Formula Sheet – EEL4413

Per-Unit Basic Equations:

$$I_{base} = \frac{MVA_{base}}{\sqrt{3}\,V_{base}} \qquad Z_{base} = \frac{kV^2_{base}}{MVA_{base}}$$

Conversions from one Base to another:

$$Z_{pu} = Z_{puGi} \quad \frac{MVA_{3\emptyset baseN}}{MVA_{3\emptyset baseGiven}} \frac{kV^2_{LLbaseGevi}}{kV^2_{LLbaseNe}}$$

Symmetrical components:

a- Conversion from symmetrical component values to phase values:

$$\underset{Ph}{\begin{bmatrix} a \\ b \\ c \end{bmatrix}} = \underset{[\Lambda]}{\begin{bmatrix} 1 & 1 & 1 \\ 1 & \alpha^2 & \alpha \\ 1 & \alpha & \alpha^2 \end{bmatrix}} \underset{Sy}{\begin{bmatrix} a_0 \\ a_1 \\ a_2 \end{bmatrix}}$$

b- Conversion from phase values to symmetrical components values:

$$\underset{Sy}{\begin{bmatrix} A_0 \\ A_1 \\ A_2 \end{bmatrix}} = \frac{1}{3} \underset{[\Lambda]}{\begin{bmatrix} 1 & 1 & 1 \\ 1 & \alpha & \alpha^2 \\ 1 & \alpha^2 & \alpha \end{bmatrix}} \underset{Ph}{\begin{bmatrix} A \\ B \\ C \end{bmatrix}}$$

c- Basic Voltage – Current network equations in sequence components:

$$\begin{bmatrix} V_{a0} \\ V_{a1} \\ V_{a2} \end{bmatrix} = \begin{bmatrix} 0 \\ E_f \\ 0 \end{bmatrix} - \begin{bmatrix} Z_0 & 0 & 0 \\ 0 & Z_1 & 0 \\ 0 & 0 & Z_2 \end{bmatrix} \begin{bmatrix} I_{a0} \\ I_{a1} \\ I_{a2} \end{bmatrix}$$

Power System Stability Analysis:

The kinetic energy of the rotor of a synchronous machine is given by:

$$KE = \frac{1}{2} J\omega^2_{sm} \times 10^{-6} \text{ MJ}$$

The inertia constant is:

$$M(pu) = \frac{H}{\pi f} \text{ s}^2\text{/elect rad}$$

The basic swing equation of the rotor of a synchronous machine is:

$$J \frac{d^2\theta_m}{dt^2} = T_m - T_e \text{ Nm}$$

The swing equation in terms of machine inertia constant is:

$$\frac{H}{\pi f}\frac{d^2\delta}{dt^2} = P_m - P_e \text{ pu}$$

Equal area criteria:

The critical clearing angle and critical clearing time of a three-phase fault:

No line disconnection:

$$\cos\delta_c = \frac{P_m}{P_{max}}(\delta_{max} - \delta_0) + \cos\delta_{max} \qquad t_c = \sqrt{\frac{2H(\delta_c - \delta_0)}{\pi f_0 P_m}}$$

With line disconnection:

$$\cos\delta_c = \frac{P_m(\delta_{max} - \delta_0) + P_{3\,max}\cos\delta_{max} - P_{2\,max}\cos\delta_0}{P_{3\,max} - P_{2\,max}}$$

The Basic Load Flow Equations:

Gauss-Seidel:

$$V_i^{[k+1]} = \frac{\dfrac{P_i^{[sch]} - jQ_i^{[sch]}}{V_i^{*[k]}} + \sum_{j=1}^{n} y_{ij} V_j^{[k]}}{\sum_{j=0}^{n} y_{ij}} \qquad j \neq i$$

$$P_i^{[k+1]} = \Re\left\{V_i^{*[k]}\left[V_i^{[k]}\sum_{j=0}^{n} y_{ij} - \sum_{j=1}^{n} y_{ij} V_j^{[k]}\right]\right\} \qquad j \neq i$$

$$Q_i^{[k+1]} = -\Im\left\{V_i^{*[k]}\left[V_i^{[k]}\sum_{j=0}^{n} y_{ij} - \sum_{j=1}^{n} y_{ij} V_j^{[k]}\right]\right\} \qquad j \neq i$$

Newton – Raphson:

$$P_i^{[k]} = \sum_{j=1}^{n} \left|V_i^{[k]}\right|\left|V_j^{[k]}\right|\left|Y_{ij}\right|\cos\left(\theta_{ij} - \delta_i^{[k]} + \delta_j^{[k]}\right)$$

$$Q_i^{[k]} = -\sum_{j=1}^{n} \left|V_i^{[k]}\right|\left|V_j^{[k]}\right|\left|Y_{ij}\right|\sin\left(\theta_{ij} - \delta_i^{[k]} + \delta_j^{[k]}\right)$$