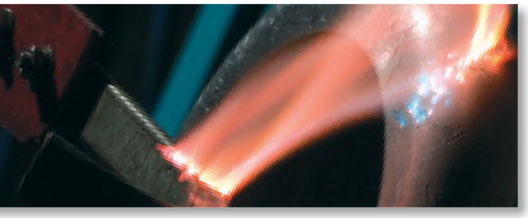
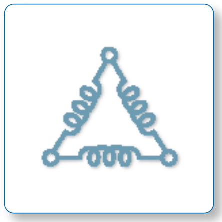
Unparalleled Protection

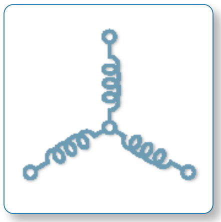
SIGMA 3-C

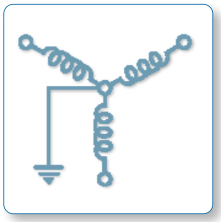
GROUND FAULT & MONITORING RELAY

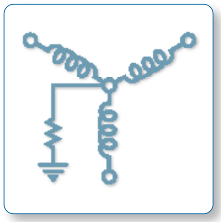
Installation & Operation Manual











C-EG44EM, Manual May 2023

***Applicable for SIGMA 3-C Serial No. 2212 and below**

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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1. INTRODUCTION

The SIGMA3-C is a combination of a ground fault protection and Resistor Path Fault (RPF) monitoring relay that protects systems from ground faults, open or short circuits within the Neutral Grounding Resistor (NGR) as well as in the conductor between the NGR and the source, typically a transformer or generator.

The SIGMA3-C is designed for both High Resistance Grounded systems (5kV or below with fault current limited to 10 amps or less) as well as Low Resistance Grounded systems (5kV or above with fault current above 10 amps and typically time-rated).

There are 4 components in a typical system, the Neutral Grounding Resistor (HRG or LRG), the SIGMA3-C relay, a Zero Sequence Current Sensor (ZSCS) (TXA or RX-YA), and an NGRXS-## sensing resistor.

The SIGMA3-C uses both current and voltage sensors to monitor the health and integrity of the ground path from the X0 source bushing to the ground. The NGRXS-## sensing resistor is used to measure the voltage across the NGR, ZSCS is used to measure the current through the NGR.

2. DESCRIPTION

The SIGMA3-C 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.

The ground fault trip levels and the trip time settings are dip switch selectable or can be configured using SIGMA3-C TDM, a touchscreen interface.

Ground fault current is measured using the ZSCS. The ground fault trip level is DIP switch SW 3 (3, 4, 5) selectable as a percentage of the NGR let-through current setting at 5%, 10%, 15%, 20%, 25%, 30%, 40%, and 50%. Trip time is a DIP switch selectable from 60 milliseconds to 9.3 seconds.

Neutral-to-ground voltage is measured by means of the NGRXS. The NGRXS sensing resistor is used by the SIGMA3-C monitor relay in combination with the ZSCS 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 (2021).

The SIGMA3-C 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.

3. OPERATION

3.1 System Components

The SIGMA3-C 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 ZSCS, which is used to sense the current through the NGR, is an I-Gard type T2A, T3A, TxA, or any Rx-yA ZSCS In addition, the SIGMA3-C 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 SIGMA3-C connections.

Important note: Terminals 39-52 are spare for future development, as well as DI1-DI6 please do not try to use these terminals.

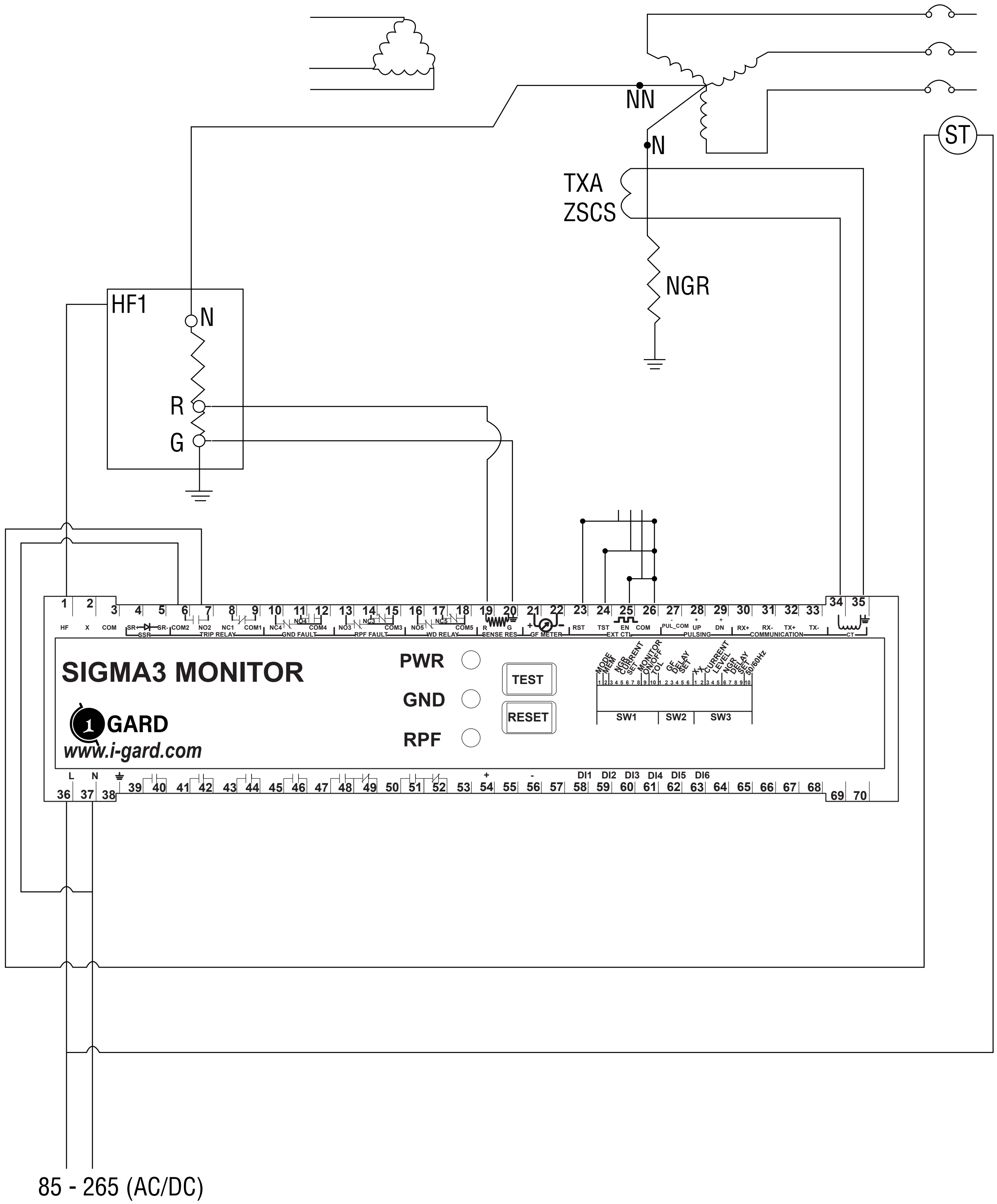


Figure 3.1: SIGMA3-C Typical System Diagram (HRG System)

4. MOUNTING AND CONNECTING THE SIGMA3-C

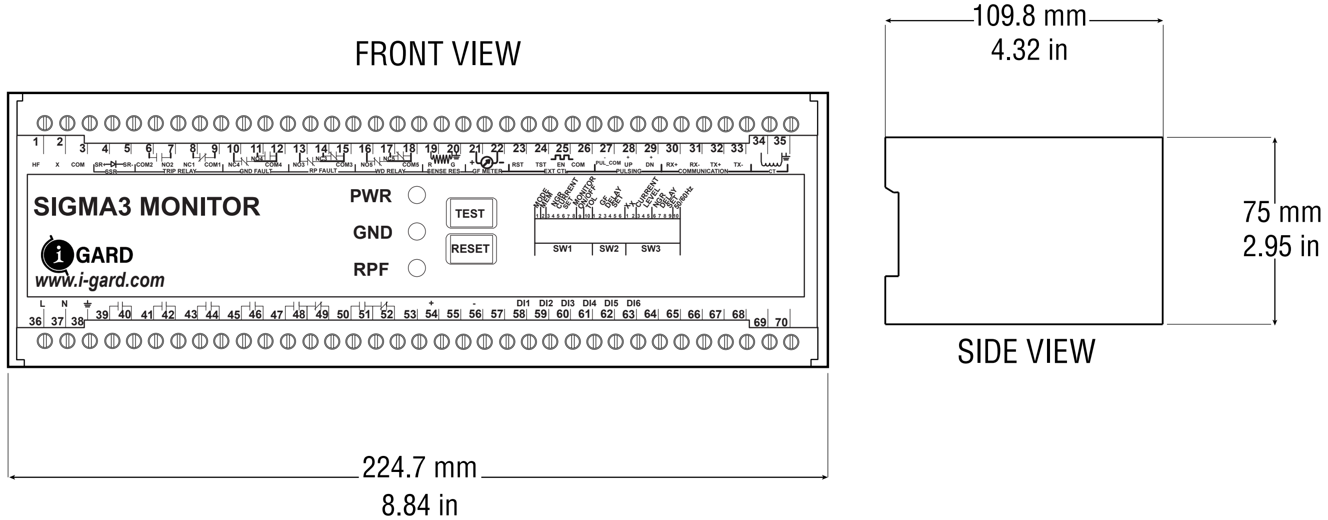


Figure 4.1: SIGMA3-C Dimensional Drawings

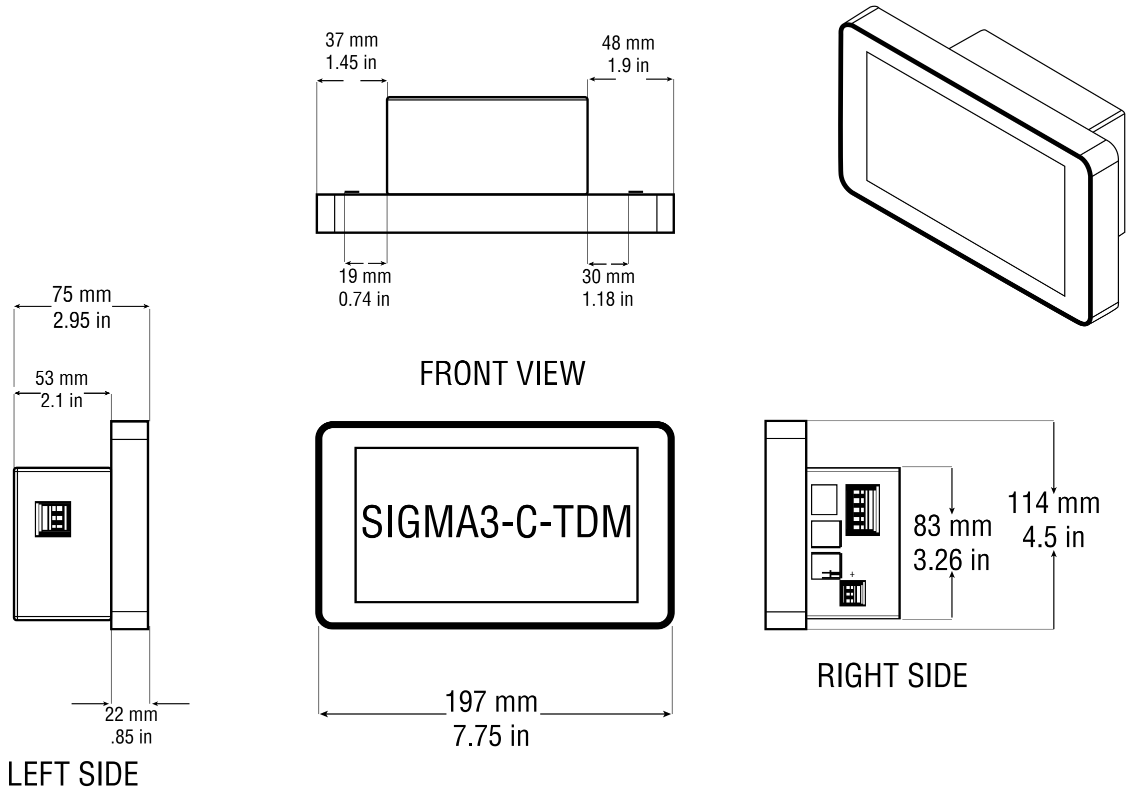


Figure 4.2: SIGMA3-C-TDM Dimensional Drawings

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

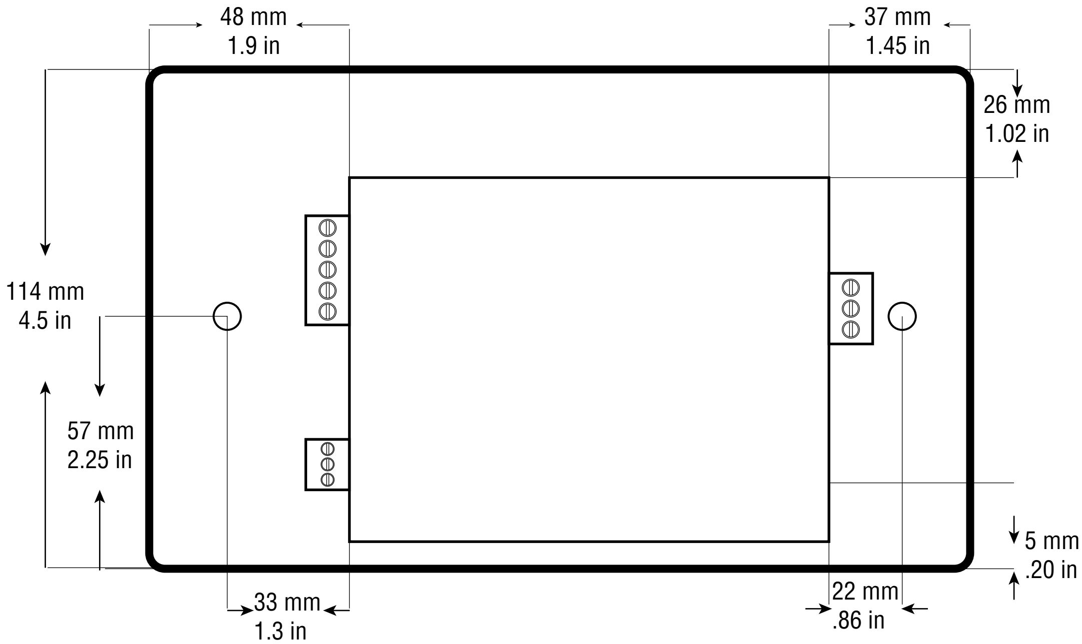


Figure 4.2.1: SIGMA3-C-TDM Dimensional Drawings back side

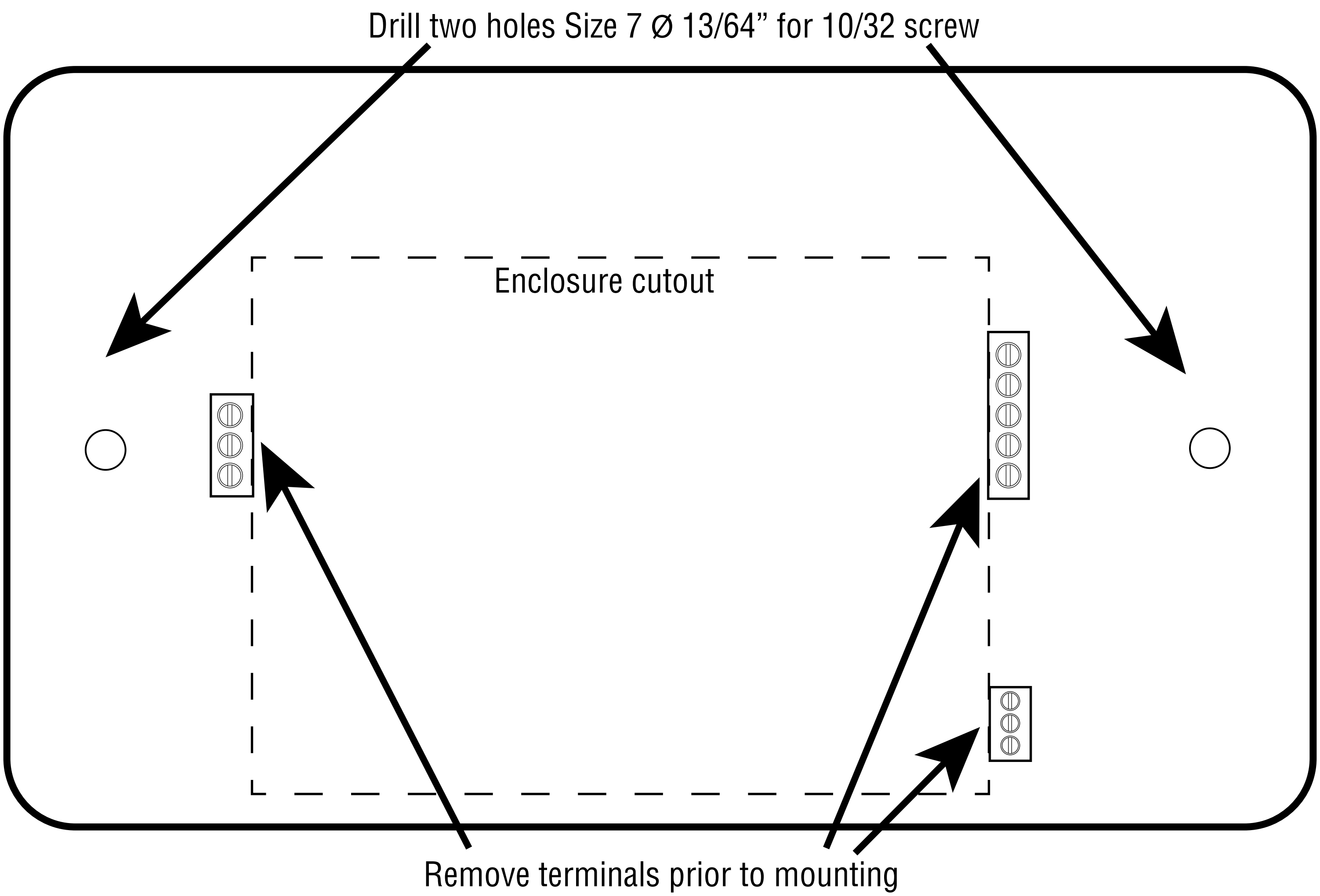


Figure 4.3: SIGMA3-C-TDM Mounting Template real size to cutout

5. SIGMA3-C FUNTIONALITY

The key functionalities of the relay are ground fault detection, pulsing to assist with locating the ground fault, as well as monitoring the integrity of the ground path from the source through the NGR to the ground.

- The trip relay shall change state when a ground fault occurs
- The ground fault relay changes state when a ground fault occurs
- The Resistor Path Fault relay shall change states when an RPF fault occurs and the time delay expires.

1) Ground Fault Detection

The SIGMA3-C monitoring relay detects ground faults by measuring the current through the NGR using the ZSCS (TxA or Rx-yA sensors). When the measured value exceeds the set point the GNDFLT LED illuminates, the GNDFLT form-C contact energizes, and the trip relays energize.

The SIGMA 3-C's NGR let-through current setting is set by DIP switches 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 a DIP switch selectable from its minimum setting of 60 milliseconds to 9.3 seconds.

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 of 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 the Figure below.

-27	28	29
-	+	+
Pulse com	UP	DN

For Relay UP
Connect Pul-com-up

For Relay Down
Connect Pull-com-dn

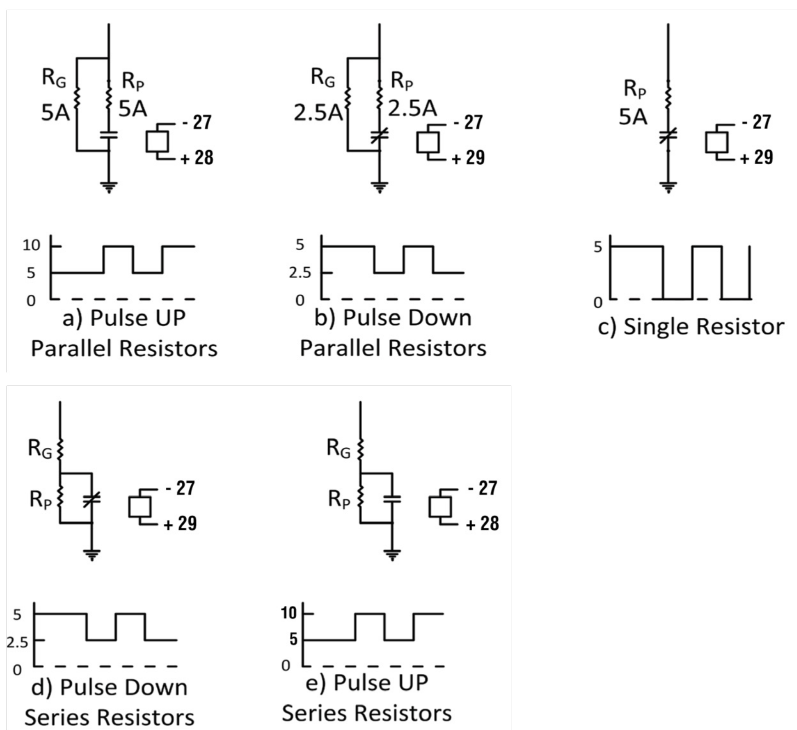


Figure 5.1: The creation of a pulse signature by cycling the let-through current under various arrangements

Pulse signals are available from the SIGMA3-C that can be used to create the fluctuating current signature by driving an N.O. solid state relay that is used as the pulsing contactor. These are available at terminals (27, 28, 29). If pulsing down, use terminals (27, and 29). If pulsing up, use terminals (27, and 28). Terminals (27, and 29) are normally energized with +5.4VDC, and terminals (27, and 28) are normally de-energized. When pulsing is enabled by closing terminals (25, and 26) or by using the SIGMA3-C - TDM touchscreen HMI, where the pulse signals cycle at a frequency of 1Hz. The cycle frequency can be changed using the SIGMA3 - TDM touchscreen HMI.

5.1 RPF Monitoring

The SIGMA 3-C relay monitors the health of the ground path from the X0 bushing through the NGR to the ground to identify an open or short circuit condition. If the SIGMA 3-C determines that this path is not healthy, the RPF LED illuminates, the RPF form-C contact energizes, and the trip relays energize.

The SIGMA 3-C monitor relay monitors the integrity of the path to the ground using one of two methods: measurement mode and injection mode.

1)Measurement mode

If the leakage current through the NGR is over 5% of the rated let-through current, the SIGMA 3-C 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-C 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-C annunciates an RPF.

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 SIGMA3-C relay actively applies a High-Frequency current 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_{HF} as this will vary depending on the system.

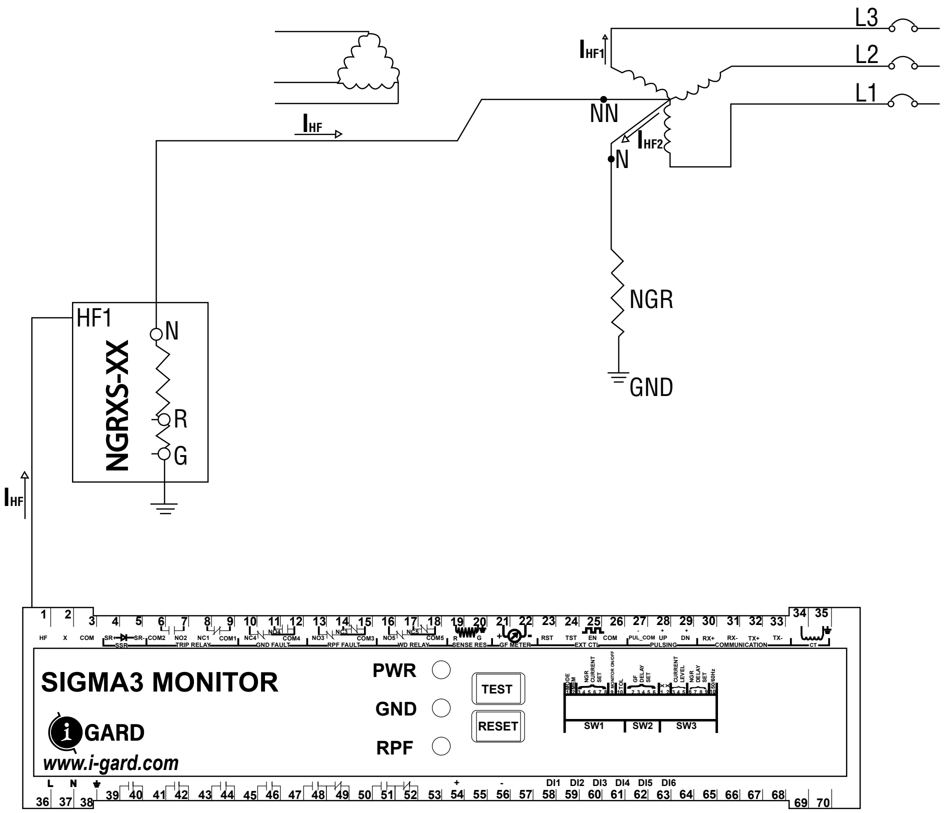


Figure 5.2: High Frequency Injection - Monitoring Integrity of the Resistor

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

Injection mode also accommodates conditions where a voltage may exist across the NGR but without current. This is 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 such cases, the following formula must be fulfilled to adjust the system sensitivity accordingly:

Online Coupling Impedance > [(Zero Drift) / 255], where NGRX Sensor Zero Drift is a user input

Once the conductance of the system is known, the limits of the open and short circuit threshold can be set. (Figure 5.3)

- 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”.

*Note: The values shown in the following images are scalar.

Figure 5.3: SIGMA3-C-TDM example of Healthy System

Online Calibration Procedure using the SIGMA3-C-TDM is only required if RPF monitoring is enabled.

1. Ensure the SIGMA3-C-TDM is connected to the SIGMA3-C as shown in Figure 10.4 or 10.1.1 below, or refer to the installation section C-EG44-E

Figure 5.4.1: SIGMA3-C-TDM to SIGMA3-C connection with only Ix Cable preferred method

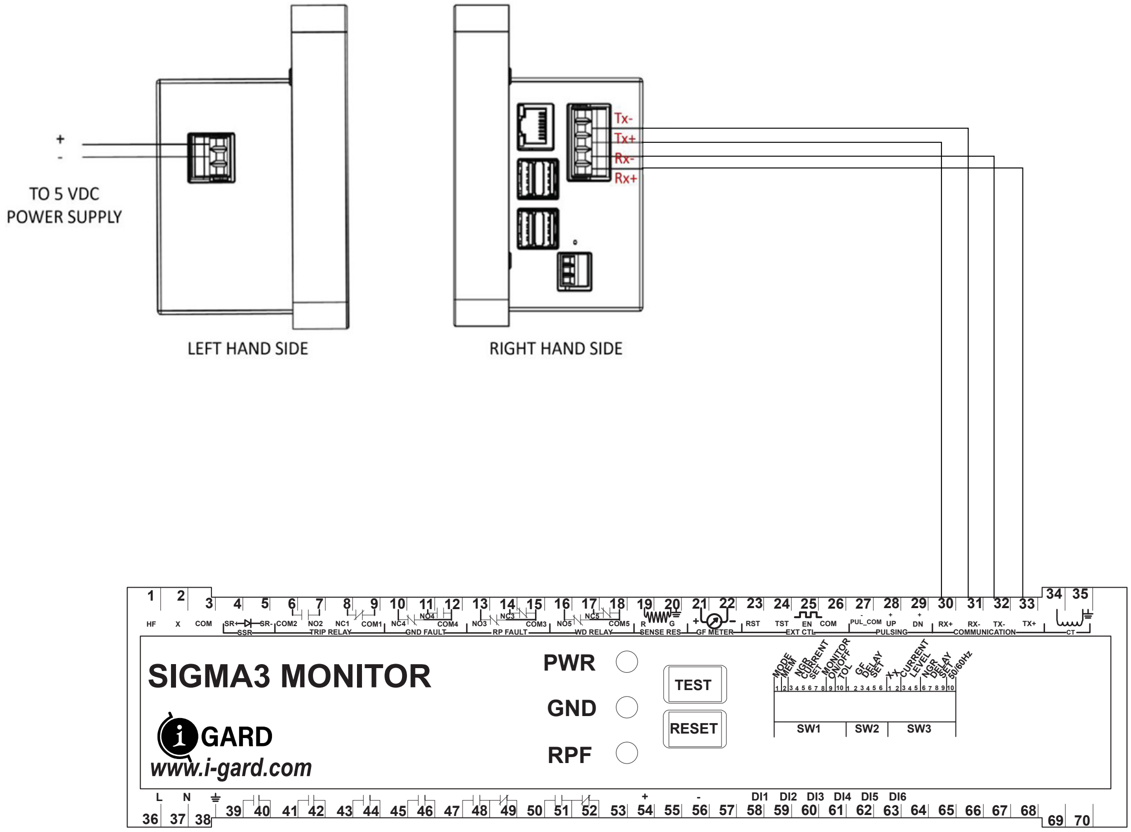


Figure 5.3: SIGMA3-C-TDM to SIGMA3-C connection

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

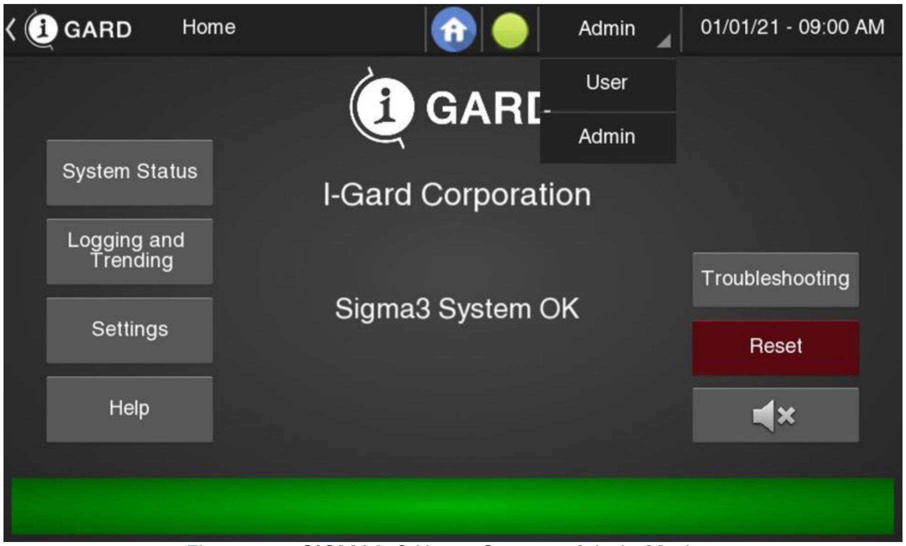


Figure 5.5: SIGMA3-C Home Screen - Admin Mode

3. From Home Screen, select "Settings".

Figure 5.6: SIGMA3-C Home Screen - Settings Tab

4. Select " SIGMA 3 & ALARM SETTINGS".

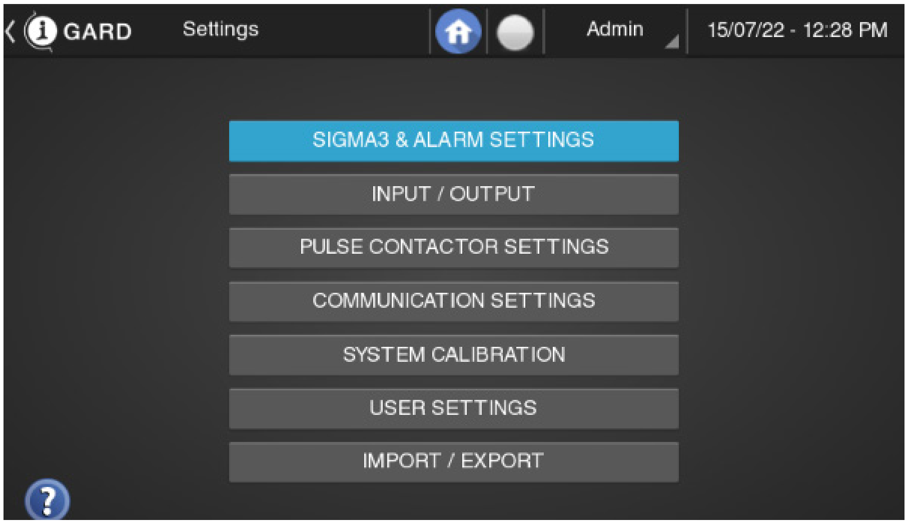


Figure 5.7: SIGMA3-C & Alarm Settings Screen

5. Enter SIGMA3-C ID - this must correspond to the last digit of the SIGMA3-C serial number (found on the right side of the SIGMA3-C relay). Then check on the “Active” box.

6. The RED pilot light will change to GREEN once communication between the SIGMA3-C and the SIGMA3-C-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".

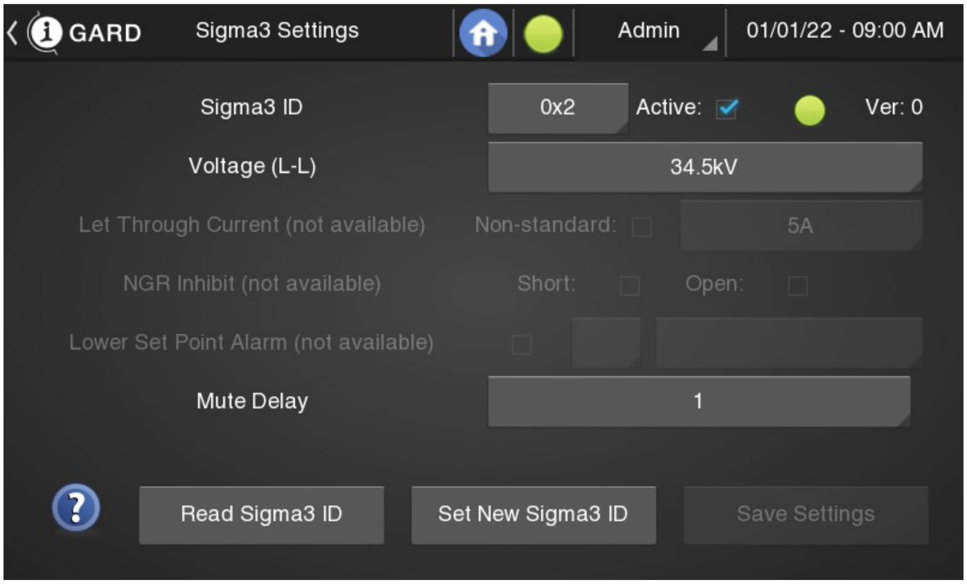


Figure 5.8: SIGMA3-C Home Screen - Admin Mode

Figure 5.9: SIGMA3-C Home Screen - Reset tab

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

Figure 5.10: SIGMA3-C 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 5.11: SIGMA3-C System Calibration Screen

*Note: The parameters are shown either green or red, if it is shown red please check the calibration values.

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
- v. CT Current

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

Table 5.1: SIGMA3-C Conductance Measurement open/short circuit reference table

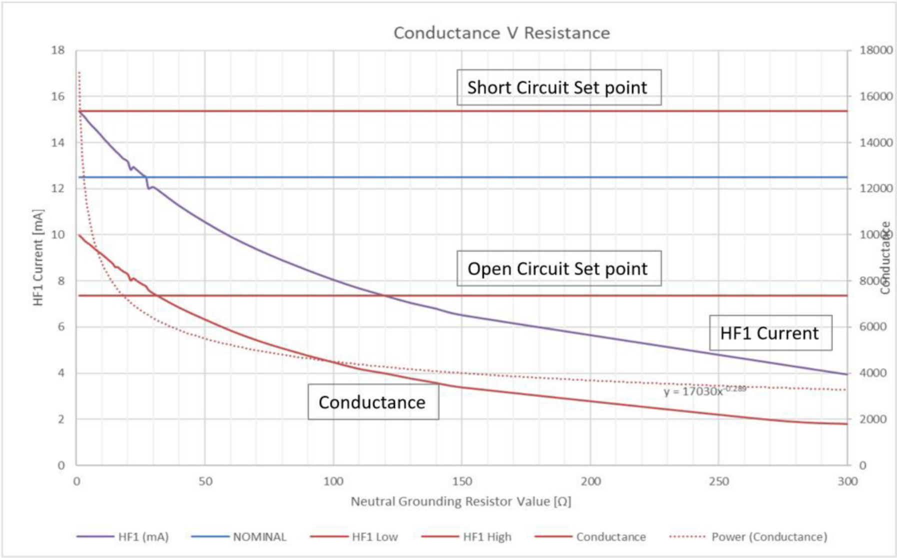


Figure 5.12: Conductance vs Resistance - HF1, Open and Short Circuit

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 RPF 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:

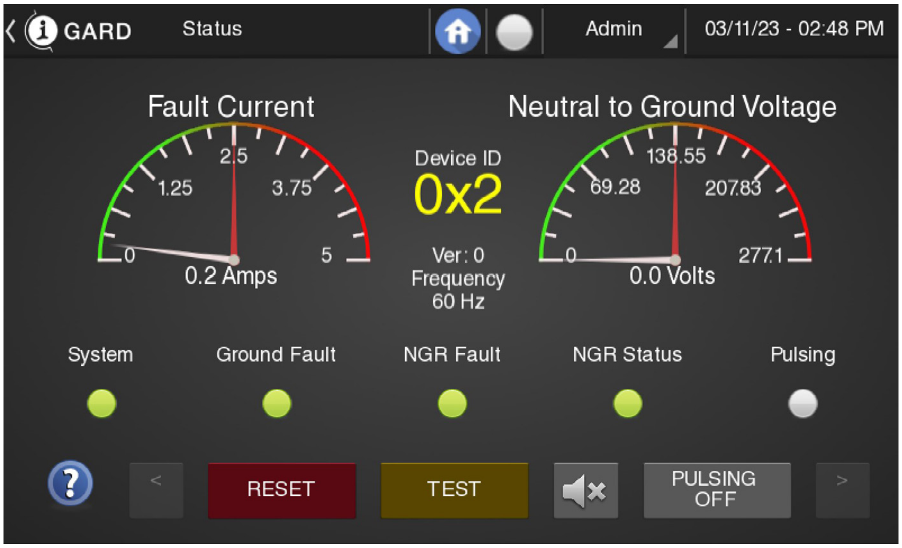


Figure 5.13: SIGMA3-C Status Screen

Figure 5.14: SIGMA3-C System Calibration Screen (RPF)

*If an RPF is still seen, continue:

14. The following formula must be fulfilled:

Online Coupling Impedance > [(Zero Drift) / 255]

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 RPF alarm.

If the problem not resolved, please contact us for remote support.

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

As the SIGMA3-C 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 SIGMA3-C 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 SIGMA3-C monitor relay and ensure the conductor is insulated.

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

4) Disconnect the conductors between the X1 and X2 terminals of the ZSCS and the SIGMA3-C monitor relay and ensure these conductors are insulated.

5) Disconnect the control power leads from the SIGMA3-C monitor relay and ensure these conductors are insulated.

6) Connect short conductors between the L, N, and G terminals of the SIGMA3-C monitor relay ensuring that the G terminal remains connected to the ground.

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

8) Reconnect the conductors between the X1 and X2 terminals of the ZSCS and the SIGMA3-C monitor relay.

9) Reconnect the conductor between terminal G of the NGRXS sensing resistor and the appropriate terminal on the SIGMA3-C monitor relay. Refer to Figure 3.1.

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

11) Remove the conductors added between the L, N, and G terminals of the SIGMA3-C monitor relay ensuring that the G terminal remains connected to the ground.

12) Reconnect the conductor from the R terminal of the NGRXS sensing resistor to the appropriate terminal of the SIGMA3-C monitor relay. Refer to Figure 3.1.

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

14) Reconnect the control power to the L and N terminals of the SIGMA3-C monitor relay.

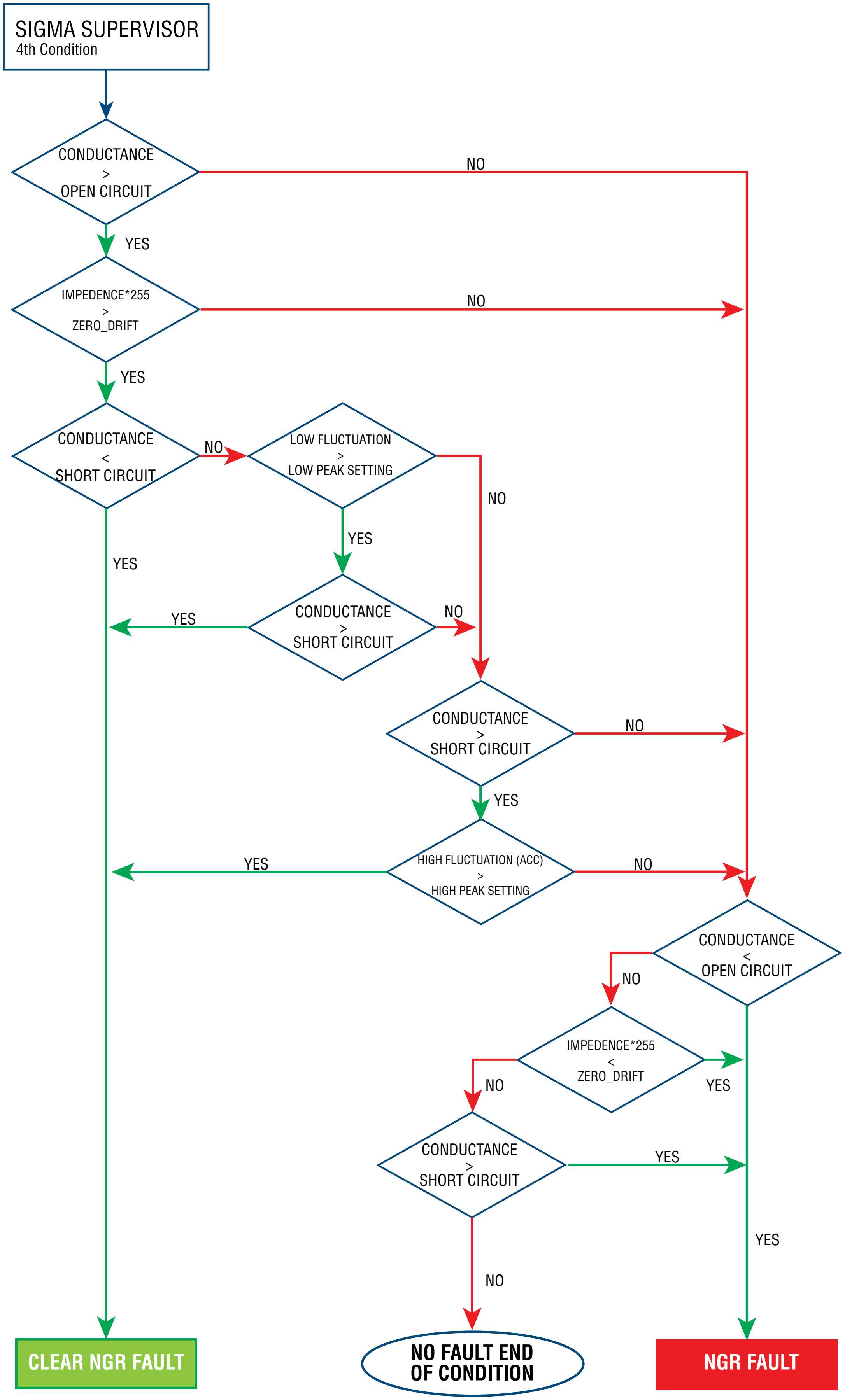


Figure 5.15: SIGMA3-C Calibration Flow Chart

6. TRIP RELAY AND CONTACTORS

The SIGMA3-C has four output relays:

- A TRIP relay
- A Ground Path 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 SIGMA3-C. 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 SW1, SW2, and SW3.

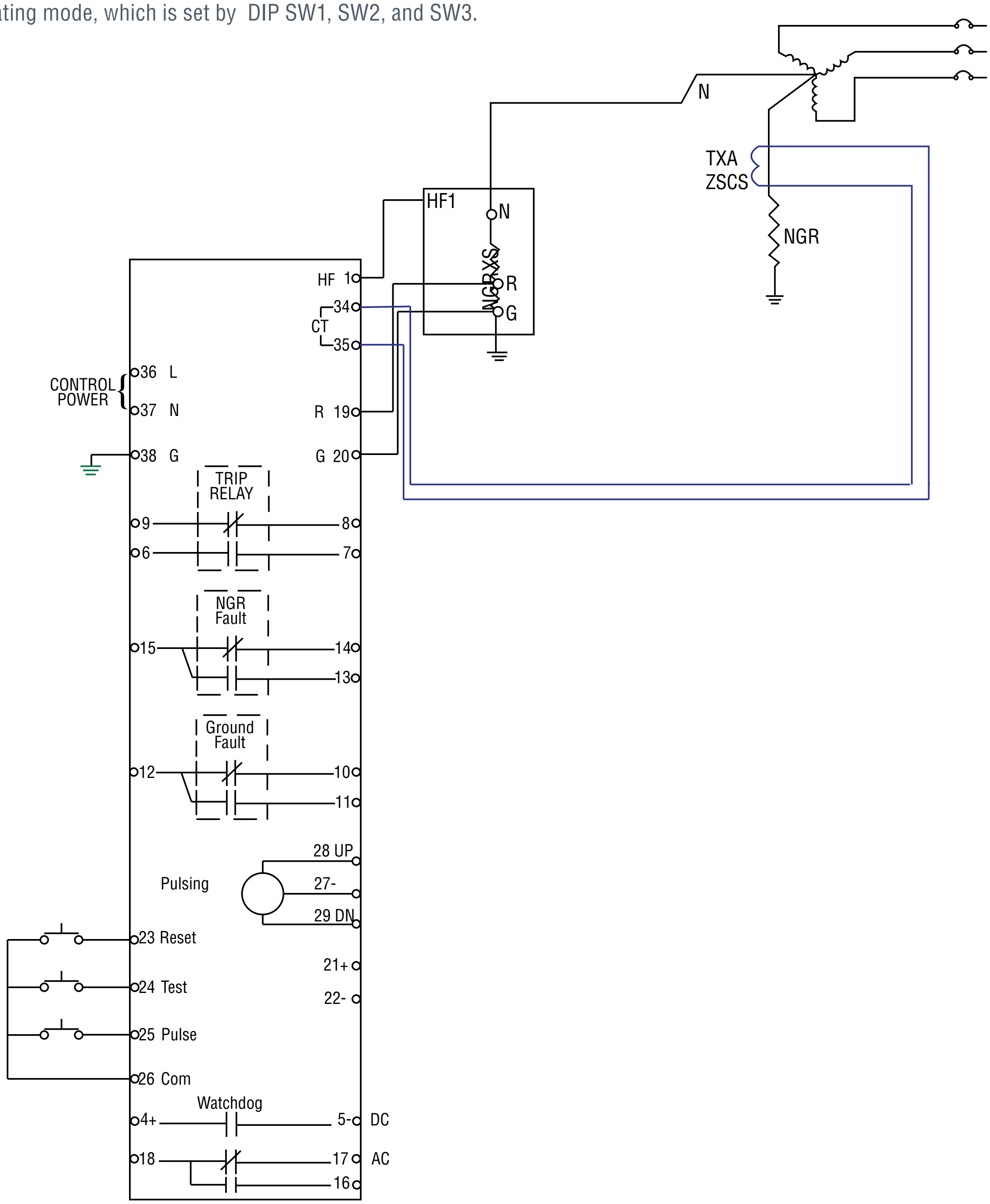


Figure 6.1: SIGMA3-C Relay and contractors diagram

6.1 Trip Relay (8-9, 6-7)

A trip relay consisting of an N.O. and N.C. pair is provided. Terminal (8-9) is normally closed and terminal (6-7) is normally open. This relay energizes on occurrence of a ground fault. The trip relay can be programmed for shunt trips or fail-safe operations.

When the SIGMA3-C 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 SIGMA3-C is operating in fail-safe mode and there is no fault condition present, the trip relay is normally idle (energized) The trip relay is tripped or de-energized if a fault condition is detected on the system. The trip relay is also de-energized when the control power is off.

6.2 Resistor Path Fault (AUXILIARY RELAY)

A Form-C auxiliary contact for RPF is provided. This is located at terminals (13, 14, 15). The RPF auxiliary relay operates exclusively in shunt trip mode regardless of DIP switch setting.

6.3 Ground Fault (AUXILIARY RELAY)

A Form-C auxiliary contact for ground faults is provided. This is located at terminals (10, 11, and 12). The GROUND FAULT auxiliary relay operates exclusively in shunt trip mode regardless of DIP switch setting.

6.4 Watchdog (4, 5)

Terminals 4-5 is a system normal watchdog. When the SIGMA3-C is de-energized it is open. When the SIGMA3-C is energized but not in alarm it is closed. If the SIGMA3-C goes into alarm mode, the watchdog changes state and opens back.

7. LED INDICATORS AND DIAGNOSTICS

The SIGMA3-C has 3 indication LEDs located on its front panel: the Green PWR (POWER) LED; the Red GND (GROUND) FAULT LED; and the Red RPF (RESISTOR PATH FAULT) LED.

7.1 Start-up and Reset Indications

The SIGMA3-C has a start-up sequence where the Red GND FAULT and RPF LEDs flash twice before being turned OFF. The Green PWR LED may also flash before it is turned ON.
Click here to watch the video, or scan the QR code.

During a manual reset the Red GND FAULT and RPF LEDs turn ON for two seconds as an 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 SIGMA3-C has gone through the start-up sequence and is operating normally the Green PWR LED will turn ON and the Red GND FAULT and RPF. LEDs will turn off.
Click here to watch the video, or scan the QR code.

7.2 Power On LED (Green)

The Green PWR LED will turn ON when control power is applied to the SIGMA3-C and the relay is operating normally.

The Green PWR LED will intermittently flash if control power is applied to the SIGMA3-C 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 SIGMA3-C.

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

7.3 GND Fault LED (Red)

The Red GND FAULT LED will turn OFF when the SIGMA3-C is operating normally and no ground fault has been detected or qualified.

The Red GND FAULT LED will turn ON when the SIGMA3-C has detected and qualified a ground fault. The Red GND FAULT LED will remain ON until the SIGMA3-C is manually reset even if the ground fault condition has been rectified.

The Red GND FAULT LED will intermittently flash when the SIGMA3-C is powered up after having been powered down while indicating a ground fault. The SIGMA3-C must be manually reset to clear this condition. The Red GND FAULT LED will turn on during manual reset as described above.

7.4 Resistor Path Fault LED (Red)

The Red Resistor Path FAULT LED will turn OFF when the SIGMA3-C is operating normally and no RPF has been detected and qualified.

The Red Resistor Path FAULT LED will turn ON when the SIGMA3-C has detected and qualified an RPF. The RED RPF LED will remain ON until the SIGMA3-C is manually reset even if the RPF condition has been corrected.

The Red Resistor Path FAULT LED will intermittently flash when the relay is powered up after having been powered down while indicating an RPF. The SIGMA3-C must be manually reset to clear this condition.

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

8. SETTINGS

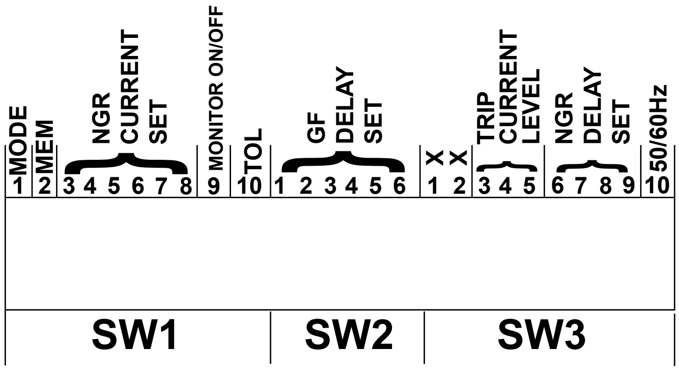


Figure 8.1: SIGMA3-C Dip Switch Array

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

8.1 Trip Relay Operating Modes

The trip relay operating settings can be set with DIP switch 1. The SIGMA3-C 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 8.1 for configuration details.

SW #1 DIP SWITCH 1 - MODE (left hand array)

(1 = Up, 0 = Down)

Mode	Dip Switch Settings
Fail-safe (Undervoltage Trip) SIGMA3-C Relay is Idle/Not-Tripped: Trip Relay is energized Aux Fault Relays are not energized SIGMA3-C Relay is Tripped: Trip Relay is energized Aux Fault Relays are energized	1
Non-fail safe (Shunt Trip) SIGMA3-C Relay is Idle/Not-Tripped Trip Relay is not Energized Aux Fault Relays are not energized SIGMA3-C Relay is Tripped Trip Relay is Energized Aux Fault Relays are energized	0

Table 8.1: Trip Relay Operating Mode Setting SW #1 DIP Switch #1 (left hand array)

8.1.1 Shunt Trip Mode

In the shunt trip mode (not fail-safe), the trip relay remains de-energized (no trip) when the control voltage is applied to the SIGMA3-C 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 exceeds 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 SIGMA3-C 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 the control voltage is applied the trip relay will at first be de-energized (no-trip) and the SIGMA3-C 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 SIGMA3-C monitor relay is reset through a local or remote reset. When reset, the SIGMA3-C 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.

8.1.2 Fail-safe (Undervoltage Trip) Mode

When programmed for the FAIL-SAFE (UNDERVOLTAGE TRIP) MODE and the SIGMA3-C is operating normally, the trip relay energizes approximately 1 second after the 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 SIGMA3-C is reset
- Control voltage is removed

The trip relay remains energized after a trip, providing control voltage is present, until the SIGMA3-C is reset whether or not the fault that caused the trip remains present on the system.

When the control voltage is applied the trip relay will at first be energized (no-trip) and the SIGMA3-C 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 SIGMA3-C is reset through a local or remote reset. When reset, the SIGMA3-C 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.

8.2 Trip Memory Setting

The trip memory settings can be set with DIP switch memory 2. The SIGMA3-C 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 SIGMA3-C can be set for trip memory ON (DIP switch memory #2 UP) or trip memory OFF (DIP switch memory #2 DOWN). See Table 8.2 for configuration details.

SW #1 DIP SWITCH 2- TRIP MEMORY SELECTION (left hand array)

(1 = Up, 0 = Down)

Trip Memory On/Off	Dip Switch Settings
TRIP MEMORY ON Control voltage off after trip: When control voltage restored Trip and Aux relays idle* then immediately re-trip (within 2 seconds).	1
TRIP MEMORY OFF Control voltage off after trip: When control voltage restored Trip and Aux relays idle* but do not immediately re-trip Trip and Aux relays will re-trip if a fault is detected after monitoring starts.	0

Table 8.2: Trip Memory Selection SW #1 DIP Switch #2 (left hand array)

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 SIGMA3-C 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 SIGMA3-C retains the states of the trip relay and auxiliary fault relays stored in non-volatile memory indefinitely.

8.3 Ground Fault Trip Time Delay

The ground fault time delay settings can be set with DIP SW 2 (1, 2, 3, 4, 5, 6). The SIGMA 3 can be programmed for ground fault trip delays ranging from 60 milliseconds to 9.3 seconds.

Refer to TABLE 8.3 GROUND FAULT TRIP TIME DELAY SETTINGS to determine the DIP switch settings for the application.

SW1 DIP SWITCH #(3,4,5,6,7), SW2 DIP SWITCH #(1, 2, 3, 4, 5, 6) - GROUND FAULT TRIP TIME DELAY (left hand array)

(1 = Up, 0 = Down)

Ground Fault Trip Time Delay (in milliseconds)	Dip Switch Settings					
	1	2	3	4	5	6
60	0	0	0	0	0	0
150	1	0	0	0	0	0
300	0	1	0	0	0	0
450	1	1	0	0	0	0
600	0	0	1	0	0	0
750	1	0	1	0	0	0
900	0	1	1	0	0	0
1050	1	1	1	0	0	0
1200	0	0	0	1	0	0
1350	1	0	0	1	0	0
1500	0	1	0	1	0	0
1650	1	1	0	1	0	0
1800	0	0	1	1	0	0
1950	1	0	1	1	0	0
2100	0	1	1	1	0	0
2250	1	1	1	1	0	0
2400	0	0	0	0	1	0
2550	1	0	0	0	1	0
2700	0	1	0	0	1	0
2850	1	1	0	0	1	0
3000	0	0	1	0	1	0
3150	1	0	1	0	1	0
3300	0	1	1	0	1	0
3450	1	1	1	0	1	0
3600	0	0	0	1	1	0
3750	1	0	0	1	1	0
3900	0	1	0	1	1	0
4050	1	1	0	1	1	0
4200	0	0	1	1	1	0
4350	1	0	1	1	1	0
4500	0	1	1	1	1	0

4650	1	1	1	1	1	0
4800	0	0	0	0	0	1
4950	1	0	0	0	0	1
5100	0	1	0	0	0	1
5250	1	1	0	0	0	1
5400	0	0	1	0	0	1
5550	1	0	1	0	0	1
5700	0	1	1	0	0	1
5850	1	1	1	0	0	1
6000	0	0	0	1	0	1
6150	1	0	0	1	0	1
6300	0	1	0	1	0	1
6450	1	1	0	1	0	1
6600	0	0	1	1	0	1
6750	1	0	1	1	0	1
6900	0	1	1	1	0	1
7050	1	1	1	1	0	1
7200	0	0	0	0	1	1
7350	1	0	0	0	1	1
7800	0	1	0	0	1	1
7950	1	1	0	0	1	1
8100	0	0	1	0	1	1
8250	1	0	1	0	1	1
8400	0	1	1	0	1	1
8550	1	1	1	0	1	1
8700	0	0	0	1	1	1
8850	1	0	0	1	1	1
9000	0	1	0	1	1	1
9150	1	1	0	1	1	1
9300	0	0	1	1	1	1
9300	1	0	1	1	1	1
9300	0	1	1	1	1	1
9300	1	1	1	1	1	1

Table 8.3: Ground Fault Trip Time Delay Settings Dip Switches #(1,2,3,4,5,6) (left hand array)

8.4 Ground Fault Trip Current Level

The ground fault trip current level setting can be set with DIP SW 3 (3, 4, 5). The SIGMA3-C 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 SIGMA3-C report ground faults falsely.

Refer to TABLE 8.4 GROUND FAULT TRIP CURRENT LEVEL SETTINGS to determine the DIP switch settings for the application.

SW #3 DIP Switch #3,4,5 - GROUND FAULT TRIP LEVEL % (Right hand array)

(1 = Up, 0 = Down)

Ground Fault Trip Level (% of NGR Let-Through Current)	Dip Switch Settings		
	3	4	5
5%	0	0	0
10%	1	0	0
15%	0	1	0
20%	1	1	0
25%	0	0	1
30%	1	0	1
40%	0	1	1
50%	1	1	1

Table 8.4: Ground Fault Trip Current Level Settings Dip Switches #3 - #4 - #5 (Right hand array)

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.

8.5 System Frequency

The system frequency setting can be set with DIP SW 3 (10). A system frequency of 50 Hz or 60 Hz can be chosen. Refer to TABLE 8.5 SYSTEM FREQUENCY SETTINGS to determine the DIP switch settings for the application.

SW #3 DIP SWITCH #10 - SYSTEM FREQUENCY SELECTION (right hand array)

(1 = Up, 0 = Down)

System Frequency 50/60 Hz	Dip Switch Setting
System Frequency 50 Hz	1
System Frequency 60 Hz	0

Table 8.5: System Frequency Selection Dip Switch #10 (right hand array)

8.6 RPF Let-Through Current

The NGR let-through current setting can be set with SW 1, DIP SWITCH (3, 4, 5, 6, 7, 8). The SIGMA monitor relay has thirty-two settings for the NGR let-through current. Refer to TABLE 8.6 FOR DIP SWITCH SETTINGS for the NGR let-through current.

SW1 DIP SWITCH (3, 4, 5, 6, 7, 8)-NGR let-through current (right hand array)

(1 = Up, 0 = Down)

RPF Let-Through Current (Amps)	Dip Switch Settings						ZSCS Employed
	3	4	5	6	7	8	
1	0	0	0	0	0	0	TxA or Rx-yA
2	1	0	0	0	0	0	TxA or Rx-yA
3	0	1	0	0	0	0	TxA or Rx-yA
4	1	1	0	0	0	0	TxA or Rx-yA
5	0	0	1	0	0	0	TxA or Rx-yA
10	1	0	1	0	0	0	TxA or Rx-yA
15	0	1	1	0	0	0	TxA or Rx-yA
20	1	1	1	0	0	0	TxA or Rx-yA
25	0	0	0	1	0	0	TxA or Rx-yA
30	1	0	0	1	0	0	TxA or Rx-yA
35	0	1	0	1	0	0	TxA or Rx-yA
40	1	1	0	1	0	0	TxA or Rx-yA
45	0	0	1	1	0	0	TxA or Rx-yA
50	1	0	1	1	0	0	TxA or Rx-yA
55	0	1	1	1	0	0	TxA or Rx-yA
60	1	1	1	1	0	0	TxA or Rx-yA
65	0	0	0	0	1	0	TxA or Rx-yA
70	1	0	0	0	1	0	TxA or Rx-yA
75	0	1	0	0	1	0	TxA or Rx-yA
80	1	1	0	0	1	0	TxA or Rx-yA
85	0	0	1	0	1	0	TxA or Rx-yA
90	1	0	1	0	1	0	TxA or Rx-yA
95	0	1	1	0	1	0	TxA or Rx-yA
100	1	1	1	0	1	0	TxA or Rx-yA
125	0	0	0	1	1	0	TxA or Rx-yA
150	1	0	0	1	1	0	TxA or Rx-yA
175	0	1	0	1	1	0	TxA or Rx-yA

200	1	1	0	1	1	0	TxA or Rx-yA
225	0	0	1	1	1	0	TxA or Rx-yA
250	1	0	1	1	1	0	TxA or Rx-yA
275	0	1	1	1	1	0	TxA or Rx-yA
300	1	1	1	1	1	0	TxA or Rx-yA
325	0	0	0	0	0	1	TxA or Rx-yA
350	1	0	0	0	0	1	TxA or Rx-yA
375	0	1	0	0	0	1	TxA or Rx-yA
400	1	1	0	0	0	1	TxA or Rx-yA
450	0	0	1	0	0	1	TxA or Rx-yA
500	1	0	1	0	0	1	TxA or Rx-yA
550	0	1	1	0	0	1	TxA or Rx-yA
600	1	1	1	0	0	1	TxA or Rx-yA
650	0	0	0	1	0	1	TxA or Rx-yA
700	1	0	0	1	0	1	TxA or Rx-yA
750	0	1	0	1	0	1	TxA or Rx-yA
800	1	1	0	1	0	1	TxA or Rx-yA
850	0	0	1	1	0	1	TxA or Rx-yA
900	1	0	1	1	0	1	TxA or Rx-yA
950	0	1	1	1	0	1	TxA or Rx-yA
1000	1	1	1	1	0	1	TxA or Rx-yA

Table 8.6: NGR Let-Through Current Settings SW1 DIP SWITCH (3, 4, 5, 6, 7, 8) (Right Hand Array)

The NGR let-through current settings in Table 9.6 show that the SIGMA3-C monitor relay can be configured for let-through currents ranging from 1 Amper through 1000 Amperes using a standard I-Gard TxA ZSCS.

The SIGMA3-C monitor relay can be configured for let-through currents over 1000 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.

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 SIGMA3-C 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 9300 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 8.2 shows the correct DIP switch toggle position according to the settings defined by the user.

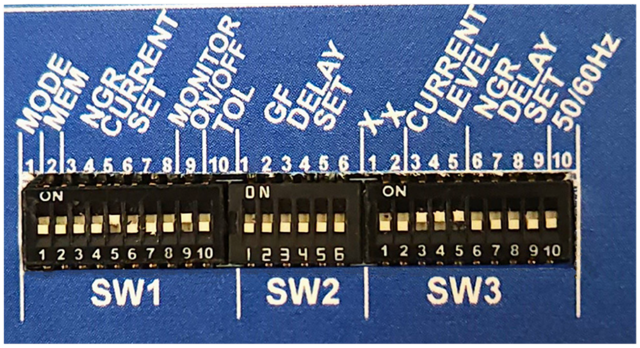


Figure 8.2: SIGMA3-C Dip switch setting example

DIP SWITCH #			DIP SWITCH POSITION	Status
SW #1	DIP SWITCH #1	Operating mode	1	Fail Safe (Under voltage Trip)
	DIP SWITCH #2	Trip Memory	1	Trip Memory ON
	DIP SWITCH #3	RPF Let-through Current (Amps)	0	5 Amps (NGR Let-through current) For 5 Amps, it should be 001000
	DIP SWITCH #4	RPF Let-through Current (Amps)	0	
	DIP SWITCH #5	RPF Let-through Current (Amps)	1	
	DIP SWITCH #6	RPF Let-through Current (Amps)	0	
	DIP SWITCH #7	RPF Let-through Current (Amps)	0	
	DIP SWITCH #8	RPF Let-through Current (Amps)	0	
	DIP SWITCH #9	Monitor ON/OFF		
	DIP SWITCH #10	TOL		
SW #2	DIP SWITCH #1	Ground Fault Trip Time Delay	1	9300 milliseconds
	DIP SWITCH #2	Ground Fault Trip Time Delay	1	
	DIP SWITCH #3	Ground Fault Trip Time Delay	1	
	DIP SWITCH #4	Ground Fault Trip Time Delay	1	
	DIP SWITCH #5	Ground Fault Trip Time Delay	1	
	DIP SWITCH #6	Ground Fault Trip Time Delay	1	
SW #3	DIP SWITCH #1	Not connected		
	DIP SWITCH #2			
	DIP SWITCH #3	Ground Fault Trip Level	0	5%
	DIP SWITCH #4	Ground Fault Trip Level	0	
	DIP SWITCH #5	Ground Fault Trip Level	0	
	DIP SWITCH #10	System Frequency (Hz)	0	50/60 Hz

Table 8.7: SW#1,2,3 DIP Switch settings

(1 = Up, 0 = Down)

RPF Delay
If 9 Switch in SW3 is OFF

	Dip Switch Settings			
Minutes	6	7	8	9
10 Seconds	0	0	0	0
6	1	0	0	0
12	0	1	0	0
18	1	1	0	0
24	0	0	1	0
30	1	0	1	0
36	0	1	1	0
48	1	1	1	0

Table 8.8.1: SIGMA3-C RPF Fault Delay SW1 OFF

(1 = Up, 0 = Down)

RPF Delay
If 9 Switch in SW3 is ON

	Dip Switch Settings			
Hours	6	7	8	9
10 minutes	0	0	0	1
6	1	0	0	1
12	0	1	0	1
18	1	1	0	1
24	0	0	1	1
30	1	0	1	1
36	0	1	1	1
48	1	1	1	1

Table 8.8.2: SIGMA3-C RPF Fault Delay SW1 ON

SW #3 DIP SWITCH (10)
1 = UP, 0 = DOWN

SYSTEM FREQUENCY 60/50 Hz	DIP SWITCH SETTING
SYSTEM FREQUENCY 50 Hz	1
SYSTEM FREQUENCY 60 Hz	0

Table 8.9: System Frequency Selection

SW #1 DIP SWITCH (10)
1 = UP, 0 = DOWN

RPF TOLERANCE %	DIP SWITCH SETTING
66% to 300%	1
66% to 150%	0
Recommended to be used with I-GARD RPF's	

Table 8.10: RPF Tolerance %

9. USE WITH SIGMA3-C-TDM TOUCHSCREEN DISPLAY MODULE

The SIGMA3-C can be used with a touchscreen HMI called the SIGMA3-C-TDM. The SIGMA3-C is connected to the SIGMA3-C-TDM using its MODBUS communication port. The connection of the SIGMA3-C to the SIGMA3-C-TDM is shown in Figure 9.1.

The SIGMA3-C-TDM touchscreen HMI provides for display of the status and readings of the SIGMA3-C; configuration and operation of pulse contactor settings; viewing of logging and trending data; remote reset of the SIGMA3-C; as well as providing TCP/IP communication.

When the SIGMA3-C is connected to the SIGMA3-C-TDM the "HOME" screen shown in Figure 9.2 below appears on the SIGMA3-C-TDM. Navigate to the SYSTEM STATUS screen using the associated button. The screen as shown in Figure 9.3 appears. Here the Fault Current and RPF Voltage can be observed as well as the System Ground Fault and RPF 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 9.4 below.

Navigate to the Settings page using the associated button on the home screen. The Settings page is shown in Figure 9.5 below. From here, the SIGMA3-C 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 9.1: SIGMA3-C to SIGMA3-C-TDM Connection

Figure 9.2: Home Screen

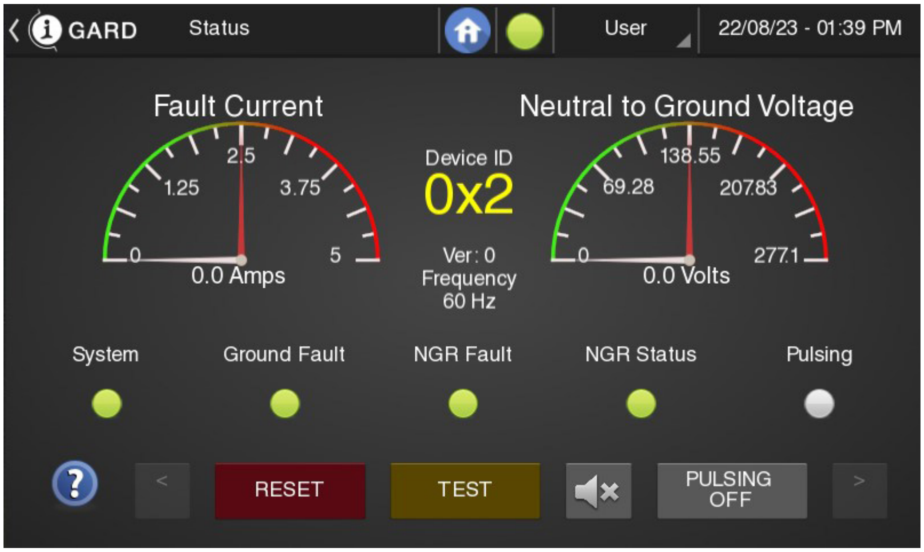


Figure 9.3: Status Screen

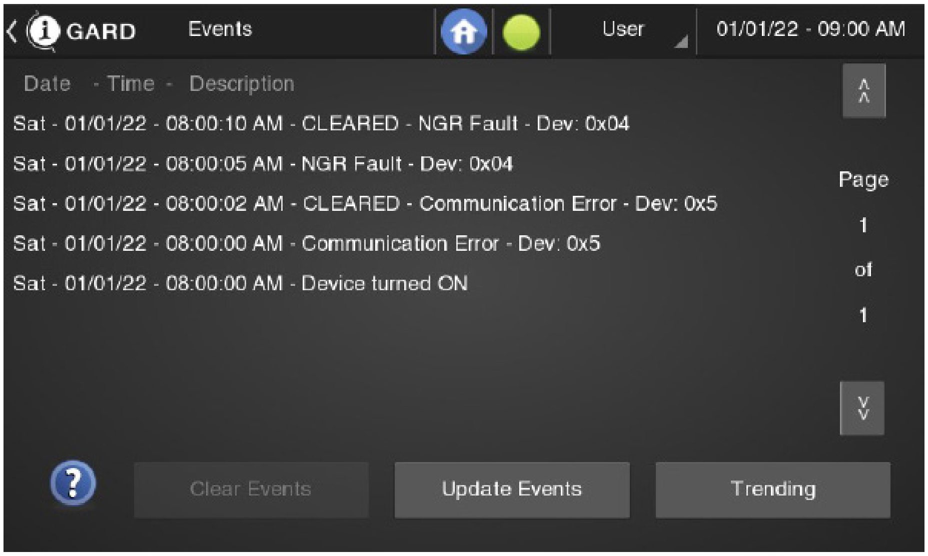


Figure 9.4: Event Log Screen

Figure 9.5: Settings Screen

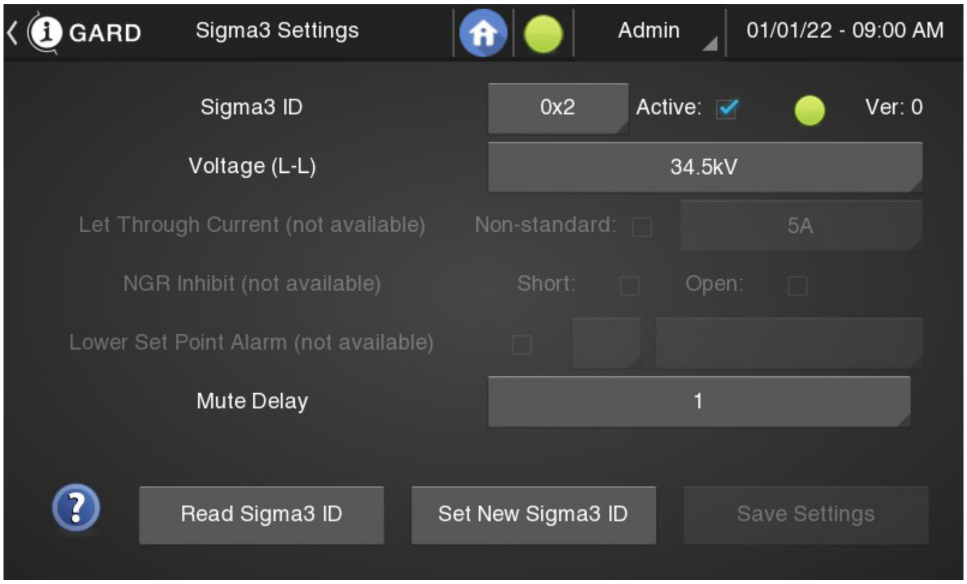


Figure 9.6: SIGMA3-C and Alarm Settings Screen

Figure 9.7: Pulse Contactor Settings Screen

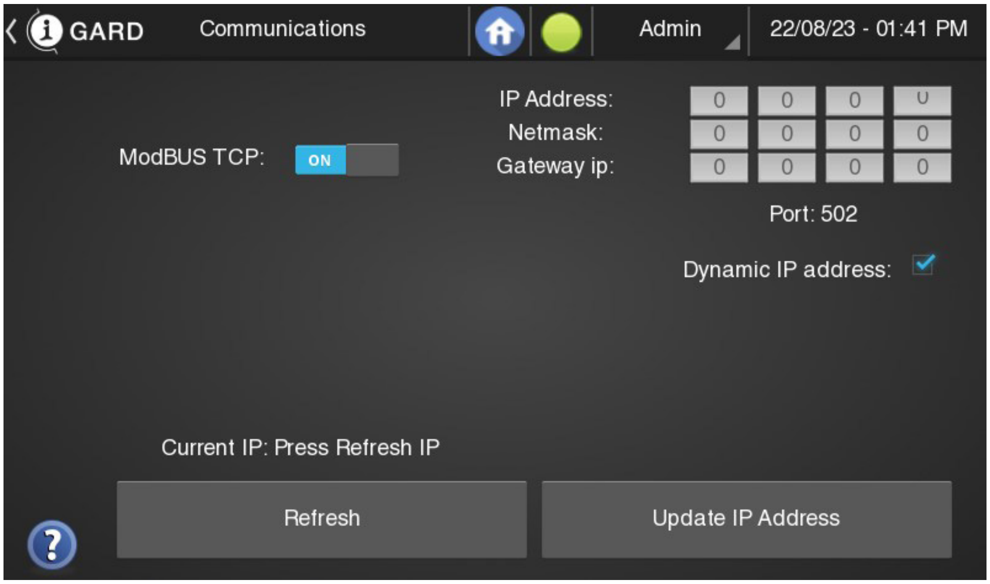


Figure 9.8: Communications Settings Screen

10. MODBUS COMMUNICATION

The SIGMA3-C has a 4-wire RS-485 communications port to allow communications to a remote terminal or network, a 4-wire. (Terminals on header: Rx + 30, Rx - 31, Tx - 32, Tx + 33) Only terminals 30, 31, 32, and 33 are to be used as shown in Figure 10.1 below, with the preferred 4-wire connection in Figure 10.1(a) and the 2-wire connection in Figure 10.1(b). Note that when the SIGMA3-C-TDM is being used, communication connections to the system should be made through the SIGMA3-C-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 SIGMA3-C is not programmable and is set according to the serial number (see Table 10.1 below). The baud rate is not programmable and is set to 38400 BPS. The frame set-up is 8-bit, with 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 electro-magnetic interference. The shield of the cable between nodes should not be continuously grounded but should be grounded at one end.

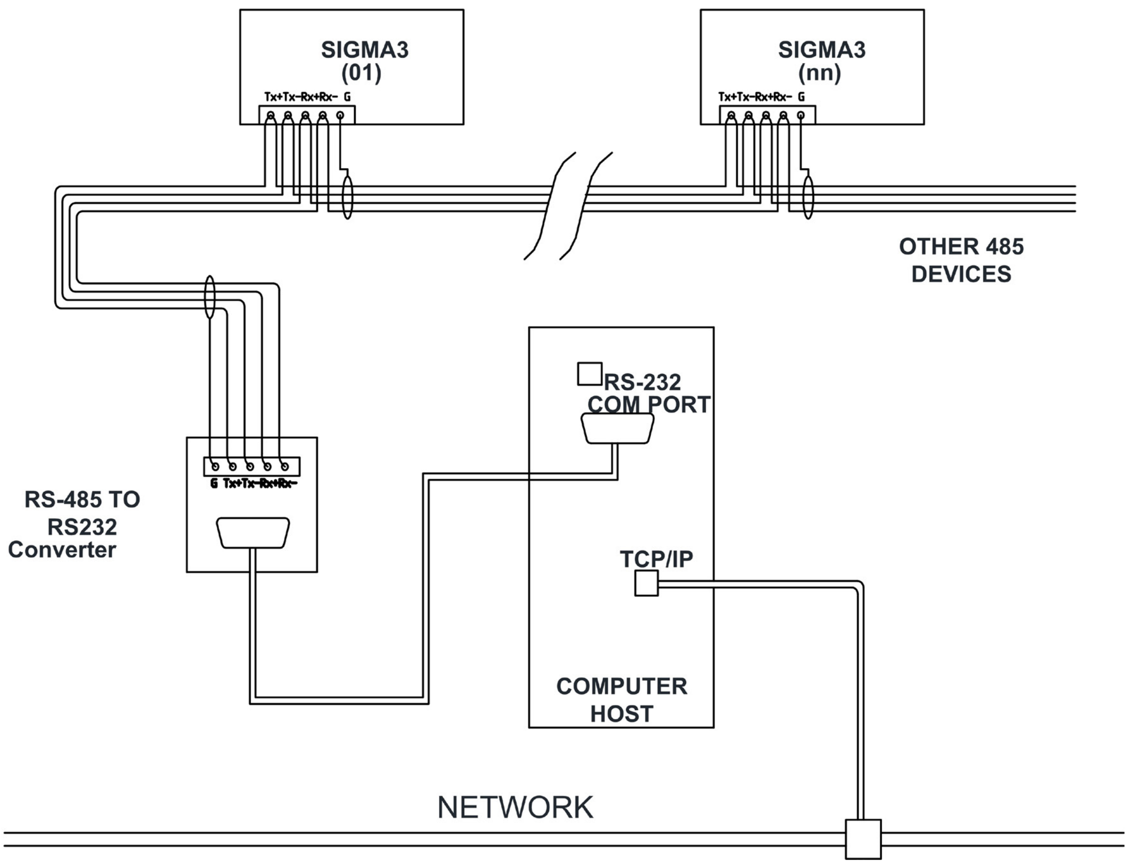


Figure 10.1 (a): Preferred 4-wire MODBUS Communication Connection

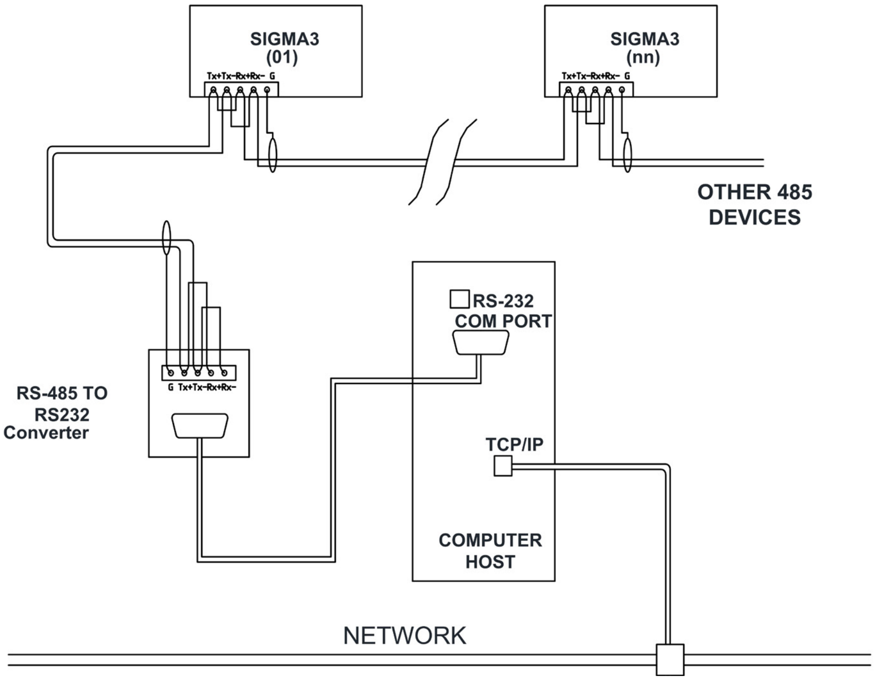


Figure 10.1 (b): Alternate 2-wire MODBUS Communication Connection

10.1 MODBUS Functions

One MODBUS function is supported, read holding register (03). The SIGMA3-C 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 is as shown in the table below. In the MODBUS RTU system, the SIGMA3-C operates in a client/server communications model or master/slave communications model. In the client/server communications model, the SIGMA3-C is the MODBUS server and will respond to requests sent to it by a MODBUS client. In the master/slave communications model the SIGMA3-C 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	0xA
XXX1	0xB
XXX2	0x2
XXX3	0x3
XXX4	0x4
XXX5	0x5
XXX6	0x6
XXX7	0x7
XXX8	0x8
XXX9	0x9

Table 10.1: MODBUS ID Address Map

The MODBUS requests sent to the MODBUS master or client are 8 bytes long as shown in Table 10.2 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 10.2: 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 SIGMA3-C will return the message shown in Table 10.3 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 10.3: Returned Information Structure for Holding Register Request

Register contents are shown in Tables 10.4 to 10.6 below.

NOTE: The 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 SIGMA3-C 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 #	Read/ Write	Function	Description
40010	R	Fault Current	Current shown in meter *100 e.g. 1A=100
40011	R	System voltage-setting	(0-18) hexadecimal (see table)
40012	R	Current setting	DIP SW3 (2-10) DIP SW2 (1-6), DIP SW1 (1-2)
40013	R	Current setting	DIP SW1 (3-10)
40014	R	Relay status	Bit 0 - Main Bit 1 - GND Bit 2 - RPF
40015	R	NGR Status	Bit 0 - GNDF LED Bit 4 - RPF LED Bit 5 - Flashing (RPF LED)
40016	R	Pulsing Frequency	Bit 5 - Pulsing Status 1 - ON, 0 - OFF
40017	R	Conductance	
40018	R	Open CKT Threshold	
40019	R	Shart CKT Threshold	
40020	R	Fault Current	(0 - 511) decimal
40021	R	Low peak setting	
40022	R	High peak setting	0-0xFFFF – (0-65535)
40024	R	Online coupling independance	
40025	R	Low fluctuation	0-0xFFFF – (0-65535)
40026	R	High fluctuation	0-0xFFFF – (0-65535)
40027	R	Calibration mode	0 - OFF, 1 - ON

Table 10.4: SIGMA3-C Relay Register Definitions

System Voltage table	
Code	V (L-L)
0x00	120 V
0x01	240 V
0x02	380 V
0x03	400 V
0x04	415 V
0x05	480 V
0x06	600 V
0x07	690 V
0x08	1050 V
0x09	2.2 kV
0x10	2.4 kV
0x11	3.3 kV
0x12	4.2 kV
0x13	6.6 kV
0x14	7.2 kV
0x15	11.0 kV
0x16	13.8 kV
0x17	23.0 kV
0x18	34.5 kV

Table 10.5

Ground Fault Trip LVL	
Code	Trip LVL(%)
0x00	5
0x01	10
0x02	15
0x03	20
0x04	25
0x05	30
0x06	40
0x07	50

Table 10.6

Table 10.5: SIGMA3-C System Voltage
Table 10.6: SIGMA3-C Ground Fault Trip Level (%)

Current Table	
Code	Amps (A)
0x00	1
0x01	2
0x02	3
0x03	4
0x04	5
0x05	15
0x06	20
0x07	25
0x08	30
0x09	35
0x10	40
0x11	45
0x12	50

0x13	55
0x14	60
0x15	65
0x16	70
0x17	75
0x18	80
0x19	85
0x20	90
0x21	95
0x22	100
0x23	125
0x24	150
0x25	175
0x26	200
0x27	225
0x28	250
0x29	275
0x30	300
0x31	325
0x32	350
0x33	375
0x34	400
0x35	450
0x36	500
0x37	550
0x38	600
0x39	650
0x40	700
0x41	750
0x42	800
0x43	850
0x44	900
0x45	950
0x46	1000
0x47	1000
0x48	1000
0x49	1000
0x50	1000
0x51	1000
0x52	1000

0x53	1000
0x54	1000
0x55	1000
0x56	1000
0x57	1000
0x58	1000
0x59	1000
0x60	1000
0x61	1000
0x62	1000
0x63	1000

Table 10.7

Table 10.7: SIGMA3-C Current

11. INSTALLATION

11.1 SIGMA3-C

11.1.1 Location

The SIGMA3-C monitor relay should be located as close as possible to the system's isolating device, circuit breaker, or contactor.

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

11.1.2 Mounting

Mount the SIGMA3-C monitor relay horizontally using a 35 mm DIN rail bolted or firmly fixed to a 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.

11.1.3 Connections

Refer to Figure 11.1 for electrical connections to the SIGMA3-C monitor relay. Terminals on the relay will accept up to #14 AWG wire.

Connect the G terminal on the SIGMA3-C 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 from being applied to the relay's internal power supply.

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

The SIGMA3-C 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 SIGMA3-C monitor relay to the PIN 19 terminal of the NGRXS sensing resistor as shown in the connection diagram below.

Connect terminals (34 and 35) on the SIGMA3-C monitor relay to the X1 and X2 terminals of the ZSCS 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 under 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 SIGMA3-C 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 SIGMA3-C monitor relay. Refer to the connection diagram below. These contacts are to be voltage-free.

11.2 ZSCS

11.2.1 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.

11.2.2 Mounting

The overall dimensions of the T2A ZSCS are 104 mm x 104 mm x 44 mm. If another size ZSCS is used please refer to document C-700EM sensors.

11.2.3 Connections

The neutral point of the system is to be connected to the ungrounded end of the NGR 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 SIGMA3-C monitor relay as shown in the connection diagram below. Do not connect to Ground.

11.3. 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.

11.3.1 Location

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

11.3.2 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 4.2.

11.3.3 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 The R terminal of the NGRXS sensing resistor must be connected to the appropriate terminal of the SIGMA3-C monitor relay as shown in Figure 3.1. 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.

11.4. SIGMA3-C-TDM

The SIGMA3-C-TDM maximum power supply is 5.25 VDC.
SIGMA3-C includes the power supply of 5 VDC, for this reason no external Power Supply is required.
Polarity of the power supply to the SIGMA 3-TDM must be checked before continue on next steps.
Refer to page 10 for pictures and diagrams.
MODBUS wiring

Note: Or use Ix Cable

	SIGMA 3-C	SIGMA 3 - TDM Touchscreen Display Module
30	Rx+	Tx+
31	Rx-	Tx-
32	Tx+	Rx+
33	Tx-	Rx-

Table 11.1: SIGMA3-C-TDM MODBUS Wiring

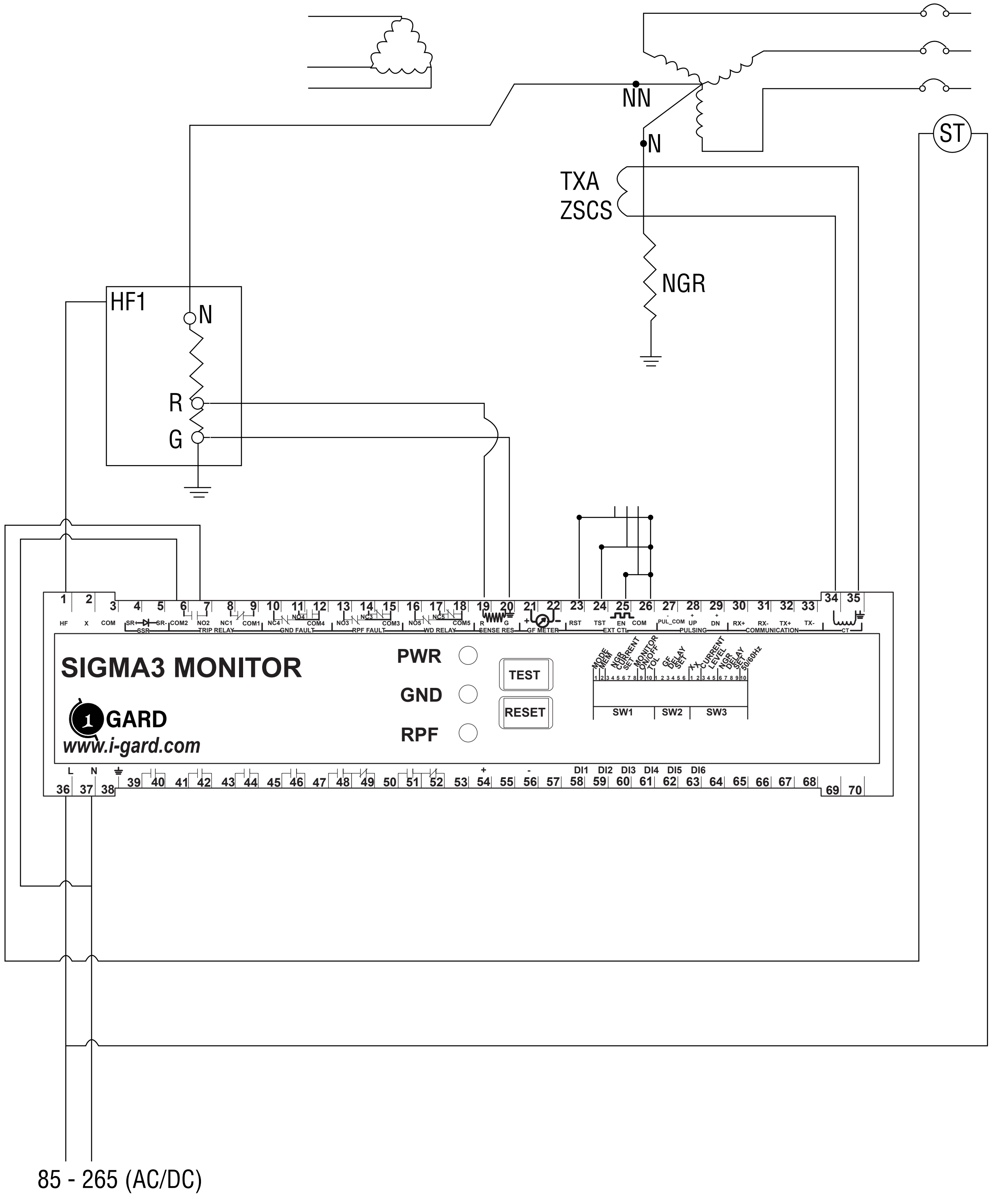
Summary of Connections to the SIGMA3-C Relay

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 PIN 1 - SIGMA3-C N
NGRS - Terminal #19 (R) and 20 (G) to SIGMA3-C Terminal #19 and #20
**Important: These terminals are Polarity Sensitive

3.- TxA Zero Sequence Current Sensors (ZSCS):
TxA to SIGMA3-C Terminal #34 and #35
** Important: These terminals are Non-Polarity Sensitive

4. Pulsing (Optional):
Pulsing Down - Terminal #27 (-) and Terminal #29 (+)
Pulsing Up - Terminal #27 (-) and Terminal #28 (+)


NN
N
TXA
ZSCS
NGR
ST
HF1
N
R
G
SIGMA3 MONITOR
PWR
GND
RPF
TEST
RESET
GARD
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SW1
SW2
SW3
85 - 265 (AC/DC)

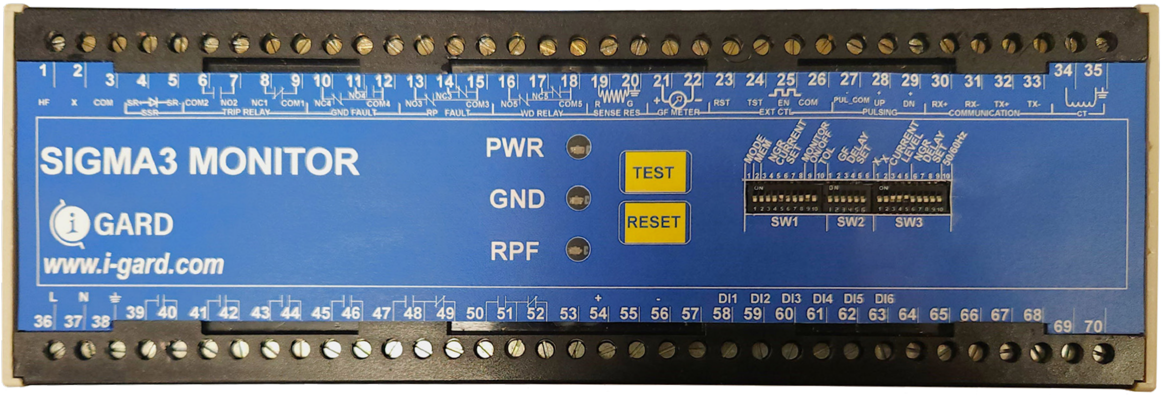

Figure 11.2: SIGMA3-C Terminal Connections

12. COMMISSIONING

A general breakdown of the commissioning of the SIGMA3-C would involve the following:

- Review of installation and condition of unit
- Verification of connections
- Verification of settings
- Energization of SIGMA3-C
- Functional Verifications:
  - Test and Reset
  - Pulsing
  - Communication with the SIGMA3-C-TDM
- Current injection (primary or secondary) to verify GND Fault functionality
- RP short circuit test
- RP open circuit test
- Energization of system
- Online Calibration (if system zero sequence impedance noticeably changes while online)

12.1 RPF Monitoring - Calibration Procedure

The SIGMA3-C relay utilizes three methods to determine if the Resistor path is within the required short/open circuit parameters.

1) Measurement Mode

Measurement mode continuously monitors the current through the 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 RPF is 5% or greater of nominal.

i) The relay SW1 (3, 4, 5, 6, 7, 8) dictates the maximum available let-through current and corresponds 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 RPF 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 an NGRXS-6 is used. The maximum voltage that can be seen across the RPF 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 RPF 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.

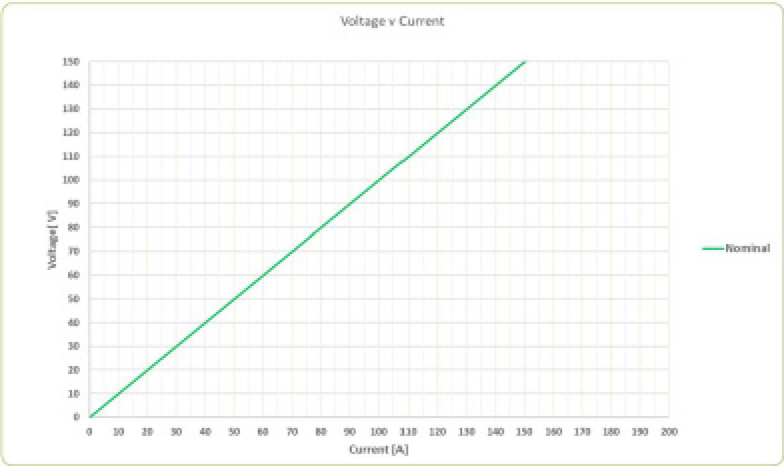

Figure 12.1: NGR Current/Voltage Graph

Limits are then added to this graph for the following:

- 66% change in resistance
- 150% change in resistance
- 300% change in resistance

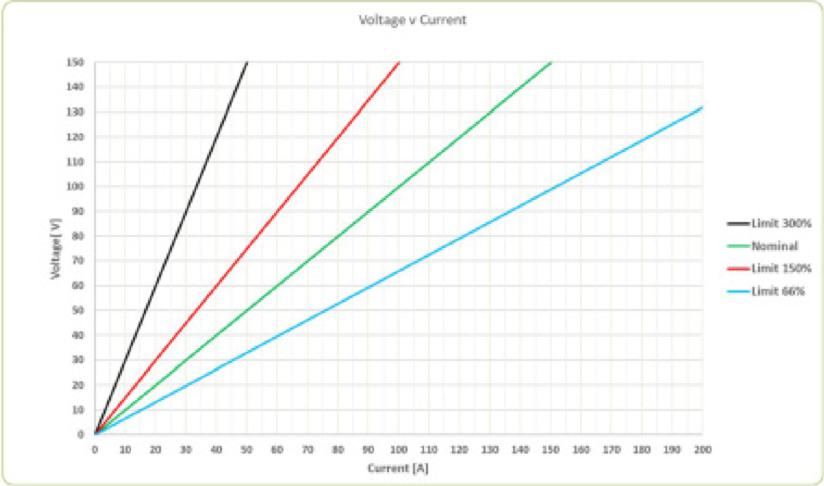

Figure 12.2: NGR Current/Voltage Graph for various Resistance Values

13. TECHNICAL SPECIFICATIONS

Electrical Ratings	Control Power:	110-240 VAC/DC 50/60 Hz 36W Power suply	
	Maximum:	-22.72% to +10% (85-264 AC/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
	Pulsing RPF Fault Relay:	Type:	1 Form C (NO/NC)
		Output:	Max: 1 A @ 12 VDC
SIGMA3-C Watchdog relays	DC	Type:	1 Form A (NO), Fail-safe Mode DC
		Rating:	1 A @ 120 VDC Relay
	AC	Type:	1 Form C (NO/NC)
		Raiting:	10 A@240 VAC, 8A@24 VDC, 1/2 HP@240VAC
Meter Output	0-1 mA DC (0-100% of Let-through Current Setting)	DC or AC Relay	
Electrical Tests	Surge test: @ 3 kV Dielectric test: @ 2 kV for 1 minute		
NGR Let-Through Current Settings	1-1000A		
Output Relay Contacts	Auxiliarity NGR Fault Relay	Type:	1 Form C (NO/NC)
		Rating:	10 A@240 VAC, 8A@24 VDC, 1/2 HP@240 VAC
Ground Fault Trip Settings	Trip Level	5%, 10%, 15%, 20%, 25%, 30%, 40%, 50%	
	Trip Time	60 - 9300 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		

Table 13.1: SIGMA3-C Technical specifications

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

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

SIGMA3-C-TDM TECHNICAL SPECIFICATIONS	System Voltage (Volts)
Screen size	7" Touchscreen
Touchscreen Technology	10-point multi-touch touchscreen
Resolution	800 x 480 RGB LCD Display, 24-bit color
Processor	Broadcom BCM2837B0, quad-core A53 (ARMv8) 64-bit, 1.4GHz
Memory	1GB LPDDR2 SCRAM Expandable non-volatile memory - 32GB
Connectivity	Gigabit Ethernet and 4x USB
Communication	MODBUS TCP, MODBUS RTU
TDM-Touchscreen Display Module available models (Part Numbers)	SIGMA3-C-TDM: Compatible with SIGMA3-C Ground Fault relay
Vertical Viewing Angle	130°
Horizontal Viewing Angle	140°
Temperature Range	(To be confirmed)

14. PART NUMBERS

SIGMA3-C: Ground Fault & Monitoring Relay
SIGMA3-C-TDM: Touchscreen Display Module for SIGMA 3 Ground Fault & RP 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.
TR XEC: Extreme Temperature Zero Seequence Current Sensors for outdoor
TxA: CTs -65°C to 130°C
TRGEC/3EC/9EC

Recommended parts with regard to sensing resistors and current sensors.

SIGMA 3-C		System Voltage (Volts)	Recommended current sensor
NGRXS-6	480 VLL or 600 VLL SENSING RESISTOR	480 and 600	T3A
NGRXS-7	400 VLL or 690 VLL SENSING RESISTOR	690	T3A
NGRXS-10	1050 VLL SENSING RESISTOR	NGR	T3A/T6A depends on the enclosure size
NGRXS-11	1.1 kVLL SENSING RESISTOR	1100	T6A
NGRXS-22	2.2 kVLL SENSING RESISTOR	2200	T6A
NGRXS-25	2.4 kVLL SENSING RESISTOR	2400	T6A
NGRXS-33	3.3 kVLL SENSING RESISTOR	3300	T6A
NGRXS-50	4.16 kVLL SENSING RESISTOR	4160	T6A
NGRXS-70	6.6 kVLL SENSING RESISTOR	6600	T6A
NGRXS-75	7.2 kVLL SENSING RESISTOR	7200	T6A
NGRXS-110	11 kVLL SENSING RESISTOR	11000	T9A
NGRXS-150	13.8 kVLL SENSING RESISTOR	13800	T9A
NGRXS-250	23 kVLL SENSING RESISTOR	23000	T9A
NGRXS-350	34.5 kVLL SENSING RESISTOR	34500	T9A

Table 14.1: SIGMA3-C Recommended current sensors

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