3-phase Symmetrical Fault Analysis

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PROBLEM STATEMENT

To write a MATLAB program to perform the complete fault analysis (finding fault current, during fault voltages, line flows) for a three phase symmetrical fault.

Flowchart

Y_{bus}

- Accept the physical impedances between buses of the power system network from the user
- Formulate the Y_{bus} matrix from the physical admittances

Z_{bus}

- Invert the Y_{bus} matrix to obtain the Z_{bus} matrix of the given network

Type of Fault

- Accept from the user, the bus at which the 3-phase fault is to be simulated
- Also ask if it is a bolted fault or a fault through an impedance

I_f

- Compute the fault current at the bus with the 3-phase fault
- Assume the pre-fault voltages at all buses are 1 p.u.

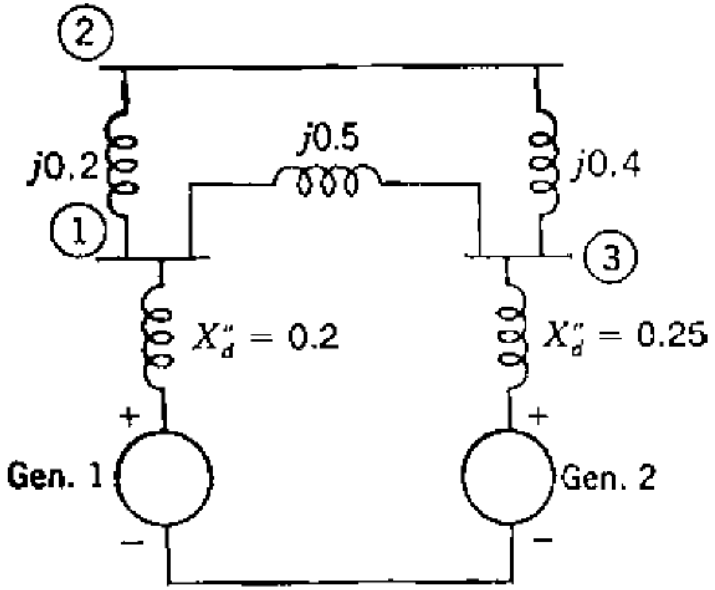
V_f

- Compute the difference matrix, by multiplying the Z_{bus} with the injected fault current matrix
- Add the pre-fault voltages to the difference matrix to get the during-fault voltages

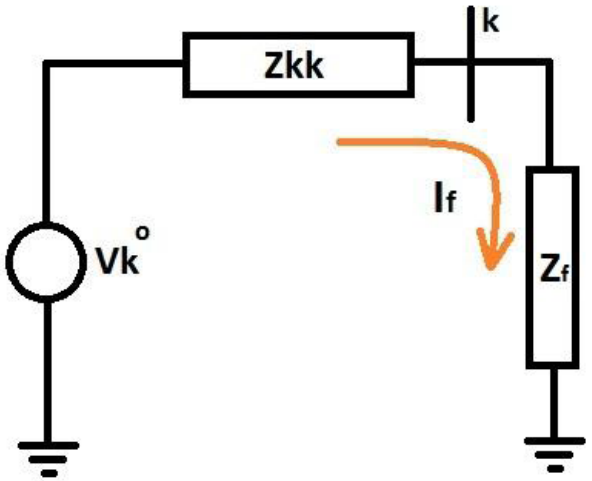
Line flows

- From the knowledge of during-fault voltages at the buses and the physical impedances between them, the line flows can be calculated

Power system network



Network



Thevenin equivalent

Fault analysis - equations

$$\begin{bmatrix} \Delta V_1 \\ \Delta V_2 \\ \vdots \\ \Delta V_k \\ \vdots \\ \Delta V_N \end{bmatrix} = \begin{bmatrix} Z_{11} & Z_{12} & \cdots & Z_{1k} & \cdots & Z_{1N} \\ Z_{21} & Z_{22} & \cdots & Z_{2k} & \cdots & Z_{2N} \\ \vdots & \vdots & \ddots & \vdots & \ddots & \vdots \\ Z_{k1} & Z_{k2} & \cdots & Z_{kk} & \cdots & Z_{kN} \\ \vdots & \vdots & \ddots & \vdots & \ddots & \vdots \\ Z_{N1} & Z_{N2} & \cdots & Z_{Nk} & \cdots & Z_{NN} \end{bmatrix} \times \begin{bmatrix} 0 \\ 0 \\ \vdots \\ -I_f \\ \vdots \\ 0 \end{bmatrix}$$

$$I_f = \frac{{V_k}^0}{Z_{kk} + Z_f}$$

$${V_k}^f = {V_k}^0 + \Delta V_k$$
$${V_k}^f = {V_k}^0 - Z_{kk} I_f$$

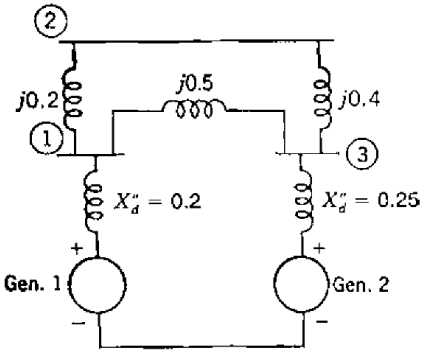
$${I_{mn}}^f = \frac{{V_m}^f - {V_n}^f}{z_{mn}}$$

Terminal Output

3-phase symmetrical fault analysis

Enter the number of buses in the existing power system (excluding reference bus): 3

Assume
1. Reference bus is denoted by "0"
2. If there is no impedance between two buses, enter NaN



Enter the physical impedances between buses:
Enter the z(1,2) (e.g. 2j): 0.2j
Enter the z(1,3) (e.g. 2j): 0.5j
Enter the z(1,0) (e.g. 2j): 0.2j
Enter the z(2,3) (e.g. 2j): 0.4j
Enter the z(2,0) (e.g. 2j): NaN
Enter the z(3,0) (e.g. 2j): 0.25j

The Zbus of the given power system is:

0 + 0.1447i	0 + 0.1195i	0 + 0.0692i
0 + 0.1195i	0 + 0.2465i	0 + 0.1006i
0 + 0.0692i	0 + 0.1006i	0 + 0.1635i

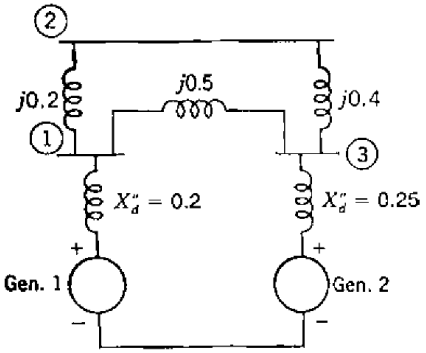
Terminal Output

```
For bus 1:
 1 -> Generator bus
 2 -> Load bus
Choose: 1

For bus 2:
 1 -> Generator bus
 2 -> Load bus
Choose: 2

For bus 3:
 1 -> Generator bus
 2 -> Load bus
Choose: 1

Enter the bus index at which a 3-phase fault is to be simulated: 4
Error!! Please enter a value between 1 and 3!
Enter the bus index at which a 3-phase fault is to be simulated: 2
Enter the fault impedance (zero in case of bolted fault): 0
```

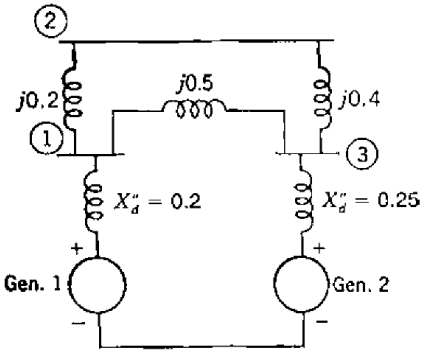


Terminal Output

```
Per-unit fault current out of bus 2:
        0 - 4.0561i

During-fault voltages (p.u.):
Vf_1 =     0.5153
Vf_2 =      0
Vf_3 =     0.5918

During-fault currents (p.u.):
If_12 =          0 - 2.5765i
If_13 =          0 + 0.1531i
If_23 =          0 + 1.4796i
If_g1 =          0 - 2.4235i
If_g3 =          0 - 1.6327i
```



Results and Discussion

- The equations required to perform the 3-phase symmetrical fault analysis are derived for an N-bus system, to support any generic system
- The N-bus system is treated as an N-port network and hence its Thevenin circuit is used to obtain the fault current
- A MATLAB code is written to simulate the fault at any specified bus, in a given power system network
- The fault current and during fault voltages are computed, from which, the line flows are calculated and displayed
- By repeatedly simulating the fault analysis at different buses in a network, the rating of the circuit breaker can be determined from the maximum of line current during each of these simulations

Thank you!