Synchronous Machine Parameters

Flux and Current Equations on the d axis (From Model - with $k_d = \sqrt{\frac{2}{3}}$)

$$\psi_d = L_d i_d + M_{df} i_f + M_{dh} i_h$$

$$\psi_f = M_{df} i_d + L_{ff} i_f + L_{fh} i_h$$

$$\psi_h = M_{dh} i_d + L_{fh} i_f + L_{hh} i_h$$

$$\frac{d\psi_f}{dt} + R_f i_f = v_f$$

$$\frac{d\psi_h}{dt} + R_h i_h = 0$$

Laplace Transform of Flux and Current Equations on the d axis

$$\Psi_d(s) = L_d I_d(s) + M_{df} I_f(s) + M_{dh} I_h(s)$$

$$\Psi_f(s) = M_{df} I_d(s) + L_{ff} I_f(s) + L_{fh} I_h(s)$$

$$\Psi_h(s) = M_{dh} I_d(s) + L_{fh} I_f(s) + L_{hh} I_h(s)$$

$$\Psi_f(s) + R_f I_f(s) = V_f(s)$$

$$\Psi_h(s) + R_h I_h(s) = 0$$

d - axis Flux-Current Transfer Function

Eliminating $\Psi_f(s), \Psi_h(s), I_f(s), I_h(s)$**,**

$$\Psi_d(s) = L_d(s) I_d(s) + G'(s) V_f(s)$$

$$L_d(s) = L_d \frac{(1 + B_N s + A_N s^2)}{(1 + B_D s + A_D s^2)}$$

$$G'(s) = \frac{M_{df}}{R_f} \frac{(1 + A_G s)}{(1 + A_D s + B_D s^2)}$$

$$B_N = \frac{L_{ff}}{R_f} + \frac{L_{hh}}{R_h} - \frac{M_{dh}^2}{L_d R_h} - \frac{M_{df}^2}{L_d R_f}$$

$$A_N = \frac{L_{ff} L_{hh}}{R_f R_h} - \frac{L_{fh}^2}{R_f R_h} - \frac{M_{df}^2 L_{hh}}{L_d R_f R_h} - \frac{M_{dh}^2 L_{ff}}{L_d R_f R_h} + 2\frac{M_{dh} M_{df} L_{fh}}{L_d R_f R_h}$$

$$B_D = \frac{L_{ff}}{R_f} + \frac{L_{hh}}{R_h}, \quad A_D = \frac{L_{ff} L_{hh}}{R_f R_h} - \frac{L_{fh}^2}{R_f R_h}$$

$$A_G = \frac{L_{hh}}{R_h} - \frac{M_{dh} L_{fh}}{M_{df} R_h}$$

Equating with Transfer Function Obtained from Measurement, with $v_f = 0$

$$\frac{\Psi_d(s)}{I_d(s)} = L_d \frac{(1 + sT'_d)(1 + sT''_d)}{(1 + sT'_{do})(1 + sT''_{do})}$$

Gives us L_d and the following relationships:

$$T'_d + T''_d = B_N$$

$$T'_d T''_d = A_N$$

$$T'_{do} + T''_{do} = B_D$$

$$T'_{do} T''_{do} = A_D$$

Equating with Transfer Function Obtained from Measurement, with $I_d = 0$

$$\frac{\Psi_d(s)}{V_f(s)} = \frac{M_{df}}{R_f} \frac{(1 + sT''_{dc})}{(1 + sT'_{do})(1 + sT''_{do})}$$

Gives us $\frac{M_{df}}{R_f}$ and the following relationship:

$$T''_{dc} = A_G$$

Model Parameters on d-axis(Eight):

$$L_d, M_{df}, M_{dh}, L_{ff}, L_{fh}, L_{hh}, R_f, R_h$$

Parameters from **One** Measurement (Five):

$$L_d, T'_d, T''_d, T'_{do}, T''_{do}$$

Note: One cannot get a unique solution for the model parameters with just one transfer function measurement.
Stator resistance also required; can be obtained from a separate measurement.

Flux and Current Equations on the q axis (From Model - with $k_q = \sqrt{\frac{2}{3}}$)

$$\psi_q = L_q i_q + M_{qg} i_g + M_{qk} i_k$$

$$\psi_g = M_{qg} i_q + L_{gg} i_g + L_{gk} i_k$$

$$\psi_k = M_{qk} i_q + L_{gk} i_g + L_{kk} i_k$$

$$\frac{d\psi_g}{dt} + R_g i_g = v_g$$

$$\frac{d\psi_k}{dt} + R_k i_k = 0$$

Laplace Transform of Flux and Current Equations on the q axis

$$\Psi_q(s) = L_q I_q(s) + M_{qg} I_g(s) + M_{qk} I_k(s)$$

$$\Psi_g(s) = M_{qg} I_q(s) + L_{gg} I_g(s) + L_{gk} I_k(s)$$

$$\Psi_k(s) = M_{qk} I_q(s) + L_{gk} I_g(s) + L_{kk} I_k(s)$$

$$\Psi_g(s) + R_g I_g(s) = V_g(s)$$

$$\Psi_k(s) + R_k I_k(s) = 0$$

q - axis Flux-Current Transfer Function

Eliminating $\Psi_g(s), \Psi_k(s), I_g(s), I_k(s)$**,**

$$\Psi_q(s) = L_q(s) I_q(s)$$

$$L_q(s) = L_q \frac{(1 + B_{Nq} s + A_{Nq} s^2)}{(1 + B_{Dq} s + A_{Dq} s^2)}$$

$$B_{Nq} = \frac{L_{gg}}{R_g} + \frac{L_{kk}}{R_k} - \frac{M_{qk}^2}{L_q R_k} - \frac{M_{qg}^2}{L_q R_g}$$

$$A_{Nq} = \frac{L_{gg} L_{kk}}{R_g R_k} - \frac{L_{gk}^2}{R_g R_k} - \frac{M_{qg}^2 L_{kk}}{L_q R_g R_k}$$

$$- \frac{M_{qk}^2 L_{gg}}{L_q R_g R_k} + 2 \frac{M_{qk} M_{qg} L_{gk}}{L_q R_g R_k}$$

$$B_{Dq} = \frac{L_{gg}}{R_g} + \frac{L_{kk}}{R_k}$$

$$A_{Dq} = \frac{L_{gg} L_{kk}}{R_g R_k} - \frac{L_{gk}^2}{R_g R_k}$$

Equating with Transfer Function Obtained from Measurement

$$\frac{\Psi_q(s)}{I_q(s)} = L_q \frac{(1+sT_q')(1+sT_q'')}{(1+sT_{qo}')(1+sT_{qo}'')}$$

Gives us L_q and the following relationships:

$$T_q' + T_q'' = B_{Nq}$$

$$T_q' T_q'' = A_{Nq}$$

$$T_{qo}' + T_{qo}'' = B_{Dq}$$

$$T_{qo}' T_{qo}'' = A_{Dq}$$

Model Parameters on q-axis(Eight):

$$L_q, M_{qg}, M_{qk}, L_{gg}, L_{gk}, L_{kk}, R_g, R_k$$

Parameters from only **One** Measurement made on the q-axis (Five):

$$L_q, T_q', T_q'', T_{qo}', T_{qo}''$$