Application Note **AP019004EN** Effective October 2018

Low-voltage high resistance grounding system basics

Introduction

Grounding

Grounding is commonly used in the electrical industry to mean an intentional connection to earth of conductive materials either solidly or through impedance.

System grounding: Intentional connection to earth of the neutral points of the current carrying conductors.

The system grounding is determined by the grounding of the power source. Grounding system circuits are isolated from each other by delta windings.

Equipment grounding: Connection to earth of the non-current carrying conductive materials.

Ground faults

A ground fault is an abnormal electric current that causes a flow of current to earth. It can also be referred to as an earth fault.

In a three-phase system, if more than one phase short circuits to ground, then the result is referred to as a phase-to-phase fault, a line-to-line fault, or a three-phase fault when all three phases are involved.

Ungrounded systems and charging current

An ungrounded system is a system, circuit, or apparatus in which there is no intentional connection between the system conductors and earth.

A system may still be considered ungrounded if there is a possible connection to earth ground through potential measuring devices or very high impedance devices [1].

The term ungrounded is somewhat of a misnomer because in reality there is a capacitive coupling to ground of the phase windings and conductors.

In normal conditions, this distributed capacitance establishes a neutral reference that permits the phase conductors to be stressed only at line-to-neutral voltages.

During ground fault conditions, the capacitive coupling provides a current path return to the unfaulted phases. This is defined as the **charging current of a system**.

Through normal switching (like the operation of a breaker), this charge can build up and cause transient overvoltages to build up. These overvoltages may cause insulation failures at other points than the original faulted points [2]. This presents a high probability of a phase-to-phase fault and equipment damage [1].

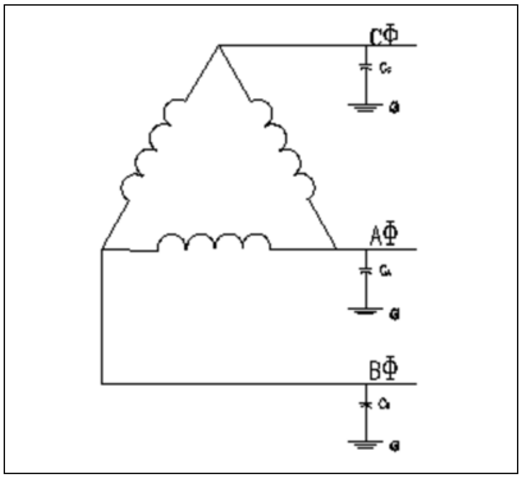

Figure 1. Ungrounded system

Advantages of an ungrounded system:

- Continuity of service

Disadvantages of an ungrounded system:

- Line-to-line voltages on unfaulted phases requiring equipment to be rated for line-to-line voltages
- Possible buildup of transient overvoltages that are several times the normal voltage, which can cause insulation failures and subsequent phase-to-phase faults
- Difficulty locating ground faults
- Inability to serve line-to-neutral loads
- Although uncommon, if the fault occurs through an inductance, there is a possibility of having resonance conditions in the system that will cause very high currents to flow and very high voltages to occur in the unfaulted phases [3]

Solidly grounded systems

A solidly grounded system is a system, circuit, or apparatus in which the neutral points have been deliberately connected to earth ground using a conductor that has no intentional impedance [2].

Solidly grounded systems are the most common found in industrial/ commercial power systems today.

A grounded conductor is bonded to the grounding electrode system at the first disconnecting means. It maintains very low impedance to ground so that a relatively high fault current will flow, thus ensuring that the circuit breakers or fuses will open quickly to minimize damage and reduce the shock hazard to personnel.

The solidly grounded system has the highest probability of escalating into a phase-to-phase or three-phase arcing fault [4].

Advantages of a solidly grounded system:

- Personnel safety
- Ability to serve line-to-neutral loads
- Transient overvoltages are avoided
- The ability to isolate the ground fault by tripping a breaker open

Disadvantages of a grounded system:

- The breaker opens after initial ground fault (no service continuity)
- During a fault, a large current may pass through equipment and cause equipment damage
- Finding the location of the ground fault can become a tedious endeavor

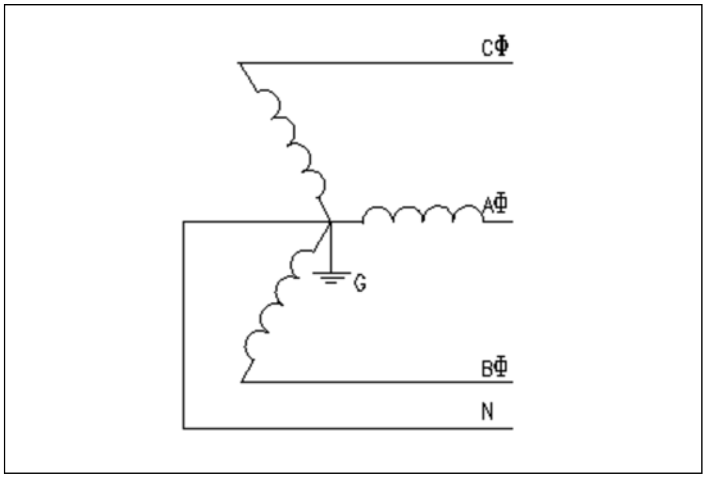

Figure 2. Solidly grounded wye system

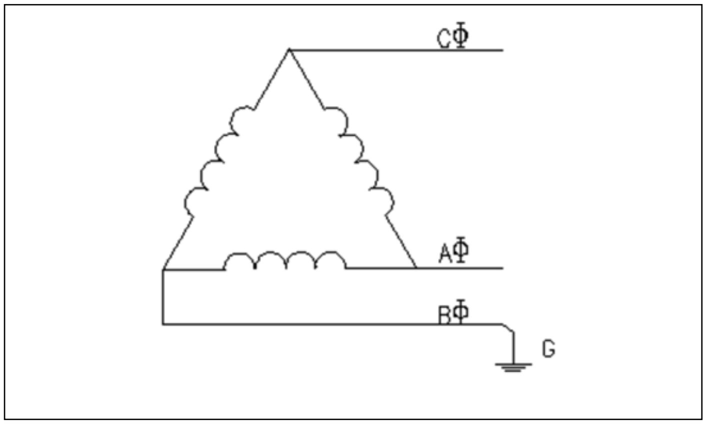

Figure 3. Corner-tapped grounded delta

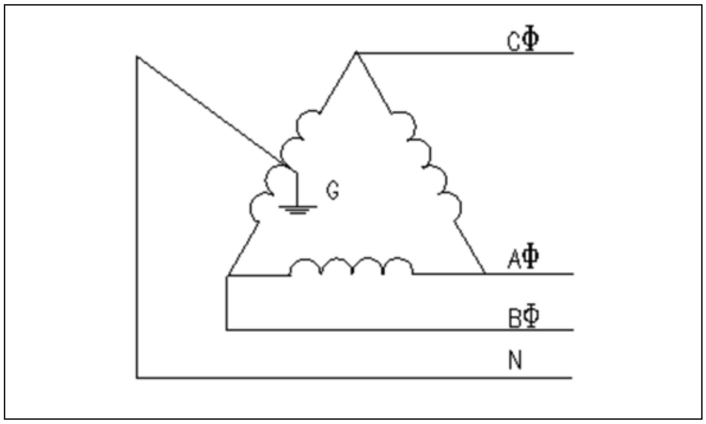

Figure 4. Center-tapped grounded delta

Resistance grounding

Low resistance grounding

Low resistance grounding is normally used on medium-voltage to high-voltage systems to limit the ground return current to a high level, typically 100 A or more [1].

This setup is chosen in systems where there is a high investment in capital equipment to limit damage to said equipment. The resistance must be low enough to let high current flow and allow detection by the protective devices, which in turn trip the circuit offline.

High resistance grounding

Mainly used in low-voltage systems, most common in 480 V and 600 V systems, this arrangement means that a certain resistance has been intentionally put between the neutral point of a system and earth ground.

If the system does not have a neutral point, it will be necessary to create one artificially. A few methods are available to accomplish this, such as a zig-zag transformer or a wye-delta transformer.

The resistance is chosen such that its magnitude is less than the magnitude of the system charging capacitance. That means it is set up so that the charging current will be less than the ground return current through the neutral resistor.

A 480 V line-to-line system will usually have charging currents of up to 2 A [5]. This means the grounding resistance should allow a ground return current with a magnitude over the magnitude of the charging current. This setup is to make sure the ground return current will flow through the resistor and not "charge" the distributed capacitance, thus causing transient overvoltages, possible restrikes, and potential phase-to-phase faults. It allows the system to stay in service but it is highly recommended to try and correct the fault as soon as safely possible.

During ground fault conditions, the voltage to ground on the two unfaulted phases is equal to the line-to-line voltage. The equipment rating has to be rated at 173% of their line-to-neutral voltages.

Advantages of high resistance grounding:

- Personnel safety and equipment protection
- Service continuity: the ground return current is limited to a low magnitude value that does not require taking the system offline
- Avoidance of large transient overvoltages that can result in restrikes and cause additional ground faults
- Possible arc flash risk reduction
- Ground fault location easier to find

Disadvantages of high resistance grounding:

- Inability to serve line-to-neutral loads

In some cases, reactance grounding is used

Reactance grounding is when an inductance is placed between the system's neutral point and ground.

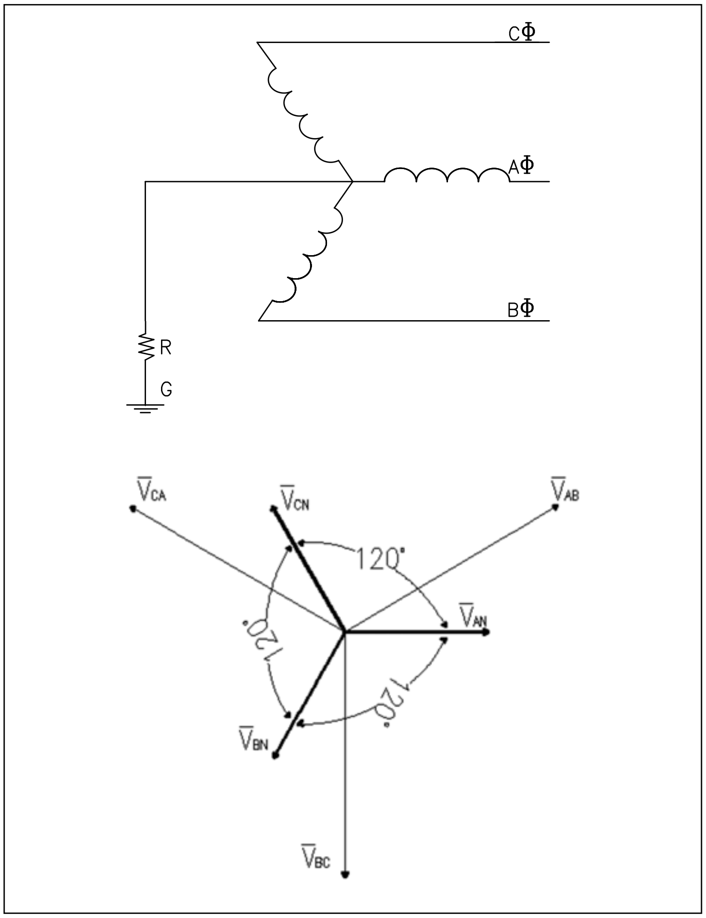

Figure 5. Resistance grounding

Factors to consider when choosing a grounding system

From **Table 1**, it is possible to compare and decide whether or not to ground a low-voltage system and which grounding method will fit one's preferences. This document is intended as a guide toward grounding in general, and high resistance grounding in particular. Thus, it is important to consider a few points when choosing high resistance grounding:

- There is a need for service continuity after the first ground fault
- There is a need to be able to easily locate ground faults
- There is no need to serve line-to-neutral loads
- If there is no available neutral, then it will be necessary to create an artificial neutral
- It will be necessary to estimate, calculate, or measure the capacitive charging current of the system
- The magnitude of maximum current acceptable on the system under ground fault conditions

Table 1. Comparative summary of different grounding systems [5]

	Ungrounded	Solidly grounded	Low resistance grounding	High resistance grounding
Phase to ground return current	Less than 1% of the three-phase fault current	Varies, can reach very high magnitudes	Typically more than 100 A and up to 800 A	Typically between 1 A and 10 A
Transient overvoltages	High	Low	Low	Low
Service continuity	Yes	No	No	Yes
Ease of first ground fault location	No	No, although the faulted section is isolated	No, although the faulted section is isolated	Yes, locating system usually in assembly
Probability of flashovers to ground	High	High	Reduced	Low

References

1. IEEE std. 142 – 2007 "IEEE Recommended Practice for Grounding of Industrial and Commercial Power Systems" (IEEE Green Book), IEEE, NY, NY.
2. Neutral Grounding Resistors Technical information, Post Glover, 2012, KY, USA.
3. D.D. Shipp, F.J. Angelini "Characteristics of Different Power Systems neutral Grounding Techniques: Fact and Fiction" Cutler-Hammer, 1988.
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5. Baldwin Bridger, Jr., "High-Resistance Grounding, IEEE Transactions on Industry Applications, Vol. IA-19, No. 1", Jan/Feb 1983.

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