

$$\textcircled{1} \quad \Delta i\% = \frac{K \cdot I_2 - I_1}{I_1} \cdot 100 = \frac{\frac{300}{5} \cdot 4,75 - 300}{300} = -5\% \Rightarrow \text{klasa točnosti 5}$$

$$\textcircled{2} \quad W_R = 5 \cdot 300 + (15-5) \cdot 800 + (24-15) \cdot 200 = 11300 \text{ kWh}$$

$$W_J = 5 \cdot 200 + (15-5) \cdot 800 + (24-15) \cdot 200 = 10800 \text{ kVAh}$$

$$W_{J, \text{DOZV}} = W_R \cdot \tan(\arccos(0,95)) \approx 11300 \cdot 0,33 = 3729 \text{ kVAh}$$

$$W_{J, \text{KON}} = W_J - W_{J, \text{DOZV}} = 10800 - 3729 = 7071 \text{ kVAh}$$

$$Q_{J, \text{KON}} = \frac{W_{J, \text{KON}}}{T} = \frac{7071}{24} = 294,625 \text{ kVAR} > Q_{\min}(200)$$

- razdvojamo kompenzaciju na određene vremenske intervale

I.) 0-5h & 15-24h

$$W_R = 5 \cdot 300 + (24-15) \cdot 200 = 3300 \text{ kWh}$$

$$W_J = 5 \cdot 200 + (24-15) \cdot 200 = 2800 \text{ kVAh}$$

$$W_{J, \text{DOZV}} = 3300 \cdot 0,33 = 1089 \text{ kWh}$$

$$W_{J, \text{KON}} = 2800 - 1089 = 1711 \text{ kVAh}$$

$$Q_{J, \text{KON}} = \frac{1711}{(5-0) + (24-15)} = \frac{1711}{14} = 122,21 \text{ kVAR} < Q_{\min}(200) \checkmark \checkmark$$

II.) 5-15h

$$W_R = (15-5) \cdot 800 = 8000 \text{ kWh}$$

$$W_J = (15-5) \cdot 800 = 8000 \text{ kVAh}$$

$$W_{J, \text{DOZV}} = 8000 \cdot 0,33 = 2640 \text{ kVAh}$$

$$W_{J, \text{KOND}} = 8000 - 2640 = 5360 \text{ kVAh}$$

$$Q_{J, \text{KOND}} = \frac{5360}{(15-5)} = \frac{5360}{10} = 536 \text{ kVAR} < Q_{\min}(800) \checkmark \checkmark$$

minimalni u tom intervalu!

$$\textcircled{3} \quad S_{\text{DOPUŠTEN}} = U_{k\%, \min} \cdot \sum_{i=1}^m \frac{S_{n_i}}{U_{k\%, i}}, \quad S_i = S_{n_i} \cdot \frac{S \cdot U_{k\%, \min}}{S_{\text{DOPUŠTEN}} \cdot U_{k\%, i}}$$

$$S_{\text{DOP.}} = 6 \cdot \left(\frac{30}{8} + \frac{50}{6} + \frac{40}{7} \right) = 106,786 \text{ MVA}$$

$$S_1 = 30 \cdot \frac{120 \cdot 6}{S_{\text{DOP.}} \cdot 8} = 25,28 \text{ MVA} = 0,84 S_{n1} \checkmark$$

$$S_2 = 50 \cdot \frac{120 \cdot 6}{S_{\text{DOP.}} \cdot 6} = 56,19 \text{ MVA} = 1,12 S_{n2} \times - \text{preopterećen}$$

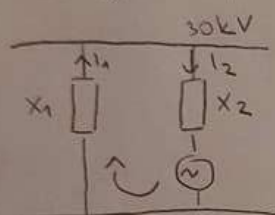
$$S_3 = 40 \cdot \frac{120 \cdot 6}{S_{\text{DOP.}} \cdot 7} = 38,53 \text{ MVA} = 0,96 S_{n3} \checkmark$$

④ $R_x = R \cdot \frac{Z_n}{Z_x} = 15 \cdot \frac{2}{5} = 6 < 5 \Rightarrow$ ne odgovara

- uzimamo $R_x = 5$

$Z_x = \frac{R}{R_x} \cdot Z_n = \frac{15}{5} \cdot 2 = 6 \Omega \Rightarrow$ to mora biti naša nova impedancija, znači trebamo dodati još otpor od 1Ω na početku 5Ω

⑤ - u praksi ne bih smjeli spojiti primar na napon viši od najnižeg napona primara među transformatorima, ali se tolerira tih 5% jer su transformatori tako građeni da mogu podnijeti više napone do 5% od nazivnog.



$\Delta V = \frac{U_1}{\sqrt{3}} \left(\frac{U_{ST2}}{U_{PT2}} - \frac{U_{ST1}}{U_{PT1}} \right) = \frac{30}{\sqrt{3}} \left(\frac{10}{28.5} - \frac{10}{30} \right) = 0.304 \text{ kV}$

$X_1 = X_2 = \frac{U_{K1}}{100} \cdot \frac{U_{N2}^2}{S_n} = \frac{8}{100} \cdot \frac{10^2}{40} = 0.2 \Omega$

$I_{1m}'' = I_{2m}'' = \frac{\Delta V}{2X} = \frac{0.304}{2 \cdot j0.2} = -j0.76 \text{ kA}$

$I_{1n}'' = I_{2n}'' = \frac{S_n}{\sqrt{3} \cdot U_{N2}} = \frac{40}{\sqrt{3} \cdot 10} = 2.31 \text{ kA}$

$I_{1j}'' = I_{2j}'' = \sqrt{I_{1n}''^2 - I_{1m}''^2} = \sqrt{2.31^2 - 0.76^2} = 2.18 \text{ kA}$

$P_1 = P_2 = \sqrt{3} \cdot U_{N2} \cdot I_{1j} = \sqrt{3} \cdot 10 \cdot 10^3 \cdot 2.18 \cdot 10^3 = 37.77 \text{ MW}$

$P_{uk} = P_1 + P_2 = 2P_1 = 2 \cdot 37.77 = 75.54 \text{ MW}$

⑥ $X_{dT2} = X_{LT2} = \frac{U_{K12}}{100} \cdot \frac{U_n^2}{S_n} = \frac{8}{100} \cdot \frac{35^2}{30} = 3.267 \Omega$

$X_{dT1} = X_{LT1} = \frac{12}{100} \cdot \frac{35^2}{50} = 2.94 \Omega$

$X_{dAM} = X_{LAM} = \frac{C \cdot U_n^2}{S_{K3}} = \frac{1.1 \cdot 35^2}{300} = 4.49 \Omega$

$X_{oAM} = C \cdot U_n^2 \left(\frac{3}{S_{K1}} - \frac{2}{S_{K3}} \right) = \infty$

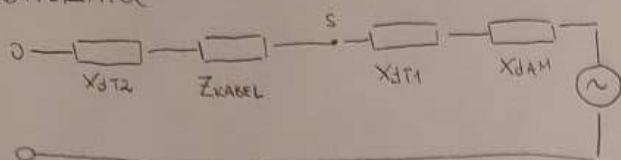
- doprimos vjetrogregata struji kratkog spoja

$I_{K1} = \frac{N \cdot S_n}{\sqrt{3} \cdot U_{2n}} = \frac{50 \cdot 500 \cdot 10^3}{\sqrt{3} \cdot 35 \cdot 10^3} = 412.39 \text{ A}$

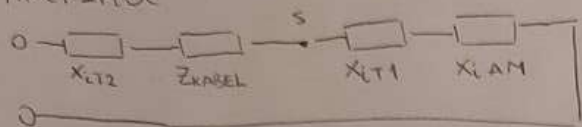
- u nedolapsnim shemama predstavlja prazni hod

$Z_{KABEL} = (R_{K1} + jX_{K1}) \cdot l = (196 \cdot 10^{-3} + j140 \cdot 10^{-3}) \cdot 1 = 0.196 + j0.14 \Omega$

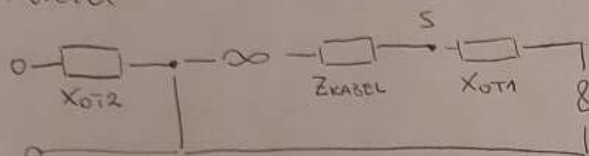
Direktna



Inverzna



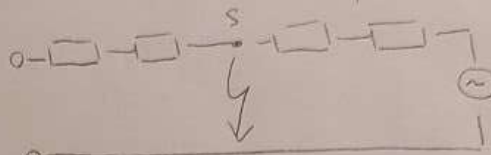
Nulta



- za dimenzioniranje sabirnica nam je potrebno:

- $I_{max, pog}$
- $I_t \rightarrow$ mjerodavna I_{k3} (piše u zadatku)
- $I_u \rightarrow$ zomemarujeemo (piše u zadatku)

- za 3KS nam treba samo direktna shema (krotki spoj na sabirnicu)



- krotki spoj - gasimo sve izvore i stavimo jedom na mjestu KS

- otpor koji se vidi s mjesta KS

$$Z_{duk} = X_{d11} + X_{dAM} = j2.94 + j4.49 = j7.43 \Omega$$

$$|I_{k3}| = \frac{C \cdot U_B}{\sqrt{3} \cdot |Z_{duk}|} = \frac{1.1 \cdot 35}{\sqrt{3} \cdot 7.43} = 2.992 \text{ kA}$$

ovo je u praznom hodu pa je otpor s te strane ∞

- ne zaboraviti doprimos vrtroagregata!

$$I_{k3_{uk}} = I_{k3} + I_{k+} = 2.992 \cdot 10^3 + 412.39 = 3404.04 \text{ A} = 3.404 \text{ kA}$$

$$I_{max, pog} = \frac{S_{max}}{\sqrt{3} \cdot U_n} = \frac{50 \cdot 10^6}{\sqrt{3} \cdot 35 \cdot 10^3} = 824.786 \text{ A} \quad \textcircled{I}$$

$$n = f\left(\frac{I_k}{I_k}, t\right) = f(6, 0.2) \approx 0.53 \quad \text{ } \left. \begin{array}{l} \text{ } \\ \text{ } \end{array} \right\} \text{ očitavamo iz doma tablice}$$

$$m = f(K, t) = f(1.645, 0.2) \approx 0.18$$

$$K = 1.02 + 0.98e^{-3 \frac{t}{\tau}} = 1.02 + 0.98e^{-3 \cdot 0.15} = 1.645$$

$$I_t = I_{k3_{uk}} \cdot \sqrt{m+n} = 3.404 \cdot \sqrt{0.18+0.53} = 2.868 \text{ kA} \quad \textcircled{II}$$

- iz doma tablice odabire se obojeni bakreni plosnati profil 40x10 dopuštenog trajnog opterećenja 835 A, presjeka

$$Q = 40 \cdot 10 = 400 \text{ mm}^2$$

- provjera presjeka za bakar: $Q_{cu} \geq 7.5 \cdot \sqrt{I_t} \cdot I_t$

$$Q_{cu} \geq 7.5 \cdot \sqrt{2.868} \cdot 2.868 = 9.62 \text{ mm}^2 \checkmark$$

- zadovoljava

$$⑦ \quad X_{dAM} = X_{iAM} = \frac{c \cdot U_B^2}{S_{K3}} = \frac{1.1 \cdot 30^2}{250} = 3.96 \, \Omega$$

$$X_{oAM} = c \cdot U_B^2 \left(\frac{3}{S_{K1}} - \frac{2}{S_{K3}} \right) = 1.1 \cdot 30^2 \cdot \left(\frac{3}{180} - \frac{2}{250} \right) = 8.58 \, \Omega$$

$$X_{dT} = X_{iT} = X_{oT} = \frac{U_{K1}}{100} \cdot \frac{U_B^2}{S_n} = \frac{8}{100} \cdot \frac{30^2}{20} = 3.6 \, \Omega$$

$$X_{dg}'' = \frac{X_d''}{100} \cdot \frac{U_B^2}{S_n} = \frac{10}{100} \cdot \frac{30^2}{20} = 4.5 \, \Omega$$

$$X_{dg}' = \frac{55}{100} \cdot \frac{30^2}{20} = 24.75 \, \Omega$$

$$X_{dg} = \frac{120}{100} \cdot \frac{30^2}{20} = 54 \, \Omega$$

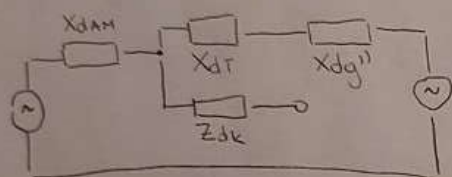
$$X_{ig} = \frac{13}{100} \cdot \frac{30^2}{20} = 5.85 \, \Omega$$

$$X_{og} = \infty$$

$$Z_{LK} = Z_{LK} = (0.1 + j0.35) \cdot 10 = 1 + j3.5 \, \Omega \quad \left\{ \begin{array}{l} \text{ali ćemo ju zanemariti pri približnom} \\ \text{proračunu KS (iz zadatka)} \end{array} \right.$$

$$Z_{oK} = (0.3 + j1.5) \cdot 10 = 3 + j15 \, \Omega$$

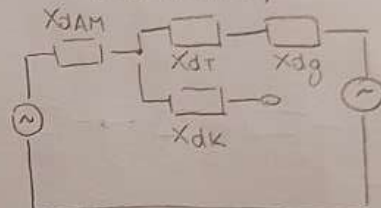
Direktna (početna)



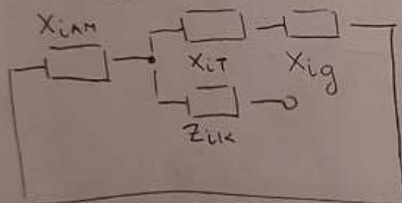
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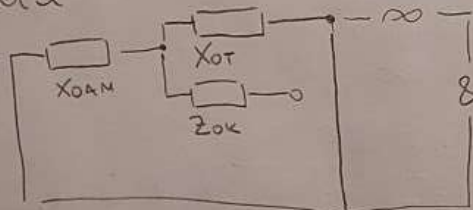
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Inverzna



Nulta



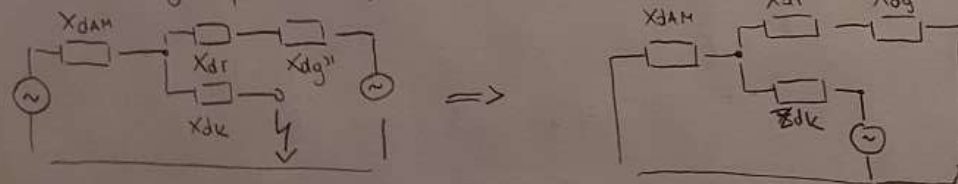
- izbor kabela se vrši prema: - $I_{max, pog}$

- I_t (mjerodavna I_{K3})

$$I_{max, pog} = \frac{S_{max}}{\sqrt{3} \cdot U_n} = \frac{(20 + 10) \cdot 10^6}{\sqrt{3} \cdot 30 \cdot 10^3} = 577.35 \, A$$

\rightarrow nema u datoj tablici

- kratki spoj (početni)



- otpor koji se vidi s mjesta KS:

$$Z_{duk} = \underbrace{Z_{LK}}_{\text{zanemaruje se}} + [X_{dAM} \parallel (X_{dT} + X_{dg}'')] = X_{dAM} \parallel (X_{dT} + X_{dg}'') = 3.96 \parallel (3.6 + 4.5) = 2.66 \, \Omega$$

$$I_{K3}'' = \frac{c \cdot U_B}{\sqrt{3} \cdot |Z_{duk}|} = \frac{1.1 \cdot 30}{\sqrt{3} \cdot 2.66} = 7.16 \, kA$$

- provjera se vrši prema:

$$Q > \alpha \cdot I_t \cdot \sqrt{t} = 8.7 \cdot 7.16 \cdot \sqrt{0.3} = 34.135 \, mm^2$$

$$I_t = I_{K3}'' \cdot \sqrt{t} = 7.16 \cdot \sqrt{0.3} = 7.16 \, kA$$

$$I_{dop} = I_{dop, tablica} \cdot k_1 \cdot k_2 \cdot k_3 \cdot k_4 \geq I_{max, pog}$$

$$= I_{dop, tablica} \cdot 1 \cdot 0.84 \cdot 1 \cdot 1.26$$

$$= 1.0584 I_{dop, tablica} \geq I_{max, pog}$$

- da smo našli odgovarajući kabel iz tablice
onda bi smo uvrstili njegov presjek i dopuštenu
struju u izrazu i provjerili da li odabrani
kabel zadovoljava

$$⑧ \quad X_{dT2} = X_{iT2} = \frac{u_k\%}{100} \cdot \frac{U_n^2}{S_n} = \frac{6}{100} \cdot \frac{30^2}{40} = 1.35 \Omega$$

$$X_{oT2} = 10 \cdot X_{dT2} = 10 \cdot 1.35 = 13.5 \Omega$$

$$X_{dv} = 0.4 \cdot 15 = 6 \Omega = X_{iv}$$

$$X_{ov} = 3 \cdot X_{dv} = 18 \Omega$$

$$X_{dT1} = X_{iT1} = \frac{8}{100} \cdot \frac{30^2}{40} = 1.8 \Omega$$

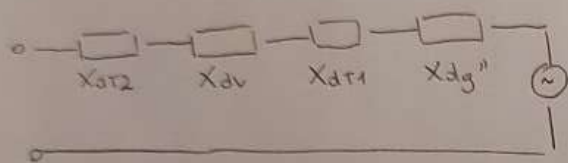
$$X_{oT1} = 10 \cdot 1.8 = 18 \Omega$$

$$X_{dg''} = \frac{X_d''}{100} \cdot \frac{U_n^2}{S_n} = \frac{15}{100} \cdot \frac{30^2}{40} = 3.375 \Omega$$

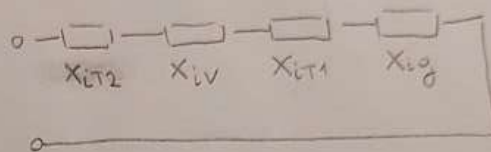
$$X_{ig} = \frac{14}{100} \cdot \frac{30^2}{40} = 3.15 \Omega$$

$$X_{og} = \frac{6}{100} \cdot \frac{30^2}{40} = 1.35 \Omega$$

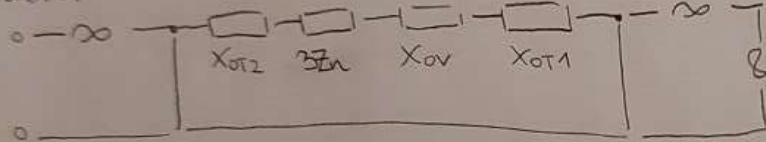
Direktna



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Nulta



- izbor rastavljača se vrši

prema: - U_n

- $I_{max, pog}$

- provjera prema:

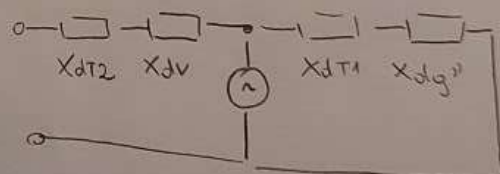
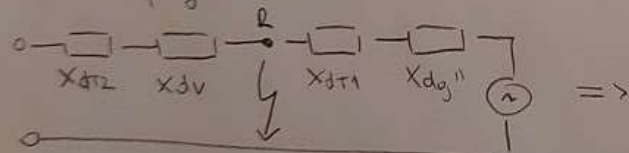
- I_t } mjeračom I_{k3}

- I_u (piše u zadatku)

$$U_n = 30 \text{ kV}$$

$$I_{max, pog} = \frac{S_{max}}{\sqrt{3} \cdot U_n} = \frac{40 \cdot 10^6}{\sqrt{3} \cdot 30 \cdot 10^3} = 769.8 \text{ A}$$

- kratki spoj



- otpor koji se vidi s mjesta KS: $Z_{duk} = (X_{dT1} + X_{dg''}) \parallel \infty = X_{dT1} + X_{dg''}$

$$I_{k3} = \frac{C \cdot U_B}{\sqrt{3} \cdot |Z_{duk}|} = \frac{1.1 \cdot 30}{\sqrt{3} \cdot 5.175} = 3.68 \text{ kA}$$

$$= 1.8 + 3.375 = 5.175 \Omega$$

$$K = 1.02 + 0.98e^{-3 \cdot \frac{R}{X}} = 1.02 + 0.98e^{-3 \cdot 0.1} = 1.746$$

$$m = f(K, t) = f(1.746, 0.4) \approx 0.1$$

$$n = f\left(\frac{I_k}{I_k''}, t\right) = f(6, 0.4) \approx 0.41$$

$$I_u = \sqrt{2} \cdot K \cdot I_{k3} = \sqrt{2} \cdot 1.746 \cdot 3.68 = 9.09 \text{ kA}$$

$$I_t = I_{k3} \cdot \sqrt{m+n} = 3.68 \cdot \sqrt{0.1+0.41} = 2.63 \text{ kA}$$

- provjera

$$I_u = 9.09 \text{ kA} < 100 \text{ kA} \checkmark$$

$$I_t \cdot \sqrt{\frac{1}{t}} = 2.63 \cdot \sqrt{\frac{1}{0.4}} = 4.16 \text{ kA} < 60 \text{ kA} \checkmark$$

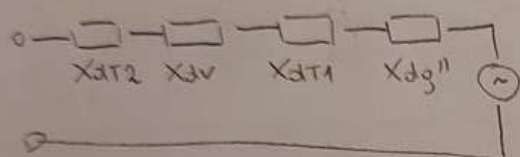
\Rightarrow odabran je dobar rastavljač

- gledamo tablicu i odabiramo rastavljač nazivnog napona 35 kV, nazivne struje 1000 A s dopuštenom $I_u = 100 \text{ kA}$ i $I_t = 60 \text{ kA}$ (kroz 1 s!)

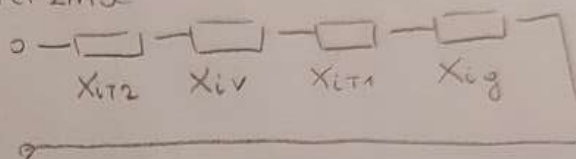
9.) $X_{dT2} = \frac{6}{100} \cdot \frac{30^2}{40} = 1.35 \Omega = X_{i2}$
 $X_{OT2} = 10 \cdot 1.35 = 13.5 \Omega$
 $X_{dV} = 0.4 \cdot 15 = 6 \Omega = X_{iV}$
 $X_{OV} = 3 \cdot 6 = 18 \Omega$
 $X_{dT1} = \frac{8}{100} \cdot \frac{30^2}{40} = 1.8 \Omega = X_{i1}$
 $X_{OT1} = 10 \cdot 1.8 = 18 \Omega$
 $X_{dg''} = \frac{15}{100} \cdot \frac{30^2}{40} = 3.375 \Omega$
 $X_{ig} = \frac{14}{100} \cdot \frac{30^2}{40} = 3.15 \Omega$
 $X_{og} = \frac{6}{100} \cdot \frac{30^2}{40} = 1.35 \Omega$

- izbor prekidača se vrši prema:
 - U_n
 - $I_{max, pog}$
 - S_r

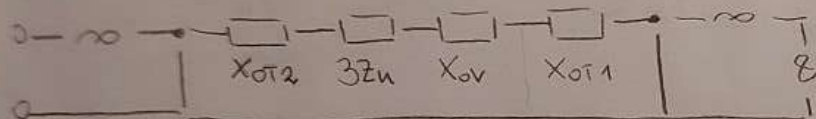
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Nulta



$$U_n = 30 \text{ kV}$$

$$I_{max, pog} = \frac{40 \cdot 10^6}{\sqrt{3} \cdot 30 \cdot 10^3} = 769.8 \text{ A}$$

$S_r = \sqrt{3} \cdot U_n \cdot I_r \rightarrow$ najveća struja koju prekidač mora moći prekinuti, pašto mreža ima jednog odvod to će biti struja kratkog spoja na sabirnici A

- možemo naći najnepovoljniji I_{k3} , dva su načina: I) izračunati sve pa viditi

II) $Z_{duk} = X_{dT1} + X_{dg''} = 1.8 + 3.375 = 5.175 \Omega$

$Z_{iuk} = X_{iT1} + X_{ig} = 1.8 + 3.15 = 4.95 \Omega$

$Z_{ouk} = X_{OT1} \parallel (X_{OT2} + 3Z_n + X_{OV}) = 18 \parallel (13.5 + 3 \cdot 10 + 18) = 13.92 \Omega$

$$\alpha \approx 0.95$$

$$\beta \approx 0.35 \Rightarrow \text{iz tablice najnepovoljniji } I_{k3}$$

$$I_{k3} = \frac{C \cdot U_n}{\sqrt{3} \cdot |Z_{duk}|} = \frac{1.1 \cdot 30}{\sqrt{3} \cdot 5.175} = 3.68 \text{ kA} = I_r$$

$$S_r = \sqrt{3} \cdot 30 \cdot 10^3 \cdot 3.68 \cdot 10^3 = 191.3 \text{ MVA}$$

Odabire se prekidač: $U_n = 30 \text{ kV}$

$$S_n = 750 \text{ MVA}$$

$$I_n = 1250 \text{ A}$$

} iz tablice