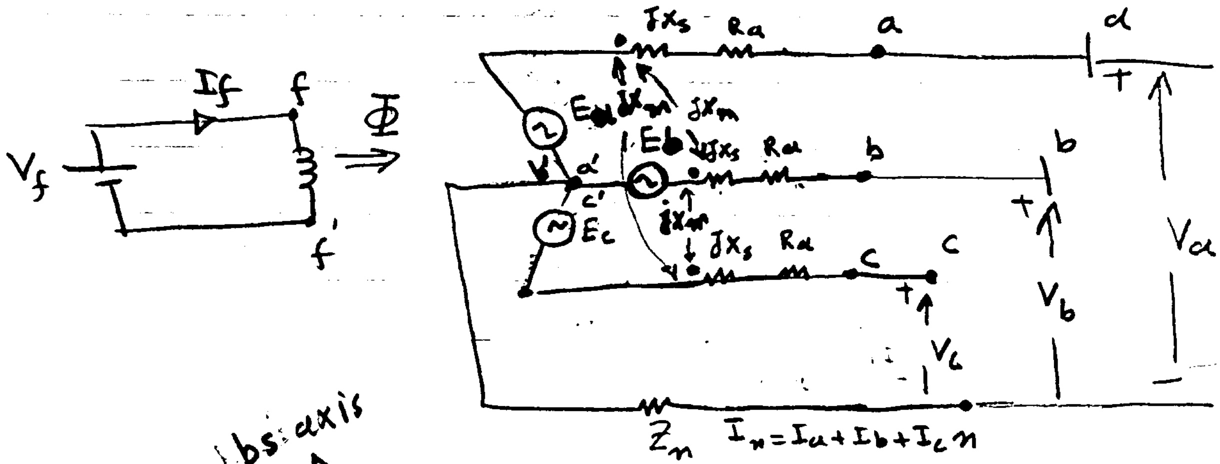
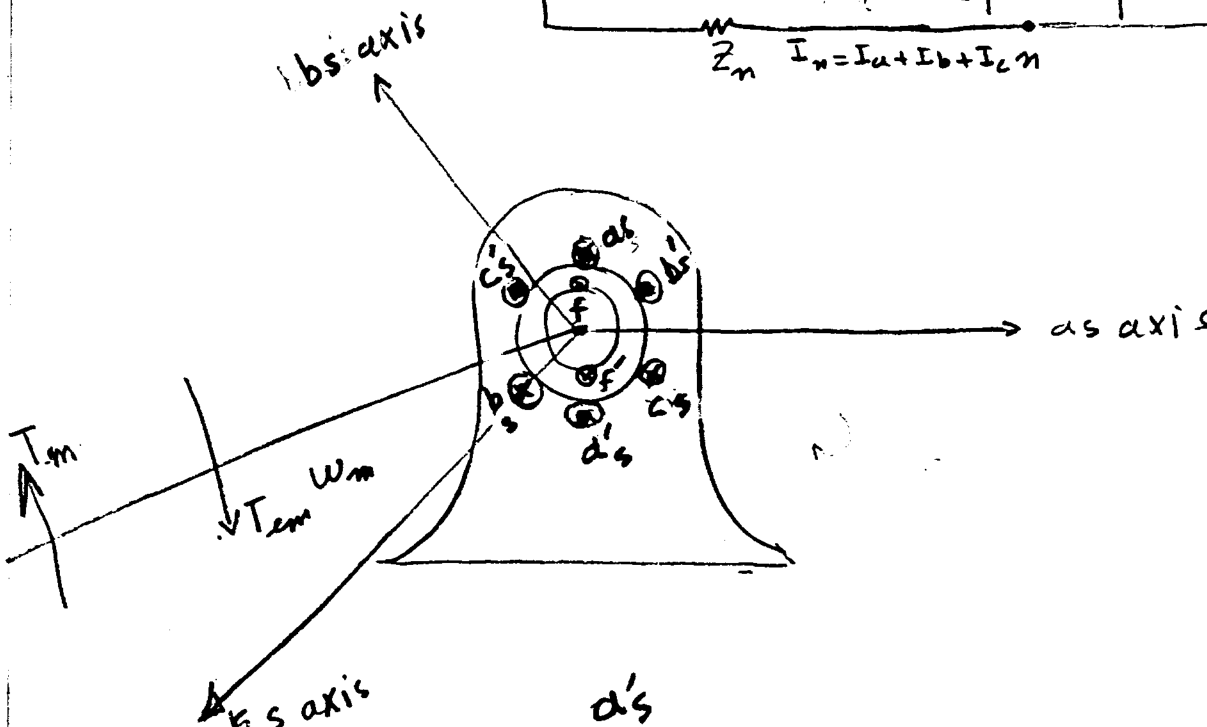
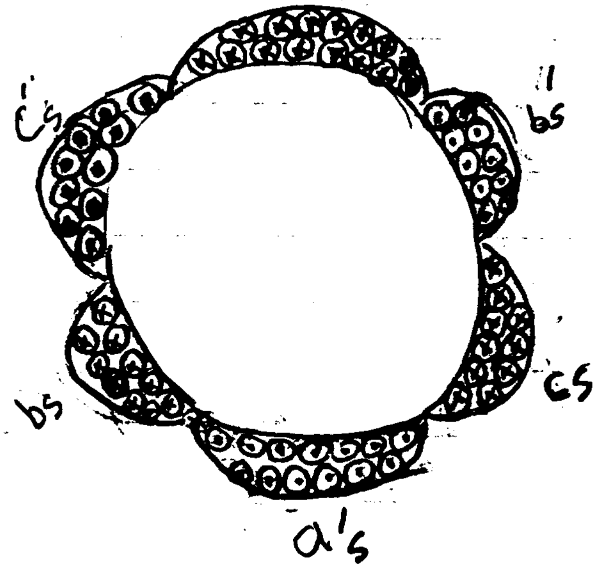
EE740
Lecture #14
Synchronous Machine Sequence Network.

Sequence Networks for Synchronous Machine







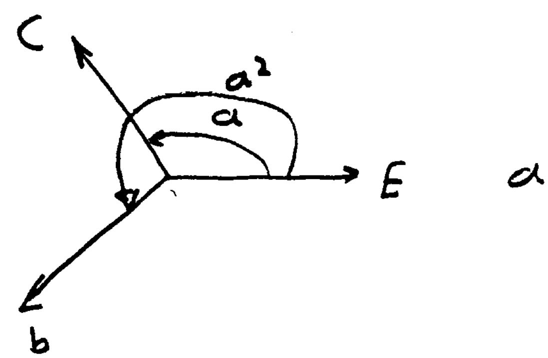
Consider the steady state operation

- ω_m constant
- constant I_f
- No saturation
- balanced 3-ϕ windings located 120° apart.

$$E_a = (R_a + jX_s + Z_n) I_a + (jX_m + Z_n) I_b + (jX_m + Z_n) I_c + V_a$$
$$E_b = (R_a + jX_s + Z_n) I_b + (jX_m + Z_n) I_a + (jX_m + Z_n) I_c + V_b \quad (1)$$
$$E_c = (R_a + jX_s + Z_n) I_c + (jX_m + Z_n) I_a + (jX_m + Z_n) I_b + V_c$$

Balanced voltage set

$$E_a = E$$
$$E_b = a^2 E \quad (2)$$
$$E_c = a E$$



Let $Z_s = R_a + jX_s + Z_n$
$$Z_m = jX_m + Z_n \quad (3)$$

Then (1) can be written as

$$\begin{bmatrix} E_a \\ E_b \\ E_c \end{bmatrix} = \begin{bmatrix} Z_s & Z_m & Z_m \\ Z_m & Z_s & Z_m \\ Z_m & Z_m & Z_s \end{bmatrix} \begin{bmatrix} I_a \\ I_b \\ I_c \end{bmatrix} + \begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix} \quad (4)$$

$$[E_{abc}] = [Z_{abc}][I_{abc}] + [V_{abc}] \qquad (5)$$

Recall

$$[E_{abc}] = [T_s][E_{012}] \qquad (6) \quad \text{or} \quad E_{012} = T_s^{-1} E_{abc}$$

$$[I_{abc}] = [T_s][I_{012}] \qquad (7)$$

multiply Eq (5) by T_s^{-1} and replace I^{abc} with Eq. 7

$$[T_s]^{-1}[E_{abc}] = [T_s]^{-1}[Z_{abc}][T_s][I_{012}] + [T_s]^{-1}[V_{abc}]$$

observe that

$$\begin{bmatrix} E_0^0 \\ E_1^+ \\ E_2^- \end{bmatrix} = \frac{1}{3}\begin{bmatrix} 1 & 1 & 1 \\ 1 & a & a^2 \\ 1 & a^2 & a \end{bmatrix}\begin{bmatrix} E \\ a^2 E \\ a E \end{bmatrix} = \frac{E}{3}\begin{bmatrix} 0 \\ 3 \\ 0 \end{bmatrix} = \begin{bmatrix} 0 \\ E \\ 0 \end{bmatrix}$$

That is, for a balanced set of voltages

$$E_0^0 = 0$$
$$E_1^+ = E \qquad (10)$$
$$E_2^- = 0$$

Recall

$$[T]^{-1}[V^{abc}_{abc}] = [V^{0+-}_{012}]$$

$$[T]^{-1}[Z^{abc}_{abc}][T] = [Z^{0+-}_{012}] = \begin{bmatrix} Z^0_0 & 0 & 0 \\ 0 & Z^+_1 & 0 \\ 0 & 0 & Z^-_2 \end{bmatrix} \quad 11$$

where $Z_0 = Z_{0gen} + 3Z_n$

$Z_{0gen} = Ra + j(X_s + 2X_m)$

$$Z^+_1 = Z_s - Z_m = Ra + j(X_s - X_m) \quad (12)$$

$$Z^-_2 = Z_s - Z_m = Ra + j(X_s - X_m)$$

Therefore Eq. 8 can be written as

$$\begin{bmatrix} 0 \\ E \\ 0 \end{bmatrix} = \begin{bmatrix} Z^0_0 & 0 & 0 \\ 0 & Z^+_1 & 0 \\ 0 & 0 & Z^-_2 \end{bmatrix} \begin{bmatrix} I^0_0 \\ I^+_1 \\ I^-_2 \end{bmatrix} + \begin{bmatrix} V^0_0 \\ V^+_1 \\ V^-_2 \end{bmatrix}$$

$$Z_0 I^0_0 + V^0 = 0$$

$$E = Z^+_1 I^+_1 + V^+_1$$

$$Z^-_2 I^-_2 + V^-_2 = 0$$