Transmisi dan Distribusi Tenaga Listrik

KARAKTERISTIK LISTRIK DARI SALURAN TRANSMISI

KARAKTERISTIK SALURAN TRANSMISI

Konstanta – konstanta saluran

- Tahanan (R)
- Induktansi (L)
- Konduktansi (G)
- Kapasitansi (C)

Untuk Saluran Udara, G sangat kecil, untuk memudahkan perhitungan dapat diabaikan, pengaruhnya masih dalam batas yang di dapat diabaikan

Tahanan

$$R = \rho \frac{l}{A}$$

- ρ = Resistivias
- L = Panjang kawat
- A = Luas penampan

Karena kebanyakan kawat penghantar adalah kawat pilin, maka terdapat faktor koreksi panjang sebesar

1 : untuk konduktor padat

1.01 : Konduktor pilin yang terdiri 2 lapis

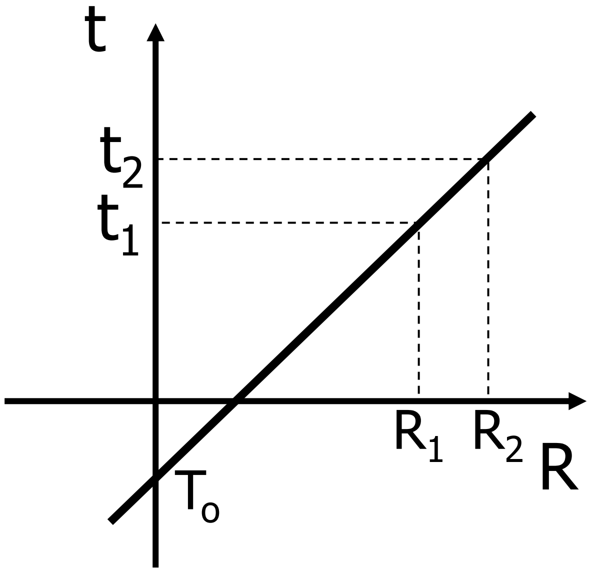
1.02 : Knduktor pilin lebih dari 2 lapis

	Mikro – Ohm – cm (pada berbagai temperatur)						
Material	ρ_0	ρ_{20}	ρ_{25}	ρ_{50}	ρ_{75}	ρ_{80}	ρ_{100}
Cu 100%	1.58	1.72	1.75	1.92	2.09	2.12	2.26
CU97.5%	1.63	1.77	1.8	1.97	2.14	2.18	2.31
Al 61%	2.6	2.83	2.89	3.17	3.46	3.51	3.74

Pengaruh suhu terhadap Tahanan

$$R_{t2} = R_{t1}[1+\alpha_{t1}(t_2 - t_1)]$$

$$\frac{R_{t2}}{R_{t1}} = \frac{T_0 + t_2}{T_0 + t_1}$$



- R_{t2}= tahanan pada temperatur t2
- R_{t1}= tahanan pada temperatur t1
- α_{t1} = koeffisien tahanan pada temperatur t1

$$T_0 = \frac{1}{\alpha_{t1}} - t_1$$

- T_0= Temperatur dimana tahanan kawat = 0

Tahanan

- α_{20} = koeffisien temperatur dari tahanan pada 20 ^{o}C

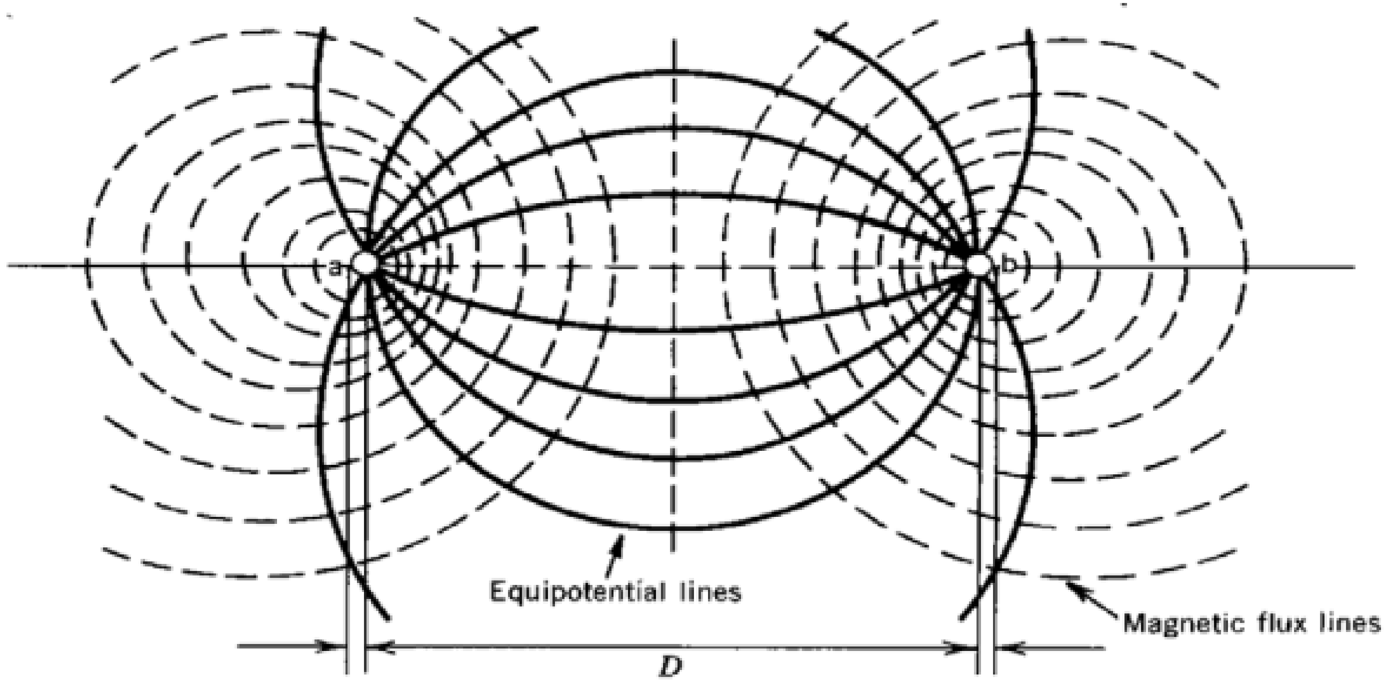
Tembaga (Cu) 100% mempunyai α_{20}= 0.00393

T_o = (1/0.00393) – 20 =234.5 ^{o}C

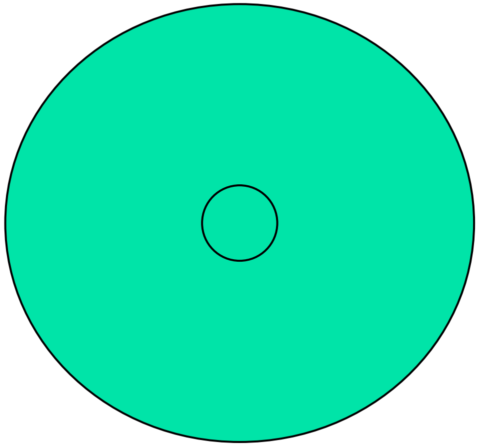
Material	α_{20} (x 10^{-3})	T_o (^{o}C)
Cu 100%	3.93	234.5
CU97.5%	3.83	241.0
Al 61%	4.03	228.1

Efek kulit adalah gejala pada arus bolak-balik karena distribusi arus yang tidak merata, meningkatnya frekuensi arus bolak balik maka distribusia arus makin tidak merata. Kerapatan arus dalam penampang konduktor tersebut makin besar ke arah permukaan kawat. Tetapi bila kita hanya meninjau frekuensi kerja (50 Hertz atau 60 Hertz) dan jari – jari yang cukup besar maka pengaruh efek kulit itu sangat kecil dan dapat diabaikan.

Efek sekitar adalah pengaruh dari kawat lain yang berada di samping kawat yang pertama (yang ditinjau) sehingga distribusi fluks tidak simetris lagi. Tetapi bila radius konduktor kecil terhadap jarak antara kedua kawat maka efek sekitar ini sangat kecil dan dapat diabaikan.



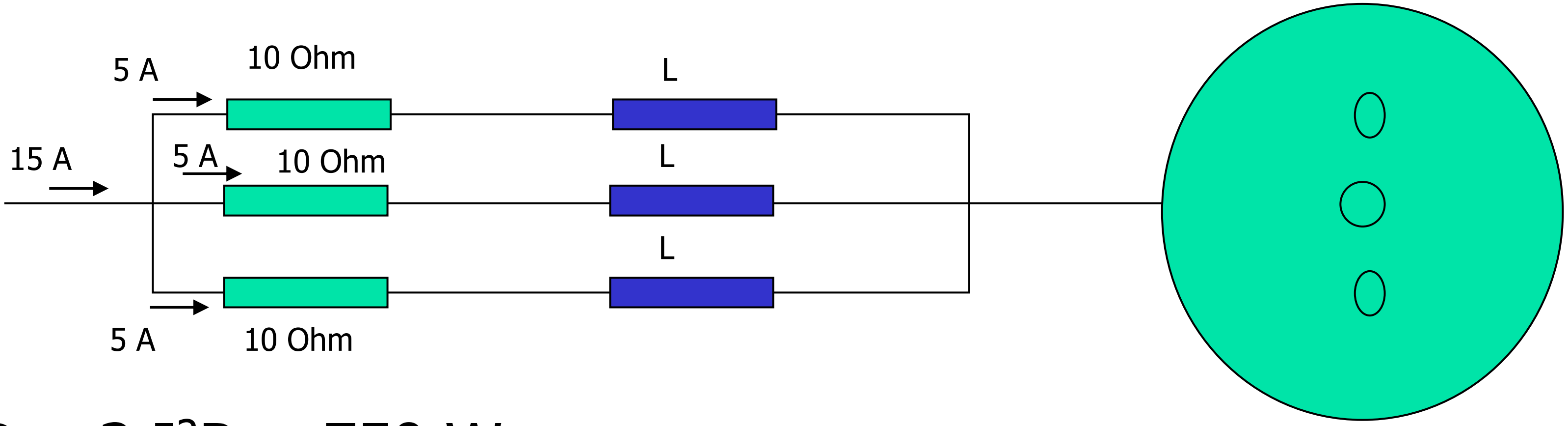
Skin Effect



Pengaruh impedansi yang makin membesar pada pusat konduktor atau pengaruh impedansi yang tergantung pada kerapatan konduktor sehingga mengakibatkan harga tahanan effektifnya akan lebih besar .

Tahanan

Sistem DC



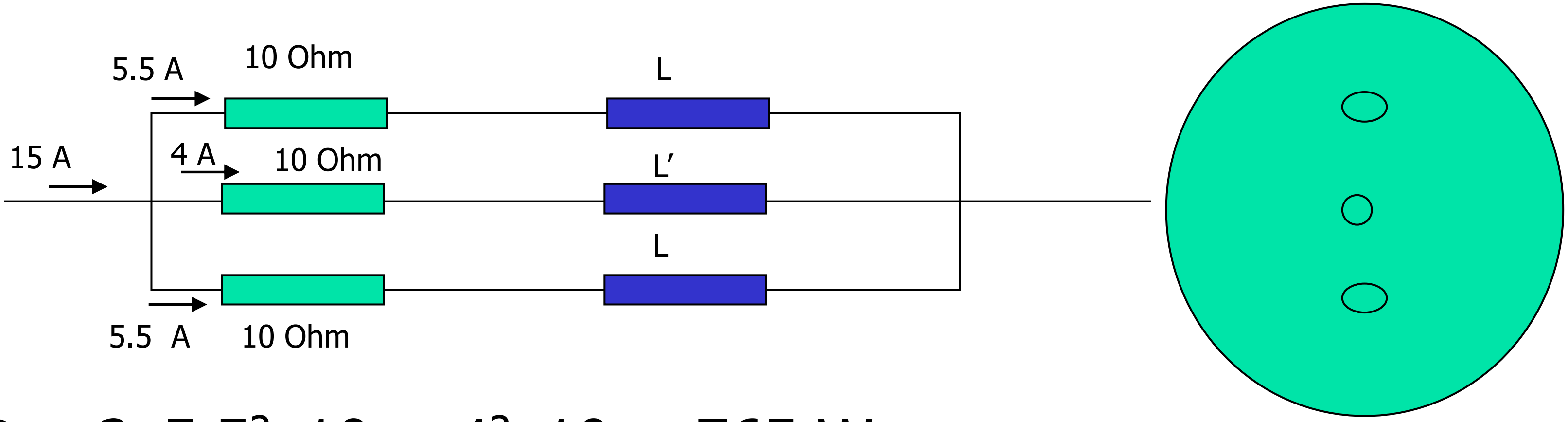
$P = 3\ I^2R = 750\ W$

$Req = P/(I^2) = 750/225 = 3.33\ Ohm$

$R_{DC} = 3.33\ Ohm$

Tahanan

Sistem AC



$P = 2x5.5^2x10 + 4^2x10 = 765$ W

$Req = P/(I^2) = 765/225 = 3.4$ Ohm

$R_{AC} = 3.4$ Ohm

INDUKTANSI DAN REAKTANSI INDUKTIF DARI RANGKAIAN FASA TUNGGAL

Untuk penurunan rumus induktansi dan reaktansi induktif konduktor, diabaikan 2 faktor :

1. Effect Kulit (Skin effect)
2. Effect Sekitar (proximity effect)

Induktansi

Adanya flux magnet pada saluran $\varepsilon = \frac{d\phi}{dt}$

Dengan permeabilitas μ yang konstant $\phi = L\,i \Rightarrow e = L\frac{di}{dt}$

$$dan\ L = \frac{d\phi}{di}$$

Fluks magnet mempunyai hub linier dengan arus dan permeablitasnya konstant, maka

$L = \frac{\phi}{i} \Rightarrow \phi = L\,i$ **Untuk AC** $\Rightarrow$ $\psi = LI$

$$\psi \ \ dan\ \ I\ \ Sephasa$$

L riel

Induktansi

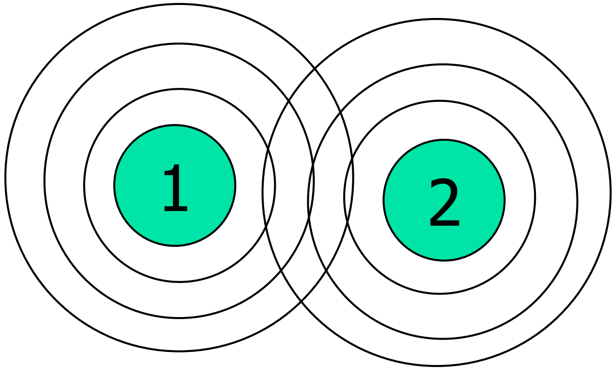
Dua Konduktor / Kumparan $\varepsilon = \dfrac{d\phi}{dt}$

Konduktor 1 arusnya I1 $\Rightarrow$ Konduktor 2 : ψ_{21}

Konduktor 2 arusnya I2 $\Rightarrow$ Konduktor 2 : ψ_{12}

$\Rightarrow$ **Timbul mutual Induktance**

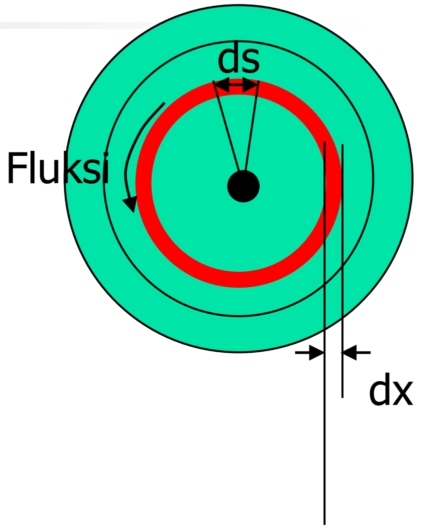
$$M_{12} = \frac{\psi_{12}}{I_2} \quad ; M_{21} = \frac{\psi_{21}}{I_1}$$



$$M_{12} = M_{21} = M$$

Induktansi disebabkan fluksi dalam

$$mmf = \oint H \bullet ds = I$$



Dari gambar disamping, jarak x dan intensitas Magnetnya Hx

$$\oint H_x \bullet ds = I_x$$

$$2\pi x H_x = I_x$$

Kerapatan arus uniformnya

$$I_x = \frac{\pi x^2}{\pi r^2} I$$

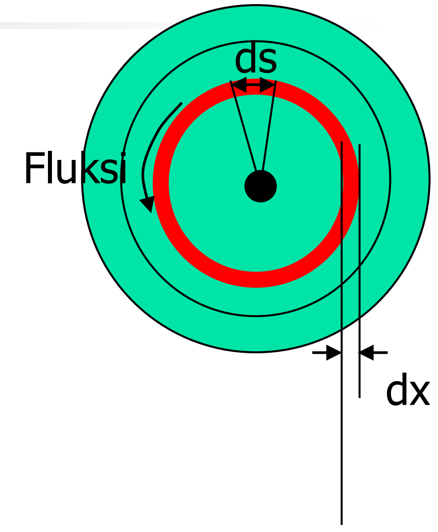
$$2\pi x H_x = \frac{x^2}{r^2} I$$

Intensitas medan magnet dengan jarak x

$$H_x = \frac{x}{2\pi r^2} I$$

Induktansi disebabkan fluksi dalam

Kerapatan Fluks



$$B_x = \mu H_x = \mu \frac{x}{2\pi r^2} I$$

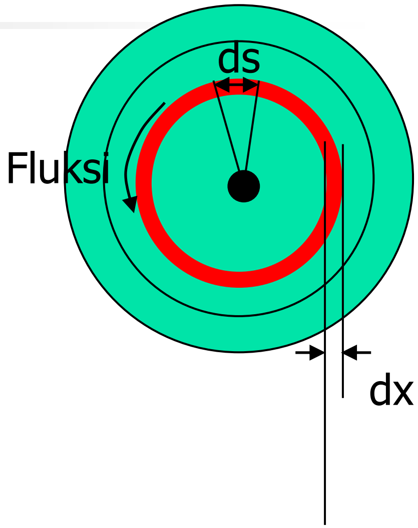
$$\mu = \mu_r \mu_o \;\; ; \mu_r = relatif \;\; permeability$$

$$\mu_o = 4\pi 10^{-7} \; H/m$$

Pada elemen setebal dx

$$fluksi/m = d\phi = \frac{\mu x}{2\pi r^2} I \, dx$$

Induktansi disebabkan fluksi dalam



Fluksi yang melingkari/m disebabkan fluksi dalam element

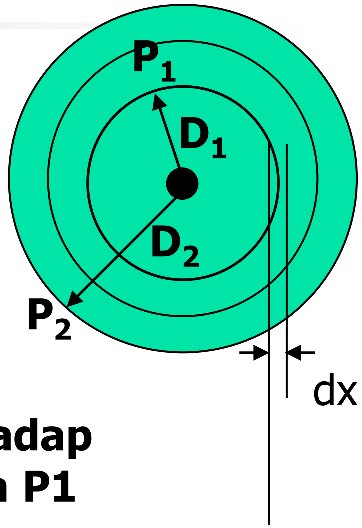
$$d\psi = \frac{\pi x^2}{\pi r^2} d\phi = \mu \frac{I x^3}{2\pi r^4}$$

$$\psi_{\text{int}} = \int_0^r \mu \frac{I x^3}{2\pi r^4} I\, dx = \mu \frac{I}{8\pi}$$

$$Jika\ \mu_r = 1\, dan\, \mu_o = 4\pi 10^{-7} H/m$$

$$\psi_{\text{int}} = \frac{1}{2} I\, 10^{-7}\ dan\ L = \frac{1}{2} 10^{-7} H/m$$

Flux Melingkar antara 2 titik Luar Konduktor



Arus pada konduktor I, Intensitas medan magnet pada elemen yang berjarak x adalah Hx

Mmf keliling elemen : $2\pi x\, H_x = I_x \; ; \; H_x = \dfrac{I}{2\pi x}$

Kerapatan flux $B_x = \mu \dfrac{I}{2\pi x}$

$$d\phi = \mu \frac{I}{2\pi x} dx$$

$$\psi_{12} = \int_{D1}^{D2} \mu \frac{I}{2\pi x} dx$$

$$= \frac{\mu\, I}{2\pi} \ln \frac{D_2}{D_1}$$

$$= 2.10^{-7}\, I \ln \frac{D_2}{D_1}$$

Induktansi yang didapat terhadap fluksi yang terkandung antara P1 dan P2

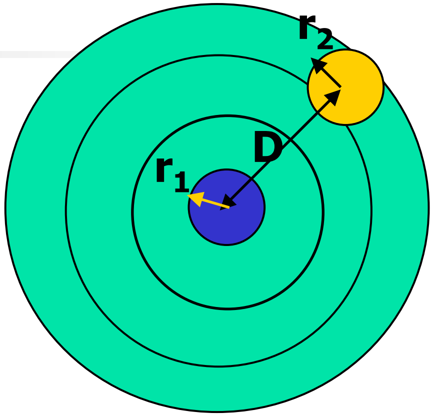
$$L_{12} = \frac{\psi_{12}}{I}$$

$$\Rightarrow L_{12} = 2.10^{-7} \ln \frac{D_2}{D_1} \; H/m$$

atau

$$L_{12} = 0{,}7411.\log \frac{D_2}{D_1} \; mH/mile$$

Induktansi Saluran 1 phasa 2 Kawat



Fluks External

$$L_1\,ext = 2.10^{-7}.\ln\frac{D_2}{r_1}$$

Fluks Internal

$$L_1\,\text{int} = \frac{1}{2}.10^{-7}$$

$L_1 = L_{1int} + L_{1ext}$

$$L_1 = (\frac{1}{2} + 2.\ln\frac{D}{r_1})10^{-7}$$

$$= 2.10^{-7}(\frac{1}{4} + \ln\frac{D}{r_1})$$

$$= 2.10^{-7}(\ln\varepsilon^{\frac{1}{4}} + \ln\frac{D}{r_1})$$

$$= 2.10^{-7}(\ln\frac{D}{r_1\varepsilon^{-\frac{1}{4}}})$$

$$dengan\; r_1' = r_1\varepsilon^{-\frac{1}{4}}$$

$$maka \quad L_1 = 2.10^{-7}.\ln\frac{D}{r'_1}\,H/m$$

$$atau \quad L_1 = 0.7441.\log\frac{D}{r'_1}\,mH/mile$$

$$\Rightarrow L_2 = 2.10^{-7}.\ln\frac{D}{r'_2}\,dan L_2 = 0.7441.\log\frac{D}{r'_2}$$

Seluruh circuit (2 kawat)

$$L = L_1 + L_2$$

$$L = 4.10^{-7}.\ln\frac{D}{r'}\,H/m$$

$$L = 1.482.\log\frac{D}{r'}\;mH/m$$

Induktansi untuk satu kawat/konduktor

$$L = 2.10^{-7} Ln \frac{D}{r'}$$ **H/m**

$$L = 0,7411 . Log \frac{D}{r'}$$ **mH/mile**

Fluksi Untuk suatu kelompok Konduktor

Konduktor 1,2,3,..n

Arus2 : $I_1, I_2, I_3, \ldots I_n$

Jarak2 : $D_{1p}, D_{2p}, D_{3p}, \ldots D_{np}$

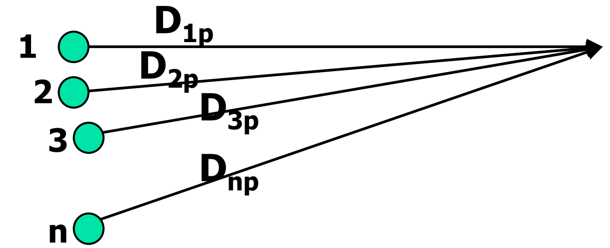
Dari persamaaan-[ersamaan terdahulu

$$\psi_{1p1} = [\frac{1}{2}.I_1 + 2.I_1 \ln \frac{D_{1p}}{r_1}].10^{-7}$$

$$\psi_{1p1} = 2.10^{-7} I_1 \ln \frac{D_{1p}}{r_1'}$$

$$\psi_{1p2} = 2.10^{-7} I_2 \ln \frac{D_{2p}}{D_{1p}}$$

Demikian untuk semua konduktor



Jadi

$$\psi_{1p} = 2.10^{-7}[I_1 \ln \frac{D_{1p}}{r_1'} + I_2 \ln \frac{D_{2p}}{D_{12}} .... + I_n \ln \frac{D_{np}}{D_{1n}}]$$

$$\psi_{1p} = 2.10^{-7}[I_1 \ln \frac{1}{r_1'} + I_2 \ln \frac{1}{D_{12}} + ... + I_n \ln \frac{1}{D_{1n}}$$

$$+ I_1 \ln D_{1p} + I_2 \ln D_{2p} + ... + I_n \ln D_{np}\ ]$$

$$\sum I = 0 \ \ jadi\ I_1 + I_2 + \ldots + I_n = 0$$

$$-(I_1 + I_2 + \ldots + I_{n-1}) = I_n$$

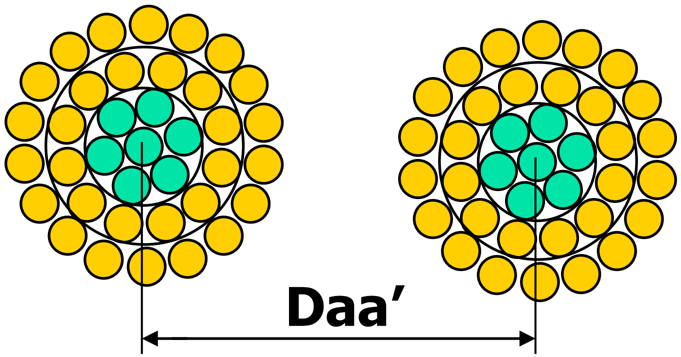
$$\psi_{1p} = 2.10^{-7}[I_1 \ln \frac{1}{r_1'} + I_2 \ln \frac{1}{D_{12}} + ... + I_n \ln \frac{1}{D_{1n}}$$

$$+ I_1 \ln \frac{D_{1p}}{D_{np}} + I_2 \ln \frac{D_{2p}}{D_{np}} + ... + I_{n-1} \ln \frac{D_{(n-1)p}}{D_{np}}$$

Secara umum $D_{1p} = D_{2p} = D_{3p} = ... = D_{np}$

$$\longrightarrow \quad \psi_1 = 2.10^{-7}[I_1 \ln \frac{1}{r_1'} + I_2 \ln \frac{1}{D_{12}} + ... + I_n \ln \frac{1}{D_{1n}}$$

Induktansi antara 2 kelompok konduktor



Konduktor X terdiri dari n filament, juga konduktor Y sedang arus dalam kedua kelompok terbagi merata

$$I_a = \frac{I_x}{n} \quad \text{dan} \quad I_{a'} = \frac{I_y}{n}$$

Sedang $I_x = -I_y \rightarrow |I_x| = |I_y| = I$

maka

$$\psi_a = 2.10^{-7}\frac{I}{n}(\ln\frac{1}{r_a'} + \ln\frac{1}{D_{ab}} + ... + \ln\frac{1}{D_{an}}) - 2.10^{-7}\frac{I}{n}(\ln\frac{1}{D_{aa'}} + \ln\frac{1}{D_{ab'}} + ... + \ln\frac{1}{D_{an'}})$$

sehingga

$$\psi_a = 2.10^{-7} I(\ln\frac{\sqrt[n]{D_{aa}D_{ab'}.....D_{an}}}{\sqrt[n]{r_a' D_{ab}D_{ac}.....D_{an}}}$$

Induktansi antara 2 kelompok konduktor

$$L_a = \frac{\psi_a}{I_a} = \frac{\psi_a}{I/n}$$

$$L_a = 2.n.10^{-7} \ln \frac{\sqrt[n]{D_{aa'} \ldots D_{an}}}{\sqrt[n]{r_a' \ldots D_{an}}}$$

$$L_{rata2} = \frac{L_a + L_b + L_c \ldots L_n}{n}$$

$$L_x = \frac{L_r}{n} = \frac{L_a + L_b \ldots L_n}{n^2}$$

sehingga

$$L_x = 2.10^{-7} \ln \frac{\sqrt[n^2]{(D_{aa'} D_{ab'} \ldots D_{an}) \ldots (D_{na'} D_{nb'} \ldots D_{nn})}}{\sqrt[n^2]{(D_{aa} D_{ab} \ldots D_{an}) \ldots (D_{na} D_{nb} \ldots D_{nn})}}$$

$$L_x = 2.10^{-7} \ln \frac{\mathrm{GMD}}{\mathrm{GMR}} \, H/m$$

$$L_x = 0{,}7411 . \log \frac{\mathrm{GMD}}{\mathrm{GMR}} \, mH/mile$$

analog

$$L_y = 2.10^{-7} \ln \frac{\mathrm{GMD}}{\mathrm{GMR}} \, H/m$$

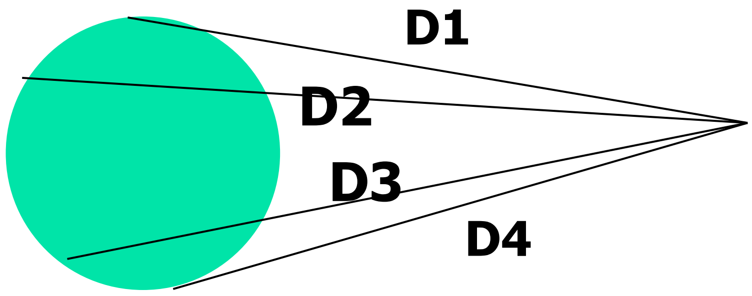
$$L_y = 0{,}7411 . \log \frac{\mathrm{GMD}}{\mathrm{GMR}} \, mH/mile$$

Untuk satu phasa 2 kelompok konduktor

$$L = L_x + L_y$$

GMD = Dm = geometric mean distance
GMR = Ds = geometric mean radius

Geometric Mean Distance

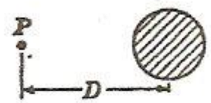
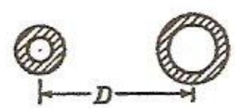


$$GMD = \sqrt[4]{D_1 D_2 D_3 D_4}$$

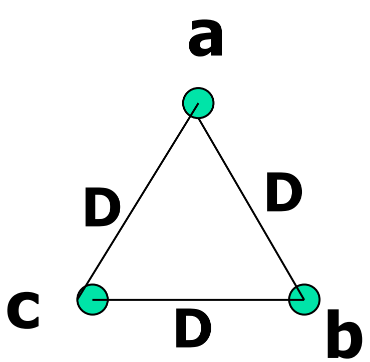
GMD = Dm = geometric mean distance

GMR = Ds = geometric mean radius

Table 2.1 Geometric Mean Distances

Description	Illustration	Value
Self GMD of a circular area		$D_s = r\epsilon^{-1/4} = 0.7788r$
GMD from one circular area to another		$D_m = D$
GMD from circular line to enclosed area		$D_m = r$
GMD from external point to circular area		$D_m = D$
GMD between n equally spaced points on a circle		$D_m = r\sqrt[n-1]{n}$
GMD from one annular area to another		$D_m = D$
Self GMD of a rectangular area		$D_s = 0.2235(a + b)$ Range of constant is 0.2231 to 0.2237, depending on ratio a/b
Self GMD of an annular area		$\ln \text{GMD} = \ln r_2 - \frac{r_1^4}{(r_2^2 - r_1^2)^2} \ln \frac{r_2}{r_1} + \frac{3r_1^2 - r_2^2}{4(r_2^2 - r_1^2)}$

Induktansi jaringan tiga phasa dengan jarak simetri



Ia +Ib + Ic = 0

Ia = - (Ib + Ic)

Dari persamaan terdahulu,utk konduktor a

$$\psi_a = 2.10^{-7}(I_a \ln\frac{1}{r'} + I_b \ln\frac{1}{D} + I_c \ln\frac{1}{D})$$

$$\psi_a = 2.10^{-7} I_a (\ln\frac{1}{r'} - \ln\frac{1}{D})$$

$$\psi_a = 2.10^{-7} I_a \ln\frac{D}{r'}$$

$$\Rightarrow L_a = 2.10^{-7} \ln\frac{D}{r'} \; H/m$$

$$L_a = 0{,}7\ 411.\log\frac{D}{r'} \; mH/mile$$

Dng banyak konduktor (stranded conductor)

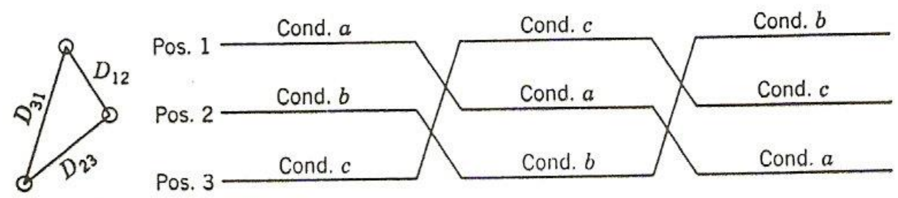
$$L_a = 2.10^{-7} \ln\frac{GMD}{GMR} \; H/m$$

$$L_a = 0{,}7411.\log\frac{GMD}{GMR} \; mH/mile$$

$$simetri \Rightarrow L_a = L_b = L_c$$

Jaringan 3 phasa dengan letak konduktor tak simetri

transposisi



Konduktor a pada posisi 1, b →2 & c →3

$$\psi_{a1} = 2.10^{-7}(I_a \ln\frac{1}{r'} + I_b \ln\frac{1}{D_{12}} + I_c \ln\frac{1}{D_{31}})$$

$$a \rightarrow 2, b \rightarrow 3 \,\&\, c \rightarrow 1$$

$$\psi_{a2} = 2.10^{-7}(I_a \ln\frac{1}{r'} + I_b \ln\frac{1}{D_{23}} + I_c \ln\frac{1}{D_{12}})$$

$$a \rightarrow 3, b \rightarrow 1 \,\&\, c \rightarrow 2$$

$$\psi_{a3} = 2.10^{-7}(I_a \ln\frac{1}{r'} + I_b \ln\frac{1}{D_{31}} + I_c \ln\frac{1}{D_{23}})$$

$$\Rightarrow \psi_a = \frac{1}{3}(\psi_{a1} + \psi_{a2} + \psi_{a3})$$

$$\psi_a = \frac{2}{3}.10^{-7}(3I_a \ln\frac{1}{r'} + I_b \ln\frac{1}{D_{12}D_{23}D_{31}} + I_c \ln\frac{1}{D_{12}D_{23}D_{31}})$$

Karena Ia = - (Ib+Ic)

$$\psi_a = \frac{2}{3}.10^{-7} I_a (3\ln\frac{1}{r'} - \ln\frac{1}{D_{12}D_{23}D_{31}})$$

$$\psi_a = 2.10^{-7} I_a \ln\frac{\sqrt{D_{12}D_{23}D_{31}}}{r'}$$

Induktansi rata2 per phasa

$$L_a = 2.10^{-7} \ln\frac{D_{eq}}{r'} \; H/m$$

$$L_a = 0{,}7411.\log\frac{D_{eq}}{r'} \; mH/mile$$

atau

$$L = 2.10^{-7} \ln\frac{GMD}{GMR} \; H/m$$

$$L = 0{,}7411.\log\frac{GMD}{GMR} \; mH/mile$$

Penggunaan tabel

- Reaktansi induktif

$$X_L = 2\pi f L = 2\pi f .0{,}7411.10^{-3} Log \frac{GMD}{GMR} \Omega / mile$$

$$X_L = 4{,}657.10^{-3} fLog \frac{GMD}{GMR}$$

$$X_L = 4{,}657.10^{-3} fLog \frac{1}{GMR} + 4{,}657.10^{-3} fLogGMD$$

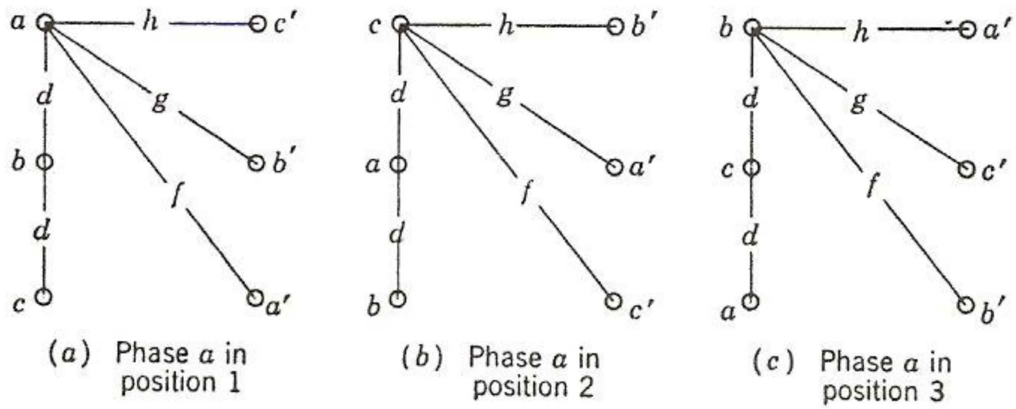
dimana

$4{,}657.10^{-3} fLog \frac{1}{GMR} \Rightarrow$ Induktive reactance at 1 ft spacing

sedang

$4{,}657.10^{-3} fLogGMD \Rightarrow$ Indictive reactance spacing factor

Jaringan 3 phasa double circuit



Bila diadakan transposisi seperti gambar diatas didapatkan

$$D_{eq} = \sqrt[3]{D_{ab} D_{bc} D_{ca}}$$

Dab = GMD antara phasa a&b posisi 1 = $\sqrt[4]{dgdg} = \sqrt{dg}$

Dbc = GMD antara phasa b&c posisi 1 = $\sqrt{dg}$

Dca = Gmd antara phasa c&a posisi 1 = $\sqrt{2dh}$

Jaringan 3 phasa double circuit

$$\Rightarrow D_{eq} = 2^{1/6} d^{1/2} g^{1/3} h^{1/6}$$

GMR dari masing2 konduktor phasa a=r' , GMR pada posisi 1 untuk seluruh phasa yang terdidi atas konduktor2 a dan a' :

$$D_{s1} = \sqrt[4]{r' f r' f} = \sqrt{r' f}$$

pada posisi 2

$$D_{s2} = \sqrt[4]{r' h r' h} = \sqrt{r' h}$$

pada posisi 3

$$D_{s3} = \sqrt[4]{r' f r' f} = \sqrt{r' f}$$

$$\Rightarrow GMR = D_s = \sqrt[3]{D_{s1} D_{s2} D_{s3}} = (r')^{1/2} f^{1/3} h^{1/6}$$

Induktansi per phasa

$$L = 0{,}7411 . \log \frac{\mathrm{GMD}}{\mathrm{GMR}}$$

$$L = 0{,}7411 . \log \left[2^{1/6} (d/r')^{1/2} (g/f)^{1/3} \right] mH / mile / ph$$

masing2 konduktor

$$L = 0{,}7411 . \log \left[2^{1/3} (d/r')(g/f)^{2/3} \right] mH / mile / kond$$

PERHITUNGAN GMD DAN GMR

KONDUKTOR KOMPOSIT (KONDUKTOR BANYAK SERAT):

$$GMD = \sqrt[mn]{(D_{aa'}D_{ab'}\cdots D_{am})(D_{ba'}D_{bb'}\cdots D_{bm})\cdots(D_{na'}D_{nb'}\cdots D_{nm})}$$

$$GMR_x = \sqrt[n^2]{(D_{aa}D_{ab}\cdots D_{an})(D_{ba}D_{bb}\cdots D_{bn})\cdots(D_{na}D_{nb}\cdots D_{nn})}$$

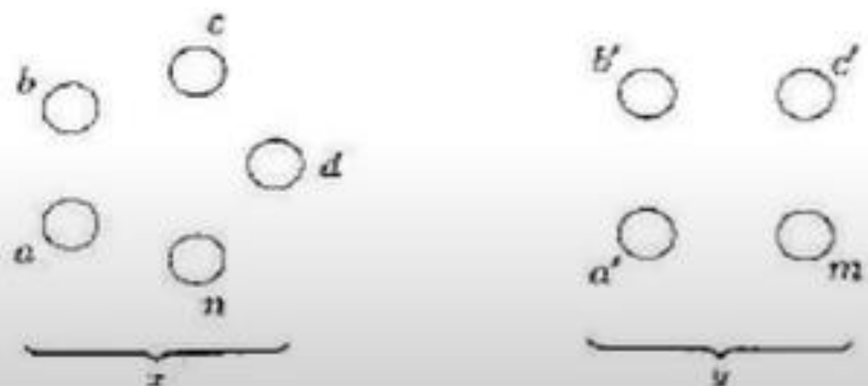
$$GMR_y = \sqrt[m^2]{(D_{a'a'}D_{a'b'}\cdots D_{a'm})(D_{b'a'}D_{b'b'}\cdots D_{b'm})\cdots(D_{ma'}D_{mb'}\cdots D_{mm})}$$

DIMANA:

$$D_{aa} = D_{bb} = \cdots = D_{nn} = 0{,}7788 r_x$$

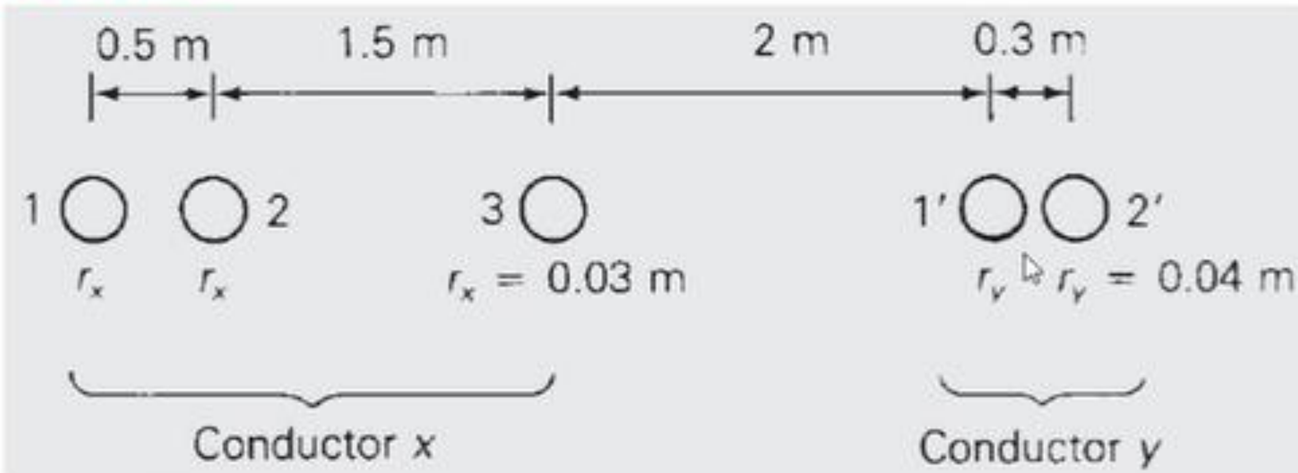
$$D_{a'a'} = D_{b'b'} = \cdots = D_{mm} = 0{,}7788 r_y$$

(PENURUNAN DI LAMPIRAN C)



PERHITUNGAN GMD DAN GMR

CONTOH SOAL:



$$GMD = \sqrt[6]{(D_{11'}D_{12'})(D_{21'}D_{22'})(D_{31'}D_{32'})}$$

$$GMR_x = \sqrt[9]{(D_{11}D_{12}D_{13})(D_{21}D_{22}D_{23})(D_{31}D_{32}D_{33})}$$

$$GMR_y = \sqrt[4]{(D_{1'1'}D_{1'2'})(D_{2'1'}D_{2'2'})}$$

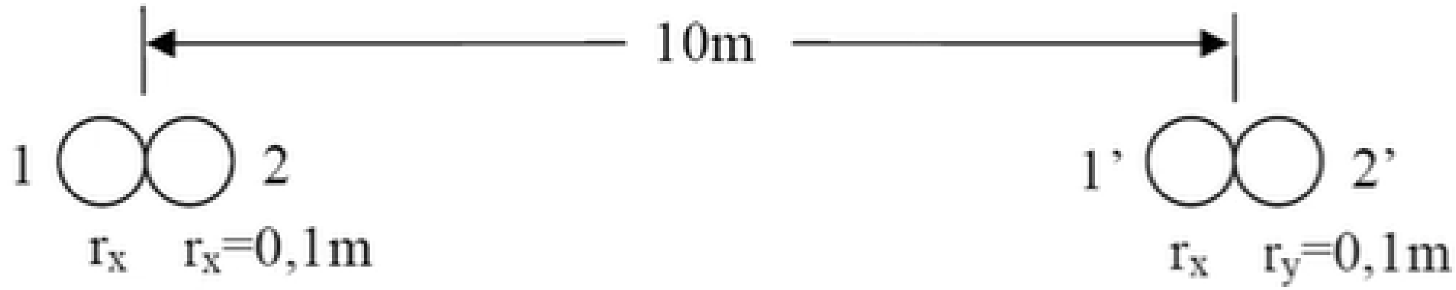
$$GMD = \sqrt[6]{(4\times 4.3)(3.5\times 3.8)(2\times 2.3)} = 3.189m$$

$$GMR_x = \sqrt[9]{(0.02336)^3(0.5)^2(1.5)^2(2.0)^2} = 0.3128m$$

$$GMR_y = \sqrt[4]{(0.03115)^2(0.3)^2} = 0.09667m$$

PERHITUNGAN GMD DAN GMR

CONTOH SOAL:



$$GMD = \sqrt[4]{(D_{11'}D_{12'})(D_{21'}D_{22'})}$$

$$GMR_x = \sqrt[4]{(D_{11}D_{12})(D_{21}D_{22})}$$

$$GMR_y = \sqrt[4]{(D_{1'1'}D_{1'2'})(D_{2'1'}D_{2'2'})}$$

$$GMD = \sqrt[4]{(10\times 10{,}2)(9{,}8\times 10)} = 9{,}999m$$

$$GMR_x = GMR_y = \sqrt[4]{(0{,}07788)^2(0{,}2)^2} = 0{,}1248m$$

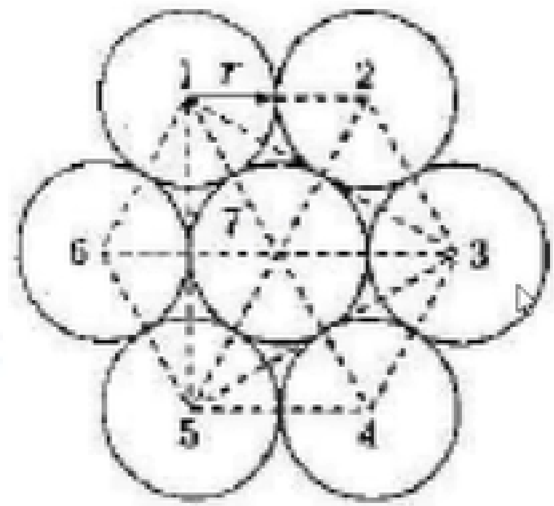
CATATAN:

Jika jarak antara konduktor jauh lebih besar dibandingkan jarak antara serat (seperti pada kasus konduktor pilin), maka GMD dapat diaproksimasi dengan jarak antara konduktor tersebut. Sehingga untuk konduktor pilin kita hanya perlu menghitung GMR.

PERHITUNGAN GMD DAN GMR

CONTOH SOAL:

Hitung GMR dari konduktor pilin
Dengan 7 serat seperti gambar.



JAWAB:

$$GMR = \sqrt[7^2]{(D_{11}D_{12}\cdots D_{17})(D_{21}D_{22}\cdots D_{27})\cdots(D_{71}D_{72}\cdots D_{77})}$$

Oleh karena:

$$D_{12} = D_{16} = D_{17} = D_{21} = D_{23} = D_{27} = D_{32} = D_{34} = D_{37}$$
$$= D_{43} = D_{45} = D_{47} = D_{54} = D_{56} = D_{57} = D_{61} = D_{65} = D_{67} = D_{71} = D_{72} = D_{73} = D_{74} = D_{75} = D_{76} = 2r$$
$$D_{14} = D_{41} = D_{25} = D_{52} = D_{36} = D_{63} = 4r$$
$$D_{13} = D_{31} = D_{24} = D_{42} = D_{35} = D_{53} = D_{46} = D_{64} = D_{51} = D_{15} = D_{62} = D_{26} = 2r\sqrt{3}$$
$$D_{11} = D_{22} = D_{33} = D_{44} = D_{55} = D_{66} = D_{77} = 0.7788r$$

Maka:
$$GMR = \sqrt[49]{(0{,}7788r)^7 (2r)^{24} (4r)^6 (2r\sqrt{3})^{12}} = 2{,}1767r$$

CATATAN: BGMN JIKA SERATNYA CUKUP BANYAK (MIS: 37 SERAT)?

PERHITUNGAN GMD DAN GMR

CONTOH SOAL:

Hitung GMR dari konduktor pilin dengan jumlah serat 7 yang masing-masing berdiameter 0,1548 inch. Konduktor pilin tersebut terbuat dari tembaga dengan konduktifitas 97,3%. Bandingkan hasil perhitungan GMR tersebut dengan nilai yang tertera pada tabel.

JAWAB:

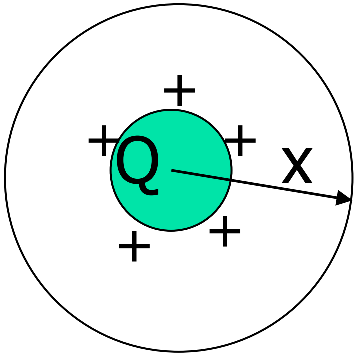
Radius dari serat konduktor: $r = 0{,}5 \times 0{,}1548 = 0{,}0774 \text{ inch}$

GMR untuk konduktor pilin tersebut adalah:

$$GMR = 2{,}1767 \times 0{,}0774 = 0{,}1685 \text{ inch} = 0{,}01404\ ft$$

Berdasarkan Tabel A1, GMR untuk konduktor pilin tersebut adalah 0,01404 ft.
Terlihat bahwa hasil perhitungan GMR dan nilai yang tercantum pada tabel adalah sesuai.

KAPASITANSI



Konduktor bermuatan Q

$$\Rightarrow \oint D.ds = Q$$

Jarak x dari pusat konduktor, besar kerapatn flux elektrik

$$D.2\pi x = Q \Rightarrow D = \frac{Q}{2\pi x}$$

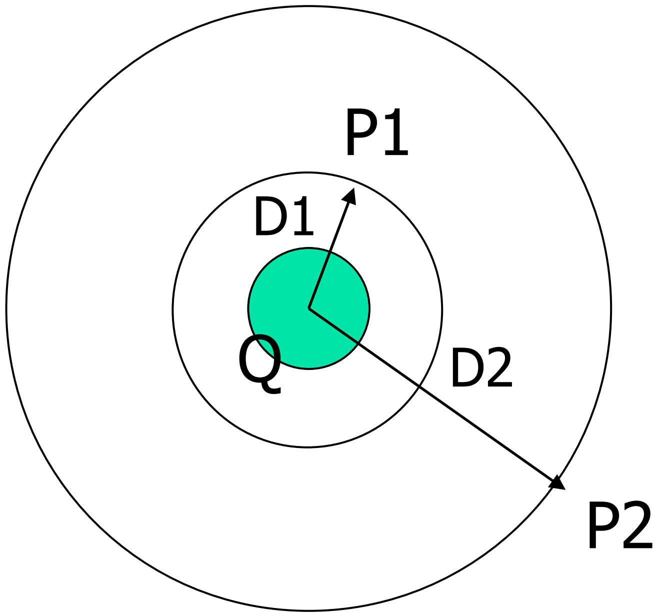
Sedang intensitas medan listrik

$$E = \frac{D}{\varepsilon} = \frac{Q}{2\pi\varepsilon x}$$

$$\varepsilon = \varepsilon_r \varepsilon_0$$

$\varepsilon_0 =$ permitivitas udara

$$\varepsilon_0 = 8{,}85.10^{-12} F/m$$

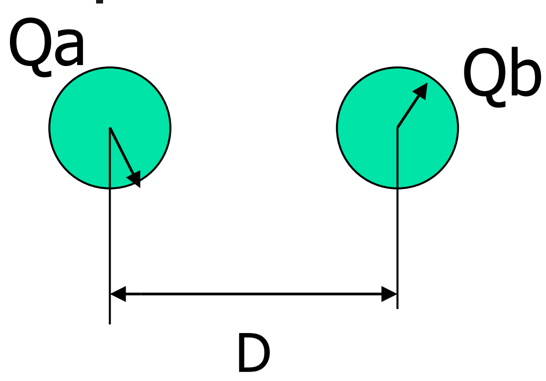


Beda potensial P1 – P2

$$V_{12} = -\int_{D_2}^{D_1} E.dx$$

$$V_{12} = \frac{Q}{2\pi\varepsilon} \ln \frac{D_2}{D_1}$$

Kapasitansi saluran 2 kawat/konduktor



Jari-jari masing-masing konduktor ra & rb, muatannya Qa & Qb dan jaraknya D

$$V_{ab} = \frac{1}{2\pi\varepsilon}\left(Q_a \ln\frac{D}{r_a} + Q_b \ln\frac{r_b}{D}\right)$$

$$Q_a = -Q_b$$

$$\Rightarrow V_{ab} = \frac{Q_a}{2\pi\varepsilon}\left(\ln\frac{D}{r_a} - Q_b \ln\frac{r_b}{D}\right)$$

sehingga

$$V_{ab} = \frac{Q_a}{2\pi\varepsilon}\ln\frac{D^2}{r_a r_b}$$

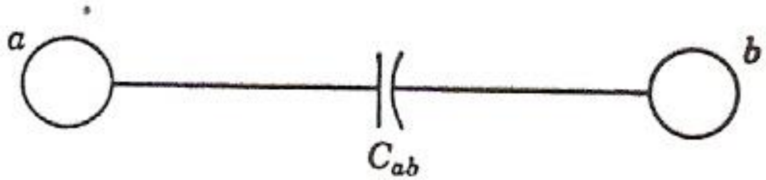
$$C_{ab} = \frac{Q_a}{V_{ab}} = \frac{2\pi\varepsilon}{\ln\left(D^2/r_a r_b\right)} F/m$$

dengan $\varepsilon_r = 1$

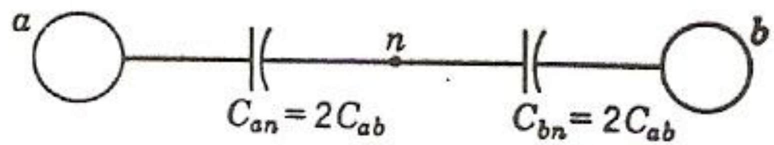
$$C_{ab} = \frac{0{,}0388}{\ln\left(D^2/r_a r_b\right)} \mu F/mile$$

$$r_a = r_b \Rightarrow C_{ab} = \frac{0{,}0194}{\ln\left(D/r\right)} \mu F/mile$$

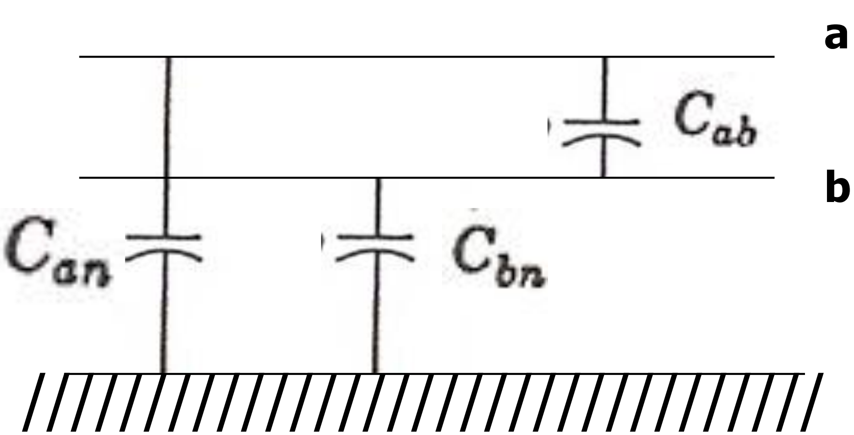
Kapasitansi saluran 2 kawat/konduktor



(a) Representation of line-to-line capacitance



(b) Representation of line-to-neutral capacitance



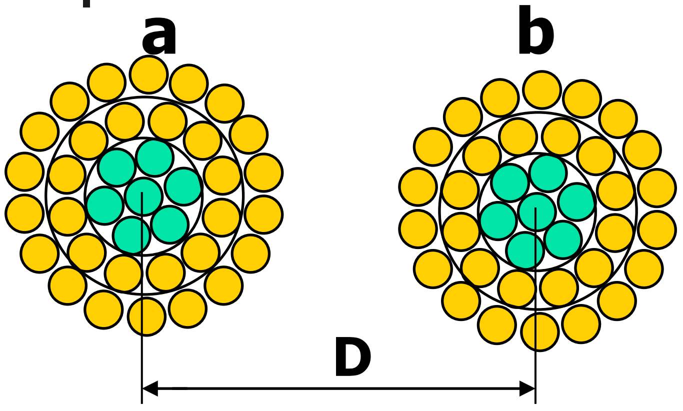
Jika seimbang

$$C_{an} = C_{bn}$$

$$C_{an} = 2C_{ab}$$

$$\Rightarrow C = \frac{0{,}0388}{\log \mathrm{D}/\mathrm{r}} \mu F / mile$$

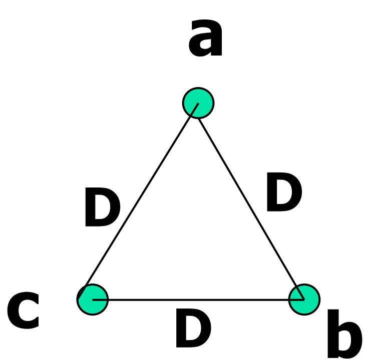
Kapasitansi antara 2 kelompok konduktor



$$C_{ab} = \frac{0{,}0194}{\log \frac{\mathrm{GMD}}{\mathrm{GMR}}} \mu F / mile$$

$$C = \frac{0{,}0388}{\log \frac{\mathrm{GMD}}{\mathrm{GMR}}} \mu F / mile$$

Kapasitansi jaringan tiga phasa dengan jarak simetri



Jarak masing2 D, jari2 konduktor masing2 r dan muatan masing2 Qa, Qb & Qc

$$V_{ab} = \frac{1}{2\pi\varepsilon}(Q_a \ln\frac{D}{r} + Q_b \ln\frac{r}{D} + Q_c \ln\frac{D}{D})$$

$$V_{ac} = \frac{1}{2\pi\varepsilon}(Q_a \ln\frac{D}{r} + Q_b \ln\frac{D}{D} + Q_c \ln\frac{r}{D})$$

$$V_{ab} + V_{ac} = \frac{1}{2\pi\varepsilon}\left(2Q_a \ln\frac{D}{r} + (Q_b + Q_c)\ln\frac{r}{D}\right)$$

Bila disekitarnya tidak ada muatan

$$\Rightarrow Q_a + Q_b + Q_c = O$$

$$Q_a = -(Q_b + Q_c)$$

$$\Rightarrow V_{ab} + V_{ac} = \frac{3Q_a}{2\pi\varepsilon}\ln\frac{D}{r}$$

$$V_{ab} + V_{ac} = 3V_{an}$$

$$V_{an} = \frac{Q_a}{2\pi\varepsilon}\ln\frac{D}{r} \qquad \Rightarrow C_n = \frac{2\pi\varepsilon}{\ln D/r} F/m$$

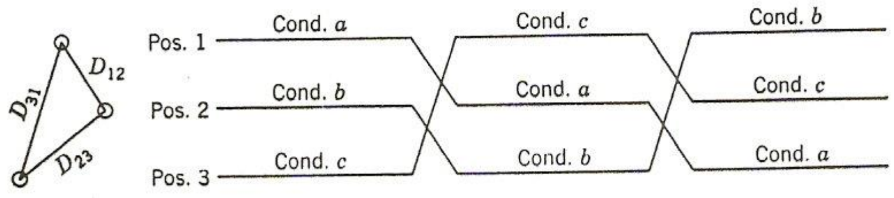
$$\varepsilon_r = 1 \Rightarrow C_n = \frac{0{,}0388}{\log D/r}\mu F/mile$$

untuk kelompok konduktor

$$C = \frac{0{,}0388}{\log\frac{GMD}{GMR}}\mu F/mile$$

Jaringan 3 phasa dengan letak konduktor tak simetri

transposisi



Konduktor a pada posisi 1, b →2 & c →3

$$V_{ab} = \frac{1}{2\pi\varepsilon}(Q_a \ln\frac{D_{12}}{r} + Q_b \ln\frac{r}{D_{12}} + Q_c \ln\frac{D_{23}}{D_{31}})$$

$$a \rightarrow 2, b \rightarrow 3 \,\&\, c \rightarrow 1$$

$$V_{ab} = \frac{1}{2\pi\varepsilon}(Q_a \ln\frac{D_{23}}{r} + Q_b \ln\frac{r}{D_{23}} + Q_c \ln\frac{D_{31}}{D_{12}})$$

$$a \rightarrow 3, b \rightarrow 1 \,\&\, c \rightarrow 2$$

$$V_{ab} = \frac{1}{2\pi\varepsilon}(Q_a \ln\frac{D_{31}}{r} + Q_b \ln\frac{r}{D_{31}} + Q_c \ln\frac{D_{12}}{D_{23}})$$

maka

$$V_{ab} = \frac{1}{6\pi\varepsilon}(Q_a \ln\frac{D_{12}D_{23}D_{31}}{r} + Q_b \ln\frac{r^3}{D_{12}D_{23}D_{31}} + Q_c \ln\frac{D_{12}D_{23}D_{31}}{D_{12}D_{23}D_{31}})$$

Jaringan 3 phasa dengan letak konduktor tak simetri

$$\Rightarrow V_{ab} = \frac{1}{2\pi\varepsilon}(Q_a \ln \frac{\mathrm{D_{eq}}}{\mathrm{r}} + Q_b \ln \frac{\mathrm{r}}{\mathrm{D_{eq}}})$$

dimana

$$\mathrm{D_{eq}} = \sqrt[3]{\mathrm{D_{12}D_{23}D_{31}}}$$

analog

$$V_{ac} = \frac{1}{2\pi\varepsilon}(Q_a \ln \frac{\mathrm{D_{eq}}}{\mathrm{r}} + Q_c \ln \frac{\mathrm{r}}{\mathrm{D_{eq}}})$$

$$V_{ab} + V_{ac} = 3V_{an}$$

$$\Rightarrow 3V_{an} = \frac{1}{2\pi\varepsilon}(2Q_a \ln \frac{\mathrm{D_{eq}}}{\mathrm{r}} + Q_b \ln \frac{\mathrm{r}}{\mathrm{D_{eq}}} + Q_c \ln \frac{\mathrm{r}}{\mathrm{D_{eq}}})$$

Saluran tiga phasa seimbang

$$Q_a + Q_b + Q_c = 0$$

$$Q_a = -(Q_b + Q)_c$$

$$\Rightarrow 3V_{an} = \frac{3}{2\pi\varepsilon} \ln \frac{\mathrm{D_{eq}}}{\mathrm{r}}$$

$$\Rightarrow C_n = \frac{2\pi\varepsilon}{\ln \frac{\mathrm{D_{eq}}}{\mathrm{r}}} F/m$$

$$\varepsilon_r = 1 \Rightarrow C_n = \frac{0{,}0388}{\log \frac{\mathrm{D_{eq}}}{\mathrm{r}}} \mu F/mile$$

untuk kelompok konduktor

$$C = \frac{0{,}0388}{\log \frac{\mathrm{GMD}}{\mathrm{GMR}}} \mu F/mile$$

Penggunaan tabel

- Reaktansi kapasitif

$$X_c = \frac{1}{2\pi fC} = \frac{1}{2\pi f .0,0388}.10^6 Log \frac{GMD}{GMR} \Omega / mile$$

$$X_L = \frac{4,093}{f}.10^6 Log \frac{GMD}{GMR} \Omega / mile$$

$$X_L = \frac{4,093}{f}.10^6 Log \frac{1}{GMR} + \frac{4,093}{f}.10^6 Log GMD$$

dimana

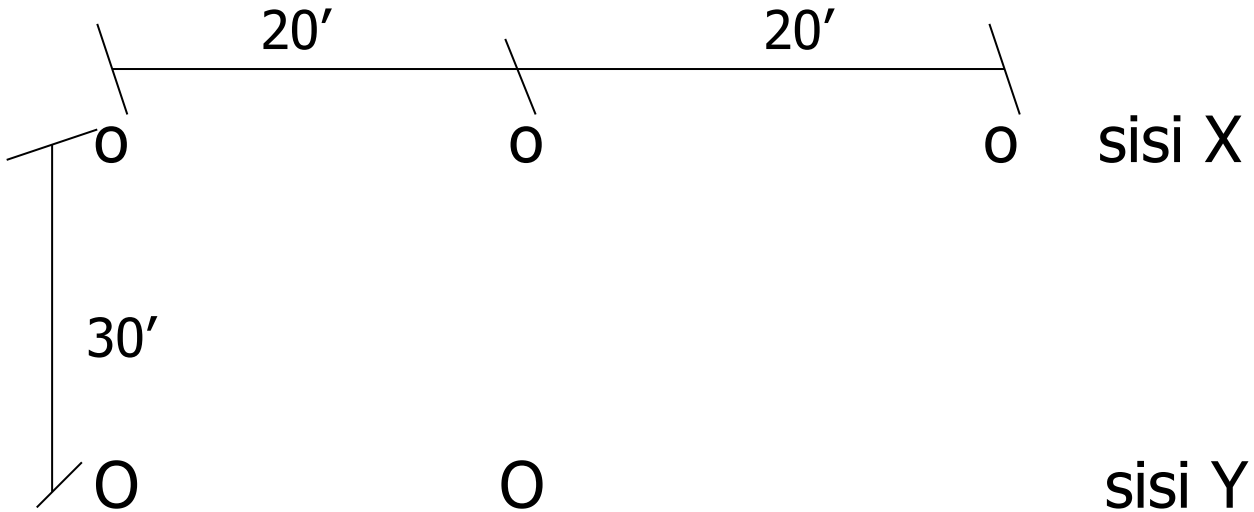
$$\frac{4,093}{f}.10^6 Log \frac{1}{GMR} \Rightarrow$$ capasitive reactance at 1 ft spacing

sedang

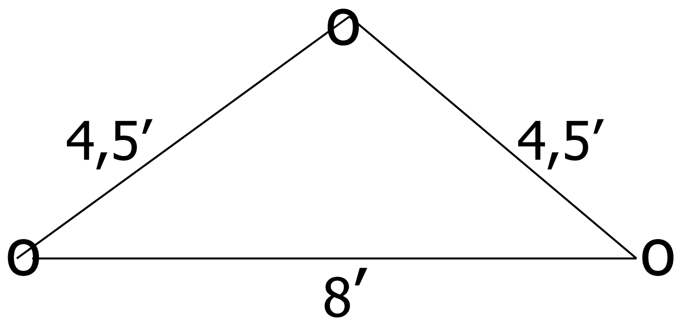
$$\frac{4,093}{f}.10^6 Log GMD \Rightarrow$$ capasitive reactance spacing factor

Contoh soal

Suatu saluran transmissi satu phasa, konduktor phasanya terdiri dari tiga konduktor solid dengan jari2 masing-masing 0,1” sedang konduktor netralnya terdiri dari dua konduktor solid dengan jari2 masing2 0,2”. Konfigurasinya seperti ditunjukkan dalam gambar. Tentukan induktansi masing2 sisi dan induktansi saluran satu phasa tersebut.



Contoh soal



Suatu saluran tiga phasa single circuit 60 HZ spt gb samping , masing2 konduktornya diameternya 0,258 in.

Tentukan :besar induktansinya dan reaktansi induktifnya per phasa per mile

Dari contoh diatas bila masing2 konduktornya adalah No.2 single strand hard drawn copper.

Tentukan besar induktansinya dan reaktansi induktifnya per phasa per mile