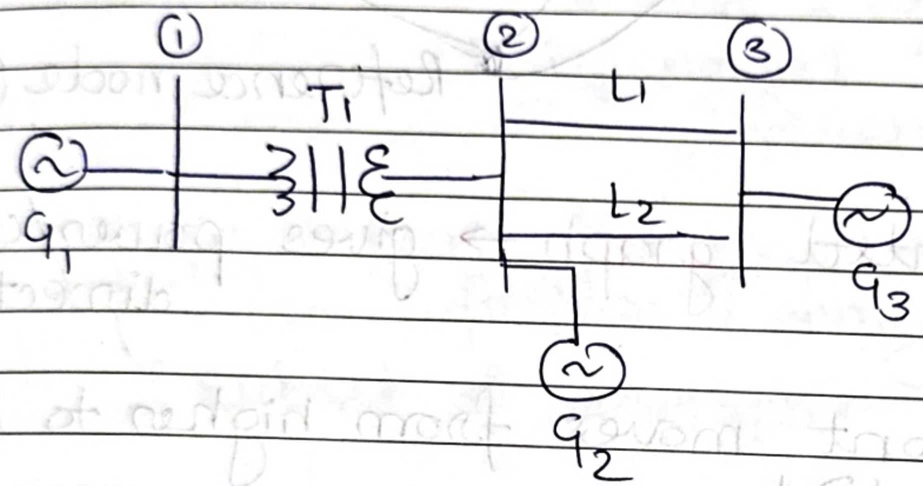
★ SLD → P.U. diagram → graph ★

Ohm's law → current is directly proportional to the voltage and R is constant

$V \propto IR$

* Directed graph → Where the branches have directions defined.

Q] Draw the graph of the SLD.



⟹ Here, components are
1) Active - G_1, G_2, G_3
2) Passive - Line, L_1, L_2, T_1
capacitor bank

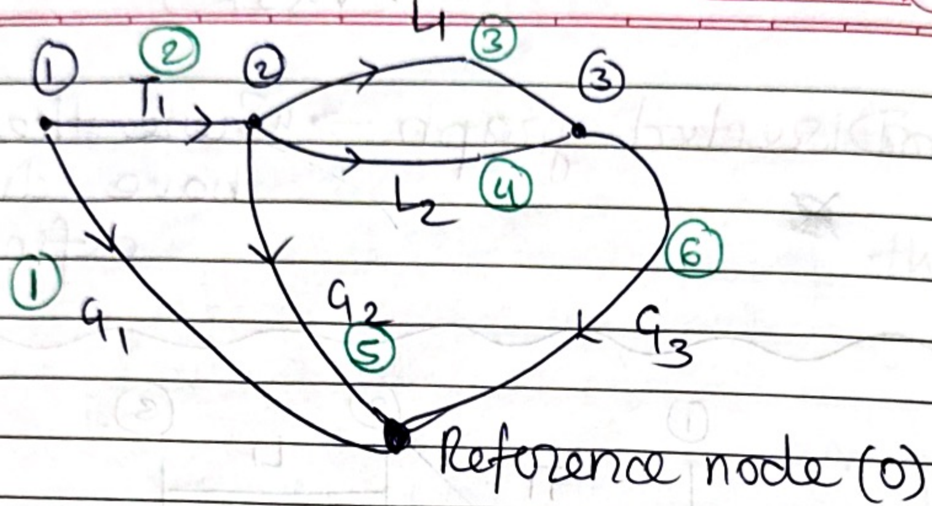
* Power delivery → lines, transformer,
* Power consumption → generators, etc.

1] Buses are nodes represented by dot

2] There is always a ground node (not shown in SLD but there is)

3] Generators are grounded together
↓
REMEMBER IN GRAPH.

★ graph is linear till machine/sink is not SATURATED.



★ Oriented graph → gives power/current direction

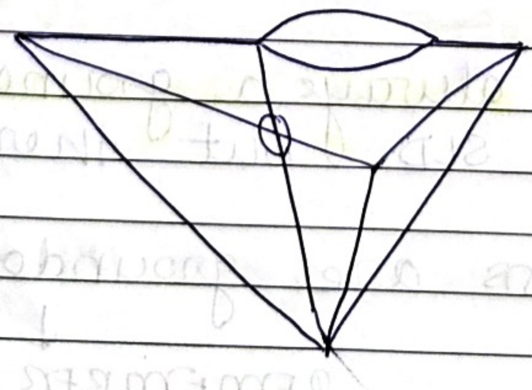
4] Current moves from higher to lower potential.

★ Planar graph → math eq^n linear in nature (no criss-cross of line segments)

★ Non-planar graph → non-linear eq^n in nature

→ line segments overlap.

→ eg-



Rank of matrix → ~~eq~~ no. of linearly independent eq^n (col or rows)

★ Rank of a graph → If there are 'n' nodes in the graph, the rank of the graph = 'n−1'

because 1 eq^n is dependant due to reference node

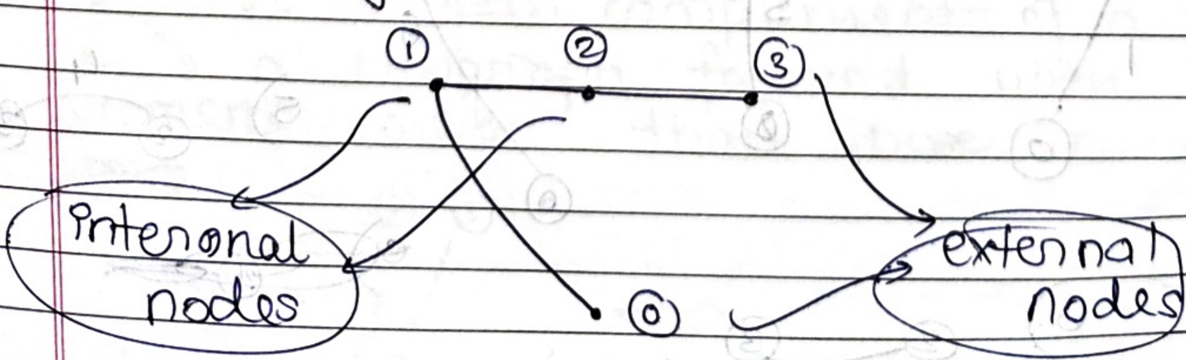
★ Sub-graph → part of a graph take for further analysis

subset of a graph.

take equivalent of neighbouring grids and then perform analysis on one subset.

★ Path → A path is a subgraph of connected elements with not more than ~~two~~ two elements are connected at the internal node

However, ~~as the~~ at the 2 terminal nodes, only one element is connected.

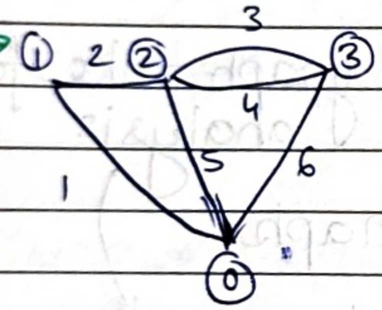


The internals nodes only to be connected by 2 out of the 6 elements.

Q Make paths & subgraphs of the previous question.

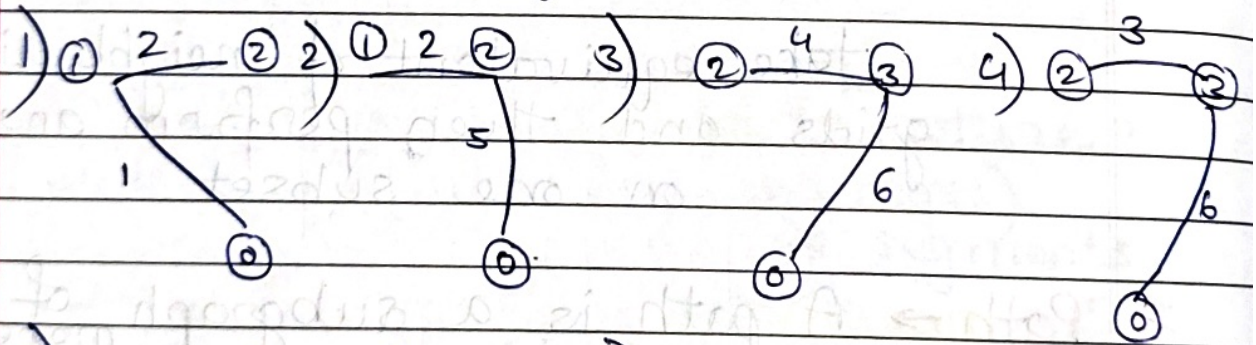
↳ elements are no numbered.

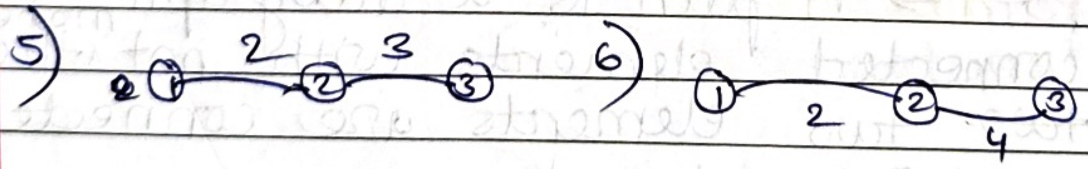
1



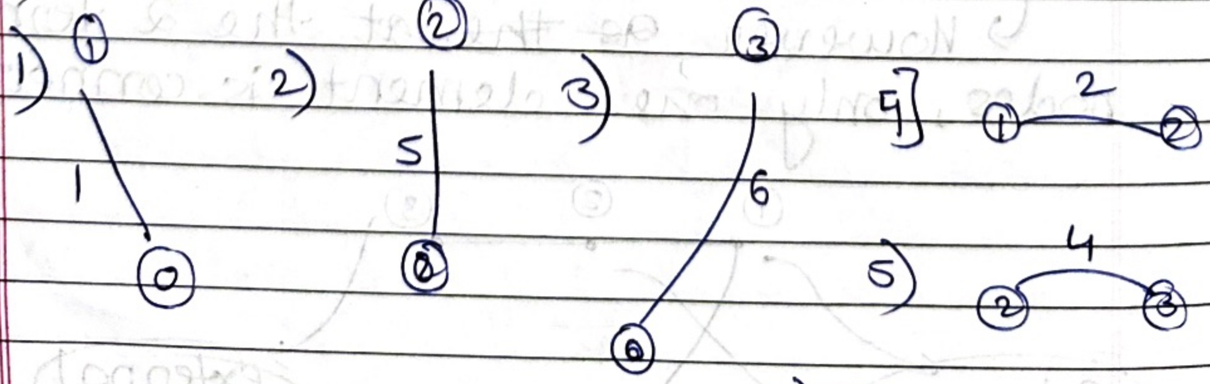
6 elements, 3 nodes, 1 reference node.

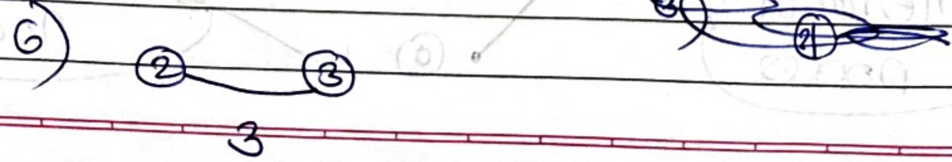
Subgraphs are:



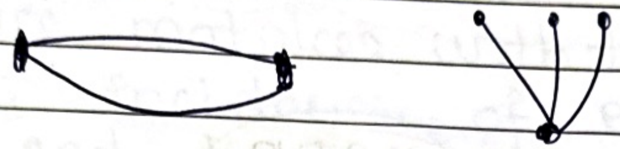


Paths are:

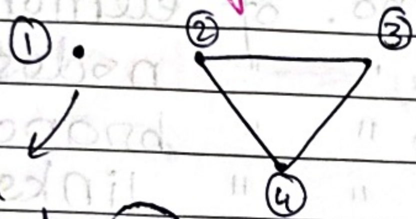




Connected graph → graph or subgraph is said to be connected where there exist atleast one path betn any two nodes.



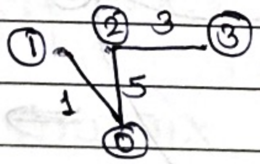
* **Non-connected graph** → self explanatory.



Isolated node ☹

* **Tree** →

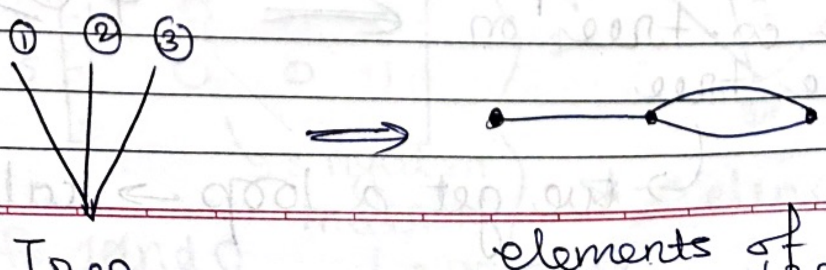
A Tree is a connected subgraph having all the nodes of a graph without any closed loop That subgraph is a Tree.



link or chord

The elements of trees are branch or twig.

* **Co-tree** → ~~A co~~ complement of a tree & is a subgraph formed with the elements other than those in the tree.



★ tree has all nodes but doesn't form a loop.

★ link/chord of co tree → connects with tree
↓
forms a closed loop.

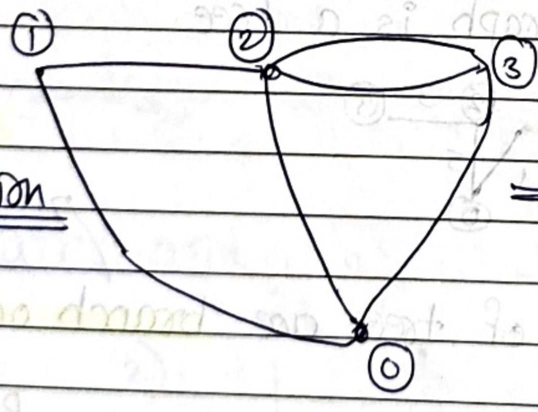
MATHS

let e = total no. of elements,
n = " " " nodes,
b = " " " branches,
l = " " " links,

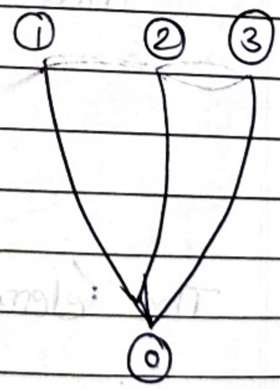
$b = n - 1$, $l = e - b = e - n + 1$

★ Basics of/fundamental loops (f loops)

Question

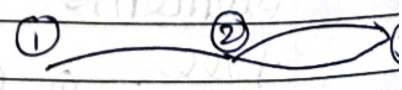


⟹



Tree

when we place the co-tree on the tree ⟸ +



↳ we get a loop → called basic loop

★ Incidence matrices → Every element of a graph is incident bet^n any two node

↳ incidence matrices with the info about the incidence of elements to nodes and their orientation.
↳ or direction.

1] Element node incident matrices → which element is connected to which node

$[\hat{A}] \to a_{ij}$ elements

$\boxed{a_{ij} = 1} \to$ if it the element i a is connected to i and j node

$\boxed{a_{ij} = 0} \to$ if the element is not connected to i & j node

Q] Form e-n matrix

j = nodes →

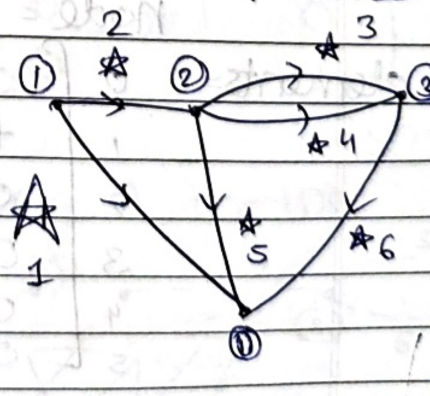
i = elements ↓

$$\begin{array}{c|cccc} & 0 & 1 & 2 & 3 \\ \hline 0 & -1 & +1 & 0 & 0 \\ 1 & 0 & +1 & -1 & 0 \\ 2 & 0 & 0 & +1 & -1 \\ 3 & 0 & 0 & +1 & -1 \\ 4 & -1 & 0 & +1 & 0 \\ 5 & -1 & 0 & 0 & +1 \end{array}$$

↳ singular matrix
↳ [illegible] = 0

element 1 connected to 1 and 0

Q] 6 elements, 4 nodes



★ → elements

Incident matrix is only formed for oriented matrix

VVIP

Sign convention → If the ith element is incident to jth node and oriented ~~tow~~ away from jth node, put +ve and vice versa

↳ higher potential → +ve
lower potential → -ve

→ Observations → 1) Sum of elements in a row is zero.

2) Bus incidence matrix $\boxed{[A]}$

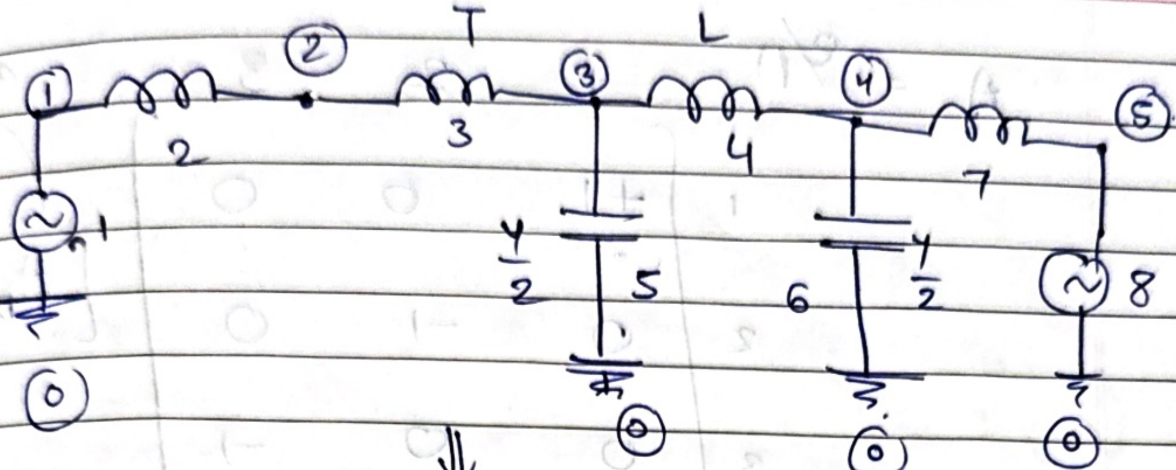
↳ Obtained from the e-n matrix by eliminating the column corresponding to the reference node.

↳ Remove the 0th node column

Q) Bus incidence matrix will be

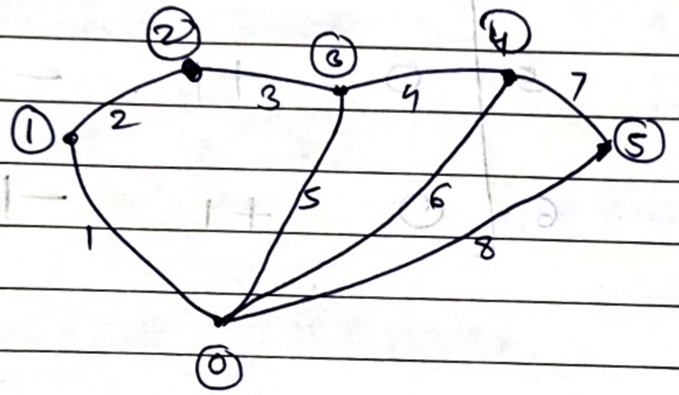
$$\begin{array}{c|c}
 & \text{node} = \;\; 1 \quad\; 2 \quad\; 3 \\
\text{elements} = \begin{array}{c} 0 \\ 1 \\ 2 \\ 3 \\ 4 \\ 5 \end{array} & \begin{bmatrix} +1 & 0 & 0 \\ +1 & -1 & 0 \\ 0 & +1 & -1 \\ 0 & +1 & -1 \\ 0 & +1 & 0 \\ 0 & 0 & +1 \end{bmatrix}
\end{array}$$

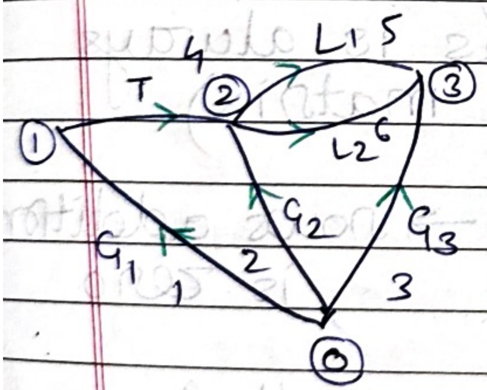
SLD



⇓

GRAPH



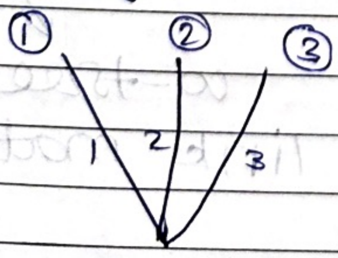


A = (bus incidence)

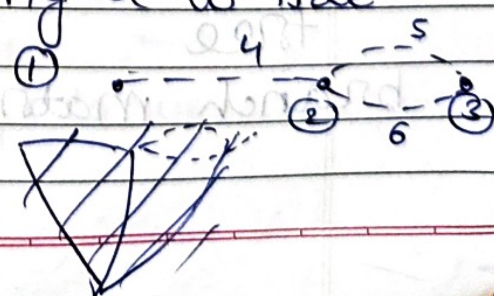
$$
\begin{array}{c|ccc}
 & 1 & 2 & 3 \rightarrow \text{nodes} \\
\hline
0 & +1 & 0 & 0 \\
1 & +1 & -1 & 0 \\
2 & 0 & +1 & -1 \\
3 & 0 & +1 & -1 \\
4 & 0 & +1 & 0 \\
5 & 0 & 0 & +1
\end{array}
$$

$e \times (n-1)$

★ Making a tree,



★ making a co-tree



$$A = \begin{array}{c} e/n \\ \\ 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \end{array} \begin{array}{c} \begin{array}{ccc} 1 & 2 & 3 \end{array} \\ \left[\begin{array}{ccc} +1 & 0 & 0 \\ 0 & -1 & 0 \\ 0 & 0 & -1 \\ \hline +1 & -1 & 0 \\ 0 & +1 & -1 \\ 0 & +1 & -1 \end{array}\right] \end{array} \begin{array}{l} \\ [A_b]_{b\times(n-1)} \\ \\ \\ [A_c]_{l\times(n-1)} \\ \downarrow \\ \text{links} \times n. \end{array}$$

always a square matrix

→ A_b is always a square matrix because branches is always $n-1$ (non-singular matrix)

→ A_c is ~~non~~ singular → rows addition is zero

→ Arrange in such a way that A_b is always on top of A_c

A_b ↓ tree branch matrix

A_c ↓ co-tree link matrix

★ $Z = R + jX \longrightarrow$ j → R (x axis real), ↓ X (Y axis imag)

★ Primitive network (Basic unit)

Impedance form (Z)

$$\boxed{Z = R + jX}$$

Admittance form (Y)

$$\boxed{Y = G + jB}$$

$$= \underbrace{\left(\frac{R}{R^2+X^2}\right)}_{\text{conductance}} - j\underbrace{\left(\frac{X}{R^2+X^2}\right)}_{\text{susceptance}}$$

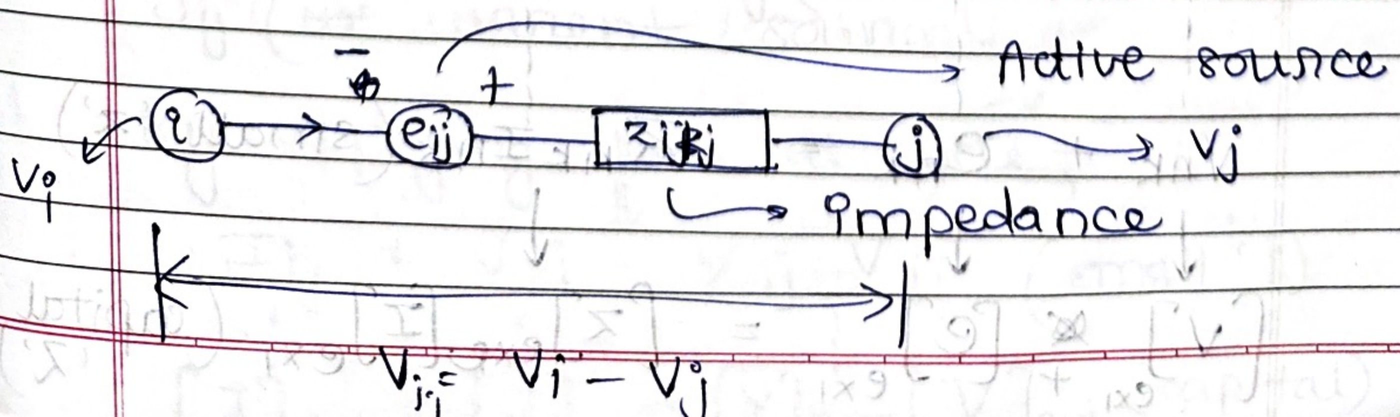
VIP

→ Each element of a network can be represented by a decoupled partial network known as a PRIMITIVE NETWORK.

→ Elements → Active (V or I)
→ Passive (Y and Z)

→ When primitive network is used, we use 'y' and 'z' for impedance & admittance.

1] Primitive network in IMPEDANCE FORM :-



Decoupled → one quantity depends on one variable

$\begin{bmatrix} 2 & 0 \\ 0 & 5 \end{bmatrix}\begin{bmatrix} x_1 \\ x_2 \end{bmatrix} = \begin{bmatrix} 4 \\ 8 \end{bmatrix}$ $2x_1 = 4$, $5x_2 = 8$

z_{ij} – self impedance of element i-j

∴ By applying KVL,

$V_i + e_{ij} - z_{ij}I_{ij} = V_j$

→ Whenever decoupled ~~matrix~~ system is considered → it is a diagonal matrix

→ ∴ $V_i - V_j = e_{ij} + z_{ij}I_{ij}$ VIP

$V_{ij} + e_{ij} = z_{ij}I_{ij}$

V_{ij} → Voltage betn the nodes

e_{ij} → internal voltage of the ~~elect~~ element/voltage source

$z_{ij}I_{ij}$ → voltage drop ($z_{ik}I_{ij}$)

→ So we will have to make eqn for 'e' elements.

⇓

$V_{ij} + e_{ij} = z_{ij}I_{ij}$ (small 'z')

$V_{nk} + e_{nk} = z_{nk}I_{nk}$ (small 'z')

$[V]_{e\times 1} + [e]_{e\times 1} = [Z]_{e\times e}[I]_{e\times 1}$ (capital 'Z') complete opp systems → dual system.

→ We want a single e matrix on the RHS.
but $[Z]_{e\times 1}$ $[I]_{e\times 1}$

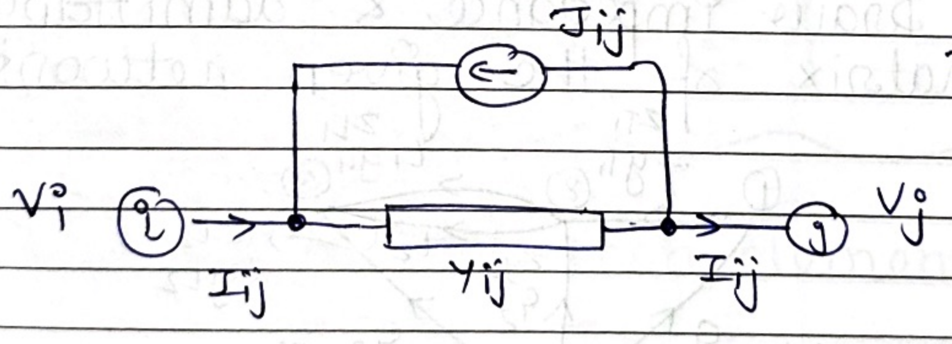
if we do, $[Z]_{1\times e}$ $[I]_{e\times 1}$ ⟹ $[\text{Total}]_{e\times e}$

$[Z]_{1\times e}$ → Should be a diagonal matrix. → of the impedance

→ $[Z]_{e\times e}$ $[I]_{e\times 1}$

→ Primitive impedance matrix is a diagonal matrix if there is no mutual coupling.

2] Primitive network in ADMITTANCE FORM



$I = \frac{V}{Z}$

$\therefore I = YV$

$\leftarrow V = V_i - V_j \rightarrow$

→ Just convert e_{ij} (voltage source) to J_{ij} (current source)

By applying KCL at node,

$I_{ij} + J_{ij} = Y_{ij} V_{ij}$ (small 'i')

$[I]_{e\times 1} + [J]_{e\times 1} = [Y]_{e\times e} [V]_{e\times 1}$ (capital)

Adv. of Y over Z :-

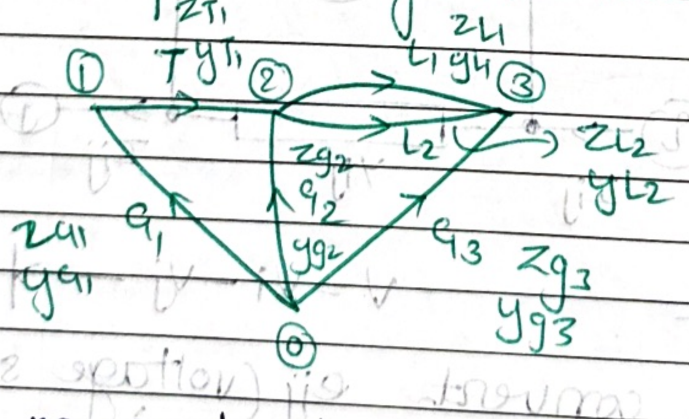
1) Data of the line will be in form of ~~im~~ 'z'

2) If no mutual coupling, we can easily convert 'z' to 'y'.

3) Fault analysis, SC analysis → done in 'z' form → we need thevenin eqⁿ of impedance

↳ so diagonal elements of 'z' primitive matrix gives thevenin eqⁿ at that bus.

Q) ~~D~~ Draw impedance & admittance matrix of the given network.

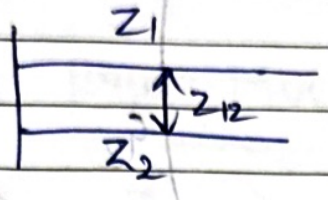


→ With no-mutual coupling, form 'y' primitive

~~A~~ With mutual coupling, first form 'z' matrix with diagonal 'z_{ij}'

and off diagonal is mutual impedance betⁿ them

↳ ex-



$$\Rightarrow \begin{bmatrix} z_1 & z_{12} \\ z_{12} & z_2 \end{bmatrix}$$

mutual

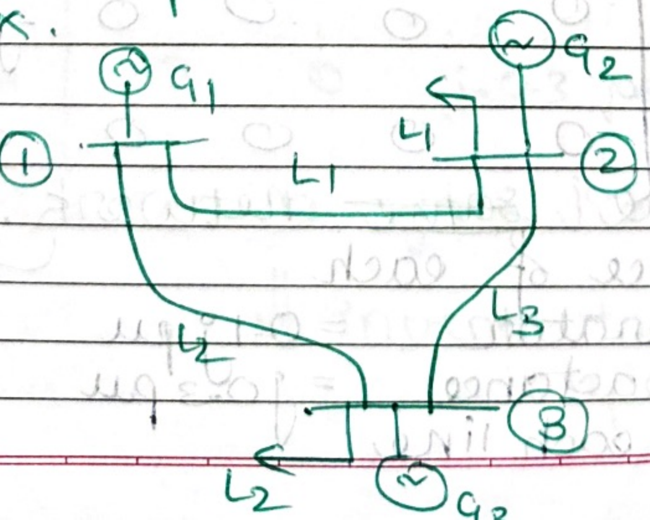
after this invert and form 'y' matrix.

Here, 'y' matrix is

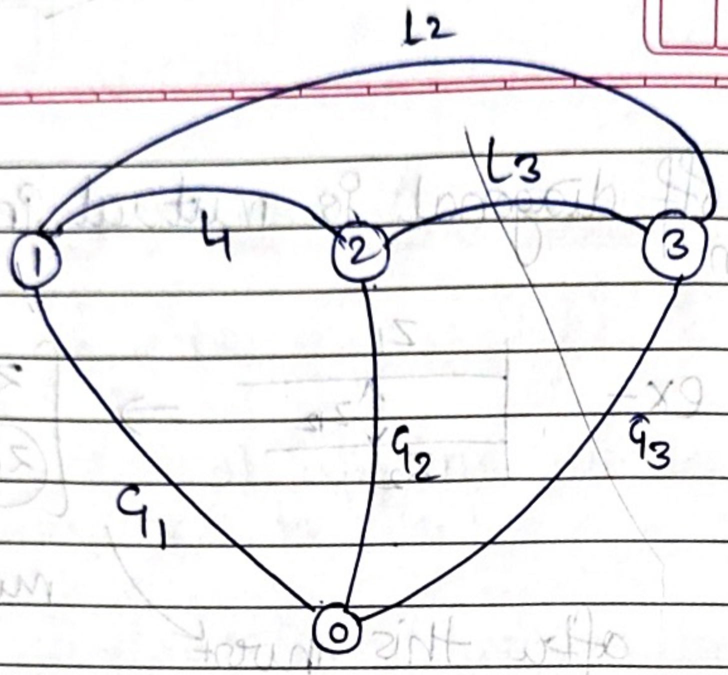
$$y = \begin{bmatrix} y_{g_1} & & & \\ & y_{g_2} & & \\ & & y_{g_3} & \\ & & & y_n \end{bmatrix}$$

Q] Reactance of ~~eti~~ each element = j0.1 pu

Formulate primitive admittance matrix.



0.1
×0.1



Ignore the load.

$Z = X = j0.1$ pu $\qquad \cancel{Z = \sqrt{R^2+X^2} = \sqrt{j^2(0.1)^2} = \sqrt{-0.01}}$

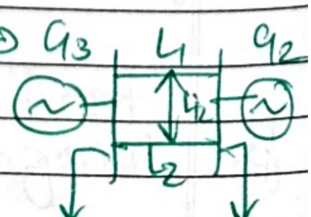
$\hookrightarrow -j10$ pu $= \dfrac{1}{Z}$

$$y = \begin{array}{c} \\ 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \end{array} \begin{array}{c} \begin{array}{cccccc} 1 & 2 & 3 & 4 & 5 & 6 \end{array} \\ \begin{bmatrix} -j10 & 0 & 0 & 0 & 0 & 0 \\ 0 & -j10 & 0 & 0 & 0 & 0 \\ 0 & 0 & -j10 & 0 & 0 & 0 \\ 0 & 0 & 0 & -j10 & 0 & 0 \\ 0 & 0 & 0 & 0 & -j10 & 0 \\ 0 & 0 & 0 & 0 & 0 & -j10 \end{bmatrix} \end{array}$$

Q Use the ~~same~~ network.

CONTD Reactance of each generator $= 0.1j$ pu

Self reactance of each line $= j0.3$ pu



Two lines have mutual impedance of j 0.01 pu.

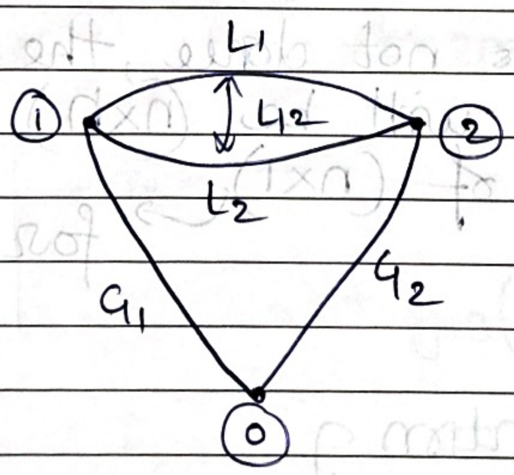
Formulate primitive impedance matrix

⇒ Z_{12} $\quad Z_{13}$ $\quad Z_{21}$ $\quad Z_{23}$ $\quad Z_{31}$ $\quad Z_{32}$

Z_{21} $\quad Z_{31}$ $\quad Z_{12}$ $\quad Z_{32}$ $\quad Z_{13}$ $\quad Z_{23}$

mutual

4 elements, so matrix will be 4×4



primitive Z = matrix

$$
\begin{array}{c}
g_1 \\ g_2 \\ L_1 \\ L_2
\end{array}
\begin{bmatrix}
j0.1 & 0 & 0 & 0 \\
0 & j0.1 & 0 & 0 \\
0 & 0 & j0.3 & j0.01 \\
0 & 0 & +j0.01 & j0.3
\end{bmatrix}
$$

⇓ invert to find 'y'

PSA Y_{bus}.

☆ Y_{bus} methods :-

1) Inspection method
2) Step by step method
3) Singular Transformation m

→ $\underset{(n\times1)}{V_{bus}} = \underset{(n\times n)}{Z_{bus}} \, I_{bus\,(n\times1)}$

$\underset{(n\times1)}{I_{bus}} = \underset{(n\times n)}{Y_{Bus}} \, V_{Bus\,(n\times1)}$

Z, Y should always ~~bet~~ be written first because of (n×n)

If this is not done, the answer will be (n×n) instead of (n×1) → for V_{bus} and I_{bus} matrices.

→ Sign convention

n tells the no. of currents flowing in & out

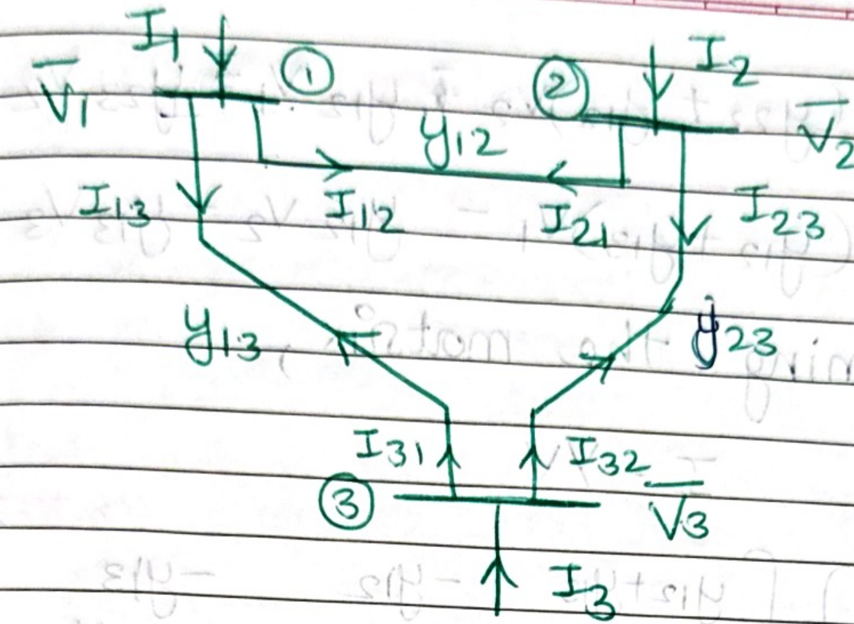
↳ injection current = +ve sign

↳ current is going out = −ve sign.

→ large voltages like 400kV are measured using potential transformers

★ Singular transformation method
↳ In trans lines, usually resistance values are very low.

eg →



Inspection method
↓
can't be easy with mutual coupling

Formulate the Y_{bus} matrix.

⟹ By applying KCL at each node,

$$I_1 = I_{12} + I_{13}$$

$$= y_{12}(V_1 - V_2) + y_{13}(V_1 - V_3) \quad \left[\because I = yV\right]$$

$$I_2 = I_{21} + I_{23}$$

$$= -y_{12}(V_2 - V_1) + y_{23}(V_2 - V_3)$$

↳ because $y_{21} = -y_{12}$

$$I_3 = -y_{13}(V_3 - V_1) - y_{23}(V_3 - V_2)$$

⟹ Now, seperating voltages & admittance

$$I_3 = -V_3(y_{13} + y_{23}) + y_{13}V_1 + y_{23}V_2$$

☆ $j0.3 \rightarrow$ impedance VIP
$-j0.2 \rightarrow$ admittance.

$$I_2 = (y_{23} + y_{12})V_2 - y_{12}V_1 - y_{23}V_2$$

$$I_1 = (y_{12} + y_{13})V_1 - y_{12}V_2 - y_{13}V_3$$

→ forming the matrix,

$$I = YV$$

$$\begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix} = \begin{bmatrix} y_{12}+y_{13} & -y_{12} & -y_{13} \\ -y_{12} & y_{23}+y_{12} & -y_{23} \\ -y_{13} & -y_{23} & y_{23}+y_{13} \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \\ V_3 \end{bmatrix}$$

☆ Observations :-

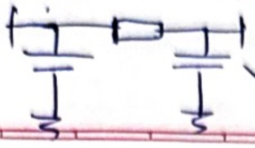
1) Diagonal elements are the sum of admittance between two nodes.

2) off diagonal elements are the Y-bus

→ We prefer ~~to~~ Y over Z-bus, because network topologies changes can be incorporated way easily than Z bus
↳ which requires more complex operations.

→ Z bus is always a full-matrix and Y bus is a sparse-matrix
↳ because a substation is often connected with 3-4 other substations

Size of y-bus → no. of bus × no. of bus.



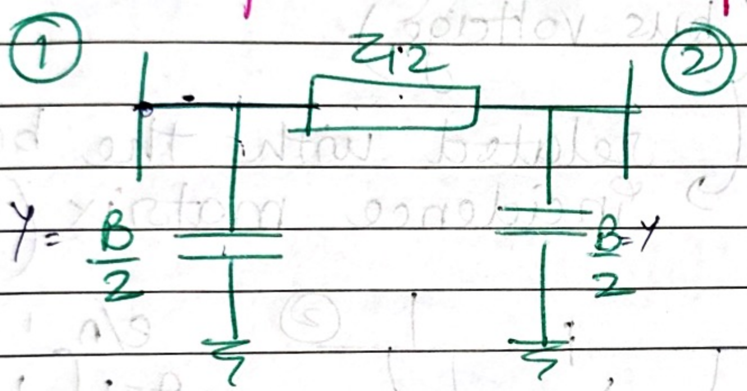
↳ half line charging capacitor

The matrix entries of the other buses is 0.

↳ so, faster computation & less ~~net~~ memory allocation.

★ Y bus will not always be symmetric (incase of mutual coupling)

eg —



Formulate the y-bus.

$$\rightarrow Y_{bus} = \begin{array}{c c} & \begin{array}{cc} 1 & 2 \end{array} \\ \begin{array}{c} 1 \\ 2 \end{array} & \begin{bmatrix} \frac{1}{Z_{12}} + \frac{B}{2} & \frac{-1}{Z_{12}} \\ \frac{-1}{Z_{12}} & \frac{1}{Z_{12}} + \frac{B}{2} \end{bmatrix}_{2\times 2} \end{array}$$

Sum of admittance betn the elements betn 2 nodes.

This is not singular matrix because there is a shunt element coming in the diagonal elements

↳ $\frac{B}{2}$ element

VIP

→ In case of a short transmission line, where no shunt elements

↳ ∴ Y_{bus} is singular

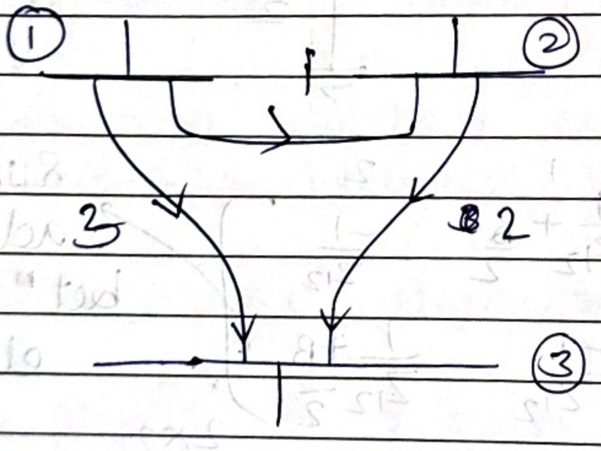
☆ Singular Transformation Matrix method.

→ use for large, complex network.

→ used when there is mutual coupling.

Relation betⁿ v (element voltage) and V (bus voltage)

related with the bus incidence matrix (A)



$$A = \begin{array}{c|ccc} e/n & 1 & 2 & 3 \\ \hline 1 & 1 & -1 & 0 \\ 2 & 0 & 1 & -1 \\ 3 & 1 & 0 & -1 \end{array}$$

$$\therefore \underset{(e\times 1)}{[v]} = \underset{(e)\times(n-1)}{[A]}\underset{((n-1)\times 1)}{[V]}$$

$v_1 = V_1 - V_2$

$v_2 = V_2 - V_3$

$v_3 = V_1 - V_3$

$$\underset{\text{element voltages}}{v} = \underbrace{\begin{bmatrix} 1 & -1 & 0 \\ 0 & 1 & -1 \\ 1 & 0 & -1 \end{bmatrix}}_{A\text{ (bus incidence matrix)}} \begin{bmatrix} V_1 \\ V_2 \\ V_3 \end{bmatrix} \rightarrow \text{bus voltages}$$

Proof

* Network ~~ifm~~ eqⁿ in Y form

$$[I]_{e\times 1} + [J]_{e\times 1} = [Y]_{e\times e}[v]_{e\times 1}$$

$[v]$ → element voltage matrix

$[Y]$ → primitive admittance matrix

Premultiply the eqⁿ with A^T,

$$[A]^T[I] + [A]^T[J] = [A]^T[Y][v]$$

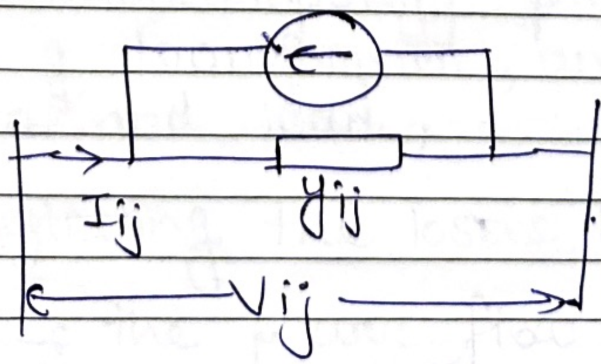
Since, $v = [A][Y]$,

$$\therefore [A]^T[I] + [A]^T[J] = [A]^T[Y][A][V]$$

$$A^T = \begin{bmatrix} 1 & 0 & 1 \\ -1 & 1 & 0 \\ 0 & -1 & -1 \end{bmatrix}$$

~~J [injection matrix~~

I (element current), J (source current)



★ Bus Injection current → current getting Injected in the grid.

$[A]^T[I] \longrightarrow$ always is zero

$[I]$ → element current

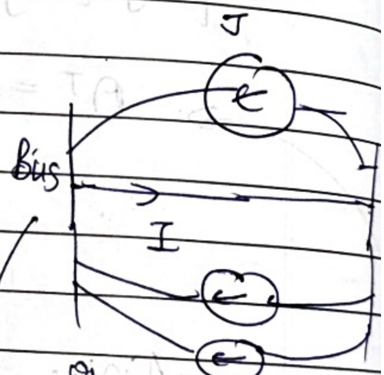
$[A]^T$ → Transpose bus incidence matrix

$$\therefore \underbrace{[A]^T[I]}_{0} + [A]^T[J] = \underline{\underline{[A^T][Y][A]}}[V_{bus}]$$

$$[I_{Bus}] = [Y_{bus}][V_{bus}]$$

VVIP

I_{Bus} → Injection due to source current matrix



It can have generator and load at the same bus

* generation ... load → freq changes
↳ demand + loss

STEADY STATE ANALYSIS

→ The eq^n will be algebraic in form.

1) Power flow analysis :- (Load flow analysis)

* generation > load → freq ↑es.
* generation < load → freq ↓es.

$$\sum P_G = \sum P_D + P_L$$

VVIP ↳ here, freq is constant.

* Assumptions :-

1) gen & load is constant, balanced in ~~steady state~~.

2) Frequency is constant here.

→ Given network topology, parameters of line & of transformer, and the generation and load,

↳ neglecting the losses temporarily,

↳ ~~we~~ the power flow analysis determines voltage at each bus of the network.

Modes of sync gen
↳ operated in over excited mode → for injecting ... (more than 1 p...)

→ When a lightly loaded or long transmission line, the $V_R > V_S$

so to compensate this, add ~~an inducti~~ a shunt inductance
↳ because it ~~observes~~ absorbs reactive power

→ Reactive power is supplied on the load end

↳ If its supplied in generator end, the active power to be transmitted decreases.

→ To supply reactive power, put a capacitor bank towards the load end.

→ Generating generator cannot be operated in under excited mode.

Q] Why is LFA (load flow analysis) done?

1) To monitor voltage at ~~at~~ each bus
2) To determine power flow of each element

↳ $S = \frac{V^2}{Z}$ → V voltage at bus, Z → impedance sync gen if it is not locally managed.

power in the circuit

3) We monitor this because if voltage varies
↳ we need to seek a solution for reactive power management.

4) We monitor LFA to see if any line is overloaded or no, if more power is flowing than the rating.
↳ all trans lines and Xformers

5) Then, find the losses in the power system

$\boxed{\text{LFA}}$

Stage-1 → To find magnitude of voltage $|V|$ and angle $\angle\delta$

Stage-2 → To find current phasors in transmission lines,

$$I = \frac{V_S - V_R}{Z}$$

$$S_R = V_R I_R^*$$

→ load farcasting → generation → dispatch

voltage → insulation
current → size of conductor

DATE

* Merit order dispatch

Scheduling of the generators

* Power system constraints

1) $\Sigma P_g = \Sigma P_d + \Sigma P_L$ (equality/operational constraint)

2) At every bus, $|V|$ must be within a range (± 5% in transmission system)

$|V_{imin}| \leq |V_i| \leq |V_{imax}|$ (voltage constraint) → operational

3) At every generator, there is a limit for power generation when it is started

$P_{Gimin} \leq P_{Gi} \leq P_{Gimax}$ (real power constraint)

$Q_{Gimin} \leq Q_{Gi} \leq Q_{Gimax}$

(reactive power constraint)

→ These are equipment constraints, hardware can get damaged

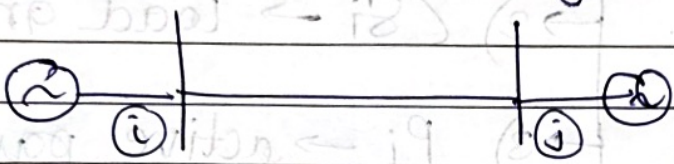
→ operational constraint → can affect the system

$f_{min} \leq f \leq f_{max}$

load angle

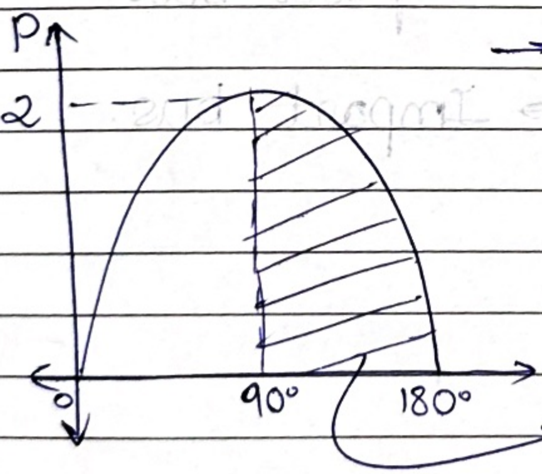
→ δ_i decides the power flow
↳ δ_i is greater, the power will flow from there.

eg –
$|V|\angle\delta_i$ $|V|\angle\delta_j$ → voltage angle



$\delta = |\delta_i - \delta_j| \leq 35°$

4) The diff betⁿ angle ≤ 35° is also an operational constraint.



→ In an AC network, the behavior of network = behavior of the sync. machine.

power angle curve

→ Beyond $\delta = 90°$, operation is unstable.
↳ to avoid this, a margin of 35° is kept

δ is always kept betⁿ 35° – 40°

→ At every bus in the power system there at 4 quantities always mentioned

- → 1) $|V_i|$ → voltage magnitude
- → 2) $\angle \delta_i$ → load angle
- → 3) P_i → active power injection
- → 4) Q_i → reactive power injection

→ If $\delta_{G_i} > \delta_{P_i}$ → Export bus

→ If $\delta_{G_i} < \delta_{P_i}$ → Import bus.