

Solutions:

**Problem 1:**

a) Impedantie van een tak:

$$\underline{Z} = j\omega L + \frac{R}{j\omega C} = j\omega L + \frac{R}{1 + j\omega RC} = j2\pi 50 + \frac{10^3}{1 + j2\pi 50 10^3 10^{-5}} = j314 + \frac{10^3}{1 + j\pi} = 92 + j25 \Omega$$

b) Stroom in tak:  $\underline{I} = \frac{\underline{U}_\Delta}{\underline{Z}} = \frac{400}{92 + j25} = 4,05 - j1,1 \text{ A}$

Vermogen in de drie fasen:  $3\underline{U}_\Delta \underline{I}^* = 3 * 400(4,05 + j1,1) = 4860 + j1320$   
 $P = 4860 \text{ W}, Q = 1320 \text{ VAr}, S = 5036 \text{ VA}$

c)

$$I_Y = \sqrt{3} I_\Delta = 7,01 - j1,91$$

**Problem 2:**

Groep A:

$$P_A = 100 \text{ kW};$$

$$\cos \varphi_A = 0,8$$

$$S_A = P_A / \cos \varphi_A = 125 \text{ kVA}$$

$$Q_A = P_A \tan \varphi_A = 75 \text{ kVAr}$$

Groep B:

$$P_B = P_{\text{tot}} - P_A = (125 - 100) \text{ kW} = 25 \text{ kW}$$

$$Q_B = Q_{\text{tot}} - Q_A = (150 - 75) \text{ kVAr} = 75 \text{ kVAr}$$

$$S_B = 79,06 \text{ kVA}$$

Na compensatie:

$$Q_{na} = P_{\text{tot}} \tan \varphi_{na} = 125 \text{ kW} 0,4843 = 60,54 \text{ kVAr}$$

$$Q_d = Q_{\text{tot}} - Q_{na} = (150 - 60,54) \text{ kVAr} = 89,46 \text{ kVAr}$$

*Triangle connection*

$$Q_c = Q_{d/3} = U^2 \omega C \Rightarrow C = (29,82 \text{ kVAr}) / (400 \text{ V})^2 2 \pi 50 \text{ Hz} = 593,25 \mu\text{F} \text{ (cheapest solution)}$$

Star connection

$$Q_c = Q_{y/3} = 1/3 U^2 \omega C \Rightarrow C = 1779.75 \mu\text{F}$$

### Problem 3:

**Solution:** The synchronous generator is  $\Delta$ -connected, so its phase voltage is equal to its line voltage  $V_\phi = V_T$ , while its phase current is related to its line current by the equation:

$$I_L = \sqrt{3} I_\phi$$

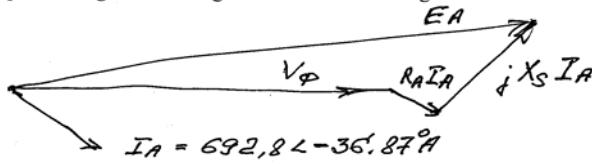
- a) The relationship between the electrical frequency produced by a synchronous generator and the mechanical speed (rate of the shaft rotation) is given by:

$$f_e = \frac{n_m P}{120}, \text{ therefore, } n_m = \frac{120 f_e}{P} = \frac{120(60 \text{ Hz})}{4 \text{ poles}} = 1800 \text{ r/min}$$

- b) In this machine  $V_\phi = V_T$ . If the generator is supplying 1200 A, then the armature current in the machine is:

$$I_A = \frac{1200 A}{\sqrt{3}} = 692.8 A$$

- c) The phasor diagram for this generator is shown in Fig.1.



- d) If the terminal voltage is kept to be 480 V, the generated voltage  $E_A$  is given by:

$$\begin{aligned} E_A &= V_T + R_A I_A + j X_s I_A = 480 \angle 0^\circ V + (0,015 \Omega) \\ &\cdot (692.8 \angle -36.87^\circ A) + (j 0.1 \Omega)(692.8 \angle -36.87^\circ A) = \\ &= 480 \angle 0^\circ + 10.39 \angle -36.87^\circ V + 69.28 \angle 53.13^\circ V = \\ &= 529.9 + j 49.2 V = 532.43 V \end{aligned}$$

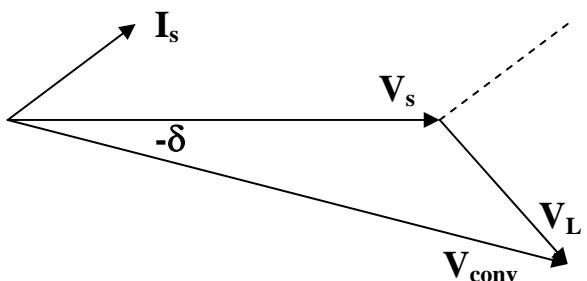
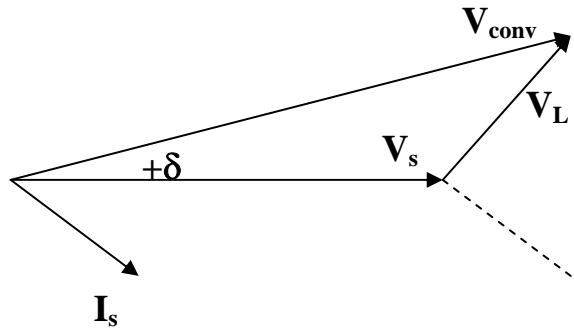
- e) The power that the generator is supplying can be found by the following way:

$$\begin{aligned} P_{out} &= \sqrt{3} V_T \cdot I_A \cos \theta = \\ &= \sqrt{3} (480 V)(1200 A) \cos 36.87^\circ = \\ &= 798 kW \end{aligned}$$

### Problem 4:

$$(a) V_{conv} = \frac{m_a V_{dc}}{\sqrt{2}} = \frac{0.8 * 700}{\sqrt{2}} = 396 V_{rms}$$

(b)



$$P = \frac{V_s V_{conv}}{X_s} \sin \delta \Rightarrow \sin \delta = \frac{2kW * (2 * \pi * 50 * 15mH)}{220 * 396} = 0.108$$

$$\cos \delta = \sqrt{1 - 0.108^2} = 0.994$$

$\delta = +0.108 \text{ rad}$  → grid behaves like an inductor

$\delta = -0.108 \text{ rad}$  → grid behaves like a capacitor

(c) By decomposition of phasors, it is possible to write:

$$V_L^2 = (I_s X_s)^2 = (V_{conv} \sin \delta)^2 + (V_{conv} \cos \delta - V_s)^2$$

$$(I_s * 2\pi * 50 * 15mH)^2 = (396 \sin \delta)^2 + (396 \cos \delta - 220)^2$$

$$I_s = \frac{\sqrt{(396 \sin \delta)^2 + (396 \cos \delta - 220)^2}}{2\pi * 50 * 15mH} = \frac{\sqrt{(42.77)^2 + (173.6)^2}}{2\pi * 50 * 15mH} = 38 \text{ Arms}$$

$$S = V_s I_s = 220 * 38 = 8.4 \text{ kVA}$$

$$S^2 = P^2 + Q^2 \Rightarrow Q = \pm \sqrt{8.4^2 - 2.0^2} = \pm 8.16 \text{ kVar}$$

### Problem 5:

a)

Slack: 150kV connection

Generator bus bar: no generator busbar, because a wind turbine is not controlling the voltage

Load bus bar: A – I

b)

Trafo, lijn A-C and C-D are quite loaded

→ high voltage losses, very bad voltage profile

→ because of the distance the losses between C-D are the highest

→ the current will flow from E to D because of the higher voltage in E

c)

→ power produced in the wind turbine is directly used in bus bar C, therefore lower power transport between A-D, reduced losses

→  $V_c$  is now higher → pos. effect also at bus D

d)

The generator is feeding bus A and increasing the voltage in A.

→ if the voltage becomes too high the tap changer will switch to a lower stand keeping the voltage into the desired margin

### Problem 6:

$$E_{PV}[\text{kWh/day}] = P_{PV}[\text{kW/m}^2] \cdot G[\text{h/day}] \cdot V_{\text{incl}} \cdot V_{\text{temp}} \cdot V_{\text{ref}} \cdot A[\text{m}^2]$$