5-4-1 Short-circuit Capacity (SCC) or Short-circuit MVA:

SCC at a bus is a common measured of the strength of a bus. The SCC at bus *K* is defined as the product of the magnitudes of the rated bus voltage and the fault current $I(F)$. The short circuit MVA is used for determining the dimension of a bus bar, and the interrupting capacity of a circuit breaker.

The SCC or the short-circuit MVA at bus *K* is given by:

$$SCC = \sqrt{3}\, V_{LK}\ I_K(F) \times 10^{-3} \quad \text{MVA} \qquad \text{............ (1)}$$

Where V_{LK} - Line to line voltage in KV

$I_K(F)$ - Fault current at node *K* in amperes.

For 3-phase fault:

$$I_K(F)_{pu} = \frac{V_K(0)}{X_{KK}} \qquad \text{.............................. (2)}$$

Where $V_K(0)$ - pre-fault bus voltage in pu.

X_{KK} - The per unit reactance to the point of fault.

(where system resistance is neglected)

System resistance is neglected and only the inductive reactance of the system is allowed for. This gives minimum impedance and maximum fault current and pessimistic answer.

The base current is:

$$I_B = \frac{S_B \times 10^3}{\sqrt{3}\, V_B} \qquad \text{.................................... (3)}$$

Where S_B - base MVA

V_B - line-to-line base voltage in KV

$$I_K(F)\ in\ amp. = I_K(F)_{pu} \times I_B$$

$$= \frac{V_K(0)}{X_{KK}} \; \frac{S_B \times 10^3}{\sqrt{3}\, V_B} \qquad \text{..................} \; (4)$$

Substituting eq.(4) in eq(1)

$$SCC = \frac{V_K(0)\, S_B}{X_{KK}} \; \frac{V_L}{V_B} \qquad \text{............................} \; (5)$$

If the base voltage is equal to the rated voltage ($V_L = V_B$)

$$\therefore \quad SCC = \frac{V_K(0)\, S_B}{X_{KK}} \qquad . \quad \text{.........................} \; (6)$$

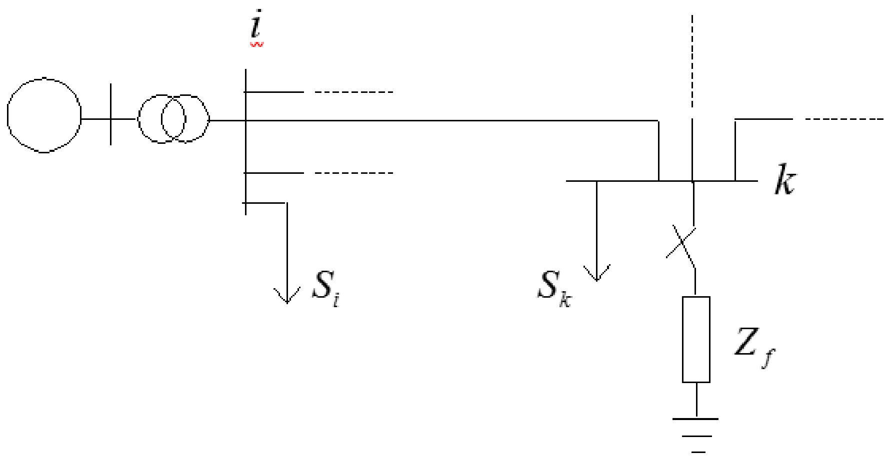
The prefault bus voltage $V_K(0)$ is usually assumed to 1.0 pu

$$\therefore \quad SCC \; (\text{short} - \text{circuit MVA}) = \frac{S_B}{X_{KK}} \quad \text{MVA} \quad .... \; (7)$$

5-5 Systematic Fault Analysis Using Z_{bus} :

For fault circuit analysis in large networks, nodal method is used. By utilizing the elements of Z_{bus} **,** the fault current and the bus voltages during fault are readily and easily calculated.

In the fig. shown below, the generator is represented by a constant voltage source behind proper reactances which may be $X''_d, X'_d, \text{or}\, X_d$. Transmission lines are represented by their equivalent π model and all impedances are in per unit on a common MVA base. A balance 3-phase fault is to be applied at bus *K* through a fault impedance Z_f .



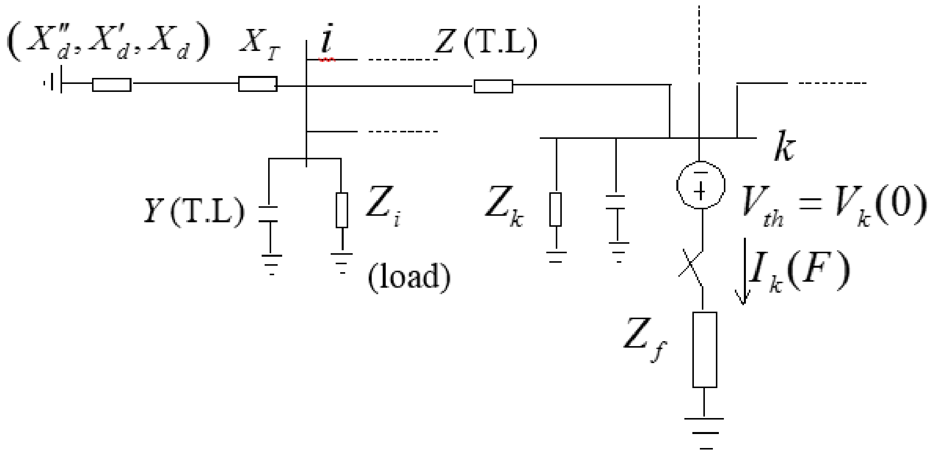
The pre fault bus voltages are obtained from the power flow solution and are represented by the column vector.

$$V_{bus}(0) = \begin{bmatrix} V_1(0) \\ \vdots \\ V_k(0) \\ \vdots \\ V_n(0) \end{bmatrix} \quad \text{.......................................(8)}$$

The bus load by a constant impedance evaluated at the pre fault bus voltage, i.e.:

$$Z_{iL} = \frac{|V_i(0)|^2}{S_L^*} \quad \text{..................................(9)}$$

Thevenin's circuit shown in fig. below.



The bus voltage changes caused by the fault in this circuit are represented by the column vector :

$$\Delta V_{bus} = \begin{bmatrix} \Delta V_1 \\ \vdots \\ \Delta V_k \\ \vdots \\ \Delta V_n \end{bmatrix} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(10)$$

By applying Thevenin's theorem, bus voltages during the fault are obtained by superposition of the pre fault bus voltages and the changes in the bus voltages i.e.:

$$V_{bus}(F) = V_{bus}(0) + \Delta V_{bus} \quad \ldots\ldots\ldots\ldots\ldots\ldots(11)$$

The node-voltage equation for an *n*-bus network:

$$I_{bus} = Y_{bus}\, V_{bus} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(12)$$

Where I_{bus} is the injected bus currents.

Y_{bus} is the bus admittance matrix.

Also , we know :

$$Y_{ii} = \sum_{j=0}^{m} y_{ij} \quad j \neq i \text{ , and } Y_{ij} = Y_{ji} = -y_{ij} \;\ldots\ldots\; (13)$$

In the Thevenin's circuit of fig. above, current entering every bus is zero except at the faulted bus. Since the current at faulted bus is leaving the bus, it is taken as a negative current entering bus *k*.

Thus the nodal equation applied to the Thevenin's circuit in fig. above becomes:

$$\begin{bmatrix} 0 \\ \vdots \\ -I_k(F) \\ \vdots \\ 0 \end{bmatrix} = \begin{bmatrix} y_{11} \ldots\ldots y_{1k} \ldots\ldots y_{1n} \\ \vdots \quad \vdots \quad \vdots \quad \vdots \quad \vdots \\ y_{k1} \ldots\ldots y_{kk} \ldots\ldots y_{kn} \\ \vdots \quad \vdots \quad \vdots \quad \vdots \quad \vdots \\ y_{n1} \ldots\ldots y_{nk} \ldots\ldots y_{nn} \end{bmatrix} \begin{bmatrix} \Delta V_1 \\ \vdots \\ \Delta V_k \\ \vdots \\ \Delta V_n \end{bmatrix} \quad \ldots\ldots\ldots\ldots (14)$$

or $\quad I_{bus}(F) = Y_{bus}\ \Delta V_{bus}$

or $\quad \Delta V_{bus} = Z_{bus}\ I_{bus}(F)$

where $\quad Z_{bus} = Y_{bus}^{-1}$ is known as the bus impedance matrix

The bus voltage vector during the fault becomes:

$$V_{bus}(F) = V_{bus}(0) + Z_{bus}\ I_{bus}(F)$$

The above matrix equation, can be writing in terms of its elements as shown:

$$\begin{bmatrix} V_1(F) \\ \vdots \\ V_k(F) \\ \vdots \\ V_n(F) \end{bmatrix} = \begin{bmatrix} V_1(0) \\ \vdots \\ V_k(0) \\ \vdots \\ V_n(0) \end{bmatrix} + \begin{bmatrix} Z_{11} \ldots\ldots Z_{1k} \ldots\ldots Z_{1n} \\ \vdots \quad \vdots \quad \vdots \quad \vdots \quad \vdots \\ Z_{k1} \ldots\ldots Z_{kk} \ldots\ldots Z_{kn} \\ \vdots \quad \vdots \quad \vdots \quad \vdots \quad \vdots \\ Z_{n1} \ldots\ldots Z_{nk} \ldots\ldots Z_{nn} \end{bmatrix} \begin{bmatrix} 0 \\ \vdots \\ -I_k(F) \\ \vdots \\ 0 \end{bmatrix} \quad \ldots\ldots\ldots (15)$$

Since we have only one single nonzero element in the current vector , the *k*th equation in eq. 15 becomes :

$$V_k(F) = V_k(0) + Z_{kk}\ I_k(F) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (16)$$

From the Thevenin's circuit shown in fig. above:

$$V_k(F) = Z_f \; I_k(F) \qquad \text{.............................. (17)}$$

From eq. (16) and eq. (17) , the fault current becomes :

$$I_k(F) = \frac{V_k(0)}{Z_{kk} + Z_f} \qquad \text{................................ (18)}$$

[For bolted fault , $Z_f = 0$ and $V_k(F) = 0$] , therefore the fault current is :

$$I_k(F) = \frac{V_k(0)}{Z_{kk}}$$

Thus, for a fault at bus k we need only the Z_{kk} element of the bus impedance matrix. This element is indeed the Thevenin's impedance as viewed from the faulted bus.

For *i* th equation in eq. (15):

$$V_i(F) = V_i(0) + Z_{ik} \; I_k(F) \qquad \text{.............................. (19)}$$

$$V_i(F) = V_i(0) - \frac{Z_{ik}}{Z_{kk} + Z_f} V_k(0) \qquad \text{..................... (20)}$$

Where $V_i(F)$ is bus voltage during the fault at bus *i*

The fault current in all the lines:

$$I_{ij}(F) = \frac{V_i(F) - V_j(F)}{z_{ij}} \qquad \text{................................. (21)}$$