Bundled conductors

Corona

⇒ Electric field on surface of conductor is greater than dielectric strength then air around the conductor ionizes.

⇒ Due to corona there is hissing sound and purple glow around the conductor.

⇒ Due to light and sound the energy is dissipited called as corona loss.

Reducing Corona

⇒ To Reduce corona loss, we need to reduce the electric field which can be done by following methods –

⇒ Reduce operating voltage

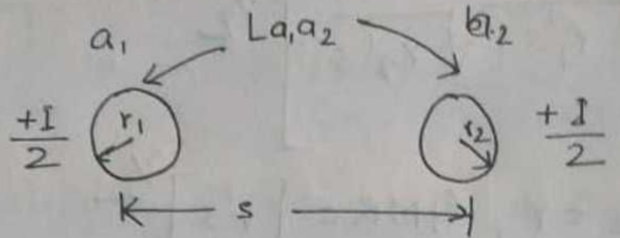
⇒ Increase GMD and GMR.

⇒ Increasing GMD requires increasing distance between conductors which requires increasing the size of tower and Hence Increasing the cost.

⇒ Increasing GMR implies increasing effective radius so that electric field reduces.

Bundle conductor

- one conductor is replaced by a group of conductors kept at certain Distance



$$\lambda_{a_1} = \frac{\mu_0 I/2}{2\pi} \ln \frac{1}{r_1'} + \frac{\mu_0}{2\pi}\frac{I}{2} \ln \frac{1}{s}$$

$$= \frac{\mu_0}{2\pi} I \ln \frac{1}{\sqrt{r_1' s}}$$

even mutual flux b/w a_1 & a_2 acts as self flux because both conductor belongs to same phase.

- solid conductor self → r'
- bundled conductor self $\sqrt{r's}$

$\sqrt{r's} > r'$ GMR ↑.

$$\lambda_{a_2} = \frac{\mu_0}{2\pi}\frac{I}{2} \ln \frac{1}{s} + \frac{\mu_0}{2\pi}\frac{I}{2} \ln 1/r_2'$$

$$= \frac{\mu_0}{2\pi} I \ln \frac{1}{\sqrt{r_2' s}}$$

Again in flux linkage

r_2' is replaced by $\sqrt{r_2' s}$

So, GMR ↑

Overal GMR

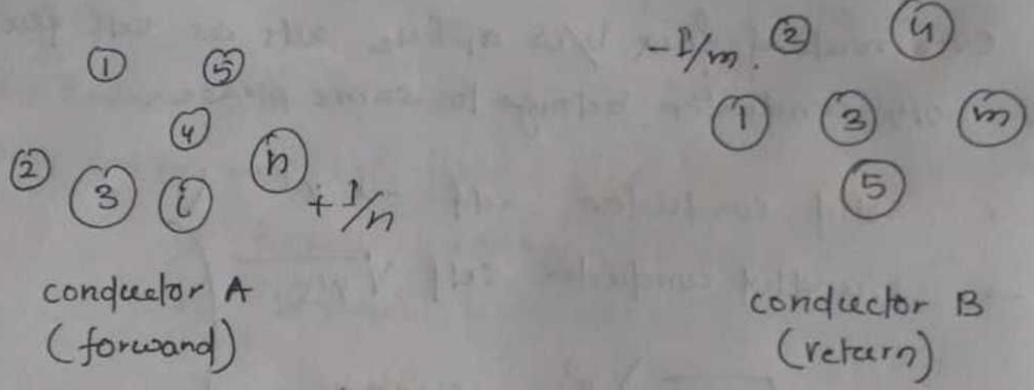
$$GMR = \left[(GMR)_1 (GMR)_2\right]^{1/2}$$

$$= \left[\sqrt{r_1's}\ \sqrt{r_2's}\right]^{1/2}$$

if $r_1 = r_2 = r$, $GMR = [r's]^{1/2}$

↓ self GMD.

Inductance of Bundled conductor



$$\lambda_i = \sum_{j=1}^{n} \frac{\mu_0 I_j}{2\pi} \ln \frac{1}{D_{ij}} + \sum_{k=1'}^{m} \frac{\mu_0 I_k}{2\pi} \ln \frac{1}{D_{ik}}$$

$$= \frac{\mu_0 I}{2\pi n} \sum_{j=1}^{n} \ln \frac{1}{D_{ij}} - \frac{\mu_0 I}{2\pi m} \sum_{k=1'}^{m} \ln \frac{1}{D_{ik}}$$

$$= \frac{\mu_0 I}{2\pi} \left[\sum_{j=1}^{n} \ln \frac{1}{(D_{ij})^{1/n}} - \sum_{k=1'}^{m'} \ln \frac{1}{(D_{ik})^{1/m}} \right]$$

$$= \frac{\mu_0 I}{2\pi} \left[\ln \frac{1}{(D_{i1} D_{i2} \dots D_{in})^{1/n}} - \ln \frac{1}{(D_{i1'} D_{i2'} \dots D_{im'})^{1/m'}} \right]$$

$$\lambda_i = \frac{\mu_0 I}{2\pi}\left[\ln \frac{(D_{i1'} D_{i2'} \ldots D_{im})^{1/m}}{(D_{i1}, D_{i2}, \ldots D_i)^{1/n}}\right]$$

$$L_i = \frac{\lambda_i}{I_i} = \frac{\lambda}{I/n} = \frac{n\lambda_i}{I}$$

$$= \frac{\mu_0 n}{2\pi} \ln \left[\frac{(D_{i1'} D_{i2'} D_{i3'} \ldots D_{im'})^{1/m'}}{(D_{i1}, D_{i2} \ldots D_i)^{1/n}}\right]$$

$$L_{avg} = \sum_{i=1}^{n} \frac{L_i}{n} = \sum_{i=1}^{n} \frac{\mu_0}{2\pi} \ln \left(\frac{(D_{i1'} D_{i2'} \ldots D_{im'})^{1/m'}}{(D_{i1} D_{i2} \ldots D_{in})^{1/n}}\right)$$

$$L_{avg} = \frac{\mu_0}{2\pi} \ln \left[\frac{\prod_{i=1}^{n} (D_{i1'} \ldots D_{im'})^{1/m'}}{\prod_{i=1}^{n} (D_{i1} D_{i2} \ldots D_{in})^{1/n}}\right]$$

$$L_f = \frac{L_{avg}}{n}$$ (due to parallel connection)

$$L_f = \frac{\mu_0}{2\pi n} \ln \left(\frac{\prod_{i=1}^{n} (D_{i1}, D_{i2'} \ldots D_{im'})^{1/m}}{\prod_{i=1}^{n} (D_{i1}, D_{i2}, \ldots D_{in})^{1/n}}\right)$$

$$= \frac{\mu_0}{2\pi} \ln \left|\frac{\{(D_{i1'} D_{i2'} \ldots D_{im'})(D_{21'} D_{22'} \ldots D_{2m'}) \ldots (D_{n1'}, D_{n2'} \ldots D_{nm'})\}^{1/m'n}}{\{(D_{11} D_{12} \ldots D_{1n})(D_{21} D_{22} \ldots D_{2n}) \ldots (D_{n1} . D_{n2} \ldots D_{nn})\}^{1/n^2}}\right|$$

$$\boxed{L_f = \frac{\mu_0}{2\pi} \ln \frac{D_m}{D_{sf}}}$$

$$\boxed{L_r = \frac{\mu_0}{2\pi} \ln \frac{D_m}{D_{sr}}}$$

D_{sr} self GMD (return)

D_m = mutual GMD

D_{self} = self GMD (forward path)

Advantages

- Electric field decreases so corona loss reduces and hence efficiency increases.
- Inductance of Bundled conductors is less than solid conductor.
- Capacitance of Bundled conductor is more than solid conductor.
- Due to increase in capacitance per phase, power factor of system increases

$$L_b = \frac{\mu_0}{2\pi} \ln \frac{D_m}{D_s} \qquad L_s = \frac{\mu_0}{2\pi} \ln \frac{D_m}{r'}$$

$\therefore$ self GMD $(D_s) > r'$

$$L_b < L_s$$

$$C_b = \frac{2\pi\epsilon_0}{\ln D_m/D_s}, \quad C_s = \frac{2\pi\epsilon_0}{\ln D_m/r}$$

$D_s > r$; $C_b > C_s$

$C \uparrow \; L \downarrow$

$\Rightarrow$ Due to reduction in inductance per phase the reactance of transmission line reduces and hence voltage drop reduces.

⇒ Due to reduction in reactance, maximum power transfer increases and hence stability improves.

$$P_{max} = \frac{V_S V_R}{X} \quad \text{as } X\downarrow \; P_{max}\uparrow$$

$$\text{stability} \propto P_{max}.$$

⇒ Surge impedance Reduces and SIL increases

$$Z_s = \sqrt{\frac{L}{C}} \downarrow$$

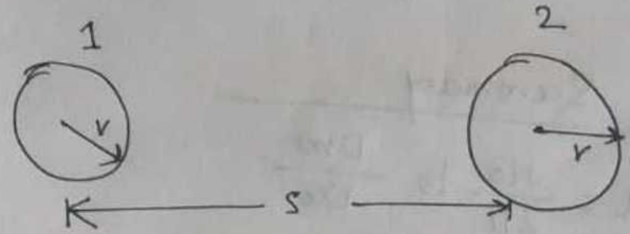
$$SIL = \frac{V^2}{Z_s} \uparrow$$

SIL = Surge impedance loadings.

⇒ Radio interference reduces.

($L\downarrow$, $\lambda\downarrow$, interference $\downarrow$)

Self GMD



$$D_s = \left[(D_{11} D_{12})(D_{21} D_{22})\right]^{1/4}$$

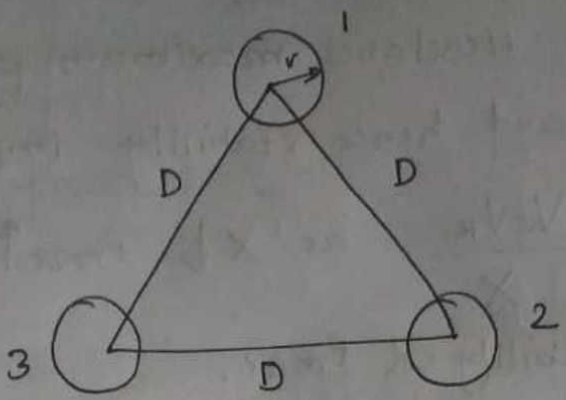
$$= \left[(r' \times s)(s \times r')\right]^{1/4}$$

$$= \left[r's\right]^{1/2}$$

Shortcut consider only 1 of 2 conductor

$$D_s = \left[D_{11} D_{12}\right]^{1/2}$$

$$= \left[r's\right]^{1/2}$$



$$D_s = \left[(D_{12} D_{13} D_{11}) \, (D_{21} D_{22} D_{23}) \, (D_{31} D_{32} D_{33}) \right]^{1/9}$$

$$= \left[(r' \times D \times D)(D \times r' \times D)(D \times D \times r') \right]^{1/9}$$

$$= \left[(r')^3 (D)^6 \right]^{1/9} = \left[r' \times D \times D \right]^{1/3}$$

OR.

Consider only 1.

$$D_s = \left[D_{11} D_{12} D_{13} \right]^{1/3}$$

$$= \left[r' \times D \times D \right]^{1/3}$$

Note:

- 2. conductor line
- 3 conduct^n eq. Δ
- 4 conductors square
- 5. conductor regular polygon,

Summary

- $L = \frac{\mu_0}{2\pi} \ln \frac{D_m}{D_s}$

  D_m = mutual GMD

  D_s = self GMD
- for conductors at corners of regular polygon self GMD of one conductor is same as entire system.