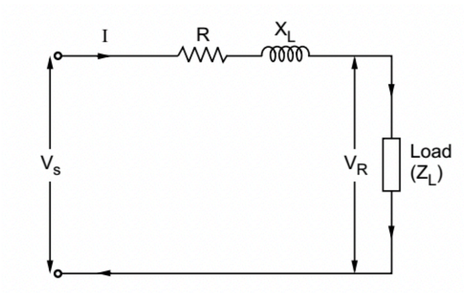
CMR INSTITUTE OF TECHNOLOGY			USN						
Internal Assessment Test II – August -2022									
Sub:	TRANSMISSION AND DISTRIBUTION						Code:	18EE43	
Date:	8/08/2022	Duration:	90 Min	Max Marks:	50	Sem:	4	Section:	A & B

Note: Answer any FIVE FULL Questions. Draw a neat diagram wherever required

1(a)	Derive an expression for sending end voltage and sending end current of a single phase short transmission line by approximate method with the help of vector diagram.	[6]	CO1 CO4	L3



The equivalent circuit for a short transmission line is represented in the Fig. In the analysis of short transmission lines, the capacitive effects are small and neglected. The resistance and inductance of the line are only taken into consideration. These parameters are taken to be lumped instead of distributed for the analysis. The circuit then simplifies to a simple a.c. series circuit

Let
I = Load Current
R = Resistance of the loop i.e. resistance of both conductors
X_L = Inductive loop reactance
V_R = Receiving end voltage
$\cos\phi_R$ = Receiving end power factor
V_S = Sending end voltage
$\cos\phi_S$ = Sending end power factor
Z_L = Load impedance

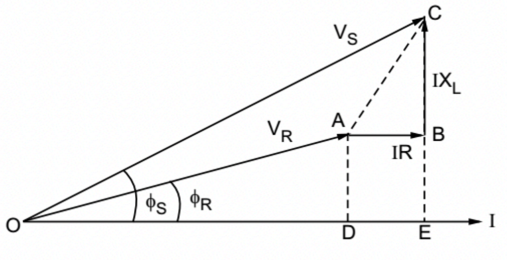


Fig. 4.4

The corresponding phasor diagram is shown in the Fig. 4.4 for lagging load power factor.

From the right angled triangle OEC we have,

$$(OC)^2 = (OE)^2 + (EC)^2$$

$$V_S^2 = (OD + DE)^2 + (EB + BC)^2$$

$$\therefore \quad V_S^2 = [V_R \cos\phi_R + IR]^2 + [V_R \sin\phi_R + IX_L]^2$$

$$\therefore \quad V_S = \sqrt{(V_R \cos\phi_R + IR)^2 + (V_R \sin\phi_R + IX_L)^2}$$

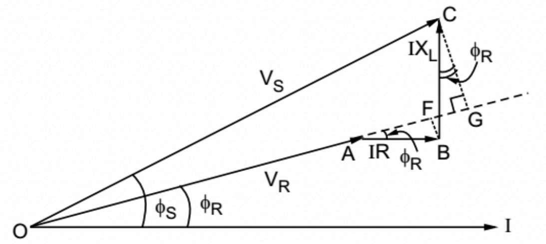


Fig. 4.5

The approximate expression for sending end voltage V_S can be obtained as follows. Draw the perpendicular from B and C on OA produced which is shown in the Fig. 4.5. By making this adjustment we can see that OC = OG.

$$
\begin{aligned}
OC &= OG \\
&= OA + AG \\
&= OA + AF + FG \\
&= OA + AF + BG
\end{aligned}
$$

$$\therefore \quad V_S = V_R + IR\cos\phi_R + IX_L \sin\phi_R$$

$$\%\ \text{Voltage regulation} = \frac{V_S - V_R}{V_R} \times 100$$

$$\text{Sending end power factor, } \cos\phi_S = \frac{OE}{OC}$$

$$\therefore \quad \cos\phi_S = \frac{V_R \cos\phi_R + I \cdot R}{V_S}$$

$$\text{Power delivered} = V_R I_R \cos\phi_R$$

$$\text{Losses in line} = I^2 R$$

$$
\begin{aligned}
\text{Sending end power} &= \text{Power delivered} + \text{Line Losses} \\
&= V_R I_R \cos\phi_R + I^2 R
\end{aligned}
$$

$$\%\ \text{Transmission efficiency} = \frac{\text{Power delivered}}{\text{Power sent}} \times 100$$

$$\therefore \quad n_T = \frac{V_R I_R \cos\phi_R}{V_R I_R \cos\phi_R + I^2 R} \times 100$$

1 (b)	Explain the term self GMD.	[4]	CO4	L2

The use of self-geometrical mean distance (abbreviated as self-GMD) and mutual geometrical mean distance (mutual-GMD) simplifies the inductance calculations, particularly relating to multiconductor arrangements. The symbols used for these are respectively Ds and Dm. We shall briefly discuss these terms.

i) **Self-GMD (Ds)** : In order to have concept of self-GMD (also sometimes called Geometrical mean radius ; GMR), consider the expression for inductance per conductor per metre already derived

$$
\begin{aligned}
\text{Inductance/conductor/m} &= 2 \times 10^{-7}\left(\frac{1}{4} + \log_e \frac{d}{r}\right) \\
&= 2 \times 10^{-7} \times \frac{1}{4} + 2 \times 10^{-7} \log_e \frac{d}{r} \qquad \ldots(i)
\end{aligned}
$$

- In this expression, the term $2 \times 10^{-7} \times (1/4)$ is the inductance due to flux within the solid conductor. For many purposes, it is desirable to eliminate this term by the introduction of a concept called self-GMD or GMR.

- If we replace the original solid conductor by an equivalent hollow cylinder with extremely thin walls, the current is confined to the conductor surface and internal conductor flux linkage would be almost zero.
- Consequently, inductance due to internal flux would be zero and the term $2 \times 10^{-7} \times (1/4)$ shall be eliminated. The radius of this equivalent hollow cylinder must be sufficiently smaller than the physical radius of the conductor to allow room for enough additional flux to compensate for the absence of internal flux linkage.
- It can be proved mathematically that for a solid round conductor of radius r, the self-GMD or GMR = $0{\cdot}7788\, r$.

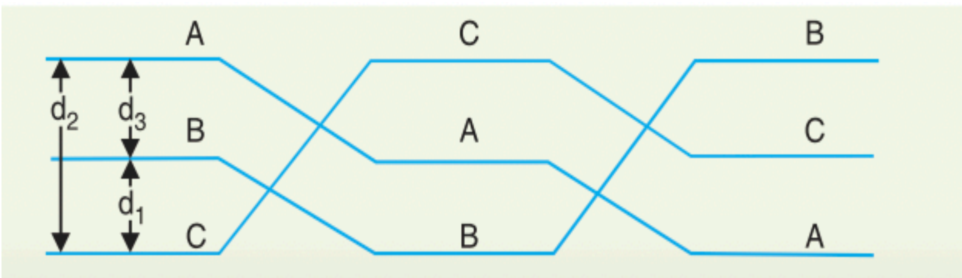
$$\text{Inductance/conductor/m} = 2 \times 10^{-7} \log_e d/D_s$$
$$\text{where} \quad D_s = \text{GMR or self-GMD} = 0{\cdot}7788\, r$$

- It may be noted that self-GMD of a conductor depends upon the size and shape of the conductor and is independent of the spacing between the conductors.

2	Derive an expression for the capacitance of a three-phase line with more than one circuit.	[10]	CO4	L3

Fig shows a 3-phase transposed line having unsymmetrical spacing. Let us assume balanced conditions

i.e. QA + QB + QC = 0. Considering all the three sections of the transposed line for phase A,



$$\text{Potential of 1st position,} \quad V_1 = \frac{1}{2\pi\varepsilon_0}\left(Q_A \log_e \frac{1}{r} + Q_B \log_e \frac{1}{d_3} + Q_C \log_e \frac{1}{d_2}\right)$$

$$\text{Potential of 2nd position,} \quad V_2 = \frac{1}{2\pi\varepsilon_0}\left(Q_A \log_e \frac{1}{r} + Q_B \log_e \frac{1}{d_1} + Q_C \log_e \frac{1}{d_3}\right)$$

$$\text{Potential of 3rd position,} \quad V_3 = \frac{1}{2\pi\varepsilon_0}\left(Q_A \log_e \frac{1}{r} + Q_B \log_e \frac{1}{d_2} + Q_C \log_e \frac{1}{d_1}\right)$$

Average voltage on condutor A is

$$V_A = \frac{1}{3}(V_1 + V_2 + V_3)$$
$$= \frac{1}{3 \times 2\pi\varepsilon_0}\left[Q_A \log_e \frac{1}{r^3} + (Q_B + Q_C)\log_e \frac{1}{d_1 d_2 d_3}\right]$$

As $Q_A + Q_B + Q_C = 0$, therefore, $Q_B + Q_C = -Q_A$

$$\therefore \quad V_A = \frac{1}{6\pi\varepsilon_0}\left[Q_A \log_e \frac{1}{r^3} - Q_A \log_e \frac{1}{d_1 d_2 d_3}\right]$$

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$$V_A = \frac{1}{6\pi\varepsilon_0}\left[Q_A \log_e \frac{1}{r^3} - Q_A \log_e \frac{1}{d_1 d_2 d_3}\right]$$

$$= \frac{Q_A}{6\pi\varepsilon_0} \log_e \frac{d_1 d_2 d_3}{r^3}$$

$$= \frac{1}{3} \times \frac{Q_A}{2\pi\varepsilon_0} \log_e \frac{d_1 d_2 d_3}{r^3}$$

$$= \frac{Q_A}{2\pi\varepsilon_0} \log_e \left(\frac{d_1 d_2 d_3}{r^3}\right)^{1/3}$$

$$= \frac{Q_A}{2\pi\varepsilon_0} \log_e \frac{(d_1 d_2 d_3)^{1/3}}{r}$$

∴ Capacitance from conductor to neutral is

$$C_A = \frac{Q_A}{V_A} = \frac{2\pi\varepsilon_0}{\log_e \frac{\sqrt[3]{d_1 d_2 d_3}}{r}} \; F/m$$

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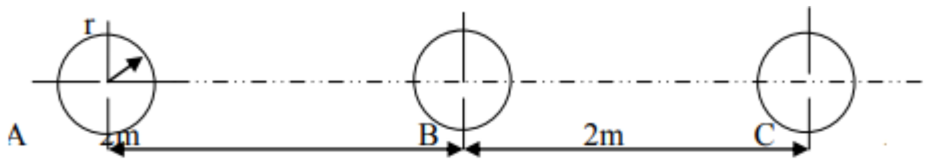
<tr><td>3</td><td>

A 3- phase, 50 Hz, 66kV overhead line conductors are placed in a horizontal plane as shown in fig. The conductor diameter is 1.25cm. The line length is 100km. Calculate the capacitance per phase and charging current per phase. Assume complete transposition of the lines.



Solution : Equivalent equilateral spacing is given by,

$$d = \sqrt[3]{d_{12}\, d_{23}\, d_{31}} = \sqrt[3]{(2)(2)(4)} = 2.5198 \text{ m}$$

$$r = \frac{1.25}{2} \text{ cm} = \frac{1.25\times10^{-2}}{2} \text{ m} = 6.25\times10^{-3} \text{ m}$$

Line to neutral capacitance is given by,

$$C_{an} = \frac{2\pi\varepsilon_0}{ln\left[\frac{d}{r}\right]} \text{ F/m} = \frac{2\pi\times8.854\times10^{-12}}{ln[2.5198 / 6.25\times10^{-3}]}$$

$$= 9.2728 \times 10^{-12} \text{ F/m}$$

For a line length of 100 km,

$$C_{an} = 9.2728\times10^{-12}\times100\times10^{3} = 9.2728\times10^{-7} \text{ F}$$

$$= \mathbf{0.92728 \times 10^{-6} \text{ F}}$$

The charging current per phase is given by,

$$I_C = \frac{V_{ph}}{X_C} = \frac{66000}{\sqrt{3}}\times2\pi f C = \frac{66000}{\sqrt{3}}\times2\pi\times50\times0.92728\times10^{-6}$$

$$\therefore \quad I_C = \mathbf{11.10 \text{ A}}$$

</td><td>[10]</td><td>CO4</td><td>L3</td></tr>
<tr><td>4(a)</td><td>Show that the inductance of a double circuit 3 phase line can be calculated by the method of GMD and GMR. Assume complete transposition.</td><td>[7]</td><td>CO4</td><td>L3</td></tr>
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(*a*) The mutual-GMD between two conductors (assuming that spacing between conductors is large compared to the diameter of each conductor) is equal to the distance between their centres *i.e.*

$$D_m = \text{spacing between conductors} = d$$

(*b*) For a single circuit 3-ϕ line, the mutual-GMD is equal to the equivalent equilateral spacing *i.e.*, $(d_1\, d_2\, d_3)^{1/3}$.

$$D_m = (d_1\, d_2\, d_3)^{1/3}$$

(*c*) The principle of geometrical mean distances can be most profitably employed to 3-ϕ double circuit lines. Consider the conductor arrangement of the double circuit shown in Fig. 9·10. Suppose the radius of each conductor is *r*.

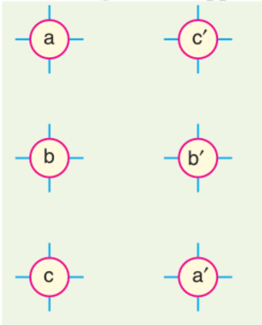


Fig. 9.10

Self-GMD of conductor = 0·7788 *r*

Self-GMD of combination *aa′ is*

$D_{s1} = (**D_{aa} \times D_{aa'} \times D_{a'a'} \times D_{a'a})^{1/4}$

Self-GMD of combination *bb′ is*

$D_{s2} = (D_{bb} \times D_{bb'} \times D_{b'b'} \times D_{b'b})^{1/4}$

Self-GMD of combination *cc′ is*

$D_{s3} = (D_{cc} \times D_{cc'} \times D_{c'c'} \times D_{c'c})^{1/4}$

Equivalent self-GMD of one phase

$D_s = (D_{s1} \times D_{s2} \times D_{s3})^{1/3}$

The value of D_s is the same for all the phases as each conductor has the same radius.

Mutual-GMD between phases *A* and *B* is

$$D_{AB} = (D_{ab} \times D_{ab'} \times D_{a'b} \times D_{a'b'})^{1/4}$$

Mutual-GMD between phases *B* and *C* is

$$D_{BC} = (D_{bc} \times D_{bc'} \times D_{b'c} \times D_{b'c'})^{1/4}$$

Mutual-GMD between phases *C* and *A* is

$$D_{CA} = (D_{ca} \times D_{ca'} \times D_{c'a} \times D_{c'a'})^{1/4}$$

Equivalent mutual-GMD, $D_m = (D_{AB} \times D_{BC} \times D_{CA})^{1/3}$

It is worthwhile to note that mutual GMD depends only upon the spacing and is substantially independent of the exact size, shape and orientation of the conductor.

- **Double Circuit Three Phase:**

: $2 * 10^{-7} log_e \frac{D_m}{D_s}$ H/m (Inductance/phase/m) ; $2 * 10^{-4} ln \frac{D_m}{D_s}$ H/km (Inductance/phase/km)

: $10^{-7} * 2 * log_e \frac{D_m}{D_s}$ H/m (Inductance/phase/m) ; $10^{-4} * 2 * ln \frac{D_m}{D_s}$ H/km (Indu/phase/km)

Where $D_s = \sqrt[3]{D_{s1} D_{s2}\, D_{s3}}$ & $D_m = \sqrt[3]{D_{AB} D_{BC}\, D_{CA}}$

$$D_{s1} = \sqrt[4]{D_{aa} D_{a'a}\, D_{a'a'}\, D_{aa'}}\ ; D_{s2} = \sqrt[4]{D_{bb} D_{b'b}\, D_{b'b'}\, D_{bb'}}\ ; D_{s3} = \sqrt[4]{D_{cc} D_{c'c}\, D_{c'c'}\, D_{cc'}}$$

$$D_{AB} = \sqrt[4]{D_{ab} D_{a'b}\, D_{b'a}\, D_{b'a'}}\ ; D_{BC} = \sqrt[4]{D_{bc} D_{b'c}\, D_{c'b}\, D_{c'b'}}\ ; D_{CA} = \sqrt[4]{D_{ac} D_{a'c}\, D_{c'a}\, D_{c'a'}}$$

4(b) Describe Composite conductors. [3] CO1 CO4 L4

Composite conductors are "the composition of different metal conductors placed in a single strand"

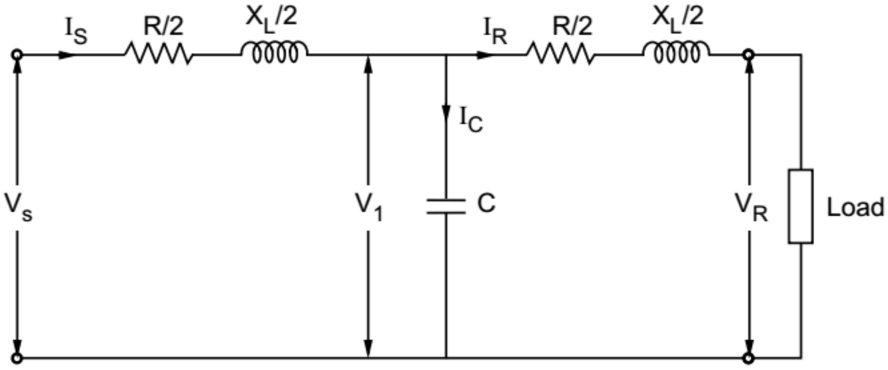
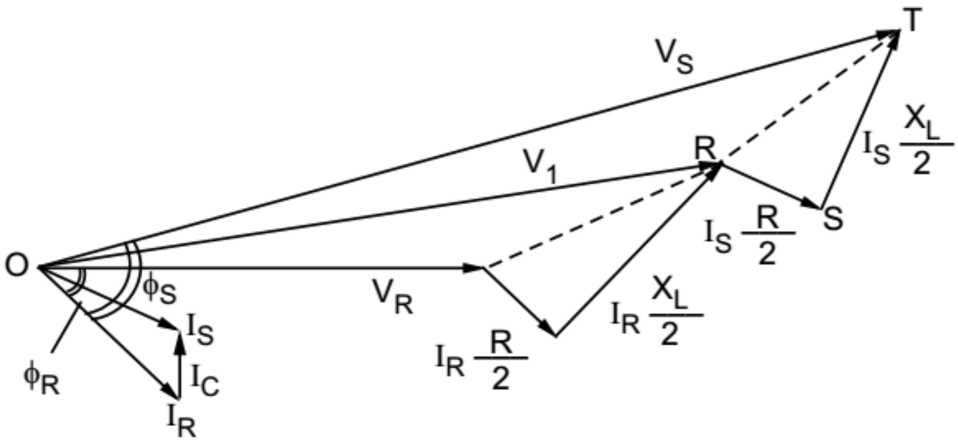
The composite conductors are made up of various metals similar to conductors. These various metal conductors are placed in a single strand. This multiple composition of conductors in a single strand is termed as composite conductors. In composite conductors the current divides equally for each conductor and flows efficiently.

Composite conductors are used as stranded conductors for transmission and distribution systems because of their substantial advantages. Composite conductors have following advantages.

1. Composite conductors allow high conductivity.

2. The mechanical strength of composite conductors is more than solid conductors. Therefore, sags are reduced and can be used for long distances.

3. The corona loss will be reduced with these conductors, and these are highly resistant for

	corrosion. 4. These are highly reliable. 5. The proximity and skin effects are reduced with these conductors.			
5(a)	Discuss the nominal T model of a medium transmission line with appropriate circuit diagram and phasor diagram  • This method is used for the analysis of medium transmission line. • In this method the total line capacitance is lumped or concentrated at the mid point of the line. • The resistance and reactance of the line are divided with half the resistance and reactance on one side and remaining half on other side of capacitor. • Half of the line carries full charging current with this arrangement. • Fig. shows the arrangement used in nominal T method for one phase. It is desirable to work in phase instead of line values.  Here the receiving end voltage V_R is taken as reference. The drop PQ $\left(I_R \cdot \frac{R}{2}\right)$ is in phase with I_R. The drop QR $\left(I_R \cdot \frac{X_L}{2}\right)$ is leading I_R by 90°. The phasor sum of these drops with V_R gives the voltage V_1 which is the voltage across the capacitor. The capacitor current I_C leads V_1 by 90°. The phasor sum of I_R and I_C gives I_S. The drop R_S $\left(I_S \cdot \frac{R}{2}\right)$ is in phase with I_S whereas drop ST $\left(I_S \cdot \frac{X_L}{2}\right)$ is leading I_S by 90°. The phasor sum of these drops along with V_1 gives the sending end voltage V_S.	[7]	CO1	L3

	Let I_R = Receiving end load current per phase R = Resistance per phase X_L = Inductive reactance C = Capacitance per phase $\cos\phi_R$ = p.f. at receiving end V_S = Sending end voltage V_1 = Voltage across capacitor Receiving end voltage, $\overline{V}_R = V_R + j0$ Load current, $\bar{I}_R = I_R(\cos\phi_R - j\sin\phi_R)$ Voltage across capacitor, $\overline{V}_1 = \overline{V}_R + \bar{I}_R\left(\frac{\overline{Z}}{2}\right)$ $= [V_R + j0] + [I_R(\cos\phi_R - j\sin\phi_R)]\left[\frac{R}{2} + j\frac{X_L}{2}\right]$ Current through capacitor, $\bar{I}_C = j\omega C\,\overline{V}_1 = j2\pi fC\,\overline{V}_1$ Sending end current, $\bar{I}_S = \bar{I}_R + \bar{I}_C$ Sending end voltage, $\overline{V}_S = \overline{V}_1 + \bar{I}_S\left(\frac{\overline{Z}}{2}\right)$ $= \overline{V}_1 + \bar{I}_S\left[\frac{R}{2} + j\frac{X_L}{2}\right]$ The efficiency and regulation can be calculated in the similar manner explained in earlier sections.			
5(b)	Explain the term Mutual GMD. The mutual-GMD is the geometrical mean of the distances form one conductor to the other and, therefore, must be between the largest and smallest such distance. In fact, mutual-GMD simply represents the equivalent geometrical spacing.	[3]	CO4	L2
6	The three conductors of a 3 phase line are arranged at the three corners of a triangle of sides 2m, 2.5m and 4.5m.calculate the inductance per km of the line when the conductors are regularly transposed. The diameter of each line conductor is 1.24cm. **Solution.** Fig. 9·12 shows three conductors of a 3-phase line placed at the corners of a triangle of sides D_{12} = 2 m, D_{23} = 2·5 m and D_{31} = 4·5 m. The conductor radius r = 1·24/2 = 0·62 cm. Equivalent equilateral spacing, $D_{eq} = \sqrt[3]{D_{12} \times D_{23} \times D_{31}} = \sqrt[3]{2 \times 2 \cdot 5 \times 4 \cdot 5} = 2 \cdot 82$ m = 282 cm Inductance/phase/m $= 10^{-7}(0 \cdot 5 + 2\log_e D_{eq}/r)$ H $= 10^{-7}(0 \cdot 5 + 2\log_e 282/0 \cdot 62)$ H $= 12 \cdot 74 \times 10^{-7}$ H Inductance/phase/km $= 12 \cdot 74 \times 10^{-7} \times 1000 = 1 \cdot 274 \times 10^{-3}$ H = **1·274 mH**	[10]	CO4	L3
7	Two conductors of a single phase line, each of 1cm diameter are arranged in a vertical plane with one conductor mounted 1m above the other. A second identical line is mounted at the same height as the first and spaced horizontally 0.25m apart from it. The two upper and the two lower conductors are connected in parallel. Determine the inductance per km of the resulting double circuit line	[10]	CO4	L3

Solution. Fig. 9.14. shows the arrangement of double circuit single phase line. Conductors a, a' form one connection and conductors b, b' form the return connnection. The conductor radius, $r = 1/2 = 0{\cdot}5$ cm.

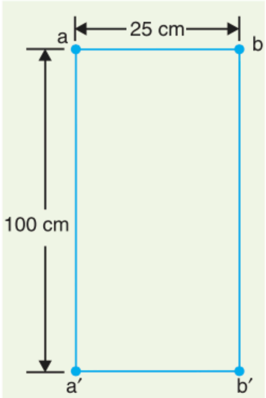


Fig. 9.14

G.M.R. of conductor $= 0{\cdot}7788\, r = 0{\cdot}7788 \times 0{\cdot}5 = 0{\cdot}389$ cm

Self G.M.D. of aa' combination is

$$D_s = \sqrt[4]{D_{aa} \times D_{aa'} \times D_{a'a'} \times D_{a'a}}$$

$$= \sqrt[4]{(0 \cdot 389 \times 100)^2} = 6{\cdot}23 \text{ cm}$$

Mutual G.M.D. between a and b is

$$D_m = \sqrt[4]{D_{ab} \times D_{ab'} \times D_{a'b} \times D_{a'b'}}$$

$$= \sqrt[4]{(25 \times 103 \times 103 \times 25)} = 50{\cdot}74 \text{ cm}$$

$$[\because D_{ab'} = D_{a'b} = \sqrt{25^2 + 100^2} = 103 \text{ cm}]$$

Inductance per conductor per metre

$$= 2 \times 10^{-7} \log_e D_m/D_s = 2 \times 10^{-7} \log_e 50{\cdot}74/6{\cdot}23 \text{ H}$$

$$= 0{\cdot}42 \times 10^{-6} \text{ H}$$

$\therefore$ Loop inductance per km of the line

$$= 2 \times 0{\cdot}42 \times 10^{-6} \times 1000 \text{ H} = \mathbf{0{\cdot}84 \text{ mH}}$$

****** ALL THE BEST ******