NEUTRAL GROUNDING RESISTORS

TECHNICAL INFORMATION

Post Glover™

"The Resistor Specialists"

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Quality System Certified to ISO 9001

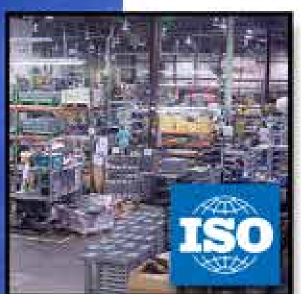
With over 130 years of combined industrial and utility experience,

Post Glover

delivers the industry's strongest, broadest and most technologically advanced products available.

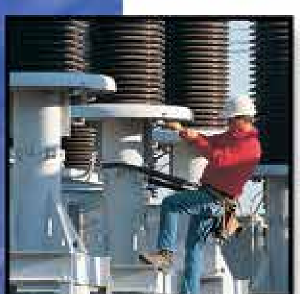
Experienced

Post Glover has grown into the world's largest power resistor company, based on its industry leading positions in grounding solutions and dynamic braking resistors. Post Glover can be trusted to deliver cost-effective, reliable products to the marketplace.



Efficient

Post Glover's factory in Erlanger, Kentucky integrates computer aided design and manufacturing with the industry's strongest engineering team for greater manufacturing capabilities and efficiencies. Post Glover continues to improve through Kaizen events, third party certifications and regular audits of our internal practices.



Focused Service

The industry's most experienced sales and engineering team and largest independent sales representative network insure a timely and accurate, same day response to your typical and complex applications. With 16 engineers on staff, we are poised to answer your product and application questions.

Certified Products

Post Glover prides itself on designing and manufacturing in accordance with all applicable standards, be they IEEE, ANSI, NEMA or IEC. Taking safety one step further, we offer the only UL listed high resistance grounding unit in the industry, as well as UL and CSA offerings in low resistance grounding resistors and dynamic braking resistors.

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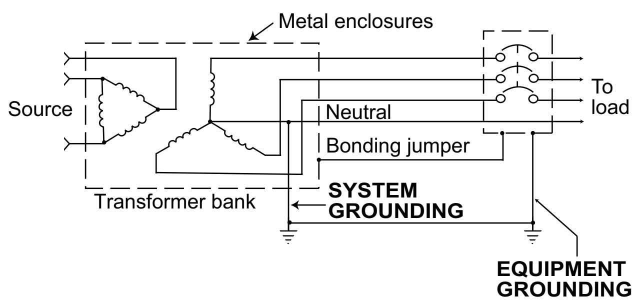
Grounding of Industrial Power Systems

Definition of Grounding

The term grounding is commonly used in the electrical industry to mean both “equipment grounding” and “system grounding”. “Equipment grounding” means the connection of earth ground to non-current carrying conductive materials such as conduit, cable trays, junction boxes, enclosures and motor frames. “System grounding” means the deliberate connection of earth ground to the neutral points of current carrying conductors such as the neutral point of a circuit, a transformer, rotating machinery, or a system, either solidly or with a current limiting device. Figure 1 illustrates the two types of grounding.

FIGURE 1

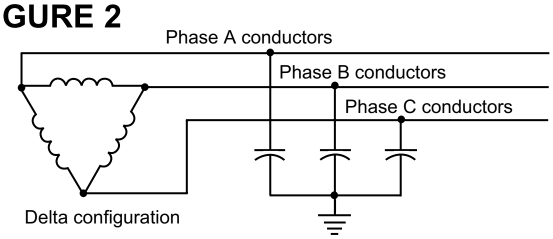


Characteristics of Ungrounded Systems

An ungrounded system is one in which there is no intentional connection between the conductors and earth ground. However, in any system, a capacitive coupling exists between the system conductors and the adjacent grounded surfaces. Consequently, the “ungrounded system” is, in reality, a “capacitively grounded system” by virtue of the distributed capacitance. This is shown in Figure 2. Under normal operating conditions, this distributed capacitance causes no problems. In fact, it is beneficial, because it establishes, in effect, a neutral point for the system, as shown in Figure 3a. As a result, the phase conductors are stressed at only line-to-neutral voltage above ground.

However, problems can arise under ground fault conditions. A ground fault on one line results in full line-to-line voltage appearing throughout the system. Thus, a voltage 1.73 times the normal voltage is present on all insulation in the system, as shown in Figure 3b. This situation can often cause failures in older motors and transformers, due to insulation breakdown.

FIGURE 2

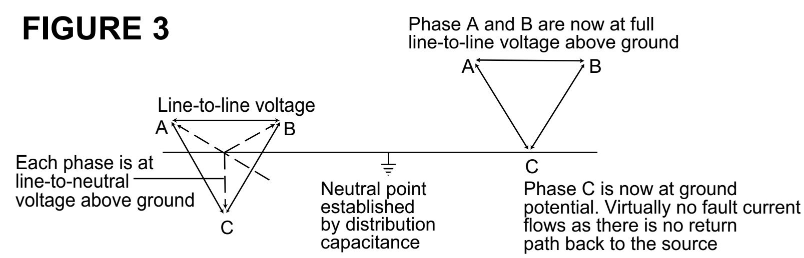


The interaction between the faulted system and its distributed capacitance may cause transient overvoltages (several times normal) to appear from line to ground during normal switching of a circuit having a line to ground fault (short). These overvoltages may cause insulation failures at points other than the original fault. In addition, a second fault on another phase may occur before the first fault can be cleared. This can result in very high line to line fault currents, equipment damage and disruption of both circuits.

In addition to the cost of equipment damage, ungrounded systems present fault locating problems. This involves a tedious process of trial and error, first isolating the correct feeder, then the branch, and finally the equipment at fault. The result is unnecessarily lengthy and expensive downtime.

Despite the drawbacks of an ungrounded system, it does have one main advantage. The circuit may continue in operation after the first ground fault, assuming it remains as a single fault. This permits continued production, until a convenient shutdown can be scheduled for maintenance.

FIGURE 3



(a) NORMAL OPERATION
Voltage relationships

(b) GROUND FAULT ON PHASE C

System Neutral Grounding

Importance

This section is devoted to the proven benefits of proper system grounding, and in particular, the added advantages of resistance (current limited) grounding.

The intentional connection of the neutral points of transformers, generators and rotating machinery to the earth ground network provides a reference point of zero volts. This protective measure offers many advantages over an ungrounded system, including:

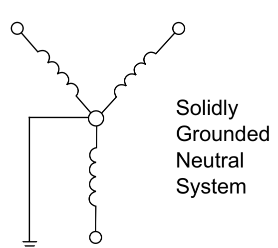
- Reduced magnitude of transient overvoltages
- Simplified ground fault location
- Improved system and equipment fault protection
- Reduced maintenance time and expense
- Greater safety for personnel
- Improved lightning protection
- Reduction in frequency of faults

Solidly Neutral Grounded Systems Offer Partial Protection

A solidly grounded system is one in which the neutral points have been intentionally connected to earth ground with a conductor having no intentional impedance, as shown in Figure 4. This partially reduces the problem of transient overvoltages found on the ungrounded system, provided the ground fault current is in the range of 25 to 100% of the system three phase fault current. However, if the reactance of the generator or transformer is too great, the problem of transient overvoltages will not be solved.

While solidly grounded systems are an improvement over ungrounded systems, and speed up the location of faults, they lack the current limiting ability of resistance grounding and the extra protection this provides. Solidly grounded systems are usually limited to older, low voltage applications at 600 volts or less.

FIGURE 4



Advantages of Grounded Neutral Systems

Resistance grounding is by far the most effective and preferred method. It solves the problem of transient overvoltages, thereby reducing equipment damage. It accomplishes this by allowing the magnitude of the fault current to be predetermined by a simple ohms law calculation (see Table 1). Thus the fault current can be limited, in order to prevent equipment damage.

Table 1

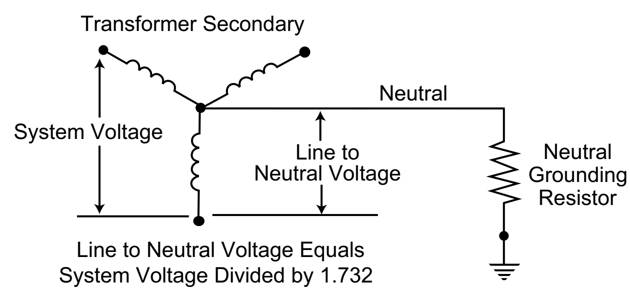
$$I = \frac{E}{R}$$

Where: I = Limit of Fault Current
E = Line-to-Neutral Voltage of System
R = Ohmic Value of Neutral Grounding Resistor

In addition, limiting fault currents to predetermined maximum values permits the designer to selectively coordinate the operation of protective devices, which minimizes system disruption and allows for quick location of the fault. There are two broad categories of resistance grounding: low resistance and high resistance.

In both types of grounding, the resistor is connected between the neutral of the transformer secondary and the earth ground, as shown in Figure 5.

FIGURE 5



Low Resistance Grounded Neutral

Low resistance grounding of the neutral limits the ground fault current to a high level (typically 50 amps or more) in order to operate protective fault clearing relays and current transformers. These devices are then able to quickly clear the fault, usually within a few seconds. The importance of this fast response time is that it:

- Limits damage to equipment
- Prevents additional faults from occurring
- Provides safety for personnel
- Localizes the fault

The limited fault current and fast response time also prevent over-heating and mechanical stress on conductors. Please note that, like the solidly grounded neutral system, the circuit must be shut down after the first ground fault.

Low resistance grounding resistors are typically rated 400 amps for 10 seconds, and are commonly found on medium and high voltage systems.

High Resistance Grounded Neutral

High resistance grounding of the neutral limits the ground fault current to a very low level (typically under 25 amps). It is used on low voltage systems of 600 volts or less (see Figure 6). By limiting the ground fault current, the fault can be tolerated on the system until it can be located, and then isolated or removed at a convenient time. This permits continued production, providing a second ground fault does not occur.

High resistance neutral grounding can be added to existing ungrounded systems without the expense of adding fault clearing relays and breakers. This provides an economical method of upgrading older, ungrounded systems.

The resistor must be sized to ensure that the ground fault current limit is greater than the system's total capacitance-to-ground charging current. If not, then transient overvoltages can occur.

By strategic use and location of ground fault sensing relays, trouble shooting can be greatly simplified.

In mining applications, high resistance neutral grounding combined with sensitive ground fault relays and isolating devices, can quickly detect and shut down the faulted circuit. This provides operating personnel with the added safety that's essential in this hostile environment.

Another major advantage is the elimination of dangerous and destructive flash-overs to ground, which can occur on solidly grounded systems.

As is the case with most systems, there are some disadvantages to high resistance neutral grounding:

- After the first ground fault, the two unfaulted phases rise to the line-to-line voltage as shown in Figure 7. This creates a 73% increase in voltage stress on the insulation of the system.

- When a ground fault occurs, the neutral point of the system rises to line-to-neutral voltage above ground. As a result, the neutral cannot be used in the system for load connections such as single phase lighting.

- Should a second ground fault occur on another phase before the first ground fault is removed, a line-to-line fault is created.

FIGURE 6

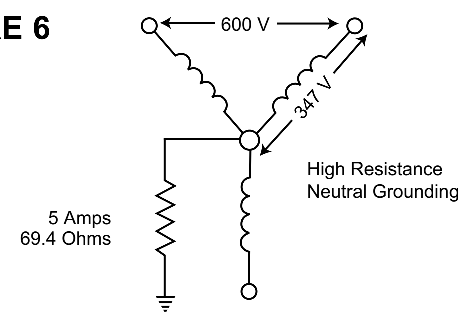
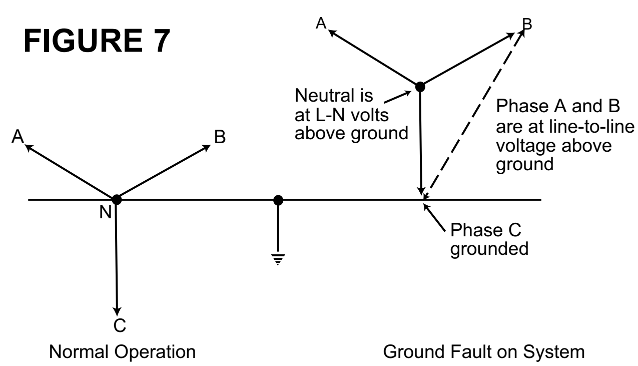


FIGURE 7



Grounding Recap

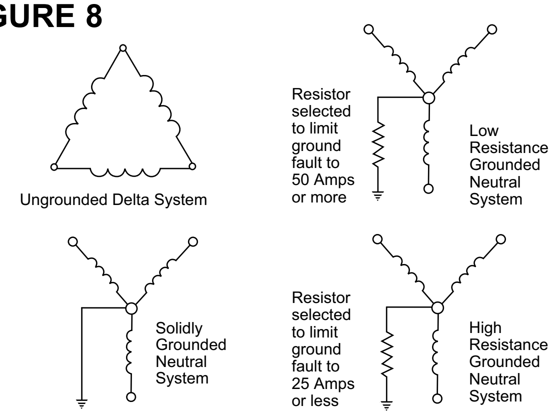
Ungrounded Delta Systems, while offering some advantages, have many operating disadvantages. High transient overvoltages can occur that are not immediately evident. In addition, ground faults are difficult to locate.

Solidly Grounded Neutral Systems provide greater safety for personnel, limit the system potential to ground, and speed the detection and location of the ground fault. However, the system must be shut down after the first ground fault.

Low Resistance Grounded Neutral Systems only limit the magnitude of the ground fault current so that serious damage does not occur. The system must still be shut down after the first ground fault. This level of resistance grounding is generally used on medium- and high-voltage systems.

High Resistance Grounding Neutral Systems offer important operating advantages. No part of the system has to be shut down after the first ground fault. The location of the ground fault can be easily determined without disrupting the operation of the system, and the hazard to operating personnel is limited.

FIGURE 8



(Table 2 provides a comparison of the performance of the different grounding methods under a variety of operating conditions and characteristics.)

Table 2 – Comparative Performance Rating Table

Comparative Performance Rating For Various Conditions Using Different Grounding Methods

	Method of Grounding			
Condition or Characteristic	**Ungrounded**	**Solid Ground**	**Low Resistance**	**High Resistance**
Immunity to Transient Overvoltages	Worst	Good	Good	Best
73% Increase in Voltage Stress Under Line-to-Ground Fault Condition	Poor	Best	Good	Poor
Equipment Protected Against Arc Fault Damage	Worst	Poor	Better	Best
Safety to Personnel	Worst	Better	Good	Best
Service Reliability	Worst	Good	Better	Best
Maintenance Cost	Worst	Good	Better	Best
Continued Production After First Ground Fault	Better	Poor	Poor	Best
Ease of Locating First Ground Fault	Worst	Good	Better	Best
Permits Designer to Coordinate Protective Devices	Not Possible	Good	Better	Best
Can Ground Fault Protection Be Added	Worst	Good	Better	Best
Two Voltage Levels on the Same System	Not Possible	Best	Not Possible	Not Possible
Reduction in Frequency of Faults	Worst	Better	Good	Best
First High Ground Fault Current Flows Over Grounding Circuit	Best	Worst	Good	Better
Potential Flashover to Ground	Poor	Worst	Good	Best
Compliance with Local Electrical Code	Acceptable	Acceptable	Acceptable	Varies
Contractor/Maintenance Familiarity With Technology and Operation	Good	Good	Best	Poor

Rating and Testing Neutral Grounding Resistors

IEEE-32-1972 Standards

IEEE-32 is the standard used for rating and testing neutral grounding resistors. The most important parameters to consider from the IEEE-32 are: the allowable temperature rises of the element for different "on" times; the applied potential tests; the dielectric tests, and the resistance tolerance tests that are required. Post Glover Neutral Grounding Resistors are designated and built to pass all these rigorous tests.

- **Time Rating**
  IEEE Standard 32 specifies standing time ratings for Neutral Grounding Resistors (NGRs) with permissible temperature rises above 30˚C ambient as shown in Table 3.

  Time ratings indicate the time the grounding resistor can operate under fault conditions without exceeding the temperature rises.

- **10-Second Rating**
  This rating is applied on NGRs that are used with a protective relay to prevent damage to both the NGR and the protected equipment. The relay must clear the fault within 10 seconds.

- **One-Minute Rating**
  One NGR is often used to limit ground current on several outgoing feeders. This reduces equipment damage, limits voltage rise and improves voltage regulation. Since simultaneous grounds could occur in rapid succession on different feeders, a 10-second rating is not satisfactory. The one-minute rating is applied.

- **Ten-Minute Rating**
  This rating is used infrequently. Some engineers specify a 10-minute rating to provide an added margin of safety. There is, however, a corresponding increase in cost.

- **Extended-Time Rating**
  This is applied where a ground fault is permitted to persist for longer than 10 minutes, and where the NGR will not operate at its temperature rise for more than an average of 90 days per year.

- **Steady-State Rating**
  This rating applies where the NGR is expected to be operating under ground fault conditions for more than an average of 90 days per year and/or it is desirable to keep the temperature rise below 385˚C.

Tests

An applied potential test (HI-POT) is required to test the insulation of the complete assembly (or sections thereof). For 600 volts or less, the applied potential test is equal to twice the rated voltage of the assembly (or section) plus 1,000 volts. For ratings above 600 volts, the applied potential test is equal to 2.25 times the rated voltage, plus 2,000 volts.

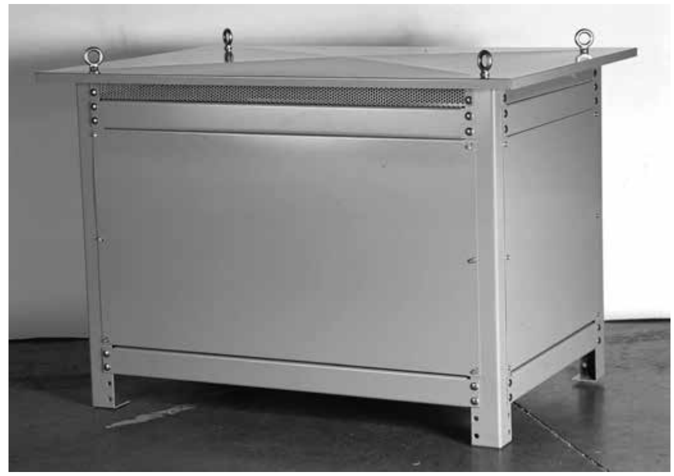
The resistance tolerance test allows plus or minus 10 percent of the rated resistance value.

Table 3 – IEEE-32

Time Ratings and Permissible Temperature Rises for Neutral Grounding Resistors

Time Rating (on time)	Permissible Temperature Rise (above 30˚C)
Ten Seconds (Short Time)	760˚C
One Minute (Short Time)	760˚C
Ten Minutes (Short Time)	610˚C
Extended Time	610˚C
Steady State (Continuous)	385˚C (CSA permissible rise is 375˚C on continuous duty)

CSA Standards and Certification



CSA provides certification services for manufacturers who, under license from CSA, wish to use the appropriate registered CSA marks on products of their manufacture to indicate conformity with CSA standards.

The Canadian Electrical Code is a publication issued by CSA. Part 1 establishes safety standards for the installation and maintenance of electrical equipment. Part 11 consists of safety standards governing the construction, testing, and marking of electrical equipment.

For resistors to be certified by CSA, they must meet the following sections of the Canadian Electrical Code:

a.) CAN/CSA-C22.2 No. 0-M91 - General Requirements - Canadian Electrical Code, Part 11.

b.) C22.2 No. 0.4-M1982 - Bonding and Grounding of Electrical Equipment (Protective Grounding).

c.) CAN/CSA-C22.2 No. 14-M91 - Industrial Control Equipment.

d.) CAN/CSA-C22.2 No. 94-M91 - Special Purpose Enclosures.

In addition, factory test must be conducted at the conclusion of manufacture and before shipment of each resistor assembly.

Post Glover Resistors supplies CSA certification equipment when specified by the customer.

Selection of Neutral Grounding Resistors for Industrial Systems

Factors to Consider

Over the years, the standard practice for neutral grounding in industrial plants has been:

a.) 600 volt and lower systems - solid grounding

b.) 2.4 to 13.8 kv - low resistance grounding

c.) above 13.8 kv- solid grounding

Recently the trend on 600 volt and lower systems has been to use high resistance grounding, with all the inherent advantages it offers the user.

The following factors should be considered when rating neutral grounding resistors:

a.) The capacitance-to-ground charging current of the circuit being protected. Rule of thumb is:
- On systems of 600 volts or lower, .5 amp per 1000 kVA of transformer capacity. - On medium and high voltage systems (above 600 volts), 1.0 amp per 1000 kVA of transformer capacity.

b.) The maximum ground fault current to be permitted on the system, after taking into consideration points a.) and b.) above. This determines the amount of fault damage considered acceptable under ground fault conditions.

c.) The importance of maintaining production in the presence of a single ground fault. Do you chose to shut down, or continue to run?

d.) The type and characteristics of the sensing relays, fault clearing relays, and circuit isolating devices. Ground fault relays are generally selected to operate from 5% to 20% of the maximum current allowed by the grounding resistor. To provide maximum system protection with minimum system damage, the trend is to select lower current ratings.

e.) Safety to operating personnel.

The Selection Process

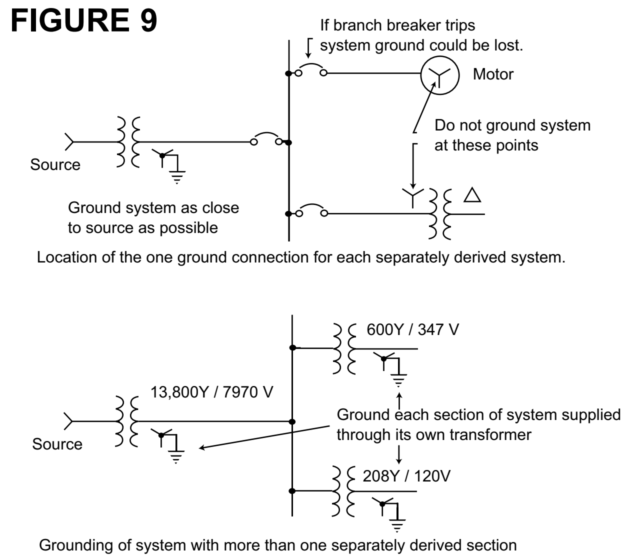
Whether solid or resistance grounding is selected, it is necessary to ground each voltage level to achieve the protection and advantages of neutral grounding. The ground connection should be at the neutral lead of the generator or the power transformer bank. In other words, ground at the power source, not at the load. The ground connection should always be on the secondary of the transformer. (See Figure 9).

When a single line-to-ground fault occurs on a resistance grounded system, a voltage equal to the normal line-to-neutral system voltage appears across the resistor.

The resistor current is equal to the current in the fault. Thus, the current is practically equal to line-to-neutral voltage divided by the resistance in ohms. For example, on a 4160 volt, 3-phase system grounded by a 12 ohm resistor, the line-to-neutral voltage is $4160 \div \sqrt{3}$, or 2400 volts. The ground current will be $2400 \div 12$, or 200 amperes. Therefore, for this example, the ground fault current would be limited to 200 amperes, and the rating of the resistor would be 2400 volts and 200 amps.

The time rating would be selected based on the length of time that the faulted circuit is allowed to be energized after the fault occurs.

FIGURE 9



Finally, the type of enclosure is selected. Typical enclosure types are:

a.) Open-frame construction where the resistor is not exposed to the elements, or may be insulated in switchgear or transformer components.

b.) Indoor/screened enclosures where it is expected that the resistors will be accessible to personnel.

c.) Outdoor enclosures which include solid side covers and elevated hood. This gives superior protection against ingress of rain, sleet, and hail, with maximum ventilation.

The neutral grounding resistor is rated as follows:

- **Voltage:** Line-to-neutral voltage of the system to which it is connected.
- **Initial Current:** The initial current which will flow through the resistor with rated voltage applied.
- **Time:** The “on time” for which the resistor can operate without exceeding the allowable temperature rise.

Other Methods of Grounding

Single Phase Transformer and Loading Resistor

If the system has a neutral which is available, a single phase distribution transformer can be used in conjunction with a loading resistor, to provide high resistance grounding. This is particularly well suited for grounding of generators, in that it allows the system to operate like an ungrounded system under normal conditions, while still retaining the ability to limit fault currents during a fault. Figure 10 shows a typical schematic.

The primary of the transformer is connected from the system neutral to ground. The loading resistor is connected across the transformer secondary.

The resistor should be sized the same way as a neutral grounding resistor, except that it will be reduced in value by the square of the turns ratio of the transformer.

When a ground fault occurs downstream of the grounding transformer, ground fault current flows through the fault, back through ground to the grounding transformer. The loading resistor limits the current flow in the secondary winding, which in turn limits the flow of the ground fault current back into the system through the primary of the grounding transformer.

The resistor is normally sized to allow a primary ground fault current in the range of 2 to 12 amps, and is rated for one minute. The transformer should be sized accordingly.

The transformer primary voltage rating should be the same as the system line-to-line voltage. The secondary voltage is normally 240 or 120 volts.

An overcurrent relay should be used to protect the transformer in case of an internal fault.

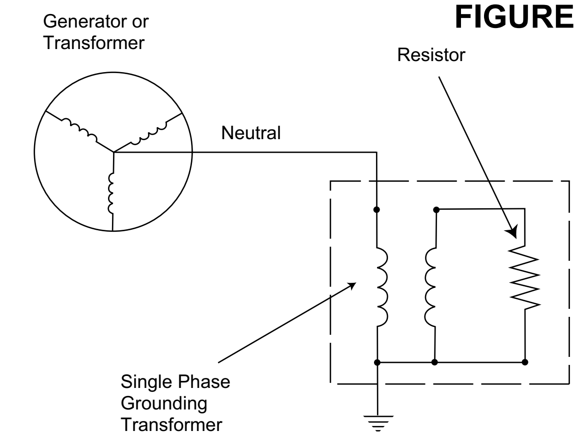
Edgewound and punched grid resistors are best for this low voltage application. A complete package consists of a transformer and a resistor with clearly labeled terminals inside a free standing enclosure.

Grounding Transformers

In older 600V and lower systems, and in many existing 2400 to 6900 volt systems, the system neutral may not be available. This is particularly true on Delta and underground Wye Connected Systems. To be able to ground these systems, grounding transformers can be used to create a neutral, which in turn can be connected to ground either directly, or more commonly, through a Neutral Grounding Resistor (NGR). These combinations are known as artificial neutrals.

Grounding transformers may be either Zigzag or Wye-Delta type. The operation of each is similar. They present high impedance to normal 3-phase current, so that under normal conditions only a small magnetizing current flows in the transformer winding. But, under line-to-ground fault conditions, a low impedance path is provided for the zero-sequence currents. These currents can flow through the fault, back through the neutral of the grounding transformer to the power source.

FIGURE 10



Zigzag Transformers

Of the two types, the Zigzag grounding transformer is more commonly used. It is a three-phase, dry-type, air-cooled auto-transformer with no secondary winding.

Each phase has two identical windings, which are wound in opposite directions to give the high impedance to normal phase currents. The windings are connected in a Wye configuration. The neutral point is then connected either directly or through a neutral grounding resistor (NGR) to ground. This is shown in Figure 11.

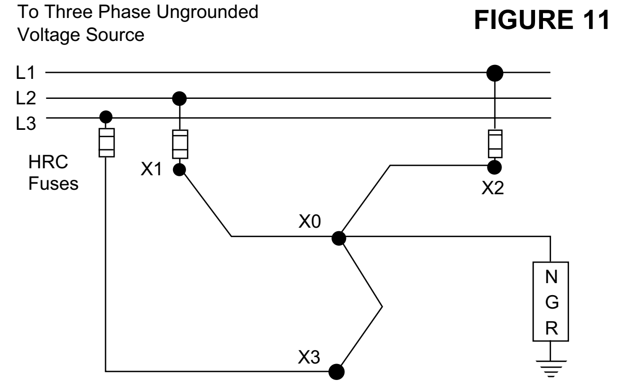


FIGURE 11

When a ground fault occurs downstream of the Zigzag transformer, ground fault current flows through the fault, back through ground and the NGR to the Zigzag where the current is divided equally in each leg of the Zigzag. Since these three currents are all equal and in time phase with each other (zero sequence), and because of the special Zigzag winding connections, they see a very low impedance. This allows the ground fault current to flow back into the system.

It can be seen that the ground fault current is only limited by the resistance of the ground fault, the NGR, and the small reactance of the Zigzag.

The Zigzag transformer is continuously rated for a specific neutral current at rated phase-neutral voltage, without exceeding the temperature rise of the insulation class (class B up to 2400 volts, class H above 2400 volts). The saturation voltage level is normally 1.5 times the rated phase-to-phase voltage.

The current and time rating of the Zigzag, when used with an NGR, should be the same as the NGR.

The Zigzag should be connected to the system on the line side of the main breaker, as close as possible to the power transformer secondary terminals. When more than one power transformer is involved, one Zigzag is required for each. Care should be taken not to have more than one Zigzag connected to the same section of the system at the same time.

Short circuit protection should be provided on each of the three line connections of the Zigzag.

Wye-Delta Transformers

These grounding transformers have a Wye-connected primary and Delta-connected secondary. The three primary line terminals are connected to the 3-phase ungrounded power source. The neutral terminal is connected either directly or through a neutral grounding resistor NGR to ground. The Delta secondary is not connected to any external circuit. This is shown in Figure 12.

During normal system conditions, the Wye-Delta grounding transformer operates unloaded, therefore providing high impedance to the three phase system current. Only a small magnetizing current flows.

When a ground fault occurs downstream of the grounding transformer, ground fault current flows through the fault, back through ground and the NGR to the Wye-Delta grounding transformer. The current is divided equally in each leg of the Wye transformer. Since these three currents are all equal and in time phase with each other (zero sequence), and since the Delta secondary is a closed series circuit, the ground fault current only sees the transformer leakage reactance.

This allows the ground fault current to flow back into the system. The ground fault current is only limited by the resistance of the ground fault, the NGR, and the small transformer leakage reactance.

The Wye-Delta grounding transformer is continuously rated for a specific neutral current at rated phase-to-neutral voltage, without exceeding the temperature rise of the insulation class.

The current and time rating of the transformer, when used with an NGR, should be the same as the NGR.

The transformer primary voltage rating should be equal to or greater than the line-to-line voltage of the system to which it is being connected.

The Wye-Delta grounding transformer should be connected to the system on the line side of the main breaker, as close as possible to the power transformer secondary terminals. When more than one power transformer is involved, one grounding transformer is required for each. Care should be taken not to have more than one grounding transformer connected to the same section of the system at the same time.

Short circuit protection should be provided on each of the primary line connections of the Wye-Delta transformer.

Alternate Wye-Delta Grounding Transformer Configuration

In this configuration, the neutral of the Wye-connected primary is connected directly to ground. A loading resistor is connected across the broken Delta-connected secondary. This is shown in Figure 13.

The loading resistor is selected the same way as a high resistance NGR, except it will be reduced in value by the square of the turns ratio of the grounding transformer.

This resistor limits the current flow in the closed Delta secondary windings, which in turn limits the ground fault current flow in each of windings of the Wye primary of the grounding transformer.

The same precautions must be followed as for the Wye-Delta grounding transformer described in the Wye-Delta Transformers section.

FIGURE 12

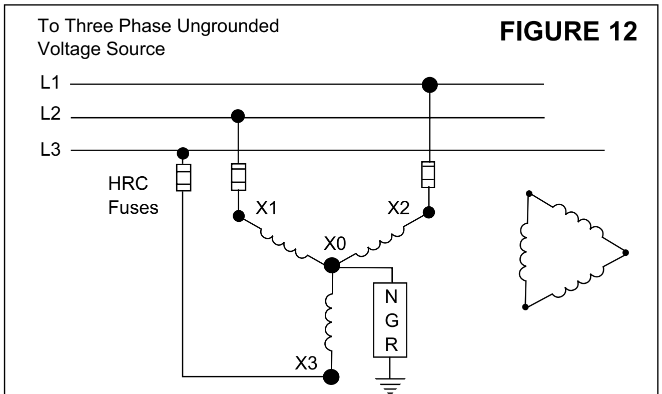
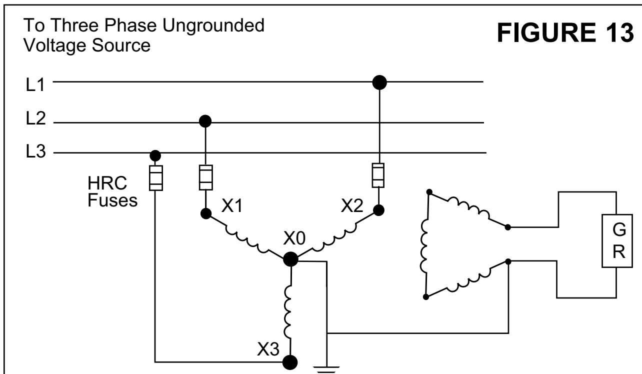


FIGURE 13



Specification for High Voltage, Low Resistance Type

Scope

This specification covers the design, manufacture and testing of high-voltage, low-resistance type Neutral Grounding Resistors (NGR) for installation outdoors onto a concrete pad or power transformer.

Applicable Standards

The NGR shall be designed, manufactured and tested as per the latest revisions of IEEE-32.

Resistors

The resistive elements shall be low temperature coefficient, resistor grade stainless steel of sufficient mass to withstand the rated current and prescribed duty.

The resistors shall be mounted in corrosion resistant support frames, using stainless-steel hardware.

The entire resistor assembly shall be mounted on insulators rated for the system voltage.

All resistor terminals and interconnections between resistor units shall be stainless-steel using stainless-steel hardware including lock washers. High current connections shall be spot or TIG welded as appropriate.

Connections between resistors and bushings or current transformers shall be solid copper or stainless steel bus or copper cables.

Enclosures

The frame of the enclosure shall be made from structural steel angles welded together, or bolted together with stainless-steel hardware. The top of the enclosure shall be solid, slightly overhung and sloped. It shall be embossed with stiffening ribs. The enclosure shall have forged eyebolts in each corner for lifting purposes.

The bottom of the enclosure shall be screened with expanded or perforated metal with openings of 1/2" or less. This screening shall be welded or bolted in and is not removable. It shall be elevated 4 to 6 inches above the base of the unit.

Bolt-on side covers on all four sides shall be used. Screened covers may be furnished for certain applications. Stainless-steel hardware shall be used. Louvered or screened openings shall not exceed 1/2".

A durable nameplate, permanently attached to one side cover shall show the manufacturer and the complete rating. Painted enclosures shall be suitably cleaned, primed and painted. Stainless-steel and aluminum enclosures (in particular) shall be protected from scratching during manufacture, assembly and shipment.

CSA Approved Enclosure

To meet CSA outdoor requirements, solid side covers and elevated, hooded roof shall be supplied. All of the other requirements outlined above shall be met.

Specification for Low or Medium Voltage, High Resistance Type

Scope

This specification covers design, manufacture and testing of low- or medium-voltage, high-resistance type Neutral Grounding Resistors (NGR) for installation indoors and outdoors onto a concrete pad or power transformer.

Applicable Standards

The NGR shall be designed, manufactured and tested as per the latest revisions of IEEE-32.

Resistors

The resistive elements shall be low temperature coefficient, resistor grade stainless steel or nickel chromium rigidly supported at each end to allow for expansion due to heating.

The resistors shall be mounted in corrosion resistant support frames, using stainless-steel hardware.

For low voltage, continuous rated above 10 amp, and all medium voltage applications, the entire resistor frame shall be mounted on insulators rated for the system voltage.

All resistor terminals and interconnections between units shall be stainless-steel, using stainless-steel hardware including lock washers. High current connections shall be spot or TIG welded as appropriate.

Connections between resistors and bushings or current transformers shall be solid copper or stainless steel bus or copper cables.

Enclosures

Low Voltage (600 volts or less)
Enclosure shall be of heavy gauge Galvanneal cold rolled steel with baked enamel finish. All mounting hardware shall be stainless steel.

Indoor enclosure shall have a screened cover with maximum openings of 1/2".

Outdoor enclosure shall have a solid heavy gauge top cover, slightly overhung to prevent ingress of rain or sleet.

CSA Approved Low Voltage
Separate external terminal junction boxes shall be provided for termination of the neutral conductor and the ground conductor. All of the other requirements outlined above shall be met.

Medium Voltage (above 600 volts to 5,000 volts)
The frame of the enclosure shall be made from structural steel angles made from heavy gauge steel, welded together, or bolted together with stainless-steel hardware. The top of the enclosure shall be solid, slightly overhung and sloped. It shall be embossed with stiffening ribs. The enclosure shall have forged eyebolts in each corner for lifting purposes.

The bottom of the enclosure shall be screened with expanded or perforated metal with openings of 1/2" or less. This screening shall be welded or bolted in and is not removable. It shall be elevated 4 to 6 inches above the base of the unit.

Bolt-on side covers on all four sides shall be used. Screened covers may be furnished for certain applications. Stainless-steel hardware shall be used. Louvered or screened openings shall not exceed 1/2".

A durable nameplate, permanently attached to one side cover shall show the manufacturer and the complete rating.

Painted enclosures shall be suitably sanded, cleaned, primed and painted. Stainless-steel and aluminum enclosures (in particular) shall be protected from scratching during manufacture, assembly and shipment.

Specification for Zigzag Grounding Transformers

Scope

This specification covers design, manufacture and testing of low- or medium-voltage Zigzag grounding transformers for use with Neutral Grounding Resistors (NGR) for installation indoors or outdoors onto a concrete pad or power transformer.

Applicable Standards

The transformer shall be designed, manufactured and tested as per the latest revisions of IEEE-32.

Transformer

The transformer shall be a three-phase, dry-type, air-cooled auto-transformer with each phase having two windings connected in a Zigzag configuration. It shall have class “B” insulation up to 2400 volts or class “H” insulation above 2400 volts.

The transformer shall be continuously rated for the charging current of the system on which it is being applied; it shall also have the same current and “on” time rating as that of the NGR with which it is being applied.

Insulation class maximum temperature rise shall not be exceeded at these currents and “on” times.

It shall be rated at the system voltage.

Enclosures

Low Voltage (600 volts or less)
The Zigzag transformer may be combined with the NGR and mounted in one enclosure where the continuous rating does not exceed 5 amps.

The enclosure shall be of heavy gauge Galvanneal cold rolled steel with baked enamel finish. All mounting hardware shall be stainless-steel.

Indoor enclosure shall have a screened cover with maximum openings of 1/2".

Outdoor enclosure shall have a solid heavy gauge top cover, slightly overhung.

CSA Approved Low Voltage
Separate external terminal junction boxes shall be provided for termination of all three line conductors and the ground conductor.

Medium Voltage (above 600 volts to 5,000 volts)
The frame of the enclosure shall be made from structural steel angles made from heavy gauge steel, welded together, or bolted together with stainless-steel hardware. The top of the enclosure shall be solid, slightly overhung and sloped. It shall be embossed with stiffening ribs. The enclosure shall have forged eyebolts in each corner for lifting purposes.

The bottom of the enclosure shall be screened with expanded or perforated metal with openings of 1/2" or less. This screening shall be welded or bolted in and is not removable. It shall be elevated 4 to 6 inches above the base of the unit.

Bolt-on side covers on all four sides shall be used. Screened covers may be furnished for certain applications. Stainless-steel hardware shall be used. Louvered or screened openings shall not exceed 1/2".

A durable nameplate, permanently attached to one side cover shall show the manufacturer and the complete rating.

Painted enclosures shall be suitably sanded, cleaned, primed and painted. Stainless-steel and aluminum enclosures (in particular) shall be protected from scratching during manufacture, assembly and shipment.

Glossary of Terms

Bushing
A high voltage terminal connection which isolates the conductor from the grounded sheet metal surface through which the bushing passes. Sometimes called "entrance" and "exit" bushings.

Cap and Pin Type Insulator
Also called Petticoat insulators because of the porcelain "skirt" around the "pin" base. The bottom flange has four mounting holes while the top has four threaded inserts. The units can be bolted together in a stack.

Current Transformer
Usually a high-voltage bar-type with the primary connected in series with the grounding resistor, and the secondary connected to external fault clearing relays.

Extended Time Rating
A rated time in which the time period Is greater than the time required for the temperature rise to become constant but is limited to a specified average number of days operation per year.

Ground Pad
A surface for terminating a ground lug to make a reliable connection to the system or equipment ground. May have one, two or four holes and is usually drilled for NEMA connectors.

Grounded Safety Enclosure
A grounded enclosure which provides protection of the resistors from birds and rodents while preventing accidental contact of live or high temperature parts by personnel. May have side or top mounted entrance bushing.

Grounding Transformer
A transformer that is used to provide a neutral point for grounding purposes. It may be a single-phase transformer such as used to reflect high resistance grounding for a generator, or it may be a special Wye - Delta or Zigzag transformer used to artificially create a neutral point on a Delta or 3 wire Wye system which has no neutral.

Insulating Bushing
A Phenolic strain relief grommet to prevent chaffing of a power cable as it passes through a sheet metal panel. Held in place with a conduit lock ring.

Neutral Grounding Resistor
A suitably rated power resistor that is connected between the neutral of a transformer (or generator) and the system ground. It serves to limit fault currents and prevent damage to the equipment.

Rated Continuous Current
The current expressed in amperes (RMS), that the device can carry continuously under specified service conditions without exceeding the allowable temperature rise.

Rated Time
The time during which the device will carry its rated thermal current under standard operating conditions without exceeding the limitations established by the applicable standards. The various "on" times established by IEEE-32 are shown in Table 3 on page 8.

Rated Time Temperature Rise
The maximum temperature rise above ambient attained by the winding of a device as the result of the flow of rated thermal current under standard operating conditions, for rated time and with a starting temperature equal to the steady-state temperature. It may be expressed as an average or a hot winding rise. The allowable temperature rises for various "on" times, as established by IEEE-32 are shown in Table 3 on page 8.

Rated Voltage
The rms voltage, at rated frequency, which may be impressed between the terminals of the device under standard operating conditions for rated time without exceeding the limitations established by the applicable standards. For the Neutral Grounding Resistor, this is equal to the line-to-neutral voltage. The line-to-neutral voltage is simply the line-to-line (system) voltage divided by 1.732.

Resistor Element
A resistor element is the conducting unit which functions to limit the current flow to a predetermined value. Usually a helical coiled, edgewound, or serpentine folded ribbon of stainless steel alloy.

Short Time Rating
(Of a grounding device) A rated time of ten minutes or less.

Standoff Insulator

A glazed porcelain or epoxy body with threaded inserts in the top and bottom. The insulators serve to mechanically connect mounting frames to enclosures, or one mounting frame to the next, while still providing electrical isolation. The body of the insulator is typically corrugated to provide a longer creepage distance to prevent tracking.

Station Post Insulator

Similar to the standoff type insulator, but usually has two threaded studs on top and bottom and is rated for higher voltages than the standoff type.

Support or Elevating Stand

An angle frame stand used to elevate the entire grounding resistor and enclosure. This may be for safety purposes to prevent personnel from reaching live parts, or may be to facilitate connection to a transformer.

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