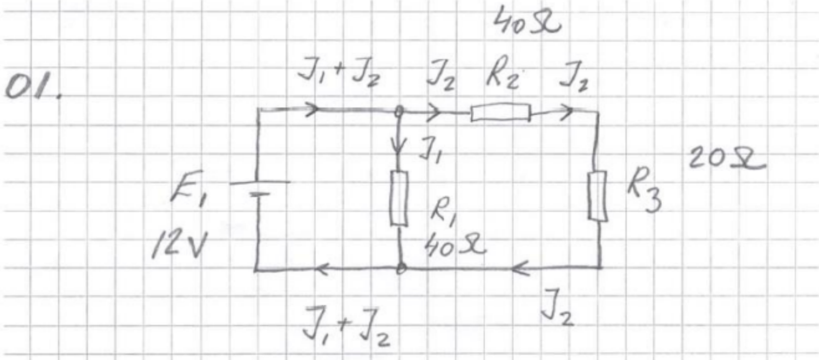
Lektion 1

1.1



OHMS LAG ⇒

$$J_1 = \frac{E_1}{R_1} \Rightarrow \underline{J_1 = 0{,}30\ A}$$

$$J_2 = \frac{E_1}{R_2 + R_3} \Rightarrow \underline{J_2 = 0{,}20\ A}$$

1.2

a) $\bar{U} = \bar{Z} \cdot \bar{I}$

$$\bar{I} = \frac{\bar{U}}{\bar{Z}_1 + \bar{Z}_2} = \frac{220\, e^{j0^\circ}}{20 - j10}$$

$$= \frac{220\,(20 + j10)}{400 + 100} \approx 8.8 + j\,4.4 \text{ A}$$

$$\bar{I} = 9.8\, e^{j27^\circ}$$

b) $\arg \bar{U}_1 = \arg \bar{Z}_1 \bar{I} = \arg \bar{Z}_1 + \arg \bar{I}$

$\arg \bar{U}_2 = \arg \bar{Z}_2 \bar{I} = \arg \bar{Z}_2 + \arg \bar{I}$

$\rightarrow \arg \bar{U}_1 - \arg \bar{U}_2 = \arg \bar{Z}_1 - \arg \bar{Z}_2 =$

$= \arg \dfrac{\bar{Z}_1}{\bar{Z}_2}$

1.3 Se Facit

1.4

$U_H = 400 \text{ V}$

$I_L = 25 \text{ A}$

$P_{axel} = 12 \text{ kW}$

$\eta = 0.85$

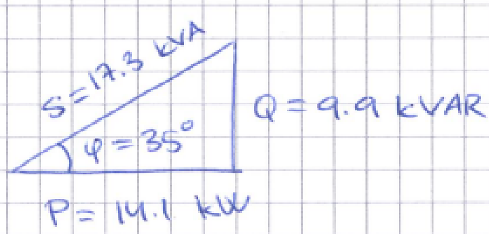
$P_{elektrisk} = P_{axel} / \eta = 14.1 \text{ kW}$

$S = \sqrt{3}\, U_H I_L = 17.3 \text{ kVA}$

$\cos\varphi = P_{elektrisk} / S = 0.8151 \approx 0.82$

$\varphi = \arccos(0.82) = 35^\circ$

$Q = S \sin\varphi = 17300 \cdot \sin(35^\circ) = 9.9 \text{ kVAR}$



1.5

Example 2.5 Good Versus Poor Power Factor. A utility supplies 12,000 V (12 kV) to a customer who needs 600 kW of real power. Compare the line losses for the utility when the customer's load has a power factor of 0.5 versus a power factor of 1.0.

Solution. To find the current drawn when the power factor is 0.5, we can start with (2.43):

$$P = VI \cdot PF$$

$$600\ \text{kW} = 12\ \text{kV} \cdot I(\text{A}) \cdot 0.5$$

so

$$I = \frac{600}{12 \times 0.5} = 100\ \text{A}$$

When the power factor is improved to 1.0, (2.43) now looks like

$$600\ \text{kW} = 12\ \text{kV} \cdot I(\text{A}) \cdot 1.0$$

so the current needed will be $I = \dfrac{600}{12} = 50$ A

When the power factor in the plant is improved from 0.5 to 1.0, the amount of current needed to do the same work in the factory is cut in half. The utility line losses are proportional to current squared, so line losses for this customer have been cut to one-fourth of their original value.

1.6

Givet den första maskinens effektfaktor $\cos\varphi_1 = 0.7$ fås $\sin\varphi_1 = \sqrt{1-0.7^2}$ och med hjälp av den givna effekten P_1 fås

$$\left.\begin{aligned} P_1 &= S_1\cos\varphi_1 \\ Q_1 &= S_1\sin\varphi_1 \end{aligned}\right\} \Rightarrow Q_1 = \frac{P_1}{\cos\varphi_1}\sin\varphi_1 \approx 102 \text{ kVAr}. \tag{1}$$

På samma sätt fås

$$Q_2 = \frac{P_2}{\cos\varphi_2}\sin\varphi_2 \approx 15.2 \text{ kVAr} \tag{2}$$

för den andra maskinen. Den reaktiva effekten som konsumeras i de tre D-kopplade kondensatorerna blir (enligt samband från formelsamling)

$$Q_3 = -3U_H^2\omega C = -3U_H^2 2\pi f C \approx -68 \text{ kVAr}. \tag{3}$$

Den totala reaktiva effekten blir därmed

$$Q = Q_1 + Q_2 + Q_3 \approx 49.2 \text{ kVAr} \tag{4}$$

och den totala aktiva effekten

$$P = P_1 + P_2 + P_3 = 100 + 13 + 0 = 113 \text{ kW} \tag{5}$$

Den skenbara effekten kan beräknas som

$$S = \sqrt{P^2 + Q^2} \approx 123.2 \text{ kVA} \tag{6}$$

och utifån detta fås strömmen genom

$$S = \sqrt{3}U_H I_L \Rightarrow I_L \frac{S}{\sqrt{3}U_H} \approx 187.2 \text{ A} \tag{7}$$

Slutligen blir effektfaktorn

$$\cos\varphi_{tot} = \frac{P}{S} \approx 0.917. \tag{8}$$

Example 2.7 Avoiding a New Transformer by Improving the Power Factor.
A factory with a nearly fully loaded transformer delivers 600 kVA at a power
factor of 0.75. Anticipated growth in power demand in the near future is 20%.
1.7 How many kVAR of capacitance should be added to accommodate this growth
so they don't have to purchase a larger transformer?

Solution. At PF = 0.75, the real power delivered at present is 0.75 × 600 kVA = 450 kW. And the phase angle is $\theta = \cos^{-1}(0.75) = 41.4^\circ$. If demand grows by 20%, then an additional 90 kW of real power will need to be supplied. At that point, if nothing is done, the new power triangle would show

$$\text{Real power } P = 450 + 90 = 540 \text{ kW}$$

$$\text{Apparent power } S = 540 \text{ kW}/0.75 = 720 \text{ kVA (too big for this transformer)}$$

$$\text{Reactive power } Q = VI \sin\theta = 720 \text{ kVA} \sin(41.4^\circ) = 476 \text{ kVAR}$$

For this transformer to still supply only 600 kVA, the power factor will have to be improved to at least

$$\text{PF} = 540 \text{ kW}/600 \text{ kVA} = 0.90$$

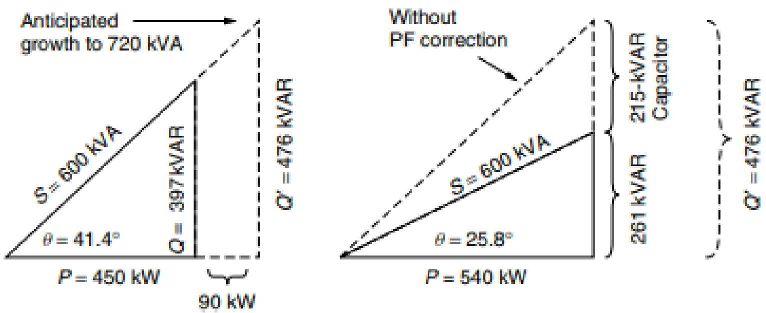
The phase angle now will be $\theta = \cos^{-1}(0.90) = 25.8^\circ$. The reactive power will need to be reduced to

$$Q = 600 \text{ kVA} \sin 25.8^\circ = 261 \text{ kVAR}$$

The difference in reactive power between the 476 kVAR needed without power factor correction and the desired 261 kVAR must be provided by the capacitor. Hence

$$\text{PF correcting capacitor} = 476 - 261 = 215 \text{ kVAR}$$

The power triangles before and after PF correction are shown below:



(a) Before correction (b) With 215-kVAR capacitor

1.8

EXAMPLE 1.2

The magnetic structure of a synchronous machine is shown schematically in Fig. 1.5. Assuming that rotor and stator iron have infinite permeability ($\mu \rightarrow \infty$), find the air-gap flux ϕ and flux density B_g. For this example $I = 10$ A, $N = 1000$ turns, $g = 1$ cm, and $A_g = 2000\ \text{cm}^2$.

■ Solution

Notice that there are two air gaps in series, of total length $2g$, and that by symmetry the flux density in each is equal. Since the iron permeability here is assumed to be infinite, its reluctance is negligible and Eq. 1.20 (with g replaced by the total gap length $2g$) can be used to find the flux

$$\phi = \frac{NI\mu_0 A_g}{2g} = \frac{1000(10)(4\pi \times 10^{-7})(0.2)}{0.02} = 0.13\ \text{Wb}$$

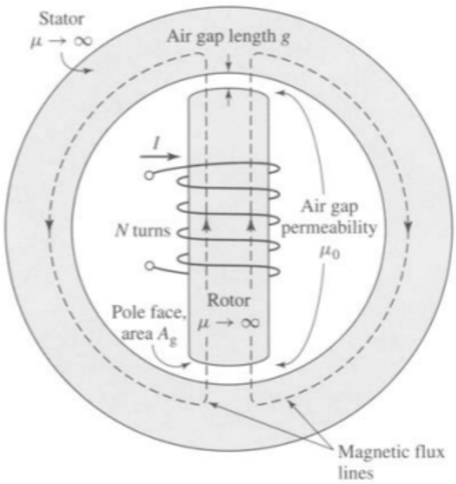


Figure 1.5 Simple synchronous machine.

and

$$B_g = \frac{\phi}{A_g} = \frac{0.13}{0.2} = 0.65\ \text{T}$$

1.9

Practice Problem 1.2

For the magnetic structure of Fig. 1.5 with the dimensions as given in Example 1.2, the air-gap flux density is observed to be $B_g = 0.9$ T. Find the air-gap flux ϕ and, for a coil of $N = 500$ turns, the current required to produce this level of air-gap flux.

Solution

$\phi = 0.18$ Wb and $i = 28.6$ A.

1.10

10.2 Givet: $X_s = 2{,}3\ \Omega/\text{fas}$

$U_H = 500\ V$

$I_a = 80\ A$

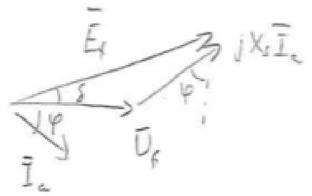
$\cos\varphi = 0{,}8$ ind.

$R_a = 0$

Sökt: a) E_f vid övermagn. samt δ

b) E_f vid undermagn. samt δ

a)



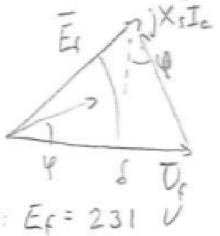
(1) $E_f^2 = (U_f + X_sI_a\sin\varphi)^2 + (X_sI_a\cos\varphi)^2$

(2) $E_f\sin\delta = X_sI_a\cos\varphi \implies \delta = \arcsin\left(\frac{X_sI_a\cos\varphi}{E_f}\right)$

(1): $E_f = 425\ V$, $E_h = \sqrt{3}E_f = 736{,}74\ V$

(2): $\delta = 20{,}25°$

b)



(3): $E_f^2 = (U_f - X_sI_a\sin\varphi)^2 + (X_sI_a\cos\varphi)^2$

(4): $E_f\sin\delta = X_sI_a\cos\varphi$

(3): $E_f = 231\ V$, $E_h = \sqrt{3}E_f = 400{,}44\ V$

(4): $\delta = 39{,}55°$