

CHAPTER 16 - SYNCHRONOUS GENERATORS

$$120F = pN$$

$$X_S = \frac{E_{oc}}{I_{sc}} \quad Z_{BASE} = \frac{E_{BASE}^2}{S_{BASE}}$$

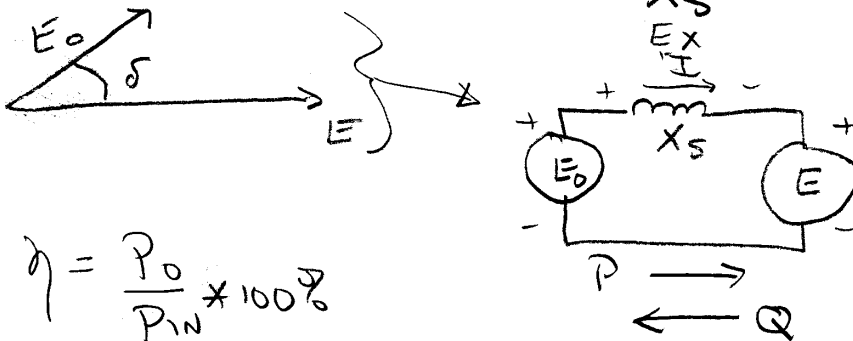
$$\% \text{ Regulation} = \frac{(E_{NL} - E_B)}{E_B} \times 100\%$$

$$\delta = \frac{p\alpha}{Z}$$

$$P = \frac{E_0 E}{X_S} \sin \delta$$

$$Q = \frac{(E_0^2 - E E_0)}{X_S} \cos \delta$$

NOTE -
 if E, E_0 Line to Neutral
 P_{is} Per Phase $P_{1\phi}$
 $P_{3\phi} = 3 P_{1\phi}$
 if E, E_0 Line to Line
 P_{is} Already 3 Phase
 value.

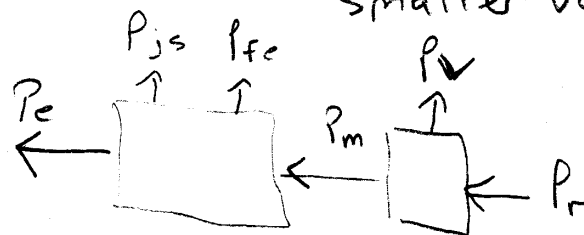


$$\vec{E}_x = \vec{I} \vec{Z}_x = \vec{E}_0 - \vec{E}$$

$$\eta = \frac{P_o}{P_{in}} \times 100\%$$

P flows from Leading voltage to Lagging voltage

Q flows from Largest voltage source magnitude to smaller voltage source magnitude



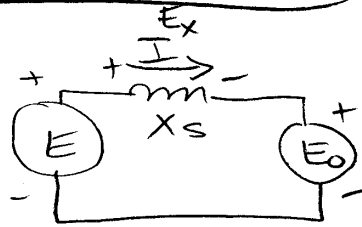
$$\eta = \frac{P_e}{P_r} \times 100\%$$

δ controlled by P_r (turbine/engine power)

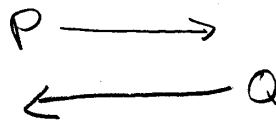
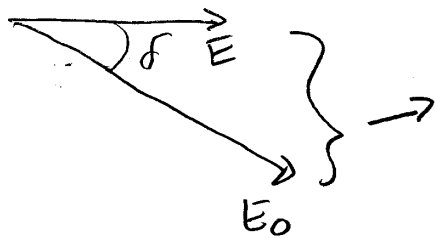
E_0 controlled by ϕ [$E_0 = \frac{Z N \phi}{60}$], ϕ controlled by field current.

Chapter 17 - SYNCHRONOUS MOTORS

$$n_s = \frac{120f}{P}$$



$$E_x = I_x Z_{x_s} = \vec{E} - \vec{E}_0$$



$$P = \frac{E_0 E}{X_s} \sin \delta$$

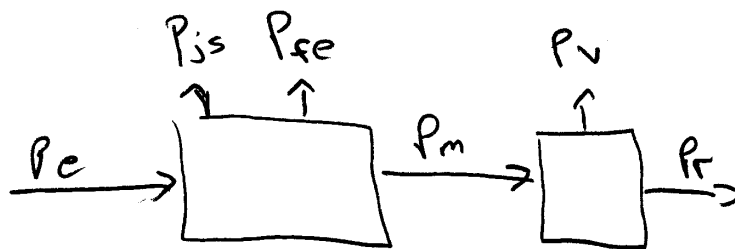
$$Q = \frac{(E_0^2 - E E_0)}{X_s} \cos \delta$$

$$9.55 P = T \cdot n_s$$

$$\delta = \frac{p\alpha}{2}$$

P flows from Leading Voltage to Lagging Voltage

Q flows From Largest Voltage Source magnitude to Smaller Voltage source magnitude.



$$\eta = \frac{P_r}{P_e} \times 100\%$$

CHAPTER 18 - Single Phase Motors

$$n_s = \frac{120f}{p}$$

$$T = K I_a I_s \sin \alpha \quad (\text{Split Phase Motor})$$

$$\eta = \frac{P_o}{P_i} \times 100\%$$

$$9.55P = T \cdot n$$

(Hysteresis Motor) $\rightarrow T = E_h / 6.28$

$$W = n E_h$$

$$\left. \begin{array}{l} E_h = \text{Energy Per Turn} \\ W = \text{Energy Per Min} \end{array} \right\}$$

$$E_k = 5.48 \times 10^{-3} J (n_s)^2$$

UNIVERSAL MOTOR \rightarrow Series DC Motor with Brushes & Commutating Section

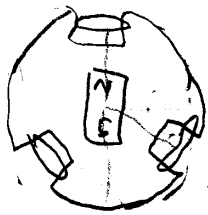
$$n = \frac{60 E}{Z \phi} \quad \text{or} \quad n \propto E \quad (\text{NOT Frequency})$$

Chapter 11 - STEPPER MOTORS

Pull out torque corresponds to slewing characteristic
Pull in torque corresponds to step without error

$$T_0 = \frac{L}{R}$$

time to final current $\approx 3T_0$



S.P.R. or

= STEPS Per REVOLUTION

$$P.P.R. = \frac{360^\circ}{\text{rev}} \frac{\text{STEP}}{\text{Degree}}$$

= Pulse Per Revolution

→ UNIPOLAR

$$\text{Degree per STEP} = \frac{(360)(2)}{P_s P_r} = \frac{(360)(2)}{(3)(2)} = 120^\circ/\text{STEP}$$

→ BIPOLAR

$$\text{Degree per STEP} = \frac{(360)}{P_s P_r} = \frac{360}{(3)(2)} = 60^\circ/\text{STEP}$$

chapter 20 - Industrial Motor Control

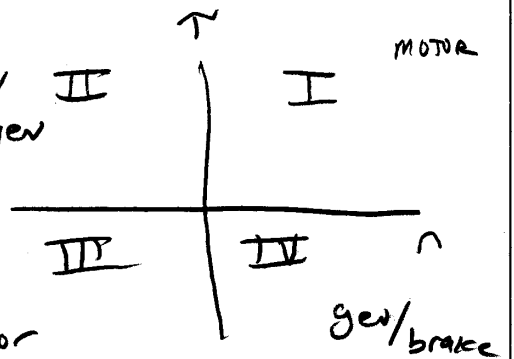
TABLE 20A (Page 452) - symbols for elements

@ Given SLIP, under Reduced Voltage START \rightarrow

$$I_2 = I_1 \left(\frac{E_2}{E_1} \right)$$

$$T_2 \approx T_1 \left(\frac{E_2}{E_1} \right)^2$$

brake/
gen



Variable frequency

SLIP (in RPM) has to be same for SAME Torque and current

for CONSTANT torque / VARIABLE freq
 $V_2 = V_B \left(\frac{f_2}{f_B} \right)$

LADDER Logic for ACROSS THE LINE START
 Reduced VOLTAGE START

Chapter 21 - Power electronics

$$E_L = L \frac{di}{dt} \rightarrow \int E \cdot dt = L di$$

$$I_{max} = \frac{A(\pm)}{L}$$

2 pulse, single phase Rectifier

$$E_d = 0.9 E \quad I_d = E_d / R \quad I_{diode}^{Avg} = \frac{I_d}{2}$$

$$E_{max} = \sqrt{2} E, E_{min} = 0, E_{pp} = \sqrt{2} E$$

$$Ripple = \frac{5.5 P_L}{f W_L}$$

$$P_L = I_d E_d$$

$$W_L = \frac{1}{2} L I^2$$

$$\beta = 180^\circ$$

$$f_p = 2 * f$$

6 pulse, Three Phase Rectifier

$$E_d = 1.35 E$$

$$E_{max} = \sqrt{2} E \quad E_{min} = 1.225 E, E_{pp} = 0.189 E$$

$$Ripple = \frac{0.17 P_L}{f W_L} \quad I_d = \frac{E_d}{R} \quad I_{diode}^{Avg} = I_d$$

$$\beta = 120^\circ$$

$$f_p = 6 * f$$

$$P_L = I_d E_d$$

$$W_L = \frac{1}{2} L I^2$$

$$I_{Line} = 0.816 I_d$$

$$I_f = 0.955 I_{Line}$$

Phase Controlled 6 pulse, 3 Phase Rectifier

$$E_d = 1.35 E \cos \alpha \quad (\text{where } 0^\circ < \alpha < 90^\circ)$$

$$I_{Line} = 0.816 I_d$$

$$Q = P \tan \alpha$$

$$P = E_d I_d$$

$$I_{diode}^{Avg} = I_d / 3$$



Phase Controlled, 6 pulse, 3 phase inverter

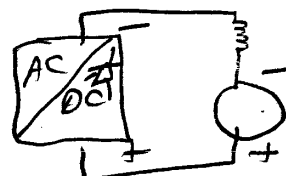
$$E_d = 1.35 E \cos \alpha \quad (\text{where } 90^\circ < \alpha < 180^\circ)$$

$$I_{Line} = 0.816 I_d$$

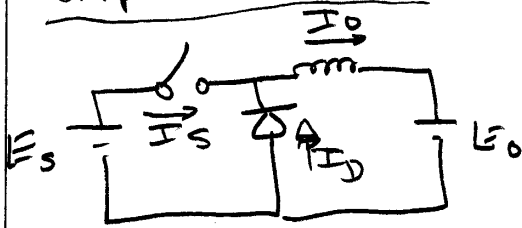
$$Q = P \tan \alpha$$

$$P = E_d I_d$$

$$I_{diode}^{Avg} = I_d / 3$$



CHAPTER 21 CONTINUED



$$D = \frac{1}{1 + R_o/R_s}, \quad f = \frac{1}{1 + R_o/R_s}$$

$$I_o = I_D + I_s$$

$$E_o = D E_s$$

$$I_s = D I_o$$

$$R_s = \frac{R_o}{D^2} = \frac{E_o}{D^2 I_o} = \frac{E_s}{I_s}$$