

ELECTROTECHNICS

3 3-PHASE ELECTRICAL CIRCUITS

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3 AC CIRCUITS

Example 1

Assignment

**3-phase asynchronous motor connected to the mains
3x400/230V draws current of 50A at power factor $\cos \varphi = 0,75$. The motor efficiency is 70%. Calculate active input power, reactive power, apparent power and output power.**

3 AC CIRCUITS

Example 1

Input cable and terminal plate connection

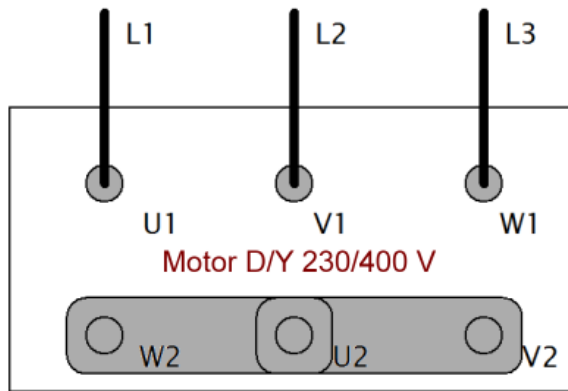
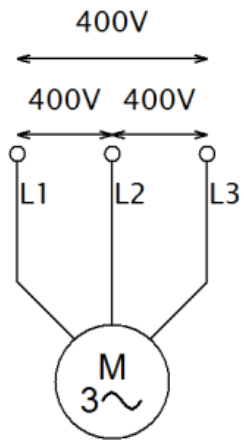


Schéma a zapojení svorkovnice D/Y 230/400V

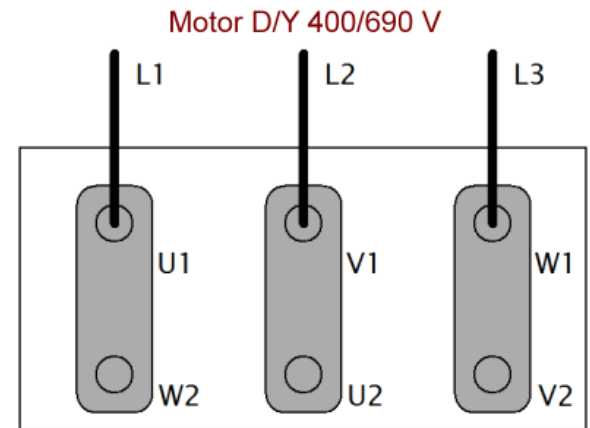
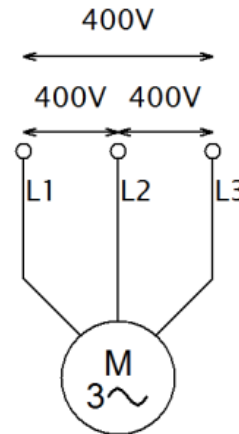
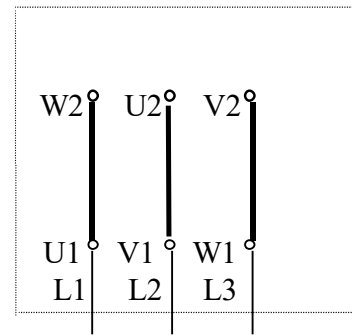
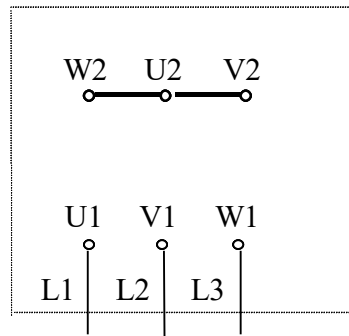
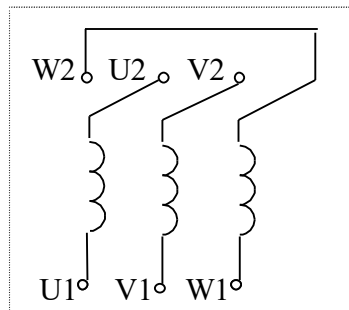


Schéma a zapojení svorkovnice D/Y 400/690V



3 AC CIRCUITS

Example 1

Solution

For the voltages in the mains:

Line voltage: $V_s = 400 \text{ V}$

Phase voltage: $V_f = 230 \text{ V}$

Input power: $P_1 = \sqrt{3} \cdot V_s \cdot I_s \cdot \cos\varphi = \sqrt{3} \cdot 400 \cdot 50 \cdot 0,75 = 26 \cdot 10^3 \text{ W} = 26 \text{ kW}$

Output power (mechanical): $P = P_1 \cdot \eta = 26 \cdot 0,7 = 18,2 \text{ kW}$

Apparent pow.: $S = \sqrt{3} \cdot V_s \cdot I_s = \sqrt{3} \cdot 400 \cdot 50 = 34,64 \cdot 10^3 \text{ VA} = 34,64 \text{ kVA}$

Reactive pow.: $Q = \sqrt{S^2 - P_1^2} = \sqrt{34,64^2 - 26^2} = 22,9 \cdot 10^3 \text{ var} = 22,9 \text{ kvar}$

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Example 2

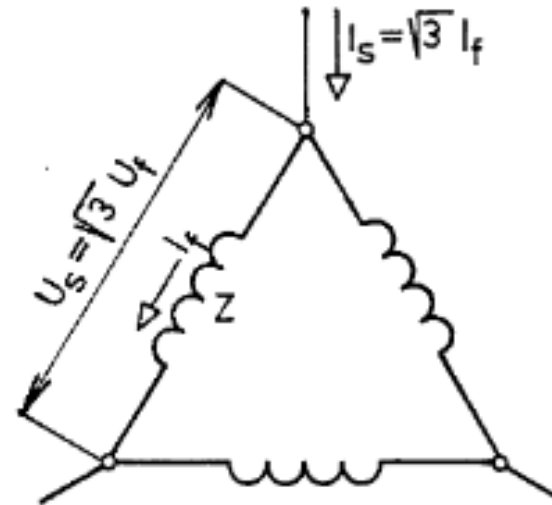
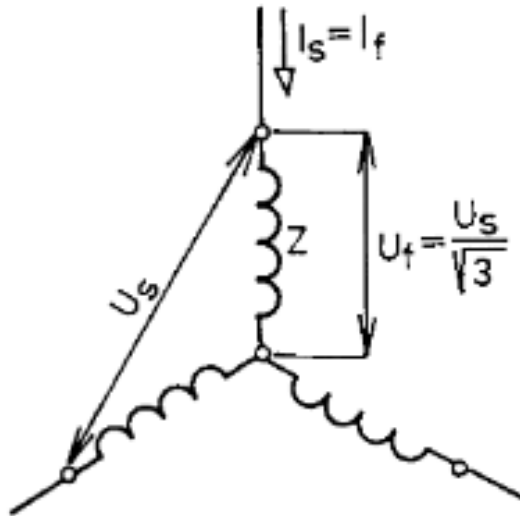
Assignment

How large line and phase current is drawn by 3-phase motor in the delta connection from the mains 3x400/230V if its power is 15 kW, efficiency 90% and power factor 0,8? Calculate also impedance of the stator winding.

3 AC CIRCUITS

Example 2

Connection Y and D



3 AC CIRCUITS

Example 2

Solution

For motors the mechanical output power is defined. Electrical quantities must be calculated from the input electrical power.

Input power:

$$P_1 = \frac{P}{\eta} = \frac{15 \cdot 10^3}{0,9} = 16,7 \cdot 10^3 \text{ W}$$

Line current:

$$I_S = \frac{P_1}{\sqrt{3} \cdot V_S \cdot \cos\varphi} = \frac{16,7 \cdot 10^3}{\sqrt{3} \cdot 400 \cdot 0,8} = 30,1 \text{ A}$$

Phase current:

$$I_f = \frac{I_S}{\sqrt{3}} = \frac{30,1}{\sqrt{3}} = 17,4 \text{ A}$$

Impedance: $Z = \frac{V_f}{I_f} = \frac{V_S}{I_f} = \frac{400}{17,4} = 23 \text{ } \Omega$

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Example 3

Assignment

How large is impedance in one phase of a 3 phase device connected into delta on voltage of 400 V if current 6A is flowing across input supply cable? How large is supply current change if the device is switched into star?

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Example 3

Solution

Delta connection: $V_f = V_S = 400 \text{ V}$

Device phase current: $I_f = \frac{I_S}{\sqrt{3}} = \frac{6}{\sqrt{3}} = 3,47 \text{ A}$

Device phase impedance: $Z = \frac{V_f}{I_f} = \frac{400}{3,47} = 115,3 \Omega$

Star connection:

$$V_f = \frac{V_S}{\sqrt{3}} = \frac{400}{\sqrt{3}} = 231 \text{ V}, \quad I_f = \frac{V_f}{Z_f} = \frac{231}{115,3} = 2 \text{ A}$$

$$I_S = I_f = 2 \text{ A}$$

Supply (line) current change:

$$\frac{I_{SD}}{I_{SY}} = \frac{6}{2} = 3$$

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Example 4

Assignment

Heat elements in electrical heater with resistance of $R = 100 \Omega$ are connected into delta and connected to the voltage of $3 \times 400/230V$. Calculate electrical input power of the heater.

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Example 4

Solution

Heat element current (phase):

$$I_f = \frac{V_f}{R} = \frac{400}{100} = 4 \text{ A}$$

Heat element voltage (phase):

$$V_f = V_S = 400 \text{ V}$$

Input power:

$$P = 3 \cdot V_f \cdot I_f \cdot \cos\varphi = 3 \cdot 400 \cdot 4 \cdot 1 = 4800 \text{ W}$$

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Example 5

Assignment

3-phase appliance has resistors connected into star with resistances as follows: $R_1 = 25 \Omega$, $R_2 = 32 \Omega$, $R_3 = 40 \Omega$. How large currents are flowing accross each of them if the appliance is connected to the mains 3x400/230V. Calculate also the appliance input power.

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Example 5

Solution

Appliance phase voltage: $V_f = 230 \text{ V}$

Appliance phase currents:

$$I_{f1} = \frac{V_f}{R_1} = \frac{230}{25} = 9,2 \text{ A}$$

$$I_{f2} = \frac{V_f}{R_2} = \frac{230}{32} = 7,2 \text{ A}$$

$$I_{f3} = \frac{V_f}{R_3} = \frac{230}{40} = 5,75 \text{ A}$$

Power: $P_1 = P_{11} + P_{12} + P_{13} = V_f \cdot I_{f1} + V_f \cdot I_{f2} + V_f \cdot I_{f3} = 230 \cdot (9,2 + 7,2 + 5,75) = 5095 \text{ W}$

Note: power factor $PF=1$

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Example 6

Assignment

Electrical heater with input power of 5 kW is fed from 3-phase supply network 3x400/230V. Calculate its input power in the case if the line voltage is only 380V, and in the case of disconnecting one phase by a fuse (fault in the heater). Heat elements of the heater are connected into the star.

3 AC CIRCUITS

Example 6

Solution

In the case of voltage drop the current must be lower, because the resistance of heat elements is the same (does not depend on the voltage, we assume the constant element temperature)

Heat element current at 400V:

$$I_S = I_f = \frac{P_1}{\sqrt{3} \cdot V_S} = \frac{5000}{\sqrt{3} \cdot 400} = 7,22 \text{ A}$$

$$I_f = \frac{V_f}{R} \rightarrow R = \frac{V_f}{I_f} = \frac{230}{7,22} = 31,9 \text{ } \Omega$$

Heat element current at 380V:

$$I_{SS} = I_{fs} = \frac{V_{fs}}{R} = \frac{\frac{V_{SS}}{\sqrt{3}}}{R} = \frac{\frac{380}{\sqrt{3}}}{31,9} = 6,88 \text{ A}$$

3 AC CIRCUITS

Example 6

Solution

Heater input power at 380V:

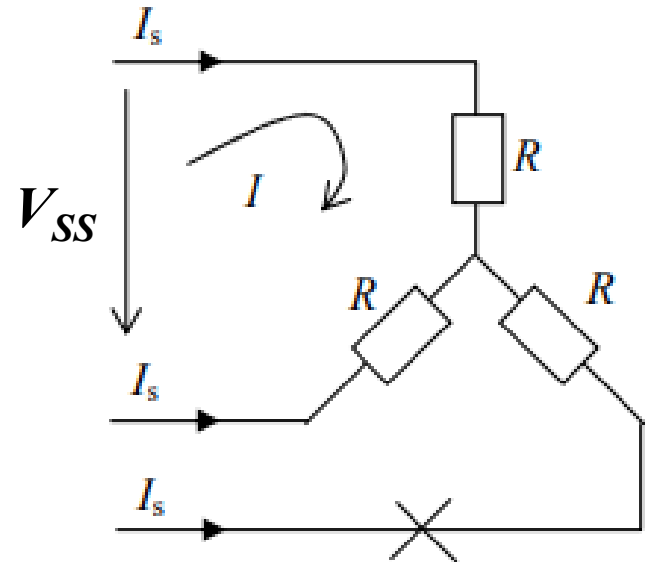
$$P_{1s} = \sqrt{3} \cdot 380 \cdot 6,88 = 4528 \text{ W} = 4,53 \text{ kW}$$

Delivered current at the fault (phase disconnected):

$$I = \frac{V_{SS}}{R + R} = \frac{380}{31,9 + 31,9} = 5,96 \text{ A}$$

Input power at the
fault:

$$P_{1p} = V_{SS} \cdot I = 380 \cdot 5,96 = 2265 \text{ W}$$



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Example 7

Assignment

Electrical 3-phase stove with elements connected into delta draws current 15 A at $PF=1$. The voltage of the mains is 3x400/230V. How large is stove input power and how large is stove consumption (kWh) after its operation lasting six hours?

3 AC CIRCUITS

Example 7

Solution

Stove input power:

$$P_1 = \sqrt{3} \cdot V_S \cdot I_S \cdot \cos\varphi = \sqrt{3} \cdot 400 \cdot 15 \cdot 1 = 10392 \text{ W} \\ = 10,4 \text{ kW}$$

Stove energy consumption:

$$W = P_1 \cdot t = 10,4 \cdot 6 = 62,4 \text{ kWh}$$