Transmission Line Performance
Module 5

PART I

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Introduction

- The performance of power system is mainly dependent on the performance of the transmission lines.
- Normally operated with a three phase balanced load and Can be represented by single phase equivalent
- Transmission line performance is governed by the four parameters-series resistance and inductance, shunt capacitance and conductance
- Difference in performance of the transmission lines depends upon the method how effect of capacitance is determined

Two port network representation

- A transmission line on a per phase basis can be represented by a two port network.

- Input port to which source is connected and output port where power is received and delivered to load
- The behaviour of the network can be represented by the equation

Modelling of short transmission lines

- Effect of shunt capacitance and shunt conductance are ignored
- Series impedance can be taken as lumped

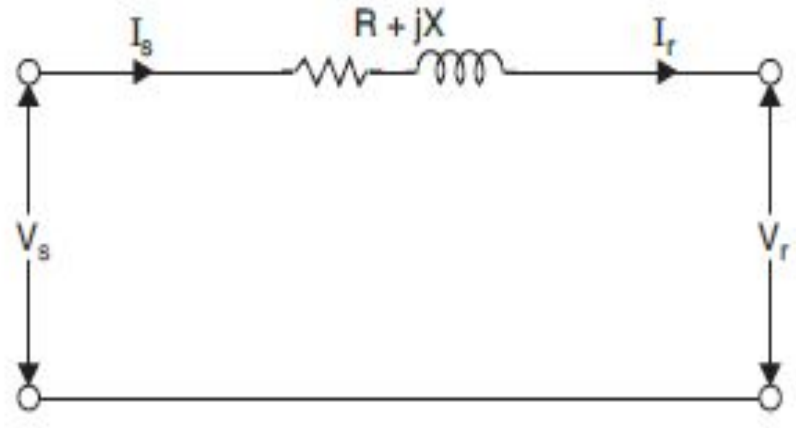

Figure 5.2: Equivalent circuit of short transmission line

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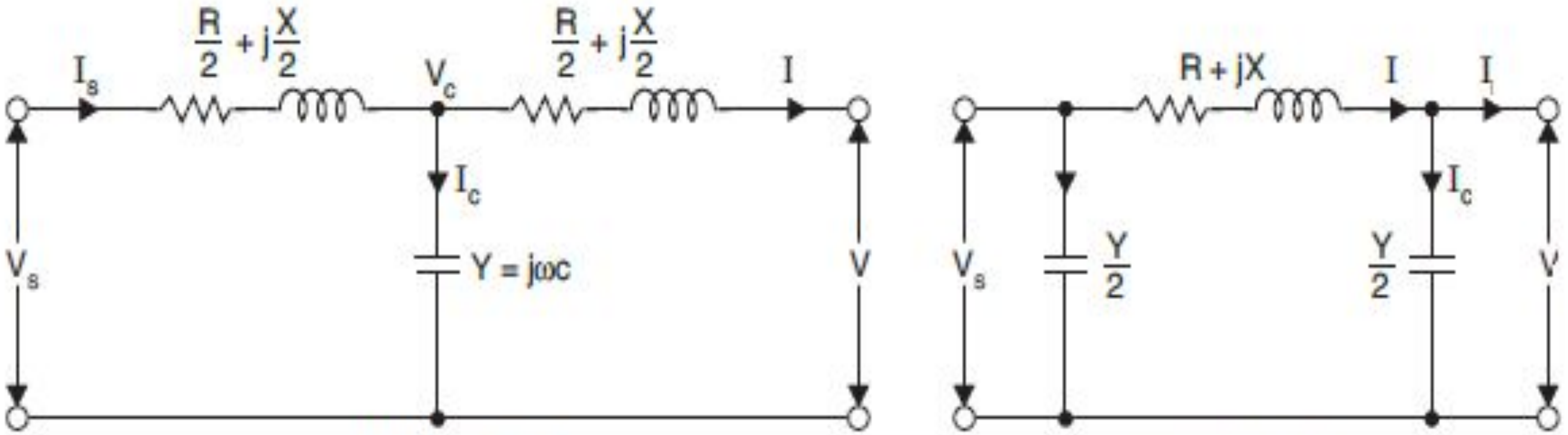
Modelling of medium transmission lines

- shunt capacitance is either assumed to be concentrated at the middle of the transmission line or half of the total capacitance at each end of the transmission line

- The two configurations are known as nominal-T and nominal-Π



(a) Nominal-T (b) Nominal-π

Nominal-T circuit

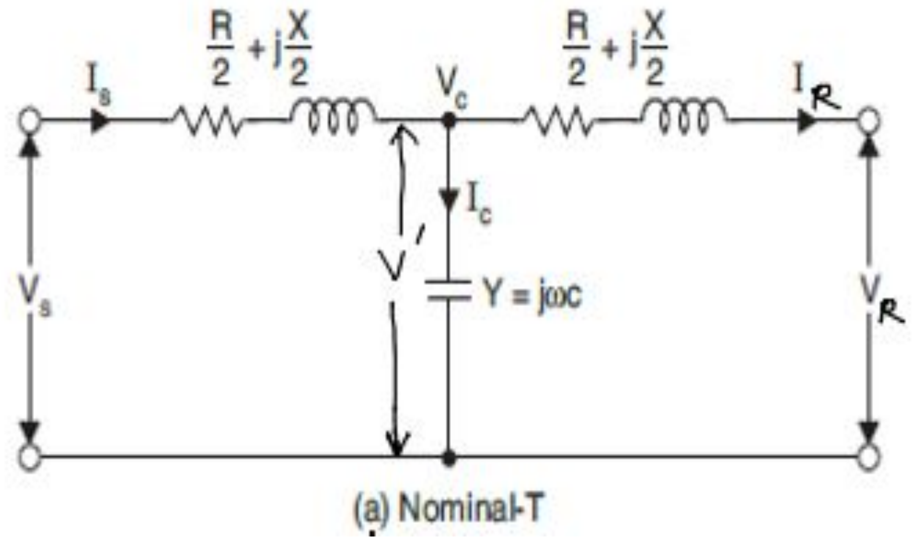
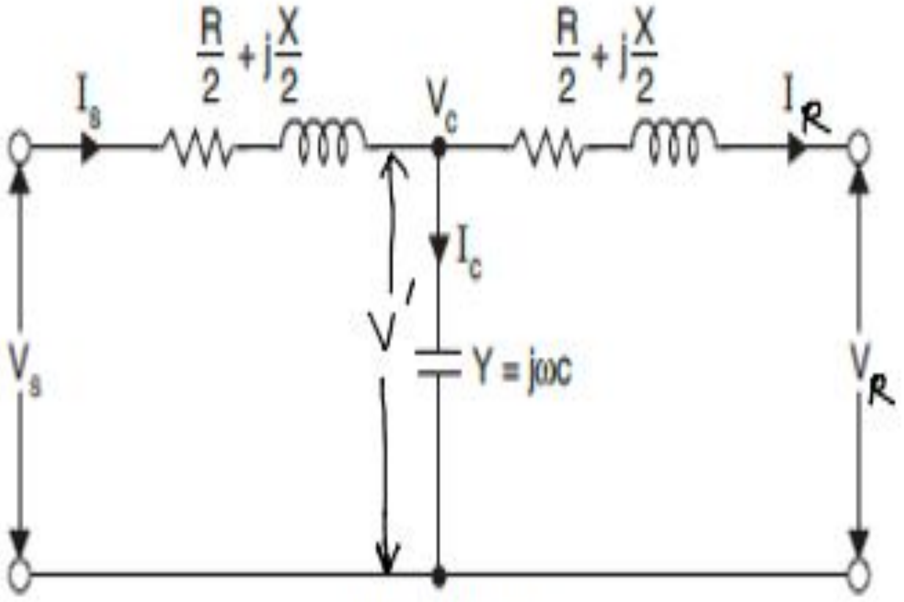


Figure 5.4 (a) Nominal T circuit



(a) Nominal-T

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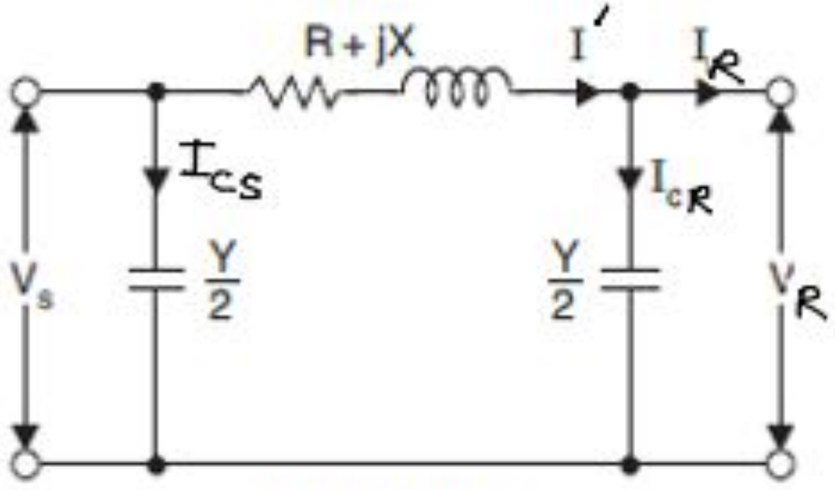
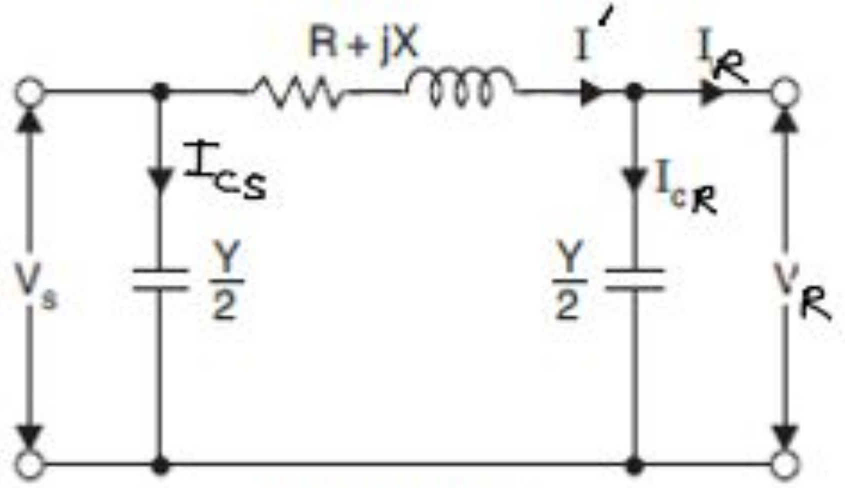
Nominal-Π circuit



(b) Nominal-π

Using Equations 5.21 and 5.22

$$\begin{bmatrix} V_S \\ I_S \end{bmatrix} = \begin{bmatrix} 1+\frac{ZY}{2} & Z \\ Y\left(1+\frac{ZY}{4}\right) & 1+\frac{ZY}{2} \end{bmatrix} \begin{bmatrix} V_R \\ I_R \end{bmatrix} \quad \text{—— } 5.23$$



(b) Nominal-π

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PART III

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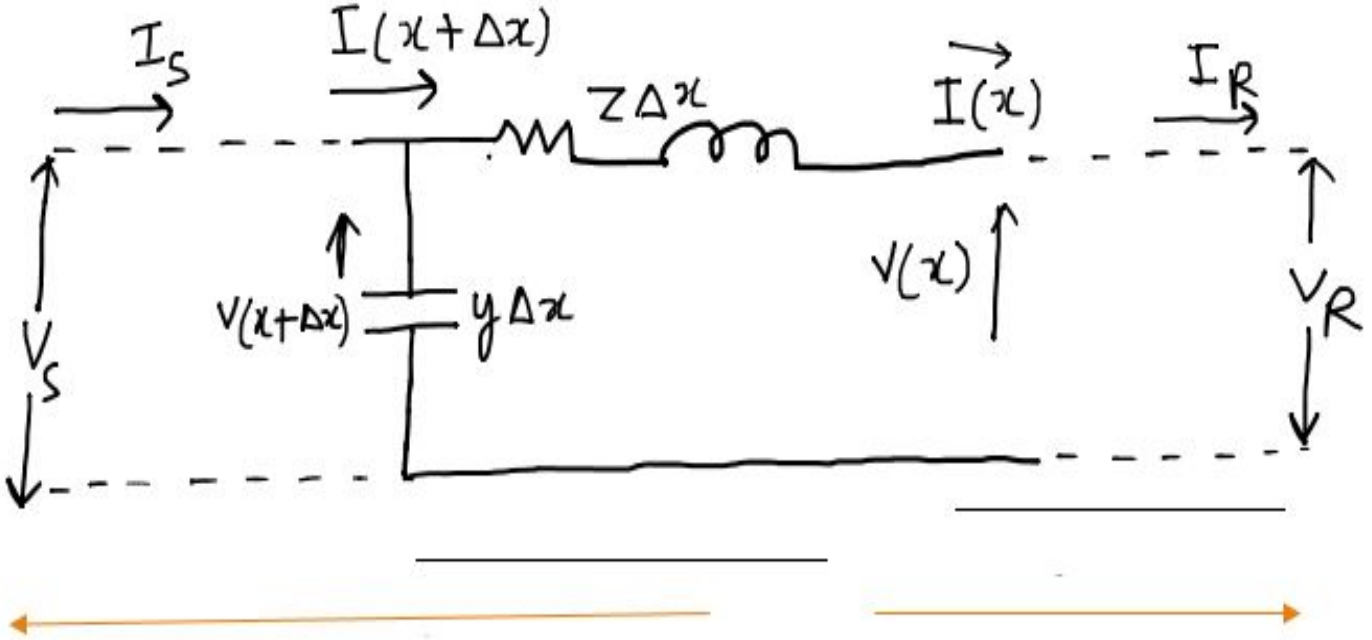
Long transmission lines

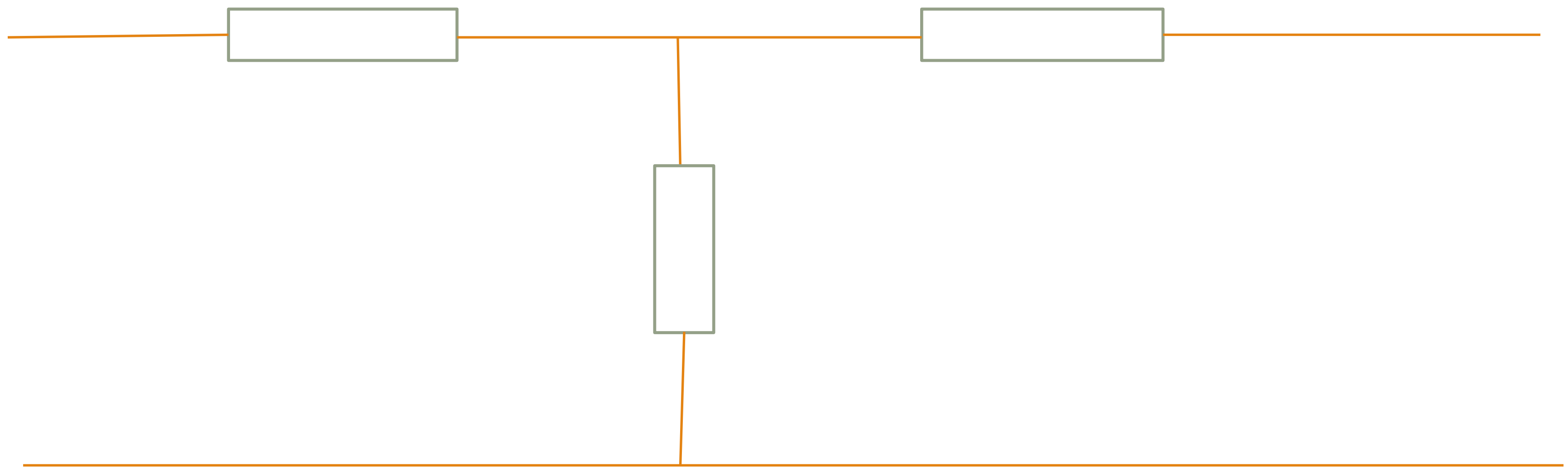
- Line parameters are distributed along the entire length of the transmission line
- Lumped parameter analysis fails in case of long transmission line



I_S
$I(x+\Delta x)$
$Z\Delta x$
$I(x)$
I_R
V_S
$V(x+\Delta x)$
$y\Delta x$
$V(x)$
V_R

Equivalent Π and T networks

Equivalent **Π network of long transmission line**



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PART IIIA

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Power flow in transmission lines

- Power flow at any point along a transmission line can be determined when voltage , current and power factor are known

Conjugates of I_R and I_S

$$I_R^* = \frac{|V_S|}{|B|}\angle\beta - \frac{|A||V_R|}{|B|}\angle\beta-\alpha \quad \text{——} \quad (5.39d)$$

$$\dot{I}_S^* = \frac{|A||V_S|}{|B|}\angle(\beta-\alpha-\delta) - \frac{|V_R|}{|B|}\angle\beta \quad \text{——} \quad (5.39e)$$

Complex power per phase at the receiving end

$$S_R = P_R + jQ_R = V_R I_R^* = |V_R|\angle 0^\circ \left[\frac{|V_S|}{|B|}\angle\beta - \frac{|A||V_R|}{|B|}\angle\beta-\alpha\right]$$

$$S_R = \frac{|V_R||V_S|}{|B|}\angle\beta - \frac{|A||V_R|^2}{|B|}\angle\beta-\alpha \quad \text{——} \quad (5.39f)$$

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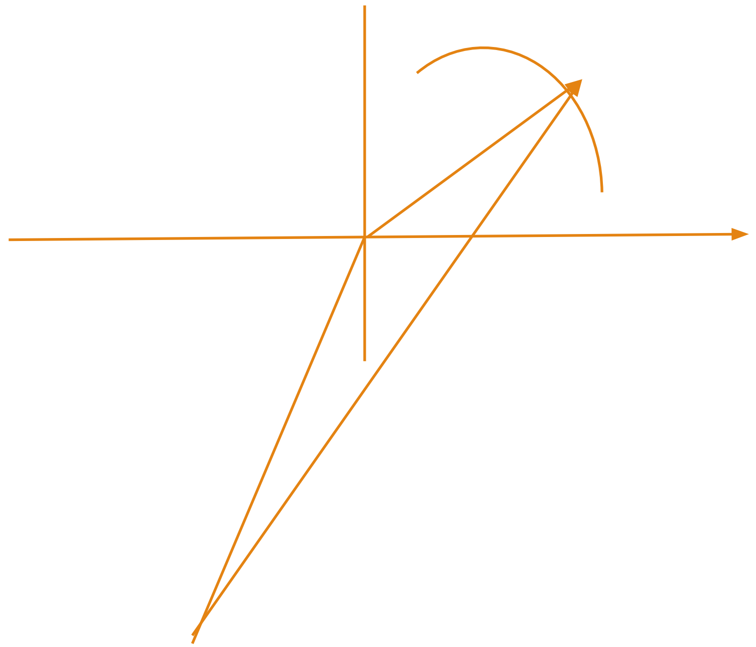
Power circle diagram

Receiving end power circle diagram

- The loci of S and S are circles drawn from the tip of the constant phasors as centres.



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PART IV

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Corona

- Ionisation of air due to various effects such as cosmic rays, ultra-violet radiations from sun etc.

- Significant change in the condition of atmospheric air surrounding the two conductors if the electric field intensity reaches critical value of 30kV/cm (peak)
- Ions attain a sufficiently high velocity and remove one or more electrons of a neutral molecule on striking
- A cumulative process initiates in which a new electron and positive ion are formed –an ion avalanche

- For the uniform field, the conditions necessary to produce ion avalanche reached simultaneously in the gap and an arc is established between the two electrodes
- In case of cylindrical conductor, due to non-uniformity of field, a layer adjacent to the conductor gets ionized and a sustained ionization will persist around the conductor
- The phenomenon of corona is accompanied by violet glow , hissing sound and production of ozone gas and increases with increase in voltage
- As the voltage applied to the conductors is increased, the corona envelopes grow larger and larger until effective diameter is increased and corona can spread no further

Difference between HVAC and HVDC

HVAC

- A faint violet glow uniform around the smooth and polished conductor throughout the length of conductor
- For dirty and rough conductors, appears only at rough points

HVDC

- Difference in the glow of two conductors
- Uniform glow in case of positive conductor and spotty in case of negative conductors

Disruptive critical voltage

- Corona formation takes place when the potential difference between conductors , at which the electric field intensity at the surface of the conductor exceeds the critical value

- It is minimum phase to neutral voltage at which corona occurs

Visual critical voltage

- Minimum phase to neutral voltage at which corona glow appears all along the line conductors

- Corona glow takes place at a higher voltage than critical disruption voltage, known as visual critical voltage

Corona loss

- The ions produced by the corona result in space charges which are being moved around by the electric field
- Energy required for this movement is taken from the conductor and this energy loss is known as power loss
- Dissipation takes place in the form of light, heat ,sound and chemical action
- Produces radio interference aspects of corona

Harmonic currents and radio interference

- Harmonic currents due to increase or decrease in effective diameter of conductor, the capacitance offered by the system pulsates at triple frequency

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- Corona discharge emit radiations which are likely to introduce noise signals in the communication channels, radio and TV receivers

Factors affecting corona

- Atmosphere factors
- Electrical factors
- Conductor heating
- Conductor size
- Spacing between the conductors

Positive and negative sides of corona

POSITIVE SIDE	NEGATIVE SIDE
Increased virtual diameter of conductor	Associated with power loss
Reduced electrostatic stress	Lowers efficiency
Safety valve for surges	Ozone causes corrosion of conductor
Smoothens conductor surface	Radio interference

Some aspects of corona

- Power loss
- Harmonic currents
- Increased effective capacitance of the conductor
- Faint violet glow around the conductor
- Maximum glow over rough and dirty conductor surface
- Hissing sound
- Production of ozone gas
- Works as safety valve for surges

Ways to reduce corona

- By increasing conductor size
- By increasing conductor spacing

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PART V

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Ferranti effect

- Rise in voltage at the receiving-end of a transmission line during no load or lightly load conditions

- A long transmission line has an appreciable capacitance and this increase in voltage at receiving end is due to flow of charging currents

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PART V A

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Electromagnetic and electrostatic interference

- Power lines may interfere with communication lines due to electromagnetic and electrostatic induction

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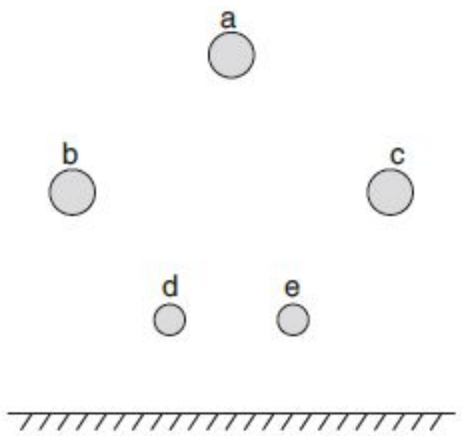
- Both depend upon the distance between the power and communication lines and the route length over which they run parallel
- The induced currents in the communication lines by electromagnetic induction superimpose on the true speech currents which causes distortion
- The electrostatic induction raises the potential of communication lines which is dangerous for equipment as well as for the user


a
b
c
d
e

With balanced currents	With unbalanced currents
❖ Very small induced emf and net flux linkages with balanced currents	❖ Emf induced and net flux are of high magnitude when line currents are heavily unbalanced
❖ If power lines are transposed with balancing currents, net flux linkages are zero ❖ If power lines are not transposed, some emf is induced even with balancing currents which can be neglected	❖ Third harmonic components may pose serious problems if present

Electrostatic interference

When a conductor runs parallel to an infinite plane (earth), the potential distribution between the conductor and plane is exactly similar to that between its image and plane

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PART VI

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Reactive power compensation

- Voltage profile is the voltage ,relative to the nominal voltage, at the different buses of the power system
- All equipment in the power system are designed to operate satisfactorily within a permissible range of voltage variations.
- Transmission lines have to transfer power with a voltage drop of less than 10%
- It is necessary to provide additional equipment ,called reactive power compensating equipment to generate or absorb vars

Series compensation

- Series compensation means reduction in the series impedance of the transmission line by adding a capacitor in series

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- Improves the power transfer capability as well as voltage profile at the receiving end of the transmission line
- Generate vars proportional to square of current