B.TECH II YEAR SEM-II

23EE405

POWER SYSTEMS-2

- **Mrs.B.Leela Radhika**
- Assistant Professor, Electrical and Electronics Engineering
  Narsimha Reddy Engineering College (Autonomous)
  Secunderabad, Telangana, India- 500100.

PRESENTATION TOPIC IS

TRANSMISSION LINE

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TRANSMISSION LINES

A transmission line is used for the transmission of electrical power from generating substation to the various distribution units. It transmits the wave of voltage and current from one end to another. The transmission line is made up of a conductor having a uniform cross-section along the line. Air act as an insulating or dielectric medium between the conductors.

CLASSIFICATION OF TRANSMISSION LINES

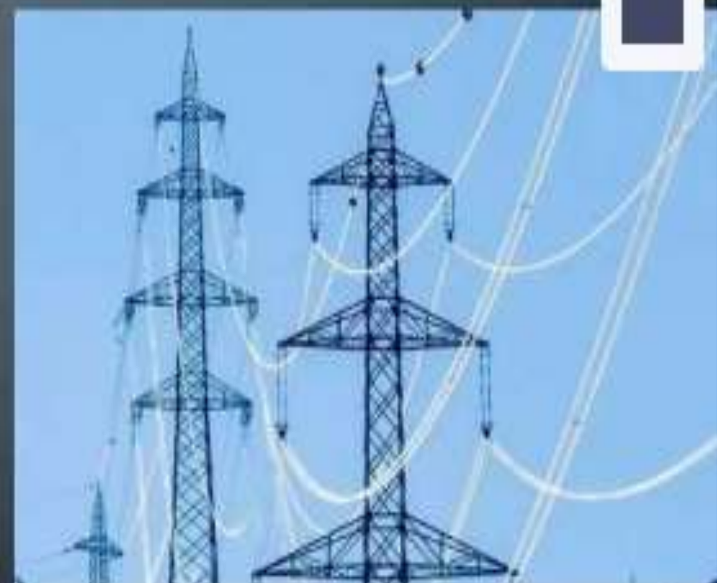
1. Overhead transmission lines
    - Short transmission lines
    - Medium transmission lines
    - Long transmission lines
2. Underground cables

Short transmission lines

- Line voltage is less than 20KV
- Length of transmission line is up to about 80Km
- Capacitance effect are small or negligible

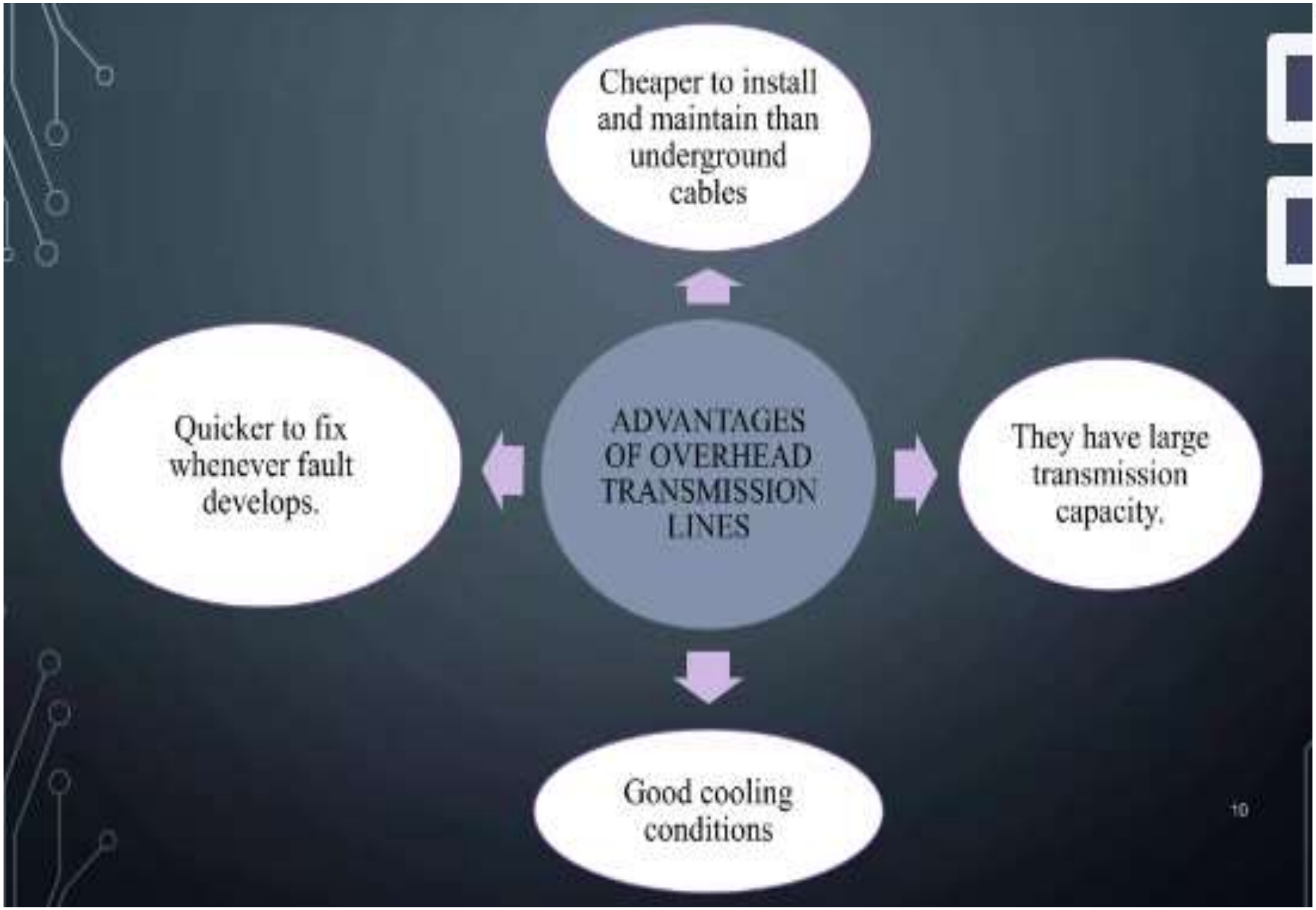
MEDIUM TRANSMISSION LINES

- Line voltage is moderately high.
- It is greater than 20KV but less than 100KV.
- Length of lines is about 50 Km to 150Km.
- Capacitance is significant.



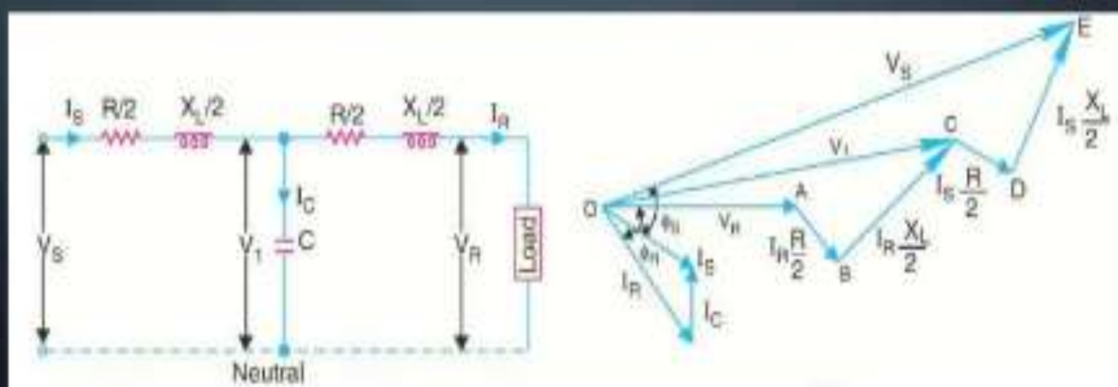
LONG TRANSMISSION LINES

- Line voltage is very high (>100KV).
- Length of an overhead line is more than 150Km.
- Line constants are considered uniformly distributed over the whole length of the line.


ADVANTAGES OF OVERHEAD TRANSMISSION LINES
Cheaper to install and maintain than underground cables
They have large transmission capacity.
Good cooling conditions
Quicker to fix whenever fault develops.
10

NOMINAL "T" METHOD

Nominal "T" Method : In this method, the whole line capacitance is assumed to be concentrated at the middle point of the line and half the line resistance & reactance are lumped on its either side as shown in fig. There fore in this arrangement full charging current flows over half the line. In fig one phase of 3 phase transmission line is shown as it is advantageous to work in phase instead of line to line values



NOMINAL "T" MODEL OF A TRANSMISSION LINE

$$I_{ab} = \frac{V_{ab}}{Z_{ab}} = YZ_{ab}$$

By Kirchoff's current law at node a,

$$I_s = I_r + I_{ab}$$

$$I_s = I_r + YV_{ab}$$

$$I_s = I_r + Y\left(V_r + \frac{Z}{2}I_r\right)$$

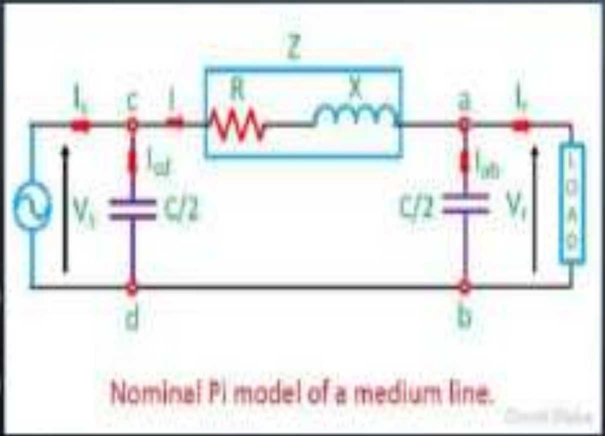
By Kirchoff's voltage law

$$V_s = V_{ab} + \frac{Z}{2}I_s$$

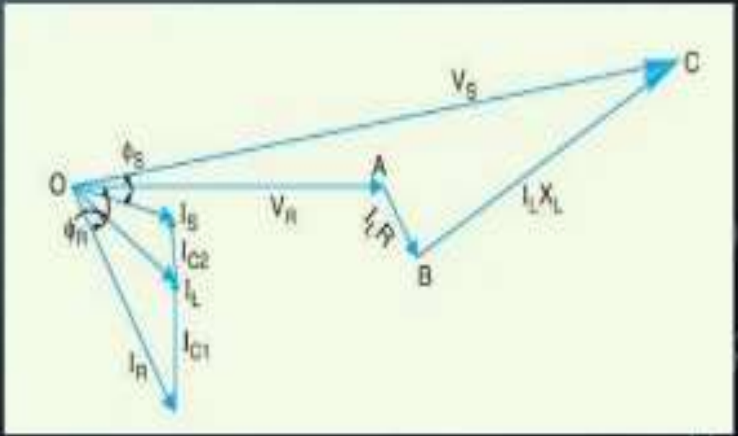
$$V_s = V_r + \frac{Z}{2}I_r + \frac{Z}{2}\left[YV_r + \left(1 + \frac{ZY}{2}\right)I_r\right]$$

NOMINAL "PI" MODEL OF A MEDIUM TRANSMISSION LINE

In the nominal pi model of a medium transmission line, the series impedance of the line is concentrated at the centre and half of each capacitance is placed at the centre of the line. The nominal Pi model of the line is shown in the diagram below



Nominal Pi model of a medium line.



❑What is Corona Effect?

- The phenomenon of ionization of surrounding air around the conductor, hissing noise and production of Ozone gas in an overhead transmission line is known as Corona Effect.

Factors Affecting Corona

- Atmosphere
- Conductor size
- Spacing between conductors
- Supply voltage
- Air density factor

❑ Advantages

- Diameter of the conductor is increased.
- The increased diameter reduces the electro-static stresses between the conductors.
- Corona effect reduces the effects of transients.
- Some industries use this effect to remove unwanted volatile organics from atmosphere.

Disadvantages

- The corona power loss reduces the efficiency of the transmission line.
- Corona effect produces Ozone which lead corrosion of the conductor.
- Voltage drops occur in the line.
- The radio and TV interference occurs on the line.
- The Corona effect can also damage the line insulation.

❑ Reducing Methods of Corona Effect

- By increasing conductor spacing
- By increasing conductor size
- Using bundled conductors

UNIT-2 VOLTAGE CONTROL AND PF IMPROVEMENT

Methods of Voltage Control in Power System

- On – Load Tap Changing Transformer
- Off – Load Tap Changing transformer
- Shunt Reactors
- Synchronous Phase Modifiers
- Shunt Capacitor
- Static VAR System (SVS)

- **Shunt Capacitors** – The shunt capacitors are the capacitors connected in parallel with the line. It is installed at the receiving end substation, distribution substations and in the switching substations. The shunt capacitor injected the reactive volt-ampere to the line. It is placed in the three phase bank.

- **Off – Load Tap Changing Transformer** – In this method, the voltage is controlled by changing the turn ratio of the transformer. The transformer is disconnected from the supply before changing the tap. The tap changing of the transformer mostly done manually.
- **On – Load Tap Changing Transformer** – This arrangement is used for changing the turn ratio of the transformer for regulating the system voltage when the transformer delivers the load. Most of the power transformer is provided with on-load tap changer.

- **Capacitor banks:**
- The most common method, where capacitors are strategically placed along the transmission line to compensate for the lagging reactive power drawn by the load.
- **Synchronous condensers:**
- Large rotating machines that can be used to provide leading or lagging reactive power depending on their excitation level, making them suitable for large power systems.
- **Harmonic filters:**
- In cases where harmonic distortion is present, specialized filters can be used to mitigate harmonic currents and improve power factor.
- **Active power factor correction (APFC) devices:**
- Advanced systems that dynamically adjust reactive power compensation based on real-time load conditions.

- Benefits of power factor improvement:
- **Reduced current flow:** By improving power factor, the current drawn from the source is reduced for the same active power, leading to lower losses in transmission lines.
- **Increased system efficiency:** Reduced current means less energy loss due to resistance in the lines.
- **Lower electricity bills:** Utilities often penalize customers with low power factors, so improving it can result in cost savings.

- Important considerations when designing power factor correction systems:
- **Load characteristics:**
- Analyzing the type and variation of load to determine the appropriate size and placement of capacitors.
- **Harmonic analysis:**
- Assessing the presence of harmonics to ensure the chosen capacitor bank can handle them.

- Compensation in a power system is the process of intentionally adding reactive power devices to a power network to improve its performance. This can be done by connecting capacitive or inductive devices in series or parallel.

- Benefits of compensation
- **Improved voltage profile**: Compensation can improve the voltage profile of a power system.
- **Improved power factor**: Compensation can improve the power factor of a power system.
- **Enhanced stability performance**: Compensation can enhance the stability performance of a power system.
- **Improved transmission capacity**: Compensation can improve the transmission capacity of a power system.
- **Reduced losses**: Compensation can reduce losses in a power system.

- Methods of compensation
- **Passive compensation**
- Uses capacitors and reactors to add reactive power to the system
- **Active compensation**
- Uses power electronic solutions like Static VAr Generators (SVG's) and STATCOMS to add reactive power to the system
- **Shunt compensation**
- Uses capacitors and reactors connected in parallel to transmission lines to regulate voltage
- **Series compensation**
- Uses capacitors connected in series to transmission lines to increase power transfer capability

- A "radial line with asynchronous load" refers to an electrical power distribution system where power flows in a single direction (radial) from a source to various loads, and those loads are primarily composed of asynchronous motors, which means they are not synchronized with the power grid frequency and can draw varying amounts of reactive power, causing voltage fluctuations along the line.

- **Radial distribution:**
- Power flows only in one direction from the source to the loads, with no alternative paths back to the source.
- **Asynchronous load:**
- The majority of the connected loads are asynchronous motors, like induction motors, which can draw significant reactive power depending on their operating conditions.

- Challenges associated with a radial line with asynchronous load:
- **Voltage fluctuations:**
- Due to the varying reactive power drawn by asynchronous motors, the voltage at different points along the line can fluctuate significantly, potentially impacting the performance of other connected devices.
- **Power factor correction:**
- To mitigate voltage fluctuations and improve system efficiency, power factor correction devices like capacitors may need to be installed at strategic locations along the line.
- **Load balancing:**
- Uneven distribution of loads across the radial line can further exacerbate voltage issues, requiring careful planning and load balancing strategies.

- Applications:
- **Industrial areas:**
- Where large industrial motors are used, often in a radial distribution system due to their dispersed locations.
- **Rural areas:**
- Rural distribution networks may rely on radial lines with a mix of residential and agricultural loads, including asynchronous motors for pumps and other equipment.

UNIT-3
PER UNIT REPRESENTATION OF POWER SYSTEMS & TRAVELLING WAVES

- The per-unit system is a mathematical method for expressing power system quantities as fractions of a base unit. It's used to simplify calculations and analyze electrical systems.

- How it works
- The per-unit value of a quantity is the ratio of its actual value to a base value.
- The units of per-unit values are per unit.
- Per-unit values are used to express voltages, currents, powers, and impedances.

Useful

- The per-unit system simplifies calculations because quantities don't change when moving across a transformer.
- It's useful for analyzing large systems with different voltage levels and equipment capacities.

- A "traveling wave" in a power system refers to a transient surge of voltage and current that propagates along a transmission line at near the speed of light, typically caused by a sudden disturbance like a fault, switching operation, or lightning strike, essentially acting as a wave moving along the line due to the inherent inductance and capacitance of the conductor.

- **Applications:**
- **Fault location:** By analyzing the time it takes for a traveling wave to reach the ends of a line after a fault occurs, the fault location can be determined.
- **Protective relaying:** Traveling wave relays are designed to detect these waves and initiate protective actions quickly in case of faults.

- When a capacitor is connected "at a junction" in a circuit, it means it is placed directly between two or more circuit paths that meet at a single point, effectively allowing it to interact with the voltage fluctuations occurring at that junction, usually to filter out noise or stabilize the voltage level in the circuit.

- Key points about capacitor connections at a junction:
- **Function:**
- The capacitor acts as a reservoir, storing and releasing charge as the voltage at the junction fluctuates, helping to smooth out voltage changes and reduce ripple effects.
- **Series or Parallel Connection:**
- Depending on the circuit design, the capacitor can be connected in series with one of the branches at the junction, or in parallel with the junction itself, which affects how it interacts with the voltage fluctuations.

- Attenuation in traveling waves is the loss of energy that occurs as a wave moves through a medium. It's also known as the reduction in the amplitude of a wave.
- Causes of attenuation
- **Transmission loss**: Energy is lost when a wave passes through an interface, such as when it reflects, diffracts, or scatters
- **Geometric divergence**: Waves spread out from a source, causing their energy to spread out as well
- **Absorption**: Energy is converted into heat through friction
- **Scattering**: Waves reflect in directions other than their original direction

- Examples of attenuation
- **Seismic waves**
- The attenuation of seismic waves can be affected by pressure, temperature, mineralogy, and melt and volatiles
- **Ocean waves**
- The attenuation of ocean waves can be caused by energy loss when water exchanges between the shelf and the inner island archipelago
- **Electromagnetic power transmission**
- The attenuation of electromagnetic power transmission can be caused by dielectric loss, which is dependent on the permittivity and permeability of the dielectric material

UNIT-IV
OVER VOLTAGE PROTECTION AND INSULATION COORDINATION

- Overvoltage protection" in a power system refers to a mechanism designed to safeguard electrical equipment from damage caused by excessively high voltage levels, typically achieved through devices like surge arrestors (lightning arresters) that divert excess voltage to the ground when a surge occurs, preventing damage to connected devices and components within the system; essentially, it's a safety feature that protects against abnormal voltage spikes caused by events like lightning strikes or switching surges.

- **Function:**
- When the voltage in a power system exceeds a predetermined threshold, the overvoltage protection device activates, diverting the excess voltage to ground, thus preventing damage to equipment.
- **Common methods:**
- **Lightning arresters:** These are specialized devices installed at substations and along transmission lines to absorb and dissipate lightning surges.
- **Overhead ground wires:** These wires run parallel to power lines and are designed to intercept lightning strikes, directing them to the ground.
- **Surge protection devices (SPDs):** Smaller devices used at the point of entry into buildings or individual equipment to protect against smaller voltage spikes.

Importance

- Overvoltage protection is critical for ensuring the reliability and lifespan of electrical equipment, preventing potential damage from sudden voltage surges which could lead to malfunctions, fires, or equipment failure.

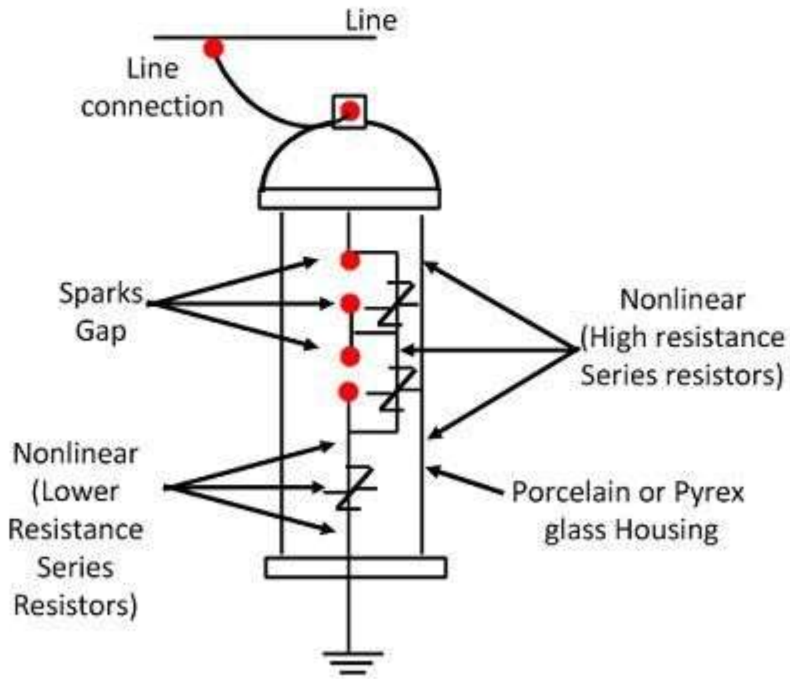
- An overvoltage due to an arcing ground can occur when a fault in a power system creates a repetitive arcing condition between a conductor and ground, causing voltage spikes; a Peterson coil is used to mitigate this overvoltage by essentially "canceling out" the capacitive current that fuels the arcing, effectively suppressing the arcing ground by introducing an equal and opposite inductive current through the coil, thus preventing excessive voltage rises.

Key points about arcing grounds and Peterson coils:

- **Arcing ground:**
- When a fault occurs between a conductor and ground, the capacitance of the power lines can create a continuous arcing phenomenon, leading to voltage fluctuations and potential overvoltages.
- **Peterson coil function:**
- This coil, connected between the neutral point of a three-phase system and ground, acts as an inductor that can be precisely tuned to generate a current that is equal in magnitude but opposite in phase to the capacitive charging current caused by the fault, essentially neutralizing it.
- **Overvoltage mitigation:**
- By effectively canceling out the arcing current, the Peterson coil minimizes the voltage fluctuations associated with an arcing ground, preventing potential damage to equipment.

- Important considerations:
- **Proper tuning:**
- To effectively suppress arcing grounds, the Peterson coil must be precisely tuned to match the system capacitance, which can vary depending on line configuration and environmental factors.
- **Limitations:**
- While effective in most cases, a Peterson coil may not completely eliminate overvoltages in extreme fault conditions or if the tuning is not optimal.

- Definition: The lightning arrester which consists the single or multi-gaps connected in series with the current controlling element, such type of arrester is known as the lightning arrester. The gap between the electrodes intercepts the flow of current through the arrester except when the voltage across the gap raises beyond the critical gap flashover. The valve type arrester is also known as gap surge diverter or silicon carbide surge diverter with a series gap.



Valve Type Lightning Arrester

- Working of Valve Type Lightning Arrester
- For low voltage, there is no spark-over across the gaps due to the effect of parallel resistor. The slow changes in applied voltage are not injurious to the system. But when the rapid changes in voltage occur across the terminal of the arrester the air gap spark of the current is discharged to ground through the non linear resistor which offers very small resistance.

UNIT-5

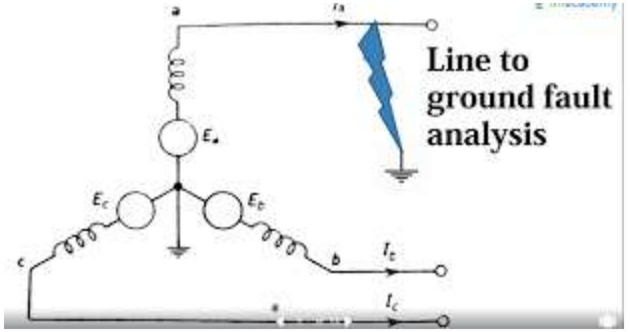
SYMMETRICAL COMPONENTS AND FAULT CALCULATIONS

- **Positive Sequence:**
- This component represents a balanced, normal rotating field, essentially the ideal condition where all phases have equal magnitudes and phase shifts, signifying healthy system operation.
- **Negative Sequence:**
- A balanced set with the opposite phase rotation compared to the positive sequence, indicating an unbalanced condition like a phase-to-phase fault, and is often used by protective relays to detect such faults.

- **Zero Sequence:**
- This component represents a set of equal magnitude phasors with the same phase angle, meaning current flows equally in all three phases and is primarily present during ground faults, making it another important indicator for fault detection.

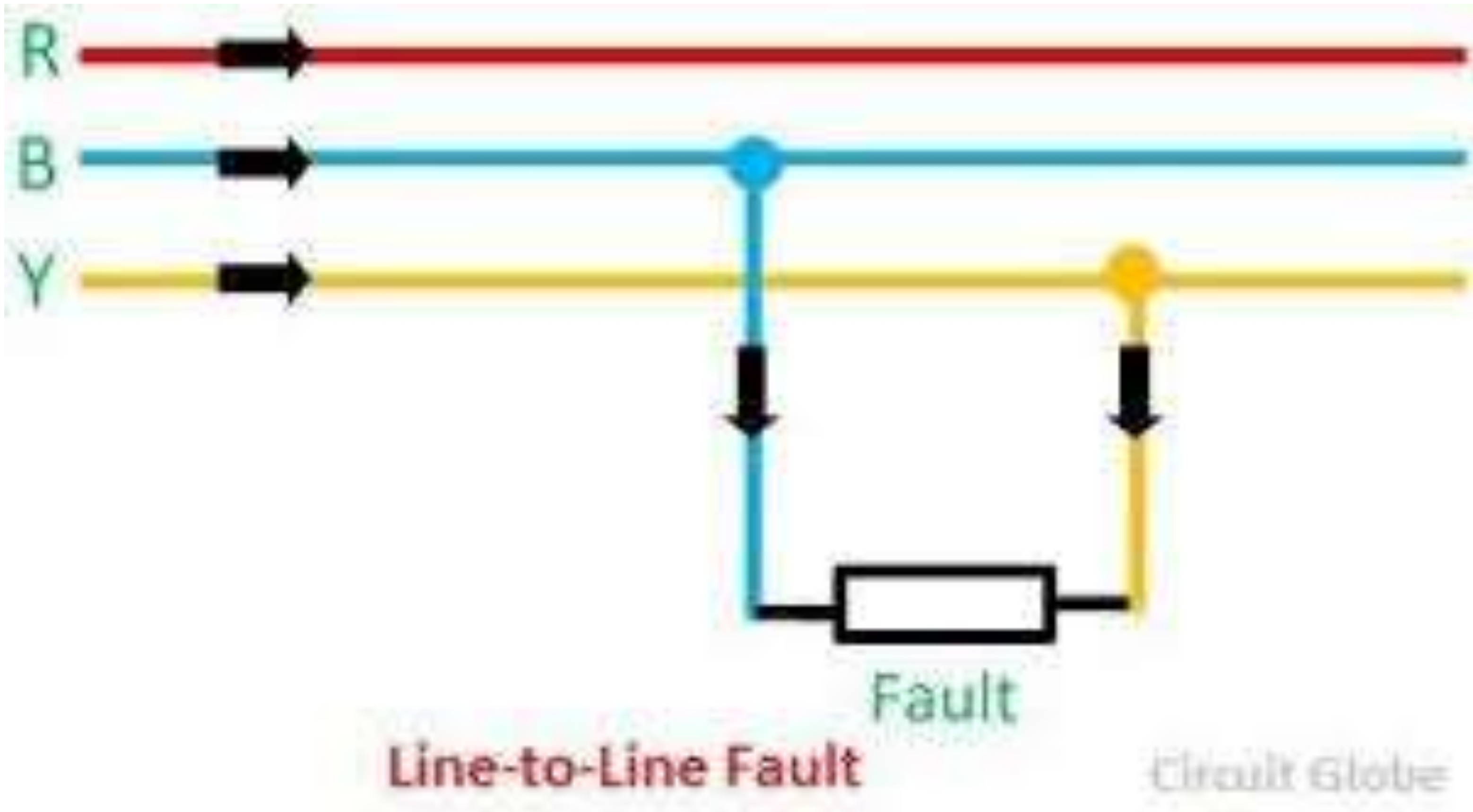
- Different types of impedances in networks:
- **Input Impedance:** The impedance seen by a signal source when connected to a network.
- **Output Impedance:** The impedance presented by a network to a connected load.
- **Characteristic Impedance:** The inherent impedance of a transmission line, important for signal reflection analysis.

- **Applications:**
- **Transmission Lines:** Properly matching the characteristic impedance of transmission lines is crucial for efficient signal transmission over long distances.
- **Antenna Design:** Impedance matching is essential for efficient power transfer between an antenna and a transmission line.
- **Audio Systems:** Matching the impedance of speakers to the amplifier output impedance ensures optimal sound quality.

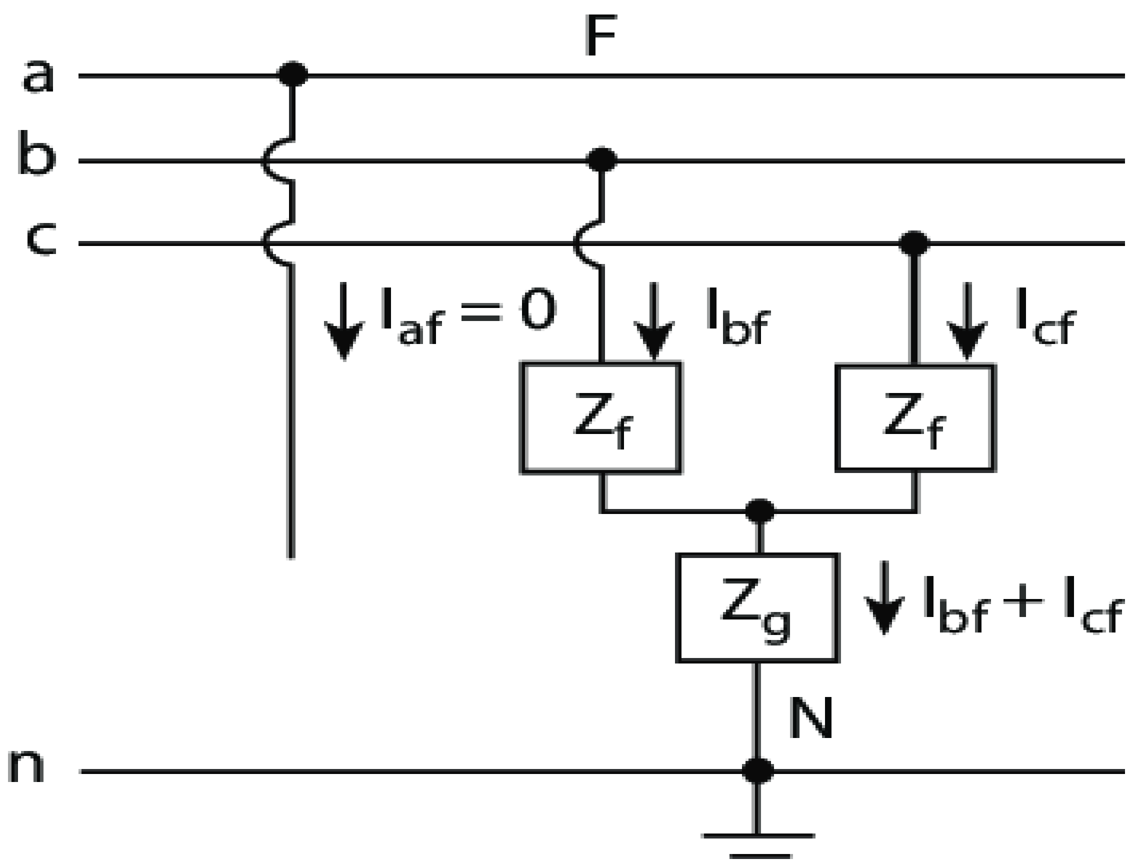


- A "single line to ground fault sequence network" refers to a circuit diagram used in power system analysis where all three sequence networks (positive, negative, and zero) are connected in series to represent a fault condition where one phase conductor touches the ground, meaning all sequence currents flow through the same path during the fault.

- **Series connection:**
- To simulate a single line to ground fault, the positive, negative, and zero sequence networks are connected in series with each other in the circuit diagram.
- **Fault current analysis:**
- By analyzing this combined network, engineers can calculate the fault current flowing through the system during a single line to ground fault condition.
- **Importance of zero sequence:**
- The zero sequence network plays a crucial role in representing the current flow to ground in a single line to ground fault, as the fault current will primarily flow through this path.


R
B
Y
Fault
Line-to-Line Fault
Circuit Globe

- double line to ground fault



- Reactors are located in power systems and nuclear power plants around the world. The location of a reactor depends on the type of reactor, its purpose, and the power system it's part of.
- Types of reactors
- **Pressurized water reactor (PWR)**: Used in the United States, France, Japan, Russia, China, and South Korea
- **Boiling water reactor (BWR)**: Used in the United States, Japan, and Sweden
- **Pressurized heavy water reactor (PHWR)**: Used in Canada and India
- **Light water graphite reactor (LWGR)**: Used in Russia
- **Current limiting reactors**: Also known as series reactors, these reactors are used to limit short circuit currents

- Locations of reactors
- **Nuclear power plants**
- Nuclear power plants are located in countries around the world, including India, the United States, France, Japan, Russia, and China
- **Power systems**
- Reactors can be located in power systems, connected in series with generators, feeders, or bus-bars

- Purpose of reactors
- **Reducing short circuit current**: Reactors are located in power systems to reduce short circuit current
- **Controlling load balance**: Series reactors are used to control load balance between parallel lines