AUDITORNE

① Na vodičima 110 kV Dalekovoda ac 95 udaljenim 4 m, izmjeren je napon 112 kV i $I = 100$ A

Izolatorski lanac ovog dalekovoda ima 6 članaka (istih kapaciteta → 120 pF) kapaciteti metalnih dijelova lanca prema vodiču iznose 3, 4, 5, 6, 7 pF, a prema uzemljenim dijelovima 8, 11, 13, 16 i 18 pF. → najbliži uzemljenom!

a) odredite koji izolatorski članak je najmanje opterećen i koliko je to opterećenje?

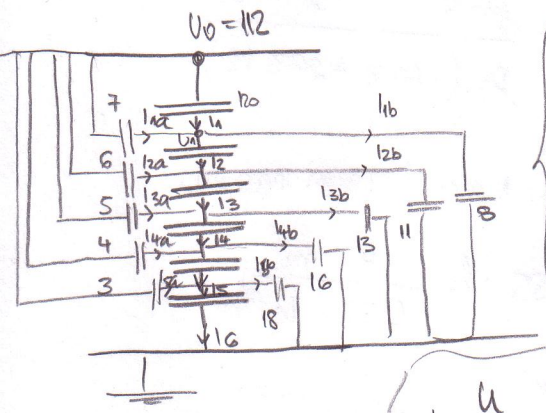
b) na kojoj min. nadmorskoj visini će se pojaviti korona na ovom vodiču (minimalnoj)

0 m n.v. → 20°C

2000 m n.v. → 0°C

$$p = p_0 e^{-\frac{z}{H}} \quad ; H = 8.15 \text{ km}$$

$m_v = 0.85$



$$\begin{aligned}
I_1 + I_{1a} &= I_2 + I_{1b} \Rightarrow \underbrace{120(112 - U_1)}_{I_1} + 7(112 - U_1) = 120(U_1 - U_2) + 8U_1 \\
I_2 + I_{2a} &= I_3 + I_{2b} \Rightarrow 120(U_1 - U_2) + 6(112 - U_2) = 120(U_2 - U_3) + 11U_2 \\
I_3 + I_{3a} &= I_4 + I_{3b} \Rightarrow 120(U_2 - U_3) + 5(112 - U_3) = 120(U_3 - U_4) + 13U_3 \\
I_4 + I_{4a} &= I_5 + I_{4b} \Rightarrow 120(U_3 - U_4) + 4(112 - U_4) = 120(U_4 - U_5) + 16U_4 \\
I_5 + I_{5a} &= I_6 + I_{5b} \Rightarrow 120(U_4 - U_5) + 3(112 - U_5) = 120U_5 + 18U_5
\end{aligned}$$

→ 5 jednadžbi s 5 nepoznanica

$$I = \frac{U}{Z} = \frac{U}{\frac{1}{j\omega C}} = U j\omega C$$

$$\begin{aligned}
255U_1 - 120U_2 &= 14225 \\
-120U_1 + 257U_2 - 120U_3 &= 672 \\
-120U_2 + 258U_3 - 120U_4 &= 560 \\
-120U_3 + 260U_4 - 120U_5 &= 448 \\
-120U_4 + 261U_5 &= 336
\end{aligned}$$

$$\begin{bmatrix} 255 & -120 & 0 & 0 & 0 \\ -120 & 257 & -120 & 0 & 0 \\ 0 & -120 & 258 & -120 & 0 \\ 0 & 0 & -120 & 260 & -120 \\ 0 & 0 & 0 & -120 & 261 \end{bmatrix} \begin{bmatrix} U_1 \\ U_2 \\ U_3 \\ U_4 \\ U_5 \end{bmatrix} = \begin{bmatrix} 14224 \\ 672 \\ 560 \\ 448 \\ 336 \end{bmatrix}$$

14224 → $112 \cdot 120 + 7 \cdot 112$

448 → $4 \cdot 112$

336 → $3 \cdot 112$

→ AES !

Anwić 8D

→ to · inverz

$$\begin{bmatrix} U_1 \\ U_2 \\ U_3 \\ U_4 \\ U_5 \end{bmatrix} = \begin{bmatrix} 85.994 \\ 64.205 \\ 45.912 \\ 29.839 \\ 15.006 \end{bmatrix}$$

14.833 → na članku

$U_G = 0$

b) → napon na kojem se počinje pojavljivati korona $U_c = 30\,\delta m_v r \ln\frac{D}{r}$

D → udaljenost vodiča; r → iz presjeka

napon na kojoj se vidi korona $U_c = 30\,\delta m_v r \left(1 + \frac{0.3}{\sqrt{\delta r}}\right) \cdot \ln\frac{D}{r}$

↓ $\frac{kV}{cm}$; vršna ef. vrijednost

$S = r^2\pi \Rightarrow r = 5.50$ mm

formula za opadanje temp. $t(z) = -10z + 20$ (u Kelvinima !)

$$\delta = \frac{p \cdot T_0}{p_0 \cdot T} = \frac{p_0 e^{-\frac{z}{H}} \cdot 293.15}{p_0(-10z + 293.15)}$$

(112 je linijski, efektivni → treba preći na vršnu ! i na faznom naponu...

$$\frac{112\sqrt{2}}{\sqrt{3}} = 30 \cdot \delta \cdot 0.85 \cdot 0.55 \cdot \ln\frac{4 \text{ m}}{0.55 \cdot 10^{-2}\text{ m}}$$

0.55 ↓ r (cm)

↓ $\delta = 0.9895$

$$e^{-\frac{z}{8.15}} = -0.03376z + 0.9895$$

$$e^{-\frac{z}{8.15}} + 0.03376z = 0.9895$$

z = 0.119 km

/provjeritiiii

(2) Jednožilni el. kabel priključen je na napon $10.7/\sqrt{3}$ kV pogonska frekvencija, dug 6.1 km; ima 2 različita dielektrika:

$\varepsilon_{r1} = 3.4 \quad \operatorname{tg}\delta_1 = 1.2 \cdot 10^{-3}$

$\varepsilon_{r2} = 2.3 \quad \operatorname{tg}\delta_2 = 1.4 \cdot 10^{-3}$

$r_1 = 20$ mm

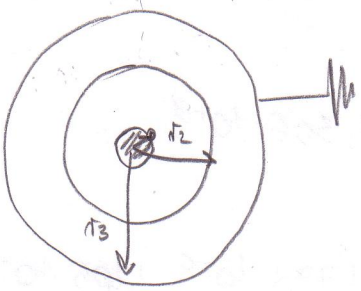
$r_2 = 9.5$ mm

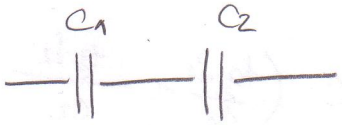
$r_3 = 12$ mm

a) koliko djelatne i jalove snage troši kabel?

b) odredite najveću vrijednost el. polja u kabelu?

→ izolacija se modelira sa C-om





→ napon je konst.

$Q = C \cdot U = \text{konst.}$

$P_g = P_{g1} + P_{g2}$

$U^2 = \frac{Q^2}{C^2}$

$\operatorname{tg}\delta = \frac{I_r}{I_c}$

$P_g = U I_r = U \cdot I_c \cdot \operatorname{tg}\delta = U \cdot U \cdot \omega C \cdot \operatorname{tg}\delta$

$U^2 \omega C \operatorname{tg}\delta = U_1^2 \omega C_1 \operatorname{tg}\delta_1 + U_2^2 \omega C_2 \operatorname{tg}\delta_2$

$\frac{Q^2}{C^2} \omega C \operatorname{tg}\delta = \frac{Q^2}{C_1^2} \cdot \omega C_1 \operatorname{tg}\delta_1 + \frac{Q^2}{C_2^2} \omega C_2 \cdot \operatorname{tg}\delta_2$

$\frac{\operatorname{tg}\delta}{C} = \frac{\operatorname{tg}\delta_1}{C_1} + \frac{\operatorname{tg}\delta_2}{C_2}$

$Q = \oint_S \vec{D} d\vec{S}$

$\int \vec{E} d\vec{S} = \frac{Q}{\varepsilon_0 \varepsilon_r}$

$d\vec{S}$ → oplošje valjka $2r\pi \cdot l$

$E = \frac{Q}{2\pi r l \varepsilon_0 \varepsilon_r}$

$U = \int_{r_1}^{r_2} E \, dr =$

$= \frac{Q}{2\pi l \varepsilon_0 \varepsilon_r} \int_{r_1}^{r_2} \frac{dr}{r} = \frac{Q}{2\pi l \varepsilon_0 \varepsilon_r} \cdot \ln \frac{r_2}{r_1}$

$$U = \frac{Q}{2\pi l \varepsilon_0 \varepsilon_r} \cdot \ln \frac{r_2}{r_1}$$

$$C = \frac{Q}{U} = \frac{2\pi \varepsilon_0 \varepsilon_r \cdot l}{\ln \frac{r_2}{r_1}}$$

$$C_1 = \frac{2\pi \varepsilon_0 \varepsilon_{r1} l}{\ln \frac{r_2}{r_1}} \qquad C_2 = \frac{2\pi \varepsilon_0 \varepsilon_{r2} \cdot l}{\ln \frac{r_3}{r_2}}$$

$C_1 = 3{,}778 \cdot 10^{-6}\ F \qquad C_2 = 3.341 \cdot 10^{-6}\ F$

$$C = \frac{C_1 C_2}{C_1 + C_2} = 1.773 \cdot 10^{-6}\ F$$

$$tg\delta = C \cdot \left(\frac{tg\delta_1}{C_1} + \frac{tg\delta_2}{C_2} \right) = 1.306 \cdot 10^{-3}$$

$$P_g = U^2 \omega C \cdot tg\delta = \left(\frac{10700}{\sqrt{3}} \right)^2 \cdot 2\pi \cdot 50 \cdot 1.773 \cdot 10^{-6} \cdot 1.306 \cdot 10^{-3} = 27.764\ W$$

PIŠI SVE!

$$Q_g = \frac{P_g}{tg\delta} = 21.259\ kVAr$$

b) U_{13} – međufazni napon

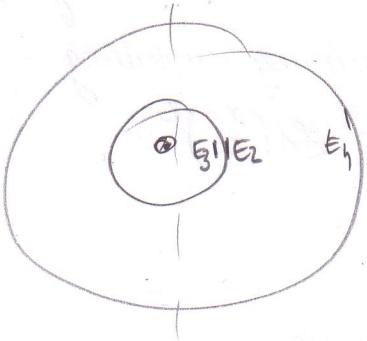
$$E = \frac{U_{13}}{\varepsilon_r \cdot r \left(\frac{1}{\varepsilon_{r1}} \ln \frac{r_2}{r_1} + \frac{1}{\varepsilon_{r2}} \ln \frac{r_3}{r_2} \right)}$$

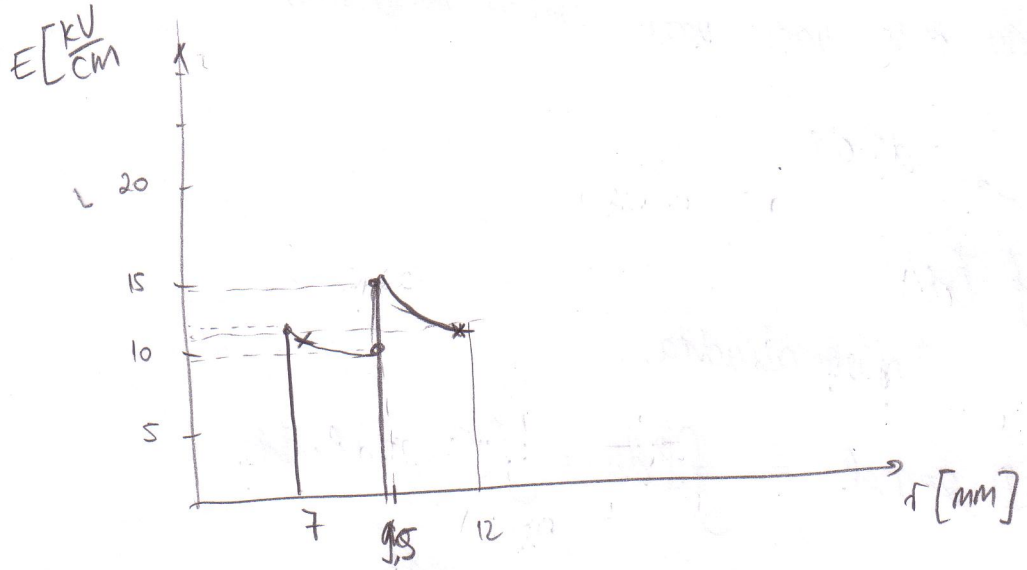
ε_r – ovisno o izolatoru; r – ovisno o smjeru

$$E_1(r_1) = \frac{10700/\sqrt{3}\ kV}{3.4 \cdot 0.7\ cm \left(\frac{1}{3.4} \ln \dots \right)} = 13.562\ kV/cm$$

$$E_2(r_2) = \frac{\dots}{2.3 \cdot} = 14.772\ kV/cm$$

→ vraćanje na sliku





$$E_3 = \frac{U_{13}}{\varepsilon_{r1} \cdot r_2 \cdot K} = 9.99 \frac{kV}{cm}$$

$$E_1 = \frac{U_{13}}{\varepsilon_{02} r_3 \cdot K} = 11.69 \frac{kV}{cm}$$

npr. r gdje je $E = 12$ kV/cm → može biti dva r-a

③ U izolaciji istosmjernog kabela postoji mala vodljivost. Duljina kabela je l, radijus $r_1 = 1.45$ cm, a radijus uzemljenog metalnog plašta $r_2 = 3.5$ cm ; $\varepsilon_r = 3$; gustoća $\rho = \rho_1 \left(\frac{r_1}{r}\right)^2$,

$\rho_1 = 12$ nAs / cm^3

Na kojem potencijalu će se naći vodič nakon iskapčanja pogonskog napona.

ds·dr

$$\oint \rho dV = \oint \vec{D} d\vec{S}$$

ploha cilindra

$$D \cdot 2\pi r l = \oint \rho dV = \int \rho \cdot 2\pi r l \cdot dr$$

$$= \rho_1 \cdot \left(\frac{r_1^2}{r^2}\right) \cdot 2\pi r l dr =$$

$$= \rho_1 \cdot r_1^2 \cdot 2\pi l \cdot \int_{r_1}^{r} \frac{dr}{r} =$$

$$= \rho_1 r_1^2 \cdot 2\pi l \cdot \ln \frac{r}{r_1}$$

$$D = \frac{\rho_1 \cdot r_1^2 \cdot \ln \frac{r}{r_1}}{r}$$

$$E = \frac{D}{\varepsilon_0 \varepsilon_r} = \frac{\rho_1 r_1^2 \ln \frac{r}{r_1}}{r \cdot \varepsilon_0 \varepsilon_r}$$

$$U = \int_{r_1}^{r_2} E dr = \int_{r_1}^{r_2} \frac{\rho_1 r_1^2 \ln \frac{r}{r_1}}{r \varepsilon_0 \varepsilon_r} \cdot dr$$

od r_1 do r_2 kompletno el. polje

supst. $\left| \begin{array}{l} \ln\frac{r}{r_1} = t \\ \frac{r_1}{r}\cdot\frac{1}{r_1} = dr = dt \end{array} \right.$ $\frac{dr}{r} = dt$

$$= \frac{\rho_1 r_1^2}{\varepsilon_0\varepsilon_r}\int t\,dt = \frac{\rho_1 r_1^2}{\varepsilon_0\varepsilon_r}\cdot\frac{t^2}{2} = \frac{\rho_1 r_1^2}{\varepsilon_0\varepsilon_r}\cdot\frac{1}{2}\ln^2\frac{r}{r_1}\Big|_{r_1}^{r_2} =$$

$$U = \frac{\rho_1 r_1^2}{\varepsilon_0\varepsilon_r}\cdot\frac{1}{2}\ln^2\frac{r_2}{r_1} = \frac{12\cdot\frac{10^{-9}}{10^{-6}}(1.45\cdot10^{-2})^2}{2\cdot 8.854\cdot10^{-12}\cdot 3}\cdot\ln^2\frac{3.5}{1.45} =$$

$$= 36.87\ kV$$

Odredite

(4) Optimalne duljine vodljivih obloga u provodnom izolatoru.

Obloge se ugrađuju u provodni izolator da bi se dobila povoljnija raspodjela potencijala odn. el. polja.

Zadaća je geom.: $l_3 = 80$ mm duljina prirubnice

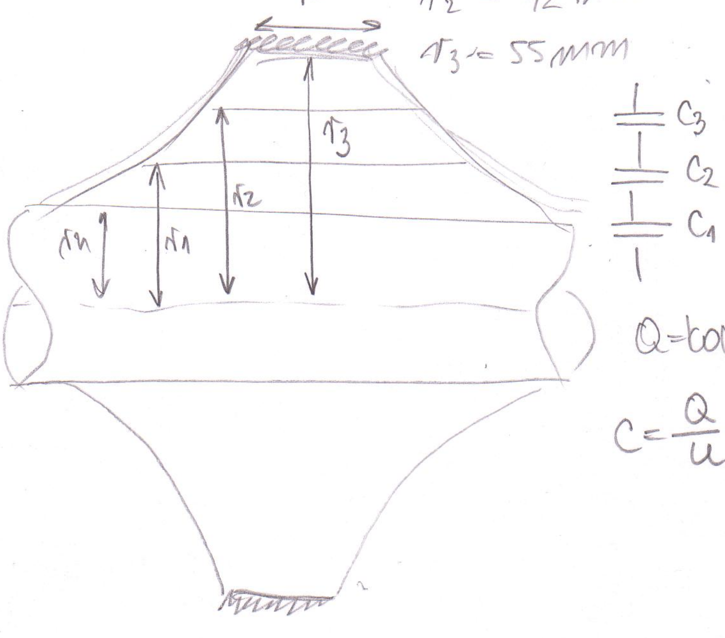
$r_u = 18$ mm

$r_1 = 30$ mm

$r_2 = 42$ mm

$r_3 = 55$ mm

$\varphi_3 - \varphi_2 = \varphi_2 - \varphi_1 = \varphi_1 - \varphi_0 = U$ želja



Q = konst.

$C = \frac{Q}{U} =$ konst

$$C_1 = \frac{2\pi\varepsilon_0\varepsilon_r l_1}{\ln\frac{r_1}{r_u}} =$$

$$C_2 = \frac{2\pi\varepsilon_0\varepsilon_r l_2}{\ln\frac{r_2}{r_1}} =$$

$$= C_3 = \frac{2\pi\varepsilon_0\varepsilon_r l_3}{\ln\frac{r_3}{r_2}}$$

izjednačimo R C2 i C3

$$l_2 = \frac{\ln \frac{r_2}{r_1}}{\ln \frac{r_3}{r_2}} \cdot l_3 = 99.82\ mm$$

$$l_1 = \frac{\ln \frac{r_1}{r_4}}{\ln \frac{r_3}{r_2}} l_3 = 151.54\ mm$$