Power system faults

Main components of the electrical power system are cables, overhead lines, HVDC lines, transformers, generators, and consumers.

Stationary balanced systems are defined by constant frequency or constant speed of all rotating machines, sinusoidal waveform of all voltages and constant amplitude, frequency, constant phase shift between phases. Three-phase equivalent circuit for lines and transformers is shown below.

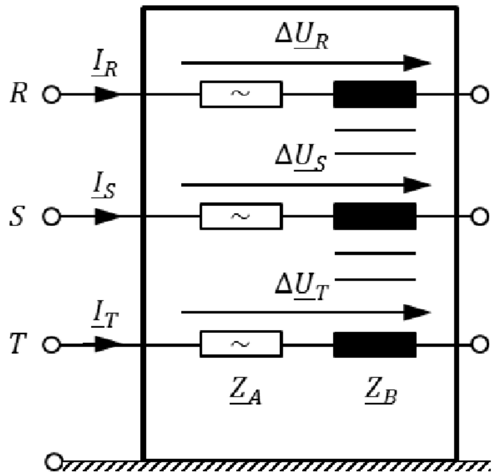


Fig. 1. Three-phase equivalent circuit

c) Characteristic of different methods of neutral earthing in MV networks

In order to improve the reliability of MV electrical networks, fault locating systems are required. Currently, the neutral points of electrical 3-ph components, which are connected to the earth ground network provides a reference point of 0 volts.

There are different types of neutral point grounding:

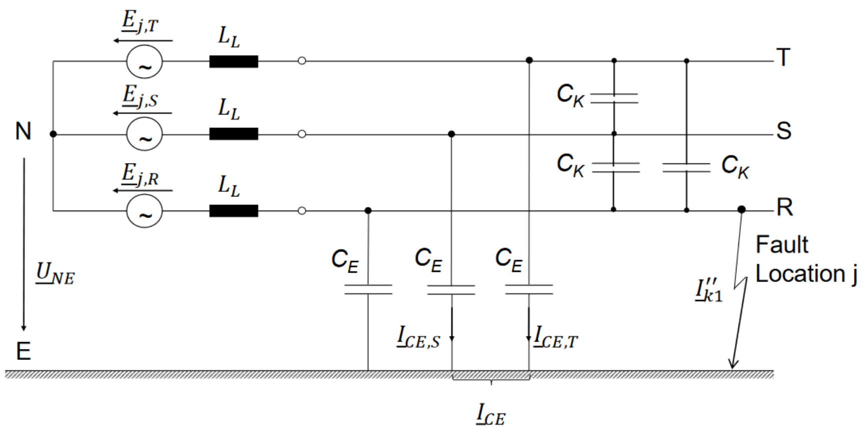
- Isolated neutral point
- Resonant-grounded neutral point (network with ground fault compensation)
- Neutral point with low-resistance grounding
- Neutral point with direct grounding

In case of small single-phase short-circuit currents in networks with **isolated** or **resonant-grounded neutral point**, the term used is ground leakage. For large single-phase currents in networks **with low-resistance** or **direct grounding of neutral point**, the term is used ground fault.

For networks, which voltage level is 10 kV, resonant-grounded neutral point is popularly utilized. In case of short-circuit, network can operate continuously. Over 95% of 20 kV networks are operated too with resonant-grounded neutral point.

Isolated neutral point

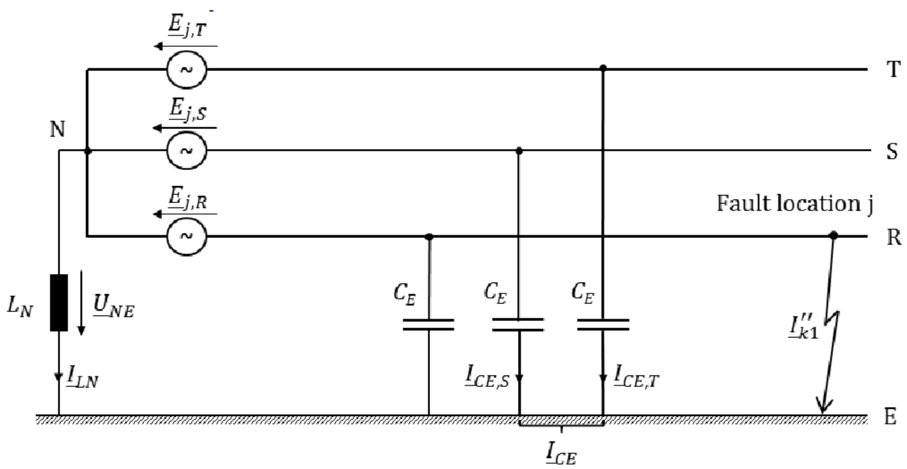
In isolated network, the neutral points of all generators, transformers are not earthed.



In such configuration, automatic electric arc extinguishing below the self-extinguishing current limit. Also, voltage increases of the healthy phases by ground fault factor 3 with a risk of double ground leakage. After, the ground leakage occurs, transient overvoltages on the healthy phases rise to 2.5 times the amplitude of the operating voltage.

As disadvantages: extinguishing of electric arc is at risk for capacitive currents because of voltage maximum at zero current crossing. Also, it is difficult to locate the fault in such network.

Resonant-grounded neutral point



In this method, a resistor is connected between the neutral point and earth. The resistor limits the fault current and reduces the risk of equipment damage. However, it can make it harder to detect ground faults. Also, as earlier, in such configuration, Electric arc faults extinguish automatically below the self-extinguishing current limit. Asymmetry of capacitances causes neutral point shift in normal operation. The consequence is over-compensated operation. To avoid ground leakage currents, relays are implemented. For example, Wattmetric relays analyze the steady state after a ground leakage occurs. Sinφ relay for measuring the reactive power flow (isolated neutral point), cosφ relay for measuring the active power flow (resonant-grounded neutral point).

Low-resistance and direct neutral point grounding

In expanded networks or network with large amounts of cables with high capacitive ground leakage or ohmic residual currents that are higher than the self-extinguishing current limit, isolated or resonance-grounded neutral points not possible.

Low-resistance or direct neutral point grounding characterize :
– High currents with conductive and inductive interference
– Limiting of the ground fault current by grounding of selected transformer neutral points only (< 2 kA in MV, 5-10 kA in HV, < 40-60% $Ik3''$ in EHV),
–Single-phase short interruption for electric arc extinguishing (exception: three-phase short interruption due to secondary capacitively coupled-in electric arc currents or circuit breakers without single-pole switching),
– Low-resistance or direct grounding of neutral points enables high transmission voltages and the use of autotransformers.

d) Digital fault locators – basics of application, fault location versus protection, application of different input data measurements

Digital fault locators (DFL) are devices used to locate faults in power systems quickly and accurately. They work by measuring the parameters of the electrical waveforms before and after the fault, analyzing the data, and calculating the distance to the fault location.

Basics of application: DFLs are used to reduce downtime and improve the reliability of power systems. They are essential tools for power system maintenance and repair, as they can help locate faults quickly, even in complex networks. DFLs can be used for both overhead and underground power systems and are suitable for use in both transmission and distribution systems.

Fault location versus protection: DFLs are primarily used for fault location, which is the process of determining the location of a fault in a power system. Fault protection, on the other hand, involves detecting and isolating faults to prevent damage to equipment and ensure the safety of personnel.

Application of different input data measurements: DFLs use various input data measurements to locate faults accurately. Some of the critical input data measurements include:

1. Voltage and current measurements: DFLs use voltage and current waveforms to determine the location of faults. The time difference between the two waveforms indicates the distance to the fault location.
2. Frequency measurements: Frequency changes occur in the vicinity of faults. DFLs can use these frequency changes to detect the location of the fault.
3. Travel time measurements: DFLs measure the time taken for a signal to travel between two points in the power system. By measuring the travel time of signals before and after a fault, the DFL can locate the fault location.
4. Phase angle measurements: DFLs use phase angle measurements to determine the location of faults accurately. The phase angle difference between the voltage and current waveforms before and after the fault can indicate the distance to the fault location.

In summary, DFLs are essential tools for fault location in power systems. They use various input data measurements to locate faults accurately, and their application can improve the reliability and safety of power systems.

Sources:

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- Protective Relaying Principles and Applications by J. Lewis Blackburn and Thomas J. Domin
- IEEE Standard C37.114-2018 - IEEE Guide for Determining Fault Location on AC Transmission and Distribution Lines