System Neutral Resistance Grounding

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Abstract

There are many neutral grounding options available for both Low and Medium voltage power systems.

However, many of the early power systems were ungrounded, primarily due to the fact that the first ground fault did not require the tripping of the system. An unscheduled shutdown on the first ground fault was particularly undesirable for continuous process industries. These power systems required ground detection systems, but locating the fault often proved difficult. Although accomplishing the initial goal, the ungrounded system provided no control of transient over-voltages.

A capacitive coupling exists between the system conductors and ground in a typical distribution system. As a result, this series resonant L-C circuit can create over-voltages well in excess of line-to-line voltage when subjected to repetitive re-strikes of one phase to ground. This in turn, reduces insulation life resulting in possible equipment failure.

Ungrounded systems may be converted to resistance grounded systems typically by adding a resistor and neutral deriving transformers.
Resistance grounding of the power distribution offers many advantages.

Introduction

The choice of system grounding method should be selected to provide the safety, reliability, and continuity of service desired for the power distribution system.

IEEE Standard 142-1991 lists several reasons for limiting the ground fault current by resistance grounding:

1. To reduce burning and melting effects in faulted electrical equipment, such as switchgear, transformers, cables, and rotating machines.
2. To reduce mechanical stresses in circuits and apparatus carrying fault currents.
3. To reduce electrical-shock hazard to personnel caused by stray ground fault currents in the ground return path.
4. To reduce the arc blast or flash hazard to personnel who may have accidentally caused or who happen to be in close proximity to the ground fault.
5. To reduce the momentary line voltage dip occasioned by the occurrence and clearing of a ground fault.

6. To secure control of transient over-voltages while at the same time avoiding the shutdown of a faulty circuit on the occurrence of the first ground fault (high-resistance grounding).

This paper will concentrate on the application of neutral grounding resistors as used on low and medium voltage systems. It is not intended to address all of the possible system grounding methods.

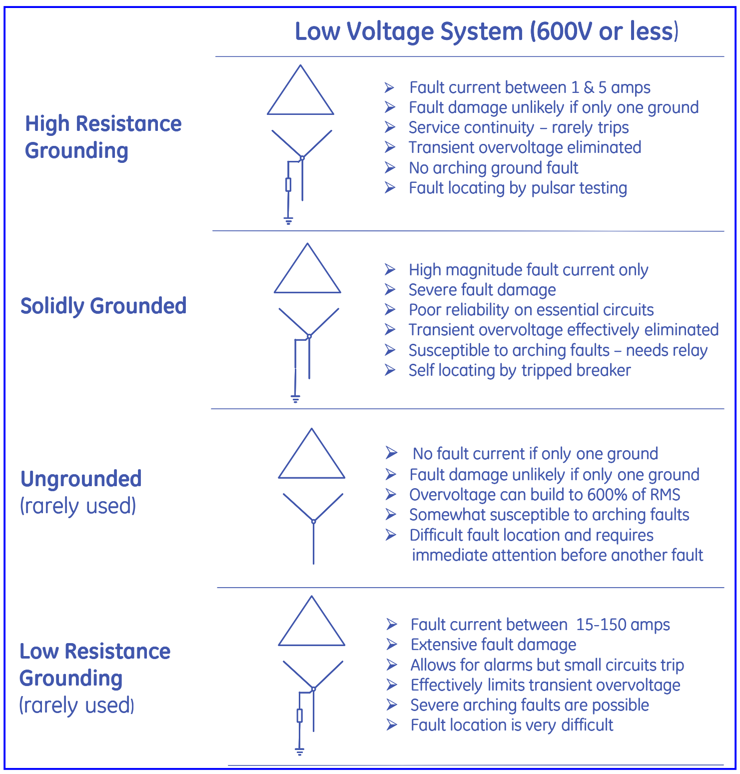
Low Voltage Systems

Traditionally the predominant LV (600 V and below) system grounding method has been solid grounding. The resistance grounding methods discussed below are low and high resistance grounding. Some of the advantages and disadvantages of various grounding methods are shown in Figure 1.

Low Resistance Grounding

Low resistance grounding is not commonly used in low voltage systems because the limited ground fault current is too low to reliably operate breaker trip units or fuses. This makes system selectivity hard to achieve. Additionally, low resistance grounded systems are not suitable for serving 4-wire loads and hence have not been used in commercial market applications. Low resistance grounding is primarily used in special situations such as Mine Safety grounding.

Fig. 1 from footnote reference #5



High Resistance Grounding

An alternative to low resistance grounding is high resistance grounding (HRG). In a high resistance grounded system a neutral resistor is sized to limit the bolted line-to-ground fault current to a value slightly greater than the system capacitive charging current. This value of grounding current will effectively limit transient over-voltages to safe levels. See Figure 2 for typical circuit. Typical charging currents are in the range of 1 – 2 amperes. Fault escalation is unlikely with ground fault currents of this magnitude. Table 1 gives estimating system charging currents for various systems.

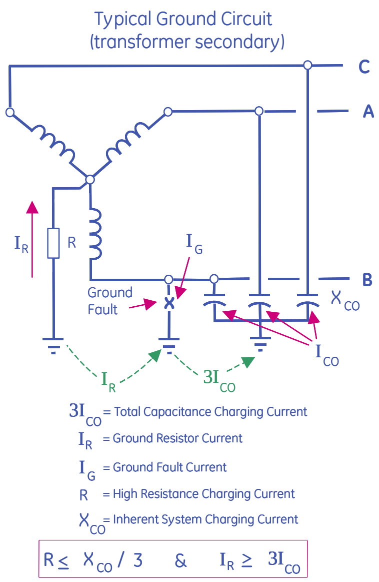


Fig. 2 from footnote reference # 5

Additional information on system charging currents can be found in "Charging Current Data for Guesswork-free Design of High-Resistance Grounded Systems," by D.S. Baker, IEEE Transactions on Industry Applications, Vol. IA-15, No. 2, March/April 1979.

A major benefit of an HRG system is not having to trip on the first ground fault, and thus avoiding an unplanned shut down. The HRG system also offers the added benefit of virtually eliminating the arc flash hazard caused by an accidental ground fault.

Once a ground fault has occurred on an HRG system, it requires a dedicated maintenance program committed to monitoring, finding and removing the fault. After the first fault, the other phases of the power system are subjected to full line-to-line voltage. There is also the possibility that another ground fault may occur on a different phase resulting in a double line-to-ground fault.

A practical way to find the initial fault is with the use of a fault locating scheme. This scheme includes a pulsing contactor to short out part of the resistor and a cycle timer to sequence the pulsing contactor at a set number of cycles per minute. A clamp-on ammeter with a large window can then be placed around the conductors to detect the cyclic nature of the current caused by the pulsing contactor. Depending on the amount of resistance shorted-out, the pulsed current is typically 1-5 A higher than the normal ground fault current.

HRG systems are not suitable for 4-wire, line-to-neutral loads for several reasons. First, a ground on the system neutral would bypass the grounding resistor and solidly ground the system. Secondly, a ground on the HRG system causes voltage instability of the power system neutral. Also, HRG systems are not permitted by Code (NEC 250.36) to furnish 4-wire line-to-neutral loads.

The neutral conductor from the neutral of the transformer or generator to the resistor must be fully insulated and in no case be smaller than # 8 AWG or # 6 AWG aluminum (NEC 250.36).

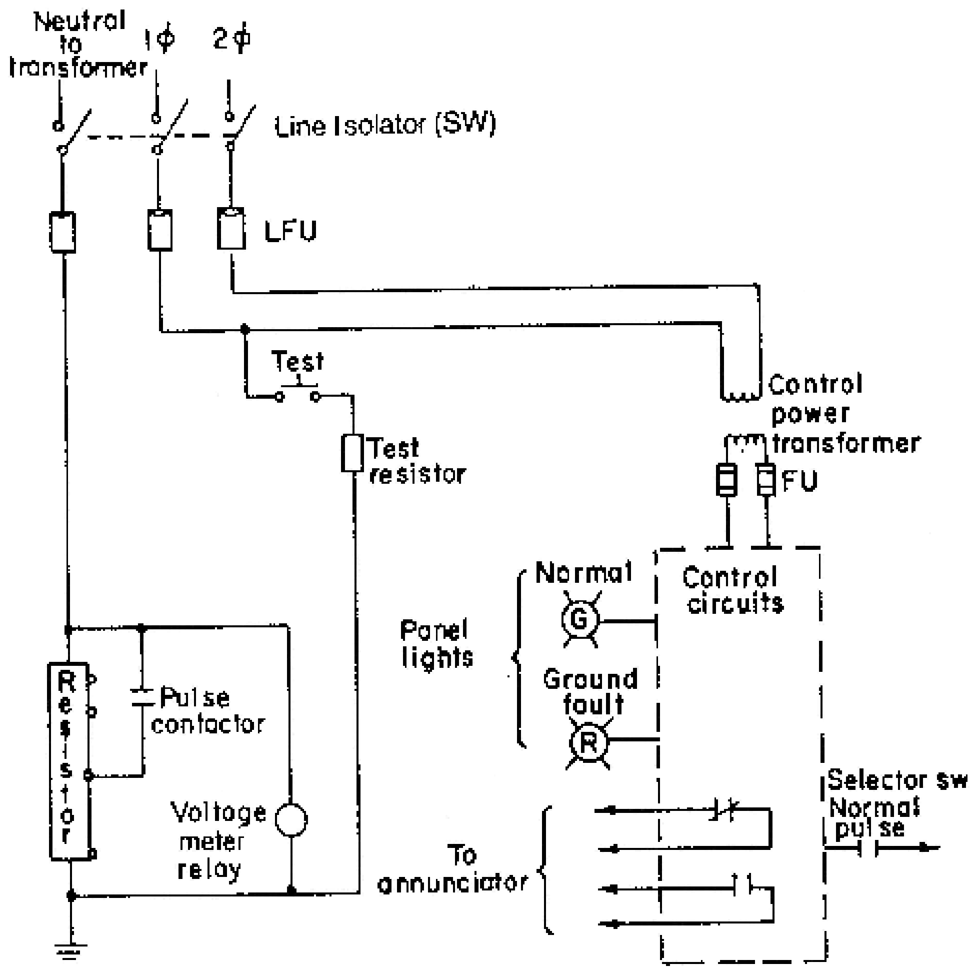
The 600 V, wye connected system is shown in Figure 3.

Table 1 from footnote reference # 2

DATA FOR ESTIMATING SYSTEM CHARGING CURRENT

13.8 kV	**Ico**
Surge capacitors	2.25 A Each Set
Cable 1000 MCM Shielded	1.15 A/1000 ft. of 3c
750 MCM Shielded	.93 A/1000 ft. of 3c
350 MCM Shielded	.71 A/1000 ft. of 3c
4/0 AWG Shielded	.65 A/1000 ft. of 3c
2/0 AWG Shielded	.55 A/1000 ft. of 3c
Transformer	Negligible
Motors	.15 A/1000 HP
4.16 kV	
Surge Capacitors	1.3 A each Set
Vulkene Cable – Shielded	
#1 – 350 MCM	.23 A/1000 ft. of 3c
Vulkene Cable – Non-shielded	
In conduit	.1 A/1000 ft. of 3c
Transformers	Negligible
Motors - Est.	.05 A/1000 HP
2.4 kV	
Surge Capacitors	.75 A Each Set
Cables – Non-shielded in	
Conduit – Est.	.05 A/1000 ft. of 3c
Motors – Est.	.03 A/1000 HP
Motors with cables (tested)	.06 A/1000 HP
480 V	
Surge Capacitors (seldom used) 1/3 A Each Set	
Cables 350 to 500 MCM in conduit	.10 A/1000 ft. of 3c
2/0 to 3/0 AWG in conduit	.05 A/1000 ft. of 3c
2/0 to 3/0 AWG in Trays	.02 A/1000 ft. of 3c
# 6 – 3/c with Ground wires	
in water	.05 A/1000 ft. of 3c
Transformers	Negligible
Motors	.01 A/1000 HP

Fig. 3 from footnote reference #5



600 volts maximum wye systems

Medium Voltage Systems

On medium voltage (2.4 kV – 13.8 kV) systems both low and high resistance grounding schemes are commonly used.

MV Low Resistance Grounding

In a MV system, limiting the ground fault current is highly desirable, especially where motors are connected directly to the system. The neutral ground resistors are typically chosen to limit the initial ground fault current to between 100 – 400 Amperes.

Low resistance grounding (LRG) is used to limit the ground fault current and minimize the equipment damage that will occur during the fault. LRG will also reduce the arcing current and arc flash hazard.

As a rule, the value of ground fault current is chosen to provide enough current for the ground fault relay to operate at 10% of rated ground fault current. This will allow the detection of a fault to within 10% of the neutral point of a motor or transformer.

The grounding resistor may be short time (10-second) rated because fault currents of this magnitude must be relayed off quickly. Also, the ground fault relaying must be sensitive enough to protect the grounding resistor on a low level fault. A 10-second rated resistor will carry approximately 10% of its rating continuously. For example, on a system with a 400 A neutral grounding resistor, the ground fault relay must pick up at a current lower that 40 amperes. This will protect the resistor and give greater protection for non-bolted line-to-ground faults.

When applying lightning arresters for use on either a low or high resistance grounded system, they must be selected the same as if used on an ungrounded system.

MV High Resistance Grounding

As in low voltage systems, MV HRG reduces fault currents and equipment damage. It also provides the same basic protection benefits as listed for the LV HRG system.

The resistor must be sized to allow the grounding current to be slightly greater than the capacitor charging current. Many MV systems contain motors operating at that utilization voltage. Captive transformer applications where a single motor is served by a single transformer are also common. Where surge capacitors are used on motors in these applications, the additional capacitive charging current of the capacitors must be taken into account. For example, a .05 uf surge capacitor can add an additional 0.75 A of charging current at 2400 V and 1.3 A of charging current at 4160 V. Refer to Table 1 for data on estimating system charging current.

It is generally accepted that HRG can be successfully applied on MV systems where the ground fault current is limited to 8 amperes or less. Above this level it is likely that the fault will escalate into a double line-to-ground fault or a phase-to-phase fault.
Higher voltages (13.8 kV) typically have considerably higher capacitive charging currents which cause the ground fault currents to easily exceed the 8 A level. For this reason HRG is not recommended for use on nominal 15 kV systems. Low resistance grounding in the range of 200 – 800 A is commonly applied on these systems.

Conclusion

HRG grounded systems offer many advantages in both low and medium voltage systems including suppression of transient over-voltages, eliminating or reducing arc flash hazards, and eliminating the need to trip and avoiding unplanned shut downs from the first ground fault. In all distribution systems, the first ground fault should be identified, located and removed as soon as possible.

Low resistance grounding in MV systems is preferred especially where motors are being directly served. The primary benefit to the electrical system is minimizing the fault damage. The grounding resistor should be chosen to limit the ground fault current to the lowest level that produces adequate sensitivity in the ground fault relay.

When applying system grounding resistors, the designer must consider the effects of temporary over-voltages on conductor insulation levels and the selection of surge arresters. An alternate method of serving 4-wire loads must also be utilized.

References

1. IEEE Standard 142-1991, Recommended Practice for Grounding of Industrial and Commercial Power Systems.
2. Baldwin Bridger, Jr., High-Resistance Grounding, IEEE Transactions on Industry Applications, Vol. IA-19, No. 1, Jan/Feb 1983.
3. 2005 National Electrical Code, NFPA 70.
4. Industrial Power Systems Data Book, General Electric Co.
5. High Resistance Grounding in the Cement Industry – A User's Experience, by John Foster, William Brown, & Larry Pryor, IEEE Cement Industry Conference, May 19-24, 1985.
6. The Reality of High-Resistance Grounding, By J.R. Dunki-Jacobs.