



IIT ROORKEE



NPTEL ONLINE
CERTIFICATION COURSE

Computer aided power system analysis

Fault Analysis

Prof. Biswarup Das

Department of Electrical Engineering



Power System State estimation

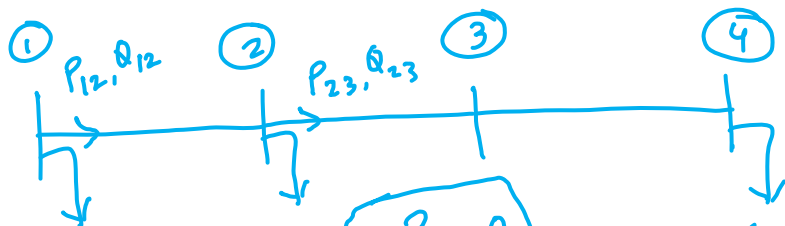
$P.M \rightarrow H$
 $V.M \rightarrow L$
 $P.M \rightarrow L$
 $m = P.M + V.M + P.M$

$N = 500$
 $n = 999$
 $m = 1000$

$$m > n$$

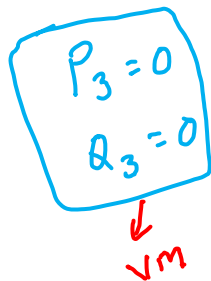
Pseudo-measurements
 Virtual measurement

Range of variation



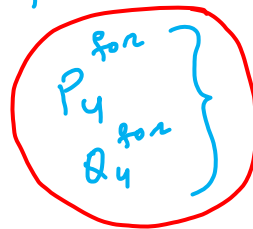
$$n = 7 = 2 \times 4 - 1$$

$$\omega_i = \frac{1}{\omega_i^2}$$



virtual measurement

$$7 - 2 = 5$$



PM



$$7 - 2 - 2 = 3$$

$\nwarrow$ $\nwarrow$
 V_M P_M



IIT ROORKEE



NPTEL ONLINE
CERTIFICATION COURSE

Traditional method

FAULT ANALYSIS

↳ Sequence networks.

(+ve) Positive sequence
(-ve) Negative sequence
(zero) zero

Interconnect these networks depending upon the type of fault

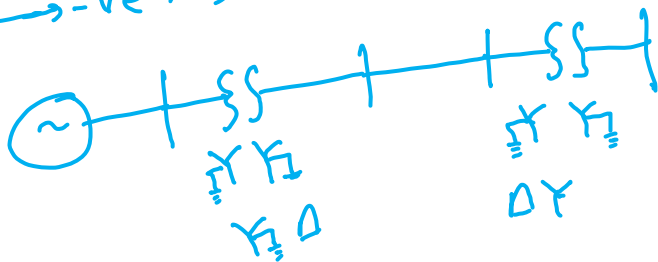
+ve $\rightarrow$ -ve $\rightarrow$ zero $\rightarrow$ connected in series

+ve $\rightarrow$ -ve $\rightarrow$ connected in parallel

L-G

L-L

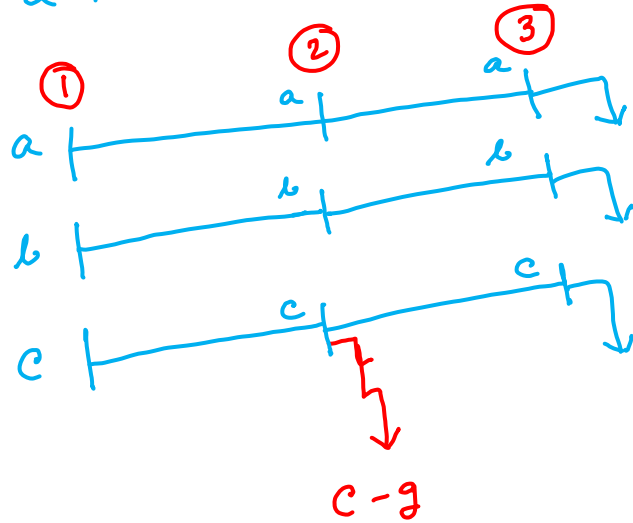
L-L-G



Analyze the fault behavior of a power network in the phase domain (not in the sequence domain)

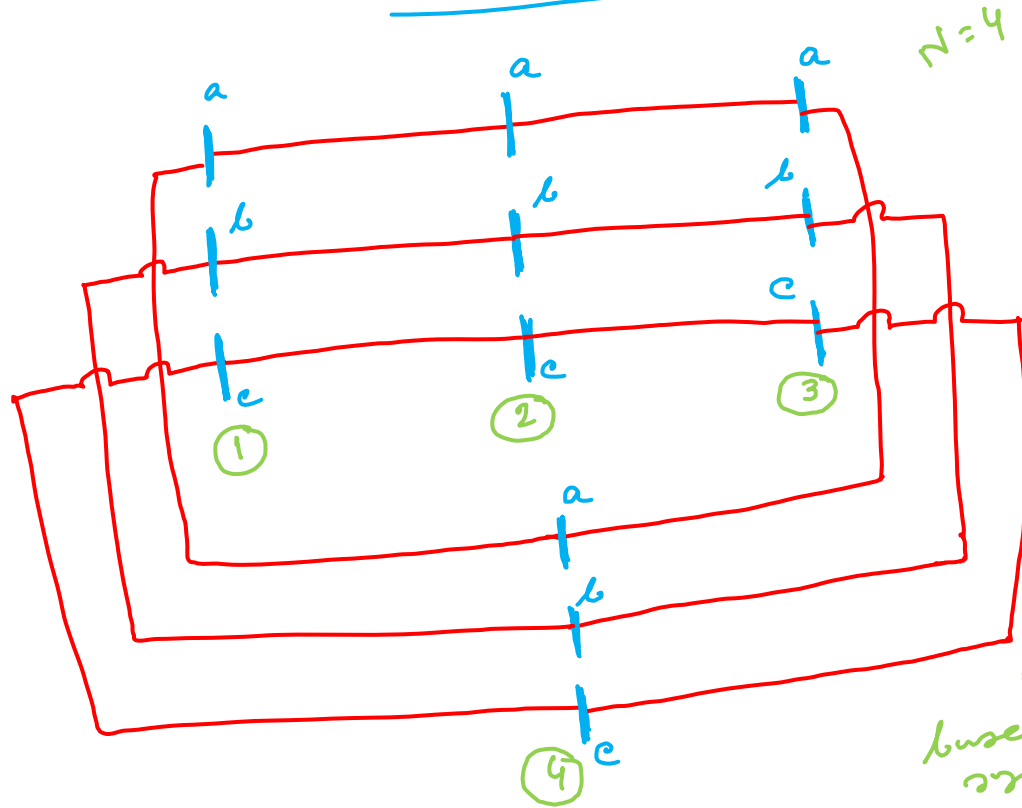
Phase-domain : a-b-c phase domain

$\begin{cases} L-G \\ L-L \\ L-L-G \end{cases}$



$\boxed{Y \text{ BUS}}$

Formation of Y_{BUS} matrix of an unbalanced network.



$\vec{I}_i^p$ → injected current at phase 'p' of bus 'i'

$i = 1, 2, 3, 4$ I_3^b

$p = a, b, c$

$\vec{V}_i^p$ → voltage at phase 'p' of bus 'i'

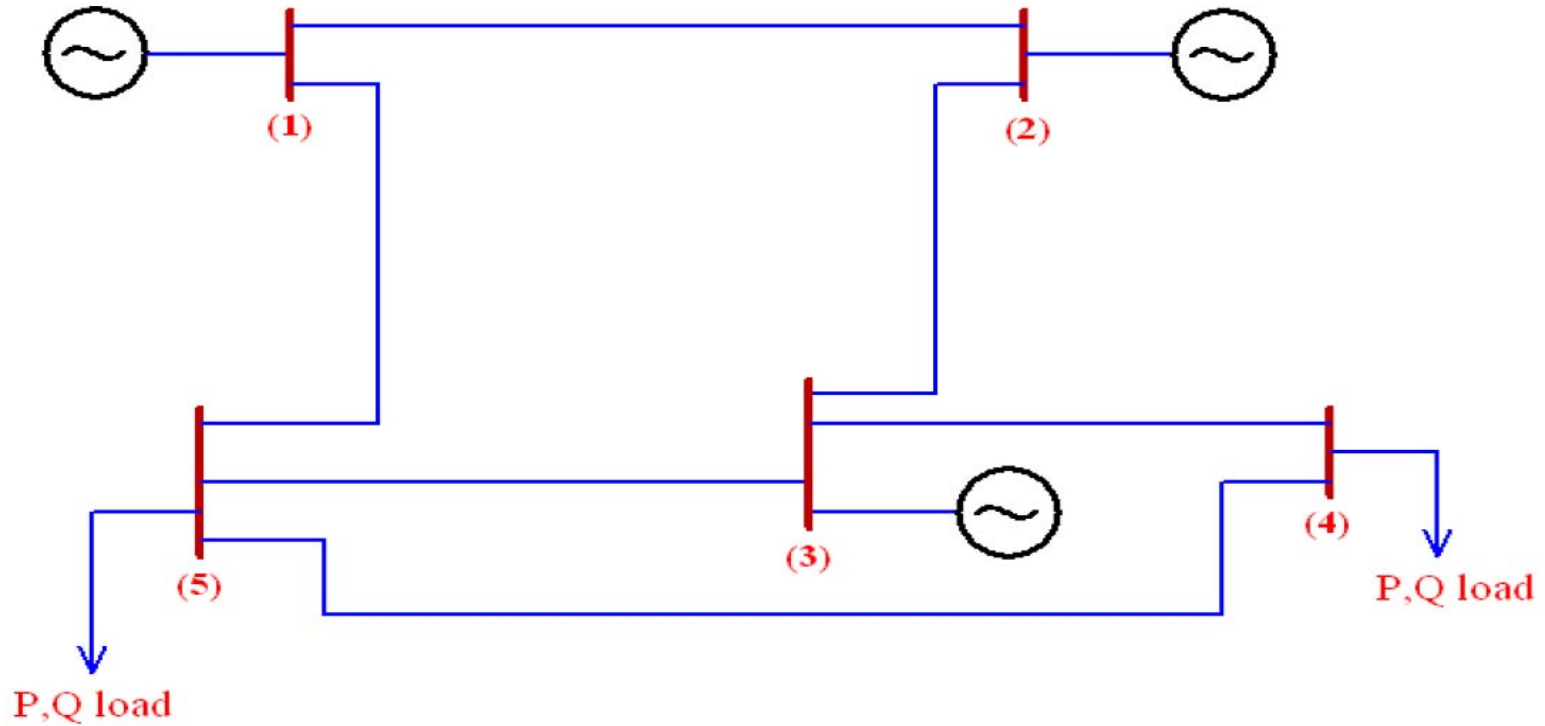
$3N$

$3N$

$N \rightarrow$ no. of buses in the system



Power system state estimation



Power system state estimation

load flow result

Bus no.	vm	theta (rad)
1	1	0
2	1	0.0289
3	1	-0.0159
4	0.9059	-0.1458
5	0.944	-0.0877

SE result (no error)
($M = 12$)

vm	theta (rad)
1	0
1	0.0289
1	-0.0159
0.906	-0.1457
0.944	-0.0877

measurements ($M = 12$)

P12, Q12, P15, Q15, P23, Q23, P34, Q34, P35, Q35, P54, Q54

Power system state estimation

SE result ($\sigma=0.02$)
($M = 12$)

vm	theta
0.9832	0
0.9832	0.0297
0.9832	-0.016
0.8892	-0.1518
0.927	-0.0914

SE result ($\sigma=0.02$)
($M = 18$)

vm	theta
0.9955	0
0.9954	0.0289
0.9957	-0.0151
0.9022	-0.1473
0.9397	-0.0894

SE result ($\sigma=0.02$)
($M = 24$)

vm	theta
0.996	0
0.9959	0.0288
0.9962	-0.015
0.9029	-0.1483
0.9402	-0.0893

measurements ($M = 18$)

(all of $M = 12$) + P21, Q21, P51, Q51, P32, Q32

measurements ($M = 24$)

(all of $M = 18$) + P43, Q43, P53, Q53, P45, Q45



Power system state estimation

- $\alpha = 0.05$
- For $M = 24$ (with no bad data error), $C(k, \alpha) = 24.9958$; $\hat{f} = 1.4789$
- For $M = 24$ and $P_{54}^{bad} = 10.2193$ ($P_{54}^{meas} = 0.2193$) $\hat{f} = 196532.65$
- For $M = 23$ (with no bad data error), $C(k, \alpha) = 23.684$; $\hat{f} = 1.4721$

