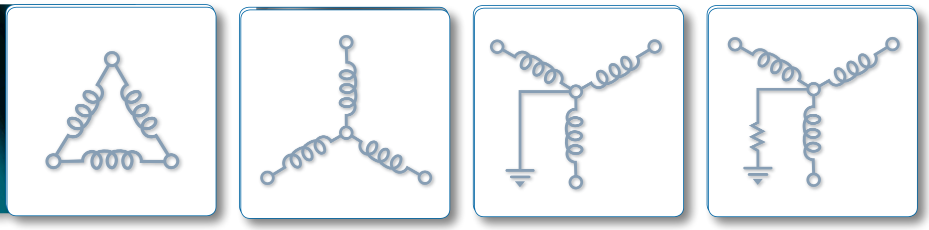
Unparalleled Protection

CONSULTANT SPECIFICATION GUIDE



C-31 Rev 1. Specification Guide, November 2022

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About I-Gard

I-Gard's commitment to electrical safety provides both industrial and commercial customers with the products needed to protect their electrical equipment and the people that operate them.
As the only electrical-safety focused company whose product portfolio includes neutral grounding resistors, high-resistance grounding systems and optical arc mitigation, we take pride in our technologies that reduce the frequency and impact of electrical hazards, such as arc flash and ground faults.

For those customers who have purchased from us over the last 30 years, you know us for the quality and robustness of our products, our focus on customer service and technical leadership. We build on this foundation by investing in developing new products in electrical safety education by actively participating in the IEEE community programs on technical and electrical safety standard, and working with local universities at discovering new technologies. We remain unrelenting in our goal of improving electrical safety in the workplace.
Our commitment to excellence is validated by long-standing relationships with industry leaders in fields as diverse as petroleum and gas, hospitals, automotive, data centers, food processing, aerospace, water and waste water plants, and telecommunications. We provide our customers with the product and application support required to ensure that their electrical distribution system is safe and reliable.

1. INTRODUCTION

The decision on which type of electrical grounding system to specify has a direct consequence of system reliability, electrical risk, and operational cost.

As noted in CSA Z462-21 clause O.2.1 - Facility owners, facility managers and employers responsible for facilities and installations where electrical energy is a potential hazard to workers and other personnel should ensure that electrical hazard risk assessments are performed during the design stage of electrical systems and installations.

CSA Z462-21 Clause O.2.2 notes: Design option decisions should facilitate the ability to eliminate hazards or reduce risk by doing the following:

a. Reducing the likelihood of exposure
b. Reducing the magnitude or severity of exposure; and
c. Enabling achievement of an electrically safe work condition

To meet the above requirements, I-Gard recommends the following with respect to grounding of the electrical system

- If under 5 kV and under 10 A , all industrial facilities should be designed to use High Resistance Grounding (HRG) over ungrounded systems due to the damaging effect of transient overvoltages and over solidly grounded systems due to the damaging effect of high levels of fault currents and the potential arc flash risk. In addition, HRG allows for process continuity in the event of a ground fault as opposed to solidly grounded systems which require the faulted circuit to trip. Lastly, HRG is considered an arc flash mitigation technique as per CSA Z462-21, Annex O.
  If servicing line-to-neutral loads, it is recommended to use an isolation transformer at the point of use. This eliminates load imbalances, increases liability, and reduces cost as the neutral conductor no longer needs to be run across the facility.

- If under 5 kV but over 10 A, all industrial facilities should be designed to use Low Resistance Grounding (LRG) as opposed to solidly grounded as a mean of lowering the energy in a ground fault. In a typical low voltage solidly grounded system the fault currents could be in the 20,000 to 50,000 A range and since the energy in the fault is I^2t the energy in a solidly grounded fault could be between 400,000 kJ to 2,500,000 kJ versus 1,600 kJ in a typical low resistance grounded system.
  A safety factor of 250 to 1,562.

- If above 5 kV or above 10 A, all industrial facilities should be designed to use (LRG) for the reasons noted above.

To meet the above requirements, I-Gard recommends the following with respect to shock protection:

All electrical cabinets should be fitted with an absence of voltage tester that complies with CSA Z462-21 and is labeled to UL 1436. This method allows for the establishment of an electrically safe work condition without opening any electrical panel doors and protects the user from unintentional contact with current carrying conductors.

Ground Fault Protection Panels are designed to prevent shock hazards, to protect equipment and personnel as they trip when the ground leakage current on the load side exceeds a safe level. The use of panels is recommended for areas which could present shock hazard to personnel such as applications feeding pump motors or wet areas such as dairies, food processing facilities, breweries or any process where water is used.

1.1 Types of Grounding Systems

Ungrounded systems are typically of the secondary delta configuration, offering three phases with no neutral point. Since the 50s, ungrounded systems have been typically used for applications that require continuous operation, as they are able to stay energized during the first single phase-ground fault condition. However, ungrounded systems have a tendency to produce high transient overvoltage conditions.

Solidly grounded systems are typically modeled using the wye configuration, with three phases and a neutral point. This neutral point is connected to ground with no intentional impedance. During a single phase to ground fault, the point of the fault will find a path through ground using the neutral on the wye secondary. Because of the lack of impedance off the neutral, solidly grounded systems generate a very high magnitude of fault current during a fault condition, and must trip on the first fault.

Resistively grounded systems are similar to solidly grounded systems as they are also typically modeled using a wye configuration where a neutral point, X0, is available, but with a current limiting resistor connected between the neutral point and ground. This resistor operates to ensure that when a single phase to ground fault occurs, the fault current circulates through the resistor off the neutral, and limits the fault current to a predetermined value.

1.1.1 Ungrounded Systems

When your system is ungrounded, each phase is coupled to ground by the distributed cable capacitance. This capacitance also includes the loads connected to your 3 phase system with reference to ground, such as VFDs, surge protector devices, motors, etc. Assuming that the length of the cable for each phase is equivalent, and the capacitance to ground for each phase in reference to ground is equal, and we know that each phase-to-ground capacitive current is 120 degrees apart, then we can state that the sum of all three equals 0 (during normal operation). With no intentional connection to ground, the first single phase ground fault will not have a specified path, and negligible current circulates throughout the system.
Ground faults in ungrounded systems are identified by measuring the L-G voltage of the three phases to monitor the elevation of the unfaulted phases and the 0 V potential shift on the faulted phase.

Due to the negligible fault current throughout the system, it is difficult to identify the location of the fault. Typical practice for addressing a fault in an ungrounded system requires operations personnel to work their way through every downstream feeder, turning off breakers to identify if the fault is cleared. This process disrupts downstream processes and is time consuming.

Ungrounded systems are also susceptible to over-voltages during intermittent or low arcing ground faults, which could elevate your phase-to-ground voltages by 6-8 times above nominal, which is devastating for cabling, equipment, and personnel (Refer to 2.1.2.2).

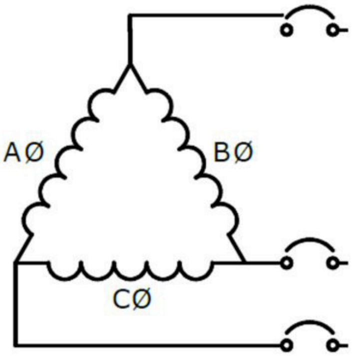


Figure 1.1: Ungrounded System

1.1.2 Solidly Grounded Systems

Solidly grounded systems must trip within a one (1) second time delay (as per CEC 14-102) when a ground fault occurs, with no possibility of maintaining process continuity. This can translate to interruption of distribution lines and critical processes. In addition, lack of protective device coordination may cause the main breaker to trip if downstream breakers are unable to isolate the point of fault in time. If a fault in a solidly grounded system remains for 1 second, the magnitude of the current can become so great that it can melt the conductor, where a possibility arises that a single phase fault can propagate into a phase-to-phase and/or 3 phase bolted fault, which can be catastrophic to equipment and personnel. When there is a need to remain or to specify solidly grounded configurations, then it is critical to address the arc flash risk while maintaining coordination where possible.

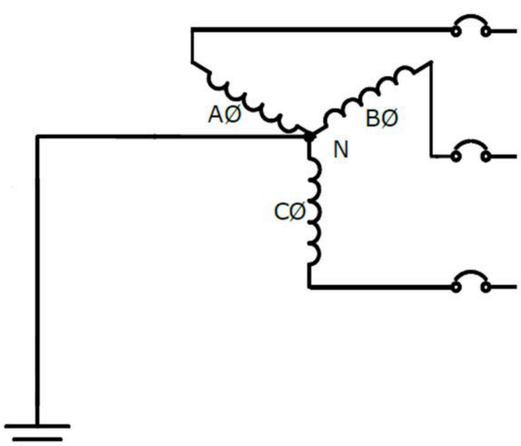


Figure 1.2: Solidly Grounded System

As per IEEE 1584, incident energy levels, regardless of system voltage, are directly proportional to the duration of the arc. CSA Z462-21, Annex O outlines methods to reduce incident energy levels, therefore translating to a reduction in the magnitude of the arc condition, including Zone Selective Instantaneous Protection (ZSIP) and arc flash relays.

- Zone Selective Instantaneous Protection (ZSIP) provides system coordination to maintain operation of unaffected loads during a ground fault condition. By utilizing such functionality, the user ensures that only the breaker closest to the point of the fault trips. Depending on the location of the fault, the user is able to maintain system operation, when possible. ZSIP improves the level of protection for circuit breakers by eliminating the need to utilize time current curves - inherently reducing the trip delay without sacrificing system coordination.

- Arc flash relays use light, current, pressure, or a combination of two or three of these inputs to detect the arc at the earliest point and initiate a trip signal, reducing the duration of the arc and the incident energy levels.

1.1.3 Resistively Grounded Systems

Resistively grounded systems employ a resistor between neutral and ground to limit the fault current to a predetermined value based on system parameters. This fault current value can be high enough to trip protective devices (Refer to section 3: "Low Resistance Grounding"), or low enough to maintain continuous operation during the first single fault condition (Refer to section 4: "High Resistance Grounding").

Unlike ungrounded systems, resistively grounded systems, when sized properly, are designed to control transient overvoltage conditions by ensuring the neutral path sees the majority of the fault current during a faulted condition. (Refer to 2.1.2.2)

In addition, resistively grounded systems limit the energy produced by a single phase-ground fault unlike solidly grounded systems. This translates to a reduction in the likelihood that the single phase fault will propagate to a phase-to-phase fault (Refer to 2.1.2.1 and 2.1.2.3).

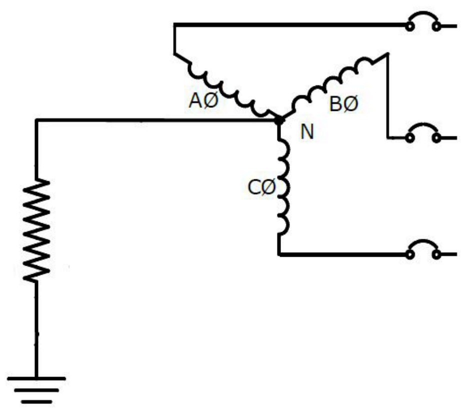


Figure 1.3 : Resistively Grounded System

1.2 How to use this Guide

This guide is intended for the consulting engineer looking to specify and utilize resistively grounded systems and other I-Gard protection/relay products in their design. The guide has different sections based on what type of resistively grounded system to be implemented from basic to advanced options. In addition, this guide provides detailed information for arc flash protection and shock protection devices that can satisfy particular code requirements.

This guide cross-references specification templates that can be used in specifying the particular type of solution based on the project requirements. Please see the table of contents for the breakdown of sections available within this guide.

2. NEUTRAL GROUNDING RESISTORS (NGR) GENERAL

2.1 Introduction

Table 2.1: Specification Sections used in this guide

Application	Specification Section
Low Resistance Grounding (LRG)	26.45.01
High Resistance Grounding (HRG)	26.45.02
Hybrid Grounding	26.45.03
Arc Flash Protection	26.45.04
Shock Protection	26.45.05

2.1.1 Scope

This section can be used to specify the NGR in general, either for an LRG system, HRG system, or HHRG system.

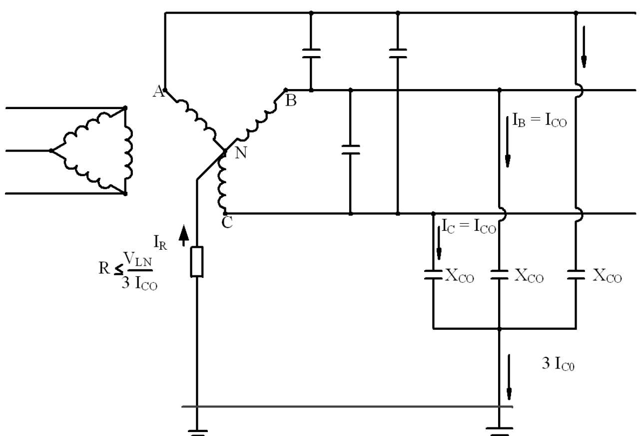
2.1.2 Benefits of Resistance Grounded Systems

2.1.2.1 Limits Fault Current to a Known Value

Resistance grounded systems provide a return path for ground fault current to flow. Figures 2.1 (a) and (b) below show a resistance grounded electrical system and phasor free of any ground faults.

Shown are the phase to phase phasors, the phase to neutral phasors as well as the individual phase to ground contribution of the capacitive current which will be discussed further in section 2.2.2. The capacitive current is a result of the difference in potential of the conductor and ground. This potential difference is isolated by an insulation medium, which basically describes a capacitor. This capacitor is distributed throughout the electrical system and is sometimes referred to as the distributed capacitance. For simplicity, the distributed capacitance is drawn as a lumped capacitor for this discussion and labeled as X_{co}. In this scenario, the phase to phase capacitance is ignored as they have no influence on the distributed capacitance of the system.

I_R=0, normal condition



(a)

Figure 2.1 (a): Schematic of an unfaulted HRG system

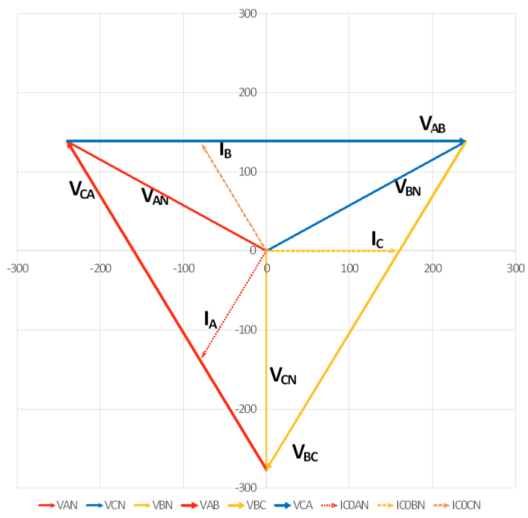
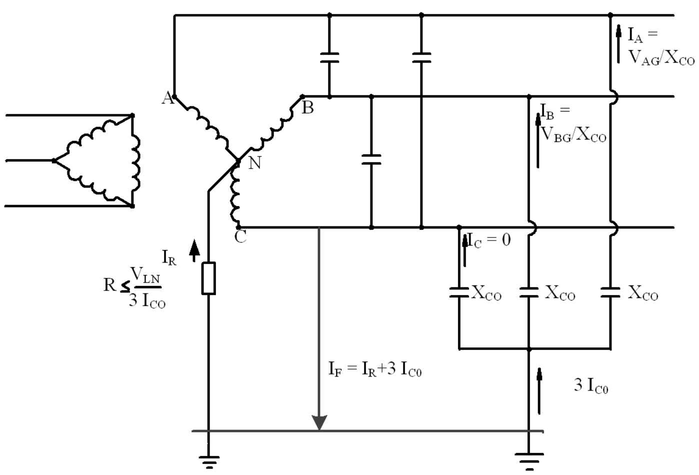


Figure 2.1 (b): Phasor Diagram

One can see that the capacitive current is leading the phase to neutral voltage by 90° as would be expected. Also, the capacitive currents are 120° apart and equal in magnitude so that the resultant $3I_{co}$ is 0.

Figures 2.2 (a) and (b) below show the same system with a ground fault on phase C. This ground fault will shunt the capacitance on phase C to ground and shift the phasor relationship in such a manner that the unfaulted phases, in this case phase A and B, will elevate to phase to phase potential with respect to ground. The current will return back to the source through three paths:

1) Through the NGR and is limited based on the ohmic value of the NGR
2) Through the capacitance on phase A and is limited by the capacitance of the phase A to ground value
3) Through the capacitance on phase B and is limited by the capacitance of the phase B to ground value



(a)

Figure 2.2 (a): Schematic of HRG system with fault on phase C

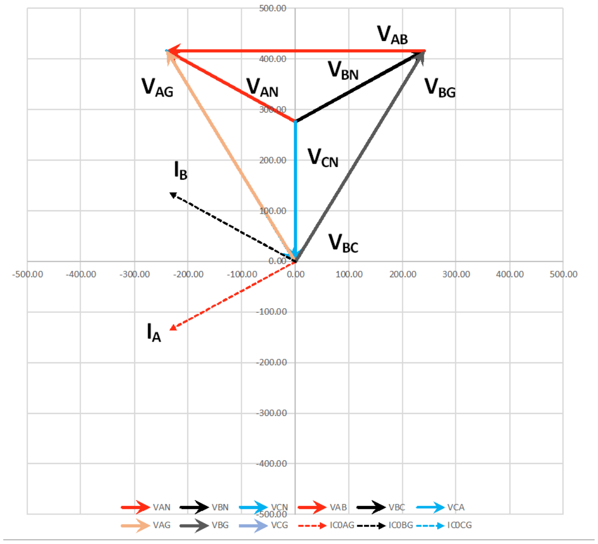


Figure 2.2 (b): Phasor Diagram

The capacitive currents I_A and I_B are derived by calculating V_{AG}/X_{co} and V_{BG}/X_{co} respectively. So $3I_{co} = I_A + I_B + I_C = 0$ using Kirchhoff's Current Law, I_C we know as 0, so $3I_{co} = -(I_A + I_B)$

The current through the resistor is calculated by V_{NG}/R, and if limited to 10 A or less on systems 5 KV and below is found to be an arc flash mitigation technique according to CSA Z462-21.

The total fault current will be the sum of the resistive current and the capacitive current. If the resistive current is equal to the capacitive current, then the resultant:

$$I_F = \sqrt{(I_R)^2 + (3I_{CO})^2}$$

$$I_F = \sqrt{2}(3I_{CO})$$

$$I_F = 1.414 \text{ X } I_R$$

$$\text{Where } I_R = 3I_{CO}$$

2.1.2.2 Control Transient Overvoltages

Another benefit of resistance grounded systems over ungrounded systems is the limiting of transient overvoltages that occur on restriking ground faults. These overvoltages can be several times normal in magnitude ground fault as referred in IEEE 3003.1 section 4.2.

IEEE -242-2001 section 8.2.5 notes that on the occurrence of a re-striking ground fault, overvoltages can be on the order of six to eight times the phase voltage to ground and can deteriorate the insulation of the system. An illustration of how these voltage excursions in the system develop in an ungrounded system is shown in Figure 2.3 below. In contrast, resistance grounded systems eliminate these transient overvoltages. As shown in Figure 2.2 (b) above, the reason for this is because of the capacitive coupling between the phases and ground.

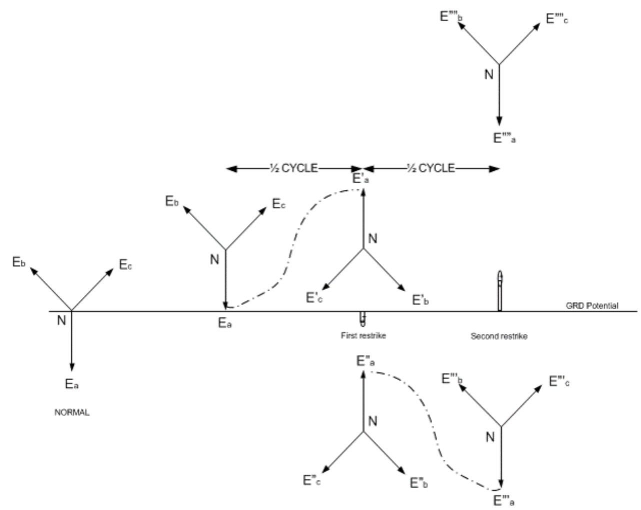


Figure 2.3: Illustration of voltage excursion of an ungrounded system during a re-striking ground fault

2.1.2.3 Reduce Burning and Melting Effects on Equipment

As shown in Figure 2.1 above, for a resistively grounded system the fault current level (I_R) is determined by the ohmic value of the NGR ($I_R = V_{LN} / R$). By keeping the current low, the energy at the fault is limited, along with burning and melting effects on equipment.

2.1.2.4 Limit Fault Current Levels to Acceptably Low Levels

Fault current returns to the system through the NGR and is limited based on the ohmic value of the NGR. If the fault current is limited to over 10 A it is considered a Low Resistance Grounded (LRG) system. If the fault current is limited to 10 A or less by the NGR then it is considered a High Resistance Grounded (HRG) system.

2.1.2.5 Maintain Continuity of Service on the occurrence of a First Ground Fault

As per CSA C22.1-21 section 10-302, for HRG systems a ground fault can remain on the system without de-energizing. Hence, a significant benefit is continuity of service.

2.1.2.6 Reduce Mechanical Stresses on Equipment

Data in the industry has been gathered to illustrate the economic benefits of resistance grounded systems. One of the areas where this can be seen is in the data on motor repair costs. As mentioned, when a fault occurs on a motor on a system that is high resistance grounded the fault current level is limited to a level where it is not necessary to trip. This means the motor does not experience the abrupt stopping that would inflict mechanical stresses onto it. Instead, the equipment can run continuously with the fault still on it until a convenient time for a shutdown to repair the equipment. Significant costs can be saved by the reduction of damage to equipment and in the reduction in down time.

2.1.3 References

IEEE 3003.1-2019, CSA Z462-21, CSA C22.1.

2.2 NGR Design, Sizing, and General Specifying

2.2.1 Voltage

The rated voltage of an NGR is specified as the line to neutral voltage (CSA 22.2 No. 295-15, section 4.1.2). The maximum neutral to ground voltage that would be seen by the NGR is equal to the line to neutral voltage.

2.2.2 System Charging Current

Systems have a characteristic distributed capacitance. It is necessary to estimate or determine a system's distributed capacitance in order to properly select the let-through current rating of the NGR. The distributed system capacitance is modeled as three ground-connected capacitors labeled X_{co} as shown in Figure 2.1. For its given distributed capacitance, the system has an associated charging current ($3I_{co}$) as shown in Figure 2.1(a).

The various equipment on a system contribute to its overall capacitance to ground. Cables, transformers, rotating machines, surge capacitors, etc. All contribute to the system capacitance, and hence the system charging current ($3I_{co}$). The system charging current can be estimated by the "Rule of Thumb" method as indicated in Table 2.2 below. More detailed calculations for a system can be made from data acquired from manufacturers or measurements. Table 2.3 below summarizes such data.

Table 2.2: Rule of Thumb Values for Estimating System Charging Current

System Voltage	Estimated Let-Through Current Per System KVA Capacity without Suppressors	Additional Current for each set of suppressors
600 V	1 A / 2000 KVA	0.5 A
2400 V	1 A / 1500 KVA	1.0 A
4160 V	1 A / 1000 KVA	1.5 A

Table 2.3: Data for Estimating System Charging Current

System Voltage		Component Type	Charging Current
Up to 600 V	Capacitors	Surge Suppression - 1.0 μF/phase	0.31 A
	Cables	600 – 1000 MCM in Conduit (3 conductor)	0.15 A / 1000 Ft.
		250 – 500 MCM in Conduit (3 conductor)	0.10 A / 1000 Ft.
		1/0 – 4/0 in Conduit (3 conductor)	0.05 A / 1000 Ft.
		1/0 – 4/0 on Trays (3 conductor)	0.02 A / 1000 Ft.
	Transformers		0.02 A / MVA
	Motors		0.01 A / 1000 HP
2400 V	Capacitors	Surge Suppression - 0.5 μF/phase	0.78 A Each Set
	Cables	Non-Shielded in Conduit all sizes (3 conductor)	0.05 A / 1000 Ft.
		Shielded all sizes (3 conductor)	0.3 A / 1000 Ft.
	Transformers		0.05 A / MVA
	Motors		0.03 A / 1000 HP
4160 V	Capacitors	Surge Suppression - 0.5 μF/phase	1.35 A Each Set
	Cables	X-Linked-Shielded 1/0 – 4/0 (3 conductor)	0.42 A / 1000 Ft.
		X-Linked-Shielded 250 – 400 MCM (3 conductor)	0.58 A / 1000 Ft.
		X-Linked-Shielded 400 – 600 MCM (3 conductor)	0.7 A / 1000 Ft.
		X-Linked-Shielded 600 – 1000 MCM (3 conductor)	0.9 A / 1000 Ft.
		X-Linked Non-Shielded in Conduit all sizes (3 conductor)	0.1 A / 1000 Ft.
	Transformers		0.05 A / MVA
	Motors		0.05 / 1000 HP
6900 V	Capacitors	Surge Suppression - 0.5 μF/phase	2.25 Each Set
	Cables	X-Linked-Shielded 1/0 – 4/0 (3 conductor)	0.6 A / 1000 Ft.
		X-Linked-Shielded 250 - 400 MCM (3 conductor)	0.79 A / 1000 Ft.
		X-Linked-Shielded 400 – 600 MCM (3 conductor)	1.0 A / 1000 Ft.
		X-Linked-Shielded 600 - 1000 MCM (3 conductor)	1.1 A / 1000 Ft.
	Transformers		0.05 A / MVA
	Motors		0.10 A / 1000 HP
13,800 V	Capacitors	Surge Suppression - 0.25 μF/phase	2.50 A Each Set
	Cables	X-Linked-Shielded 1/0 – 4/0 (3 conductor)	0.92 A / 1000 Ft.
		X-Linked-Shielded 250 – 400 MCM (3 conductor)	1.1 A / 1000 Ft.
		X-Linked-Shielded 400 – 600 MCM (3 conductor)	1.3 A / 1000 Ft.
		X-Linked-Shielded 600 – 1000 MCM (3 conductor)	1.6 A / 1000 Ft.
	Transformers		0.05 A / MVA
	Motors		0.15 A / 1000 HP

2.2.3 NGR Let-Through Current

The let-through current rating of the NGR is made after calculating or measuring the system charging current. For a resistively grounded system, $I_R \geq 3I_{co}$. When $I_R \leq 10$ A, the system can be considered to be High Resistance Grounded. When $I_R > 10$ A, the system can be considered to be Low Resistance Grounded.

Furthermore, it should be appreciated that the current through the NGR changes over the duration of a fault due to the increase in temperature. During a fault, an NGR becomes hotter as it draws current. The resistance of the resistor increases with temperature, according to the following formula:

$$R2 = R1\,(1 + \alpha(\theta 2 - \theta 1)) \qquad \text{Equation 2-1}$$

Where:

α	is the temperature coefficient of resistance of the active material (1/°C)
θ1	is the initial Temperature (°C)
θ2	is the final Temperature (°C)
R1	is the initial Resistance at θ1 (Ω)
R2	is the final Resistance at θ2 (Ω)

This is particularly significant because the ground fault current is equal to the voltage across the resistor divided by the resistance. If the resistance increases the current will decrease. The temperature coefficient of resistance (α) is determined by the type of steel used for the resistor.

2.2.4 Rated Time

An NGR shall be specified with a rated time of 10 seconds, 30 seconds, 1 minute, and continuous duty (CSA C22.2 No. 295-15 section 4.1.2). There are maximum temperature rise requirements for different rated times (see Table 2.4 below). This has implications for the quality of the construction, particularly with regards to the material of the resistor element. This table implies that stainless steel is a superior material than cast iron.

Table 2.4: Temperature Rises above 40°C ambient for Resistors Materials

Rating Type	Stainless Steel
Steady state for continuous ratings	375 K
10 min	600 K
< 10 min	750 K

Source: Table 9 of CSA C22.2 No. 295-15

The choice of what time to specify is made in part as a result of the type of grounding system: HRG or LRG. If a system is HRG it may be allowed to run without de-energization on the occurrence of a ground fault is permitted by the insulation levels as illustrated in Table 2.5 below. If a system is LRG then the strategy on the occurrence of a ground fault is to de-energize.

2.2.5. NGR Element Material

As mentioned above, the resistance of the material that comprises the NGR increases with temperature. In other words, it has an appreciable temperature coefficient of resistance. The temperature coefficient of resistance of a material describes the suitability of that material to resist change in resistance with temperature and is given by the formula shown in Equation 2-1.

When specifying an NGR it is important to ensure that it is comprised of a material that has a low temperature coefficient of resistance to ensure that its performance does not violate the requirements in CSA C22.2 No 295-15. In section 6.2.1 the requirement for the rated voltage test is described. The assembly shall be operated at the maximum line to neutral rated voltage. The current shall be measured immediately for a short-time rated device, or after 60 minutes for a continuously rated assembly. The current shall not vary from the rated current by more than 20%.

It can be illustrated that this is a necessary factor to consider from the example shown in Figure 2.4. Here, a 6 Ω resistor carries 400 A of current for a duty cycle of 10 seconds. It can be observed in Figure 2.4 (a) that the rise in temperature causes the resistance to also rise. This causes the current through the resistor to decrease, as shown in Figure 2.4 (b). From Table 2.4, the 10 seconds rating can have a temperature rise of no more than 750°C.
Table 2.6 references various materials and their respective temperature coefficients of resistance. It can be seen that a significant reduction in expected let-through current during a ground fault condition may impact the ability of the protective device scheme to identify and react to the fault in a timely manner.

Table 2.5: Sample of Temperature Coefficient of Resistance and Materials

Alloy	Temperature Coefficient of Resistance (1/^{o}C) α
AISI 304	0.00092
AISI 430	0.00146
18SR	0.000358
1JR	0.000241

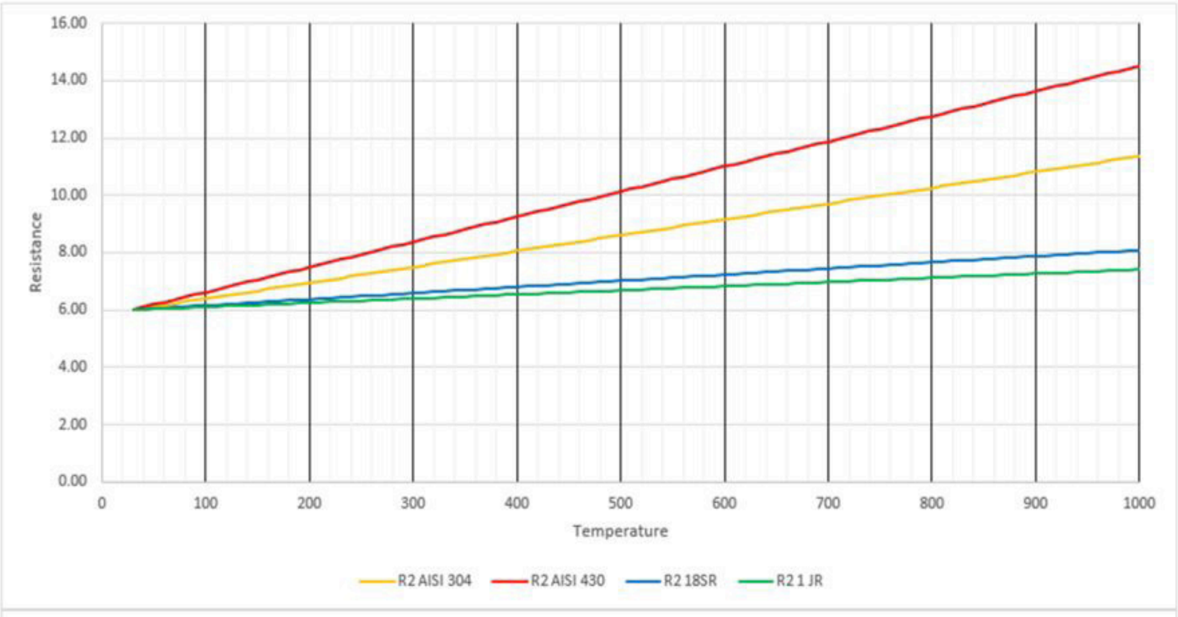


Figure 2.4 (a): An example of an NGR's Resistance rising as it increases in temperature.

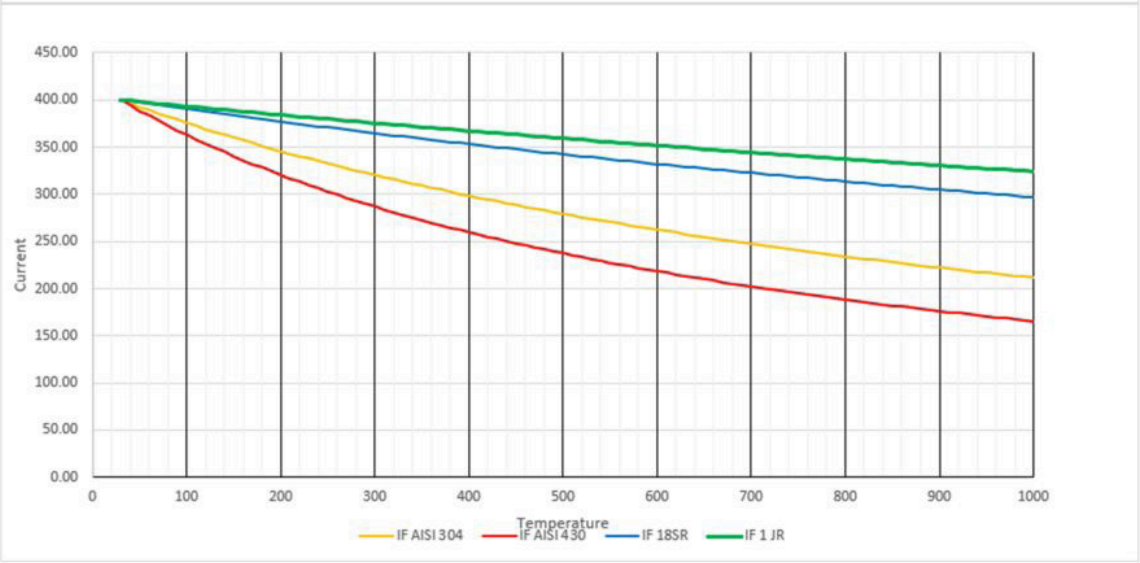


Figure 2.4 (b): An example of an NGR's Current decreasing as it increases in temperature.

Table 2.6: Sample of Temperature Coefficient of Resistance and Materials

Alloy	Temperature Coefficient of Resistance (1/^{0}C) α	Percent change in Resistance	Current decrease as a percentage
AISI 304	0.00092	70% Increase to 10.2 Ω	41.1 % to 235 A
AISI 430	0.00146	110% Increase to 12.65 Ω	52.5 % to 189 A
18SR	0.000358	27 % Increase to 7.63 Ω	21 % to 314 A
1JR	0.000241	18% Increase to 7.1 Ω	15.4 % to 338 A

As can be seen, the first three materials violate the rated voltage test of CSA as the current decreases by more than 20%.

2.2.6 Resistor Monitoring

An important necessity for NGRs is resistor monitoring. This comes as a requirement from CSA C22.1-21 rule 10-302 where it states that:

2) The integrity of an impedance grounded system shall be monitored, and the system shall have an audible or visual alarm that corresponds to the occurrence of:

a) A ground fault on current-carrying conductors, including the neutral conductor where line-to neutral loads are served;

b) A ground fault on the conductor connecting the impedance grounding device to the source;

c) A loss of continuity of the impedance grounding circuit from the system source through the impedance grounding device to the grounded non-current-carrying conductive parts of the electrical system.

The illustration of these conditions that are to be monitored as part of resistor monitoring are shown in Figure 2.5 below. This monitoring requires that the NGR be outfitted with sensors, typically a voltage sensor, an NGR sensing resistor and a current sensor. The outputs of the sensors are connected to a relay that monitors the resistor integrity. Furthermore, it should be emphasized that such a resistor monitoring relay must comply with all clauses in CSA C22.1-21 rule 10-302. This involves monitoring the entire ground path from the system source to the NGR, through the NGR and to the ground point. Table 17 in CSA22.1-21 states the conditions for initiation of automatic alarm and de-energization of systems. The conditions are listed below in Table 2.7

Table 2.7: Conditions for initiation of automatic alarm and de-energization of systems

Impedance grounded system configuration	Ground fault on current carrying conductors	Ground fault from source to impedance grounding device	Loss of continuity from the source through the impedance grounding device to ground
Line to neutral loads are served	Alarm and de-energize system immediately	Alarm and de-energize system immediately	Alarm and de-energize system immediately
Line to neutral loads not served ≤ 5 kV and ≤ 10 A	Alarm and de-energize the system within the time rating of the impedance grounded device	Alarm and De-energize system within 48 hours	Alarm
Line to neutral loads not served > 5 kV or > 10 A	Alarm and de-energize the system within the time rating of the impedance grounded device	Alarm and De-energize system within 48 hours	Alarm

Note: On the occurrence of a loss of continuity of the impedance grounding circuit from the system through the impedance grounding device to ground, the device monitoring the system can continue to detect a ground fault on an ungrounded system. If the system is unable to detect a ground fault on an ungrounded system, it must alarm and de-energize within 48 hours.

Resistor monitoring can be accomplished with either of I-Gard's two ground fault relay systems. One is the SIGMA 3 ground fault relay, which can be used to both monitor resistor integrity and detect a ground fault by monitoring fault current from X_o to ground. The SIGMA 3 has a broad range of settings that can allow it to be used in HRG or LRG arrangements. The SIGMA 3 can monitor the path from the neutral to ground which is in compliance with CSA C22.1-21 rule 10-302.

Another resistor monitoring relay is the DSP-DRM3, which is a module that is used in the DSP ground fault relay system. The DSP system is an advanced modular ground fault relay system that offers many features to monitor an HRG system. The DSP-DRM3 can monitor the path from neutral to ground which is in compliance with CSA C22.1-21 rule 10-302.

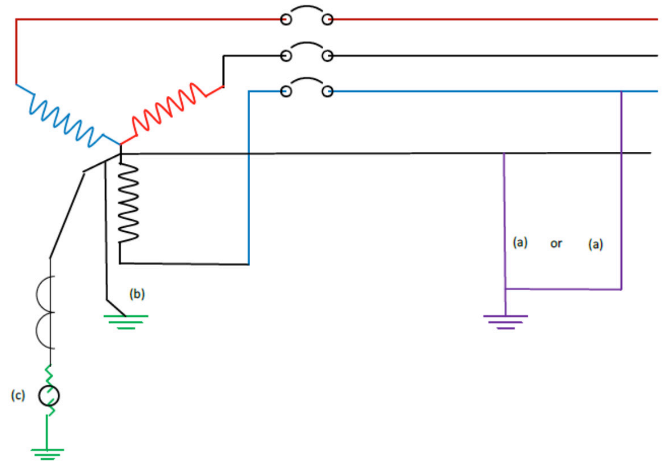


Figure 2.5: Illustration of conditions that are monitored according to CSA C22.1-21

The I-Gard relays utilize a high frequency AC based injection to confirm continuity. It can be showcased why this is beneficial for two distinct reasons:

i) The use of wye-wye connected PTs downstream for metering purposes is not uncommon, and the traditional DC injection poses issues when it comes to this. A DC injection will identify the PTs as a short circuit, and confirm continuity through an alternate path. This may cause a false negative, as the system has a loss of continuity from the neutral path, but identifies a normal condition due to the completion of the loop through the PTs.

ii) The High Frequency (HF) injection reduces the amount of injection that is seen as leakage through the source coils. Identifying that the impedance of each phase through the corresponding coil is $Z = 2*\pi*f*L$, we see that when an injection where frequency, f, is large, we are inherently limiting the injection between the neutral paths, N, and NN.

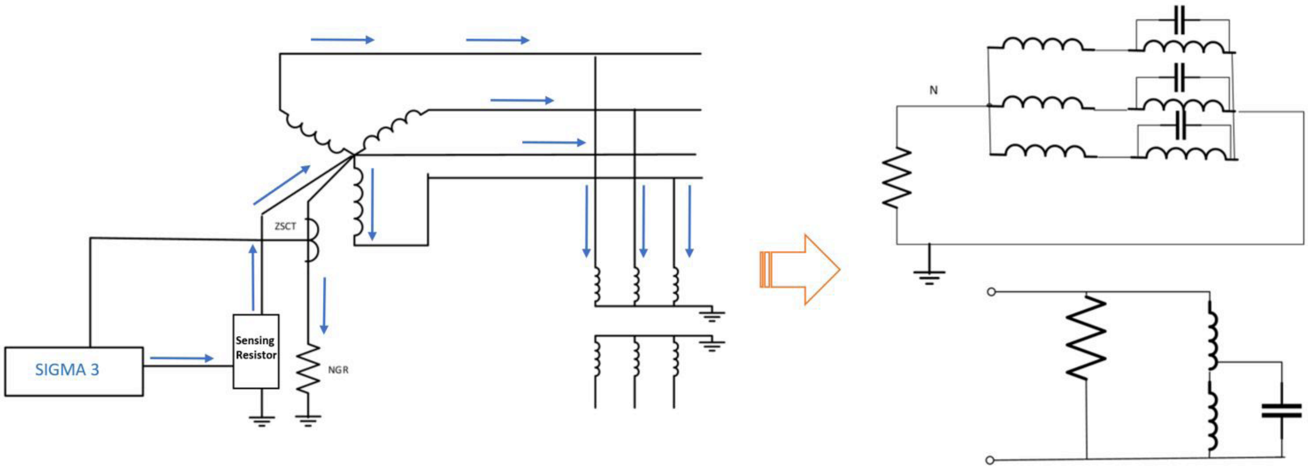


Figure 2.6 : High Frequency AC injection diagram and Equivalent Circuit

2.2.7 Pulsing

Another feature that should be considered in specifying an NGR for High Resistance Grounded Systems, is equipping it with the capacity to pulse. Pulsing is a ground fault locating technique where the let-through current of the NGR is changed in a given cycle to create a pulsing signature that can be observed anywhere on the path of the fault. A flexible current sensor can be used to trace the fault while employing pulsing. In order for an NGR to be outfitted with the capacity to pulse it is completed with a contactor that shorts out a portion of the NGR in a cycle. This is shown in Figure 2.7 below.

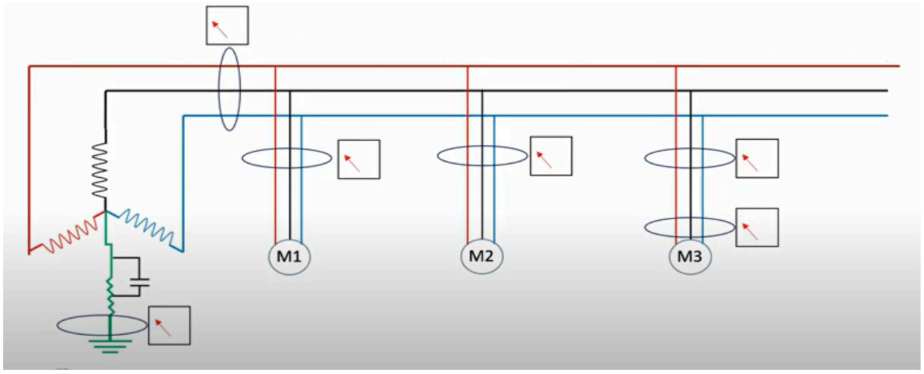


Figure 2.7: An NGR with pulsing capability being employed to locate a ground fault

3.1 Introduction

In this section, various LRG system topologies are introduced and correlated to specification templates to facilitate the process of understanding what I-Gard products can be used to realize an application.

3.2 Application Topologies

Low Resistance Grounded - Medium Voltage > 5 kV
Specification Reference: Section 26.45.01

For medium voltage applications, the distribution system can benefit from being resistively grounded, as this limits the fault current, thus limiting the damage that occurs at the location of the fault.

In the event of a ground fault on one phase, the level of current contributed to the fault from the Neutral Grounding Resistor (NGR) to keep the system voltages to ground on the unfaulted phases stable must equal or be more than the net charging current contributed to the fault by the system charging current ($3I_{co}$). Therefore the $3I_{co}$ must be roughly estimated. A procedure for such calculation is provided in I-Gard application guide C-400EA. The traditional practice of using 200 A to 1000 A causes extensive damage and is no longer considered best practice. The NGR current should be kept to a minimum, it should be simply more than $3I_{co}$. This minimizes fault damage. Typically these resistors have a let-through current of 20 A to 100 A. Here the let-through current is chosen to allow for a sufficient level of fault current to actuate overcurrent protection devices so that the fault can be cleared. Thus, when selecting the NGR let-through current rating, factors such as breaker sizes, trip settings, and coordination should be taken into account.

When the application is at voltage higher than 5 KV and a ground fault is detected then the fault must be removed by tripping the upstream circuit breaker of the affected circuit. The NGR need not be continuously rated. The CSA Specification for NGRs (C 22.2 No. 295-2015) requires that such NGRs to be rated for 10 seconds, 30 seconds, or 60 seconds. I-Gard provides the CSA approved NGRs at these ratings.

For all voltages and NGR let through current ratings of more than 10 A the systems are called Low Resistance Grounded (LRG). The NGR can be mounted close to the source (i.e. transformer or generator) in the substation and is available in a weatherproof enclosure.

The Canadian Code CEC C22.2 -2021 requires that upon detection of a ground fault the supply to the fault must be tripped to isolate the fault therefore trip devices like circuit breakers are required. In addition the Code also requires that the Neutral to Ground path through the resistor must be monitored and its failure indicated. When the Neutral of the transformer is not available or it is desired to place the NGR on, for instance, a common bus supplied by multiple sources, an artificial neutral or Zig-Zag grounding transformer (I-Gard part number DDAI) can be used to create a neutral. The two approaches are shown in Fig 3.1 and 3.2.

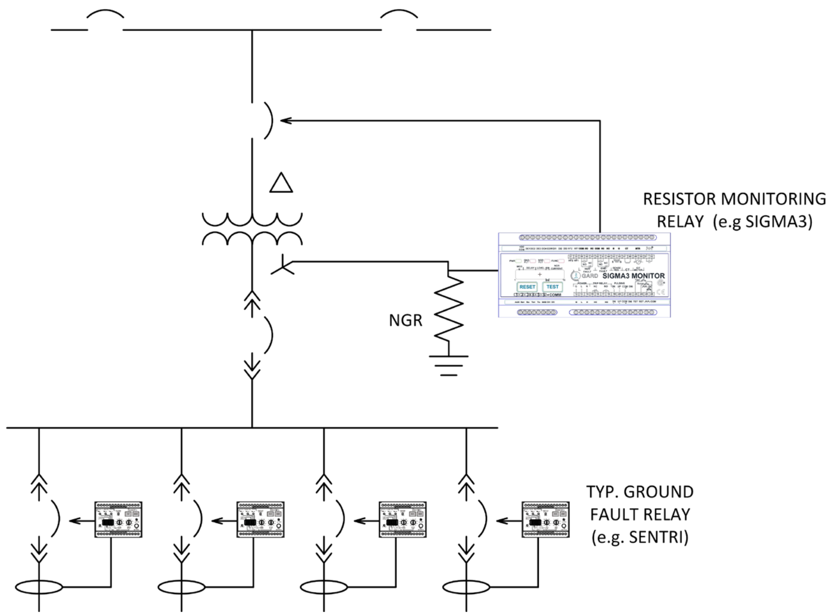


Figure 3.1: Low Resistance Grounded MV System (>5 kV)

In the application shown in Figure 3.1, the NGR is shown connected to the transformer neutral. Zero Sequence Current Sensors (ZSCS) on each feeder are connected to SENTRi relays, function 64 for tripping individual breakers. Resistor monitoring relay SIGMA 3 and its trip contact to trip the line side breaker to protect the NGR is also shown.

In the application shown in Figure 3.2, an artificial neutral (Zig-Zag transformer) is used to derive a neutral point.

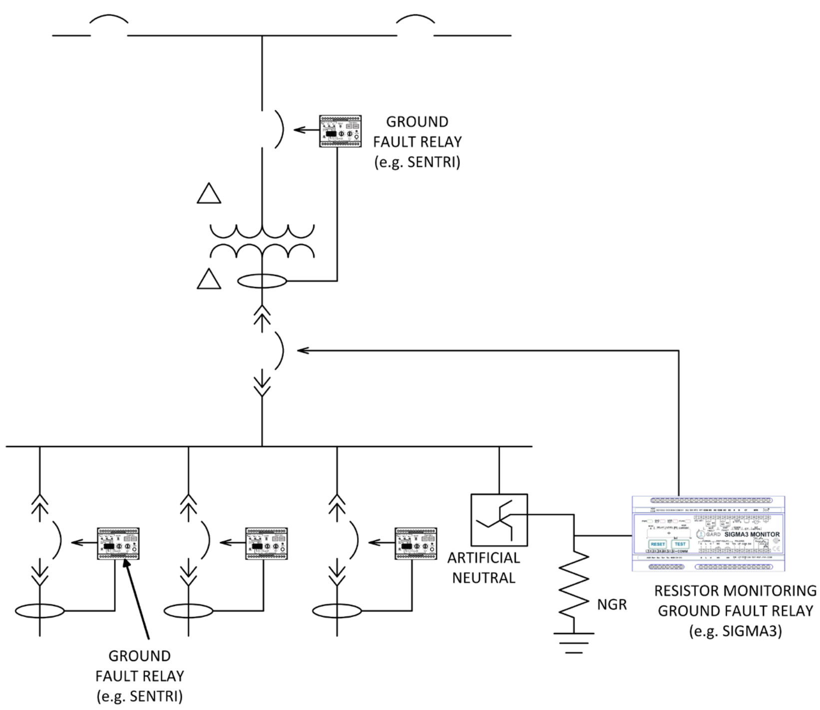


Figure 3.2: Low Resistance Grounded System

4.1 Introduction

In this section, various HRG system topologies are introduced and correlated to specification templates to facilitate the process of understanding what I-Gard products can be used to realize an application.

4.2 Application Topologies

Multiple LV Generators

Low Voltage HRG if NGR 10 A or less - SMART HRG - DSP OHMNI

Specification Reference: Section 26.45.02 MV HRG

For Voltages of 5 KV and below the CEC 2021 allows continuous operation, without tripping, with an alarm when the NGR let through current contributed to the fault is 10 A or less. Such systems are called High Resistance Grounded (HRG). The Canadian Electrical Code (CEC 22.2 - 2021) permits continuous operation in a single phase to ground condition. The L-G fault must be detected and an alarm must be provided. The NGR must be able to carry this continuously hence is rated for continuos operation. To determine whether 10 A would be sufficient to overcome the $3I_{co}$ an estimate should be undertaken. A procedure for such calculation is provided in section 2.2.2 of this guide.

The NGR can be mounted close to the transformer in the substation and is available in weatherproof enclosure and is connected to the Transformer Neutral. When the neutral is not available or it is desired to place the NGR on a common bus, a Zig-Zag transformer can be used to create a neutral to connect to the resistor. The two approaches are shown in Fig 4.1 and 4.2.

The application in Figure 4.1 below is a DSP-OHMNI system. Here the NGR is shown connected to the transformer Neutral. Zero Sequence Current Sensors (ZSCS) on each feeder connected to the modular DSP relay system, giving function 64 to provide alarm on the occurrence of L-G fault and then trip a breaker on second fault. Resistor monitoring is accomplished with the DSP-DRM3 module.

The application in Figure 4.2 below shows a system similar to that of Figure 4.1 except that a Zig-Zag transformer (artificial neutral) is used to provide the connection point for the NGR.

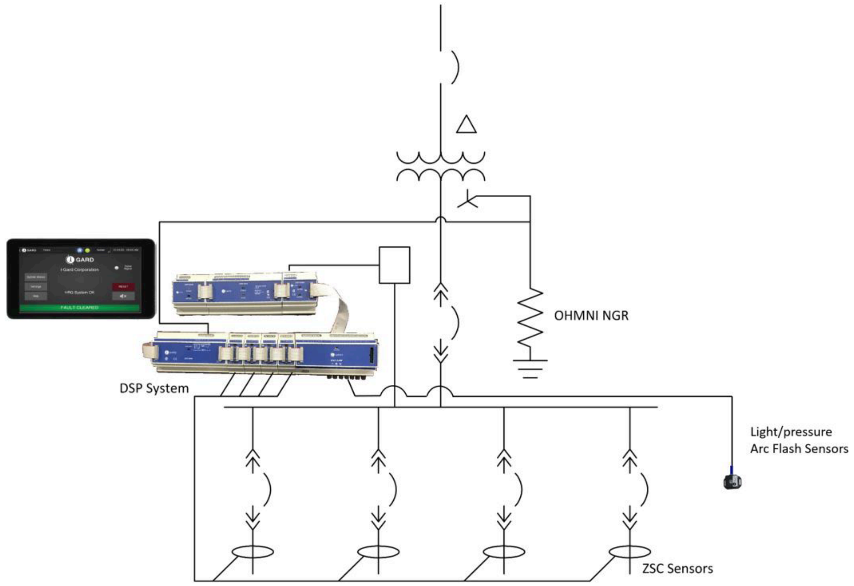


Figure 4.1: Example when 3Ico < 10 A. NGR is rated for 2400 V, 10 A continuous duty.

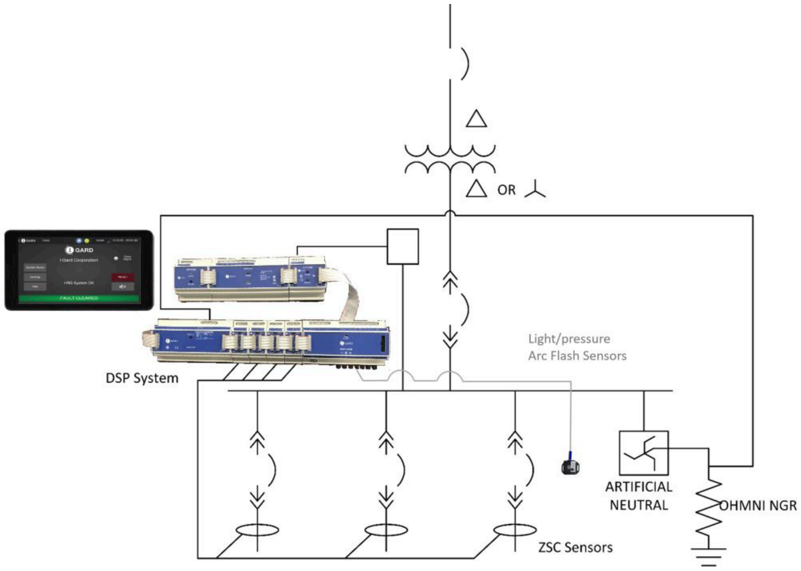


Figure 4.2: Example when $3I_{CO}$ < 10 A. NGR is rated for 2400 V, 10 A continuous duty.

Low Voltage HRG: Sleuth-RM, Stoplight-RM, or Gemini (Fail-Safe) - STANDARD HRG
Specification Reference: Section 26.45.02 High Resistance Grounded

With High Resistance grounding the fault damage is very low and is easily repairable since the fault current is 10 A or less. The Canadian Code CEC 2021 also requires that the Neutral to Ground path be monitored for integrity. I-Gard's product line includes standalone HRG solutions that include this function built-in, such as the Stoplight-RM, the Sleuth-RM and the Sentinel where the resistor monitoring feature is specified.

The fault location is usually not evident hence assistance is required from the relaying system to help locate the fault while the system remains energized and loads remain undisturbed. I-Gard NGRs are provided with controls to allow pulsing the ground current to help locate the fault very easily. This is the Sleuth-RM option, whereas the Stoplight-RM option does not have the pulsing feature. Another HRG, the Gemini, also has a pulsing option. The Gemini is an HRG solution similar to the Sleuth-RM except that the resistor is divided into two legs to provide increased reliability, as one leg acts as a fail-safe in the unlikely event that the main resistor fails.

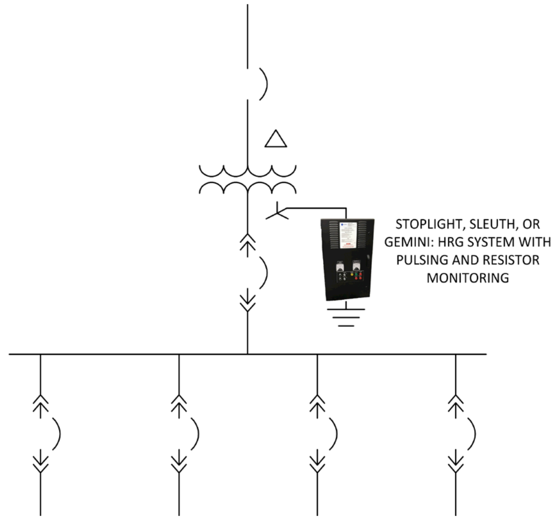


Figure 4.3: Sleuth-RM HRG system with pulsing and resistor monitoring. (Stoplight-RM option does not have pulsing capability)

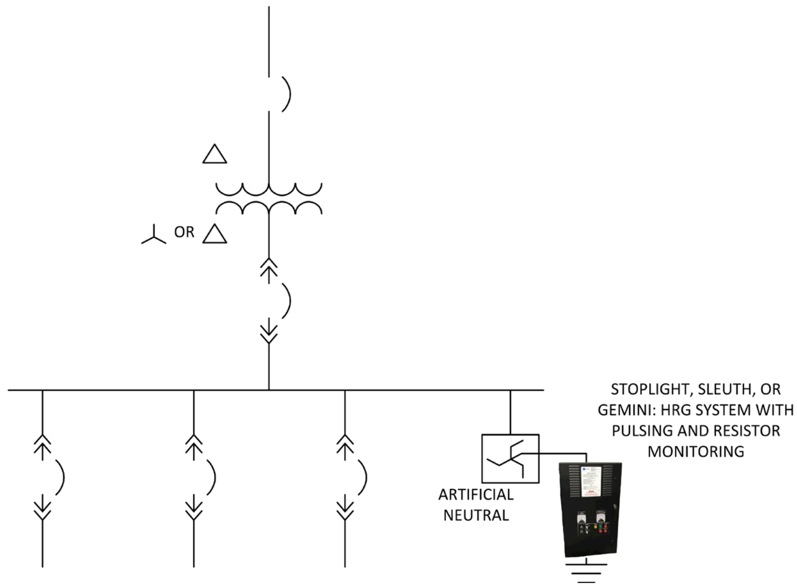


Figure 4.4: Sleuth-RM HRG system with pulsing and resistor monitoring. Artificial neutral employed.

Simple and very cost effective approach, complies with the code, provides ground fault alarm, and allows easy location by pulsing is shown in Fig 4.3 and 4.4.

Please refer to specifications section, Standard Feature Template: 26.45.02 v2.6.1 for I-Gard type Stoplight, Sleuth, or Gemini.

Low Voltage HRG: DSP-OHMNI or Sentinel - SMART HRG
Specification Reference: Section 26.45.02 High Resistance Grounded

Another HRG solution is the DSP-OHMNI. This HRG solution provides more advanced features such as feeder monitoring; feeder tripping, including the capacity to prioritize feeders and selectively trip on the occurrence of a second ground fault; indication of the faulted phase; resistor monitoring compliant with CEC 22.1-2021; and options for an arc flash detection module. The system also includes a user-friendly interface including the ability to easily name and describe the feeders in addition to extended event-logging capability. It also includes additional advanced features including MODBUS TCP/IP communication, the ability to add arc detection module DSP-ADM and event fault trend analysis.

The DSP also has the option to trip on first fault with delay of up to 99 hours or trip on second fault with no intentional delay. DSP refers to the modularized system of relays that monitors the electrical system and the OHMNI is the model name of the Neutral Grounding Resistor. They can be integrated into the switchgear with the DSP installed in the switchboard and the OHMNI resistor in its own enclosure or they can be combined into a standalone unit which is referred to as a Sentinel.

DSP-ADM Arc detection module

The I-Gard DSP-ADM is an arc detection module that continuously monitors the area to be protected for flashes of light and for air pressure waves caused by arc flashes, the DSP-ADM can monitor up to 21 sensors through up to seven channels (21 possible fault sources), when any of the sensors identify an incident, the internal Form C contact transfers the signal to trip the breaker interrupting energy to the circuit.

DSP-ADM module must be present in the lineup of the DSP-OHMNI system to monitor for arc flash incidents, the status of the seven channels of this module can be viewed from the DSP-TDM touchscreen display module.

DSP-ADM offers a first line of defense in the arc detection feature of the DSP-OHMNI system protecting both personnel and equipment from severe damages.

DSP-TDM Touchscreen display module

The DSP-TDM is a panel-mounted touchscreen display interface which provides the means to set-up and control the DSP-OHMNI system. It provides key information about alarms, event capture with time stamp, type of fault, priority settings, resistor settings, status of the feeder modules, DSP-ADM channels status, it also provides manual control of the pulse location system among other advanced features.
The DSP-TDM provides communication ports for MODBUS RTU through a RS-485 network and MODBUS TCP/IP through Ethernet Network to external communication systems.

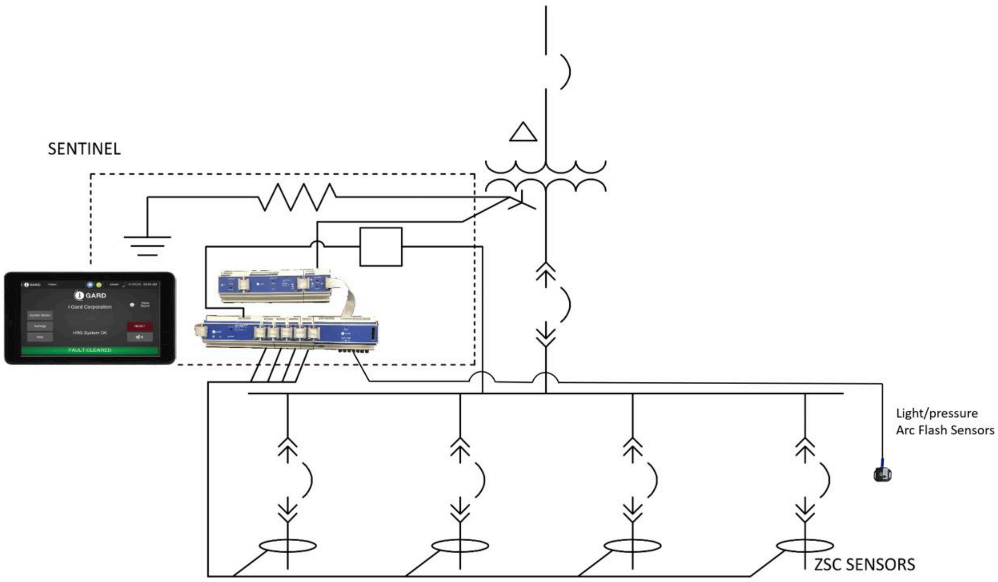


Figure 4.5: Sentinel HRG system with pulsing, resistor monitoring, and feeder monitoring.

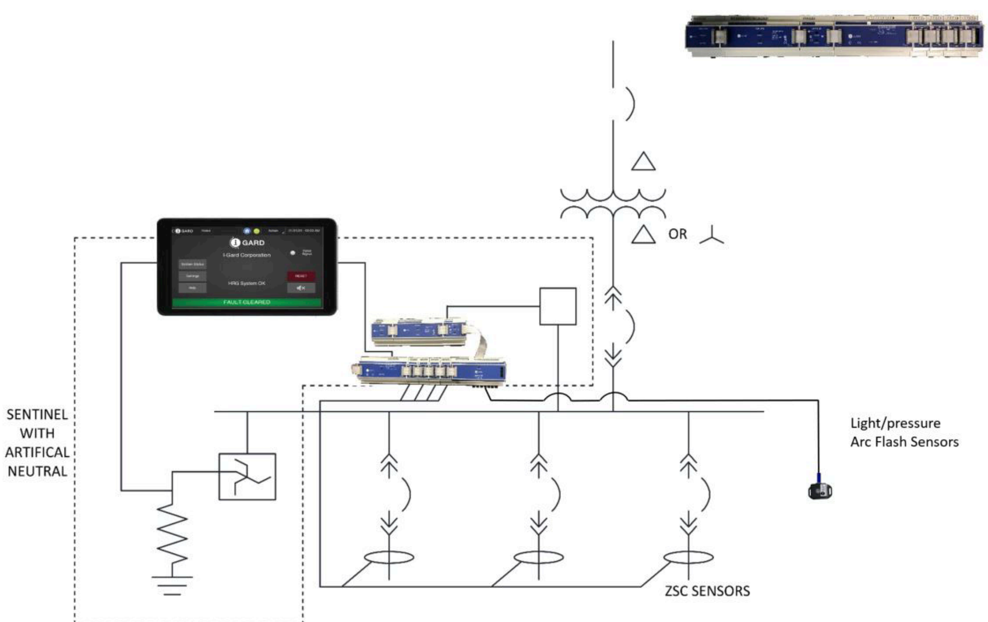


Figure 4.6: Sentinel HRG system with pulsing, resistor monitoring, and feeder monitoring. Artificial neutral employed

- Zero Sequence Current Sensors one per feeder are mounted in the switchgear, switchboard or panelboard.
- Variety of window sizes are available to specify the type and quantity required. These are supplied loose for mounting by others.
- Specify the fault locating accessory portable sensor type TS-sensor.

Multiple transformers using secondary selective M-T-M (Main-Tie-Main)

For a main-tie-main application such as shown in Figure 4.8, two DSP-OHMNIs are shown, one for each source. A DSP-CA/CAS module is used in each DSP lineup to communicate between the two DSP systems in order to coordinate prioritization of second fault tripping when the tie- breaker is closed. Please refer to 26.45.02 High Resistance Grounded.

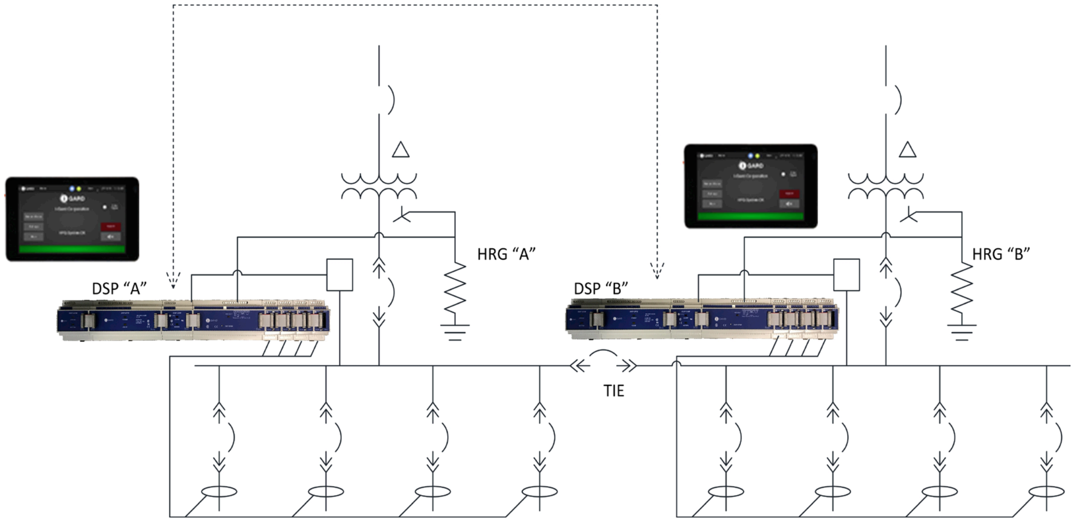


Figure 4.7: Main-tie-main application involving two Sentinels

Grounding Generators

Best practices for grounding of generators are described in IEEE 142-2007 section 1.7. Various configurations are described in this section. Resistance grounding a generator can offer similar benefits to resistance grounding a transformer: limiting fault current and controlling transient overvoltages. An extension of this benefit is protection against faults in the stator windings of the generator. Case studies have shown that this is a necessary scenario to consider especially where low resistance grounding is being employed. If a generator that is low resistance grounded experiences a stator fault and is then isolated from the system, fault current will still be supplied to the stator fault as the generator coasts down. This can inflict significant damage to the generator. This can be solved by hybrid grounding, described in section 5 below, where NGRs are incorporated to protect each generator as well a common-bus NGR to protect the system.

Integrating 5 KV Generators up to 10 MW
Specification Reference: Section 26.45.02 HRG Generators

For a single Generator a 5 A or 10 A NGR is chosen and is continuously rated; only alarm needs to be provided. Optionally the relay contact can be used to shut down the system. Resistor integrity monitoring is provided by the I-Gard SIGMA 3 relay shown in Fig 4.8.

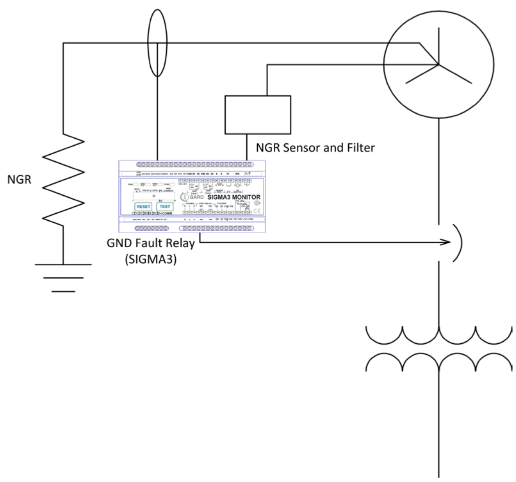


Figure 4.8: High Resistance Grounded system with SIGMA 3

Integrating LV Standby Generators up to 2 MW

Many distribution systems have single generators as stand by power supplying the three phase-three wire emergency loads through three pole transfer switches. HRG can be applied on the generator.

Arrangement is shown in Fig 4.9. This increases reliability and power continuity as any ground faults are not going to trip any breakers only alarm is needed.

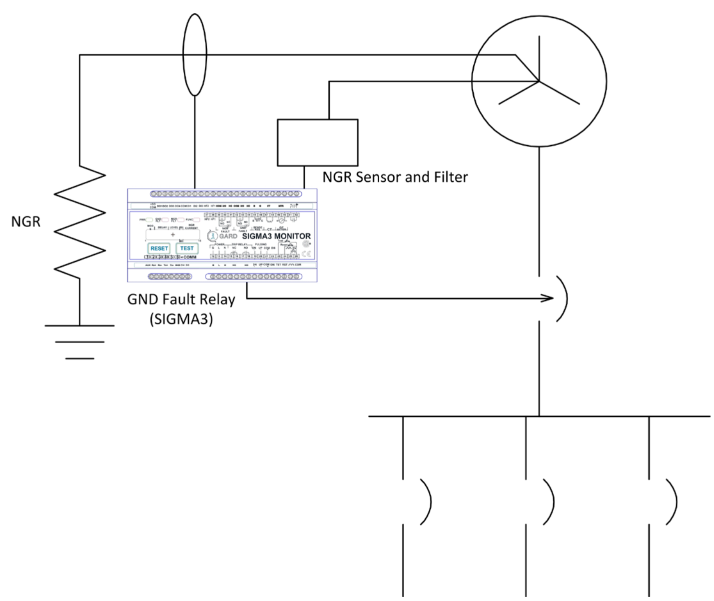


Figure 4.9: Standby generator with HRG and monitored by SIGMA 3

Multiple LV Generators (more than 2)

In this application, generators supply through a three wire paralleling bus, the emergency load is three phase -three wire. The generators are ungrounded and feed through a High Resistance Grounded main bus arrangement is shown in Fig 4.10.

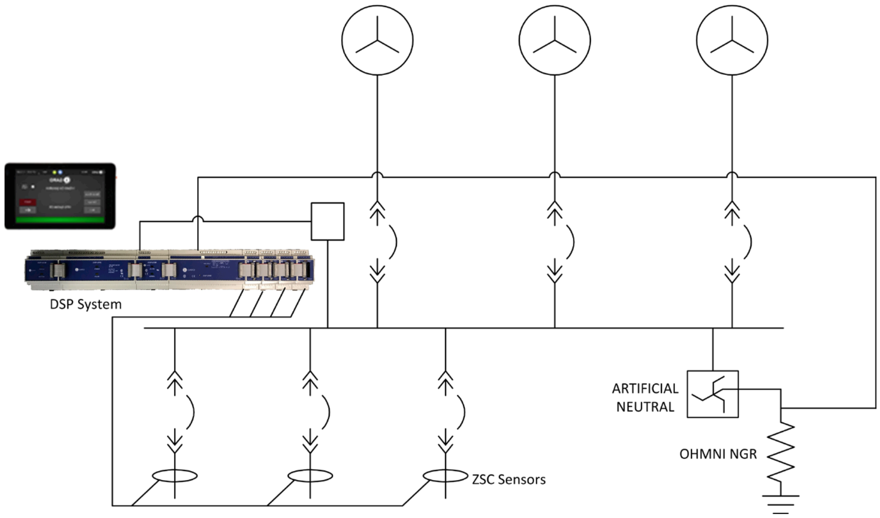


Figure 4.10: Generators on a common bus grounded by HRG using an artificial neutral

5. HYBRID HIGH RESISTANCE GROUNDING (HHRG) SECTION 26.45.03

Single Large generators more than 10 MW feeding MV distribution without step up or step down transformers Specification Reference: Section 26.45.03 Hybrid Grounding

Utility scale generators are often Low Resistance Grounded. However, if a stator winding fault occurs then the fault current can be very high and the consequential damage is enormous. To mitigate this, the ANSI standard C37.101 recommends Hybrid Grounding the generator, with an interrupter which removes the LRG while the HRG remains connected to allow discharge of the trapped charges in the stator windings. This application is shown in Figure 5.1.

The ANSI standard also recommends retrofitting this to existing Low Resistance Grounded Generators.
Hybrid Grounding is applied with both LRG and HRG at the generator if a stator winding fault is detected by 87G protection provided by I-Gard type SENTRi relay. The generator is isolated from the MV bus and the LRG. I-Gard can provide the solution as shown in the figure 5.1

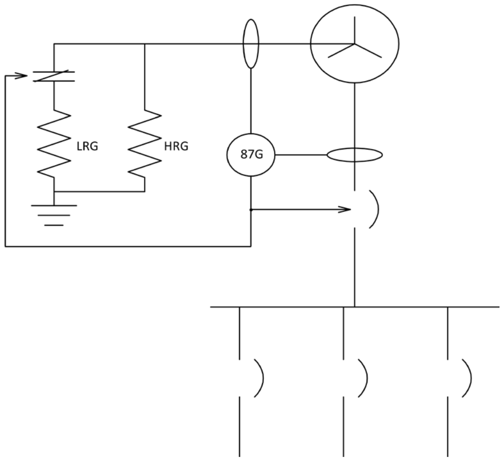


Figure 5.1: Grounding solution for single generator.

Multiple Generators on a paralleling bus feeding extensive distribution (5 KV to 15 kV)
Specification Reference: Section 26.45.03 Hybrid Grounding

In such applications usually the current contributed by the distributed cable capacitance $3I_{co}$ can be more than 10 A and thus the NGR let through current required from the NGR will also be more than 10 A. This fault current can cause substantial damage in case of an internal fault in the generator stator winding so smaller let through current Resistors are applied on the generators themselves and a separate NGR is applied on the paralleling bus through a Zig-Zag transformer . Such applications are called Hybrid Grounding shown in Figure 5.2.
The HRG at the generator has to overcome the generator contributed charging current so they can be 1 A to 5 A. The LRG on the main bus can be rated to suit to overcome $3\ I_{co}$ typically greater than 50 A.

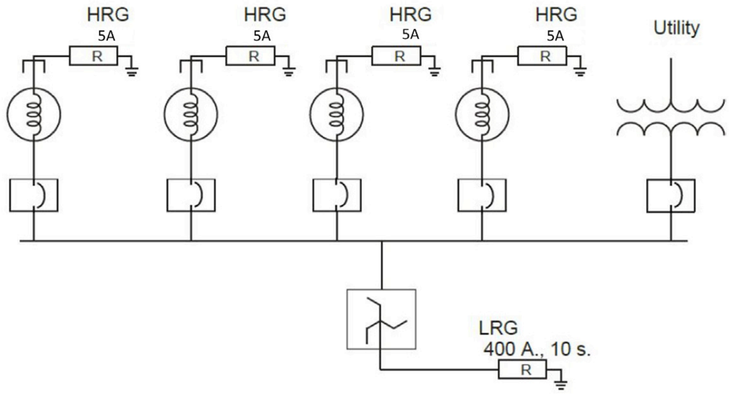


Figure 5.2: LRG system on a parallel bus using an artificial neutral

6. ARC FLASH MITIGATION SECTION 26.45.04

6.1 Introduction

Arc flash mitigation operates to reduce the potential incident energy levels to protect personnel from arc flash hazards.

Solidly grounded configurations, due to the lack of intentional impedance between the neutral connection to ground, generate high magnitude fault currents during a ground fault condition. These high magnitude fault currents cause degradation in the insulation. When arcing faults are not picked up promptly and isolated, the ground copper conductor may be susceptible to melting. This contaminates the air and decreases the insulation between phases, which increases the likelihood of a single phase fault propagating into a phase-to-phase fault.
It is important to note that because of these high magnitude faults, solidly grounded systems are the most susceptible to an arc flash risk. The utilization of an incident energy reduction method, as described in CSA Z462-21, Annex O.2.3, ensures that the protection system is able to identify the arcing condition as fast as possible to prioritize de-energization immediately. By reducing the duration of the arc before isolation, the incident energy is inherently reduced as well.

High Resistance Grounding is an arc flash mitigation technique as described in CSA Z462-21 Annex O.2.3 where it states:

"A great majority of electrical faults are of the phase-to-ground type. High Resistance Grounding will insert an impedance in the ground return path and will limit the fault current, leaving insufficient fault energy and thereby helping reduce the arc flash hazard".

HRG will not affect arc-flash energy for line-to-line or line-to-line-to-line arcs. The distinction is made when comparing single phase-to-ground faults with line-to-line and line-to-line-to-line faults. In the latter, fault current does not return to the system through the NGR and so is not limited in terms of fault current, so fault current is high. In contrast, when there is a single phase to ground fault on an HRG system, fault current returns to the system through the NGR and fault current is limited. The benefit is reducing the energy on a single phase-to-ground arc to a level that is too low for the arc to be sustained. This is advantageous since the majority of electrical incidents are of the phase-to-ground type. Further protection can be achieved by implementing arc flash relays in addition to the standard HRG configuration. With arc flash relays, light and/or pressure sensors are used to detect the presence of the arcing fault and the relay trips the system instantaneously. By utilizing arc flash relays in conjunction with HRG, the user enables the ability to reduce both the likelihood and magnitude of exposure for arcing conditions - thus enabling achievement of an electrically safe work condition as per CSA Z462-21, O.2.2.

6.2 Product Implementation

6.2.1 Arc Flash Relay for Solidly Grounded Systems

The I-Gard SENTRi relay is designed as a ground fault protection and arc flash mitigation system. It contains ZSIP to isolate the ground fault at the point of fault with relay coordination. The SENTRi has a wide range of sensitivity up to 1200 A and trips within a 1 second time delay to satisfy CSA, C22.1-21, section 14-102.

In addition to this requirement, the SENTRi relay also has three inputs for arc flash sensors that can be used to trip the system even faster in the event that the arc flash light is detected. Arc flash relays are listed as an incident energy reduction method in CSA Z462-21 Annex O, O.2.3 because of the speed in which it can isolate the arc from the system. Because the magnitude of the arc flash incident energy is directly correlated with the time that the arc remains in the system, we are effectively reducing the magnitude of the arc flash condition by tripping instantaneously.

Reference sections 1.1.2 and 6.1 within this guide for further information.

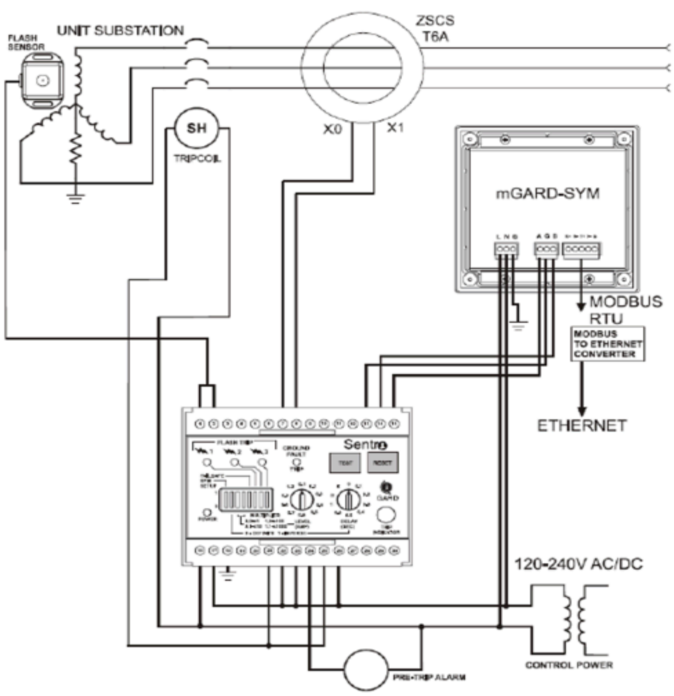


Figure 6.1: SENTRi Arc flash relay with flash sensors

6.2.2 Arc Flash Relay for High Resistance Grounded Systems

HRG is an arc flash mitigation technique. Some arc flash relays are used in combination with HRG systems. HRG reduces the likelihood of an arc flash while using an arc flash relay to lower the incident energy, hence reducing the overall severity of the arc flash.

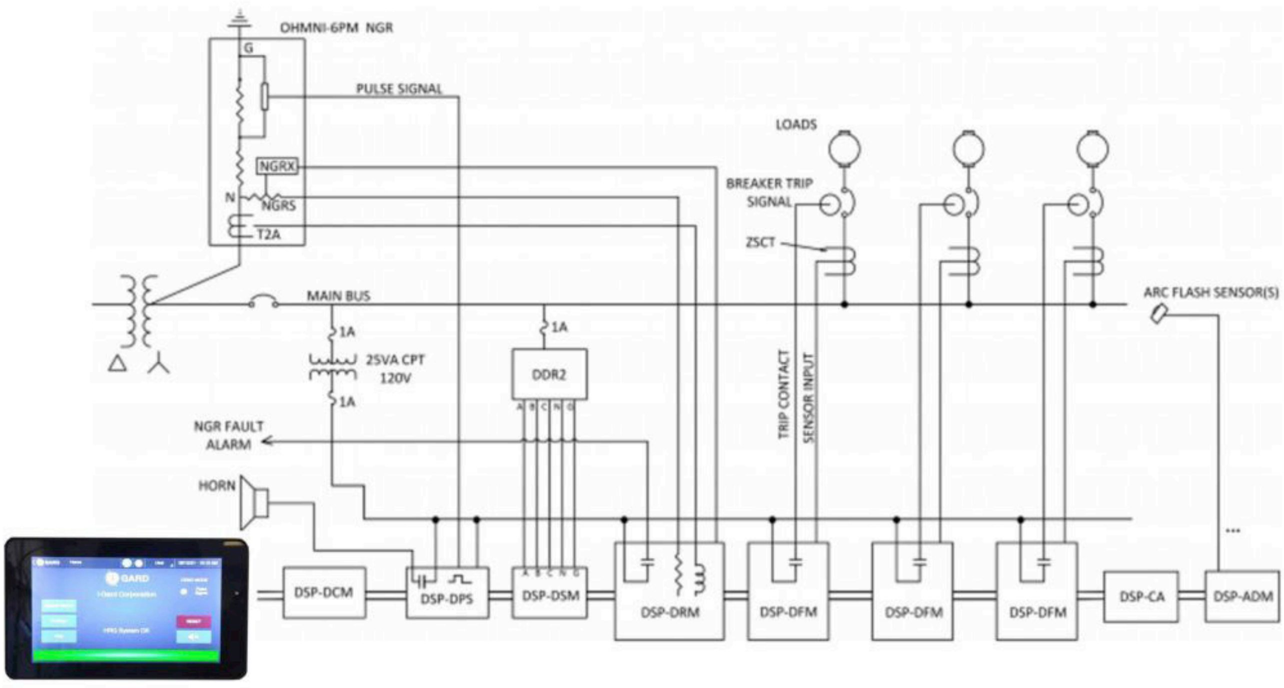


Figure 6.2: Arc Flash relay used with HRG system

DSP-ADM Arc detection module

The I-Gard DSP-ADM is an arc detection module that continuously monitors the area to be protected for flashes of light and for air pressure waves caused by arc flashes, the DSP-ADM can monitor up to 21 sensors (7 point sensor flash inputs, 7 optic ports, 7 pressure sensor inputs) through up to seven channels. When any of the sensors identify an incident, the internal Form C contact transfers the signal to trip the breaker interrupting energy to the circuit. DSP-ADM module must be present in the lineup of the DSP-OHMNI system to monitor for arc flash incidents, the status of the seven channels of this module can be viewed from the DSP-TDM touchscreen display module.

The DSP-ADM is designed to be used with:

- Sensor L1 point light sensor
- Sensor F1 modified point sensor with fiber optic tail
- Sensor iPS2 or iPS4 pressure arc sensors

Up to 7 of each three styles of sensors can be connected to the DSP-ADM module

Refer to section 4.2, “SMART HRG”, to satisfy the requirements of CSA Z462-21, Annex O, O.2.2.

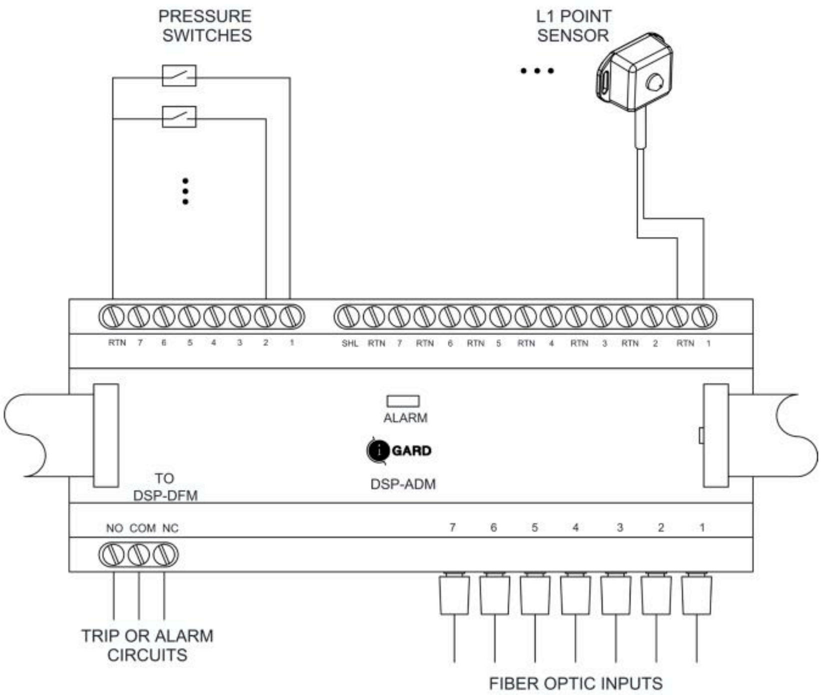


Figure 6.3 : DSP-ADM - Arc Detection Module Connections

6.2.3 Arc Flash Relay with Combination Logic

Some arc flash relays employ a combination of logic with current or pressure as a method to confirm an arc flash. This is shown in Figure 6.4 and Figure 6.5 with the Arc-i-tec relay.

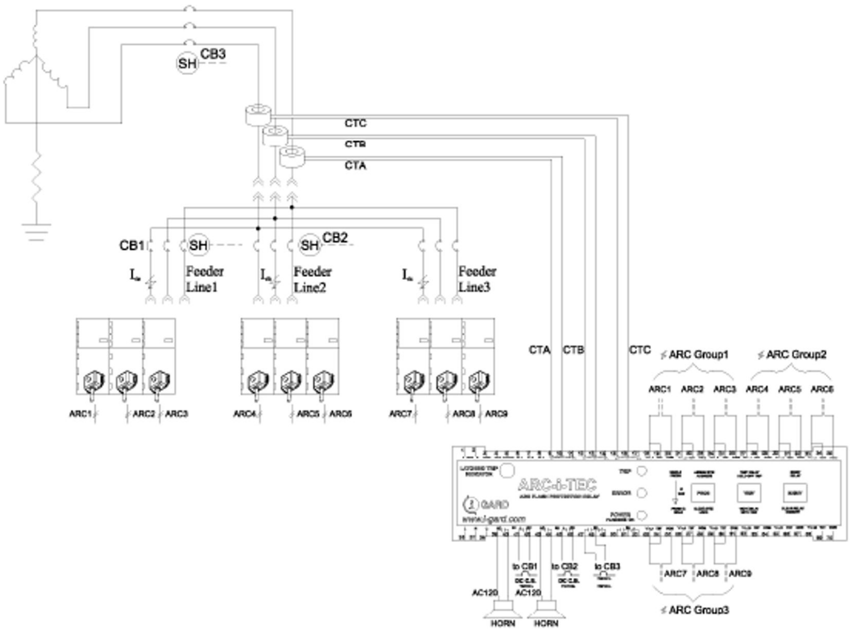


Figure 6.4: Arc-i-Tec relay with combination logic with current

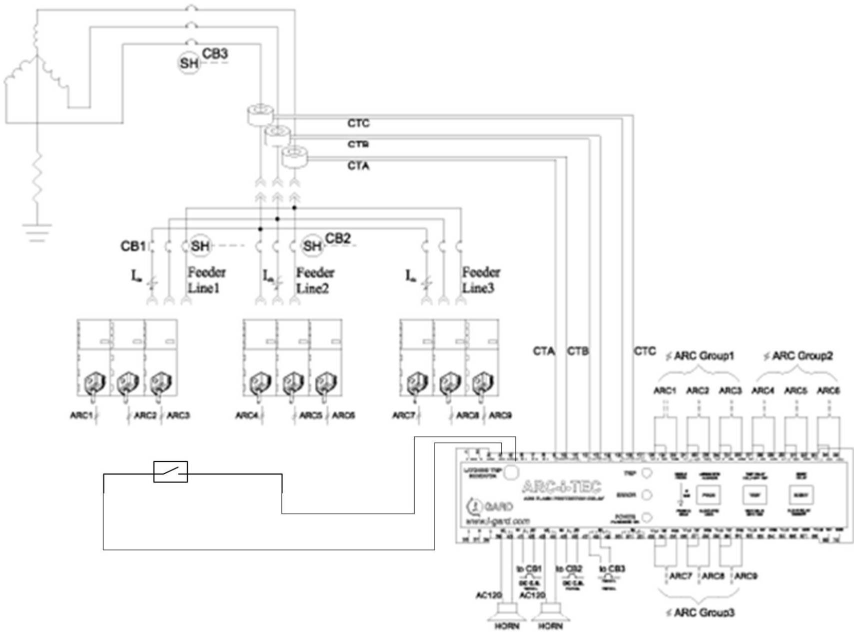


Figure 6.5: Arc-i-Tec relay with combination logic with pressure switch

7.1 Absence of Voltage Tester

Additional protection can be provided for a system in the form of shock protection as a mean of protecting personnel. Including devices such as Absence of Voltage Testers to a system can allow personnel to perform a test to verify that a panel or piece of equipment is de-energized, allowing personnel to safely access such equipment.
Absence of Voltage Testers are permanent installed devices, typically connected to a system as shown in Figure 7.2 below. CSA Z462-21 states that an adequately rated permanently mounted test device shall be permitted to be used to verify the absence of voltage of the conductors or circuit parts at the work location. They provide a facility for the user to initiate an absence of voltage test, without the necessity of opening any doors, where the device checks that the bus of the panel has no voltage >3 VAC or 3 VDC. The device then gives the user positive indication that panel can be safely accessed.

The Absence of Voltage Tester provides the following indications:

- Positive indication of absence of voltage via three solid GREEN LED lights.
- Presence of hazardous voltage via three solid RED LED lights.
- Additionally, the Absence of Voltage Tester conducts a continuity check to ensure all leads are properly connected.

Absence of Voltage Testers must be listed under UL 1436 and are different from Voltage Indicators Lights or Test Portals. Absence of Voltage Tester is certified to CSA STD C22.2#160, and is SIL 3 rated.

Figure 7.1: Positive indication of hazardous voltage (red lights) and absence of voltage (green lights)

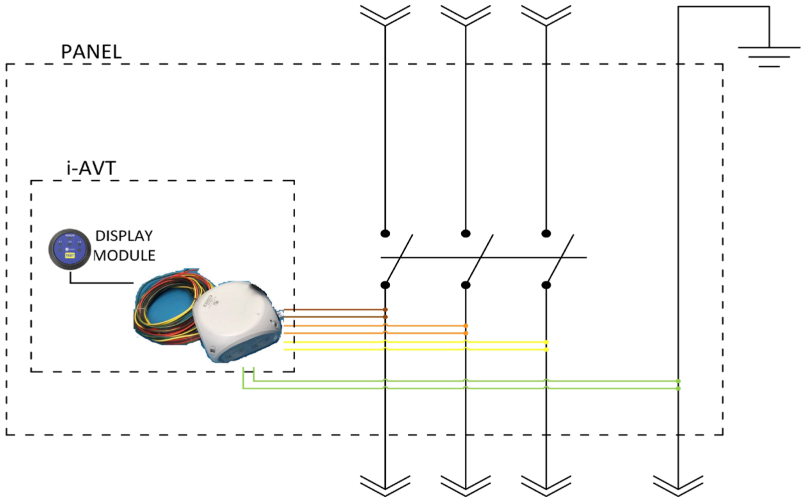


Figure 7.2: Absence of Voltage Tester typical installation

7.2 Personnel Protection Panel

Shock protection can also be provided by ground fault protection panels that detect and trip ground faults at levels low enough to protect personnel. Such panels are typically used in marine applications. Typical installation connections are shown in Figure 7.3 below.

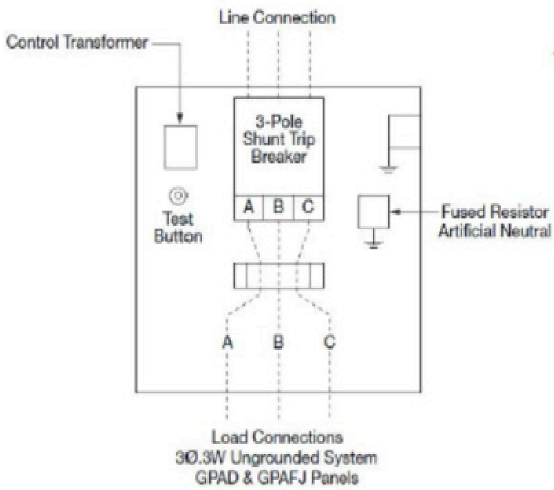


Figure 7.3: Typical installation connection of ground fault protection panel for personnel protection

Figure 7.4: Example of a Personnel Protection Panel

7.3 Ground Check Relay

To accommodate for underground mining applications, Ground Check Relays are utilized on lines where mobile equipment is fed by portable power cables. As per CSA, M421-16 (4.5.6, 4.5.7), the Ground Check Relay monitors for the following conditions:

1. A circuit supplying mobile electrical equipment operating at a voltage exceeding 150 V to ground shall have ground fault protection. This is achieved with the utilization of a Zero Sequence Current Sensor (ZSCS) around the three phases to monitor for an imbalance in current so that the ground check relay will trip the overcurrent protective device upstream within 1 second as specified within the standard.

2. A circuit supplying mobile electrical equipment operating at a voltage exceeding 150 V to ground shall have ground-conductor monitoring. This feature utilizes a pilot wire that is applied from the relay to the load from the GC terminal and from the load back to the relay at the G terminal. A zener diode at the load clamps the voltage to its rated value of either 6 V or 12 V and allows for induced currents to flow through to confirm that there is ground continuity within the circuit. If the ground check conductor shorts to ground, the voltage between both the G and GC terminals will be at 0 V potential. If the ground check or ground return conductor opens, the voltage between both G and GC terminals will be the voltage supplied from the relay which is either 12 V (when using 6 V diode) or 24 V (when using a 12 V diode).

3. When ground fault protection is required by this standard, supply shall be grounded through a neutral-grounding device that limits the frame voltage during a ground-fault to 100 V or less. With the use of our pilot wire, a reference from the frame voltage can be provided to the relay and effectively trip the circuit to reduce exposure to personnel near the equipment from an electrical shock hazard.

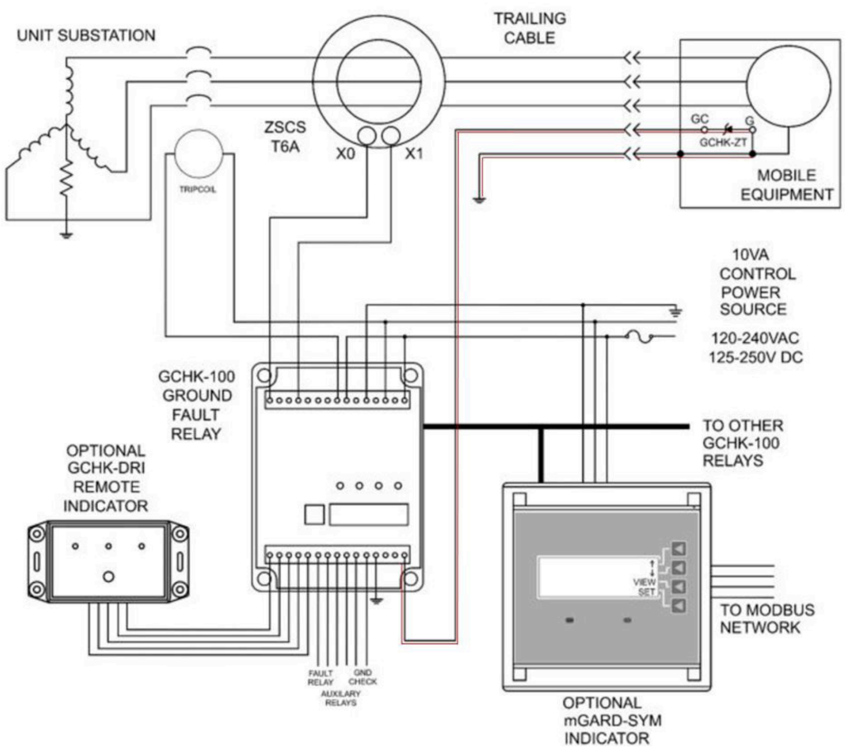


Figure 7.5: GCHK-100 Ground Check Relay. (Ground Check loop shown in red)

7.3.1 Ground Fault Protection

Ground fault protection utilizes a Zero Sequence Current Sensor (ZSCS) to monitor the leakage seen at the current carrying conductors.
In the event of a ground fault, the unit will detect and trip based on the ground fault setting of the relay.

7.3.2 Ground Check

Ground check is achieved by the use of a pilot wire (GC). This wire is usually a part of the power cable. It is used to carry a monitoring current to the machine being monitored. The pilot wire must be properly terminated at its end point (the machine being monitored). A zener diode terminator such as the GCHK-ZT or equivalent is required.

7.3.3 Frame Voltage

The frame voltage monitor is an additional feature that is monitored through the ground-check pilot wire. No additional wiring is required for the frame voltage monitor. This feature will cause a trip twice as fast as the ground check and five times faster for frame voltages exceeding 100 V.

APPENDIX A. SPECIFICATION TEMPLATES

Low Resistance Grounding for 5 kV and above systems - NGR and SIGMA 3 relay Specification Template: 26.45.01

1.0 GENERAL

1.01 SCOPE

A. This specification covers the basic requirements for Low Resistance Grounding equipment;

1. To be mounted external to electrical distribution equipment.

B. These devices are used:

1. To ground the neutral of a three-phase power system using a power resistor.
2. To limit the magnitude of the ground fault to a predetermined non damaging level.
3. To reduce the frequency and number of arc flash and arc blast hazard.

C. Electrical system parameters

1. System line to line voltage (i.e. 4160 V)
2. System line to neutral voltage (i.e. 2400 V)
3. Resistor to be connected between neutral and ground.
4. The NGR shall have a let-through current rating of _ A (>10 A).
5. If installed on three-phase, three-wire ungrounded system, artificial neutral assembly also required and installed to create reference point for HRG system.

1.02 REFERENCES

A. The Neutral Grounding Resistor shall be designed and manufactured in accordance with the following standards:

1. ANSI C19.3 – Industrial Control Apparatus – General
2. IEEE C57.32a-2020 – IEEE Standard for Requirements, Terminology, and Test Procedures for Neutral Grounding Devices
3. IEEE 142-2007 – IEEE Recommended Practice for Grounding of Industrial and Commercial Power Systems
4. NFPA 70– National Electrical Code
5. UL 50 – Enclosures for Electrical Equipment, Non-Environmental Considerations
6. UL 508 – Standard for Industrial Control Equipment
7. CSA C22.2 No. 295-15 – Neutral Grounding Devices
8. Z462-21 – Workplace Electrical Safety
9. CSA C22.1-2021

B. The manufacturer of the Neutral Grounding Resistor shall have produced similar electrical equipment for minimum period of 5 years.

C. The manufacturer of the Neutral Grounding Resistor shall be ISO 9001:2015 certified.

1.03 SUBMITTALS

A. Product data and manufacturer's installation instructions for non-approved manufacturers shall be submitted for review ten days prior to the bid date.

B. The submittals shall also include

1. Reference dimensional drawing of the enclosure.
2. Bills of material for internal components.
3. Schematic and wiring diagrams of interconnection.

2.0 PRODUCT

2.01 NEUTRAL GROUNDING RESISTOR

A. The resistive elements shall be edge-wound type and made of stainless steel alloy with low temperature coefficient of resistance less than 0.0002 1/°C. The element shall have sufficient mass to withstand the rated current and prescribed duty.

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

C. The fault current does not decrease more than 20 % when the resistor heats up from ambience to the full operating temperature.

D. The resistor shall be mounted in aluminum 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.

E. High current connections shall be spot or TIG welded as appropriate. Connections between resistors and bushings or current transformers shall be by solid copper bus or copper cable.

2.02 NEUTRAL GROUNDING PATH MONITORING

A. NGR monitoring relay shall be provided to verify the integrity of the neutral ground path according to CSA C22.1-2021

B. Provide Modbus TCP protocol for communication

C. Provide ground fault alarm auxiliary relay output form C, 10 A, 240 Vac contact for remote indication.

D. A sensing resistor designed for Line to Line voltage and a zero sequence current sensor shall be installed inside the NGR enclosure.

E. NGR fault trip shall occur within 3.5 seconds or as required by code if any abnormal condition is detected as indicated in table 17 of the CSA-C22.1-2021.

F. The ground fault trip level shall be selectable from 5% to 50% of the NGR let-through current and ground fault trip time delay shall be 60 ms to 3.15 seconds with 100 ms increment.

G. The monitoring system shall monitor the continuity of the impedance grounding circuit from the system source through the impedance grounding device to the grounded non-current-carrying conductive parts of the electrical system.

H. The monitoring relay shall be I-Gard SIGMA 3 or equivalent.

2.03 ENCLOSURE

A. The enclosure shall include a Neutral Grounding Resistor, a current sensor, and a sensing resistor. The enclosure shall be free standing NEMA 3R rated for outdoor installation.

MANUFACTURERS

A. Approved vendors: I-GARD Corporation (or approved equal)

B. Product to be I-GARD SIGMA 3 relay and NGR (or approved equal)

= END OF SECTION =

High Resistance Grounding for 5 kV or less systems – Standard (Stoplight-RM): Specification Template: 26.45.02

1.0 GENERAL

1.01 SCOPE

A. This specification covers the basic requirements for the High Resistance Grounding equipment;

1. To be mounted external to electrical distribution equipment.
2. To be assembled and integrated into low voltage equipment, such as panel board, motor control center, switchboard, or switchgear.

B. These devices are used to:

1. Ground the neutral of a three-phase power system using a power resistor.
2. Limit the magnitude of the ground fault to a predetermined low value (<10 A).
3. Reduce the frequency and number of arc flash and arc blast hazard.
4. Give immediate indication when a ground fault occurs.

C. Electrical system parameters

1. System line to line voltage to be 480/600/690/4160 Vac.
2. System line to neutral voltage to be 277/347/400/2400 Vac.
3. The NGR shall have a let-through current rating of _ A (maximum of 10 A)
4. Resistor to be connected between neutral and ground.
5. If installed on three-phase, three-wire ungrounded system, artificial neutral assembly also required and installed to create reference point for HRG system.

1.02 REFERENCES

A. High Resistance Grounding system shall be designed and manufactured in accordance with the following standards:

1. ANSI C19.3 – Industrial Control Apparatus – General
2. IEEE C57.32a-2020 – IEEE Standard for Requirements, Terminology, and Test Procedures for Neutral Grounding Devices
3. IEEE 142-2007 – IEEE Recommended Practice for Grounding of Industrial and Commercial Power Systems
4. NFPA 70– National Electrical Code
5. UL 50 – Enclosures for Electrical Equipment, Non-Environmental Considerations
6. UL 508 – Standard for Industrial Control Equipment
7. CSA C22.2 No. 295-15 – Neutral Grounding Devices
8. Z462-21 – Workplace Electrical Safety
9. CSA C22.1-2021

B. The manufacturer of the High Resistance Grounding equipment shall have produced similar electrical equipment for minimum period of 5 years.

C. The manufacturer of the High Resistance Grounding equipment shall be ISO 9001:2015 certified.

1.03 SUBMITTALS

A. Product data and manufacturer's installation instructions for non-approved manufacturers shall be submitted for review ten days prior to the bid date.

B. The submittals shall also include

1. Reference dimensional drawing of the enclosure.
2. Bills of material for internal components.
3. Schematic and wiring diagrams of interconnection.

2.0 PRODUCT

2.01 STANDARD HIGH RESISTANCE GROUNDING SYSTEM

A. Resistor: The resistive elements shall be wire-wound or edge-wound type and made of stainless steel alloy with low coefficient of resistance. The resistor assembly shall be rated for the system voltage.

B. Provide a ground fault and resistor monitoring relay (SIGMA 3) integral to the HRG system.

1. The relay ground fault trip settings shall be from 5% to 50% of the let-through current.
2. The relay shall monitor the condition of the neutral ground path and alarm/trip under abnormal condition as indicated in table 17 of the CSA C22.1-2021.

C. Standard HRG systems shall also:

1. Provide Modbus TCP protocol for communication
2. Provide ground fault alarm auxiliary relay output form C, 10 A, 240 Vac contact for remote indication.

D. Provide artificial neutral assembly if installed on three-phase, three-wire ungrounded system to create reference point for HRG system.

E. To be mounted in an outdoor-rated enclosure (or indoor-rated enclosure, or inside the switchgear cabinet).

2.02 OPERATION OF A STANDARD HRG SYSTEM

A. The HRG system shall have a touchscreen HMI to provide positive indication that the system is healthy.

1. Upon the occurrence of a ground fault, through the HMI, the system will alarm and provide a visual indication.
2. Upon the occurrence of a NGR fault, the system will alarm and/or trip as per the condition established in table 17 of CSA C22.1-2021.

MANUFACTURERS

A. Approved vendors: I-GARD Corporation (or approved equal)

B. Product to be I-GARD Stoplight-RM series (if the intention is to have a separate enclosure for HRG box), or SIGMA 3 relay and NGR (or approved equal)

= END OF SECTION =

High Resistance Grounding for 5 kV or less systems – Standard Pulsing (Sleuth-RM): Specification Template: 26.45.02

1.0 GENERAL

1.01 SCOPE

A. This specification covers the basic requirements for the High Resistance Grounding equipment;

1. To be mounted external to electrical distribution equipment.
2. To be assembled and integrated into low voltage equipment, such as panel board, motor control center, switchboard, or switchgear.

B. These devices are used to:

1. Ground the neutral of a three-phase power system using a power resistor.
2. Limit the magnitude of the ground fault to a predetermined low value (<10 A)
3. Reduce the frequency and number of arc flash and arc blast hazard.
4. Give immediate indication when a ground fault occurs.
5. Provide a method for quickly locating the phase to ground fault (pulsing feature), allowing the user to correct the problem or allow for an orderly shutdown of the process.

C. Electrical system parameters

1. System line to line voltage to be 480/600/690/4160 Vac.
2. System line to neutral voltage to be 277/347/400/2400 Vac.
3. The NGR shall have a let-through current rating of _ A (maximum of 10 A), pulsing up/down to _ A.
4. Resistor to be connected between neutral and ground.
5. If installed on three-phase, three-wire ungrounded system, artificial neutral assembly also required and installed to create reference point for HRG system.

1.02 REFERENCES

A. High Resistance Grounding system shall be designed and manufactured in accordance with the following standards:

1. ANSI C19.3 – Industrial Control Apparatus – General
2. IEEE C57.32a-2020– IEEE Standard for Requirements, Terminology, and Test Procedures for Neutral Grounding Devices
3. IEEE 142-2007 – IEEE Recommended Practice for Grounding of Industrial and Commercial Power Systems
4. NFPA 70– National Electrical Code
5. UL 50 – Enclosures for Electrical Equipment, Non-Environmental Considerations
6. UL 508 – Standard for Industrial Control Equipment
7. CSA C22.2 No. 295-15 – Neutral Grounding Devices
8. Z462-21 – Workplace Electrical Safety
9. CSA C22.1-2021

B. The manufacturer of the High Resistance Grounding equipment shall have produced similar electrical equipment for minimum period of 5 years.

C. The manufacturer of the High Resistance Grounding equipment shall be ISO 9001:2015 certified.

1.03 SUBMITTALS

A. Product data and manufacturer's installation instructions for non-approved manufacturers shall be submitted for review ten days prior to the bid date.

B. The submittals shall also include

1. Reference dimensional drawing of the enclosure.
2. Bills of material for internal components.
3. Schematic and wiring diagrams of interconnection.

2.0 PRODUCT

2.01 STANDARD HIGH RESISTANCE GROUNDING SYSTEM

A. Resistor: The resistive elements shall be wire-wound or edge-wound type and made of stainless steel alloy with low coefficient of resistance. The resistor assembly shall be rated for the system voltage.

B. Provide a ground fault and resistor monitoring relay (SIGMA 3) integral to the HRG system.

1. The relay ground fault trip settings shall be from 5% to 50% of the let-through current.
2. The relay shall monitor the condition of the neutral ground path and alarm/trip under abnormal condition as indicated in table 17 of the CSA C22.1-2021.

C. Standard HRG system shall also:

1. Provide Modbus TCP protocol for communication
2. Provide ground fault alarm auxiliary relay output form C, 10 A, 240 Vac contact for remote indication.

D. Provide artificial neutral assembly if installed on three-phase, three-wire ungrounded system to create reference point for HRG system.

E. Pulsing characteristic to cyclically limit the fault current to 100% -> 75% -> 50% of the available ground fault current (e.g. 5 A to 2.5 A) to allow tracing the faulted circuit to the point of the fault.

F. Handheld pulse tracing sensor allows user to follow pulses to field locate the ground fault without de-energizing the load.

G. To be mounted in an outdoor-rated enclosure (or indoor-rated enclosure, or inside the switchgear cabinet).

2.02 OPERATION OF A STANDARD HRG SYSTEM

A. The HRG system shall have a touchscreen HMI to provide positive indication that the system is healthy.

1. Upon the occurrence of a ground fault through the HMI, the system will alarm and provide a visual indication.
2. Upon the occurrence of a NGR fault, the system will alarm and/or trip as per the condition established in table 17 of CSA C22.1-2021

B. Provide the capacity to pulse as a method of fault location (Sleuth-RM).

MANUFACTURERS

A. Approved vendors: I-GARD Corporation (or approved equal)

B. Product to be I-GARD Sleuth-RM Series (if the intention is to have a separate enclosure for HRG box), or SIGMA 3 relay and NGR (or approved equal).

= END OF SECTION =

High Resistance Grounding for 5 kV or less systems – Standard fail-safe (Gemini): Specification Template: 26.45.02

1.0 GENERAL

1.01 SCOPE

A. This specification covers the basic requirements for the High Resistance Grounding equipment;

1. To be mounted external to electrical distribution equipment.
2. To be assembled and integrated into low voltage equipment, such as panel board, motor control center, switchboard, or switchgear.

B. These devices are used to:

1. Ground the neutral of a three-phase power system using a power resistor.
2. Limit the magnitude of the ground fault to a predetermined low value (<10 A).
3. Give immediate indication when a ground fault occurs.
4. Provide a method for quickly locating the phase to ground fault (Pulsing feature), allowing the user to correct the problem or allow for an orderly shutdown of the process.
5. Provide fail-safe ground fault protection with a redundant resistor system.
6. Reduce the frequency and number of arc flash and arc blast hazard.

C. Electrical system parameters

1. System line to line voltage to be 480/600/690/4160 Vac.
2. System line to neutral voltage to be 277/347/400/2400 Vac.
3. The NGR shall have a let-through current rating of _A (maximum of 10 A), pulsing up/down to _ A.
4. Resistor to be connected between neutral and ground.
5. If installed on three-phase, three-wire ungrounded system, artificial neutral assembly also required and installed to create reference point for HRG system.

1.02 REFERENCES

A. High Resistance Grounding system shall be designed and manufactured in accordance with the following standards:

1. ANSI C19.3 – Industrial Control Apparatus – General
2. IEEE C57.32a-2020 – IEEE Standard for Requirements, Terminology, and Test Procedures for Neutral Grounding Devices
3. IEEE 142-2007 – IEEE Recommended Practice for Grounding of Industrial and Commercial Power Systems
4. NFPA 70– National Electrical Code
5. UL 50 – Enclosures for Electrical Equipment, Non-Environmental Considerations
6. UL 508 – Standard for Industrial Control Equipment
7. CSA C22.2 No. 295-15 – Neutral Grounding Devices
8. Z462-21 – Workplace Electrical Safety
9. CSA C22.1-2021

B. The manufacturer of the High Resistance Grounding equipment shall have produced similar electrical equipment for minimum period of 5 years.

C. The manufacturer of the High Resistance Grounding equipment shall be ISO 9001:2015 certified.

1.03 SUBMITTALS

A. Product data and manufacturer's installation instructions for non-approved manufacturers shall be submitted for review ten days prior to the bid date.

B. The submittals shall also include

1. Reference dimensional drawing of the enclosure.
2. Bills of material for internal components.
3. Schematic and wiring diagrams of interconnection.

2.0 PRODUCT

2.01 STANDARD HIGH RESISTANCE GROUNDING SYSTEM

A. Resistor: The resistive elements shall be wire-wound or edge-wound type and made of stainless steel alloy with low coefficient of resistivity. The resistor assembly shall be rated for the system voltage.

B. Provide a ground fault and resistor monitoring relay (SIGMA 3) integral to the HRG system.

1. The relay ground fault trip settings shall be from 5% to 50% of the let-through current.
2. The relay shall monitor the condition of the neutral ground path and alarm/trip under abnormal condition as indicated in table 17 of the CSA C22.1-2021.

C. Standard HRG system shall also:

1. Provide Modbus TCP protocol for communication
2. Provide ground fault alarm auxiliary relay output form C, 10 A, 240 Vac contact for remote indication.

D. The HRG system shall have a dual resistor path to ground for fail-safe operation

E. Provide artificial neutral assembly if installed on three-phase, three-wire ungrounded system to create reference point for HRG system.

F. Pulsing characteristic to cyclically limit the fault current to 100% -> 50% of the available ground fault current (e.g. 5 A to 2.5 A) to allow tracing the faulted circuit to the point of the fault.

G. Handheld pulse tracing sensor allows user to follow pulses to field locate the ground fault without de-energizing the load.

H. To be mounted in an outdoor-rated enclosure (or indoor-rated enclosure, or inside the switchgear cabinet).

2.02 OPERATION OF STANDARD HRG SYSTEM

A. The HRG system shall have a touchscreen HMI to provide positive indication that the system is healthy.

1. Upon the occurrence of a ground fault through the HMI, the system will alarm and provide a visual indication.
2. Upon the occurrence of a NGR fault, the system will alarm and/or trip as per the condition established in table 17 of CSA C22.1-2021

B. Provide the capacity to pulse as a method of fault location (Gemini).

MANUFACTURERS

A. Approved vendors: I-GARD Corporation (or approved equal)

B. Product to be I-GARD Gemini Series (if the intention is to have a separate enclosure for HRG box), or SIGMA 3 relay and NGR (or approved equal).

= END OF SECTION =

High Resistance Grounding for 5 kV or less systems - Advanced HRG (DSP-OHMNI/ Sentinel): Specification Template: 26.45.02

1.0 GENERAL

1.01 SCOPE

A. This specification covers the basic requirements for the High Resistance Grounding equipment;

1. To be mounted external to electrical distribution equipment.
2. To be assembled and integrated into low voltage equipment, such as panel board, motor control center, switchboard, or switchgear.

B. These devices are used to:

1. Ground the neutral of a three-phase power system using a power resistor.
2. Limit the magnitude of the ground fault to a predetermined non-damaging level.
3. Reduce the frequency and number of arc flash and arc blast hazard.
4. Reduce the severity of an arc flash event.
5. Give immediate indication when a ground fault occurs.
6. Provide ground fault feeder identification by means of an HMI, allowing the user to correct the problem or allow for an orderly shutdown of the process.
7. Avoid power interruption of critical processes in case of a second ground fault in a different phase and feeder.
8. Provide enhanced second fault tripping control by providing prioritization of feeders on the occurrence of a second ground fault. Feeders are assigned priority levels from 0 to 15.

C. Electrical system parameters

1. System line to line voltage to be 480/600/690/4160 Vac.
2. System line to neutral voltage to be 277/347/400/2400 Vac.
3. The NGR shall have a let-through current rating of _ A(maximum of 10 A), pulsing up/down to _ A.
4. Resistor to be connected between neutral and ground.
5. If installed on three-phase, three-wire ungrounded system, artificial neutral assembly also required and installed to create reference point for HRG system.

1.02 REFERENCES

A. High Resistance Grounding system shall be designed and manufactured in accordance with the following standards:

1. ANSI C19.3 – Industrial Control Apparatus – General
2. IEEE C57.32a-2020 – IEEE Standard for Requirements, Terminology, and Test Procedures for Neutral Grounding Devices
3. IEEE 142-2007 – IEEE Recommended Practice for Grounding of Industrial and Commercial Power Systems
4. NFPA 70– National Electrical Code
5. UL 50 – Enclosures for Electrical Equipment, Non-Environmental Considerations
6. UL 508 – Standard for Industrial Control Equipment
7. CSA C22.2 No. 295-15 – Neutral Grounding Devices
8. Z462-21 – Workplace Electrical Safety

B. The manufacturer of the High Resistance Grounding equipment shall have produced similar electrical equipment for minimum period of 5 years.

C. The manufacturer of the High-Resistance Grounding equipment shall be ISO 9001:2015 certified.

1.03 SUBMITTALS

A. Product data and manufacturer's installation instructions for non-approved manufacturers shall be submitted for review ten days prior to the bid date.

B. The submittals shall also include

1. Dimensional drawing of each enclosure.
2. Bills of material for internal components and details.
3. Schematic and wiring diagrams of interconnection.

2.0 PRODUCT

2.01 ADVANCED HIGH RESISTANCE GROUNDING SYSTEM

A. Configuration via a central HMI of all critical feeder protection and pulsing HRG system components.

B. Pulsing power resistor to limit current flow to 10 A or below during a single phase to ground fault condition.

1. Pulsing characteristic to cyclically limit the fault current to 100% and 50% of the available ground fault current (e.g. 5 A to 2.5 A) to allow tracing the faulted circuit to the point of the fault.

C. Monitor each individual feeder breaker via Zero Sequence Current Sensor for local and remote indication.

1. Monitor up to 50 critical feeders per advanced HRG system.
2. Assign priority level (0-15) for each monitored feeder for second ground fault occurrence.
3. Sensors to be rated 600 Vac.

D. An individual feeder module shall be provided for each monitored feeder. The feeder module shall:

1. Provide local ground fault indication via a red LED indicator on front of module.
2. Provide a trip signal directly to associated critical feeder breaker shunt trip during the second phase to ground fault when identified as the lowest priority faulted feeder.
3. Shall provide the alternative to trip on first fault with a delay from instantaneous to up to 99 hours, or to trip on second fault.
4. Have provisions for future system expansion by adding additional feeder modules and zero sequence current sensors.

E. System to assist in locating ground fault by annunciating via an HMI display indication of:

1. Alarm or trip with delay on 1st fault or selective priority tripping on second fault
2. Faulted phase.
3. Individual feeder ID.
4. Magnitude of ground fault for:
    a. Overall system.
    b. Individual feeder locations.
5. Feeder “trip” ID due to second phase to ground fault.
6. Feeder assigned priority levels.
7. Status of NGR.
8. Loss of phase voltages.
9. BUS Fault
10. Arc flash detection

F. Advanced HRG system shall also:

1. Provide Modbus RTU/TCP protocol for communication of information
2. Monitor phase to ground voltages.
3. Provide ground fault alarm auxiliary relay output form C, 10 A, 240 Vac contact for remote indication.
4. Advanced touchscreen display module (DSP-TDM)

G. The system can be installed within the switchgear with a separated NGR mounted in a NEMA 3R enclosure, or integrated (NGR and relay) in a single NEMA 1 box to be wall mounted external to the switchgear. Individual Zero Sequence Current Sensors are mounted at individual feeder locations.

H. Provide a resistor monitor function (DSP-DRM3), integral to the advanced HRG system to verify the integrity of the neutral grounding resistor (NGR) according to CSA C22.1.-21 section 10-302.

I. Provide Arc flash detection module (DSP-ADM) to provide tripping on the occurrence of an arc flash using light and pressure sensors. System to continuously monitor up to 21 arc fault sensors.

J. Provide artificial neutral assembly if installed on three-phase, three-wire ungrounded system to create reference point for HRG system.

K. Handheld pulse tracing sensor allows user to follow pulses to field locate the ground fault without de-energizing the load.

2.02 OPERATION OF ADVANCED HRG SYSTEM

A. During the first phase to ground fault, the customer will have the option to:

1. Alarm only - allowing the user to correct the problem or allow for an orderly shutdown of the process.
2. Trip with time delay adjustable from 0-99 hours.

B. During the second phase to ground fault, the advanced HRG system will provide selective feeder trip by initiating a trip signal directly to the shunt trip of the feeder breaker identified as the faulted feeder with the lowest assigned priority.

MANUFACTURERS

A. Approved vendors: I-GARD Corporation (or approved equal)

B. Product to be I-GARD Sentinel Series(if the intention is to have a separate enclosure for HRG box), or DSP-OHMNI (if the intention is for HRG to be supplied within switchgear cabinet (or approved equal)

= END OF SECTION =

Solidly Grounding Systems - SENTRi:

1.0 GENERAL

1.01 SCOPE

A. These devices are used to:

1. Provide protection during a ground fault condition on three-phase power systems.
2. Provide arc flash detection and mitigation through the use of arc flash sensors.
3. Utilize Zone Selective Interlocking Protection (ZSIP) or an equivalent for system coordination.

1.02 REFERENCES

A. Solidly Grounded relays shall be designed and manufactured in accordance with the following standards:

1. NFPA 70E - Standard for Electrical Safety in the Workplace (National Fire Protection Association).
2. CEC C22.1-2021, 14-102 - Canadian Electrical Code, Impedance Grounded Systems.
3. Z462-21 – Workplace Electrical Safety.

2.0 PRODUCT

2.01 STANDARD SOLIDLY GROUNDED SYSTEM

A. Provide a ground fault protection relay (SENTRi)

1. The relay ground fault trip settings shall range from 100 mA to 1,200 A.
2. The relay shall monitor the fault current leakage and trip in accordance with CSA, C22.1, 14-102.
3. The relay time delay settings shall range from instantaneous (<2 ms) to 5 seconds.
4. The relay shall utilize Zone Selective Interlocking Protection (ZSIP) or an equivalent to assist in maintaining. continuity of unaffected circuits during a ground fault condition.

MANUFACTURERS

A. Approved vendors: I-GARD Corporation (or approved equal).

B. Product to be I-GARD SENTRi (or approved equal).

= END OF SECTION =

I-GARD

Unparalleled Protection

C-31 REV1_2022
CONSULTANT
SPECIFICATION GUIDE

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ISO 9001:2015