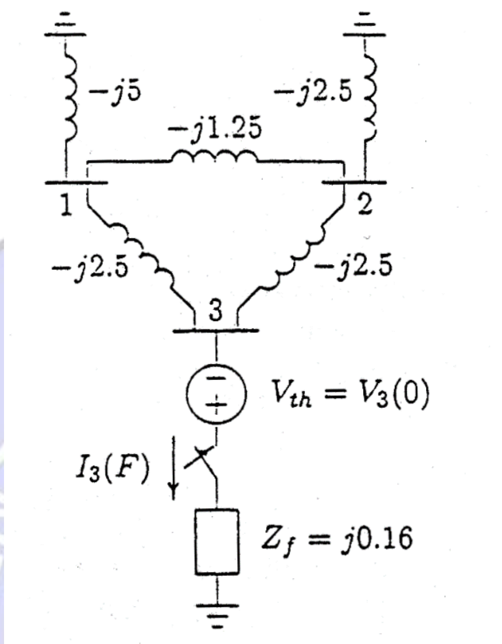
For previous example, to compute the fault current, the bus voltages , and the line currents during the fault at bus 3 , by using the bus impedance matrix method , the Thevenin's equivalent network is redraw with impedances converted to admittances as shown in fig. below , in order to find the bus admittance matrix .



The admittance diagram for system of previous example.

Referring to above fig., the bus admittance matrix by inspection is:

$$Y_{bus} = \begin{bmatrix} -j8.75 & j1.25 & j2.5 \\ j1.25 & -j6.25 & j2.5 \\ j2.5 & j2.5 & -j5.0 \end{bmatrix}$$

$$Z_{bus} = Y_{bus}^{-1} = \begin{bmatrix} j0.16 & j0.08 & j0.12 \\ j0.08 & j0.24 & j0.16 \\ j0.12 & j0.16 & j0.34 \end{bmatrix}$$

From eq. (18), for a fault at bus 3 with fault impedance $Z_f = 0.16$ pu:

$$I_3(F)\frac{V_3(0)}{Z_{33}+Z_f} = \frac{1.0}{j0.34 + j0.16} = -j2.0 \text{ pu}$$

From eq. (19), bus voltages during the fault are:

$$V_1(F) = V_1(0) - Z_{13}I_3(F) = 1.0 - (j0.12)(-j2.0) = 0.76 \text{ pu}$$

$$V_2(F) = V_2(0) - Z_{23}I_3(F) = 1.0 - (j0.16)(-j2.0) = 0.68 \text{ pu}$$

$$V_3(F) = V_3(0) - Z_{33}I_3(F) = 1.0 - (j0.34)(-j2.0) = 0.32 \text{ pu}$$

From eq. (21), the short circuit currents in the lines are:

$$I_{12}(F) = \frac{V_1(F) - V_2(F)}{z_{12}} = \frac{0.76 - 0.68}{j0.8} = -j0.1 \text{ pu}$$

$$I_{13}(F) = \frac{V_1(F) - V_3(F)}{z_{13}} = \frac{0.76 - 0.32}{j0.4} = -j1.1 \text{ pu}$$

$$I_{23}(F) = \frac{V_2(F) - V_3(F)}{z_{23}} = \frac{0.68 - 0.32}{j0.4} = -j0.9 \text{ pu}$$

The results are exactly the same as the values found previously.

The values of the diagonal elements in the bus impedance matrix are equal to the thevenin's impedances for other fault locations , i.e. if the fault occurs at bus2 , the thevenin's impedance is $j0.24$***, and equal to*** $j0.16$ ***if the fault occurs at bus1, then can be used eq. (18) to find directly the fault current at buses 1 and 2 , as following :***

$$I_1(F)\frac{V_1(0)}{Z_{11} + Z_f} = \frac{1.0}{j0.16 + j0.16} = -j3.125 \text{ pu}$$

$$I_2(F)\frac{V_2(0)}{Z_{22} + Z_f} = \frac{1.0}{j0.24 + j0.16} = -j2.5 \text{ pu}$$

Furthermore, the 0ff-diagonal elements are utilized in eq. (20) to obtain bus voltages during the fault.

Therefore, the bus impedance matrix method is an indispensable tool for fault studies.

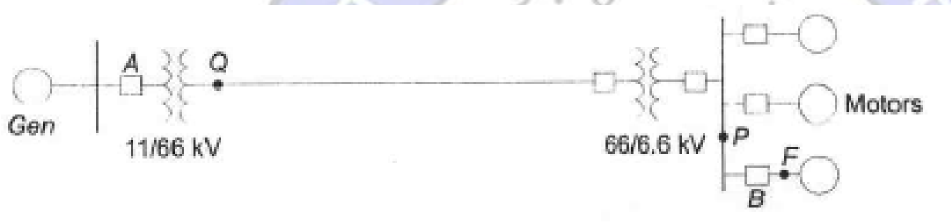
The matrix inversion for a large power system with a large number of buses is not feasible. A computationally attractive and efficient method for finding Z_{bus} matrix is (building) or (assembling) the impedance matrix by adding one network element at a time. In effect, this is an indirect matrix inversion of the bus admittance matrix.

Example 1/ A 25 MVA, 11 kV generator with Xl = 20Vo is connected through a transformer, line and a transformer to a bus that supplies three identical motors as shown in Fig. Each motor has X_d'' = 25% and X_d' = 30%on a base of 5 MVA, 6.6 kV. The three-phase rating of the step-up transformer is 25 MVA, 11/66 kV with a leakage reactance of l0% and that of the step-down transformer is 25 MVA, 6616.6k V with a leakage reactance of l0%. The bus voltage at the motors is 6.6 kV when a three-phase fault occurs at the point F. For the specified fault, calculate

(a) the sub transient current in the fault,

(b) the sub transient current in the breaker B.

Given: Reactance of the transmission line = 15% on a base of 25 MVA, 66 kV. Assume that the system is operating on no load when the fault occurs.



Sotution

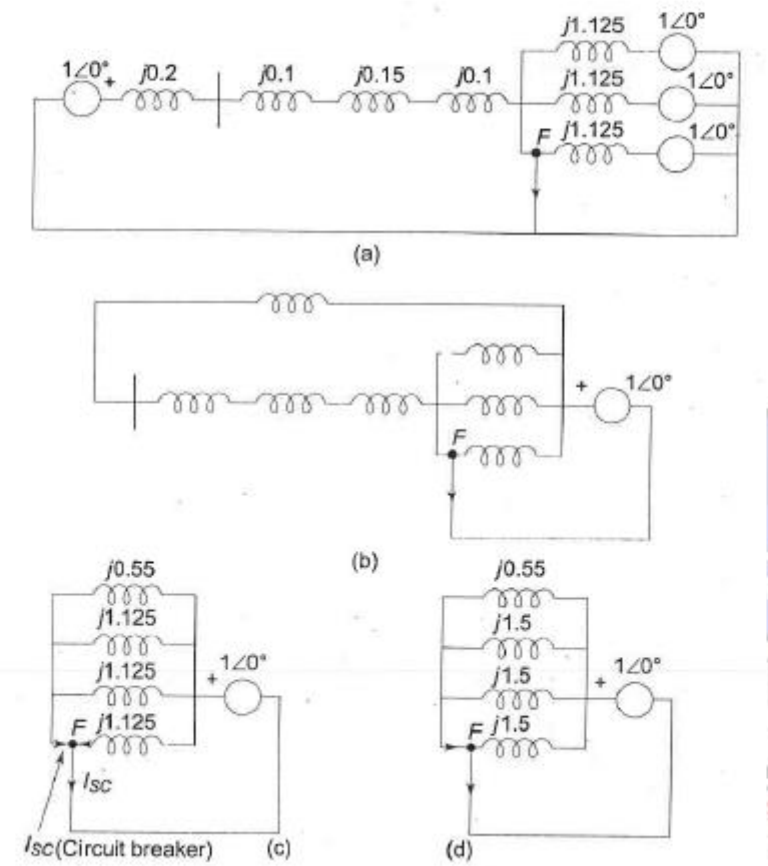
Choose a system base of 25 MVA.

For a generator voltage base of 11 kV, line voltage base is 66 kV and motor voltage base is 6.6 kV.

(a) For each motor

$$X''_{dm} = j0.25 \times \frac{25}{5} = j1.25 \text{ pu}$$

Line, transtbrmersa nd generatorr eactancesa re already given on proper base values. The circuit model of the system for fault calculations is given in Fig.a. The system being initially on no load, the generator and motor induced emfs are identical. The circuit can therefore be reduced to that of Fig. b and then to Fig.c. Now



$$I_{SC} = 3 \times \frac{1}{j1.25} + \frac{1}{j0.55} = -j4.22 \text{ pu}$$

$$\text{Base current in 6.6 kV circuit} = \frac{25 \times 1{,}000}{\sqrt{3} \times 6.6} = 2{,}187 \text{ A}$$

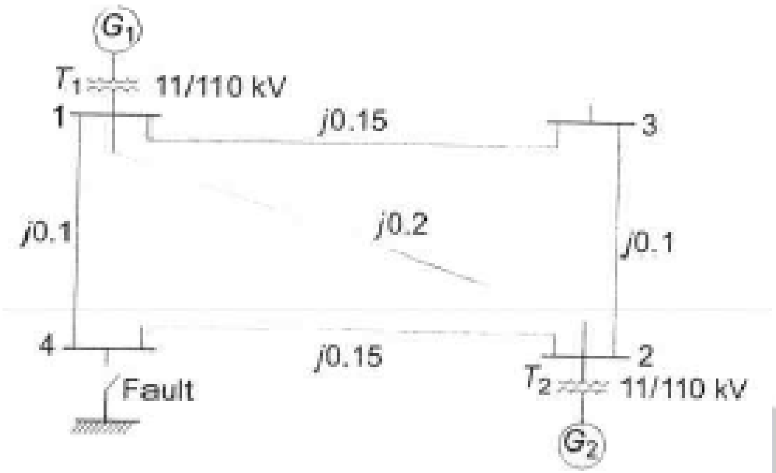
$$\therefore \quad I_{SC} = 4.22 \times 2{,}187 = 9{,}229 \text{ A}$$

(b) From Fig. c, current through circuit breaker B is

$$I_{SC}(B) = 2 \times \frac{1}{j1.25} + \frac{1}{j0.55} = -j3.42$$

$$= 3.42 \times 2{,}187 = 7{,}479.5 \text{ A}$$

Example 2/ Consider the 4-bus system of Fig. Buses1 and 2 are generator buses and 3 and 4 are load buses. The generators are rated 11kv, 100 MVA, with transient reactance of l0% each. Both the transformers are 11/110 kV, 100 MVA with a leakage reactance of 5%. The reactances of the lines to a base of 100 MVA, 110 kv are indicated on the figure. obtain the short circuit solution for a three-phase solid fault on bus 4 (load bus).
Assume pre-fault voltages to be 1 pu and pre-fault currents to be zero.



Solution

Changes in voltages and currents caused by a short circuit can be calculated from the circuit model of Fig.1. Fault current I_f is calculated by systematic network reduction as in Fig.2,

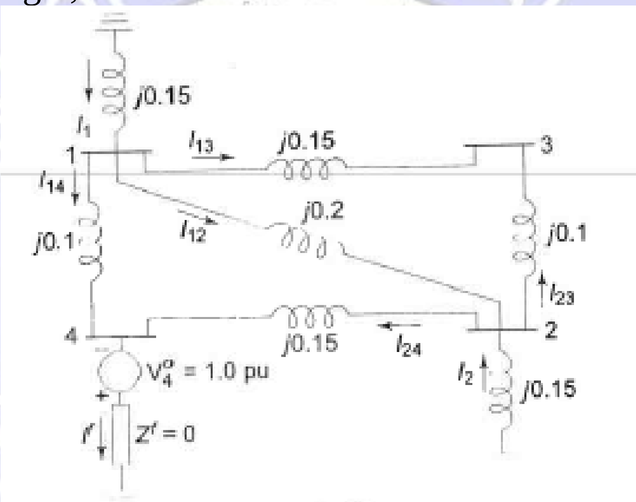


Fig. 1

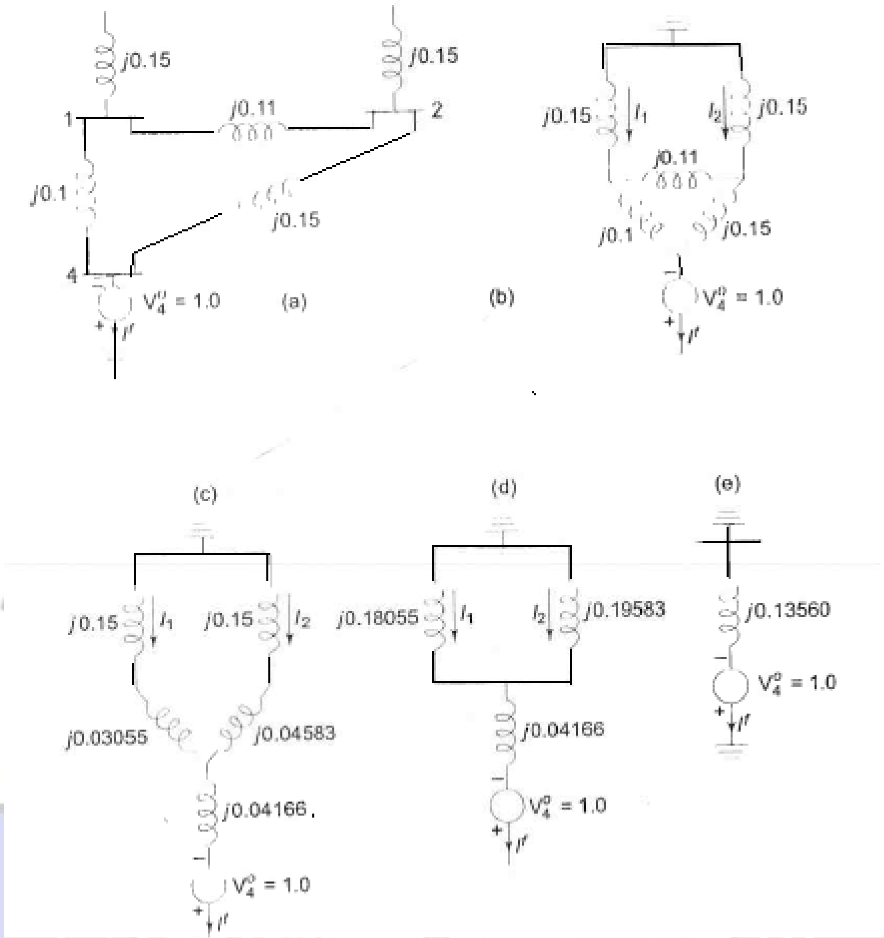


Fig 2

From Fig.e, we get directly the fault current as

$$I^f = \frac{1.0}{j0.13560} = -j7.37463 \text{ pu}$$

From Fig. d, it is easy to see that

$$I_1 = I_f \times \frac{j0.19583}{j0.37638} = -j3.83701 \text{ pu}$$

$$I_2 = I_f \times \frac{j0.18055}{j0.37638} = -j3.53762 \text{ pu}$$

Let us now compute the voltage changes for buses 1, 2 and 3. From Fig b, we give

$$\Delta V_1 = 0 - (j0.15)(-j3.83701) = -0.57555 \text{ pu}$$

$$\Delta V_2 = 0 - (j0.15)(-j3.53762) = -0.53064 \text{ pu}$$

Now

$$V_1^f = 1 + \Delta V_1 = 0.42445 \text{ pu}$$

$$V_2^f = 1 + \Delta V_2 = 0.46936 \text{ pu}$$

$$\therefore \quad I_{13} = \frac{V_1^f - V_2^f}{j0.15 + j0.1} = j0.17964 \text{ pu}$$

Now $\Delta V_3 = 0 - [(j0.15)\ (-j3.83701) + (j0.15)\ (j0.17964)]$

$= -0.54860$ pu

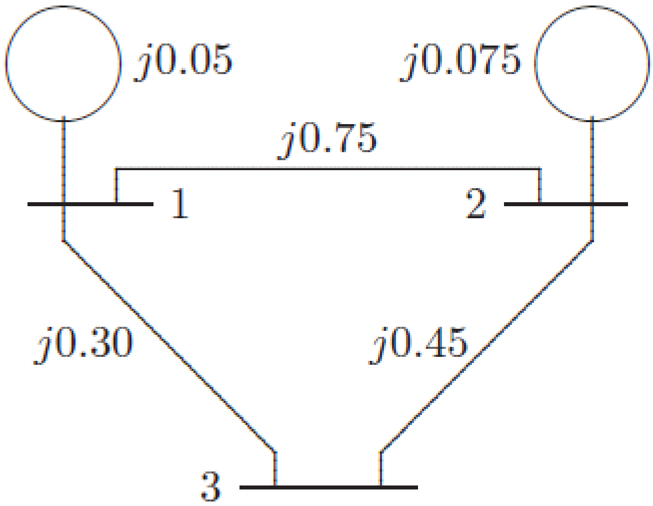
$V^f_3 = 1 - 0.54860 = 0.4514$ pu

$V^f_4 = 0$

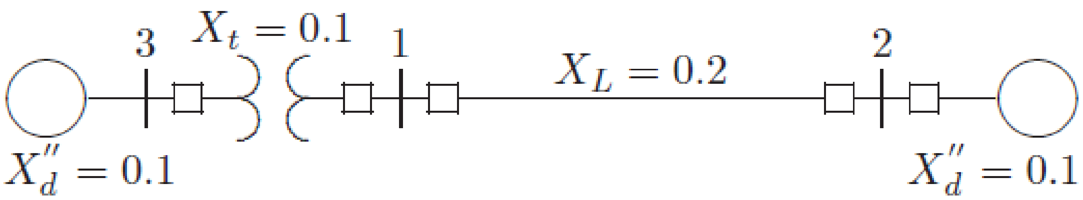
The determination of currents in the remaining lines is left as an exercise to
The reader. Short circuit study is completew ith the computation of SCMVA at bus 4.
$(\text{SC MVA})_4 = 7.37463 \times 100 = 737.463$ MVA

HW.

Q1/ The one-line diagram of a simple three-bus power system is shown in Figure. Each generator is represented by an emf behind the sub transient reactance. All impedances are expressed in per unit on a common MVA base. All resistances and shunt capacitances are neglected. The generators are operating on no load at their rated voltage with their emfs in phase. A three-phase fault occurs at bus 3 through a fault impedance of $Z_f = j0.19$ per unit.
(a) Using Thevenin's theorem obtain the impedance to the point of fault and the fault current in per unit.
(b) Determine the bus voltages and line currents during fault.

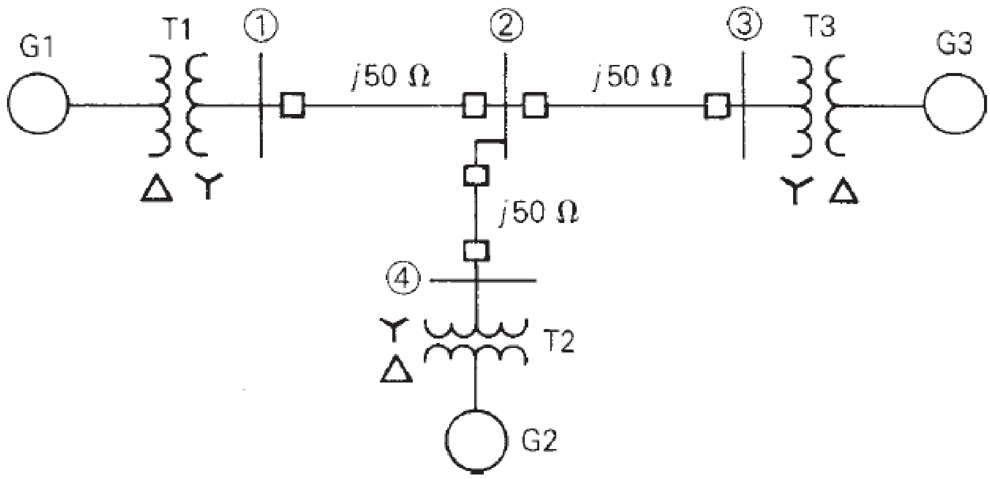


Q2/ The one-line diagram of a simple power system is shown in Figure. Each generator is represented by an emf behind the transient reactance. All impedances are expressed in per unit on a common MVA base. All resistances and shunt capacitances are neglected. The generators are operating on no load at their rated voltage with their emfs in phase. A three-phase fault occurs at bus 1 through a fault impedance of $Z_f = j0{:}08$ per unit.
(a) Using Thevenin's theorem obtain the impedance to the point of fault and the fault current in per unit.
(b) Determine the bus voltages and line currents during fault.

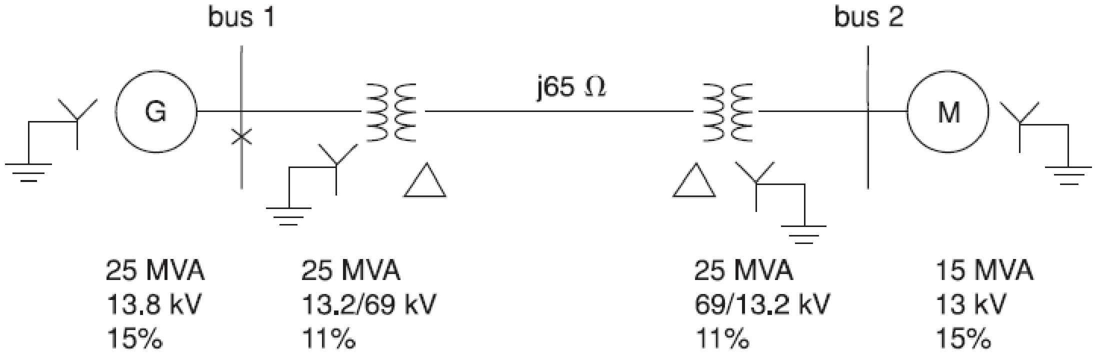


Q3/ Equipment ratings for the four-bus power system shown in Figure are as follows:
Generator G1: 500 MVA, 13.8 kV, X"= 0:20 per unit
Generator G2: 750 MVA, 18 kV, X"= 0.18 per unit
Generator G3: 1000 MVA, 20 kV, X"=0.17 per unit
Transformer T1: 500 MVA, 13.8 Δ/500Y kV, X =0.12 per unit
Transformer T2: 750 MVA, 18 Δ/500Y kV, X =0.10 per unit
Transformer T3: 1000 MVA, 20 Δ/500Y kV, X =0.10 per unit
Each 500-kV line: X1 =50 Ω

A three-phase short circuit occurs at bus 1, where the pre fault voltage is 525 kV. Pre fault load current is neglected. Draw the positive-sequence reactance diagram in per-unit on a 1000-MVA, 20-kV base in the zone of generator G3. Determine (a) the Thevenin reactance in per-unit at the fault, (b) the sub transient fault current in per unit and in kA rms, and (c) contributions to the fault current from generator G1 and from line 1–2.



Q4/A three-phase short circuit occurs at the generator bus (bus 1) for the system shown in Figure. Neglecting pre fault currents and assuming that the generator is operating at its rated voltage, determine the subtransient fault current using superposition.


bus 1
bus 2
G
M
j65 Ω
25 MVA
13.8 kV
15%
25 MVA
13.2/69 kV
11%
25 MVA
69/13.2 kV
11%
15 MVA
13 kV
15%