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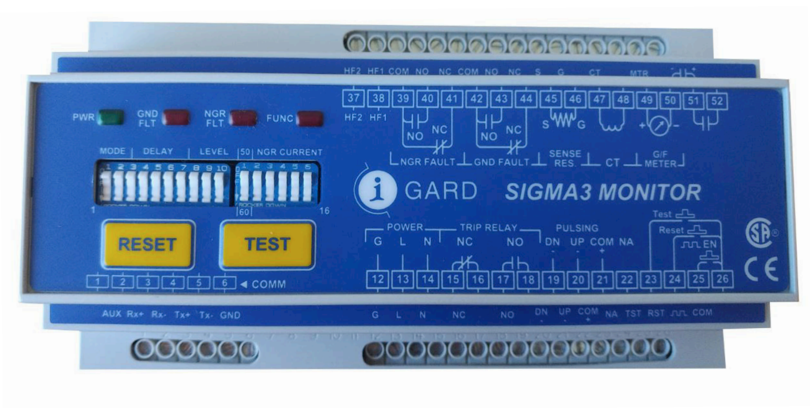
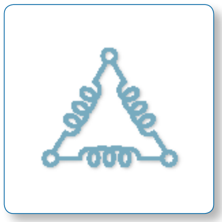
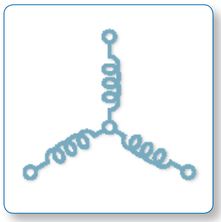
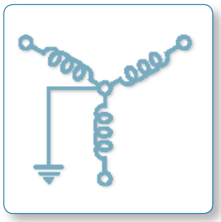


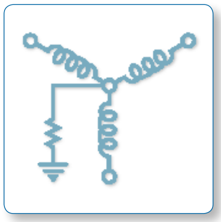

# SIGMA 3

## GROUND FAULT & MONITORING RELAY









C-EG44EM, Manual Rev 1. May 2023

# 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.

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FIGURES

# 1. INTRODUCTION

The I-Gard SIGMA 3 is a combination of a Ground Fault Relay and Neutral Grounding Resistor (NGR) Monitoring Relay. The SIGMA 3 monitor relay protects against ground faults and abnormal resistance values of the NGR.

The SIGMA 3 monitor relay is specifically designed for a variety of system voltages and an NGR limiting the maximum NGR current to the relay's set let-through current.

The SIGMA 3 monitor relay is designed to operate with a TxA or Rx-yA zero sequence current sensor, an NGRXS sensing resistor, and an NGR sized to limit the ground fault current to a predetermined value.

The let-through current measured by the zero sequence current sensor will be the vector sum of any leakage currents or charging currents normally in the system and any ground fault currents that may be present.

# 2. DESCRIPTION

The SIGMA 3 monitor relay measures the current through the NGR, the transformer neutral-to-ground voltage, and the NGR resistance. The relay compares the measured values with the field settings of the relay and provides relay outputs and LED indications when an abnormal condition is detected.

Ground fault current is measured using the zero sequence current sensor. The ground fault trip level is DIP switch selectable as a percentage of the NGR let-through current setting at 5%, 10%, 15%, 20%, 25%, 30%, 40%, and 50%. Trip time is DIP switch selectable from 60 milliseconds to 3.15 seconds.

Neutral-to-ground voltage is measured by means of the NGRXS. The NGRXS sensing resistor is used by the SIGMA 3 monitor relay in combination with the zero sequence current sensor as part of a comparator to monitor the NGR resistance. This NGR resistance monitoring complies with the requirements of CSA C22.1 section 10-302.

The SIGMA 3 monitor relay provides a current source output for connection to a 1mA full scale ammeter. The output signal is proportional to the measured current and is expressed as a percentage of the NGR let-through current setting.

A watchdog fail-safe normally open contact is also provided.

Pulsing signal terminals are provided to facilitate pulsing of the NGR as a ground fault locating technique where the NGR is outfitted with a solid state relay pulsing contactor.

The SIGMA 3 can be used with the SIGMA 3-TDM touchscreen display module to provide an advanced HMI.

# 3. OPERATION

## 3.1 System Components

The SIGMA 3 is used with voltage and current sensors to monitor the system. The NGRXS-## sensing resistor is used to sense the voltage over the NGR. The zero sequence current sensor, which is used to sense the current through the NGR, is an I-Gard type T2A, T3A, TxA or any Rx-yA zero sequence current sensor. In addition, the SIGMA 3 operates in injection mode when the current through the NGR is low, whereby a high frequency signal is injected into the system to measure the zero sequence impedance.

See Figure 3.1 below for the typical system with the SIGMA 3 connections.

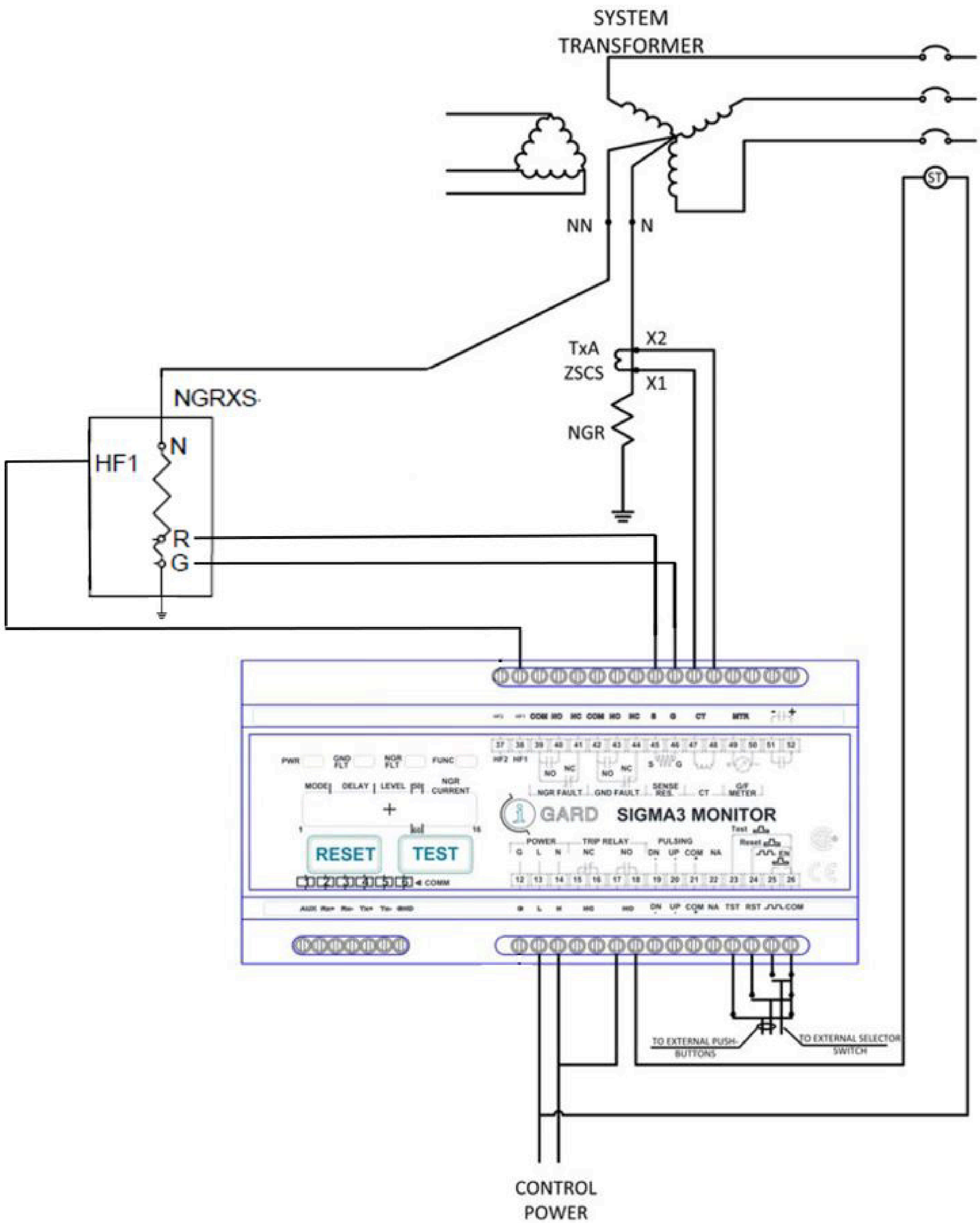



Figure 3.1: SIGMA 3 Typical System Diagram (HRG System)

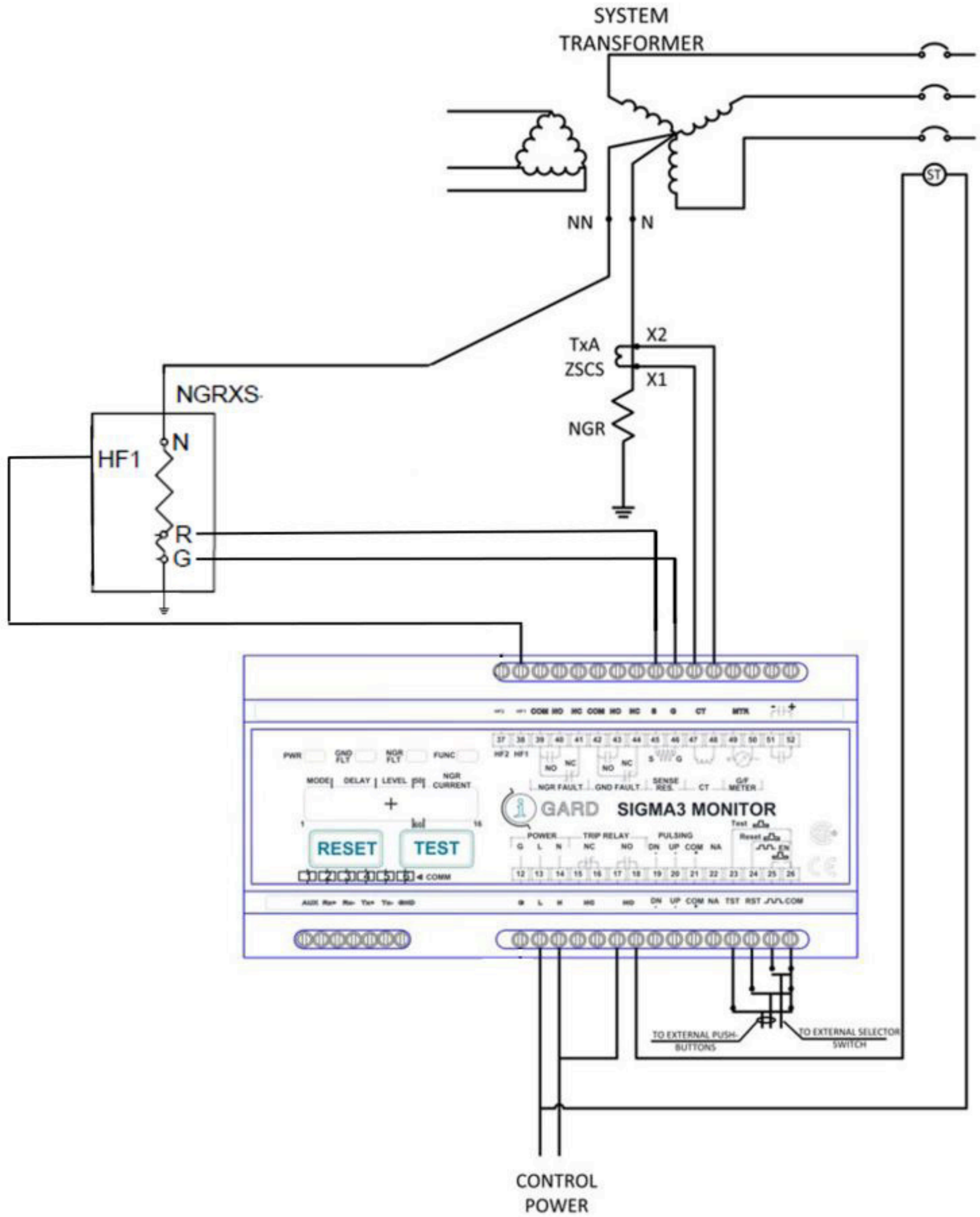



Figure 3.2: SIGMA 3 Typical System Diagram (LRG System)

## 3.2 Ground Fault Detection

The SIGMA 3 monitor detects ground faults by measuring the current through the NGR using the zero sequence current sensor (TxA or Rx-yA sensors). When the measured value exceeds the set-point the GND FLT LED illuminates, the GND FLT form-C contact energizes, and the trip relays energize.

The SIGMA 3's NGR let-through current setting is set by DIP switch to match the rating of the NGR. The trip level is DIP switch selectable as a percentage of the NGR let-through current setting and can be set as: 5%, 10%, 15%, 20%, 25%, 30%, 40%, and 50%.

The ground fault trip delay setting defines the length of time that a ground fault must persist before the fault is qualified as such. This setting is DIP switch selectable from its minimum setting of 60 milliseconds to 3.15 seconds.

### 3.3 NGR Monitoring

The SIGMA 3 monitor relay also monitors the health of the NGR to identify an open or short circuit condition. If the SIGMA 3 determines that the NGR is not healthy the NGR FLT LED illuminates, the NGR FLT form-C contact energizes, and the trip relays energize.

The SIGMA 3 monitor relay monitors the NGR using one of two methods: measurement mode and injection mode. If the leakage current through the NGR is over 5% of the rated let-through current, the SIGMA 3 operates in measurement mode. In measurement mode, the leakage current through the NGR is measured by the ZSCS and the voltage across the NGR is measured by the NGRXS. The SIGMA 3 uses these values to calculate the apparent resistance of the NGR. If this calculated value is determined to be over 150% of the nominal value or less than 66% of the nominal value, the SIGMA 3 annunciates an NGR fault.

If the leakage current through the NGR is below 5% of the rated let-through current, the SIGMA 3 operates in injection mode. In injection mode, a high frequency signal is injected into the system through a band-pass filter that is provided by the NGRXS. The SIGMA 3 uses the current and voltage of the high frequency signal to calculate the apparent resistance of the NGR. If this calculated value is determined to be over 150% of the nominal value or less than 66% of the nominal value, the SIGMA 3 annunciates an NGR fault.

### 3.4 Pulsing

Pulsing is a technique that is employed in high resistance grounded systems to locate a ground fault. The NGR is divided into a non-pulsing section and a pulsing section that includes a contactor. The pulsing section can be inserted into the system by the operation the contactor. This cycles the let-through current of the NGR between different values (usually from 50% to 100% of the rated let-through current) and this signature can be used to trace the location of the ground fault. Various pulse arrangements are shown in Figure 3.3 below.

Pulse signals are available from the SIGMA 3 that can be used to create the fluctuating current signature by driving a N.O. solid state relay that is used as the pulsing contactor. These are available at terminals 19, 20, and 21. If pulsing down, use terminals 19 and 21. If pulsing up, use terminals 20 and 21. Terminals 19-21 are normally energized with +12VDC and terminals 20-21 are normally de-energized. When pulsing is enabled by closing terminals 25-26 or by using the SIGMA 3-TDM touchscreen HMI, where the pulse signals cycle at a frequency of 1Hz. The cycle frequency can be changed using the SIGMA 3-TDM touchscreen HMI.

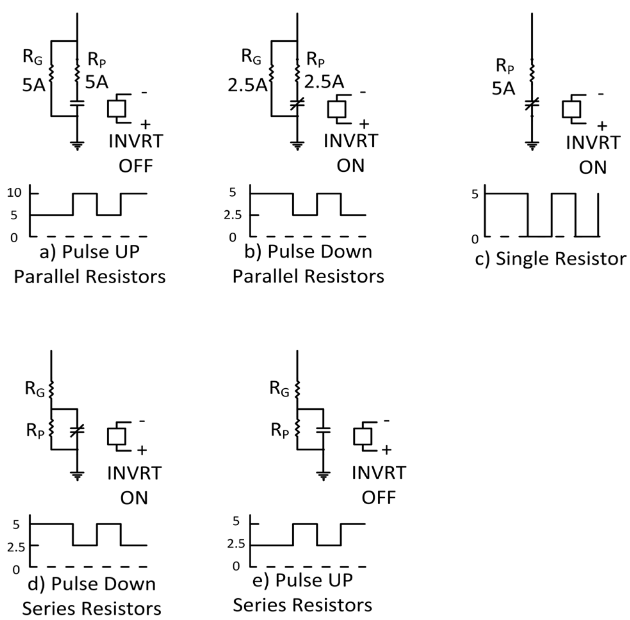



Figure 3.3: The creation of a pulse signature by cycling the let-through current under various arrangements

# 4. TRIP RELAY AND AUXILIARY FAULT RELAYS

The SIGMA 3 has four output relays:

- A TRIP relay
- An NGR  FAULT auxiliary relay
- A GROUND FAULT auxiliary relay
- A WATCHDOG auxiliary relay

All relays are electrically held, i.e. when control power is off, the relays are always in the de-energized state. The de-energized states are shown on the front of the SIGMA 3. Note that this is irrespective of the trip relay operating mode. All relays can be in one of two states: idle or tripped. For the trip relay, its status (energized or de-energized) when in each of these states depends on its operating mode, which is set by  DIP switch 1.

### 4.1 Trip Relay (15-16, 17-18)

A trip relay consisting of a N.O. and N.C. pair is provided. Terminal 15-16 is normally closed and terminal 17-18 is normally open. This relay energizes on occurrence of a ground fault or NGR fault. The trip relay can be programmed for shunt trip or fail-safe operation.

When the SIGMA 3 is operating in shunt trip mode and there is no fault condition present, the trip relay remains idle (de-energized). If a fault condition is detected and qualified, the trip relay trips (energized).

When the SIGMA 3 is operating in fail-safe mode and there is no fault condition present, the trip relay is normally idle or energized. The trip relay is tripped of de-energized if a fault condition is detected on the system. The trip relay is also de-energized when control power is off.

### 4.2 NGR Fault (AUXILIARY RELAY)

A Form-C auxiliary contact for NGR faults is provided. This is located at terminals 39, 40, and 41. The NGR FAULT auxiliary relay operates exclusively in shunt trip mode regardless of the setting of DIP switch.

### 4.3 Ground Fault (AUXILIARY RELAY)

A Form-C auxiliary contact for ground faults is provided. This is located at terminals 42, 43, and 44. The GROUND FAULT auxiliary relay operates exclusively in shunt trip mode regardless of the setting of DIP switch.

### 4.4 Watchdog (51-52)

Terminals 51-52 is a system normal watchdog. When the SIGMA 3 is de-energized it is open. When the SIGMA 3 is energized but not in alarm it is closed. If the SIGMA 3 goes into alarm mode, the watchdog changes state and opens back.

# 5. LED INDICATORS AND DIAGNOSTICS

The SIGMA 3 has 4 indication LEDs located on its front panel: the Green PWR (Power) LED; the Red GND (Ground) FAULT LED; the Red NGR FAULT LED; and the ZONE GR. (Zone Grading) LED.

### 5.1 Start-up and Reset Indications

The SIGMA 3 has a start-up sequence where the Red GND FAULT, NGR FAULT and ZONE GR. LEDs flash twice before being turned OFF. The Green PWR LED may also flash before it is turned ON.

During a manual reset the Red GND FAULT, NGR FAULT and ZONE GR. LEDs turn ON for two seconds as indication that the reset sequence is taking place. During this time the Green PWR LED will intermittently flash. After this sequence the LEDs give the start-up sequence described above.

After the SIGMA 3 has gone through the start-up sequence and is operating normally the Green PWR LED will turn ON and the Red GND FAULT, NGR FAULT and ZONE GR. LEDs will turn off.

### 5.2 Power On LED (Green)

The Green PWR LED will turn ON when control power is applied to the SIGMA 3 and the relay is operating normally.

The Green PWR LED will intermittently flash if control power is applied to the SIGMA 3 but the relay is not operating correctly due to a malfunction in the microprocessor circuit. Control power must be cycled in order to reset the SIGMA 3.

The Greed PWR LED will intermittently flash during a manual reset or a power-up reset.

### 5.3 GND Fault LED (Red)

The Red GND FAULT LED will turn OFF when the SIGMA 3 is operating normally and no ground fault has been detected or qualified.

The Red GND FAULT LED will turn ON when the SIGMA 3 has detected and qualified a ground fault. The Red GND FAULT LED will remain ON until the SIGMA 3 is manually reset even if the ground fault condition has been rectified.

The Red GND FAULT LED will intermittently flash when the SIGMA 3 is powered up after having been powered down while indicating a ground fault. The SIGMA 3 must be manually reset to clear this condition.

The Red GND FAULT LED will turn on during manual reset as described above.

### 5.4 NGR Fault LED (Red)

The Red NGR FAULT LED will turn OFF when the SIGMA 3 is operating normally and no NGR Fault has been detected and qualified.

The Red NGR FAULT LED will turn ON when the SIGMA 3 has detected and qualified an NGR Fault. The RED NGR FAULT LED will remain ON until the SIGMA 3 is manually reset even if the NGR fault condition has been corrected.

The Red NGR FAULT LED will intermittently flash when the relay is powered up after having been powered down while indicating an NGR Fault. The SIGMA 3 must be manually reset to clear this condition.

The Red NGR FAULT LED will turn ON during a manual reset as described above.

### 5.5 Function (Red)

The FUNCTION LED will turn ON when the ZONE I/L input circuit is active, i.e. Normally Open (NO) contacts connected to these inputs are closed.

The FUNCTION LED will intermittently flash when the relay's self-test circuit is enabled through the operation of the TEST push button on the front panel.

The FUNCTION LED will turn ON while the installer is adjusting the operational settings on the SIGMA 3 by way of the DIP switches. When the relay detects that the installer has stopped making adjustments to these settings the Red ZONE GR. LED will turn OFF.

The FUNCTION LED will turn ON during a manual reset as described above.

# 6. SETTINGS

Settings are defined using selectable DIP switches. A picture of the DIP switch array is shown in Figure 6.1 below.

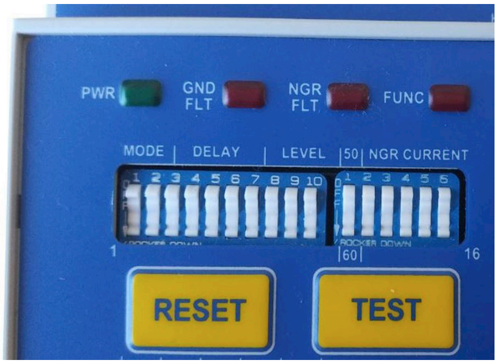



Figure 6.1: SIGMA 3 Dip Switch Array

## 6.1 Trip Relay Operating Modes

The trip relay operating settings can be set with DIP switch 1. The SIGMA 3 can be set for a shunt trip operating mode (not fail-safe) or an undervoltage trip operating mode (fail-safe) operation with the trip relay operating mode dip switch. See Table 6.1 for configuration details.

### 6.1.1 Shunt Trip Mode

In the shunt trip mode (not fail-safe), the trip relay remains de-energized (no trip) when control voltage is applied to the SIGMA monitor relay and the system is operating normally. The trip relay is energized (trip) when the measured values of the ground fault current or NGR Resistance exceed the threshold settings for the time specified.

The trip relay will energize (trip) after a fault is qualified and will remain energized (tripped) until the SIGMA monitor relay is reset whether or not the fault that caused the trip remains present on the system. The trip relay will be de-energized (no-trip) if the control voltage is removed.

When control voltage is applied the trip relay will at first be de-energized (no-trip) and the SIGMA monitor relay will start operating normally. If the trip memory option is OFF the trip relay will remain de-energized (no-trip). However, if the trip memory option is ON and a trip state is stored in the non-volatile memory, the trip relay will energize (trip) approximately 1 second after control voltage is applied and will remain energized (tripped), regardless of whether a fault is present on the system.

The trip relay will de-energize (no-trip) if the SIGMA monitor relay is reset through a local or remote reset. When reset, the SIGMA monitor relay will resume monitoring of the system and, if a fault remains on the system, will detect the fault and will re-trip, energizing the trip relay.

### 6.1.2 Fail-safe (Undervoltage Trip) Mode

When programmed for the FAIL-SAFE (UNDERVOLTAGE TRIP) MODE and the SIGMA 3 is operating normally, the trip relay energizes approximately 1 second after control voltage is applied. The trip relay de-energizes (trips) under any of the following conditions:

- The measured values of the ground fault current or NGR resistance exceed the threshold settings for the time specified
- The SIGMA 3 is reset
- Control voltage is removed

The trip relay remains energized after a trip, providing control voltage is present, until the SIGMA 3 is reset whether or not the fault that caused the trip remains present on the system.

When control voltage is applied the trip relay will at first be energized (no-trip) and the SIGMA 3 will start operating normally. If the trip memory option is OFF the trip relay will remain energized (no-trip). However, if the trip memory option is ON and a trip state is stored in the non-volatile memory, the trip relay will de-energize (trip) approximately 1 second after control voltage is applied to the relay and will remain de-energized (tripped), regardless of whether a fault is present on the system.

The trip relay will energize (no-trip) if the SIGMA 3 is reset through a local or remote reset. When reset, the SIGMA 3 will resume monitoring of the system and, if a fault remains on the system, will detect the fault and will re-trip, de-energizing the trip relay.

### 6.2 Trip Memory Setting

The trip memory settings can be set with DIP switch 2. The SIGMA 3 stores the states of the trip relay and auxiliary fault relays in non-volatile memory and can, if programmed to do so by means of the TRIP MEMORY Setting, restore the state of the trip relay when control power is applied.

The SIGMA 3 can be set for trip memory ON (DIP switch #2 UP) or trip memory OFF (DIP switch #2 DOWN). See Table 6.2 for configuration details.

When the trip memory option is OFF the trip relay and auxiliary fault relays are returned to their idle operating states when control power is applied.

When the trip memory is ON the trip relay and auxiliary fault relays are restored to the state these relays had prior to the loss of control power. If the SIGMA 3 was indicating a fault condition when control power was lost, the states of the trip relay and auxiliary fault relays will be maintained until the relay is manually reset.

The SIGMA 3 retains the states of the trip relay and auxiliary fault relays stored in non-volatile memory indefinitely.

### 6.3 Ground Fault Trip Time Delay

The ground fault time delay settings can be set with DIP switches 3-7. The SIGMA 3 can be programmed for ground fault trip delays ranging from 60 milliseconds to 3.15 seconds.

Refer to TABLE 6.3 GROUND FAULT TRIP TIME DELAY SETTINGS to determine the DIP switch settings for the application.

### 6.4 Ground Fault Trip Current Level

The ground fault trip current level setting can be set with DIP switches 8-10. The SIGMA 3 can be programmed for a number of ground fault trip levels expressed as a percentage of the NGR let-through current setting. Eight ground fault trip level settings are available and are: 5%; 10%; 15%; 20%; 25%; 30%; 40%; 50%.

I-Gard recommends that the ground fault trip level setting be set as low as possible to provide maximum operating personnel and equipment protection without having the SIGMA 3 report ground faults falsely.

Refer to TABLE 6.4 GROUND FAULT TRIP CURRENT LEVEL SETTINGS to determine the DIP switch settings for the application.

Caution: CAN/CSA-M421-00 Use of Electricity in Mines Paragraph 3.5.5 states, in part, that "Where ground-fault protection is used, the supply shall be … de-energized in less than 1 second if ground-fault current exceeds 20% of the prospective ground-fault current". Therefore, I-Gard recommends that the ground fault trip level be set as low as possible and not higher than 20% when complying with this CSA Mine Safety Standard.

### 6.5 System Frequency

The system frequency setting can be set with DIP switches 11. A system frequency of 50 Hz or 60 Hz can be chosen. Refer to TABLE 6.5 SYSTEM FREQUENCY SETTINGS to determine the DIP switch settings for the application.

### 6.6 NGR Let-Through Current

The NGR let-through current setting can be set with DIP switches 12-16. The SIGMA monitor relay has thirty two settings for the NGR let-through current. Refer to TABLE 6.6 FOR DIP SWITCH SETTINGS for the NGR let-through current.

The NGR let-through current settings in Table 9.6 show that the SIGMA 3 monitor relay can be configured for let-through currents ranging from 5 Amperes through 400 Amperes using a standard I-Gard TxA ZSCS.

The NGR let-through current settings in Table 6.6 are intended to show that the SIGMA 3 monitor relay can be configured for let-through currents ranging from 1 Ampere through 4 Amperes using a standard I-Gard TxA ZSCS with the conductor carrying the NGR current wrapped through the CT's primary window 10 times to create a primary winding of 10 turns.

The SIGMA 3 monitor relay can be configured for let-through currents over 400 Amperes using an I-Gard ZSCS sized for the intended application.

Contact the factory if settings other than those are required in the intended application.

### 6.7 DIP Switch Configurations

DIP SWITCH #1 - MODE (left hand array)

| Mode | Dip Switch Setting |
|---|---|
| Fail-safe (Undervoltage Trip)<br><br>SIGMA 3 Relay is Idle/Not-Tripped:<br>Trip Relay is energized<br>Aux Fault Relays are not energized<br><br>SIGMA 3 Relay is Tripped:<br>Trip Relay is energized<br>Aux Fault Relays are energized | UP |
| Non-fail safe (Shunt Trip)<br><br>SIGMA 3 Relay is Idle/Not-Tripped<br>Trip Relay is not Energized<br>Aux Fault Relays are not energized<br><br>SIGMA 3 Relay is Tripped<br>Trip Relay is Energized<br>Aux Fault Relays are energized | DOWN |

Table 6.1: Trip Relay Operating Mode Setting Dip Switch #1 (left hand array)

## DIP SWITCH #2 - TRIP MEMORY SELECTION (left hand array)

| Trip Memory On/Off | Dip Switch Settings |
|---|---|
| TRIP MEMORY ON<br><br>Control voltage off after trip:<br>When control voltage restored<br>Trip and Aux relays idle* then immediately re-trip (within 2 seconds). | UP |
| TRIP MEMORY OFF<br><br>Control voltage off after trip:<br>When control voltage restored<br>Trip and Aux relays idle* but do not immediately re-trip<br>Trip and Aux relays will re-trip if a fault is detected after monitoring starts. | DOWN |

Table 6.2: Trip Memory Selection Dip Switch #2 (left hand array)

## DIP SWITCH #3,4,5,6,7 - GROUND FAULT TRIP TIME DELAY (left hand array)

(U = Up, D = Down)

| Ground Fault Trip Time Delay (in milliseconds) | Dip Switch Settings | | | | |
|---|---|---|---|---|---|
| | 3 | 4 | 5 | 6 | 7 |
| 60 | D | D | D | D | D |
| 150 | D | D | D | D | U |
| 250 | D | D | D | U | D |
| 350 | D | D | D | U | U |
| 450 | D | D | U | D | D |
| 550 | D | D | U | D | U |
| 650 | D | D | U | U | D |
| 750 | D | D | U | U | U |
| 850 | D | U | D | D | D |
| 950 | D | U | D | D | U |
| 1050 | D | U | D | U | D |
| 1150 | D | U | D | U | U |
| 1250 | D | U | U | D | D |

(U = Up, D = Down)

| | | | | | |
|---|---|---|---|---|---|
| 1350 | D | U | U | D | U |
| 1450 | D | U | U | U | D |
| 1550 | D | U | U | U | U |
| 1650 | U | D | D | D | D |
| 1750 | U | D | D | D | U |
| 1850 | U | D | D | U | D |
| 1950 | U | D | D | U | U |
| 2050 | U | D | U | D | D |
| 2150 | U | D | U | D | U |
| 2250 | U | D | U | U | D |
| 2350 | U | D | U | U | U |
| 2450 | U | U | D | D | D |
| 2550 | U | U | D | D | U |
| 2650 | U | U | D | U | D |
| 2750 | U | U | D | U | U |
| 2850 | U | U | U | D | D |
| 2950 | U | U | U | D | U |
| 3050 | U | U | U | U | D |
| 3150 | U | U | U | U | U |

Table 6.3: Ground Fault Trip Time Delay Settings Dip Switches #3-#4-#5-#6-#7 (left hand array)

## DIP SWITCH #8,9,10 - GROUND FAULT TRIP LEVEL % (left hand array)

(U = Up, D = Down)

| Ground Fault Trip Level (% of NGR Let-Through Current) | Dip Switch Settings | | |
|---|---|---|---|
| | 8 | 9 | 10 |
| 5% | D | D | D |
| 10% | D | D | U |
| 15% | D | U | D |
| 20% | D | U | U |
| 25% | U | D | D |
| 30% | U | D | U |
| 40% | U | U | D |
| 50% | U | U | U |

Table 6.4: Ground Fault Trip Current Level Settings Dip Switches #8 - #9 - #10 (left hand array)

DIP SWITCH #11 - SYSTEM FREQUENCY SELECTION (right hand array)

| System Frequency 50/60 Hz | Dip Switch Setting |
|---|---|
| System Frequency 50 Hz | UP |
| System Frequency 60 Hz | DOWN |

Table 6.5: System Frequency Selection Dip Switch #11 (right hand array)

DIP SWITCH # 12, 13, 14, 15, 16- NGR let-through current (right hand array)

(U = Up, D = Down)

| NGR Let-Through Current (Amps) | Dip Switch Settings | | | | | ZSCS Employed |
|---|---|---|---|---|---|---|
| | 12 | 13 | 14 | 15 | 16 | |
| 1 | D | D | D | D | U | TxA or Rx-yA w/10 Turns Through Primary |
| 2 | D | D | D | U | U | TxA or Rx-yA w/10 Turns Through Primary |
| 3 | D | D | U | D | U | TxA or Rx-yA w/10 Turns Through Primary |
| 4 | D | D | U | U | U | TxA or Rx-yA w/10 Turns Through Primary |
| 5 | D | D | D | D | D | TxA or Rx-yA |
| 10 | D | D | D | D | U | TxA or Rx-yA |
| 15 | D | D | D | U | D | TxA or Rx-yA |
| 20 | D | D | D | U | U | TxA or Rx-yA |
| 25 | D | D | U | D | D | TxA or Rx-yA |
| 30 | D | D | U | D | U | TxA or Rx-yA |
| 35 | D | D | U | U | D | TxA or Rx-yA |
| 40 | D | D | U | U | U | TxA or Rx-yA |
| 45 | D | U | D | D | D | TxA or Rx-yA |
| 50 | D | U | D | D | U | TxA or Rx-yA |
| 55 | D | U | D | U | D | TxA or Rx-yA |
| 60 | D | U | D | U | U | TxA or Rx-yA |
| 65 | D | U | U | D | D | TxA or Rx-yA |
| 70 | D | U | U | D | U | TxA or Rx-yA |

(U = Up, D = Down)

| | | | | | | |
|---|---|---|---|---|---|---|
| 75 | D | U | U | U | D | TxA or Rx-yA |
| 80 | D | U | U | U | U | TxA or Rx-yA |
| 90 | U | D | D | D | U | TxA or Rx-yA |
| 95 | U | D | D | U | D | TxA or Rx-yA |
| 100 | U | D | D | U | U | TxA or Rx-yA |
| 125 | U | D | U | D | D | TxA or Rx-yA |
| 150 | U | D | U | D | U | TxA or Rx-yA |
| 175 | U | D | U | U | D | TxA or Rx-yA |
| 200 | U | D | U | U | U | TxA or Rx-yA |
| 225 | U | U | D | D | D | TxA or Rx-yA |
| 250 | U | U | D | D | U | TxA or Rx-yA |
| 275 | U | U | D | U | D | TxA or Rx-yA |
| 300 | U | U | D | U | U | TxA or Rx-yA |
| 325 | U | U | U | D | D | TxA or Rx-yA |
| 350 | U | U | U | D | U | TxA or Rx-yA |
| 375 | U | U | U | U | D | TxA or Rx-yA |
| 400 | U | U | U | U | U | TxA or Rx-yA |
| 500 | D | U | D | D | U | 10,000:1 |
| 600 | D | U | D | U | U | 10,000:1 |
| 800 | D | U | U | U | U | 10,000:1 |
| 1000 | U | D | D | U | U | 10,000:1 |
| 1250 | U | D | U | D | D | 10,000:1 |
| 1500 | U | D | U | D | U | 10,000:1 |
| 2000 | U | D | U | U | U | 10,000:1 |
| 2250 | U | U | D | D | D | 10,000:1 |
| 2500 | U | U | D | D | U | 10,000:1 |

Table 6.6: NGR Let-Through Current Settings Dip Switches #12-#13-#14-#15-#16 (Right Hand Array)

## Example of a DIP Switch Configuration

For this example's purposes let's consider a Neutral Grounding Resistor (NGR) part number NGR347-5-C which stands for:

NGR: Neutral Grounding Resistor
347: 347 VL-N (Line-to Neutral Voltage), System Voltage VL-L 600 (Line-to-Line Voltage)
5: Rated Current, 5 Amps
C: Continuous Duty

The user is about to configure SIGMA 3 DIP switches according to the particular system; the user is planning to set up fail-safe operating mode, he decides to turn on the Trip Memory toggle, Ground Fault Trip Time Delay will be set at 3150 milliseconds, 5% Ground Fault Trip Level will be set up at 5% (of the NGR let-through current (5% of 5 Amps for this particular example) and frequency system is 60 Hz.

Figure 6.2 shows the correct DIP switch toggles position according to the settings defined by the user.

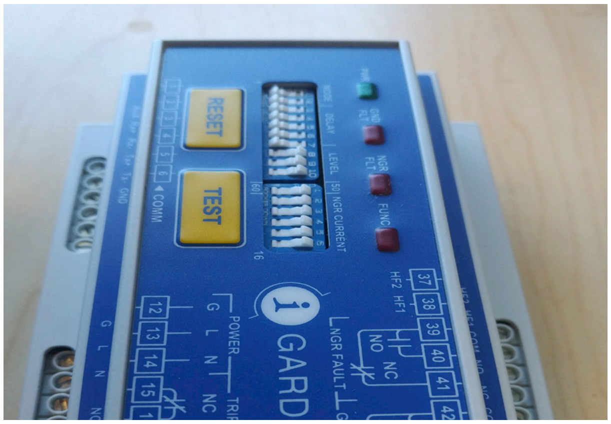



Figure 6.2: SIGMA 3 Dip switch setting example

| Toggle # | | | Toggle Position | Status |
|---|---|---|---|---|
| DIP SWITCH #1 (Left hand array) | Toggle #1 | Operating mode | UP | Fail Safe (Under voltage Trip) |
| | Toggle #2 | Trip Memory | UP | Trip Memory ON |
| | Toggle #3 | Ground Fault Trip Time Delay | UP | 3150 milliseconds |
| | Toggle #4 | Ground Fault Trip Time Delay | UP | |
| | Toggle #5 | Ground Fault Trip Time Delay | UP | |
| | Toggle #6 | Ground Fault Trip Time Delay | UP | |
| | Toggle #7 | Ground Fault Trip Time Delay | UP | |
| | Toggle #8 | Ground Fault Trip Level | DOWN | 5% of the NGR Let-through current setting. For this particular example is 5% of 5 Amps |
| | Toggle #9 | Ground Fault Trip Level | DOWN | |
| | Toggle #10 | Ground Fault Trip Level | DOWN | |
| DIP SWITCH #2 (Right hand array) | Toggle #11 | System Frequency (Hz) | DOWN | 60 Hz |
| | Toggle #12 | NGR Let-through Current (Amps) | DOWN | 5 Amps (NGR Let-through current) |
| | Toggle #13 | NGR Let-through Current (Amps) | DOWN | |
| | Toggle #14 | NGR Let-through Current (Amps) | DOWN | |
| | Toggle #15 | NGR Let-through Current (Amps) | DOWN | |
| | Toggle #16 | NGR Let-through Current (Amps) | DOWN | |

# 7. USE WITH SIGMA 3-TDM TOUCHSCREEN DISPLAY MODULE

The SIGMA 3 can be used with a touchscreen HMI called the SIGMA 3-TDM. The SIGMA 3 is connected to the SIGMA 3-TDM using its MODBUS communication port. The connection of the SIGMA 3 to the SIGMA 3-TDM is shown in Figure 7.1.

The SIGMA 3-TDM touchscreen HMI provides for: display of the status and readings of the SIGMA 3; configuration and operation of pulse contactor settings; viewing of logging and trending data; remote reset of the SIGMA 3; as well as providing TCP/IP communication.

When the SIGMA 3 is connected to the SIGMA 3-TDM the "HOME" screen shown in Figure 7.2 below appears on the SIGMA3-TDM. Navigate to the SYSTEM STATUS screen using the associated button. The screen as shown in Figure 7.3 appears. Here the Fault Current and NGR Voltage can be observed as well as the System Ground Fault and NGR Fault statuses. TEST and RESET can be activated here, as well as pulsing.

Navigate to the "EVENTS LOGGING AND TRENDING PAGE" using the associated button on the home screen. The Logging and Trending page is shown in Figure 7.4 below.

Navigate to the Settings page using the associated button on the home screen. The Settings page is shown in Figure 7.5 below. From here, the SIGMA 3 Settings page can be accessed. Select the system voltage (i.e. L-L Voltage). Pulse frequency can be selected. Settings for the alarm annunciation can be selected here as well.

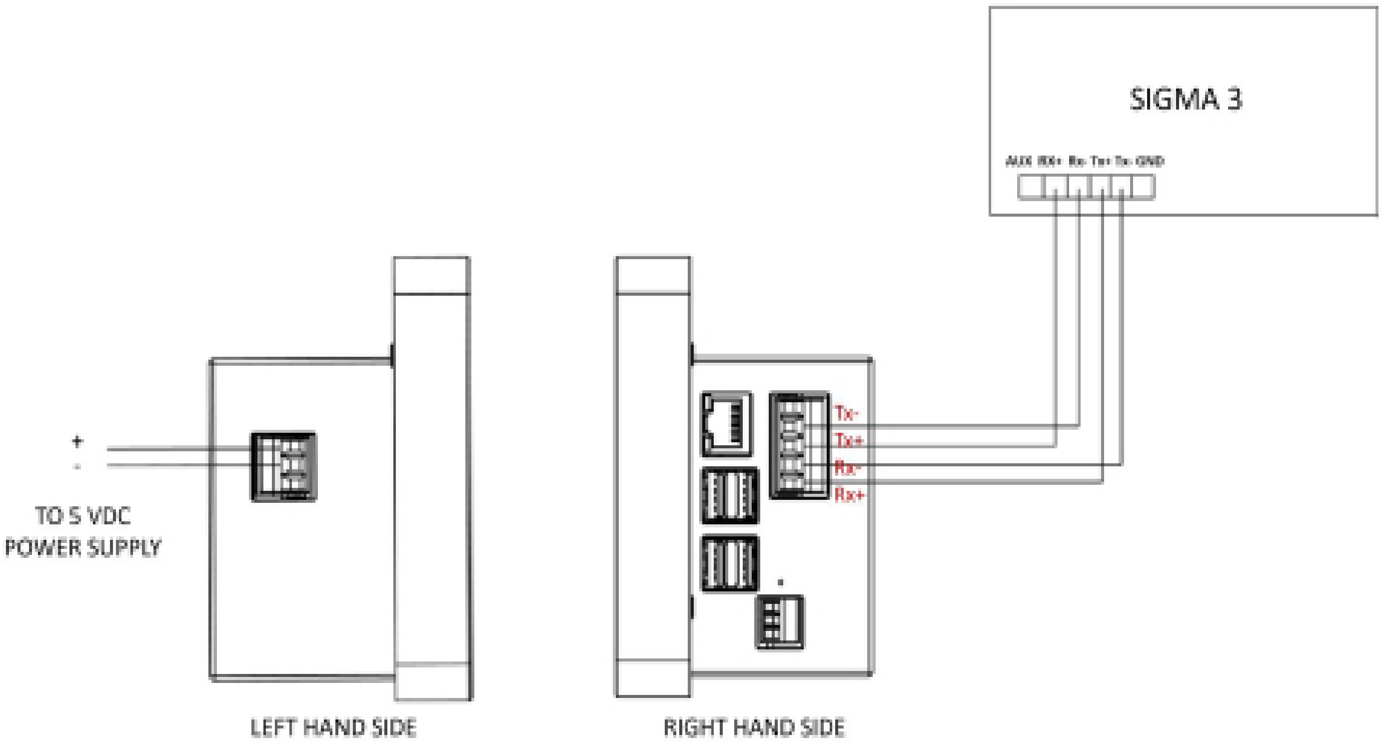



Figure 7.1: SIGMA 3 to SIGMA 3-TDM Connection Diagram


Figure 7.2: Home Screen

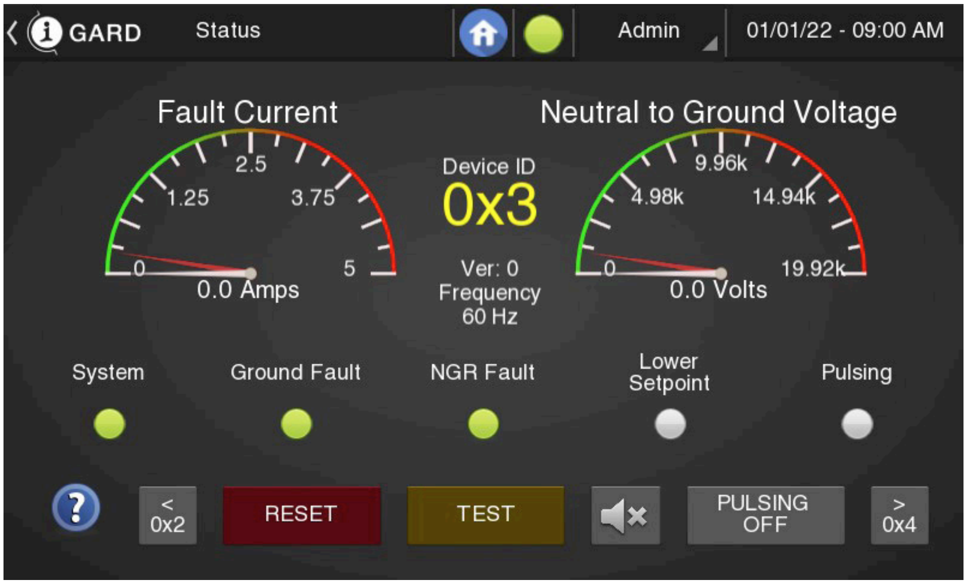



Figure 7.3: Status Screen

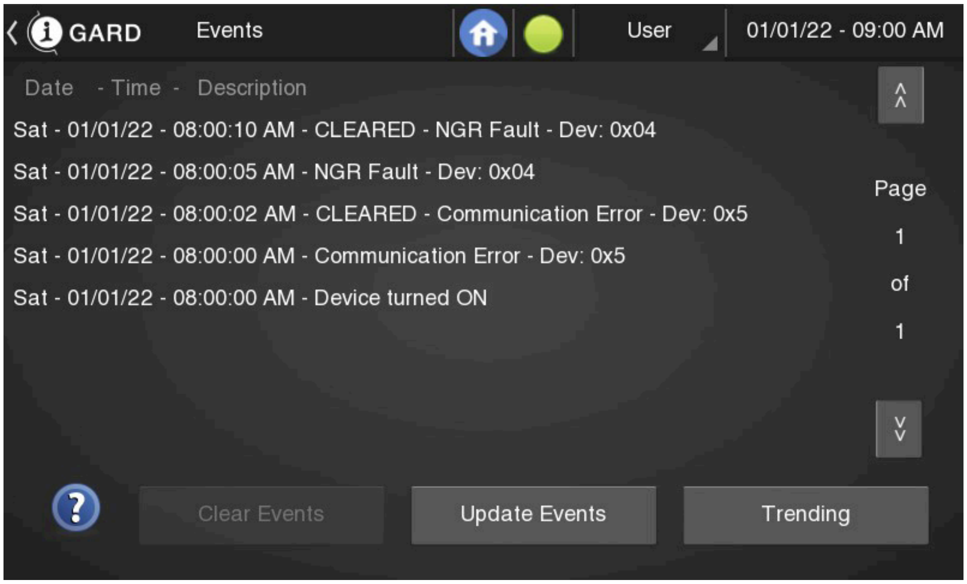



Figure 7.4: Event Log Screen


Figure 7.5: Settings Screen

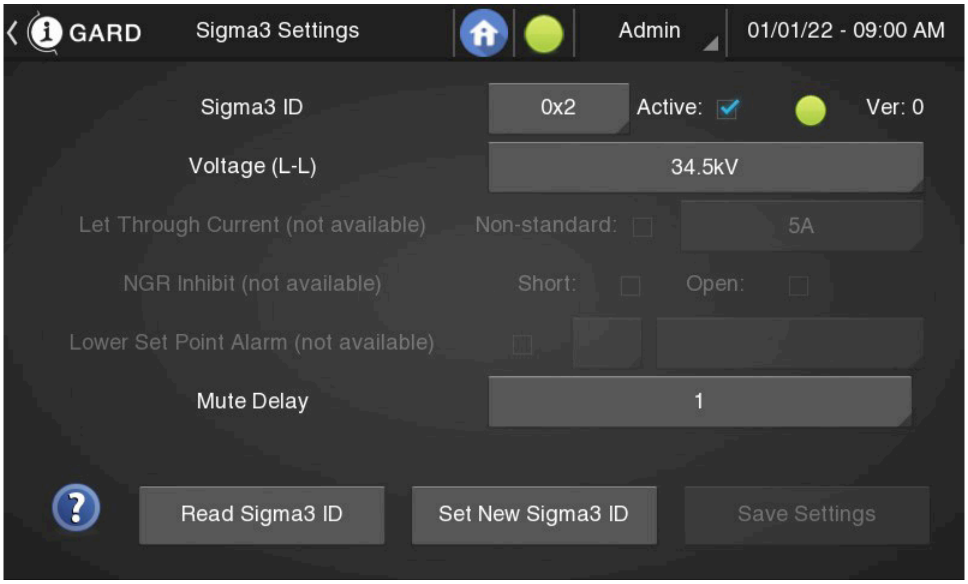



Figure 7.6: SIGMA 3 and Alarm Settings Screen


Figure 7.7: Pulse Contactor Settings Screen

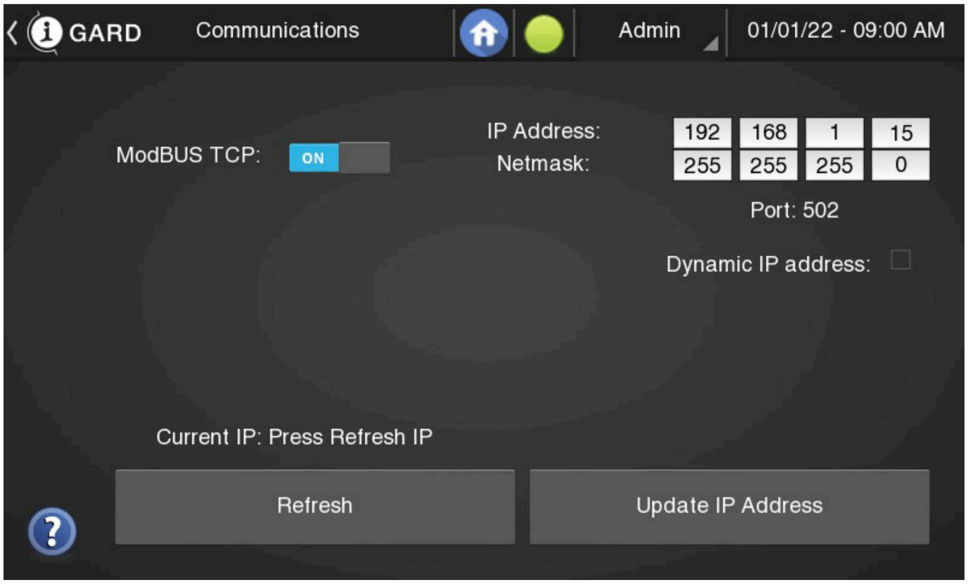



Figure 7.8: Communications Settings Screen

# 8. MODBUS COMMUNICATION

The SIGMA 3 has 4-wire RS-485 communications port to allow communications to a remote terminal or network, a 4-wire RS-485 communications port is provided at the bottom left of the SIGMA 3. The 6-slot terminal block supplied has screw terminals. Terminal # 1 must not be used. Only terminals 2, 3, 4, 5 and 6 are to be used as shown in Figure 8.1 below, with the preferred 4-wire connection in Figure 8.1(a) and the 2-wire connection in Figure 8.1(b). Note that when the SIGMA 3-TDM is being used, communication connections to the system should be made through the SIGMA 3-TDM. This is through the SIGMA 3-TDM TCP/IP communication port.

The protocol supported is MODBUS RTU. The MODBUS I/D number for the SIGMA 3 is not programmable and is set according to the serial number (see Table 8.1 below). The baud rate is not programmable and is set to 38400 BPS. The frame set-up is 8 bit, no parity and 1 stop bit.

The communications cable should ideally be standard 4-wire with two twisted-pairs, and a grounding shield to prevent electromagnetic interference. The shield of the cable between nodes should not be continuously grounded but should be grounded at one end. The cable may be grounded at the SIGMA 3 using the ground connection provided on terminal # 6.

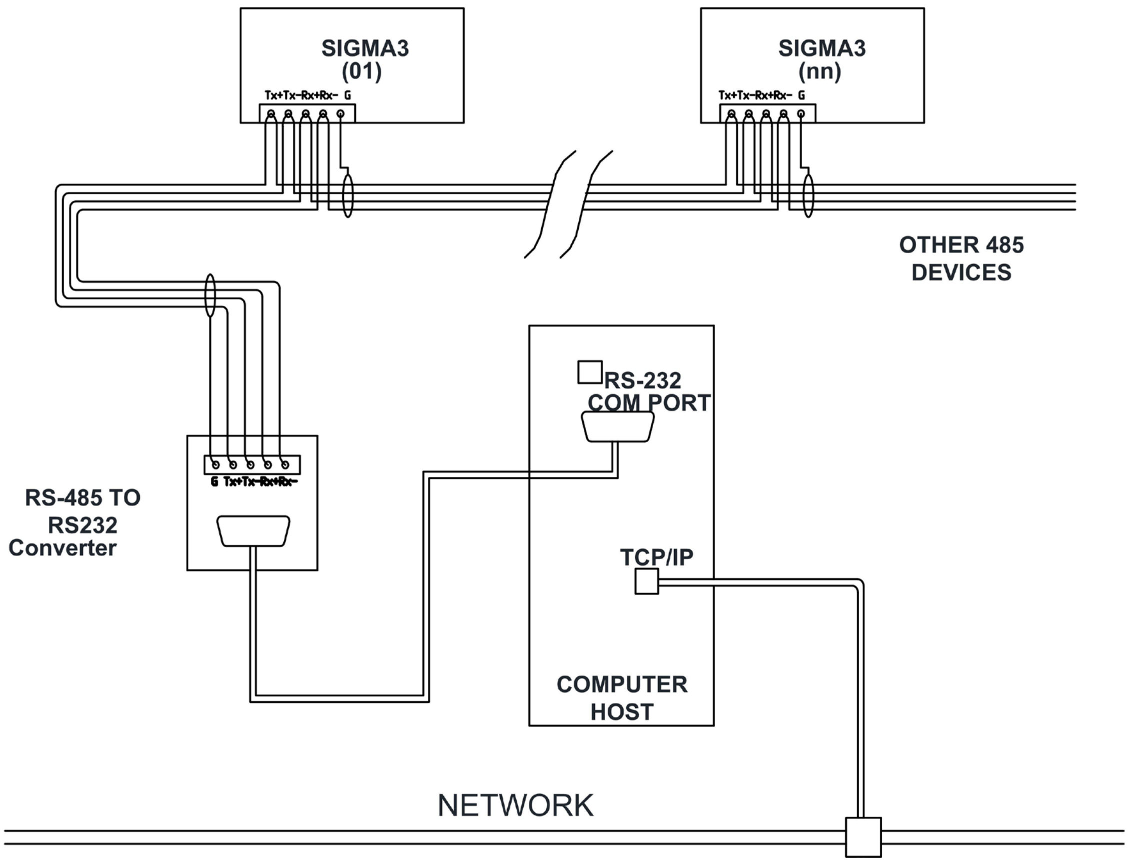



Figure 8.1 (a): Preferred 4-wire MODBUS Communication Connection

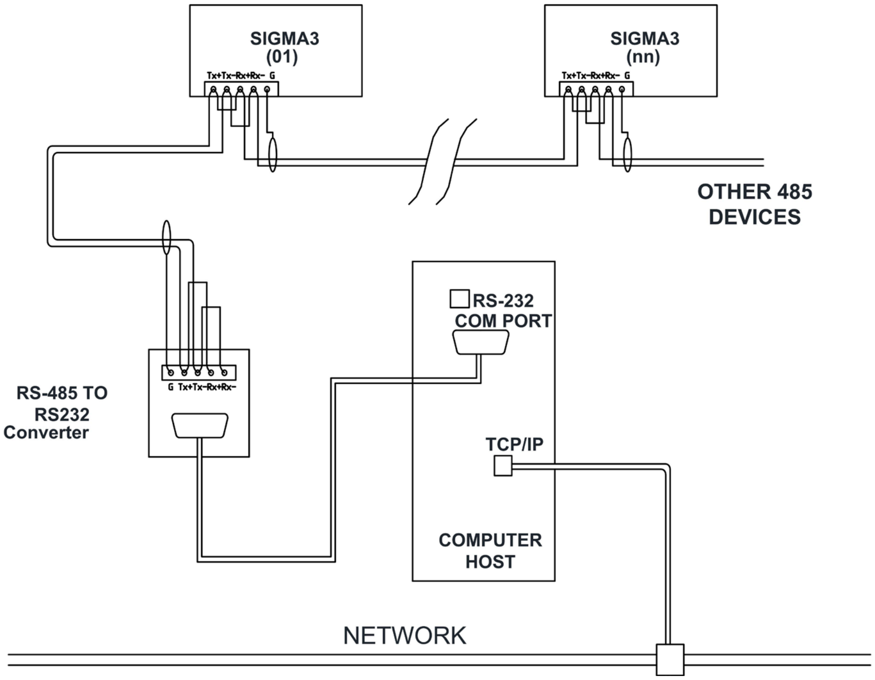



Figure 8.1 (b): Alternate 2-wire MODBUS Communication Connection

## 8.1 MODBUS Functions

One MODBUS function is supported, read holding register (03). The SIGMA 3 provides access to 32 MODBUS registers available. This document summarizes the format and function of these registers. The request from the master is always 8 bytes long and are as shown in the table below. In the MODBUS RTU system the SIGMA 3 operates in a client/server communications model or master/slave communications model. In the client/server communications model the SIGMA 3 is the MODBUS server and will respond to requests sent to it by a MODBUS client. In the master/slave communications model the SIGMA 3 relay is the MODBUS slave and will respond to requests sent to it by a MODBUS master.

| Last Digit of SIGMA 3 Serial Number | MODBUS Slave ID (Hex) |
|---|---|
| XXX0 | 0A |
| XXX1 | 0B |
| XXX2 | 02 |
| XXX3 | 03 |
| XXX4 | 04 |
| XXX5 | 05 |
| XXX6 | 06 |
| XXX7 | 07 |
| XXX8 | 08 |
| XXX9 | 09 |

Table 8.1: MODBUS ID Address Map

The MODBUS requests sent to the MODBUS master or client are 8 bytes long as shown in Table 8.2 below.

| Unit I/D | Function | Starting Address | | No. of Registers Requested | | CRC | |
|---|---|---|---|---|---|---|---|
| | | High | Low | High | Low | High | Low |
| 02 | 03 | nn | nn | nn | nn | cc | cc |

Table 8.2: MODBUS RTU Standard 8 Byte Holding Register Read Function (03)

The data format of the MODBUS registers is nnnnH for four hexadecimal digits, ddddB for four binary digits and ddddddddB for eight binary digits. Numbers above are, for example, a request for 2 registers only, starting from address 02. CRC checksum is a 16 bit CRC as described in MODBUS information.

If successful, the SIGMA 3 will return the message shown in Table 8.3 below.

| Unit I/D | Function | No. of Bytes | | Data 1 | | Data N | | CRC | |
|---|---|---|---|---|---|---|---|---|---|
| | | High | Low | High | Low | High | Low | High | Low |
| 02 | 03 | nn | nn | nn | nn | nn | nn | cc | cc |

Table 8.3: Returned Information Structure for Holding Register Request

Register contents are shown in Tables 8.4 to 8.6 as below.

NOTE: Register number is shown in decimal but must be sent in hexadecimal form in the request.

The MODBUS register number is translated in the request such that register number 40001 is sent as hexadecimal address 0000H, register number 40002 is sent as hexadecimal address 0001H, register number 40003 is sent as hexadecimal address 0002H and so on.

The MODBUS registers can be read using the starting address in a block and the number of registers required up to the number of registers available in a given block.

There are times when the SIGMA 3 relay processor will not be able to respond to a request since it is busy with other tasks and no response will be returned. For this reason it is recommended to request the maximum number of registers used by the system in a single request.

| Register # | Contents | Read/ Write | Function | Description |
|---|---|---|---|---|
| 40026 | nnnnH | R | N to G Voltage | 0-0x1FF (0-511) |
| 40027 | nnnnH | R | Voltage Full Scale | See System Voltage table below (page 24) |
| 40028 | nnnnH | R | Current Full Scale<br>Frequency<br>Trip Level | Bit 4 to Bit 0 – (See Current table, page 24)<br>Bit 5 – Frequency - 0:60Hz/1:50Hz<br>Bit 6 to bit 8 – (See Trip Level table, page 24) |
| 40029 | nnnnH | R | Relay Status | Bit 0 – Main Relay: 0 – OFF / 1 – ON<br>Bit 1 – Ground Fault Relay: 0 – OFF / 1 – ON<br>Bit 2 – NGR Fault Relay: 0 – OFF / 1 – ON |
| 40030 | nnnnH | R | NGR Status | Bit 3-0: GND Fault LED status: 0 – OFF / 1 – ON /3- Flashing Bit 7-4: NGR Fault LED status: 0 – OFF / 1 – ON /3- Flashing |
| 40031 | nnnnH | R | Pulsing Frequency | Bit 4 to Bit 0 – Pulsing frequency - (See Pulsing Frequency table, page 24)<br>Bit 5 – Pulsing Status |
| 40032 | nnnnH | R | Operating Mode | Bit 0 - 0 - Normal Operating / 1 - Calibration |
| 40033 | nnnnH | R | Conductance | 0-0xFFFF – (0-65535) |
| 40034 | nnnnH | R | Open-Circuit Threshold | 0-0xFFFF – (0-65535) |
| 40035 | nnnnH | R | Short-Circuit Threshold | 0-0xFFFF – (0-65535) |
| 40036 | nnnnH | R | Fault Current | 0-0x1FF (0-511) |
| 40037 | nnnnH | R | NGRXS Sensor Zero Drift | 0-0xFFFF – (0-65535) |
| 40038 | nnnnH | R | Low Peak Limitation | 0-0xFFFF – (0-65535) |
| 40039 | nnnnH | R | High Peak Limitation | 0-0xFFFF – (0-65535) |
| 40040 | nnnnH | R | Coupling Impedance | 0-0xFFFF – (0-65535) |
| 40041 | nnnnH | R | Value Fluctuating - Low | 0-0xFFFF – (0-65535) |
| 40042 | nnnnH | R | Value Fluctuating - High | 0-0xFFFF – (0-65535) |

Table 8.4: SIGMA 3 Relay Register Definitions

| System Voltage table | |
|---|---|
| Code | V (L-L) |
| 0x0 | 120 V |
| 0x1 | 240 V |
| 0x2 | 380 V |
| 0x3 | 400 V |
| 0x4 | 415 V |
| 0x5 | 480 V |
| 0x6 | 600 V |
| 0x7 | 690 V |
| 0x8 | 1050 V |
| 0x9 | 2.2 kV |
| 0xA | 2.4 kV |
| 0xB | 3.3 kV |
| 0xC | 4.2 kV |
| 0xD | 6.6 kV |
| 0xE | 7.2 kV |
| 0xF | 11.0 kV |
| 0x10 | 13.8 kV |
| 0x11 | 23.0 kV |
| 0x12 | 34.5 kV |

Table 8.5

| Current table | |
|---|---|
| Code | Amperes |
| 0x0 | 5 A |
| 0x1 | 10 A |
| 0x2 | 15 A |
| 0x3 | 20 A |
| 0x4 | 25 A |
| 0x5 | 30 A |
| 0x6 | 35 A |
| 0x7 | 40 A |
| 0x8 | 45 A |
| 0x9 | 50 A |
| 0xA | 55 A |
| 0xB | 60 A |
| 0xC | 65 A |
| 0xD | 70 A |
| 0xE | 75 A |
| 0xF | 80 A |
| 0x10 | 85 A |
| 0x11 | 90 A |
| 0x12 | 95 A |
| 0x13 | 100 A |
| 0x14 | 125 A |
| 0x15 | 150 A |
| 0x16 | 175 A |
| 0x17 | 200 A |
| 0x18 | 225 A |
| 0x19 | 250 A |
| 0x1A | 275 A |
| 0x1B | 300 A |
| 0x1C | 325 A |
| 0x1D | 350 A |
| 0x1E | 375 A |
| 0x1F | 400 A |

Table 8.6

| Trip Level table | |
|---|---|
| Code | % |
| 0x0 | 5 |
| 0x1 | 10 |
| 0x2 | 15 |
| 0x3 | 20 |
| 0x4 | 25 |
| 0x5 | 30 |
| 0x6 | 40 |
| 0x7 | 50 |

Table 8.7

| Pulsing Frequency table | |
|---|---|
| Code | Frequency Hz |
| 0 | 1.00 |
| 1 | 1.25 |
| 2 | 1.50 |
| 3 | 1.75 |
| 4 | 2.00 |
| 5 | 2.25 |
| 6 | 2.50 |
| 7 | 2.75 |
| 8 | 3.00 |
| 9 | 3.25 |

Table 8.8

Table 8.5: SIGMA 3 System Voltage
Table 8.6: SIGMA 3 Current
Table 8.7: SIGMA 3 Ground Fault Trip Level (%)
Table 8.8: SIGMA 3 Pulsing Frequency table

# 9. INSTALLATION

## 9.1 SIGMA 3

### 9.1.1 Location

The SIGMA 3 monitor relay should be located as close as possible to the system's isolating device, circuit breaker or contactor.

Recommended height to install the SIGMA 3-TDM (Display Module) is between 3 to 5 feet (1-1.5 meters) from the floor to the center of the SIGMA 3-TDM Display which will allow the user to comfortably set up system parameters, to conduct calibration procedure and to take advantage of the SIGMA3-TDM functionality.

### 9.1.2 Mounting

Mount the SIGMA 3 monitor relay horizontally using 35 mm DIN rail bolted or firmly fixed to flat surface. Allow at least 20 mm of rail to extend beyond each end of the relay.
Secure the relay to the DIN rail ensuring the release latches at the bottom of the relay engage the rail. If the relay is to be mounted in any other position take appropriate steps to prevent the relay from disengaging from the DIN rail.

### 9.1.3 Connections

Refer to Figure 9.1 for electrical connections to the SIGMA 3 monitor relay. Terminals on the relay will accept up to #14 AWG wire.

Connect the G terminal on the SIGMA 3 monitor relay to a suitable grounding point. Connect control power to terminals L and N. An isolation transformer is recommended as the source of supply to prevent excessive voltage being applied to the relay's internal power supply.

This grounding point should be electrically common to the grounding point of the NGR.

The SIGMA 3 monitor relay must be grounded as described above. As the relay's housing is non-metallic, no chassis bond is required.

Connect the sensing resistor input terminals on the SIGMA 3 monitor relay to the R terminal of the NGRXS sensing resistor as shown in the connection diagram below.

Connect terminals #47 and #48 on the SIGMA 3 monitor relay to the X1 and X2 terminals of the Zero Sequence Current ensor as shown in the connection diagram below.

Refer to the description of the trip relay operating mode settings for an explanation of the shunt (not fail-safe) and unde-voltage (fail-safe) operating modes and the relay contact states for each of these operating modes. The connection of field devices to the terminals of the SIGMA 3 monitor relay must be as specified in the installation specifications. These include the trip relay terminals, the auxiliary fault relay terminals, the external reset, test and the G/F meter terminals.
If door/panel mounted or remote test and/or reset controls are required, connect momentary single pole single throw (SPST) normally open contact push buttons to the appropriate terminals on the SIGMA 3 monitor relay. Refer to the connection diagram below. These contacts are to be voltage free.

## 9.2 Zero Sequence Current Sensor

### 9.2.1 Location

The ZSCS should be mounted near the system transformer neutral (whether a transformer or a generator) along with the NGRXS sensing resistor and NGR.

### 9.2.2 Mounting

The overall dimensions of the T2A Zero Sequence Current Sensors (ZSCS) are 104 mm x 104 mm x 44 mm. If another size zero sequence current sensor is used please refer to document C-700EM sensors.

9.2.3 Connections

The neutral point of the system is to be connected to the ungrounded end of the neutral grounding resistor such that this conductor passes through the window of the ZSCS.
The secondary terminals, X1 and X2, must be connected to the appropriate terminals on the SIGMA 3 monitor relay as shown in the connection diagram below.

## 9.3. NGRXS-## Sensing Resistor

The NGRXS sensing resistor must be selected from those available from I-Gard and must be one that is designed for use in a system with a system voltage in which it will be installed.

9.3.1 Location

The NGRXS sensing resistor should be mounted near the system transformer, along with the ZSCS and the NGR.

9.3.2 Mounting

The overall dimensions of NGRXS-1 to NGRXS-7 (from 140 to 700 volts) sensing resistor are 89 mm x 65 mm x 71 mm. A metal mounting bracket extends from one side of the housing. The bracket has two 6 mm mounting holes in it through which bolts or self threading screws can be used to mount the 1 to NGRXS-7 sensing resistor to a flat surface. Refer to Figure 11.1.

9.3.3 Connections

The neutral terminal of the NGRXS sensing resistor must be connected to the ungrounded end of the NGR. This is the same connection point as it is connected to the system neutral. Refer to Figure 3.1 or 3.2. The R terminal of the NGRXS sensing resistor must be connected to the appropriate terminal of the SIGMA 3 monitor relay as shown in Figure 3.1 or 3.2. The G terminal of the NGRXS sensing resistor should be connected to a suitable ground point. This grounding point should be separate from the ground path from the NGR so that the ground path from the NGR is monitored as well as the NGR itself.

## 9.4. SIGMA 3-TDM

The SIGMA 3-TDM maximum power supply is 5.25 VDC.
Power supply should not be less than 5 VDC, if that is the case a communication error will show up.
Polarity of the power supply to the SIGMA 3-TDM must be checked before continue on next steps.

MODBUS wiring

| SIGMA 3 | SIGMA 3 - TDM Touchscreen Display Module |
|---|---|
| Rx+ | Tx+ |
| Rx- | Tx- |
| Tx+ | Rx+ |
| Tx- | Rx- |

NOTE: DO NOT connect it to ground

## Summary of Connections to the SIGMA 3 Relay

### 1. Neutral Grounding Resistor (NGR):

Terminal N and NN - Source secondary (X0)
Terminal G - System Ground
Important: Neutral is bonded to ground ONLY through the resistor (NGR)

### 2.- Sensing Resistors:

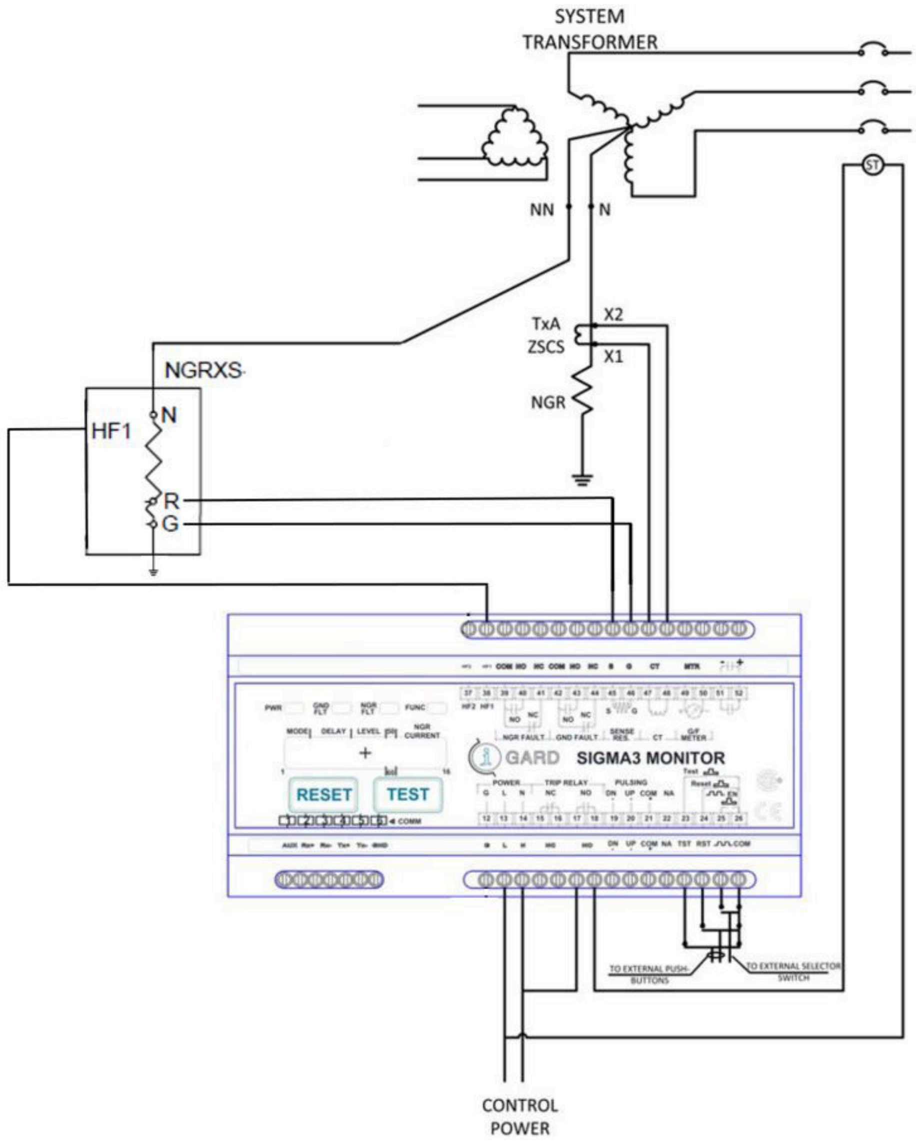
NGRX to Terminal  # 38 - SIGMA 3 HF1
NGRS - Terminal # 45(R) and #46 (G) to SIGMA 3 Terminal #45 and #46
**Important:  These terminals are Polarity Sensitive

### 3.- TxA Zero Sequence Current Sensors:

TxA to SIGMA 3 Terminal #47 and # 48
** Important: These terminals are Non-Polarity Sensitive

### 4. Pulsing (Optional):

Pulsing Down - Terminal #19 (+) and Terminal #21 (-)
Pulsing Up - Terminal #20 (+) and Terminal #21 (-)



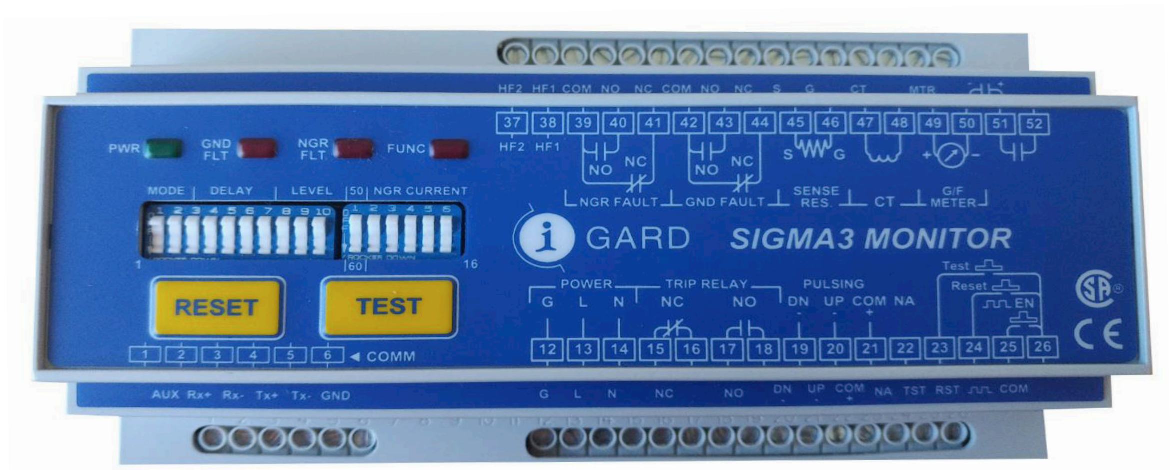


Figure 9.1: SIGMA 3 Terminal Connections

# 10. COMMISSIONING

A general breakdown of commissioning of the SIGMA 3 would involve the following:

- Review of installation and condition of unit
- Verification of connections
- Verification of settings
- Energization of SIGMA 3
- Functional Verifications:
    - Test and Reset
    - Pulsing
    - Communication with the SIGMA 3-TDM
- Current injection (primary or secondary) to verify GND Fault functionality
- NGR short circuit test
- NGR open circuit test
- Energization of system
- Online Calibration (if system zero sequence impedance noticeably changes while online)

## 10.1 NGR Monitoring - Calibration Procedure

The SIGMA 3 relay utilizes three methods to determine if the NGR path is within the required short/open circuit parameters -

### 1) Measurement Mode

Measurement mode continuously monitors the current through the Zero Sequence Current Sensor (ZSCS) and the voltage across the NGR to monitor the condition of the expected impedance between N and G. This method is used when the measured voltage and current across the NGR is 5% or greater of nominal.

i) The relay dip switches (12-16) dictate the maximum available let-through current and correspond to a percentage that must be linearly proportional to the voltage seen across the resistor. Thus, if the dip switches are set to 5A, then 5A represents 100% of the maximum let-through current being dissipated by the NGR.
ii) The voltage across the NGR is normalized by utilizing the NGRXS-XX, where XX represents the line-to-line voltage of the system. If the line-to-line voltage is 600V, then a NGRXS-6 is used. The maximum voltage that can be seen across the NGR is 347V (line-to-neutral voltage), and represents 100% of the maximum voltage seen at the neutral during phase to ground fault condition as a normalized parameter.

For simplicity, we will use an NGR that is rated for a line-to-line voltage of 173.2V and is grounded through a 100A resistor. The line-to-neutral voltage across the resistor in this case is ~100V (173.2V/sqrt(3)). The NGR will have an impedance of 1 Ohm. Plotting the voltage across the resistor with the current through the resistor, it can be shown that there is a linear relationship between voltage and current.


Figure 10.1: NGR Current/Voltage Graph

Limits are then added to this graph for the following:

- 67% change in resistance
- 150% change in resistance
- 300% change in resistance


Figure 10.2: NGR Current/Voltage Graph for various Resistance Values

2) Injection Mode

When there is no voltage or current being measured by the system (less than 5%), the integrity of the resistor can no longer be monitored by using the method described in 1). To accommodate for this scenario, the SIGMA 3 relay actively applies a High Frequency current (HF) through the NGRXS to the resistor to confirm that the resistor is still connected from neutral to ground. The following diagram depicts the current path for $I_{HF}$. The relay must be calibrated for the normalized $I_{HF1}$ as this will vary depending on the system.

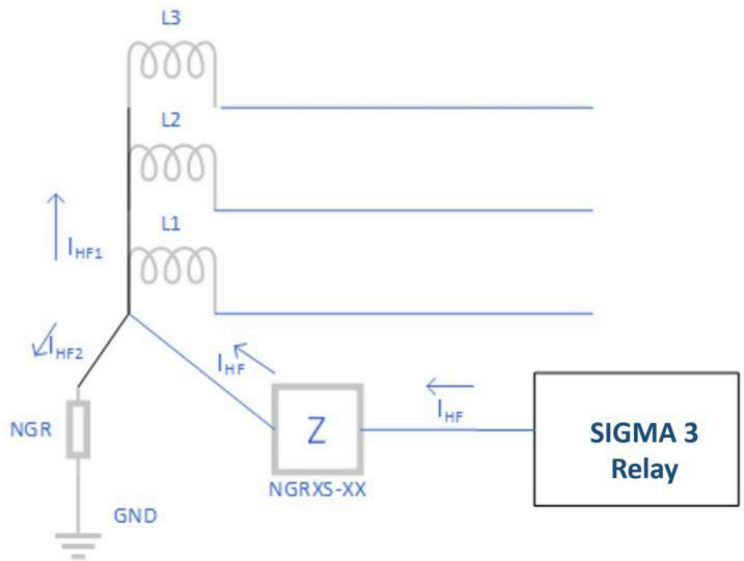



Figure 10.3: High Frequency Injection - Monitoring Integrity of the Resistor

The current $I_{HF}$ is represented by the Conductance Measurement seen on the calibration screen of the TDM. $I_{HF}$ varies with relation to the impedance of the NGR. As the NGR impedance decreases, the $I_{HF}$ increases.

The following depicts the relationship between the Conductance and $I_{HF}$ current.

Once the conductance of the system is known, the limits of the open and short circuit threshold can be set.

- The “Low Peak” must be greater than the “Low Fluctuating Value”.
- The “High Peak” must be greater than the “High Fluctuating Value”.
- The “Conductance Measurement” during normal operation must be greater than the “Open Circuit Threshold”.
- The “Conductance Measurement” during normal operation must be less than the “Short Circuit Threshold”.

3) Revision Mode

Revision mode is considered for NGR integrity monitoring when there may exist a voltage across the NGR but no current. This is typically evident by high fluctuating values, and occurs when some voltage is measured across the neutral but lacks enough current to trigger the Measurement Mode described in 1).

In this case, the following table must be used to dictate a theoretical threshold value:

Once the corresponding theoretical threshold value is identified, the following formula must be fulfilled:

For example, a 480V system will correspond to a conductance of 12000 as the theoretical threshold.

The NGRX Sensor Zero Drift is a user input and must be set to ensure that it falls in line with the nominal online coupling impedance.

### Calibration Procedure using the SIGMA 3-TDM

1. Ensure the SIGMA 3-TDM is connected to the SIGMA 3 as shown in Figure 10.4 below, or refer to the installation section C-EG44-EM

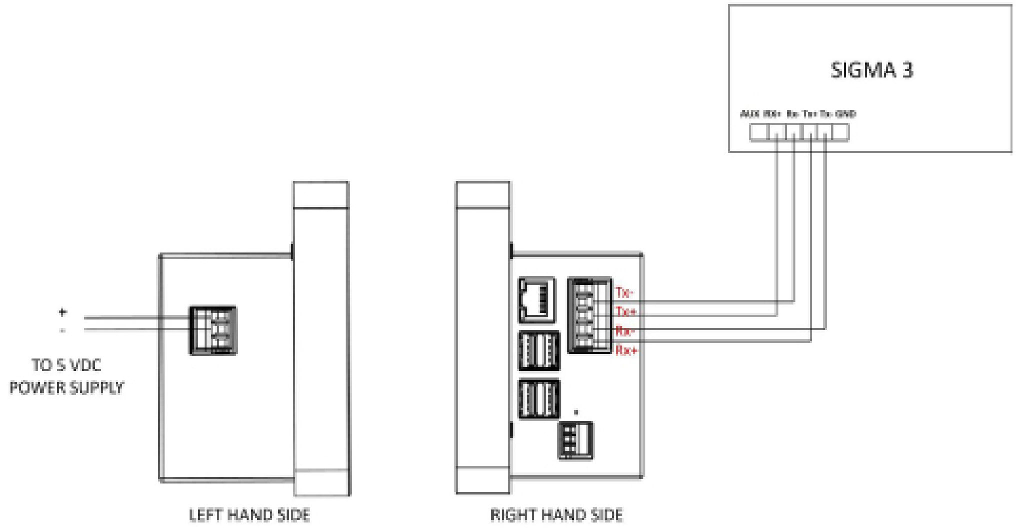



Figure 10.4: SIGMA 3 -TDM to SIGMA 3 connection

2. From the home page, select "Admin" and enter password (default password is 8421), and press "Enter".

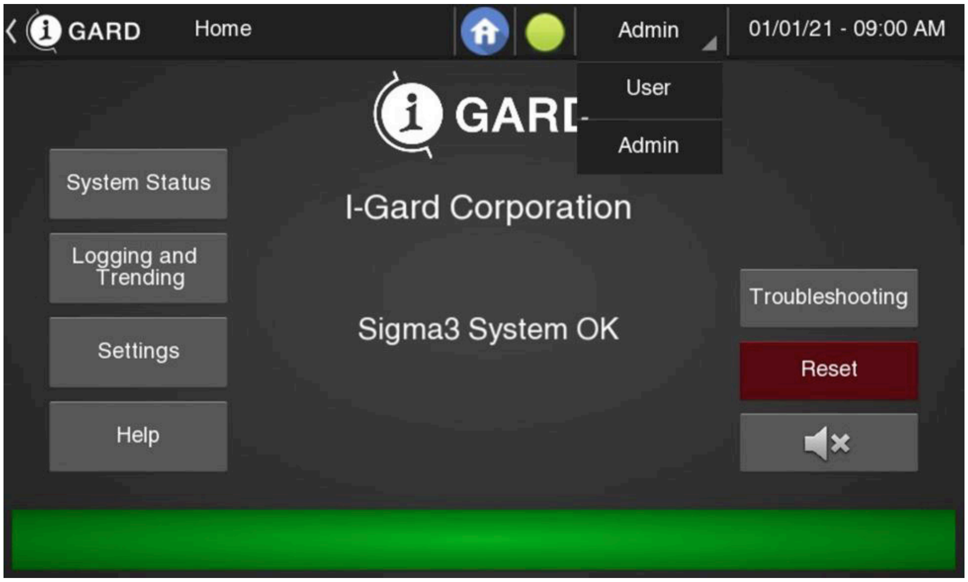



Figure 10.5: SIGMA 3 Home Screen - Admin Mode

3. From Home Screen, select "Settings".


Figure 10.6: SIGMA 3 Home Screen - Settings Tab

4. Select " SIGMA 3 & ALARM SETTINGS".

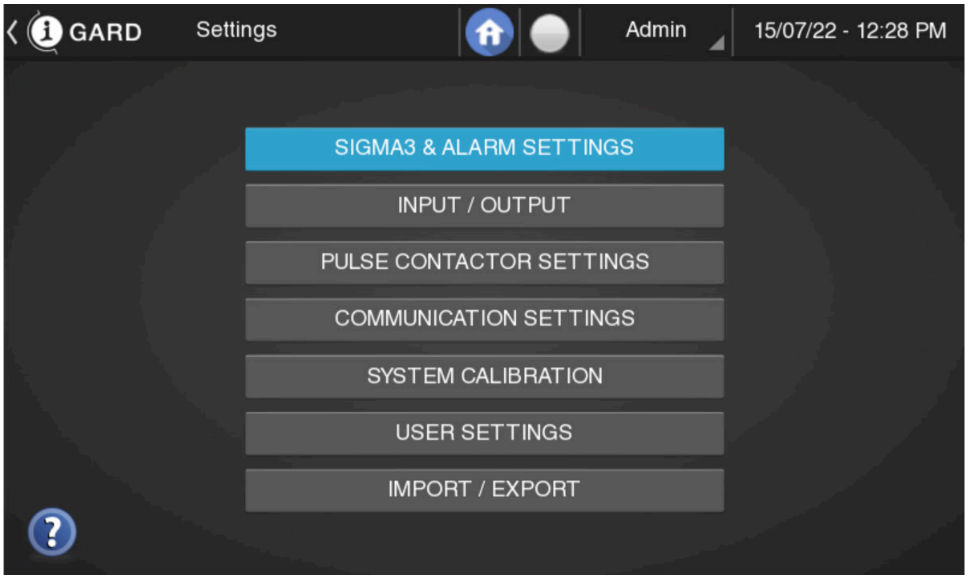



Figure 10.7: SIGMA 3 & Alarm Settings Screen

5. Enter SIGMA 3 ID - this must correspond to the last three digits of the SIGMA 3 serial number (found on the right side of the SIGMA 3 relay). Then check on “Active” box.

6. The RED pilot light will change to GREEN once communication between the SIGMA 3 and the SIGMA 3-TDM has been successfully established.

7. Enter the appropriate System Voltage (L-L) from the available drop down menu.

8. Once complete, "Save Settings", return to the "Home" screen, and press "RESET".

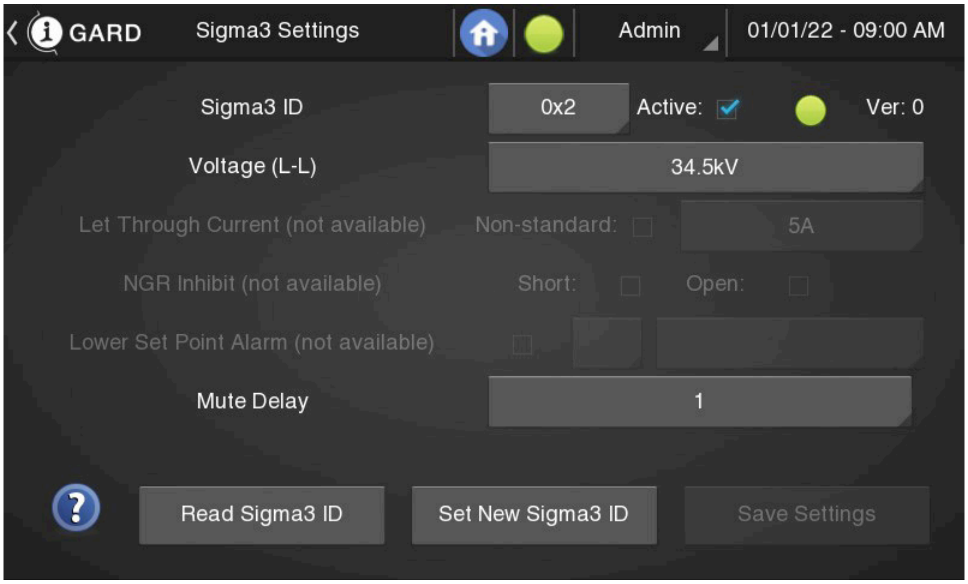



Figure 10.8: SIGMA 3 Home Screen - Admin Mode


Figure 10.9: SIGMA 3 Home Screen - Reset tab

9. Select "Settings" and enter the "SYSTEM CALIBRATION" screen.


Figure 10.10: SIGMA 3 Settings Screen - System Calibration tab

10. Turn "Calibration Mode" ON. Confirm your SIGMA 3 ID is correct and the GREEN pilot light is visible.

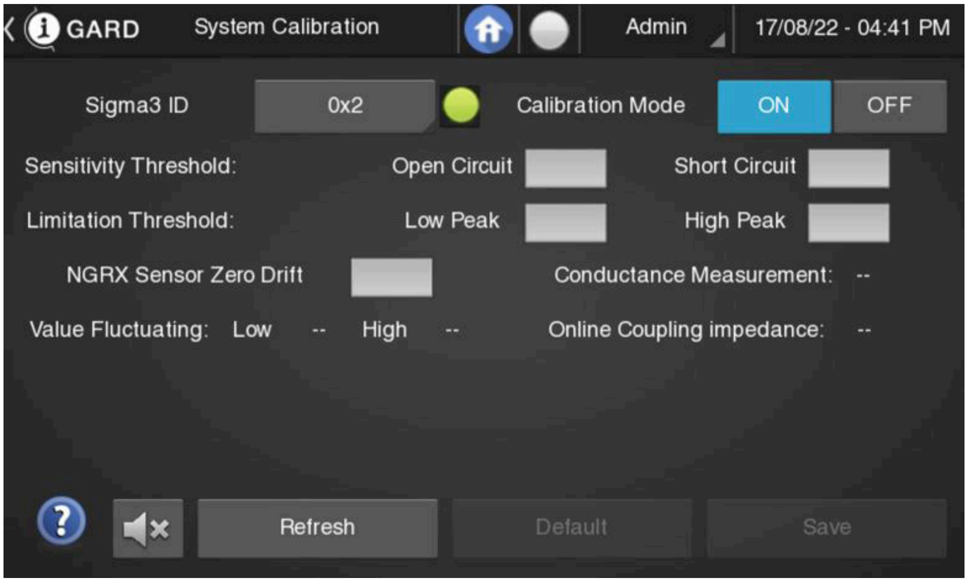



Figure 10.11: SIGMA 3 System Calibration Screen

11. The “System Calibration” screen provides the following:

a. Given Parameters:
- i. Conductance Measurement
- ii. Online Coupling Impedance
- iii. Low Fluctuating Value
- iv. High Fluctuating Value

b. User Inputs:
- i. Open Circuit Threshold
- ii. Short Circuit Threshold
- iii. Low Peak Threshold
- iv. High Peak Threshold
- v. NGRX Sensor Zero Drift

12. Proceed to enter values for the user inputs as per the following instructions:

a. Open/Short Circuit Thresholds are determined by the “Conductance Measurement”.
- i. The Conductance Measurement must be greater than the “Open Circuit Threshold”.
- ii. The Conductance Measurement must be less than the “Short Circuit Threshold”.

| Conductance Measurement | Open Circuit Threshold | Short Circuit Threshold |
|---|---|---|
| 5000 | 2000 | 8000 |
| 6000 | 2500 | 9000 |
| 7000 | 4000 | 10000 |
| 8000 | 4000 | 10500 |
| 9000 | 4000 | 11000 |
| 10000 | 4000 | 12000 |
| 11000 | 4000 | 12500 |
| 12000 | 4000 | 13200 |

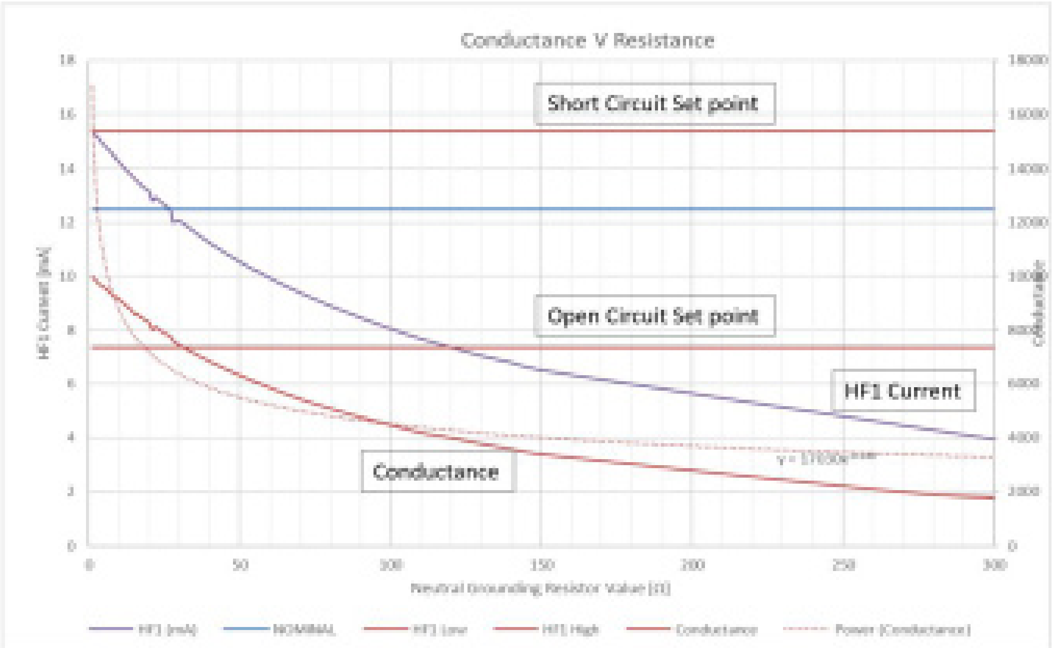



Figure 10.12: Conductance vs Resistance - HF1, Open and Short Circuit

b. Peak Threshold values are determined by the Fluctuating values:

i. "Low Peak Threshold" must be slightly greater than the "Low Fluctuating".

ii. "High Peak Threshold" must be slightly greater than the "High Fluctuating".

c. Press "SAVE".

13. Return to the "Home" screen and press "RESET". Examine the system for approximately 5 minutes until communications have reset and confirm that there is no NGR FLT alarm.

*This is typically enough to finalize calibration. In some cases, there may exist a voltage across the NGR but lacks enough current to trigger measurement mode. This is evident by i) high "Fluctuating Values", and ii) Neutral-Ground Voltage with minimal current, as seen below:


Figure 10.13: SIGMA 3 Status Screen

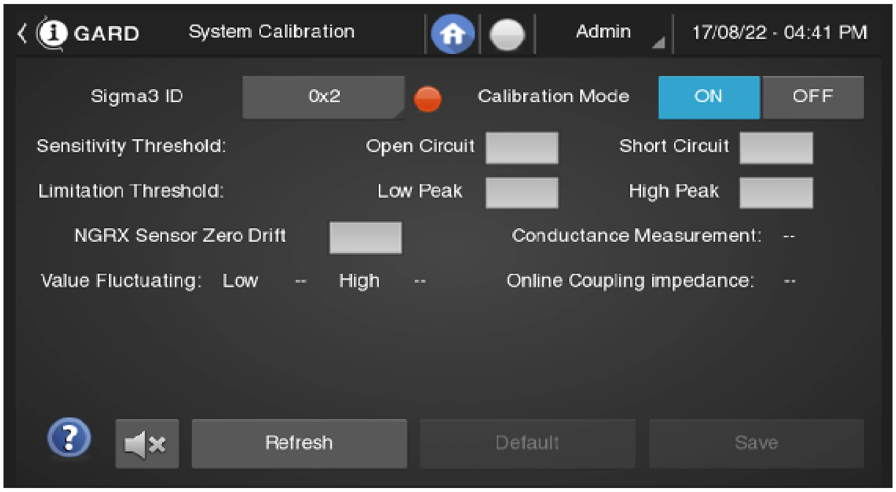



Figure 10.14: SIGMA 3 System Calibration Screen (NGR FLT)

*If an NGR FLT is still seen, continue:

14. The following formula must be fulfilled:

$$\text{Online Coupling Impedance} > [(V_{THEORETICAL} + \text{Zero Drift}) / 255]$$

Where $V_{THEORETICAL}$ can be identified from the following table:

| System Voltage (V) | $V_{THEORETICAL}$ (V) |
|---|---|
| 120 | 24000 |
| 240 | 23000 |
| 380 | 22000 |
| 400 | 21000 |
| 415 | 20000 |
| 480 | 12000 |
| 600 | 12000 |
| 690 | 17000 |
| 1050 | 16000 |
| 2200 | 15500 |
| 2400 | 12000 |
| 3300 | 11800 |
| 4200 | 8000 |
| 6600 | 8000 |
| 7200 | 8000 |
| 11000 | 8000 |
| 13800 | 8000 |
| 23000 | 8000 |
| 34500 | 8000 |

15. Set an appropriate “Zero Drift” value that fulfills the formula above.

16. Press “SAVE”. Return to the “Home” screen and press “RESET”. Examine the system for approximately 5 minutes until communications have reset and confirm that there is no NGR FLT alarm.

## 10.2 Warning Concerning Hi-Pot and Dielectric Testing of the System

As the SIGMA 3 monitor relay, NGRXS sensing resistor and ZSCS have undergone and passed high-pot testing at the factory, field testing of the relay is unnecessary and may damage these components. For any high-pot tests or dielectric withstand tests on the system conducted in the field, the SIGMA monitor relay, NGRXS sensing resistor and ZSCS must be prepared as described below to avoid damaging this equipment.

1) Ensure all control circuits are disconnected and insulated.

2) Disconnect the conductor on terminal R of the NGRXS sensing resistor from the SIGMA 3 monitor relay and ensure the conductor is insulated.

3) Disconnect the conductor on terminal G of the NGRXS sensing resistor from ground and ensure the conductor is insulated.

4) Disconnect the conductors between the X1 and X2 terminals of the ZSCS and the SIGMA 3 monitor relay and ensure these conductors are insulated.

5) Disconnect the control power leads from the SIGMA 3 monitor relay and ensure these conductors are insulated

6) Connect short conductors between the L, N and G terminals of the SIGMA 3 monitor relay ensuring that the G terminal remains connected to ground.

7) Perform the high-pot or dielectric withstand tests required.

8) Reconnect the conductors between the X1 and X2 terminals of the CT and the SIGMA 3 monitor relay.

9) Reconnect the conductor between terminal G of the NGRXS sensing resistor and the appropriate terminal on the SIGMA 3 monitor relay. Refer to Figure 3.1.

10) Reconnect the conductor from the G terminal on the NGRXS sensing resistor to ground.

11) Remove the conductors added between the L, N and G terminals of the SIGMA monitor relay ensuring that the G terminal remains connected to ground.

12) Reconnect the conductor from the R terminal of the NGRXS sensing resistor to the appropriate terminal of the SIGMA 3 monitor relay. Refer to Figure 3.1.

13) Reconnect all control circuits which were disconnected in step 1.

14) Reconnect the control power to the L and N terminals of the SIGMA 3 monitor relay.

# 11. TECHNICAL SPECIFICATIONS

| | | | |
|---|---|---|---|
| Electrical Ratings | Control Power: | 110-240 VAC/DC 50/60 Hz 5 VAC or 5 W DC | |
| | Maximum: | -45% to +10% (60-264 VAC/DC) | |
| Output Relay Contacts | Main Trip Relay: | Type: | Form Z (NO and NC pair) |
| | | Rating: | 10 A@240 VAC, 10 A@30 VDC, 1/2 HP@240 VAC |
| | Auxiliary Ground Fault Relay: | Type: | 1 Form C (NO/NC) |
| | | Rating: | 10 A@240 VAC, 8A@24 VDC, 1/2 HP@240 VAC |
| | Auxiliary NGR Fault Relay: | Type: | 1 Form C (NO/NC) |
| | | Rating: | 10 A@240 VAC, 8A@24 VDC, 1/2 HP@240 VAC |
| | Pulsing NGR Fault Relay: | Type: | 1 Form C (NO/NC) |
| | | Output: | Max: 1 A @ 12 VDC |
| | SIGMA 3 Health Monitoring Relay (Watchdog Relay) | Type: | 1 Form A (NO), Fail-safe Mode |
| | | Rating: | 1 A @ 120 VDC |
| Meter Output | 0-1 mA DC (0-100% of Let-through Current Setting) | | |
| Electrical Tests | Surge test: @ 3 kV Dielectric test: @ 2 kV for 1 minute | | |
| NGR Let-Through Current Settings | 5-400 A | | |
| Ground Fault Trip Settings | Trip Level | 5%, 10%, 15%, 20%, 25%, 30%, 40%, 50% | |
| | Trip Time | 60 - 3150 ms | |
| Operating Modes | * Fail-safe (Under-voltage Trip) / Shunt-trip | | |
| | Trip Memory On / Trip Memory Off | | |
| Frequency | 50 / 60 Hz | | |
| Temperature Range | Operating: -40˚C to +60˚C Storage: -50˚C to +70˚C | | |

All relays are electrically held and are de-energized when control power is OFF.

*Fail-safe: When the fail-safe option is ON, the trip relay is normally energized when control power is ON and is de-energized in a trip state. When in shunt trip mode, the trip relay is normally de-energized when control power is ON and is energized in a trip state.

# 12. DIMENSIONAL DRAWINGS

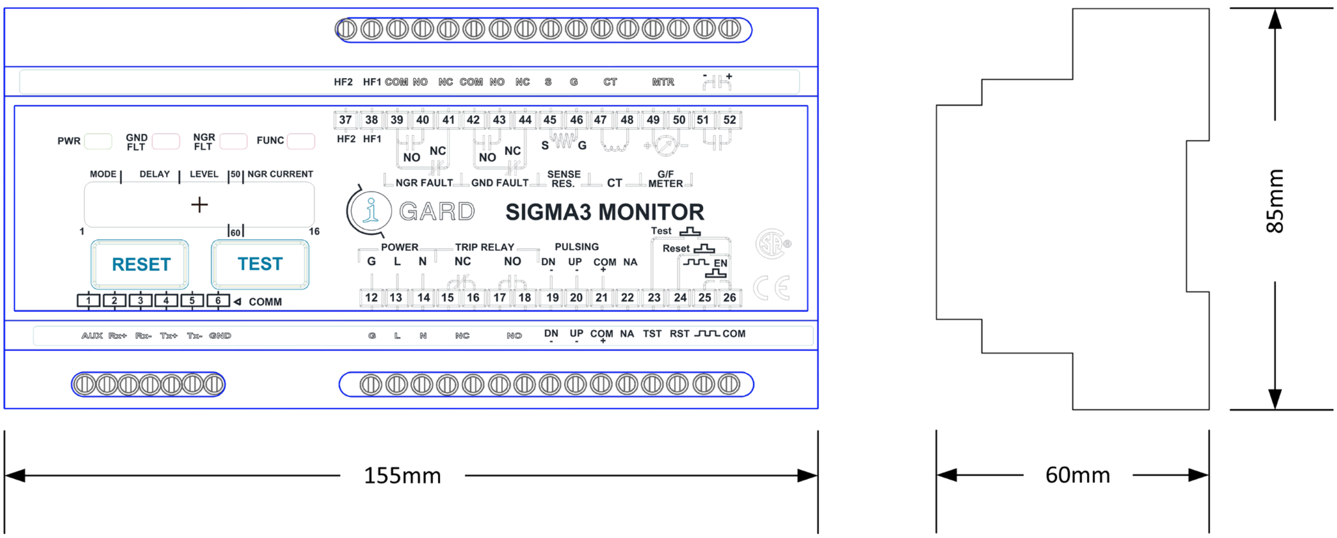



Figure 12.1: SIGMA 3 Dimensional Drawings

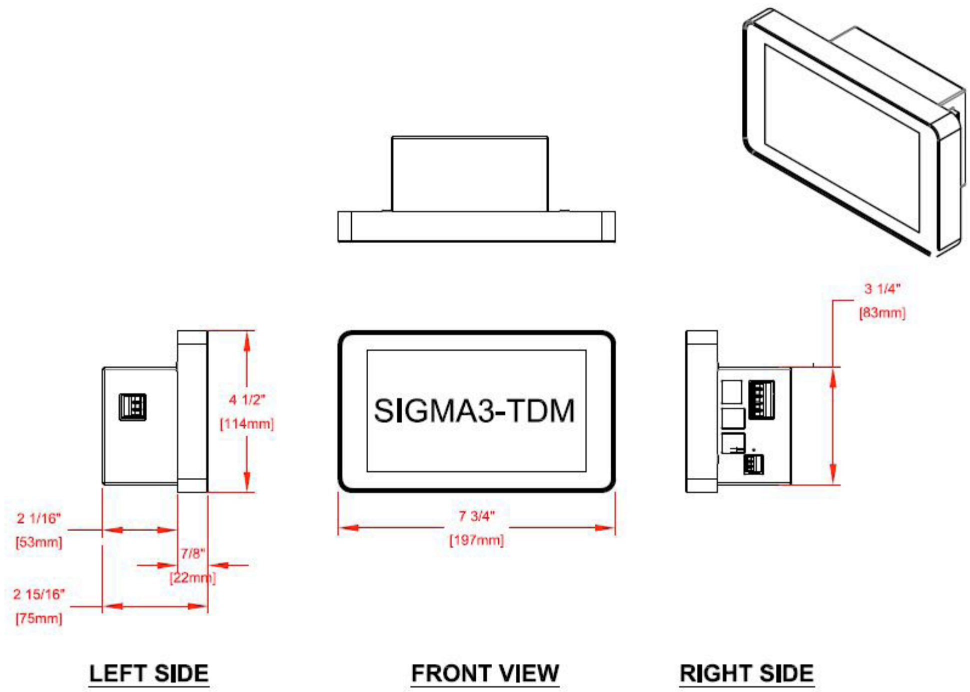



Figure 12.2: SIGMA 3-TDM Dimensional Drawings

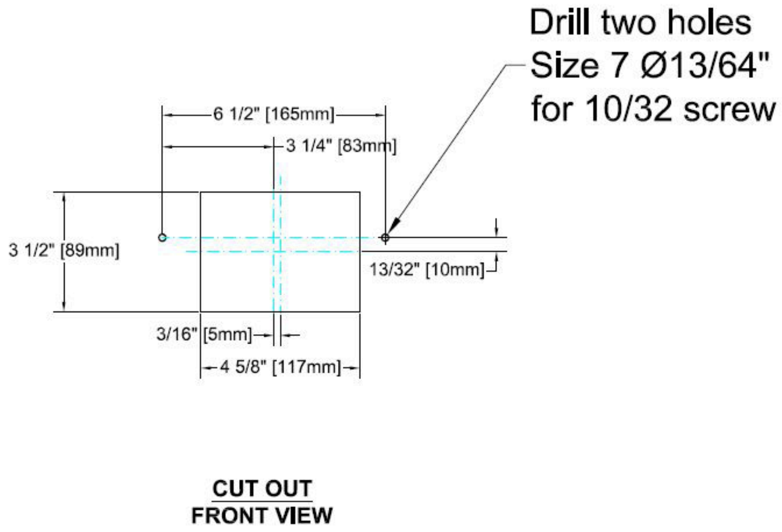



Figure 12.3: SIGMA 3-TDM Mounting Details

Recommended height to install the SIGMA 3-TDM (Display Module) is between 3 to 5 feet (1-1.5 meters) from the floor to the center of the SIGMA 3-TDM Display which will allow the user to comfortably set up system parameters, to conduct calibration procedure and to take advantage of the SIGMA3-TDM functionality.

# 13. PART NUMBERS

SIGMA 3: Ground Fault & Monitoring Relay
SIGMA 3-TDM: Touchscreen Display Module for SIGMA 3 Ground Fault & Monitoring Relay
NGRXS: Sensing Resistor
TxA ZSCS: T2A, T3A, T6A or T9A Zero Sequence Current Sensors.
Rx-yA ZSCS: R4-17A, R7-13A or R8-26A Zero Sequence Current Sensors.

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