1 Synchronous Machine Model

$$u_f = v_f + \Delta v_f = v_f + L_l \frac{d}{dt} i_f \tag{1}$$

$$\frac{d}{dt}\psi_d^r = u_d^r - L_l \frac{d}{dt} i_d^r + \omega_m L_l i_q^r - R_s i_d^r + \omega_m \psi_q^r \tag{2}$$

$$\frac{d}{dt}\psi_q^r = u_q^r - L_l \frac{d}{dt} i_q^r - \omega_m L_l i_d^r - R_s i_q^r + \omega_m \psi_d^r \tag{3}$$

$$\frac{d}{dt}\psi_q^r = u_q^r - L_l \frac{d}{dt} i_q^r - \omega_m L_l i_d^r - R_s i_q^r + \omega_m \psi_d^r \tag{4}$$

$$\begin{bmatrix} \psi_d \\ \psi_F \\ \psi_D \end{bmatrix} = \begin{bmatrix} L_d + L_l & M_F & M_D \\ M_F & L_F^{'} & M_{FD} \\ M_D & M_{FD} & L_D^{'} \end{bmatrix} \begin{bmatrix} i_d^r \\ i_F \\ i_D \end{bmatrix} \tag{5}$$

$$\begin{bmatrix} \psi_q \\ \psi_Q \end{bmatrix} = \begin{bmatrix} L_q + L_l & M_Q \\ M_Q & L_Q^{'} \end{bmatrix} \begin{bmatrix} i_q^r \\ i_Q \end{bmatrix} \tag{6}$$