

































**Appendix III**

$$E \frac{d}{dt} x = Fx + u$$

$$E = \frac{1}{\omega_b} \begin{bmatrix} -X_{ss} & 0 & X_m & 0 & 0 \\ 0 & -X_{ss} & 0 & X_m & 0 \\ -X_m & 0 & X_{rr} & 0 & 0 \\ 0 & -X_m & 0 & X_{rr} & 0 \\ 0 & 0 & 0 & 0 & 2H\omega_b \end{bmatrix}$$

$$F = \begin{bmatrix} -R & \omega^* X_s & 0 & -\omega^* X_m & 0 \\ -\omega^* X_s & -R & \omega^* X_m & 0 & 0 \\ 0 & s^* \omega^* X_m & R & -s^* \omega^* X_r & \frac{X_{cr} i_{q\theta}^* - X_m i_{q\theta}^*}{\omega} \\ -s^* \omega^* X_m & 0 & s^* \omega^* X_r & R & \frac{X_m i_{d\theta}^* - X_{cr} i_{d\theta}^*}{\omega} \\ -X_m i_{q\theta}^* & X_m i_{d\theta}^* & X_m i_{q\theta}^* & -X_m i_{d\theta}^* & 0 \end{bmatrix}$$

$$\dot{x} = Ax + Bu$$

$$y = Cx + Du$$

System matrix A,  $A = (E)^{-1}F$

Control matrix B,  $B = (E)^{-1}u$

Output matrix C,  $C = \begin{bmatrix} 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 \end{bmatrix}$

Feed forward matrix D,  $D = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$

**Appendix IV**

The elements of system matrix are as follows:

$$A_{11} = \frac{\omega_b}{X_{rr}X_{ss} - X_m^2} \{-R_s X_{rr} - R_e X_{rr}\}$$

$$A_{12} = \frac{\omega_b}{X_{rr}X_{ss} - X_m^2} \{(-X_{rr}X_{ss} + sOX_m^2)\omega_s - X_T X_{rr}\}$$

$$A_{13} = \frac{\omega_b}{X_{rr}X_{ss} - X_m^2} \{-R_r X_m\}$$

$$A_{14} = \frac{\omega_b}{X_{rr}X_{ss} - X_m^2} \{(X_m X_{rr} - sOX_m X_{rr})\omega_s\}$$

$$A_{15} = \frac{\omega_b}{X_{rr}X_{ss} - X_m^2} \{(-X_m ids0 + X_{rr}idr0)X_m\}$$

$$A_{21} = \frac{\omega_b}{X_{rr}X_{ss} - X_m^2} \{(X_{rr}X_{ss} - sOX_m^2)\omega_s + X_T X_{rr}\}$$

$$A_{22} = \frac{\omega_b}{X_{rr}X_{ss} - X_m^2} \{-R_s X_{rr} - R_e X_{rr}\}$$

$$A_{23} = \frac{\omega_b}{X_{rr}X_{ss} - X_m^2} \{(-X_m X_{rr} + sOX_m X_{rr})\omega_s\}$$

$$A_{24} = \frac{\omega_b}{X_{rr}X_{ss} - X_m^2} \{-R_r X_m\}$$

$$A_{25} = \frac{\omega_b}{X_{rr}X_{ss} - X_m^2} \{(X_m iqs0 - X_{rr}iqr0)X_m\}$$

$$A_{31} = \frac{\omega_b}{X_{rr}X_{ss} - X_m^2} \{-R_s X_m - R_e X_m\}$$

$$A_{32} = \frac{\omega_b}{X_{rr}X_{ss} - X_m^2} \{(-X_m X_{ss} + sOX_m X_{ss})\omega_s - X_T X_m\}$$

$$A_{33} = \frac{\omega_b}{X_{rr}X_{ss} - X_m^2} \{-R_r X_{ss}\}$$

$$A_{34} = \frac{\omega_b}{X_{rr}X_{ss} - X_m^2} \{(X_m^2 - sOX_{ss} X_{rr})\omega_s\}$$

$$A_{35} = \frac{\omega_b}{X_{rr}X_{ss} - X_m^2} \{(-X_m ids0 + X_{rr}idr0)X_{ss}\}$$

$$A_{41} = \frac{\omega_b}{X_{rr}X_{ss} - X_m^2} \{(X_m X_{ss} - sOX_m X_{ss})\omega_s + X_T X_m\}$$

$$A_{42} = \frac{\omega_b}{X_{rr}X_{ss} - X_m^2} \{-R_s X_m - R_e X_m\}$$

$$A_{43} = \frac{\omega_b}{X_{rr}X_{ss} - X_m^2} \{(-X_m^2 + sOX_{ss} X_{rr})\omega_s\}$$

$$A_{44} = \frac{\omega_b}{X_{rr}X_{ss} - X_m^2} \{-R_r X_{ss}\}$$

$$A_{45} = \frac{\omega_b}{X_{rr}X_{ss} - X_m^2} \{(X_m iqs0 - X_{rr}iqr0)X_{ss} - X_m idr0\}$$

$$A_{51} = \frac{2H}{X_m iqr0}$$

$$A_{52} = \frac{2H}{X_m ids0}$$

$$A_{53} = \frac{2H}{-X_m iqs0}$$

$$A_{54} = \frac{2H}{2H}$$

$$A_{55} = 0$$