-1-

8-17 3-ϕ 60 Hz 575 V

System load 1.5 MW $F_p = 0.92$ lagging

Synchronous motor 500 HP, 575 V 1200 RPM

Rated output $F_p = 0.84$ leading $\eta = 96.2\%$

$X_s = 0.567\ \Omega/\text{phase}$

a.) Reactive powers supplied by motor

Motor active power $P_o = 500\,HP(746\,W/HP) = 373\ kW$

Apparent Power motor $P_{in} = \frac{P_o}{\eta} = \frac{373\ kW}{0.962} = 387.73\ kW$

$$S_m = \frac{P_{in}}{F_p} = \frac{387.73\ kW}{0.84} = 461.6\ kVA$$

$$Q_m = \sqrt{(461.6)^2 - (387.73)^2}$$

$Q_m = 250.5\ kVAR \Rightarrow Q_m = -250.5\ kVAR$ Leading P.F.
VAR GENERATED

System Apparent and Reactive power

$$S_s = \frac{1500\ kW}{0.92} = 1630.4\ kVA$$

$$Q_s = \sqrt{(1630.4)^2 - (1500)^2} = 639\ kVARs$$

with motor disconnected (Remove Q_m and P_m from load)

$Q_s' = 639\ kVAR + 250.5\ kVAR = 889.5$ Add VARS

$P_s' = 1500\ kW - 387.7\ kW = 1112\ kW$ subtract kW

Computed new S_s'

$$S_s' = \sqrt{(1112)^2 + (889.5)^2} = 1424.0\ KVA$$

$$F_p' = \frac{P_s'}{S_s'} = \frac{1112\ kW}{1424.0\ kVA} = \boxed{0.781 \text{ Lagging}}$$

78.1 % Lagging

TOPS 35500

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b.) Synchronous motor connected, motor unloaded excitation unchanged

$P_{in} = 3V_T I_a \cos\theta \Rightarrow$

$P_{in} = 387.7$ kW

$\cos\theta = 0.84$

$V_T = \frac{575}{\sqrt{3}} = 332$ V

$\frac{P_{in}}{3V_T \cos\theta} = |I_a|$

$\theta = \cos^{-1}(F_p)$

$\frac{387{,}700\text{W}}{3(332)(0.84)} = |I_a| = 463.4$ A

$\theta = \cos^{-1}(0.84) = 32.9°$

$\bar{I}_a = 463.4 \angle 32.9°$ A

$E_f = V_T - \bar{I}_a \bar{X}_s$

$E_f = 332\angle 0° - 463.4\angle 32.9° (0.567\angle 90°)$

$E_f = 332\angle 0° - 262.7\angle 122.9°$

$E_f = 524.4\angle -24.9°$

with P_m reduced to 0 $\delta = 0$

$|E_f| = 524.4$ V

$Q_{m1} = \frac{3(V_T E_f \cos\delta - V_T^2)}{X_s}$

$Q_{m1} = \frac{3(\overset{174{,}100.8}{332(524.4)} - \overset{110{,}224}{332^2})}{0.567} = 338$ kVARs

191,232 (37,424)

$Q_s'' = Q_s' - Q_{m1} = 889.5$ kVAR $- 338$ kVAR $= 551.5$ kVAR

$P_s'' = 1500$ kW $- 387.7$k $= 1112$ kW

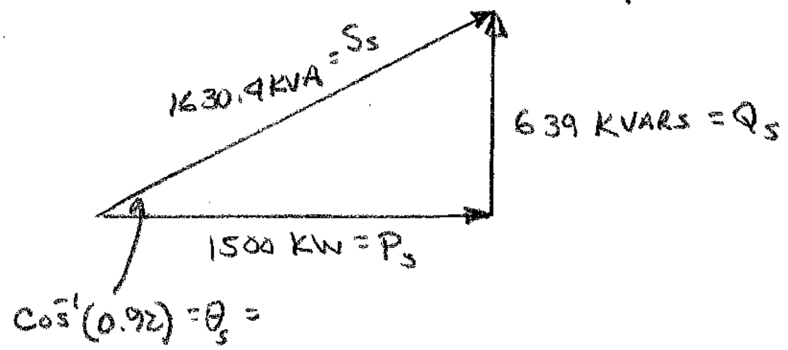
$S_s'' = \sqrt{(P_s'')^2 + (Q_s'')^2} = \sqrt{(1112)^2 + (551.5)^2} = 1241$ kVA

$F_p = \frac{P_s''}{S_s''} = \frac{1112\text{ kW}}{1241\text{ kVA}} = \boxed{0.896}$

-3 8-12 Power Triangles

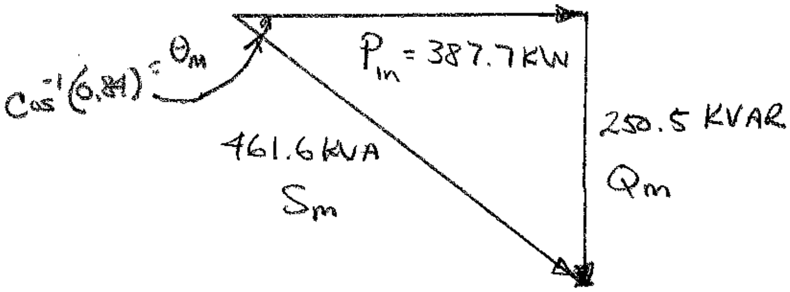
System load with motor delivering 500 HP output

$F_p = 0.92$ Lag



Synchronous Motor Power Triangle when delivering rated load

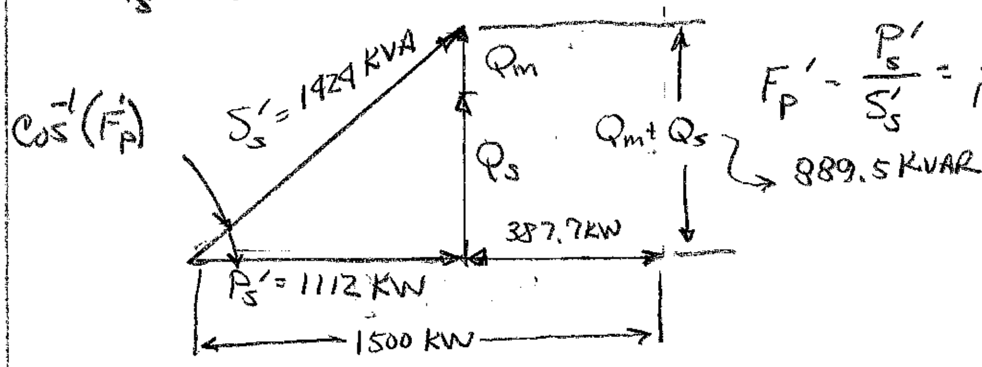
$F_p = 0.84$ Leading



Removing motor from system Reduces P_s by P_{in} of motor and increases VAR loading by Q_m

$P_s' = P_L - P_{in} = 1112$ KW motor active power removed

$Q_s' = Q_s - (-Q_m) = 639 - (-250.5) = 889.5$ KVARS



$$F_p' = \frac{P_s'}{S_s'} = \frac{1112\text{ KW}}{1424\text{ KVA}} = 0.781 \text{ Lag}$$

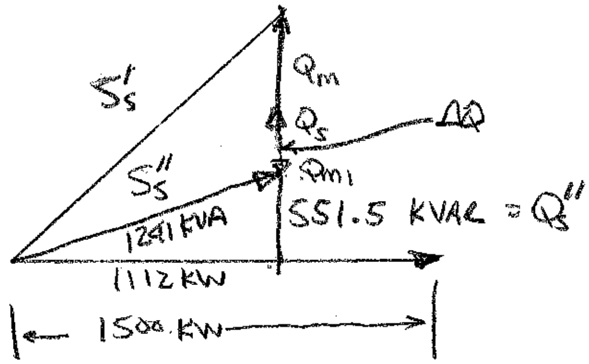
8-17 power triangles

Motor connected to system with zero active power output so

$P_s'' = P_s - P_{in}$

Remains connect and supplies reactive power only.

$Q_{m1} = 338$ Kvars Reactive Power with $P_{in} = 0$ on motor



$$-Q_{m1} - (-Q_m) = \Delta Q$$

$$-Q_{m1} + Q_m = -338 \text{ KVAR} + 250.5 \text{ KVAR} = -87.5 \text{ KVAR}$$

Additional Reactive power supplied

Can use $Q_s + \Delta Q$ to find net reactive power OR

$$(+Q_m) + Q_s + Q_{m1} = Q_s''$$

$$250.5 \text{ KVAR} + 639 \text{ KVAR} - 338 \text{ KVAR} = 551.5 \text{ KVAR}$$

$$639 \text{ KVAR} - 87.5 \text{ KVAR} = 551.5 \text{ KVAR}$$