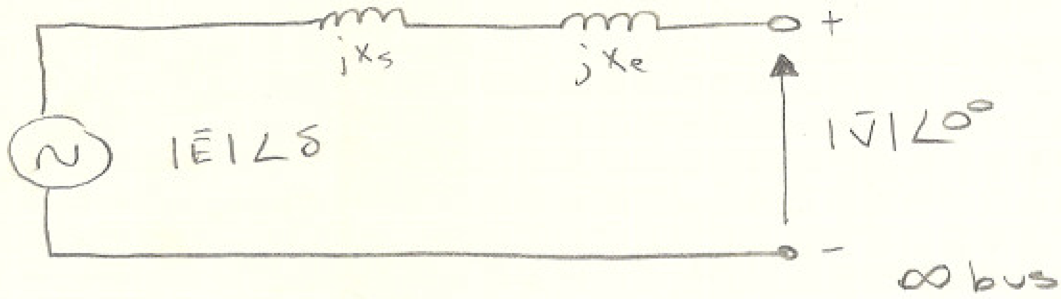


Synch Generator connected to ∞ bus.

$$X_t = X_s + X_e = X$$

From our set of equations, we have

$$P = \frac{|\bar{E}||\bar{V}|}{X}\sin\delta$$

where

$$P_{max} = \frac{|\bar{E}||\bar{V}|}{X}$$

$$Q_2 = \frac{|\bar{E}||\bar{V}|\cos\delta - |\bar{V}|^2}{X}$$

If $|\bar{E}|\cos\delta > |\bar{V}|$, then $Q_2 > 0$

In this case, the generator appears to the network as a capacitor. This condition applies for high magnitude $|\bar{E}|$, and the m/c is said to be over excited.

If $Q_2 < 0$, m/c is underexcited, it consumes reactive power.

Faults

Faults occur when two or more conductors come into contact with each other. The contact may be physical or it may be an arc. In physical contacts, the voltage drops to zero. In arc contacts the voltage through the contact will be very small

Faults are classified as:

1. Balanced 3ϕ faults
2. Single line to ground. (SLG)
3. Line to Line (double line)(DL)
4. Double line to ground (DLG)

we should start with 3ϕ balanced faults.

BALANCED 3ϕ FAULTS (using Z bus approach)

This is a generalised Thevenin's approach which is suited for computer processing. This method requires the evaluation of Z_{bus} of the system, once this is found, the procedure is straight forward.

Consider a system with an addmitance matrix (Y_{bus}) where Y_{bus} includes source admitances and equivalent load admitances (treated as constants) although not strictly true.

System equations in compaq form

$$\overline{\underline{I}}_{bus} = \overline{\underline{Y}}_{bus} \overline{\underline{V}}_{bus}.$$

or..

$$\overline{\underline{V}}_{bus} = \overline{\underline{Z}}_{bus} \overline{\underline{I}}_{bus}.$$

and

$$\overline{\underline{Z}}_{bus} = \left[\overline{\underline{Y}}_{bus} \right]^{-1}$$

Expanding

$$|\underline{V}|_{bus} = |\underline{\underline{Z}}|_{bus}\, \underline{I}_{bus}$$

$$\begin{bmatrix} V_1 \\ \vdots \\ V_n \end{bmatrix} = \begin{bmatrix} Z_{11} & \cdots & Z_{1n} \\ \vdots & & \vdots \\ Z_{n1} & \cdots & Z_{nn} \end{bmatrix} \begin{bmatrix} I_1 \\ \vdots \\ I_n \end{bmatrix}$$

If a 3ϕ balanced fault occurs on bus X (say) there will be voltages and currents in the system due to the fault. The effect of the fault can be examined by injecting a current I_f (f for fault) into the faulted bus, with all other current injections made equal to zero (ie sources removed).

In the $\underline{Z}$bus approach, we have the following:-

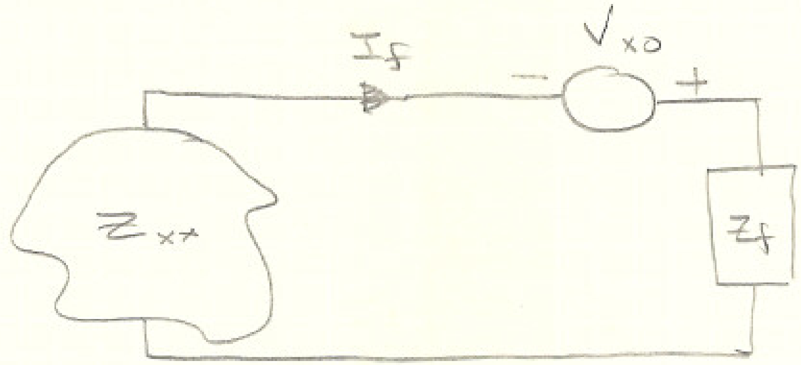
$$\begin{bmatrix} V_{1f} \\ \vdots \\ V_{xf} \\ \vdots \\ V_{nf} \end{bmatrix} = \begin{bmatrix} Z_{11} & \cdots & Z_{1x} & \cdots & Z_{1n} \\ \vdots & & \vdots & & \vdots \\ Z_{x1} & \cdots & Z_{xx} & \cdots & Z_{xn} \\ \vdots & & \vdots & & \vdots \\ Z_{n1} & \cdots & \cdots & \cdots & Z_{nn} \end{bmatrix} \begin{bmatrix} 0 \\ \vdots \\ I_f \\ \vdots \\ 0 \end{bmatrix}$$

At the faulted bus, using Thevenin's Theorem, the voltages $-V_{xo}$ and Z_{xx} is the driving point impedance at bus X, therefore

$$I_f = \frac{-V_{xo}}{Z_{xx}}$$

Negative sign is based on the sign convention that bus currents are considered positive when injected into the bus

If the fault has an impedance Z_f to ground then.



hence

$$\bar{I}_f = \frac{-V_{x0}}{Z_{xx} + Z_f}.$$

from last matrix we have

$$\bar{V}_{1f} = \bar{Z}_{1x}\,\bar{I}_f = \frac{-Z_{1x}V_{x0}}{Z_{xx} + Z_f}$$

$$\bar{V}_{21f} = \bar{Z}_{2x}\,\bar{I}_f = \frac{-Z_{2x}V_{x0}}{Z_{xx} + Z_f}$$

$$V_{nf} = \bar{Z}_{nx}\,\bar{I}_f = \frac{-Z_{nx}V_{x0}}{Z_{xx} + Z_f}$$

therefore bus voltages at each bus due to the fault at X are found using the bus voltages, the branch currents can also be found as given below

For Branch P-q we have

$$I_{pqf} = \frac{V_{pf} - V_{qf}}{Z_{pq}}$$

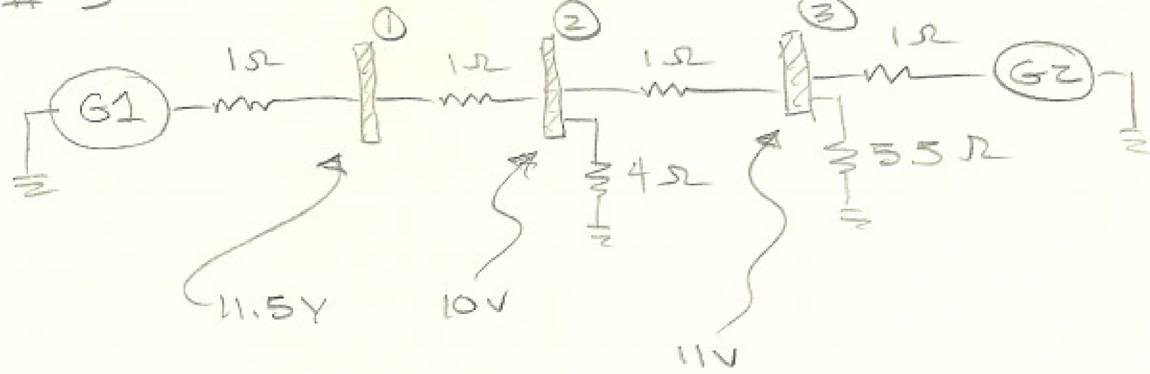
The total quantities are then evaluated from

$$V_p = V_{p0} + V_{pf}$$

$$I_{pq} = I_{pq0} + I_{pqf}$$

"0" indicates prefault condition

EX: Use the Z_{bus} method to solve the system below for a 3ϕ fault on bus #3



there is a 3ϕ fault on bus 3.