EE8501 POWER SYSTEM ANALYSIS

INTRODUCTION

- General perspective & Overview of Power System.
- Need for system planning and operational studies

OVERVIEW OF POWER SYSTEM

- GENERATION
- TRANSMISSION &
- DISTRIBUTION

Components of power system

- Generator
- Transformer
- Transmission Lines
- Distribution Lines
- Loads &
- Compensating Devices (like Shunt, Series, Static VAR Compensators)

Function of power system Analysis

- Need to monitor the voltages at various buses, real & reactive power flow between buses.
- To design the circuit breakers
- To plan future expansion of the existing system.
- Analyze system fault under different conditions (3Φ fault, L-G, L-L, L-L-G faults.)
- Study of small & large disturbances (sudden changes in load)

Need of power system analysis in planning &operation

- System planning & operation covers the whole period ranging from the incremental stage of system development

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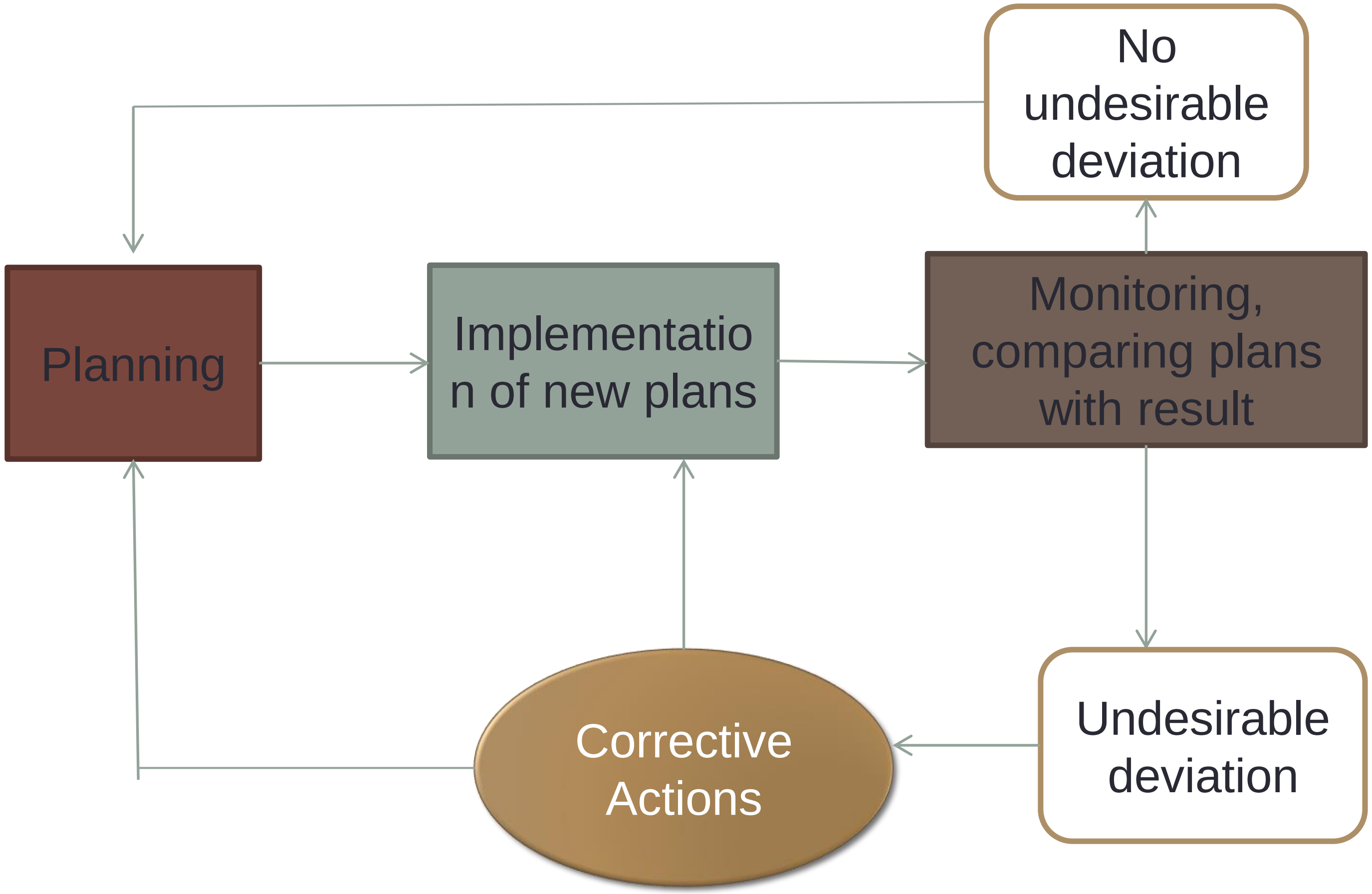
- Required area , spacing , RLDC & NLDC for dispatching power .

- Total demand = Sum of real power generation

- System must be reliable & uninterrupted .

- Required to maintain over all system (generation, transmission & distribution) facilities

Block diagram of Planning & Operation of PS



Dealing of power system analysis

- Load (or) Power Flow Analysis
- Short Circuit Analysis
- Stability Analysis

LOAD (or) POWER FLOW ANALYSIS:

- System stability.
- To determine the voltage, current , active & reactive power flows in the PS
- Operating conditions can be analyzed such as loss in generation, transmission lines & transformer or load.
- Equipment overload & unaccepted voltage levels.
- To fix optimum size & location of the capacitors for improving power factor.
- LFA, is used to evaluate the effect of various loading conditions of a system.

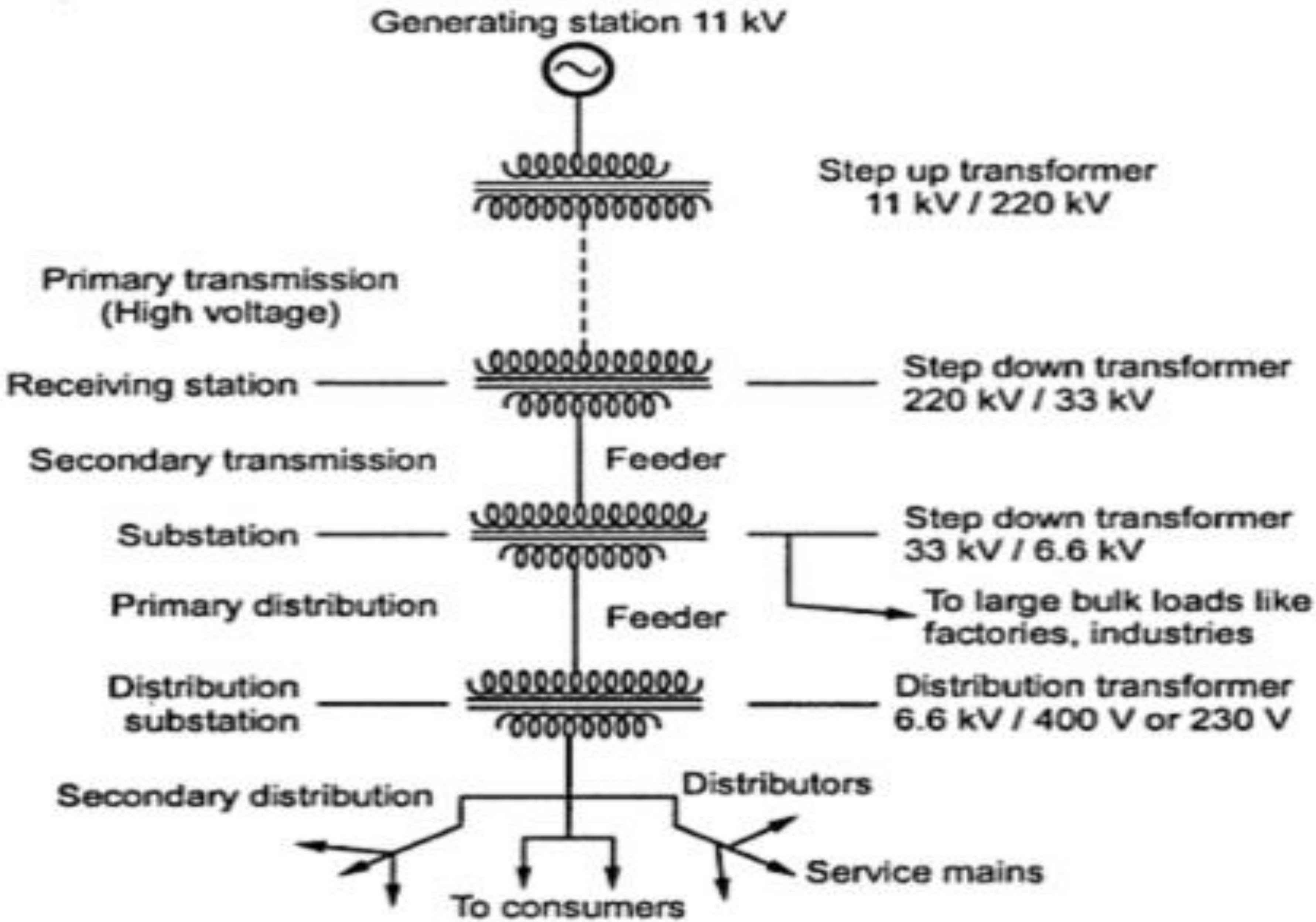
Short Circuit Analysis:

- Multiple increase in current & forms abnormal system
- To find the magnitude of current flow in the system at different interval of times, until it meets steady state.
- Types of fault (Unsymmetrical)
- Rescue the system from fault condition.
- To analyze SC, symmetrical components & sequence network are used .

Stability Analysis:

- Type- Steady state & Transient stability.
- Stability depends on power flow pattern, generator characteristics, system loading level & line parameters, etc..
- Steady state Stability – PS remains Synchronism & follows relatively slow load change.
- Transient stability – PS remains Synchronism under large disturbance

Structure of power system

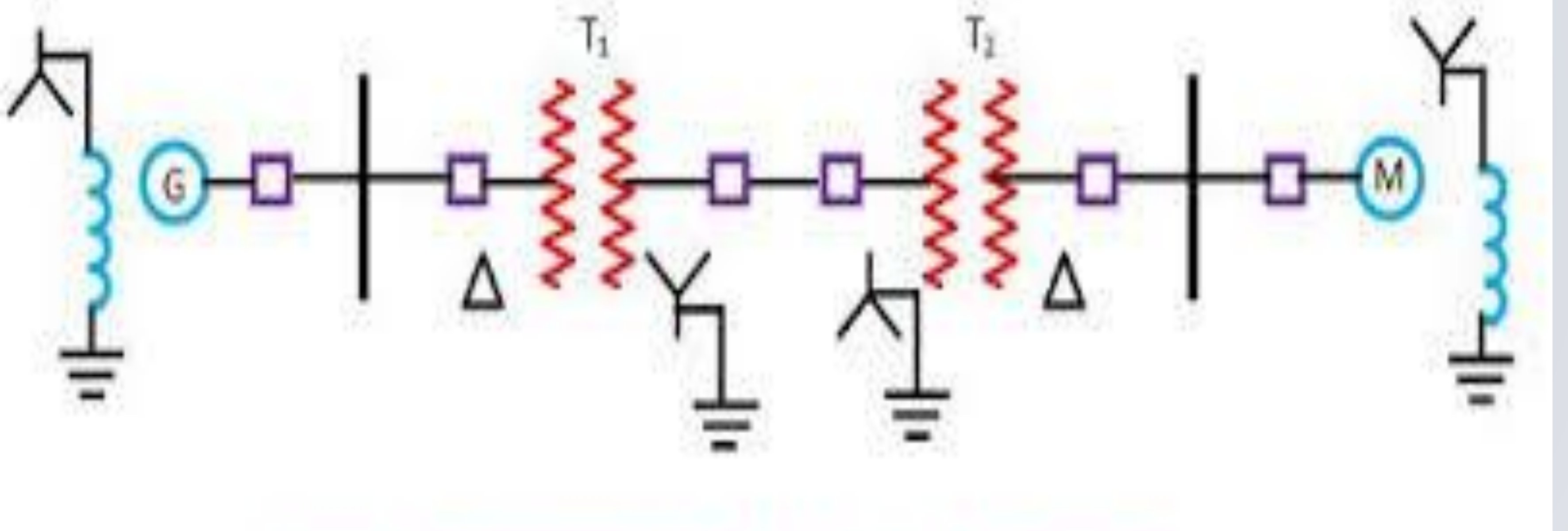


- Generator – Converts mechanical energy to electrical energy [6.6KV, 10.5KV, 11KV, 13.8KV & 15.75KV]
- Transformer – Transfer energy for one circuit to another circuit without changing the frequency (for increasing & decreasing the Voltage level)
- Transmission Lines – Power transfer from one location to another
- Distribution Lines – Distributes power to commercial, domestic & small consumers

    - ✓ Primary Transmission Lines –11KV/110KV or 132KV or 220KV or 400KV or 765KV
    - ✓ Secondary Transmission Lines – (step down value) 66KV or 33KV or 22 KV or 11KV.
    - ✓ Primary Distribution Line- 3Φ, 3 wire system, 33 KV or 66KV feeder
    - ✓ Secondary Distribution Line- 400 V (for 3Φ) or 230 V (for 1Φ)

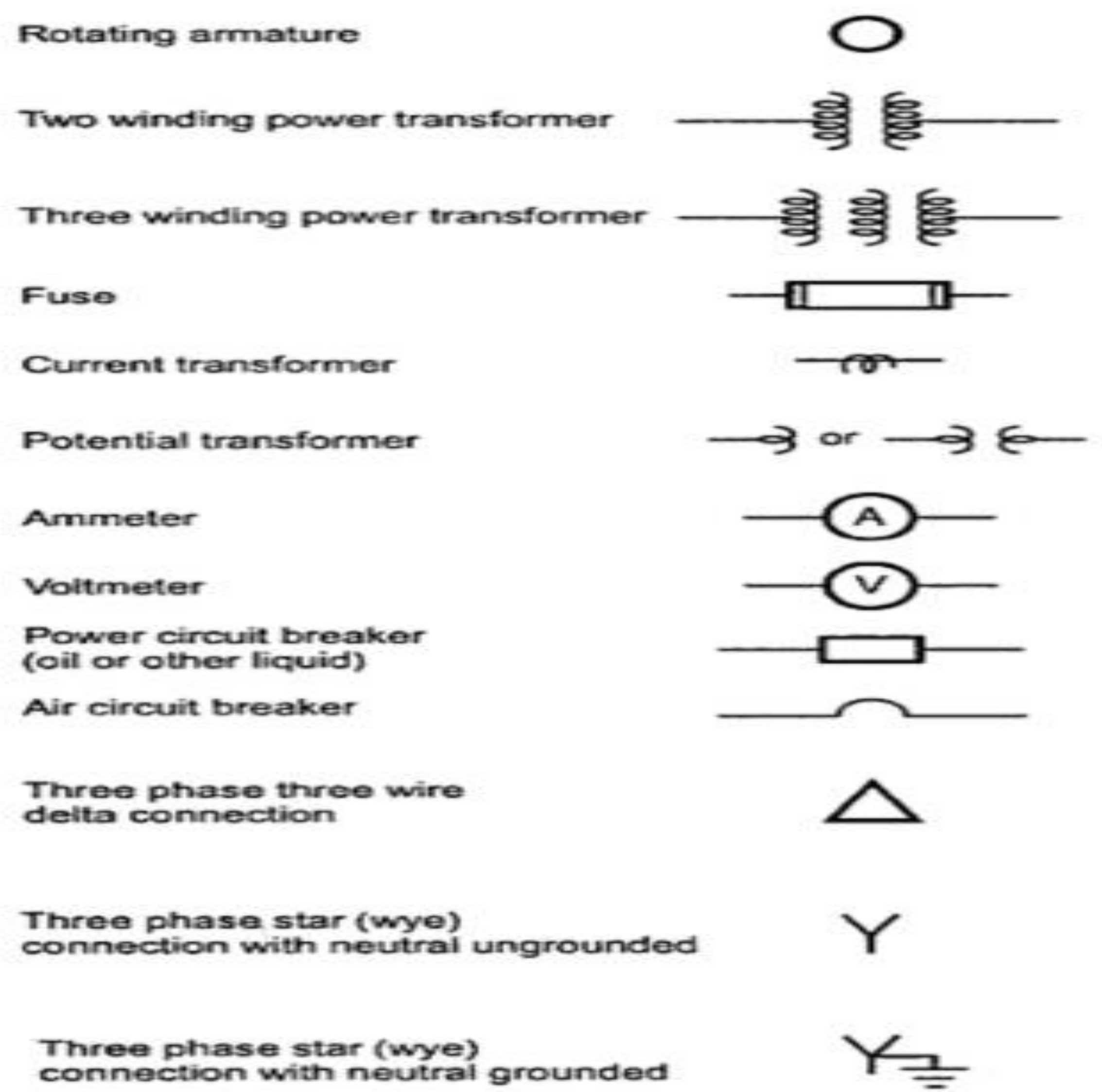
SINGLE LINE DIAGRAM :

- **It gives diagrammatic & easy identification of power system network.**
- **Components are represented in the form of symbols & they are interconnected in a straight line.**



Single Line Representation of a Typical Power System

Symbols of Single Line diagram



Per-unit system

- Voltages different level has to transformed to single voltage level in Per-Unit (P.U) form.
- In PS, impedance, current, voltage & power are expressed in P.U values.
- P.U systems are ideal for the computerized analysis & simulation of complex PS problems.
- Generally, manufacturers are preferring equipment impedance values in P.U rating.

P.U values of any quantity is defined as the ratio of ACTUAL QUANTITY to its BASE QUANTITY

TRANSMISSION LINE MODELS

- Short Transmission line
- Medium Transmission line
- Long Transmission line

The types of Transmission lines differ from the distance (km) & voltage level (KV).

SHORT TRANSMISSION LINE

- When the length of the transmission line is up **to 80km** and the line voltage is **less than 20kV**.
- Due to smaller length and lower voltage, the capacitance (C) effects are small and hence can be **NEGLECTED**.
- Only resistance (R) and inductance (L) are considered.

$$\boxed{Z = R + jX = (r + j\omega L)l}$$

where, Z = series impedance

r = per-phase resistance

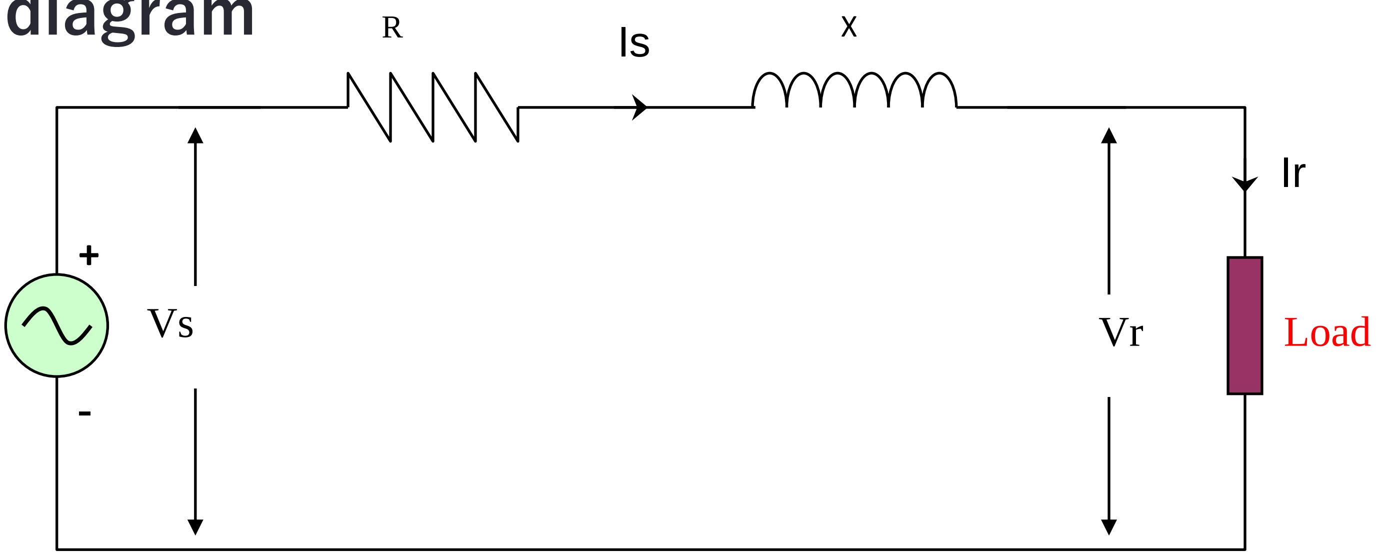
L = per-phase inductance

l = line length

- In this case, the capacitive effect is negligible and only the resistance and inductive reactance are considered.

SHORT TRANSMISSION LINE

Circuit diagram

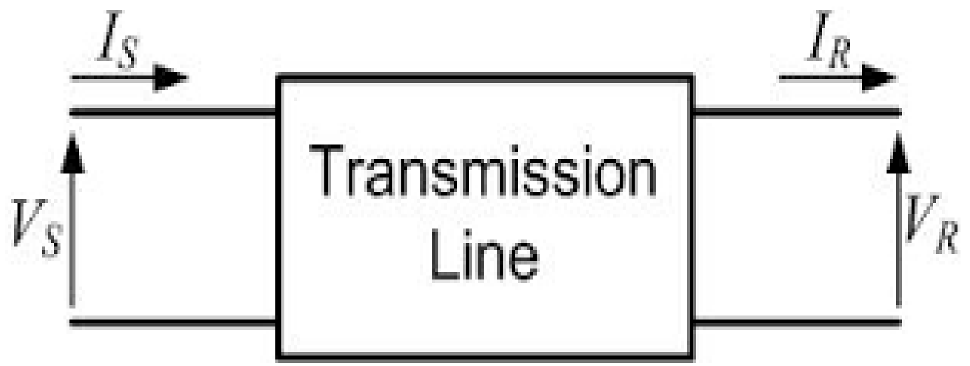


Vs - sending end voltage Vr - receiving end voltage I - load current
R - Loop resistance (Ω) X - Loop inductance (Ω)

$V_S = V_R + Z\, I_R$ ⟶ (1)

$I_S = I_R$ ⟶ (2)

Generalized Circuit Constant of a TL



$$V_S = AV_r + BI_r \quad (3)$$

$$I_s = CV_r + DI_r \quad (4)$$

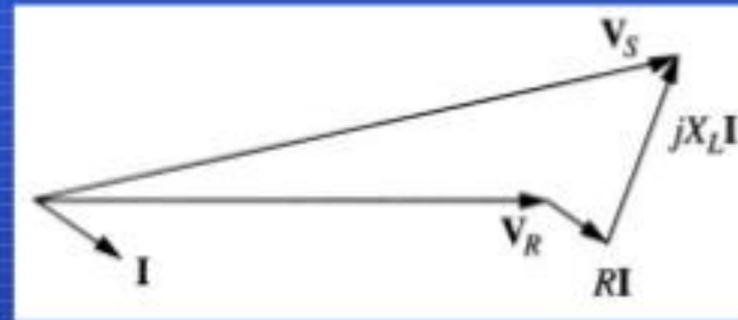
$$\begin{pmatrix} V_S \\ I_S \end{pmatrix} = \begin{pmatrix} A & B \\ C & D \end{pmatrix} \begin{pmatrix} V_R \\ I_R \end{pmatrix}$$

A=1 ; B=Z ; C=0 ; D=1

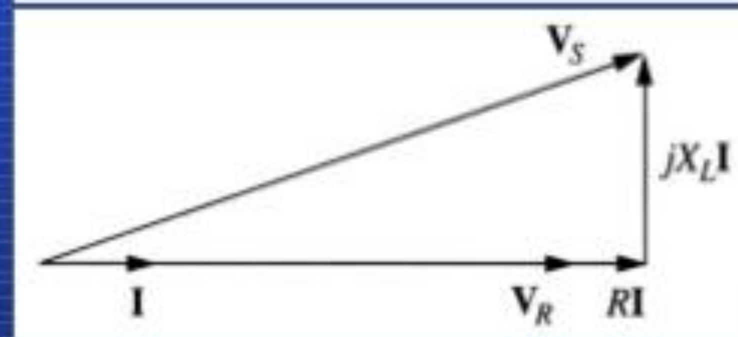
Short transmission line: phasor diagram

AC voltages are usually expressed as phasors.

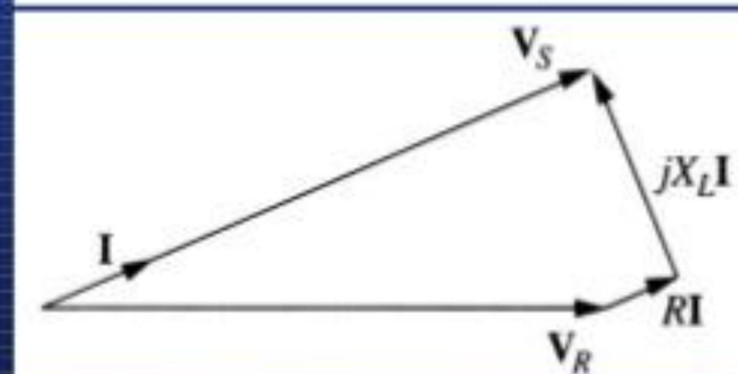
Load with lagging power factor.



Load with unity power factor.



Load with leading power factor.

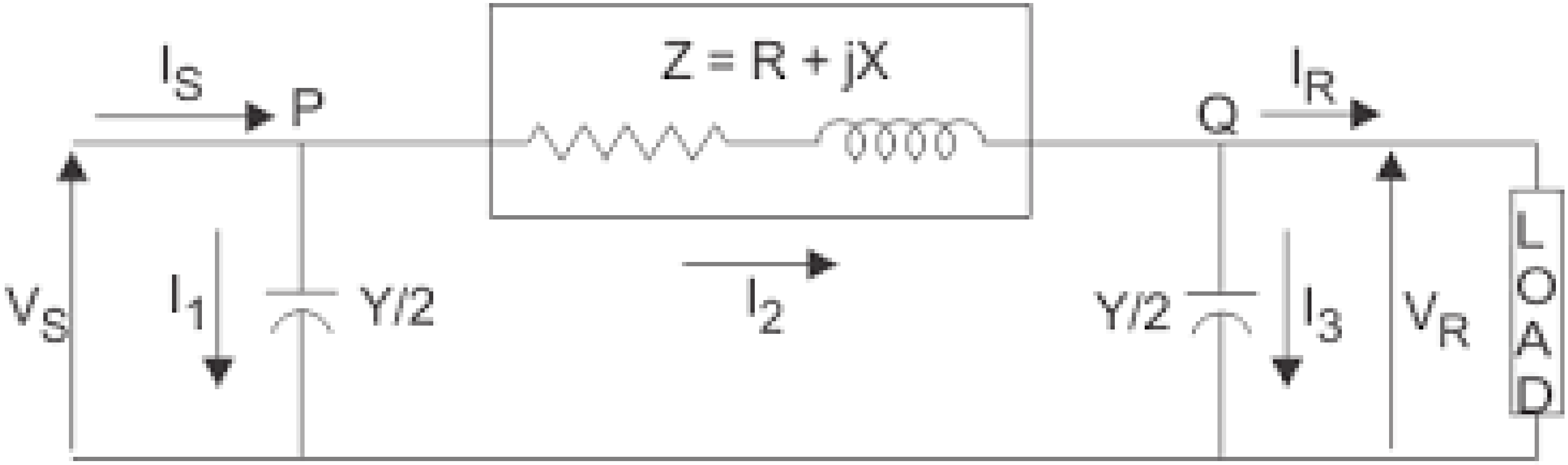


For a given source voltage V_S and magnitude of the line current, the received voltage is lower for lagging loads and higher for leading loads.

MEDIUM TRANSMISSION LINE

- When the length of the line is about **80km to 250km (50-150 miles)** and the line voltage is moderately high between **20kV to 100kV.**

- Due to sufficient length and line voltage, capacitance (C) is considered.



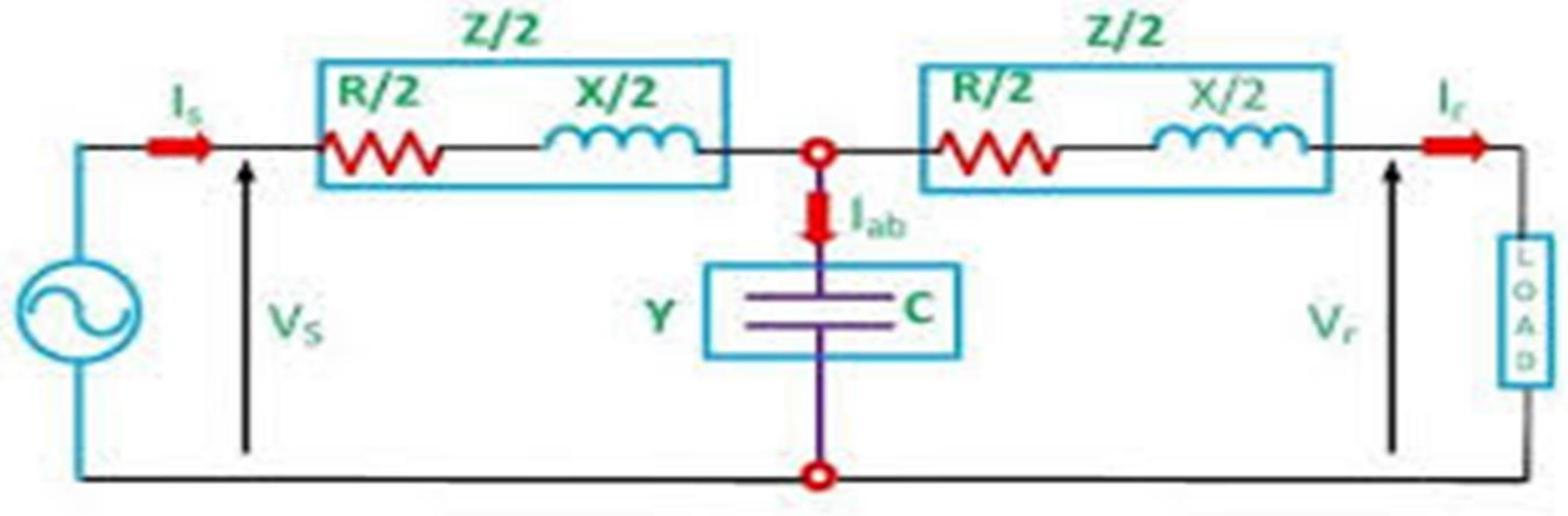
Nominal network of medium transmission line

$$A = \left(\frac{Y}{2}Z + 1\right)$$

$$B = Z\ \Omega$$

$$C = Y\left(\frac{Y}{4}Z + 1\right)$$

$$D = \left(\frac{Y}{2}Z + 1\right)$$



Nominal T model of a Medium Line

$$A = D = 1 + \frac{ZY}{2}$$

$$B = Z\left(1 + \frac{ZY}{4}\right)$$

$$C = Y$$

LONG TRANSMISSION LINE

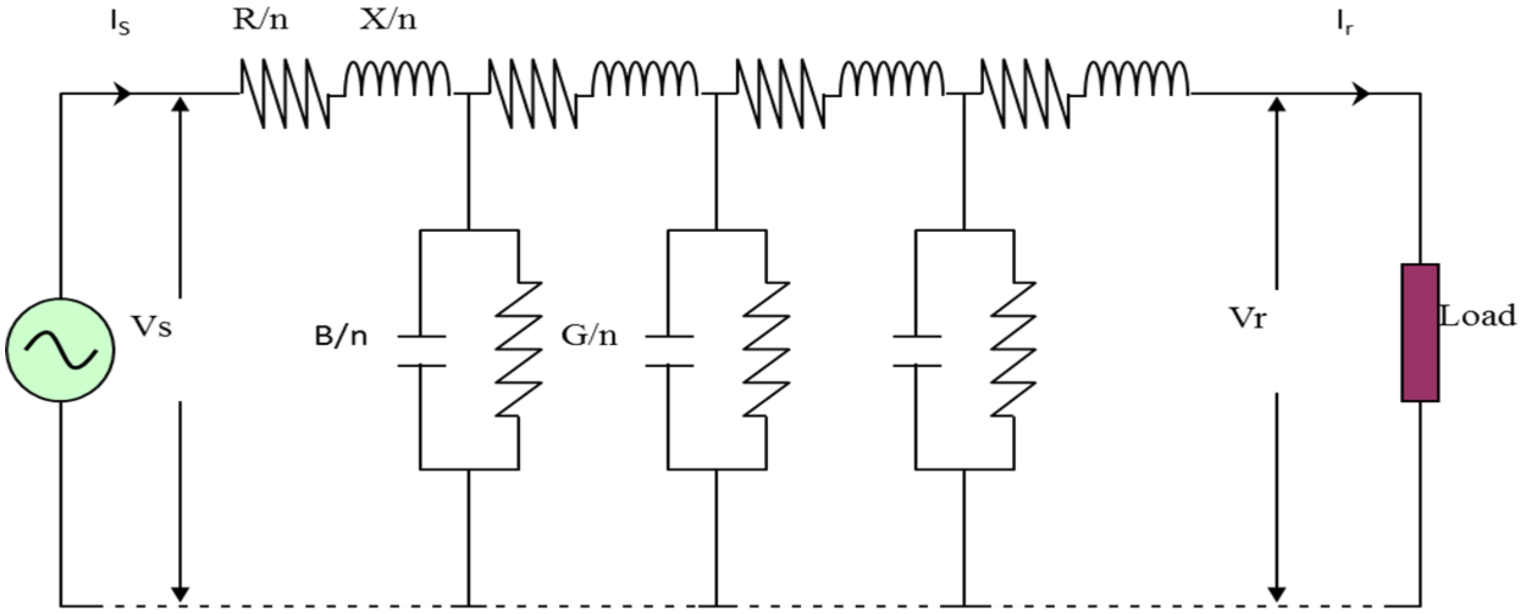
- When the length of the line is **more than 250km** and line voltage is very high which is **more than100kV.**

- The line constants **(R,L,C,G)** are uniformly distributed over the whole length of the line.

- **Resistance** (R) and **inductance** (X) are serial elements of transmission line.

- **Capacitance** (C) and **conductance** (G) are shunt elements of transmission line. It caused the power losses and corona effects.

LONG TRANSMISSION LINE CKT



Vs- sending end voltage
Vr- receiving end voltage
Is- sending end current
Ir- receiving end current
Ic- capacitance current
R- loop Capacitance (Ω)
X- loop Inductance (Ω)
C- capacitance (F)
G - loop conductance

$$A = cosh\delta l$$
$$B = Z_C sinh\delta l$$
$$C = \frac{sinh\delta l}{Z_C}$$
$$D = cosh\delta$$

- Thank You