1. Industrial plant consumed the active power $P = 1280\,\mathrm{kW}$ with power factor $cos\,\varphi = 0{,}76$. Calculate consumed apparent power and power factor when is add the capacitor bank with the size $Q_c = 550\,\mathrm{kvar}$ (reactive power).

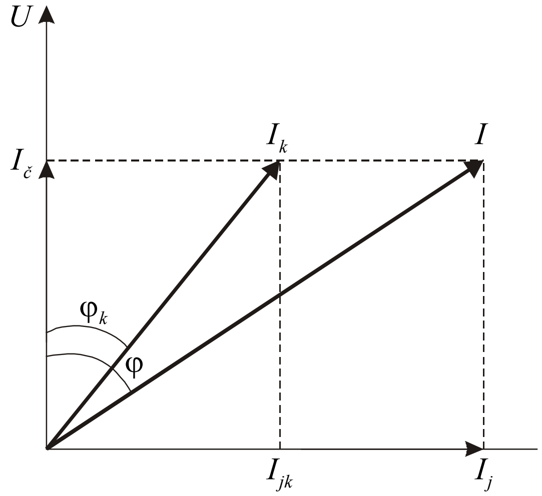

Fig. 1 – Phasor diagram (by compensation)

Calculation of apparent power:

$$S = \frac{P}{cos\,\varphi} = \frac{1280}{0{,}76} = 1684\,\mathrm{kVA}\ . \tag{1.1}$$

The power factor $cos\,\varphi = 0{,}76$ is equal to $sin\,\varphi = 0{,}65$

The reactive power:

$$\mathrm{Q} = \mathrm{S} \cdot \sin\varphi = 1684 \cdot 0{,}65 \doteq 1095\ \mathrm{kVAr} \tag{1.2}$$

Adding the capacitor bank (see fig. 1) is compensated a part of reactive power Q to the value:

$$\mathrm{Q_k} = \mathrm{Q} - \mathrm{Q_c} = 1095 - 550 = 545\ \mathrm{kVAr}\ . \tag{1.3}$$

Before compensation:

$$\mathrm{tg}\varphi = \frac{\mathrm{Q}}{\mathrm{P}} = \frac{1095}{1280} \doteq 0{,}86\,, \tag{1.4}$$

The phase angle is $\varphi \doteq 40{,}7^\circ$.

After compensation:

$$\mathrm{tg}\varphi_\mathrm{k} = \frac{\mathrm{Q_k}}{\mathrm{P}} = \frac{545}{1280} \doteq 0{,}43\,, \tag{1.5}$$

This correspond with the phase angle $\varphi_\mathrm{k} \doteq 23^\circ$. The power factor after compensation will be $cos\,\varphi_k = 0{,}92$.

2. Industrial plant is supplied from transformer $22/0{,}4\text{kV}$ with nominal apparent power $S_n = 800\text{kVA}$. Mean consumed active power is $P = 460\text{kW}$ with power factor $cos\,\varphi = 0{,}79$. Calculate the needed reactive power for compensation power factor to the value $cos\,\varphi_k = 0{,}95$ with the same consume of active power. Calculate the reserve of active power which can be used.

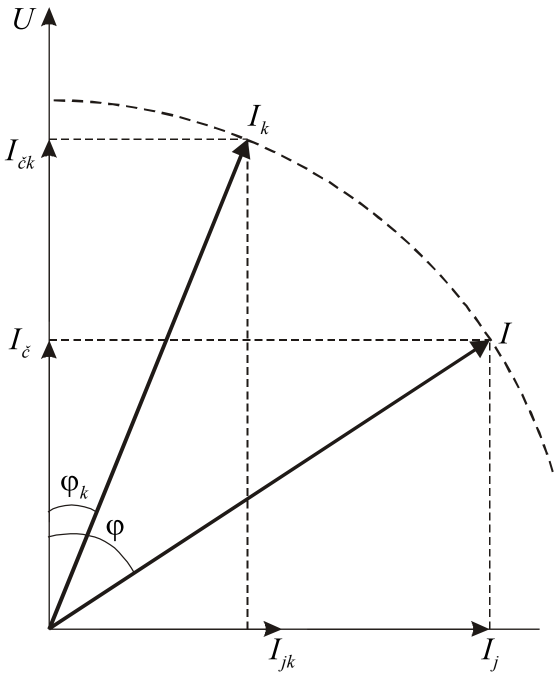

Fig. 2 – The proportion before and after compensation (while the same size of apparent power)

The power factor before compensation $cos\,\varphi = 0{,}79$ is equal to $\text{tg}\varphi \doteq 0{,}78$. After compensation is power factor $cos\,\varphi_k = 0{,}95$ and this is equal to $tg\varphi_k = 0{,}33$.

Consumed reactive power before compensation:

$$\text{Q} = \text{P} \cdot \text{tg}\varphi = 460 \cdot 0{,}78 \doteq 359 \text{ kVAr} . \tag{2.1}$$

Reactive power after compensation:

$$\text{Q}_\text{k} = \text{P} \cdot \text{tg}\varphi_\text{k} = 460 \cdot 0{,}33 \doteq 152 \text{ kVAr} . \tag{2.2}$$

Reactive power of capacitor bank:

$$\text{Q}_\text{c} = \text{Q} - \text{Q}_\text{k} = 359 - 152 = 207 \text{ kVAr} . \tag{2.3}$$

Before compensation is the reserve active power P_{rez}:

$$S_n = \sqrt{\left(P + P_{rez}\right)^2 + Q^2} , \tag{2.4}$$

$$P_{rez} = \sqrt{S_n^2 - Q^2} - P = \sqrt{800^2 - 359^2} - 460 \doteq 255 \text{ kW}. \tag{2.5}$$

After compensation is the reserve active power P_{rez} (is higher):

$$P_{k\,rez} = \sqrt{S_n^2 - Q_k^2} - P = \sqrt{800^2 - 152^2} - 460 \doteq 325 \text{ kW}. \tag{2.6}$$

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3. The asynchronous motor 1600kW is working in discontinuous operation. Three minutes is working with nominal power with current 350 A, two minutes in no-load mode with active power 100 kW and current 150 A. The nominal voltage is $U_n = 3\text{kV}$.

Calculate the capacitor bank when the power factor must be by nominal power $cos\,\varphi_k = 0{,}96$. Calculate the power factor in no-load mode.

The nominal apparent power of motor:

$$S_n = \sqrt{3} \cdot U_n \cdot I_n = \sqrt{3} \cdot 3 \cdot 10^3 \cdot 350 \doteq 1{,}82 \text{ MVA}. \tag{3.1}$$

The power factor without compensation:

$$cos\,\varphi = \frac{P_n}{S_n} = \frac{1600.10^3}{1{,}82.10^6} = 0{,}879. \tag{3.2}$$

The apparent power in no-load mode:

$$S_0 = \sqrt{3} \cdot U_n \cdot I_0 = \sqrt{3} \cdot 3 \cdot 10^3 \cdot 150 \doteq 779 \text{ kVA}, \tag{3.3}$$

And there power factor

$$cos\,\varphi_0 = \frac{P_0}{S_0} = \frac{100}{779} = 0{,}128. \tag{3.4}$$

The reactive power is solved (without compensation):

$$Q = P \cdot tg\varphi = 1600 \cdot 10^3 \cdot 0{,}543 \doteq 869 \text{ kVAr}. \tag{3.5}$$

The reactive power when power factor is $cos\,\varphi_k = 0{,}96$:

$$Q_k = P \cdot tg\varphi_k = 1600 \cdot 10^3 \cdot 0{,}292 \doteq 467 \text{ kVAr}. \tag{3.6}$$

The power of capacitor bank (for assigned power factor $cos\,\varphi_k = 0{,}96$)

$$Q_c = Q - Q_k = 869 - 467 = 402 \text{ kVAr}. \tag{3.7}$$

The reactive power in no-load mode before compensation:

$$Q_0 = P_0 \cdot tg\varphi_0 = 100 \cdot 10^3 \cdot 7{,}75 \doteq 775 \text{ kVAr}. \tag{3.8}$$

Capacitor banks after compensation contribute 402 kVAr of the reactive power. The consumed reactive power from power grid in no-load mode after compensation will be:

$$Q_{0k} = Q_0 - Q_c = 775 - 402 = 373 \text{ kVAr}. \tag{3.9}$$

This value is equal to power factor after compensation in no-load mode with this equation:

$$Q_{0k} = P_0 \cdot tg\varphi_{0k} \,, \tag{3.10}$$

And there:

$$tg\varphi_{0k} = \frac{Q_{0k}}{P_0} = \frac{373}{100} = 3{,}73 \,. \tag{3.11}$$

Power factor in no-load mode: $\cos\varphi_{0k} \doteq 0{,}26$.

The capacitor banks is constructed from three condenser connected to the triangle (delta). Each condenser contribute reactive power in amount:

$$\mathrm{Q_{c1}} = \frac{\mathrm{Q_c}}{3} = 134 \text{ kVAr} \tag{3.12}$$

Capacity of each condenser:

$$\mathrm{C_1} = \frac{\mathrm{Q_{c1}}}{\omega \cdot \mathrm{U}^2} = \frac{134 \cdot 10^3}{100 \cdot \pi \cdot 3000^2} \doteq 47{,}4 \ \mu\mathrm{F} \tag{3.13}$$