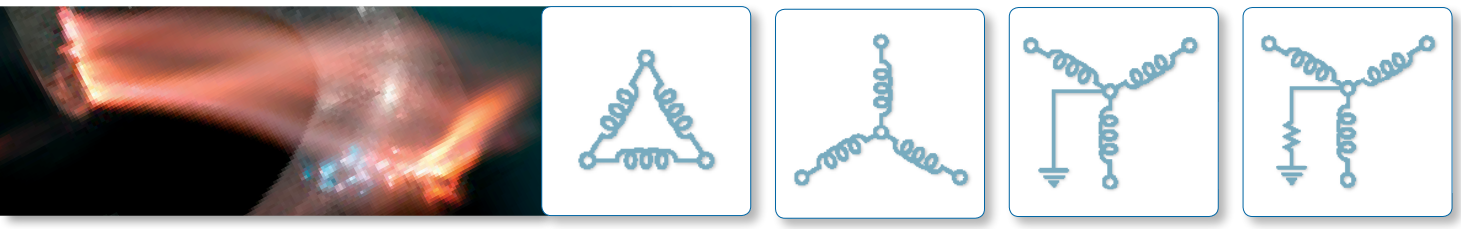
GARD

Unparalleled Protection

NGR

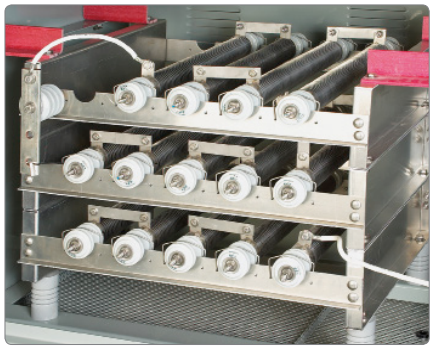
NGR

NEUTRAL GROUNDING RESISTORS



C-098EB Product Brochure, April 2022

NEUTRAL GROUNDING RESISTORS



I-Gard offers a complete range of Neutral Grounding Resistors, from 480V to 69,000V for resistance grounding of industrial power systems.

All of our NGRs are manufactured in Canada. Designed and tested under our CSA SMTC program meaning they are approved by CSA and meet all applicable standards including CSA 295-15 and CSA 22.2 Part 1.

We have UL rated, seismic rated and OSHPD approved designs available.

NGR

Neutral grounding resistors limit the maximum fault current to a predetermined value which will protect the power system against damage produced by high levels of ground fault current typically seen in solidly grounded systems; yet allowing for sufficient flow of current to coordinate protection relays and clear the fault as recommended by IEEE and CSA.

What does IEEE say about Low Resistance Grounding?

IEEE Standard 142-1991 Recommended Practice for Grounding of Industrial and Commercial Power Systems

Clause 1.4.3 Resistance Grounding

The low-resistance method has the advantage of immediate and selective clearing of the grounded circuit, but requires that the minimum ground-fault current be large enough to positively actuate the applied ground-fault relay.

IEEE Standard 242-1986 Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems

Clause 7.2.3 Low-Resistance Grounding

The magnitude of the grounding resistance is selected to allow sufficient current for ground- fault relays to detect and clear the faulted circuit.

IEEE Standard for Requirements, Terminology, and Test Procedures for Neutral Grounding Devices (IEEE Std C57.32a)

Clause 7.1 Resistor Element

A resistor element is the conducting unit which functions to limit the current flow to a predetermined value.

The element material shall possess a balanced combination of properties, uniformity of resistance, and mechanical stability over the intended operating temperature range, without any injurious effects to the elements and its associated insulation.

Clause 7.2.1 Rated Voltage

Since the active material used in resistors has an appreciable temperature coefficient, the resistance is materially changed during the time of operation causing the current to decrease. When the product of the fault current and resistance at 30 °C exceeds 80% of the line-to-neutral voltage of the circuit, the resistor shall be rated for constant voltage and the rated voltage shall be taken equal to the line-to-neutral voltage.

Clause 7.3 Temperature Coefficient of Resistance

The resistor element resistance changes with temperature. The change may be calculated from the temperature coefficient of resistance.

$$\alpha = \frac{R_2 - R_1}{R_1(\theta_2 - \theta_1)} \qquad R_2 = R_1\left[1 + \alpha(\theta_2 - \theta_1)\right]$$

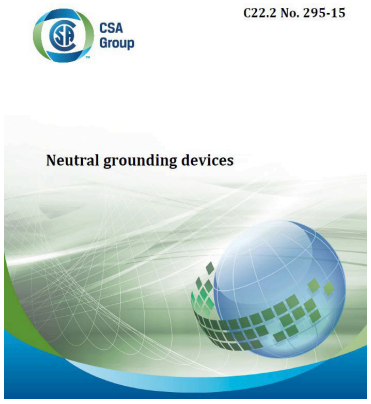
R_1 and R_2 are resistances in ohms at temperatures θ_1 and θ_2 in degrees Celsius, respectively, and α is the temperature coefficient of resistance ($1/^0C$).

The resistance of the NGR should not change by more than 67% from the initial value over the temperature range. This is to help ensure that the final fault current is sufficiently high to allow protective circuitry to operate as intended.

What Other Codes or Standards reference Neutral Grounding Resistors?

CSA C22.2 295-15 Neutral Grounding Resistors

4.1.2 Construction requirements. General



Neutral grounding resistor assemblies shall be rated as follows:

a) Voltage: The rated voltage shall be taken equal to the line to neutral voltage.

b) Current: The basis for this rating shall be the thermal current. This will be the current through the neutral device during a ground fault condition at the device location, at thermal equilibrium for continuously rated devices. For non- continuously rated devices the current through the device shall not vary by more than 20% from the rated current during the rating test in Clause 6.2.

c) Rated time: Rated time shall be 10 seconds, 30 seconds, 1 minute or continuous time.

6.1 Tests. General

Neutral Grounding assemblies shall be subjected to the following tests:

- Rated voltage for low-voltage and high-voltage assemblies (see Clause 6.2);
- Temperature for low-voltage and high-voltage assemblies (see Clause 6.3);

6.2.1 Rated voltage test

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%.

6.3.2.1 Duty Rated Devices

Assemblies with a duty rating, and intended for indoor application, shall be type tested as follows:

a) Assemblies shall be tested at rated current and rated voltage for their rated time.

CEC 22.1 Canadian Electrical Code - 2021

10-302 Use of Impedance Grounded Systems

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.

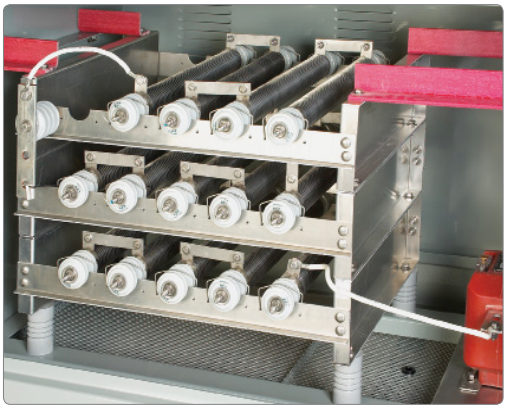
Sizing the Neutral Grounding Resistor

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

The charging current of a system can be calculated by summing the zero-sequence capacitance or determining capacitive reactance of all the cable and equipment connected to the system.

When it is impractical to measure the system charging current, the "Rule of Thumb" method may be used:

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



All I-Gard's low-resistance grounding products are standardized on the edgewound element design. Due to the rapid heating and very high temperatures encountered, this design has been proven superior for the NGR application.

The edgewound element material is mounted on porcelain supports, which are not affected by the high temperature or high voltages. The sturdy, helically coiled element is free to expand and does not deform when heated and offers consistent current density.

The element material is critical in ensuring high operating performance of the neutral grounding resistor. It is a special grade of electrical alloy with a very low temperature coefficient of resistance.

This prevents the resistance value from increasing significantly as the resistor operates through a wide temperature range. It also ensures a stable value of the fault current for proper metering and relaying.

Some manufacturers offer stamped and cast alloy grid resistors for low-resistance grounding applications but the mica paper insulation they incorporate limits the temperature at which they can operate. The mica paper insulation can also absorb moisture and fail while the flat grid stamping may severely warp when rapidly heated. Also, the grids have hot spots which may burn when overloaded by the fault.

To ensure sufficient fault current is available to positively actuate the over-current relay and that the fault current does not decrease by more than 20% between ambient and the full operating temperature, it is recommended that the NGR element material to be specified to have a temperature coefficient of resistance no greater than 0.0002 Ohms /^{0}C.

In the examples below we can see the significance of the temperature coefficient of resistance and how it affects the final resistance of the NGR and the associated current.

Example 1: 2400 Volt Line to Neutral NGR, 400 Amp, 10 seconds.

$$R_2 = R_1[1+\alpha(\theta_2-\theta_1)]$$

(R_1 = 6 Ω, θ_2 = 760°C)

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

- First 3 rows violate CSA standard as the current decreases by more than 20%.
- First 2 rows violate IEEE C57.32 as resistance increases by more than 67%.

Example 2: 277 Volt Line to Neutral NGR, 5 Amp, continuous.

$$R_2 = R_1[1+\alpha(\theta_2-\theta_1)]$$

(R_1 = 55.4 Ω, θ_2 = 385 °C)

Alloy	Temperature Coefficient of Resistance (1/^{0}C) α	Percent change in Resistance	Current decrease as a percentage
AISI 304	0.00092	35% Increase to 74.79 Ω	26.15 % to 3.7 A
AISI 430	0.00146	56% Increase to 86.42 Ω	36 % to 3.2 A
18SR	0.000358	13.7 % Increase to 62. 898 Ω	12 % to 4.39 A
1JR	0.000241	9% Increase to 60.39 Ω	9.1 % to 4.6 A

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

Resistor Monitoring

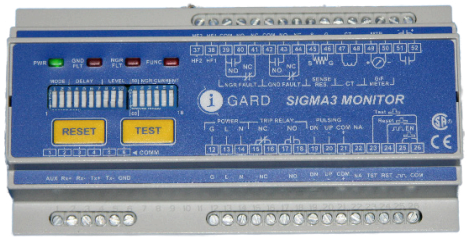


Fig.1 SIGMA 3 Ground Fault Relay

- All Neutral Grounding Resistors from I-Gard comply with CEC 2021 which requires complete neutral-to-ground path monitoring.
- The SIGMA 3 is the I-Gard ground fault relay that fully complies with the requirements of the novel CEC 2021, it can be used across the whole range of High and Low Resistance Grounding Systems, in voltages from 480V to 69 kV.
- The SIGMA 3 Monitor Relay is a combination of Neutral Grounding Resistor (NGR)monitoring and Ground Fault Relay.

Unlike other monitoring products on the market, the SIGMA 3 has been specially designed to ensure effective monitoring of the NGR circuit, even when de-energized.

In addition to its reliable performance, the SIGMA 3 relay includes a watchdog circuit and built-in test circuitry, making it the most reliable relay in the market.

Finally, the SIGMA 3 is fully compatible with all power-circuit elements, including those that intentionally connect the power system to the ground (single-phase grounding transformers, grounded-wye-primary potential transformers, and grounded- wye-primary power transformers).

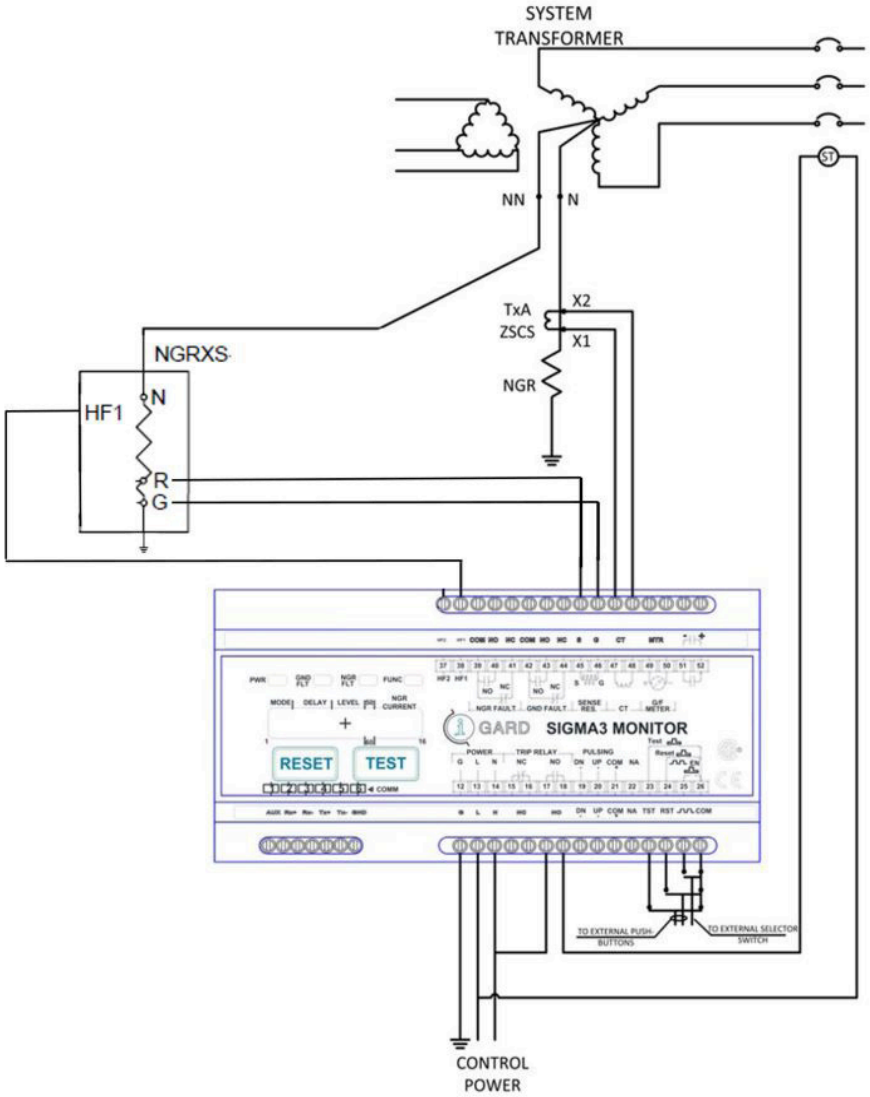


Fig.2 SIGMA 3 Typical System Diagram (LRG)

CEC 2021, Table 17.

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:

CEC 2021 Requirements	SIGMA 3 Monitoring Relay
a) A ground fault on current-carrying conductors, including the neutral conductor where line-to-neutral loads are served.	The SIGMA 3 relay is a also a ground fault relay, therefore any ground fault on any current-carrying conductors will be detected and alarmed.
b) A ground fault on the conductor connecting the impedance grounding device to the source.	The SIGMA 3 measures the impedance value of the ground path from the source neutral to ground. During a short condition, the equivalent impedance of the parallel circuit formed by the NGR and the short, will be very low. The SIGMA 3 will detect this abnormal condition and alarm.
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.	During an open circuit, the SIGMA 3 will automatically switch to injection mode, injecting a high frequency signal to the NGRS (sensing resistor) circuit. There will be no return of the signal due to the open circuit. This condition will be alarmed.

CEC 2021, Table 17. Summary of conditions (a), (b) and (c):

Configuration	A Ground Fault on the current carrying conductors (a)	A Ground Fault on the conductor from the source to the resistor (b)	Loss of Continuity from the source through the resistor to ground (c)
Distributed Neutral	Alarm and de-energize immediately	Alarm and de-energize immediately	Alarm and de-energize immediately
≤ 5 kV and ≤ 10 A	Alarm and de-energize within the time rating of NGR	Alarm and de-energize within 48 hours	Alarm
> 5 kV or >10 A	Alarm and de-energize within the time rating of NGR	Alarm and de-energize within 48 hours	Alarm

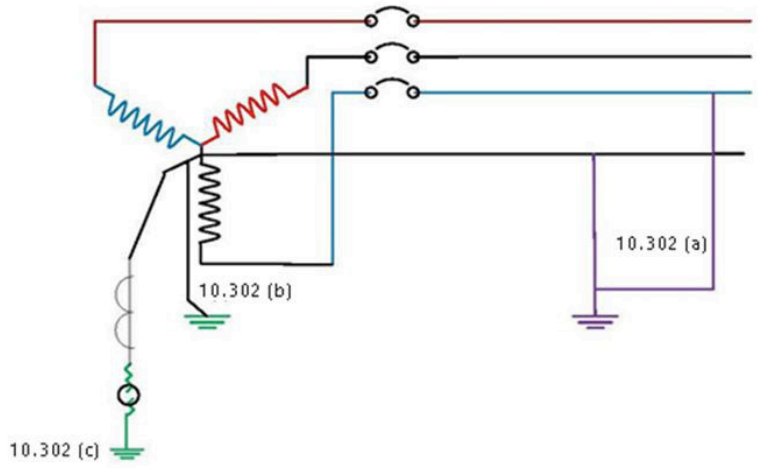


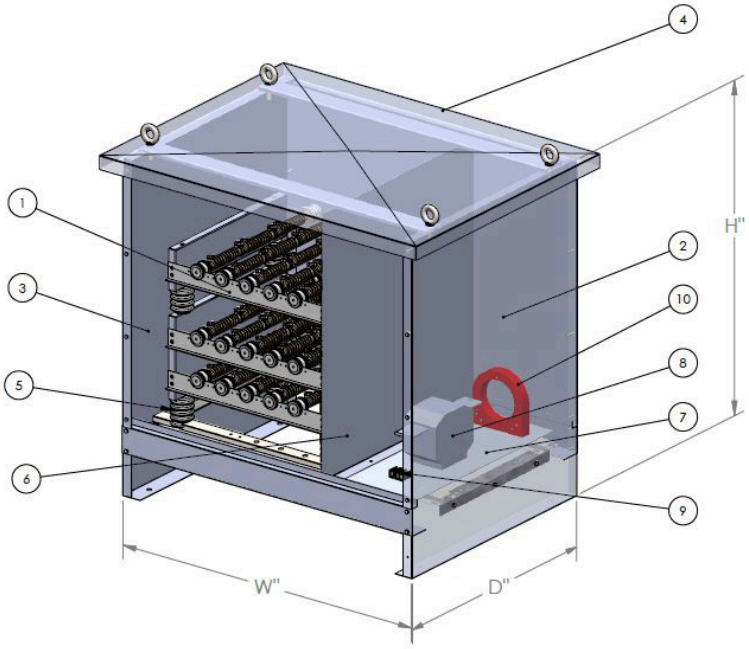
Fig.3 Illustration of conditions that are monitored according to CEC 2021, 10-302.

Neutral Grounding Resistor (NGR) Ratings and Dimensions

Line to Neutral Voltage	Current	Time Rating	Temperature Rise	Dimensions (for reference) D" x W" x H"
277 V	5	Continuous	375 °C	(16" x 23" x 7")
347 V	5	Continuous	375 °C	(16" x 23" x 7")
	50	10 seconds	760 °C	(24" x 36" x 24")
	100	10 seconds	760 °C	(24" x 36" x 24")
1390 V	200	10 seconds	760 °C	(24" x 36" x 24")
	400	10 seconds	760 °C	(24" x 36" x 24")
	5	Continuous	375 °C	(32" x 36" x 36")
	10	Continuous	375 °C	(32" x 48" x 48")
	25	10 seconds	760 °C	(32" x 36" x 36")
	50	10 seconds	760 °C	(32" x 36" x 36")
	100	10 seconds	760 °C	(32" x 36" x 36")
	200	10 seconds	760 °C	(32" x 36" x 36")
2400 V	400	10 seconds	760 °C	(32" x 36" x 36")
	5	Continuous	375°C	(32" x 48" x 36")
	10	Continuous	375°C	(32" x 48" x 48")
	25	Continuous	375 °C	(46" x 46" x 66")
	25	10 seconds	760 °C	(32" x 36" x 48")
	50	10 seconds	760 °C	(32" x 36" x 48")
4160 V	100	10 seconds	760 °C	(32" x 48" x 48")
	200	10 seconds	760 °C	(32" x 48" x 48")
	400	10 seconds	760 °C	(46" x 46" x 36")
	25	10 seconds	760 °C	(46" x 46" x 66")
	50	10 seconds	760 °C	(32" x 48" x 48")
8000 V	100	10 seconds	760 °C	(46" x 46" x 66")
	200	10 seconds	760 °C	(46" x 46" x 66")
	400	10 seconds	760 °C	(46" x 46" x 66")

**Dimensions are provided for information purposes only and are subject to change depending on specific design requirements or additional accessories.

Neutral Grounding Resistor 3D-Drawing



Item No.	Description
1	Resistor Elements
2	Side Cover
3	End Pan
4	Top Cover
5	5kV Standoffs
6	Heat Shield (if required)
7	Mounting Plate
8	Indoor CT
9	NG Terminal Block
10	T6A sensor

Fig.4 Typical NGR configuration dimensions: D":Depth x W": Width x H": Height

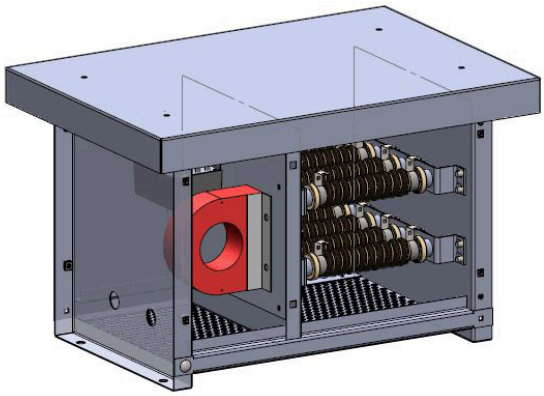


Fig.5 Typical NGR configuration 277 VL-N, 5 Amps continuous, with T sensor.

NEUTRAL GROUNDING RESISTOR (NGR) FEATURES

- Designed with high quality element material with low temperature coefficient of resistance for consistent fault current levels
- Edgewound element design eliminates hot-spots
- CSA certified and UL approved
- NGR monitoring compliant with CEC 2021
- For use in HRG and LRG applications up to 69kV

GARD

Unparalleled Protection

C-098EB NGR 2022

Phone: 905-673-1553
Toll Free: 1-888-737-4787

e-mail: support@i-gard.com
Website: www.i-gard.com

ISO 9001:2015