Franklin Electric
GRID SOLUTIONS

INCON® OPTIMIZER3 CIRCUIT BREAKER MONITOR

USER GUIDE

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000-1533 r4

Conventions used in this manual

This manual includes safety precautions and other important information presented in the following format:

NOTE: This provides helpful supplementary information.

IMPORTANT: This provides instructions to avoid damaging hardware or a potential hazard to the environment, for example: fuel leakage from equipment that could harm the environment.

⚠ **CAUTION**: This indicates a potentially hazardous situation that could result in minor or moderate injury if not avoided. This may also be used to alert against unsafe practices.

⚠ **WARNING**: This indicates a potentially hazardous situation that could result in severe injury or death if not avoided.

⚠ **DANGER**: This indicates an imminently hazardous situation that will result in death if not avoided.

Operating precautions

⚠ **WARNING**: IMPORTANT SAFETY INSTRUCTIONS. BEFORE INSTALLING ANY FRANKLIN ELECTRIC GRID SOLUTIONS EQUIPMENT, READ THIS GUIDE AND FOLLOW SAFETY AND OPERATING INSTRUCTIONS. SAVE THESE INSTRUCTIONS.

⚠ **WARNING**: Do not disassemble any equipment; contact Franklin Electric Grid Solutions when a repair is required. Incorrect reassembly may result in a risk of electric shock or fire.

⚠ **WARNING**: To avoid electric shock, abide by your company's safety practices and the following guidelines:

⚠ **WARNING**: Perform service work only for which you have been trained.

⚠ **WARNING**: Refer to NFPA 70E for electrical safety requirements.

⚠ **WARNING**: Use of Personal Protection Equipment (PPE) and Protective Clothing per NFPA 70E guidelines is required. Some examples of these, but not limited to, are: Electrical-insulating Protective gloves, Protective footwear; Protective clothing for voltage levels, Insulated rescue hooks or other means for pulling personnel from live circuits.

⚠ **WARNING**: Before working with electricity, remove personal metal items such as rings, bracelets, necklaces, watches, etc. A short-circuit current can be high enough to weld such items, causing a severe burn.

⚠ **WARNING**: Always wear safety glasses with side shields.

⚠ **WARNING**: To avoid a risk of serious injury or death, DO NOT come into contact with any source of live, electric current!

⚠ **WARNING**: Avoid simultaneous contact with live conductors and enclosures, racks, or hardware that may be grounded.

CONTENTS

INTRODUCTION

SAFETY OVERVIEW

The Optimizer3 Circuit Breaker Performance and SF_6 Gas Density Monitor is intended to be used on high voltage energized circuit breakers or equipment. Personnel using equipment on energized equipment must be authorized by the relevant regulatory bodies to carry out such work and must have appropriate training.

The information given in this document is given as a guide only. It is the user's responsibility to ensure that correct and safe procedures are followed at the actual worksite. Franklin Electric Grid Solutions offers no warranty or indemnity for accidents that may occur when following these instructions.

HAZZARD ASSESSMENT

Prior to installing the equipment, the operator must carry out a worksite, pre-job hazard assessment to identify the safety and environmental needs. This must be done prior to commencing work and prior to recommencing work after leaving and returning to the worksite. As a minimum, this hazard assessment should:

- Identify possible hazards and risks.
- Identify the safety needs of the job.
- Identify the correct procedures, practices and equipment.
- Eliminate unsafe conditions and actions from the worksite.
- Identify the need for personal protective equipment.
- Inspect equipment before use.

Prior to working with and installing Optimizer3, you should check the following:

- The sheaths of all cables are secured and undamaged.
- Plugs and connectors are properly connected and serviceable.
- There should also be an ongoing risk assessment during the job.

WORKING ON ENERGIZED CONDUCTIONS AND EQUIPMENT

For the correct and safe use of this equipment, it is essential that all operating personnel follow appropriate safety procedures. Check with your employer and relevant regulatory body's rules for working with energized equipment.

OPTIMIZER3 OVERVIEW

This guide is written for the Optimizer3 with firmware version 1.9.1 and higher.

The Optimizer3 is an on-line continuous performance monitor for high voltage circuit breakers. It provides information for the process of Condition-Based Maintenance

Optimizer3 performs four main functions:

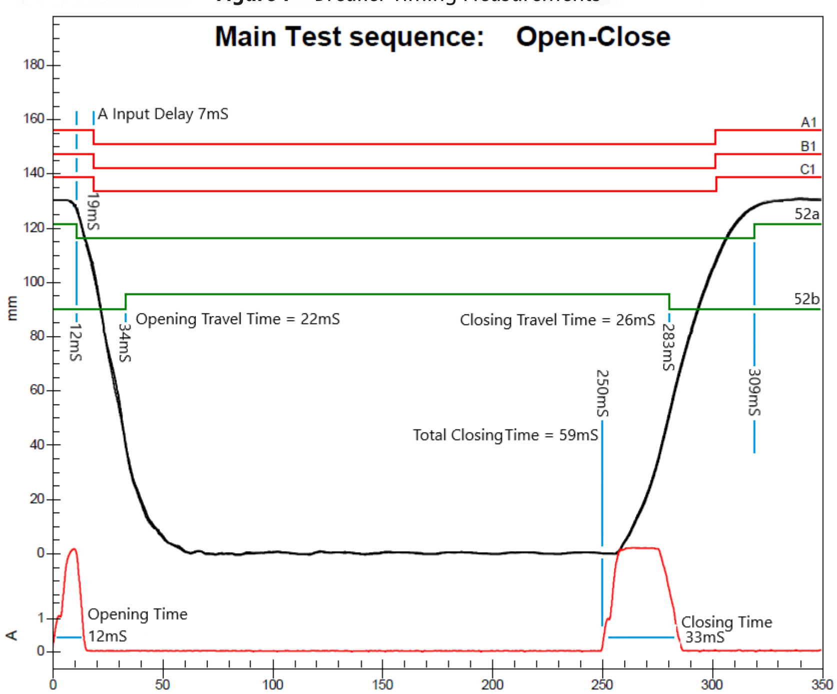
1. Mechanism Timing.
2. Estimation of interrupter condition as degraded by internal arcing effects.
3. Measurement of SF_6 gas density, pressure, and dew point temperature.
4. Status Monitoring of Auxiliary systems.

The Optimizer3 is designed to be installed in the circuit breaker control cabinet. Usually this is the most convenient place because there is easy access to SF_6 plumbing for the density sensors, bushing CT circuits, and control circuits. Often the O&M technicians have no access to the control building where the protective relays are located. If it is not possible to locate the Optimizer3 in the control cabinet, then it may be installed in the control building. Most often this decision is based on access to communication links or SCADA RTU access.

For use as a SF_6-only monitor, such as for monitoring compartments of GIS or SF_6 insulated bus, the Optimizer3 may be located up to 2000 feet from the digital SF_6 density or pressure sensors if AWG 14 wire is used. This makes it feasible to locate the Optimizer3 in a control building, near communications access points.

If access to circuit breaker control cabinets is restricted, Optimizer3 may also be installed in a separate enclosure, mounted to the frame of the circuit breaker. This way, Optimizer3 can be accessed without opening the circuit breaker control cabinet, without restriction of the breaker being taken out of service.

Figure 1 – Breaker Timing Measurements



Optimizer3 measures and logs the following information:

- Breaker status OPEN/CLOSE
- SF_6 Density
- SF_6 Temperature
- SF_6 Dew Point
- Sensor Malfunction
- Motor Run Time
- Motor Runs per Day
- Motor I^2T
- Motor Total Run Time
- Heater Status On/Off
- Heater Current
- Optimizer3 Line Voltage
- Ambient Cabinet Temperature
- Days since Last Operation
- Restrike Occurrence
- Contact Life; cumulative I^2T or IT
- Last Trip Coil Energized (TC1/ TC2)
- Open Latch Time
- Close Latch Time
- Open Average Velocity
- Close Average Velocity
- Open Operation Arcing Time
- Clearing Time
- Opening Travel Time
- Closing Travel Time
- Total Operation Count
- Non-Fault Operation Count
- Fault Operations Count

The Optimizer3 continuously monitors the SF_6 attributes according to what sensors are used. Available sensors include:

1. Temperature-Compensated Pressure analog 4-20 mA.
2. Temperature-Compensated Pressure and Temperature (Model PSDP Digital Pressure Sensor).
3. SF_6 Density and Temperature (model DSDP Digital True Density Sensor).
4. SF_6 Density analog 4-20 mA.
5. SF_6 Dew Point Temperature analog 4-20 mA.

The Optimizer3 uses these measured attributes to calculate other user-defined properties in desired units. Optimizer3 calculates density, pressure, trends, trend rates, changes in mass, etc. Most attributes can be compared to static alarm settings for assertion when they go out-of-tolerance. Optimizer3 issues alarms via contacts, through DNP3.0 points, and via HTTPS web service, locally or remotely.

The Optimizer3 Installation has been kept simple, with few connections required to the circuit breaker control circuits. Simple electrical connections are made to trip and close circuits. Split-core Pickup Coils are attached to bushing CT secondary circuits. SF_6 gas sensors may be installed on the gas plumbing in several ways.

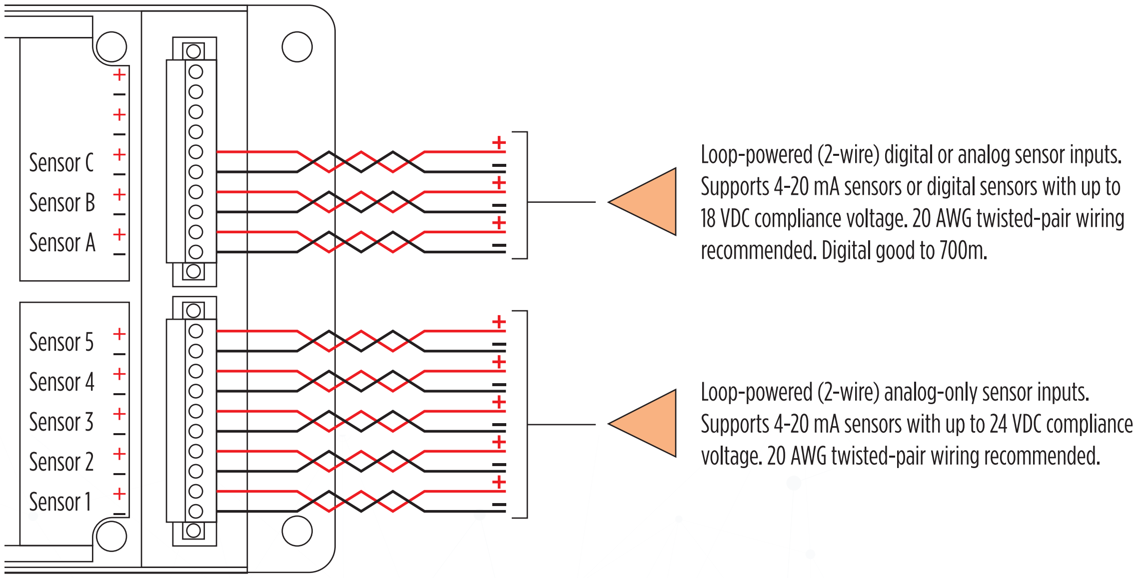
The Optimizer3 can be applied to any type of circuit breaker- vacuum, bulk oil, minimum oil, air blast, SF_6, live tank or dead tank. Optimizer3 is useful on small sub-transmission circuit breakers to large EHV circuit breakers.

Contact wear models vary slightly by manufacturer and technology used. During set up, the manufacturer’s limits for contact wear and timing should be used. If this information is not available, then IEEE C37.06-1989 standard should be used as a guide.

SENSOR INPUTS

The Optimizer3 includes eight inputs for sensors and five inputs for control signals.

Figure 2 – Sensor Field Wiring



Sensor inputs A, B, and C are dual-function. They accept either 2-wire 4-20 mA analog sensors or 2 wire Sensors with a Proprietary Digital Protocol. Sensor inputs 1-5 are 4-20 mA analog only and do not accept the digital protocol. For each 4-20 mA analog sensor, there is a corresponding setup area in the CONFIGURATION web pages where the scaling of the input is done. The digital Sensors require no scaling. The Optimizer3 scales those signals automatically.

- 18 VDC sensor power is provided for sensors A, B, and C.
- 24 VDC sensor power is provided for Sensors 1-5.

CT INPUTS

The Optimizer3 measures the current flowing through the bushing CT secondaries of the circuit breaker. These measurements are used in the contact wear calculations, arc time, and determination of Fault versus Non-Fault operations. Line current is also logged. During installation, small split-core Pickup Coils are attached to the relevant bushing CT circuits, noting the bushing CT turns ratio. Depending on the maximum current expected in the bushing CT circuits, an optimal split-core Pickup Coil is selected. INCON® offers split-core Pickup Coils with the following full-scale ratings:

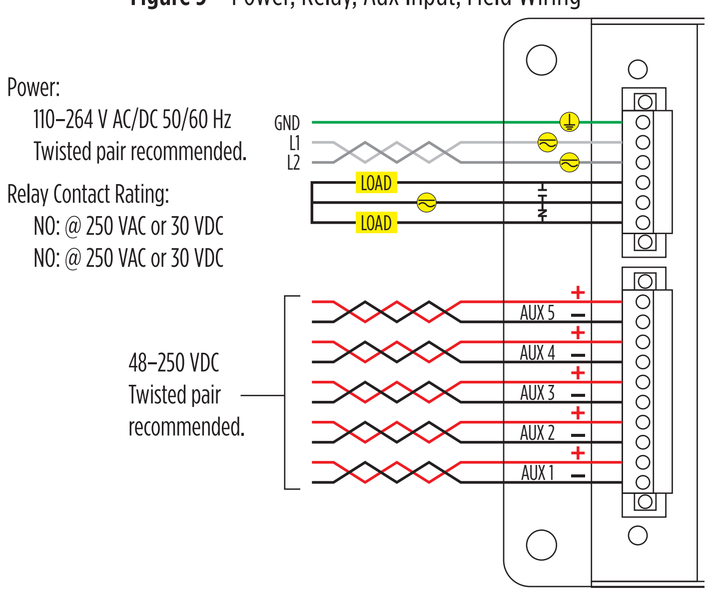
	Table 1 – Pickup Coil Ratings.							
INCON® Part Number	CT-20	CT-30	CT-50	CT-100	CT-160	CT-250	CT-400	CT-800
Full Scale Rating (A)	20	30	50	100	160	250	400	800
Range (A)	1.4-20	2.1-30	3.5-50	7-100	11.2-160	17.5-250	28-400	56-800

Each "CT-nn" part number is for a set of three Pickup Coils. The Pickup Coils are compatible with 50 or 60 Hertz power systems. The split-core Pickup Coils snap on over existing insulated bushing CT secondary circuits without tools and are rated 1.0 % accuracy and 0.05 VA burden at 5 amps. Removal or disruption of bushing CT circuits is not necessary. Although referred to as a CT, these are sensors that give 0-5 VAC output for 0 to Full Scale current.

CONTROL INPUTS

The use of each input is determined by the circuit breaker application and Mode of operation. Each control input is multi-function and is defined in the system CONFIGURATION. The control inputs are continuously interrogated to detect when the control circuit nodes are in the active or inactive state. Each AUX input is fused on both legs, optically isolated from the monitoring processor circuits, and has an input impedance of 540 kΩ. The Off/On voltage threshold is approximately 35 volts.

Figure 3 – Power, Relay, Aux Input, Field Wiring



CONTROL INPUT LOGIC MONITORING

The logical state of each Control Input is continuously monitored and compared with the Input Polarity settings, in the context of the Input Mode setting. Based upon these settings, the Optimizer3 knows the normally expected logic state of each Input, when the breaker is closed or open. If the voltage state of an Input violates its closed or open state for longer than 3 seconds, the A-B Logic Alarm will activate. This alarm is self-clearing once the provoking condition returns to the normal state. A record of the alarm is written in the Event History, along with the dates and times the alarm occurred and was cleared.

This A-B Logic alarm serves as a Trip Coil integrity monitor in Input Modes 2, 4, 5, 6 and 7. The normal voltage state of the Control Input wired across the Trip Coil is low. The low impedance (approximately 50 ohms) of the Trip Coil, energized through the high-impedance Red Light, will normally produce a very low voltage to the Optimizer3 Control Input. If the Trip Coil impedance significantly increases or it becomes open-circuited, the voltage drop across the damaged coil will be high, causing the Optimizer3 to assert the A-B Logic alarm.

INPUT POWER, GROUNDING, ISOLATION

The Optimizer3 operates from station battery DC or AC station service. Nominal current draw is 0.5 amp. The power input automatically accepts either AC or DC. Both power supply legs are fused. If external fuses are used, 3.15 amp slow-blow are recommended. Power input leads are isolated from chassis and are floating and not referenced to ground.

Ground connection is internally connected to the metal chassis. It is recommended that the ground be connected to the station ground or ground bar inside the circuit breaker cabinet. Follow the electrical grounding standard in effect at your utility.

All wiring connections are made to removable Phoenix connectors. The Optimizer3 may be electrically isolated by pulling out all the connectors from their mating sockets. Follow the electrical isolation standard in effect at your utility. If fused-cutouts are desired, locate them physically near the Optimizer3 with 3.15 Amp Slow-Blow fuses for all input and control wiring. The Optimizer3 uses a switch-mode power supply with universal input. On power-up, it draws more than nominal current for 1 mS. Slow-Blow fuses are mandatory if external fuses are used.

IMPORTANT: The Optimizer3 contains flash storage (SD card) for booting the device and saving data. Flash storage has the potential to be corrupted under rare circumstances due to power loss while the software is writing to the SD card. The Optimizer3 has both hardware and software features to prevent corruption from occurring on boot-up or shut down.

The protection features begin working after 20 seconds of operation. It is important to make sure the power to the Optimizer3 is solidly connected to terminals without the chance of disconnection and loss of power during the first 20 seconds of operation.

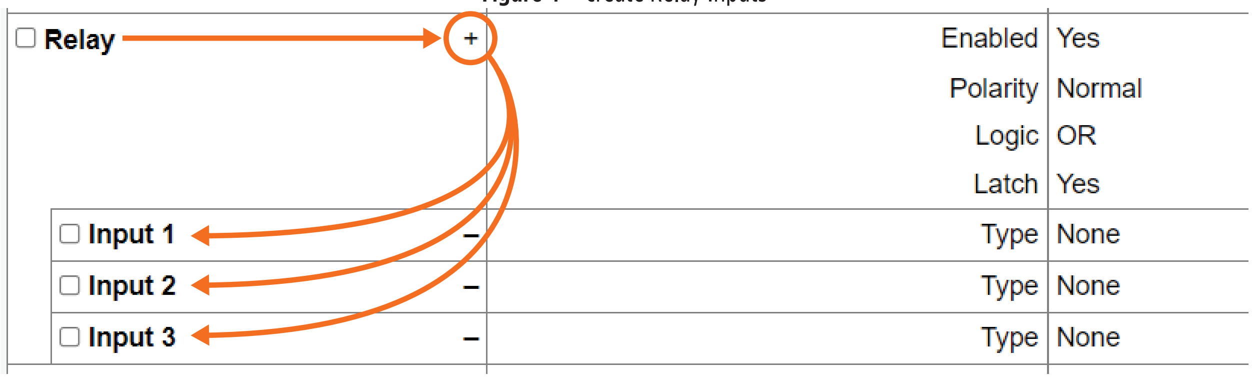
RELAY

The Optimizer3 is equipped with one Form C (SPDT) dry contact relay. The relay is asserted by the state of alarms or Digital Inputs. The relay is fully programmable and must be setup as needed. The relay is un-programmed in the default settings.

PROGRAMMING

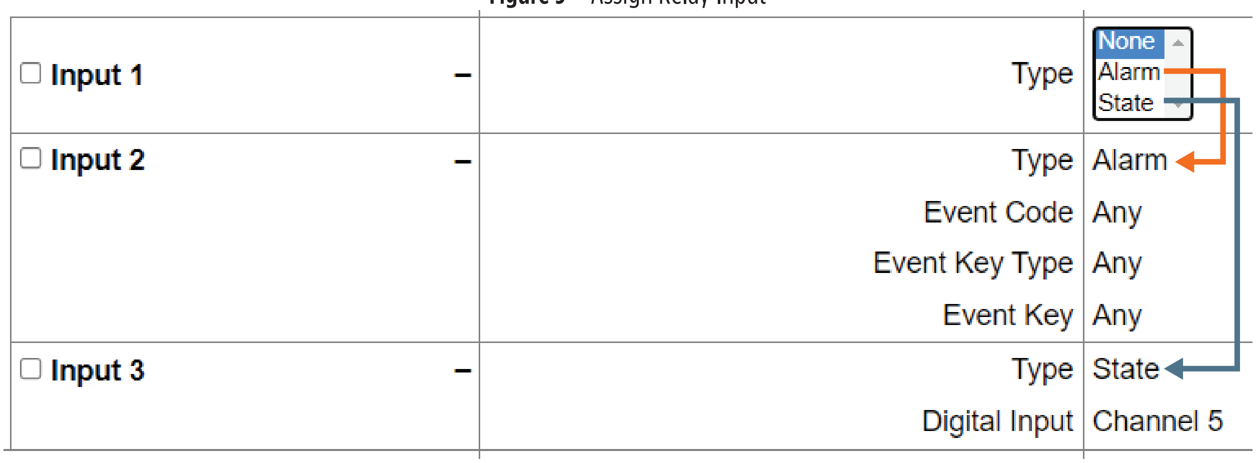
The relay is programmed by adding an input for each alarm or Digital Input required to assert the relay. Inputs are added by clicking the "+" sign. New numbered inputs appear below.

Figure 4 – Create Relay Inputs



The inputs can each be assigned to an "Alarm" or "State", selected from the "Type" menu.

Figure 5 – Assign Relay Input



Digital Inputs are AUX input channels that are unused, depending upon the Input Mode being used (see page 38). There may be only one or two to choose from. When the AUX input is energized, the relay will be asserted.

If the Relay Input is an Alarm, it can be left in a generic mode, allowing any alarm to assert the relay. If only specific alarms are desired to assert the relay, further programming is needed to assign the Event Code, and possibly the Event Key.

Select the Event Code from a menu of all possible alarms and conditions. Some Event Codes allow an Event Key to limit the relay assertion to a specific CT phase or sensor channel associated with the Event. In most cases, the Event Key can be set to "Any", which will allow any alarm event of the same Event Code to assert the relay.

Figure 6 – Assign Relay Event Code

☐ **Input 1**	–	Type	Alarm
		Event Code	A-B Logic
☐ **Input 2**	–	Type	Alarm
		Event Code	Low Gas Warning Limit
		Event Key	Sensor A
☐ **Input 3**	–	Type	Alarm
		Event Code	CT Input Failure
		Event Key	Any

The relay's Polarity can be programmed to "Invert". This causes the relay to assert when no alarms are active and de-assert when an alarm occurs. This mode can be used to create a "fail-safe self-diagnostic" alarm of sorts. If the Optimizer3 should lose power or experience a catastrophic failure, the asserted relay would release. The normally closed contacts would close, notifying the supervisory system of the failure.

Figure 7 – Program Relay Polarity

☐ **Relay**	+	Enabled	Yes
		Polarity	Normal / Invert
		Logic	OR
		Latch	Yes

If desired, the relay can be programmed to "Latch" in the asserted state. This is useful for bringing attention to alarm conditions that are occasional or momentary. The relay will remain in the asserted state until manually reset or until the Optimizer3 reboots. The Relay Latch Reset button is located on the Action page.

Figure 8 – Reset Latched Relay

Relay	
Reset Latch	Reset

COMMUNICATION PORTS

Communication ports are used for Configuration of alarms and settings, history data retrieval, resets, data viewing, and data transfer using DNP3.0 protocol.

RS-485 is half duplex. This port is used for DNP3 communication only. No user interface actions can be done through this port. If the Optimizer3 is the last device in the network, a wire jumper is needed between terminals marked Term Jump. This jumper places an internal 120Ω resistor into the circuit for termination. Factory defaults are Data bits: 8, Stop bits: 1, Parity: 1, Baud Rate: 9600 bps, flow control: none.

USB Port is used for manual data dumping and password resetting. (Contact Technical Service). A USB memory stick with special script files is necessary to perform specific operations, each operation requires a different script. Script files must be located in the root directory of the USB memory stick. Files in directories on the memory stick will not be seen by the Optimizer3.

Mini USB Port default IP address from the factory is https://192.168.171.171 . Drivers may be required. It is recommended that the PC or laptop be connected to a network with internet access upon first connection to the Optimizer3 using the Mini USB. The PC or laptop will better be able to find the necessary driver files for the device. If this is not possible or does not work, a Mini USB driver file is included on the documentation memory stick, which is included with the Optimizer3. It also contains the Optimizer3 User's Guide, DNP3 Profile Document and other information. The Mini USB Port can be used for local data dumping, alarm resetting, downloading, and uploading configuration settings, firmware upgrades and all user interface functions.

Ethernet 1 (Copper) and Ethernet 2 (Fiber Optic) with multiple user's ports are used with DNP 3.0 and TCP/IP protocols. Optimizer3 is multi-session so both can be run simultaneously. When connected to a secure local area network, the Optimizer3 can be accessed remotely with a web browser by using its unique IP address. Firmware upgrades can be performed (locally or remotely) via this port using the INCON® upgrade tool.

- Ethernet 1 (Copper) Default IP Address is https://192.168.168.168
- Ethernet 2 (Fiber) Default IP Address is https://192.268.169.169 -100 Mbps ST Connection.
- The Ethernet 2 hardware uses multi-mode-capable transceivers.

Ethernet 2 is a hardware option included with the model OM3D-F only. Even when so equipped, it is NOT turned on by default. It must be enabled and configured before use.

IMPORTANT: Ethernet 1 and Ethernet 2 cannot have the same IP address. If this occurs, the network will be unstable and unreliable. If these ports get accidentally set the same, connect to the Optimizer3 with the mini-USB port and change the configuration settings of the Ethernet ports so they are different IP addresses.

Customizing the ports is done on the Configuration Page in the Networking Section.

Figure 9 – Network Settings

Networking		
Ethernet 1	Enabled	Yes
IPv4	Method	Manual
	Address	192.168.168.168
	Netmask	255.255.255.0
	Gateway	
	DNS Servers	
	Search Domains	
	DHCP Server	Disabled
Ethernet 2	Enabled	Yes
IPv4	Method	Manual
	Address	192.168.169.169
	Netmask	255.255.255.0
	Gateway	
	DNS Servers	
	Search Domains	
	DHCP Server	Disabled
Wi-Fi	Enabled	No
USB	Enabled	Yes
IPv4	Address	192.168.171.171
	Netmask	255.255.255.0
	DHCP Server	Enabled
DHCP Server	Start	100
	Limit	50
	Lease Time	60 min

Clicking on each section reveals the fields where the settings are configured.

If using wired Ethernet 1 network connection, use settings as provided by your network administrator.

If using fiber-optic Ethernet 2 network connection, use settings as provided by your network administrator.

The settings for USB networking should be left as shown, so that the local access IP address is always known.

Note: The port addresses are saved in the .XML file during a configuration download. If multiple Optimizer3 monitors are to be configured using one setup file, the addresses can be edited with a word processor, then uploaded for each monitor.

Dynamic Host Configuration Protocol (DHCP) is a network protocol that enables a server to automatically assign an IP address to a computer from a defined range of numbers (i.e., a scope) configured for a given network.

Static IP address may be assigned (manually by giving it the XXX.XXX.XXX.XXX number), or they may be automatically assigned by pointing the Optimizer3 to a DHCP server that manages a range of addresses and "dynamically" assigns these addresses.

COMMUNICATIONS SOFTWARE

The Optimizer3 is a web server. A web browser is required to communicate with it using the TCP/IP protocol via the Mini-USB port or either of the Ethernet ports. If DNP 3.0 protocol is used, the DNP master device will have software for network communication. Optimizer3 responds to validated DNP commands.

SELF-DIAGNOSTICS

A blinking green LED "Flashing OK" indicates normal operation of the microprocessor system.

See page 11 regarding programming the relay for use in a "fail-safe, self-diagnostic" mode.

SPECIFICATIONS

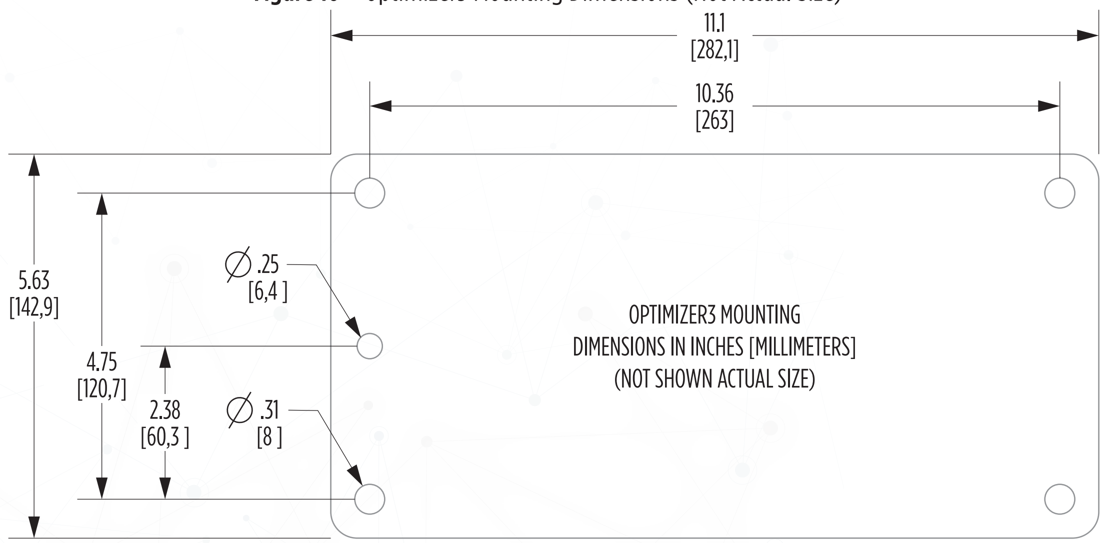
Table 2 – Specifications.

Specifications
Size: 11.125W X 5.625H X 2.625D, Inches Nominal, Shipping Weight: 6 Lbs.
Input Power: 110-250 VDC or 90-264 VAC (50/60 Hz). Power consumption is 60 VA max.
Recommended External Fuse Rating: 3.15 Amp Slow-Blow
Operating Temperature: -40° C to +65° C
Alarm Relay Contact: One form C, 1 amp at 30 VDC, 2 amps at 250 VAC rating.
Analog Sensor Input Accuracy: ±1% max, ±0.5% typical
Pluggable Connector Wire Size: 12 to 24 AWG
Data Storage- Non-volatile memory with capacity of:
10,000 Application Events
10,000 Alarm Events
5000 Circuit Breaker Monitoring Events
5000 SF_6 Gas Parameter data points
750 Daily Summary logs
5000 3 phase Line Current (measured and scaled from bushing CT secondaries)
1000 Line Voltage Measurements (as measured at power input)
5000 Ambient Temperature Measurements (as measured at the monitor)
Test Standards:
IEEE C37.10
CISPR 16-2-1 (Conducted Emissions)
CISPR 16-2-3 (Radiated Emissions)
IEC61000-4-2 (ESD)
IEC61000-4-3 (Radiated RF)
IEC61000-4-4 (EFT)
IEC61000-4-5 (Surge)
IEC61000-4-6 (Conducted RF)
IEC 61000-4-11 (Voltage Dips & Interrupts)
IEC 61000-4-12 (Damped oscillatory wave- Power Ports)
FCC Part 15, Subpart B; ICES-003 (Emissions)

INSTALLATION

MOUNTING

Figure 10 – Optimizer3 Mounting Dimensions (Not Actual Size)



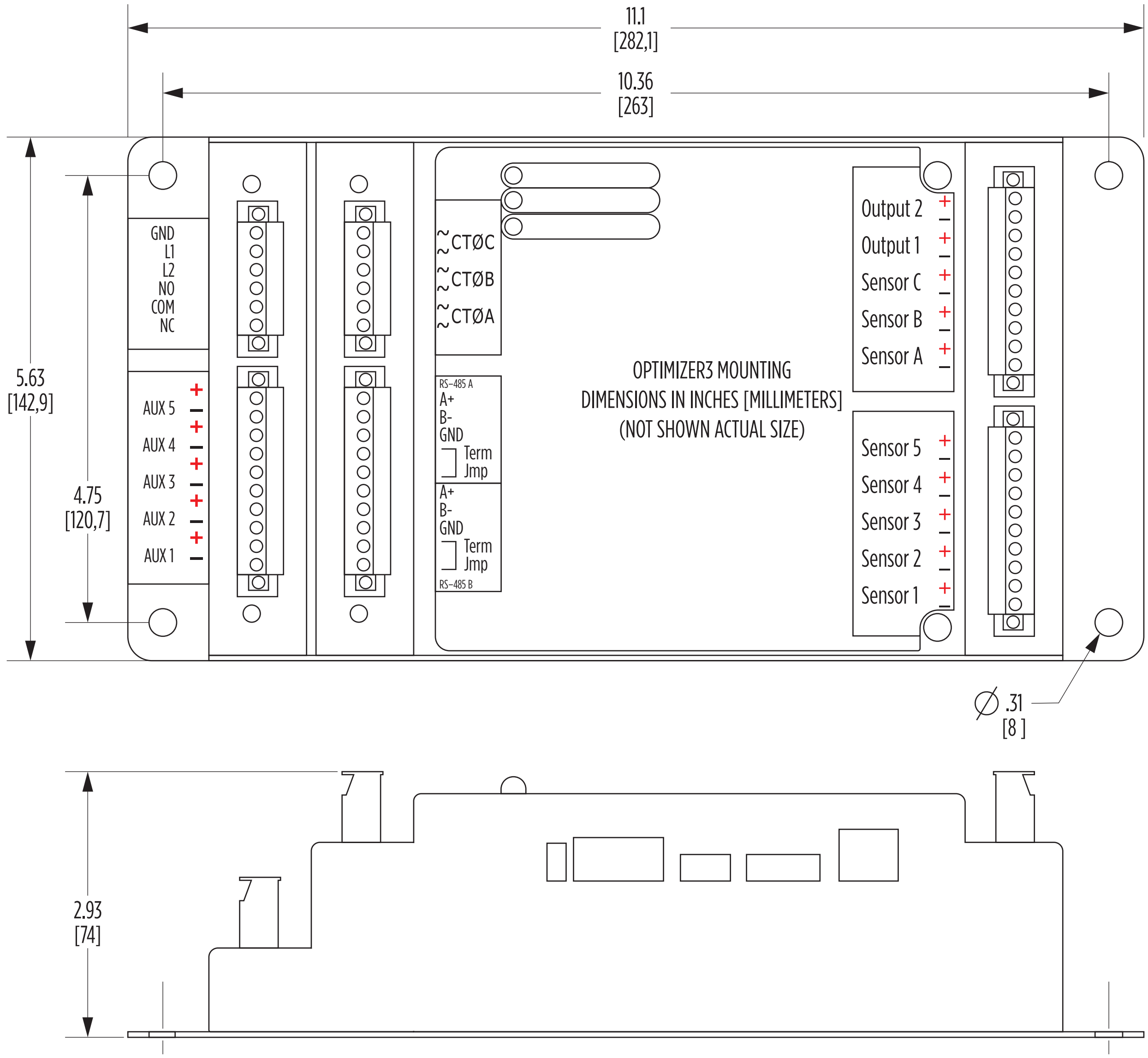
Optimizer3 may be mounted to the circuit breaker cabinet on interior side walls, on swing panels, or any other convenient location within the control cabinet. It must be mounted horizontally so that the air vent holes on the bottom and top can provide cooling by convection air flow. If Optimizer3 cannot be mounted horizontally, the ambient temperature measured by the sensor may read slightly higher than expected.

There are two rows of pluggable connectors on the left side and one row on the right side. Each plug is fastened by two screws, one on each end of each connector. These must be tightened during installation to assure the plugs stay engaged and do not come loose from normal shock and vibration of the circuit breaker.

In the event that isolation of the monitor is required, or replacement is necessary, the fasteners are unscrewed at each end and the connectors unplugged.

CAD files of dimensioned drawings are available from INCON® Technical Service.

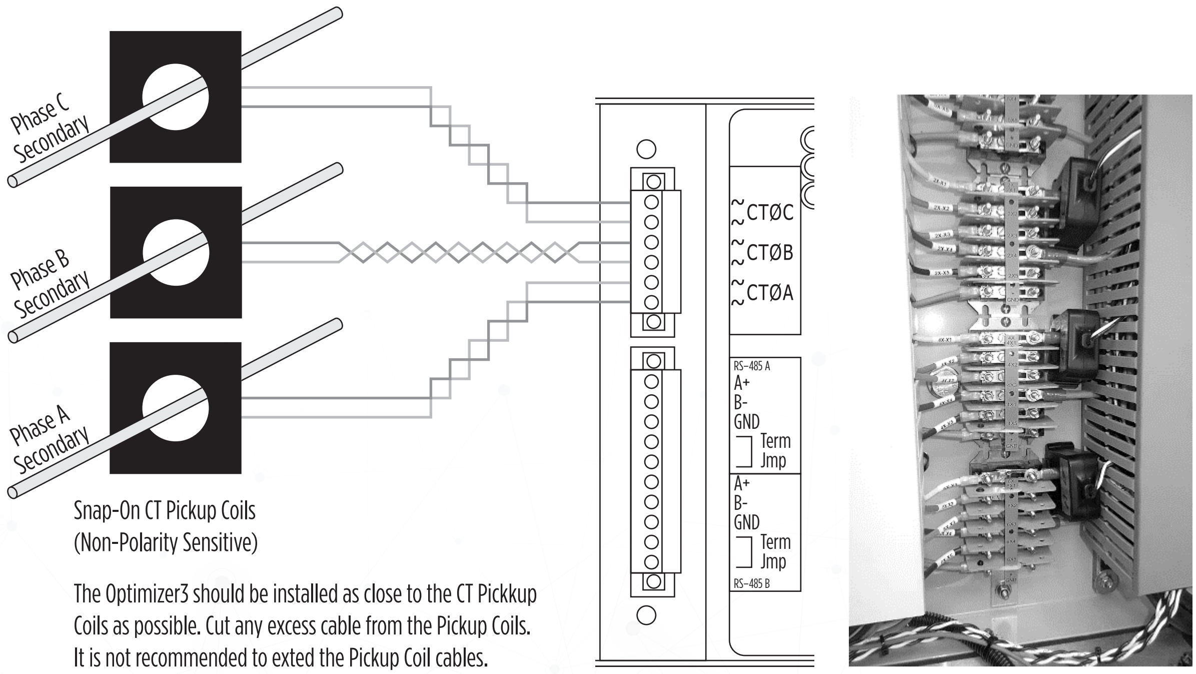
Figure 11 – Optimizer3 General Dimensions



CURRENT PICKUP COILS

Mounting the Optimizer3 as close as possible to the CT area will minimize Pickup Coil lead length and reduce the possibility of noise. The 20 AWG twisted pair leads should be cut to length and neatly run in a cable management product or secured with wire ties. The connections are not polarized even though they are colored black and white. If longer length is needed, do not extend the leads in the field. Contact Technical Service. The pickup coil output is 0-5 Volts AC.

Figure 12 – Optimizer3 Wiring of Current Transducers/Typical Arrangement



NAVIGATION

Optimizer3 functions as a web server. The only required software is a web browser. Using a browser and the mini-USB cable supplied with the unit, log into the unit. Enter the IP address "https://192.168.171.171" into the address bar to initiate the connection.

The FIRST login attempt will require a new Admin password. The password is blanked from view and needs to be entered two times to ensure accuracy.

Figure 13 – Initial Entry of the Admin Password.

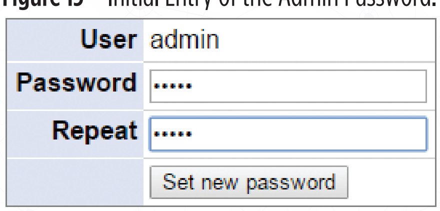
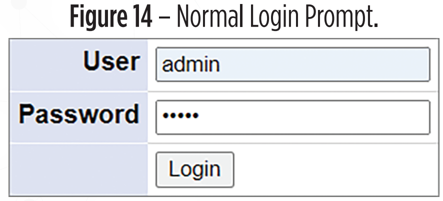


Figure 14 – Normal Login Prompt.



After the Admin password is set, the normal login prompt will appear.

Login with the "admin" username and password just created. The landing page after login is the CBM page which shows the present status of the circuit breaker.

Figure 15 – CBM Status Page

CBM Sensors Active Events Event History Export Action Configuration Date/Time Upgrade Reset Preferences About

Breaker State	Closed
Opening Time	OK
Opening Travel Time	OK
Closing Time	OK
Closing Travel Time	OK
Time Of Last Operation	May 17, 2017, 3:15:42 PM
Days Since Last Operation	0
No Operation Time	OK
Operation Count	0 - OK
Fault Interrupt Count	0 - OK
Non Fault Interrupt Count	0 - OK
Operation Number	0
Aux Input Failure	Alarm

	Phase A	Phase B	Phase C
RMS Current	0.0	0.0	0.0
Remaining Contact Life	100.0	100.0	100.0
Contact Life Warning	Disabled	Disabled	Disabled
Contact Life Danger	OK	OK	OK
Restrike	Disabled	Disabled	Disabled
Excess Arc	OK	OK	OK
Over Interrupting Time Limit	OK	OK	OK
Failed CT Pickup	OK	OK	OK

Click on Configuration to begin. Each category can be individually expanded by clicking on the cell or click on "Group >>" to expand all categories. Click the "Show Errors" button.

Figure 16 – Configuration Page

CBM Sensors Active Events Event History Export Action Configuration Date/Time Upgrade Reset Preferences About

Drag and drop: Move | Download | Upload... | Merge... | Revert | Save | Show errors

Group »	Parameter Name	Parameter Value
Passwords »	...	...
System Preferences »	...	...
Networking »	...	...
Date/Time »	...	...
Diagnostics »	...	...
System ID »	...	...
RS-485 »	...	...
Sensors »	...	...
SF6 »	...	...
Circuit Breaker Information »	...	...
Circuit Breaker Monitor »	...	...
Digital Inputs »	...	...
Relay »	...	...
DNP3	Mode	Disabled

Fill-in the three passwords and Site Name showing as “<not set>” and then click “Save”.

Figure 17 – Setting Passwords and Site Name

Group »	Parameter Name	Parameter Value
Passwords	admin	******
	installer	<not set>
	user	<not set>
	guest	<not set>
System Preferences »	...	...
Networking »	...	...
Date/Time »	...	...
Diagnostics »	...	...
System ID	Site Name	<not set>
	ID Line 1	
	ID Line 2	
	ID Line 3	
	ID Line 4	
	ID Line 5	

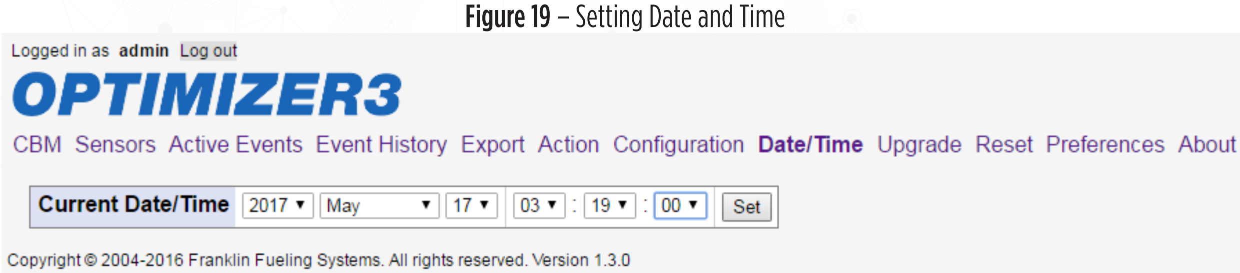
It is best to set the Time Zone at this time. If the Time is set first and then the Time Zone is changed, the time will be adjusted automatically. Therefore, set the Time Zone first, THEN set the time. Click the “Save” button

Figure 18 – Selecting the Time Zone

Date/Time	Time Zone	United States - Kentucky/Monticello United States - Los Angeles United States - Menominee United States - Metlakatla United States - New York
	NTP Servers	

Set the Time by clicking in the Date/Time tab. Adjust as needed, then click the “Set” button.

Figure 19 – Setting Date and Time



The Optimizer3 system time can be synchronized with an NTP server or from a DNP3 master. The NTP server’s IP address is specified in the Configuration Page, in the Date/Time group, ‘NTP Servers’ option. Multiple NTP servers can be used by placing a space between the addresses.

Figure 20 – Setting the NTP Server IP Address

Date/Time	Time Zone	United States - New York
	NTP Servers	

There are 4 levels of user for Optimizer3, Guest, User, Installer and Admin. Each has a password. The four roles are given different permissions.

- The Guest has permission only to view the pages listed below.
  The Guest can change their own Preferences and save them.

- The User has permission to view the same pages as the Guest.
  The User can also download reports from the Export Page and Clear/Preset/Reset alarms and counters on the Action Page.

- The Installer has permission to view all pages.
  The Installer has permission to make and save changes on the Configuration and Date and Time Pages.
  The Installer has permission to use the Upgrade and Reset Pages.
  The Installer has access to some secret data download pages for debugging.

- The Administrator has full permission to all pages and functions, including additional secret diagnostic pages.

Table 3 – Login Level Permissions

Guest
CBM
Sensors
Active Events
Event History
Date/Time (read only)
Preferences (read and write personal preferences)
About
User- All Guest rights plus:
Export
Action
Configuration (read only)
Installer- All User rights plus:
Configuration (write access)
Date and Time (write access)
Upgrade
Reset- reboot, erase data, erase all config,
Secret pages: download event debug
Admin- All Installer rights plus:
Secret pages: Shell, dbus

Before any further Configuration programming is done, it is best to set the System Preferences, since many other settings will be affected by these choices.

Figure 21 – Selecting Language

Group »	Parameter Name	Parameter Value
Passwords »	...	...
System Preferences	Language	English Español Português français Deutsch русский
	Regional Formats	United States

The details and choices for each parameter are shown by clicking on its cell. When setup is complete, click Save to keep the changes.

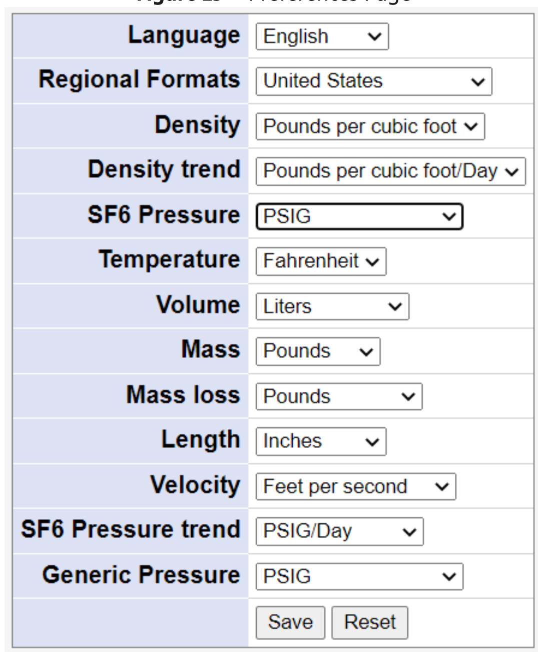
Figure 22 – System Preferences

Drag and drop: Move | Download | Upload... | Merge... | **Revert** | **Save**

Group »	Parameter Name	Parameter Value
Passwords »	...	...
System Preferences	Language	English
	Regional Formats	United States
Units	Density	Pounds per cubic foot
	Density trend	Pounds per cubic foot/Day
	SF6 Pressure	PSIG
	Temperature	Celsius Fahrenheit
	Volume	Liters
	Mass	Pounds
	Mass loss	Pounds
	Length	Inches
	Velocity	Feet per second
	SF6 Pressure trend	PSIG/Day
	Generic Pressure	PSIG

Internally, the Optimizer3 works in Metric units. To ensure each user always sees measurements in their preferred chosen units, their preferred units of measure can also be entered in the Preferences Page. These are "Personal Preferences" and override the System Preferences in terms of what is seen on screens served from the Optimizer3 to their browser. Each user's Personal Preferences are stored in their browser cache.

Figure 23 – Preferences Page



SF_6 GAS MONITORING

The standard installation is for SF_6 density or pressure to be measured with the DSDP digital density sensor or PSDP digital pressure sensor. These "digital" sensor types can only be wired to sensor input channels A, B or C. SF_6 temperature-compensated-pressure can be measured with an SF_6 sensor that outputs a scaled milliamp signal. These "analog" sensor types can be wired to any sensor input channel. The Mode for sensor types is found in the Sensors section of the Configuration page.

Figure 24 – Select Sensor Mode

☐ **Sensors**		
☐ **Sensor 1**	Mode	Off
☐ **Sensor 2**	Mode	Off
☐ **Sensor 3**	Mode	Off
☐ **Sensor 4**	Mode	Off
☐ **Sensor 5**	Mode	Off
☐ **Sensor A**	Mode	Analog Density Current Dew Point Digital Compensated Pressure Digital Density
☐ **Sensor B**	Mode	Off
☐ **Sensor C**	Mode	Off

The Optimizer3 can measure density with the DSDP sensor and calculate the equivalent gas pressure. It can also measure pressure with the PSDP sensor and calculate the equivalent gas density. These calculations are based on entered SF_6 fill weight and fill pressure values, taken from the breaker's nameplate. A daily Density or Pressure Trend is calculated from the measured density or pressure and temperature, using gas law equations. The daily trend is the decrease or increase per day in density or pressure, averaged over a sliding 15-day period.

The Optimizer3 continuously monitors the quality of the sensor signals.

- When the signal from a digital sensor is intermittent, weak or the Optimizer3 has lost sync with the sensor, an "Erratic Signal" error will be recorded.
- When the digital sensor signal is lost, a "Sensor Malfunction" error will be recorded.
- When the signal from an analog sensor is above or below the programmed signal high scale or low scale limits by 2% or more, a "Sensor Signal Range" error will be recorded.
- When the signal from an analog sensor is less than 2 milliamps, a "Sensor No Current" error will be recorded.

SF_6 PARAMETER SET UP

The parameters for SF_6 are set in the Gas Monitor section of Configuration Page. The first setting determines which SF_6 measurement type (Density or Pressure) is to be displayed. Density is the default choice. The System measurement units are given according to the selection made in the System Preferences section, under Units.

Figure 25 – Gas Monitor Settings

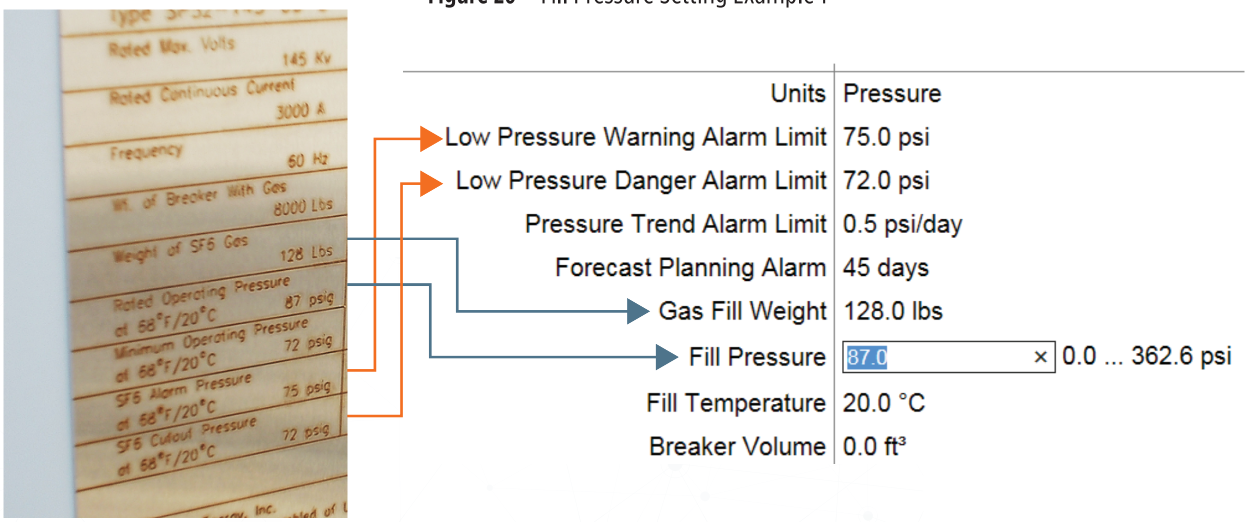
SF6		
Gas Monitor	Units	Pressure / Density
	Low Pressure Warning Alarm Limit	0.0 psi
	Low Pressure Danger Alarm Limit	0.0 psi
	Pressure Trend Alarm Limit	0.0 psi/day
	Forecast Planning Alarm	0 days
	Gas Fill Weight	0.0 lbs
	Fill Pressure	0.0 psi
	Fill Temperature	20.0 °C
	Breaker Volume	0.0 ft^3

SF_6 ALARM SETTINGS

Optimizer3 continuously records SF_6 density and SF_6 pressure. This is done separately for every SF_6 sensor that is used, up to the maximum of 8 sensors.

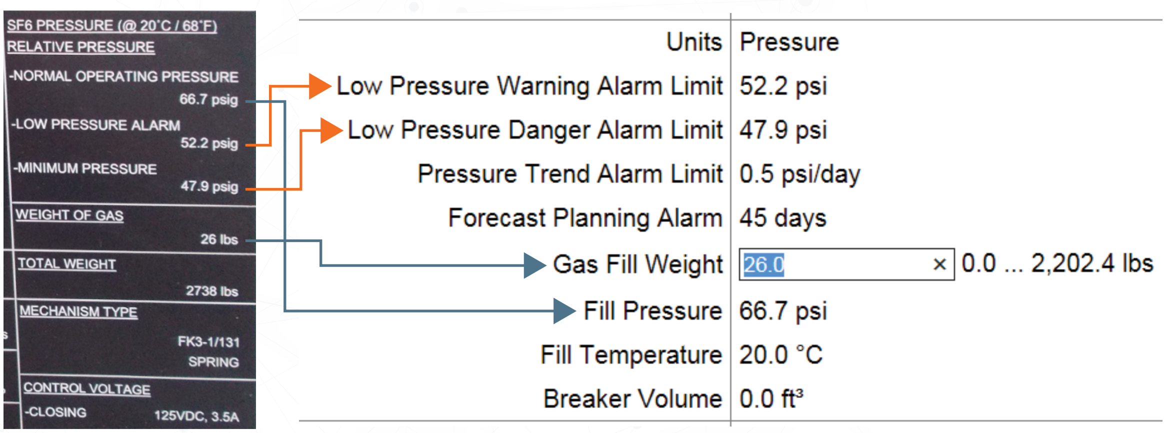
The Fill Pressure, Warning, and Danger alarm pressures should always correspond to what is written on the circuit breaker nameplate. In Figure 26, the Operating Pressure is the Fill Pressure and is 87 PSIG, the Alarm Pressure is 75 PSIG, and the Minimum/ Cutout Pressure is 72 PSIG. The Gas Fill Weight is 128 lbs.

Figure 26 – Fill Pressure Setting Example 1



In Figure 27, the Normal Operating Pressure is the Fill Pressure and is 66.7 PSIG, the Low-Pressure Alarm is 52.2 PSIG, and the Minimum Pressure is 47.9 PSIG. The Gas Fill Weight is 26 lbs.

Figure 27 – Fill Pressure Setting Example 2

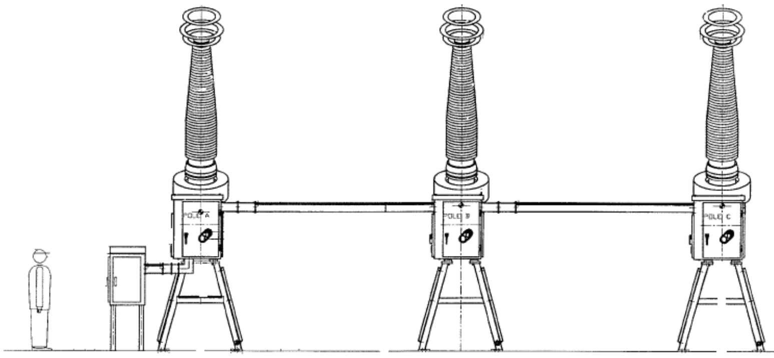


The examples in Figures 26 and 27, apply to circuit breakers with one common SF_6 system, using one density sensor. For circuit breakers having three independent SF_6 systems (one for each pole), the settings are slightly different.

The Fill, Warning, and Danger alarm pressures will be the same for each pole. For this type of circuit breaker, with separate SF_6 systems for each pole, one SF_6 density sensor must be installed on each pole. Each SF_6 density sensor works independently and leak calculation for each pole uses the fill weight value programmed, as if it were for each individual pole.

Therefore, in the case of three SF_6 pressure or density sensors used on three separate poles, the Total Weight of SF_6 Gas given on the nameplate must be divided by three. 360 ÷ 3 = 120 lbs. See Figure 29.

Figure 28 – Fill Weight for IPO Breakers



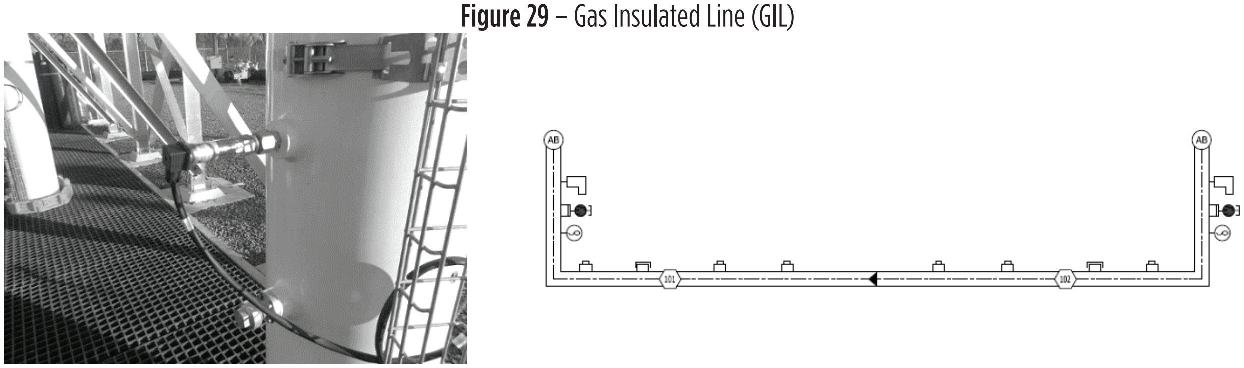
Units	Pressure
Low Pressure Warning Alarm Limit	75.5 psi
Low Pressure Danger Alarm Limit	72.5 psi
Pressure Trend Alarm Limit	0.5 psi/day
Forecast Planning Alarm	45 days
Gas Fill Weight	120.0 lbs
Fill Pressure	80.0 psi
Fill Temperature	20.0 °C
Breaker Volume	0.0 ft³

Terminal to Terminal Circuit Breaker Open..................1300 KV	Normal SF^6 gas pressure at 20° C........ 80.0 PSIG.........0.55 MPaG
Total weight of breaker w/ gas............29707 lbs.............13475kg	Alarm SF^6 gas pressure at 20° C........... 75.5 PSIG........ 0.52 MPaG
Total weight of SF^6 gas .... 360 lbs.............13475kg	Minimum SF^6 gas pressure at 20° C ..... 72.5 PSIG........ 0.50 MPaG

SF_6 GIL (GAS INSULATED TRANSMISSION LINE) APPLICATION

Optimizer3 is a useful SF_6 gas monitoring system for GIL. There are 8 sensor inputs which all may be used for SF_6 density or pressure measurement, using analog Temperature-Compensated sensors.

Figure 29 – Gas Insulated Line (GIL)



In Figure 29, a three-pole GIL was monitored. Each pole was made up of two SF_6 gas zones. An SF_6 gas density sensor is installed on each riser, making up a total of 6 gas zones. The GIL manufacturer supplies the following information:

Table 4 – Gas Insulated Line Fill Weight

Compartment Gas Volume (ft^3), Weight (lbs), and Length (ft)				
Circuit 1		Phase		
		A	B	C
Zone 101	Zone Volume	365.25	352.42	339.59
	Zone Weight	701.79	677.14	652.49
	Zone Length	341.67	329.67	317.67
Circuit 1		Phase		
		A	B	C
Zone 102	Zone Volume	365.25	378.07	390.90
	Zone Weight	701.79	726.44	751.09
	Zone Length	341.67	353.67	365.67

Figure 30 – Optimizer3 Settings for Gas Insulated Lines

SF_6 GAS SYSTEM SPECIFICATIONS		
Compressed Gas Insulated Transmission Bus	**Nominal Gas Density**	**1.92 lb/ft^3**
	Nominal Gas Pressure at 20° C	55.0 psig
	1ST ALARM Gas Pressure at 20° C	50.0 psig
	2ND ALARM Gas Pressure at 20° C	43.5 psig

Units	Pressure
Low Pressure Warning Alarm Limit	50.0 psi
Low Pressure Danger Alarm Limit	43.5 psi
Pressure Trend Alarm Limit	0.5 psi/day
Forecast Planning Alarm	45 days
Gas Fill Weight	702.0 lbs
Fill Pressure	55.0 psi
Fill Temperature	20.0 °C
Breaker Volume	0.0 ft^3

Fill Pressure is 55 PSIG, Warning Alarm is 50 PSIG, and Danger Alarm is 43.5 PSIG.
The Fill Weight is the average of all six compartments since they are all slightly different.
Fill Weight = (701.79 + 677.14 + 652.49 + 701.79 + 726.44 + 751.09) ÷ 6 = (4211 ÷ 6) = 702.0 lbs

PRESSURE/DENSITY TREND, FORECAST PLANNING ALARMS

If an SF_6 leak is detected in any of the SF_6 zones and it exceeds the Pressure/Density Trend Alarm Limit, the alarm relay can be asserted, if desired. The alarm status is available as a DNP SCADA point.

Pressure Trend Alarm Limit	0.5 ×	0.0 ... 580.2 psi/day

LOW GAS ALARM FORECAST & FORECAST PLANNING ALARM

The Low Gas Alarm Forecast reports how many days until the Density/Pressure Danger Alarm will be reached. Based on this SF_6 leak trend, the number of days until this alarm is asserted is given on the Sensors Page and available via DNP.

The maximum Forecast Planning Alarm limit is 180 days:

Forecast Planning Alarm	30 ×	0 ... 180 days

The Forecast Planning Alarm adds a user-defined number of days to the Low Gas Alarm Forecast to allow for planning, equipment preparation, and outage scheduling. When the SF_6 gas pressure decreases so that the predicted number of days until the Danger Alarm is asserted is equal to or less than the Forecast Planning Alarm, the alarm relay can be asserted, if desired. The alarm status and the forecast value are available as DNP SCADA points.

The Pressure/Density Trend status is shown on the Sensors Page:

Pressure Trend (PSIG/day)	0.2
Trend Limit	OK

Forecast status is shown on the Sensors Page:

Low Gas Alarm Forecast (days)	45
Forecast Limit	OK

To clear the low-gas alarm:

1. Add SF_6 to a value greater than 5% over the alarm limit that is set, then...
2. Manually clear the alarm from the Action Page

Figure 31 – Clearing Low Gas Alarms

SF6 Gas Monitor		
Low Gas Alarms	Sensor A	Clear
Trend Data and Trend Alarm	Sensor A	Reset

OTHER SENSOR MONITORING

TEMPERATURE MONITORING

Figure 32 – Temperature Monitor Settings

Mode	Temperature Voltage Current Heater Monitor UPSM-241 LenSense 2TC/105
Signal Low	4.0 mA
Signal Low Represents Temperature	-20.0 °C
Signal High	20.0 mA
Signal High Represents Temperature	120 °C
Low Temperature Alarm Limit	-30 °C
High Temperature Alarm Limit	50 °C

Optimizer3 can record temperature from the internal Ambient sensor, analog loop-powered 4-20 mA temperature transducers, or from the temperature given by Digital Density or Pressure sensors. A temperature transducer can be used to monitor cabinet temperature, interrupter heater blankets, etc.

NOTE: Although temperature measurements from the Ambient sensor and Digital Density or Pressure sensors are logged in the history, there are NO ALARM LIMITS associated with these temperature measurements. Only the analog loop-powered 4-20 mA temperature transducers have associated programmable alarm limits.

When the “Temperature” sensor mode is selected, scaling for the mA current range and temperature range appear. High and Low Temperature Alarm Limits appear.

If an Alarm Limit is set to -60.0° C (-76.0° F), the alarm is disabled.

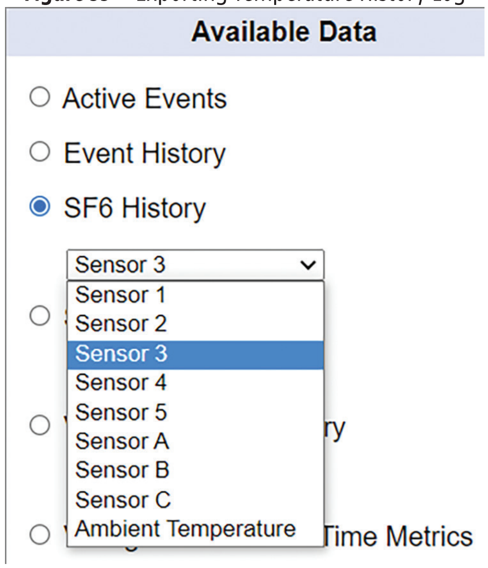
The Low Temperature Alarm Limit is asserted if the measured temperature is less than or equal to the setting.

The High Temperature Alarm Limit is asserted if the measured temperature is greater than or equal to the setting.

A hysteresis of 3 degrees is applied to an active alarm, to reduce nuisance toggling of the alarm. The alarms are non-latching and clear themselves when the measured temperature is between the alarm limits.

The history log of the Ambient and Sensor temperatures can be downloaded from the Export Page, by selecting "SF_6 History" and then selecting the specific sensor from the pull-down menu. Only the Temperature will be listed in the CSV file when the Ambient sensor or an analog loop-powered 4-20 mA temperature transducer is selected. Density and Pressure will be blank.

Figure 33 – Exporting Temperature History Log



There are DNP points for each temperature sensor type: Ambient, Analog, and Digital sources.

Figure 34 – DNP3 Points for Temperature Sensors

Analog	Default static variation	Group 30 Variation 1 - 32-bit with flags
	Override defaults	No
	Number of measurements	3
1	Category	Other
	Source	Ambient Temperature
2	Category	Sensor 1
	Source	Sensor 1 Temperature (Analog)
3	Category	Sensor A
	Source	Sensor A Temperature (Digital)

VOLTAGE MONITORING

Figure 35 – Voltage Monitor Settings

Mode	Voltage Current Heater Monitor UPSM-241 LenSense 2TC/105 LenSense 2TC/106
Signal Low	4.0 mA
Signal Low Represents Voltage	0.0 V
Signal High	20.0 mA
Signal High Represents Voltage	150.0 V
Low Voltage Alarm Limit	110.0 V
High Voltage Alarm Limit	135.0 V
Run-Time Metrics	No
Monitor Continuous Voltage	No

Optimizer3 monitors Voltage with loop-powered 4-20 mA Voltage transducers. The transducers can be used to monitor DC station battery voltage at the circuit breaker, AC station service voltage at the circuit breaker, or motor activity. When Voltage is selected, scaling for the mA current range and voltage range appear.

High and Low Voltage Alarm Limits appear. If either Limit is set to 0 (zero), the alarm is disabled. The Low Voltage Alarm Limit is asserted if the measured voltage is less than or equal to the setting. The High Voltage Alarm Limit is asserted if the measured voltage is greater than or equal to the setting.

A hysteresis of 3 volts is applied to an active alarm to reduce nuisance toggling of the alarm. The alarm is non-latching and clears itself when the measured voltage is between the alarm limits.

If Yes is selected for Run-Time Metrics, it is assumed the voltage sensor input is connected in parallel to a spring charging motor, air compressor motor, or hydraulic pump motor. The cumulative run time, the number of runs per day, and average run duration are reported and logged. If Yes is selected for Monitor Continuous Voltage, the daily average, minimum, maximum, and sample count are reported and logged.

CURRENT MONITORING

Figure 36 – Current Monitor Settings

Mode	Current Heater Monitor UPSM-241 LenSense 2TC/105 LenSense 2TC/106 LenSense 2TC/108
Signal Low	4.0 mA
Signal Low Represents Current	0.0 A
Signal High	20.0 mA
Signal High Represents Current	30.0 A
Low Current Alarm Limit	0.0 A
High Current Alarm Limit	20.0 A
Monitor Run Metrics	Yes
Monitor Load Metrics	Yes

Optimizer3 monitors Current with loop-powered 4-20 mA current transducers. The transducers can be used to monitor motor current, heater current, or the current of other accessory equipment. When Current is selected, scaling for the mA current range and measured current range appear.

When Current mode is selected, scaling for the mA current range and measured Current range appear. High and Low Current Alarm Limits appear. If either Alarm Limit is set to 0 (zero), the alarm is disabled.

The Low Current Alarm Limit is asserted if the measured current is less than or equal to the setting.

The High Current Alarm Limit is asserted if the measured current is greater than or equal to the setting.

A hysteresis of 1 (one) amp is applied to an active alarm to reduce nuisance toggling of the alarm. The alarm is non-latching and clears itself when the measured current is between the alarm limits.

If Yes is selected for Run-Time Metrics, it is assumed the current sensor input is connected around the input conductor to a spring charging motor, air compressor motor, or hydraulic pump motor. The cumulative run time, the number of runs per day, and average run duration are reported and logged. If Yes is selected for Monitor Load Metrics, the maximum current per run, run time, and I^2T for the run is reported and logged. Load Metrics are useful for spring charging motors and Run Time Metrics are useful for air compressors or hydraulic pumps.

MOTOR RUN-TIME METRICS

VOLTAGE MODE

In Voltage sensor mode, the Run Time Threshold is 3% of the programmed voltage range. Above this threshold the motor is considered running, below it, the motor is considered off.

On the Action Page, the Preset Run Time (hrs.) function allows the user to preset the Optimizer3 counter to match the mechanical Motor Run Hours counter on the breaker.

Monitor Run Metrics, shown on the Sensors Page:

1. Voltage = Present scaled input measurement.
2. Accumulated Run Time (hrs.) = Totalized running time for all starts (logged in database after each Run).
3. Average Run Time (sec.) = Running time for the last 10 runs averaged (logged in database after each Run).
4. Average Time Between Runs (hrs.) = "OFF Times", measured from the end of one run to the beginning of the next, for the last 10 runs averaged (logged in database after each Run).
5. Run Frequency (avg. runs per day) = 30-day average number of starts (logged in database after each Run).

Monitor Continuous Voltage, shown on the Sensors Page:

1. Voltage = Same as above.
2. Today's Average = Average voltage since the previous MIDNIGHT (logged in database once a day).
3. Today's Minimum = Lowest measured voltage since the previous MIDNIGHT (logged in database once a day – with date/time stamp when they occurred).
4. Today's Maximum = Highest measured voltage since the previous MIDNIGHT (logged in database once a day – with date/time stamp when they occurred).
5. Sample Count = Number of voltage samples since the previous MIDNIGHT.

CURRENT MODE

In Current sensor mode, the Run Time Threshold is 3% of the programmed current range. Above this threshold the motor is considered running, below it, the motor is considered off.

On the Action Page, the Preset Run Time (hrs.) function allows the user to preset the Optimizer3 counter to match the mechanical Motor Run Hours counter on the breaker.

Current is sampled at a high rate but averaged in roughly 1-second time buckets. These 1-second buckets are used in all calculations.

Monitor Run Metrics, shown on the Sensors Page:

1. Current (A) = Present scaled input measurement of the last 1-second time bucket.

2. Accumulated Run Time (hrs.) = Totalized running time for all starts (logged in database after each Run).
3. Average Run Time (sec.) = Running time for the last 10 runs averaged (logged in database after each Run).
4. Average Time Between Runs (hrs.) = “OFF Times”, measured from the end of one run to the beginning of the next, for the last 10 runs averaged (logged in database after each Run).
5. Run Frequency (avg. runs per day) = 30-day average number of starts (logged in database after each Run).

Monitor Load Metrics, shown on the Sensors Page:

1. IxT (A x sec.) = Sum of IxT calculations for all time buckets from the last run (logged in database after each Run).
2. I^2xT (A^2 x sec.) = Sum of I^2xT calculations for all time buckets from the last run (logged in database after each Run).
3. Maximum Current = Highest 1-second average current during the last run (logged in database after each Run).

HEATER MONITORING

The Universal Power Status Monitor (UPSM-241) accessory detects when the thermostat is calling for heat and measures the current in the main heater circuit.

The design assumes that all failures of electric heating elements are caused by open circuits. If the measured heater current is too low alarm relay can be asserted, if desired. The alarm status is available as a DNP SCADA point.

Figure 37 – Tank Heater Circuit

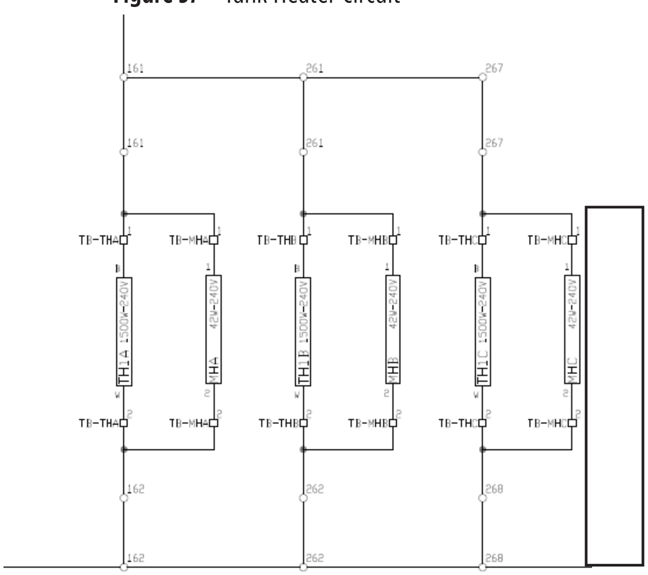


Figure 38 – Heater Monitor Settings

Mode	Heater Monitor UPSM-241 LenSense 2TC/105 LenSense 2TC/106 LenSense 2TC/108 LenSense 2TC/115
Current Range	0-30 Amps
Low Current Alarm Limit	18.4 A

Figure 39 – Heater Monitor Status

	Sensor 1
Heater	On
Current (A)	18.6
Low Current	OK

In this example of an IPO circuit breaker with separate mechanism cabinets, there is a 1500-watt heater for each interrupter tank running at 240 VAC. There is a 42-watt heater running at 240 VAC in each cabinet. The total current is 18.6 amps. The loss of one cabinet heater is the lowest reduction that could occur. This would reduce total current to 18.4 amps. For this example, the Low Current Alarm Limit should be set to 18.4 amps.

A simpler alternate approach is to use the ambient temperature sensor and poll the temperature versus the current draw on the heater circuit. If ambient is colder than the thermostat setting, then there should be current associated with the heaters in the circuit. This analytic would be done in the SCADA environment as a “back office” application.

GENERIC PRESSURE MONITORING

Figure 40 – Generic Pressure Monitor Settings

Mode	Off, Analog Compensated Pressure, Analog Density, Current, Generic Pressure (selected)
Signal Low	4.0 mA
Signal Low Represents Generic Pressure	0.0 PSIG
Signal High	20.0 mA
Signal High Represents Generic Pressure	9,999.0 PSIG
Low Generic Pressure Alarm Limit	0.0 PSIG
High Generic Pressure Alarm Limit	0.0 PSIG

Optimizer3 monitors Generic Pressure with loop-powered 4-20 mA Pressure transducers. The transducers can be used to monitor air pressure, hydraulic pressure, or any generic pressure at the circuit breaker. When Generic Pressure is selected, scaling for the mA current range and pressure range appear.

When Generic Pressure mode is selected, scaling for the mA current range and pressure range appear. High and Low Pressure Alarm Limits appear. If an alarm limit is set to -14.5 PSIG (-1BAR), the alarm is disabled.

The Low Pressure Alarm Limit is asserted if the measured pressure is less than or equal to the setting.

The High Pressure Alarm Limit is asserted if the measured pressure is greater than or equal to the setting.

A hysteresis of 3% of full range is applied to an active alarm to reduce nuisance toggling of the alarm. The alarm is non-latching and clears itself when the measured pressure is between the alarm limits.

DEW POINT MONITORING

The Optimizer3 monitors moisture with 4-20 mA Dew Point sensors. This moisture is expressed as a Dew Point Temperature – the temperature at which the water vapor will condense into a liquid. The Dew Point sensors can be used to monitor the moisture content of SF_6 gas when plumbed into the SF_6 gas system, typically alongside the density or pressure sensors.

The Optimizer3 calculates and records the Average Dew Point every two hours. This calculation uses the measured Dew Point values from the previous 30 days. When Dew Point is selected, scaling for the mA current range and Dew Point range appear.

The High Dew Point Alarm Limit will also appear. If this Limit is set to -60˚C (-76˚F) the alarm is disabled. The High Dew Point Alarm Limit is asserted when the AVERAGE Dew Point value is equal to or higher than the setting.

A hysteresis of 0.2˚C is applied to an active alarm to reduce nuisance toggling of the alarm. The alarm is non-latching and clears itself when the measured Dew Point is below the alarm limit.

Figure 41 – Dew Point Monitoring Settings

Mode	Off, Analog Compensated Pressure, Analog Density, Current, Dew Point (selected)
Signal Low	4.0 mA
Signal Low Represents Dew Point	-60.0 °C
Signal High	20.0 mA
Signal High Represents Dew Point	20.0 °C
High Dew Point Alarm Limit	-60.0 °C

Figure 42 – Dew Point Displayed on the Sensors Page

	Sensor 1
Dew Point (°C)	-45.9
Average Dew Point (°C)	-45.2

CIRCUIT BREAKER MONITOR FUNCTION

PURPOSE OF CIRCUIT BREAKER MONITORING

Circuit breakers are complex mechanical and electrical systems which require periodic maintenance. The need for maintenance is affected by

- Number of fault operations
- Number of total operations
- SF_6 sealing system integrity
- Environmental conditions
- Time since last operation
- Time since installation (equipment age)

There are symptoms associated with the maintenance needs which the Optimizer3 detects.

- Longer-than-normal arcing times
- Occurrence of restrikes
- Longer-than-normal Opening (Trip Latch) Time
- Longer-than-normal Opening Travel Time
- Spring-Charging motor high peak current or longer-than-normal run times
- Trip Coil or Close Coil exhibiting high forward voltage drop (=open coil)

Extended arcing time can result from blast nozzles on puffer circuit breakers that have a high accumulated arcing duty. The exposure to hot arcs causes ablation of the Teflon nozzle material so the nozzle diameter gets larger and the velocity of the SF_6 blasted into the arc is reduced, with reduced effectiveness to extinguish the arc. For Oil Circuit Breakers, extended arcing times may be the symptom of contaminated oil or fault currents in excess of its rating.

Longer-than-normal Opening Travel Time is equivalent to slower-than-normal average velocity. In most cases, long measured Opening Travel Times are caused by poor lubrication or bearings that have seized with grease where liquids have evaporated and only the clay or other thickener remain.

Optimizer3 will detect fugitive emission (leaks) of SF_6 far earlier than the 63X pressure switch or SF_6 controller. Leaks are not only detected, but the day on which the low-gas alarm will assert is determined and made known to the maintenance planner. Beyond this, Optimizer3 calculates how much SF_6 has leaked and when the circuit breaker is re-filled and with how much SF_6 gas. Circuit breakers that have had leak problems over their life are likely to also have high moisture content in the SF_6 gas. These circuit breakers are good candidates for SF_6 Dew Point monitoring with an added OM-DPS sensor.

Optimizer3 monitors the phase currents and calculates the I^2T during the arcing portion of the circuit interruption. I^2T is an abbreviation for $\int I^2T\,dt$ from contact part until the time when the arc is extinguished. This is done for each phase separately. By keeping track of the cumulative duty for each pole separately, a pole replacement might be justified in certain circumstances compared with a full circuit breaker replacement, thereby reducing O&M expense.

OPERATING MODES

The Optimizer3 has five pairs of control inputs which are connected to specific combinations of open coils, close coils, auxiliary switches, red light bulbs, green light bulbs, and other control circuit inputs as appropriate for a circuit breaker. The DC voltage levels (states) of these circuit nodes and their transitions are interpreted by the Optimizer3 to produce operating times, main contact state (OPEN/CLOSE), and other parameters.

NOTE: The Optimizer3 is limited to 20 mS minimum time between successive OPEN - CLOSE or CLOSE - OPEN operations. Operations that occur more rapidly than this might not be recorded.

Figure 43 – Circuit Breaker Monitoring-Input Modes

		Mode 1	Mode 2	Mode 3	Mode 4
		Continuous A & B	Pulse Open Coil	Continuous A	Pulse Open Coil
			No B	No B	Continuous B
Input Channels	Aux 1	Red Light or 52a Switch	Open Coil	Red Light or 52a Switch	Open Coil
	Aux 2	Green Light or 52b Switch			Green Light or 52b Switch
	Aux 3				
	Aux 4				
	Aux 5				
Timing Measurements	Open Time Start	N/A	Open Coil Active Edge	N/A	Open Coil Active Edge
	Open Time Stop	N/A	Open Coil Deactive Edge + AD	N/A	Open Coil Deactive Edge + AD
	Interrupting Time Start Ø	N/A	Open Coil Active Edge	N/A	Open Coil Active Edge
	Arcing Time Start Ø	Aux A Active Edge + AD	Open Coil Deactive Edge + AD	Aux A Active Edge + AD	Open Coil Deactive Edge + AD
	Arcing Time End Ø	<7% Amplitude	<7% Amplitude	<7% Amplitude	<7% Amplitude
	Interrupting Time End Ø	N/A	<7% Amplitude	N/A	<7% Amplitude
	Travel Time Start	Aux A Active Edge	N/A	N/A	Open Coil Deactive Edge
	Travel Time Stop	Aux B Active Edge	N/A	N/A	Aux B Active Edge
	Close Trip Start	N/A	N/A	N/A	N/A
	Close Trip Stop	N/A	N/A	N/A	N/A
	Closing Time Start	Aux B Deactive Edge	N/A	N/A	N/A
	Closing Time Stop	Aux A Active Edge	N/A	N/A	N/A
	A-B Input Logic Failure Modes	52a and 52b inputs are active at the same time	Open coil input is active continuously	N/A	Open Coil input is active continuously

NOTE: AD represents "A Input Delay" the time skew between the control signal that begins the monitor recording (usually the assertion of the 52a auxiliary switch), and main breaker contact parting.

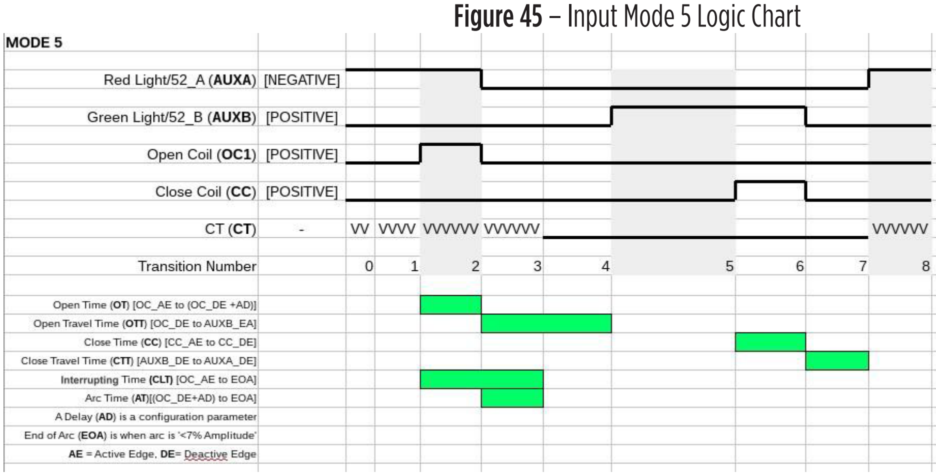
The only reference to breaker main contact parting is to the 52a auxiliary switch. It is very important to accurately know the time difference between 52a assertion and the main contact parting on an OPEN breaker operation. The quality of the arcing time and I^2T calculation of main contact duty depends on the accuracy of this parameter.

Figure 44 – Circuit Breaker Monitoring – Input Modes Continued

		Mode 5	Mode 6	Mode 7
		Pulse Open Coil & Close Coil	Two Open Coils, No Close Coil	Two Open Coils, One Close Coil
		52a and 52b input	52a and 52b input	52a and 52b input
Input Channels	Aux 1	Open Coil	Open Coil 1	Open Coil 1
	Aux 2	Close Coil	Open Coil 2	Open Coil 2
	Aux 3	Red Light 52a Switch	Red Light 52a Switch	Close Coil
	Aux 4	Green Light 52b Switch	Green Light 52b Switch	Red Light 52a Switch
	Aux 5			Green Light 52b Switch
Timing Measurements	Open Trip Time Start	Open Coil Active Edge	1st Open Coil Active Edge	1st TC Active Edge
	Open Trip Time Stop	Open Coil Deactive Edge + AD	Open Coil Deactive Edge + AD	Last TC Deactive Edge + AD
	Interrupting Time Start Ø	Open Coil Active Edge	1st Open Coil Active Edge	1st TC Active Edge
	Arc Time Start Ø	Open Coil Deactive Edge + AD	Open Coil Deactive Edge + AD	TC Deactive Edge + AD
	Arc Time End Ø	<7% Amplitude	<7% Amplitude	<7% Amplitude
	Interrupting Time End Ø	<7% Amplitude	<7% Amplitude	<7% Amplitude
	Open Travel Time Start	Open Coil Deactive Edge	Last Open Coil Deactive Edge or 52a Active Edge	Last Open Coil Deactive Edge or 52a Active Edge
	Open Travel Time Stop	52b Active Edge	52b Active Edge	52b Active Edge
	Close Time Start	Close Coil Active Edge	N/A	CC Active Edge
	Close Time Stop	Close Coil Deactive Edge	N/A	CC Deactive Edge
	Close Travel Time Start	52b Deactive Edge	52b Deactive Edge	52b Deactive Edge
	Close Travel Time Stop	52a Active Edge	52a Active Edge	52a Active Edge
	Velocity	Time Duration between 52a and 52b	Time Duration between 52a and 52b	Time Duration between 52a and 52b
	A-B Input Logic Failure Modes:	Open Coil or Close Coil input is active continuously, or both 52a and 52b inputs are active at the same time	Open Coil or Close Coil input is active continuously, or both 52a and 52b inputs are active at the same time	Open Coil 1, Open Coil 2 or Close Coil input is active continuously, or both 52a and 52b inputs are active at the same time

Optimizer3 Operating Modes, Measurements Made, Required Wiring Connections.

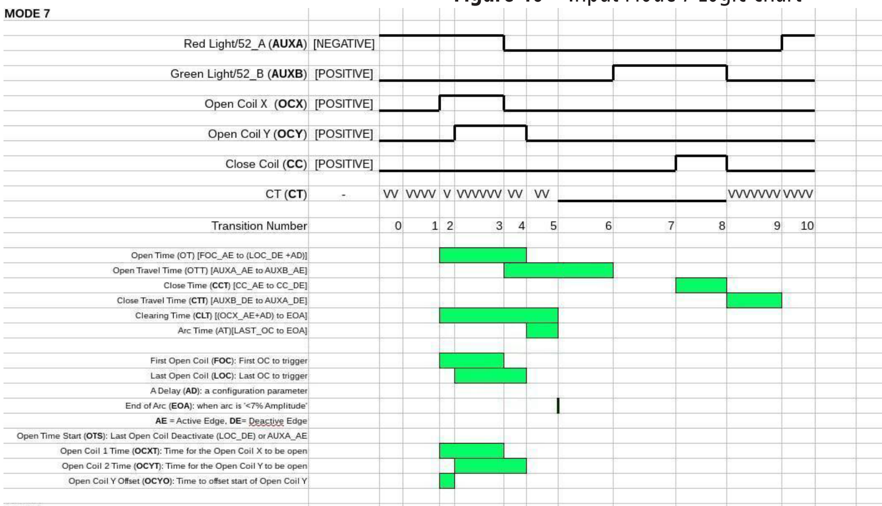
Figure 45 – Input Mode 5 Logic Chart



Transition Table

		D03	D05	D06	D09	D12
Transition	**t (ms)**	**AUXA**	**AUXB**	**OC**	**CC**	**CT**
0	0	1	0	0	0	1
1	1000	1	0	1	0	1
2	OT	1	0	0	0	1
3	AT	0	0	0	0	1
4	OTT-AT	0	1	0	0	0
5	500	0	1	0	1	0
6	CC	0	0	0	0	0
7	CTT	1	0	0	0	1
8	500	1	0	0	0	1

Figure 46 – Input Mode 7 Logic Chart



Transition Table

		D03	D05	D06 or D09	D09 or D06	D10	D12
Transition	**t (ms)**	**AUXA**	**AUXB**	**OCX**	**OCY**	**CC**	**CT**
0	0	1	0	0	0	0	1
1	1000	1	0	1	0	0	1
2	OCYO	1	0	1	1	0	1
3	(OCXT-OCYO)	0	0	0	1	0	1
4	(OCYT+OCYO)-OCXT	0	0	0	0	0	0
5	AT						
6	OTT-AT-((OCYT+OCYO)-OCXT)	0	1	0	0	0	0
7	500	0	1	0	0	1	0
8	CCT	0	0	0	0	0	1
9	CTT	1	0	0	0	0	1
10	500	1	0	0	0	0	1

NOTES:
* Open Coil 'X' (OCX) opens before Open Coil 'Y (OCY).
* At runtime, the outputs of OCX and OCY are assigned to either OC1 or OC2 to simulate the operation of the redundant coil (FIRST_COIL=OC1 or FIRST_COIL=OC2)

CHOOSING THE DESIRED OPERATING MODE

For circuit breaker characteristic monitoring, there are seven operating modes to select from.

MODE 1

Figure 47 – Selecting Input Mode 1

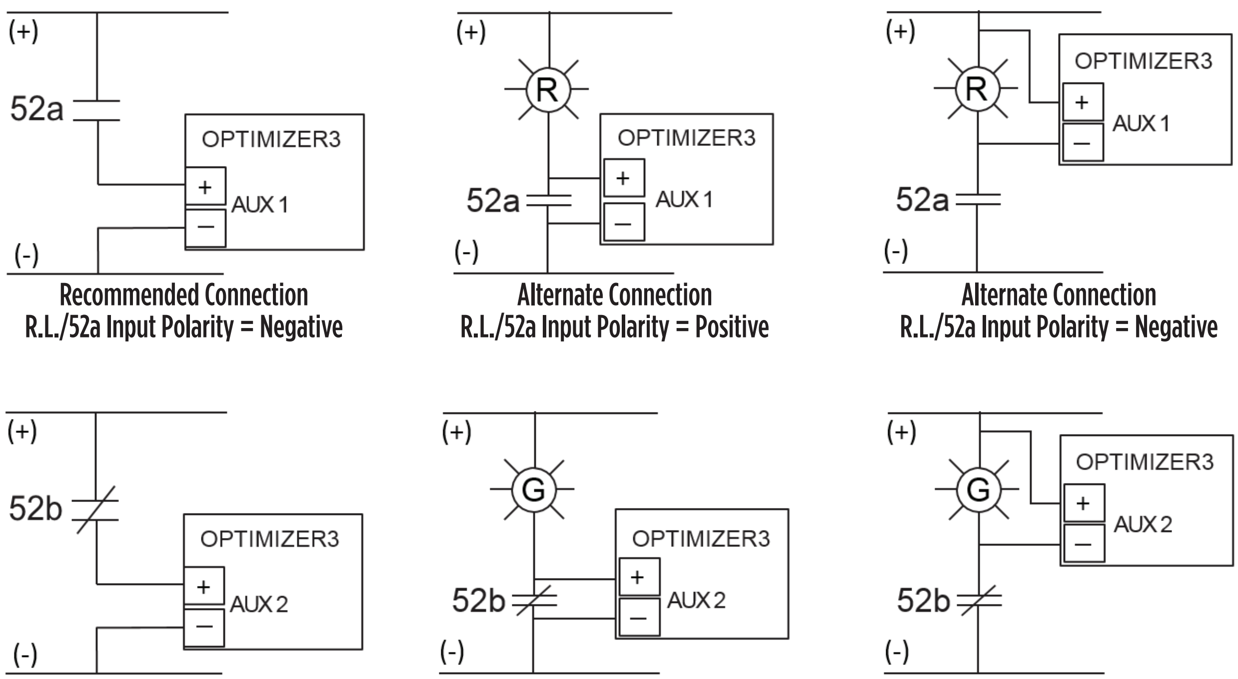
Circuit Breaker Monitor		
	Power System Frequency	60 Hz
	Bushing CT Turn Ratio - n:1	240
	Current Transducer Rating	100 A
	Fault Detect Threshold	2000 amps
	Input Mode	1 (Continuous A, With B Input) 2 (Opening Coil, No B Input) 3 (Continuous A, No B Input) 4 (Opening Coil, With B Input) 5 (Opening Coil, Closing Coil, With A and B Input)
	Stroke Length	45 mm
	Red Light/52A Input Select	1
	Green Light/52B Input Select	2
	Red Light/52A Input Polarity	Negative
	Green Light/52B Input Polarity	Positive
	Operation Number Increments On	Open
	A Input Delay	0 ms
	Contact Wear Mode	$I^2 \times T$
	Contact Life Danger Limit	300,000,000 $A^2 \times$ sec
	Contact Life Warning Limit	0 %
	Arcing Time Limit	16 ms
	Opening Travel Time Limit	0 ms
	Closing Travel Time Limit	0 ms
	Operations Count Limit	300
	Fault Interrupt Count Limit	100
	Non-Fault Interrupt Count Limit	200
	No Operations Limit	500 days
	Restrike Alarm	Disabled
	CT Failure Alarm	Enabled

This choice monitors the state of the 52a and 52b auxiliary switches for the circuit breaker. When the 52a changes state, the monitor registers an Open operation, modifies it by the A Input Delay setting to calculate Contact Duty and records the time duration until the 52b changes state. This time duration is called Opening Travel Time, given in milliseconds. Opening Travel Time is the actual measurement and is not modified by the A Input Delay.

When the 52b transitions from closed to open, the monitor registers a Close operation and records the time duration until the 52a closes. This time duration is called Closing Travel Time, given in milliseconds.

Optimizer3 pre-assigns the control inputs as a default, but they can be changed if desired. The AUX 1 input can be assigned to the 52a switch and the AUX 2 input can be assigned to 52b auxiliary switch. The recommended connection is to spare 52a and 52b switches that are wetted by the station battery voltage. An equivalent timing signal is to connect in parallel with the Red Light and Green light. In both cases, the Input Polarity for Red Light/52a is Negative because the voltage level transitions from high to low on the Open operation. Similarly, the Input Polarity for Green Light/52b is Positive because the voltage level transitions from low to high on the Open operation.

Figure 48 – Connection Options for Mode 1



Recommended Connection
R.L./52a Input Polarity = Negative

Alternate Connection
R.L./52a Input Polarity = Positive

Alternate Connection
R.L./52a Input Polarity = Negative

Recommended Connection
G.L./52b Input Polarity = Positive

Alternate Connection
G.L./52b Input Polarity = Negative

Alternate Connection
G.L./52b Input Polarity = Positive

NOTE: All wiring diagrams are shown with circuit breaker in the OPEN position.

MODE 2

Figure 49 – Selecting Input Mode 2

Circuit Breaker Monitor	Power System Frequency	60 Hz
	Bushing CT Turn Ratio - n:1	240
	Current Transducer Rating	100 A
	Fault Detect Threshold	2000 amps
	Input Mode	1 (Continuous A, With B Input) 2 (Opening Coil, No B Input) 3 (Continuous A, No B Input) 4 (Opening Coil, With B Input) 5 (Opening Coil, Closing Coil, With A and B Input)
	Stroke Length	45 mm
	Red Light/52A Input Select	1
	Green Light/52B Input Select	2
	Red Light/52A Input Polarity	Negative
	Green Light/52B Input Polarity	Positive
	Operation Number Increments On	Open
	A Input Delay	0 ms
	Contact Wear Mode	I²×T
	Contact Life Danger Limit	300,000,000 A² × sec
	Contact Life Warning Limit	0 %
	Arcing Time Limit	16 ms
	Opening Travel Time Limit	0 ms
	Closing Travel Time Limit	0 ms
	Operations Count Limit	300
	Fault Interrupt Count Limit	100
	Non-Fault Interrupt Count Limit	200
	No Operations Limit	500 days
	Restrike Alarm	Disabled
	CT Failure Alarm	Enabled

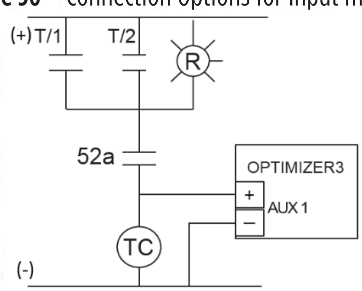
This choice monitors the state of a single Opening Coil only. When the Opening Coil is energized, the monitor registers an Open operation and records the time duration of the Opening Coil energization. The start is the protective relay closing the trip circuit. The end is the opening of the 52A auxiliary switch, modified by the A Input Delay, which begins the Contact Duty measurement. This time duration is called Opening Time, given in milliseconds. The Opening Time measurement is modified by the A Input Delay.

Mode 2 is used on older field retrofits when there is no opportunity for connecting to 52b auxiliary switches or Green Light. Optimizer3 does not provide any Close operation data in Mode 2.

Assign the Opening Coil connection to AUX 1.

The Polarity set to Positive because the Opening Coil energization is a positive-going pulse.

Figure 50 – Connection Options for Input mode 2



Opening Coil Input Polarity = Positive

MODE 3

Figure 51 – Selecting Input Mode 3

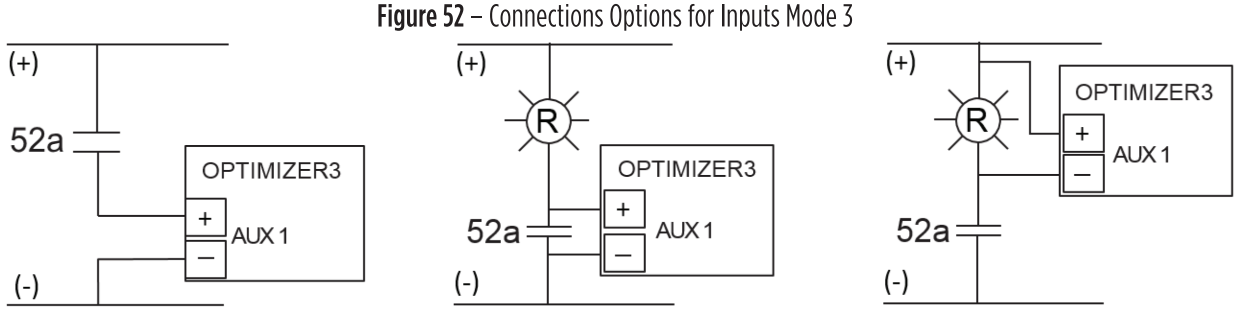
Circuit Breaker Monitor	Power System Frequency	60 Hz
	Bushing CT Turn Ratio - n:1	240
	Current Transducer Rating	160 A
	Fault Detect Threshold	2000 amps
	Input Mode	1 (Continuous A, With B Input) 2 (Opening Coil, No B Input) 3 (Continuous A, No B Input) 4 (Opening Coil, With B Input) 5 (Opening Coil, Closing Coil, With A and B Input)
	Red Light/52A Input Select	3
	Red Light/52A Input Polarity	Negative
	Operation Number Increments On	Open
	A Input Delay	0 ms
	Contact Wear Mode	$I^2 \times T$
	Contact Life Danger Limit	300,000,000 $A^2 \times$ sec
	Contact Life Warning Limit	0 %
	Arcing Time Limit	16 ms
	Operations Count Limit	300
	Fault Interrupt Count Limit	100
	Non-Fault Interrupt Count Limit	200
	No Operations Limit	500 days
	Restrike Alarm	Disabled
	CT Failure Alarm	Enabled

This choice monitors the state of the 52a auxiliary switch only. When the 52a changes state, the monitor registers an Open operation, modifies it by the A Input Delay setting, and calculates contact duty. Mode 3 is used on older field retrofits when the only connection that can be made is to the 52a auxiliary switch or Red Light.

Assign the 52a auxiliary switch connection to AUX 1.

The recommended connection is in series with a wetted spare 52a auxiliary switch. Alternate connection may be made in parallel to an in-service 52a auxiliary switch or in parallel with the red-light bulb.

Figure 52 – Connections Options for Inputs Mode 3



Recommended Connection R.L./52a Input Polarity = Negative | **Alternate Connection R.L./52a Input Polarity = Positive** | **Alternate Connection R.L./52a Input Polarity = Negative**

MODE 4

Figure 53 – Selecting Input Mode 4

Circuit Breaker Monitor	Power System Frequency	60 Hz
	Bushing CT Turn Ratio - n:1	240
	Current Transducer Rating	100 A
	Fault Detect Threshold	2000 amps
	Input Mode	1 (Continuous A, With B Input) 2 (Opening Coil, No B Input) 3 (Continuous A, No B Input) 4 (Opening Coil, With B Input) 5 (Opening Coil, Closing Coil, With A and B Input)
	Green Light/52B Input Select	2
	Opening Coil 1 Select	1
	Green Light/52B Input Polarity	Positive
	Opening Coil 1 Polarity	Positive
	Operation Number Increments On	Open
	A Input Delay	0 ms
	Contact Wear Mode	$I^2 \times T$
	Contact Life Danger Limit	300,000,000 $A^2 \times$ sec
	Contact Life Warning Limit	0 %
	Arcing Time Limit	16 ms
	Interrupting Time Limit	0 ms
	Opening Time Limit	0 ms
	Opening Travel Time Limit	0 ms
	Operations Count Limit	300
	Fault Interrupt Count Limit	100
	Non-Fault Interrupt Count Limit	200
	No Operations Limit	500 days
	Restrike Alarm	Disabled
	CT Failure Alarm	Enabled

This choice monitors the state of a single Opening Coil and the 52b auxiliary switch. When the Opening Coil is energized, the Optimizer3 registers an Open operation and records the time duration of the Opening Coil pulse. The start is the protective relay closing the trip circuit. The end is the opening of the 52A auxiliary switch, modified by the A Input Delay, which begins the Contact Duty measurement . This time duration is named Opening Time, given in milliseconds. The Opening Time measurement is modified by the A Input Delay.

The Opening Travel Time is defined by the time duration beginning with the falling edge of the Opening Coil pulse (52a auxiliary switch opening) and ending with 52b auxiliary switch closing. This segment of time is recorded and reported as Opening Travel Time, given in milliseconds. Opening Travel Time is the actual measurement and is not modified by the A Input Delay.

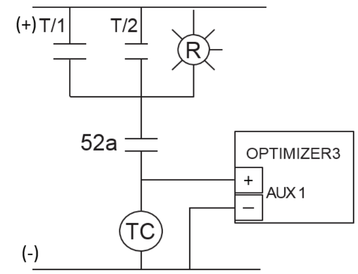
Circuit breaker Close operations are detected from the 52b auxiliary switch transitioning from closed to open. In Mode 4, no timing information is recorded for the Close operation other than a date and time stamp.

The Optimizer3 pre-assigns the control inputs as a default, but they can be changed if desired. The AUX 1 input can be assigned to the Opening Coil and the AUX 2 input can be assigned to 52b auxiliary switch.

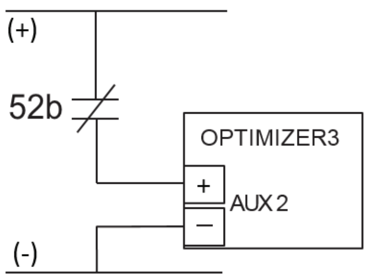
The recommended AUX 2 connection is to a spare 52b switch that is wetted by the station battery voltage. There are other wiring connections which give an equivalent timing signal for AUX 2 - in parallel to an in service 52b auxiliary switch or connection in parallel with the green light bulb. The Green Light/52b Polarity setting is specific to the connection location.

NOTE: Recommended connection diagrams are shown in the following diagram (Figure 54).

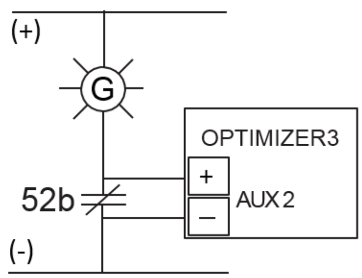
Figure 54 – Connection Options for Inputs Mode 4



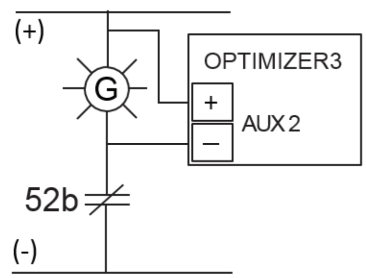
Opening Coil Input Polarity = Positive



Recommended Connection
G.L./52b Input Polarity = Positive



Alternate Connection
G.L./52b Input Polarity = Negative



Alternate Connection
G.L./52b Input Polarity = Positive

MODE 5

Figure 55 – Selecting Input Mode 5

Circuit Breaker Monitor		
	Power System Frequency	60 Hz
	Bushing CT Turn Ratio - n:1	240
	Current Transducer Rating	100 A
	Fault Detect Threshold	2000 amps
	Input Mode	3 (Continuous A, No B Input) 4 (Opening Coil, With B Input) 5 (Opening Coil, Closing Coil, With A and B Input) 6 (2 Opening Coils, With A and B Input) 7 (2 Opening Coils, Closing Coil, With A and B Input)
	Stroke Length	45 mm
	Red Light/52A Input Select	3
	Green Light/52B Input Select	4
	Opening Coil 1 Select	1
	Closing Coil Select	2
	Red Light/52A Input Polarity	Negative
	Green Light/52B Input Polarity	Positive
	Opening Coil 1 Polarity	Positive
	Closing Coil Polarity	Positive
	Operation Number Increments On	Open
	A Input Delay	-9 ms
	Contact Wear Mode	$I^2 \times T$
	Contact Life Danger Limit	300,000,000 $A^2 \times$ sec
	Contact Life Warning Limit	0 %
	Arcing Time Limit	16 ms
	Interrupting Time Limit	0 ms
	Opening Time Limit	0 ms
	Closing Time Limit	0 ms
	Opening Travel Time Limit	0 ms
	Closing Travel Time Limit	0 ms
	Total Closing Time Limit	0 ms
	Operations Count Limit	300
	Fault Interrupt Count Limit	100
	Non-Fault Interrupt Count Limit	200
	No Operations Limit	500 days
	Restrike Alarm	Disabled

This choice monitors the state of a single Opening Coil, the Closing Coil, the 52a and 52b auxiliary switches . When the Opening Coil is energized, the Optimizer3 registers an Open operation and records the time duration of the Opening Coil pulse. The start is the protective relay closing the trip circuit. The end is the opening of the 52A auxiliary switch, modified by the A Input Delay, which begins the Contact Duty measurement. This time duration is named Opening Time, given in milliseconds. The Opening Time measurement is modified by the A Input Delay.

The Opening Travel Time is defined by the time duration beginning with the falling edge of the Opening Coil pulse (52a auxiliary switch opening) and ending with 52b auxiliary switch closing. This segment of time is recorded and reported as Opening Travel Time, given in milliseconds. Opening Travel Time is the actual measurement and is not modified by the A Input Delay.

When the Closing Coil is energized, the monitor registers a Close operation. The time duration from Closing Coil energization to 52b auxiliary switch opening is reported as Closing Time, given in milliseconds. The time duration from 52b auxiliary switch opening to 52a auxiliary switch closing is reported as Closing Travel Time, given in milliseconds. Closing Travel Time is the actual measurement and is not modified by the A Input Delay. Total Closing Time is the sum of the Closing Time and Closing Travel Time measurements.

Optimizer3 pre-assigns default control inputs, but they can be changed if desired:

- AUX 1 input can be assigned to the Opening Coil
- AUX 2 input can be assigned to the Closing Coil.
- AUX 3 input can be assigned to the 52a auxiliary switch
- AUX 4 input can be assigned to the 52b auxiliary switch

The recommended AUX 3 connection is to a spare 52a auxiliary switch that is wetted by the station battery voltage. There are alternate wiring connections which give an equivalent timing signal for AUX 3- connection in parallel to an in service 52a auxiliary switch or connection in parallel with the Red Light bulb. The Red Light/52a Polarity setting is specific to the connection type.

Table 5 – Aux 3 Input Polarity

AUX 3 Input Wiring Connection	AUX 3 Polarity setting	Type
In series with wetted spare 52a auxiliary switch	Negative	Recommended
In parallel with in service 52a auxiliary switch	Positive	Alternate
In parallel with red light bulb	Negative	Alternate

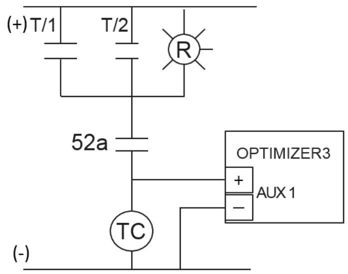
The recommended AUX 4 connection is to a spare 52b auxiliary switch that is wetted by the station battery voltage. There are other wiring connections which give an equivalent timing signal for AUX 4- connection in parallel to an in service 52b auxiliary switch or connection in parallel with the Green Light bulb. The Green Light/52b Polarity setting is specific to the connection location.

Table 6 – Aux 4 Input Polarity

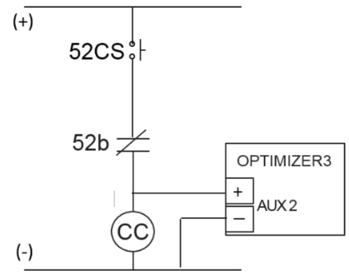
AUX 4 Input Wiring Connection	AUX 4 Polarity setting	Type
In series with wetted spare 52b auxiliary switch	Positive	Recommended
In parallel with in service 52b auxiliary switch	Negative	Alternate
In parallel with green light bulb	Positive	Alternate

NOTE: Wiring connections shown in the following diagrams (Figure 56).

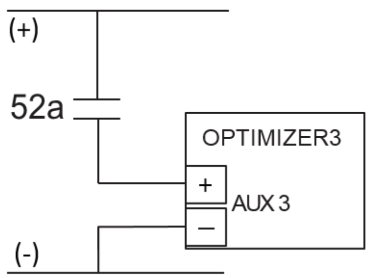
Figure 56 – Connection Options for Input Mode 5



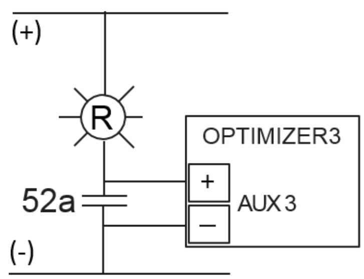
Opening Coil Input Polarity = Positive



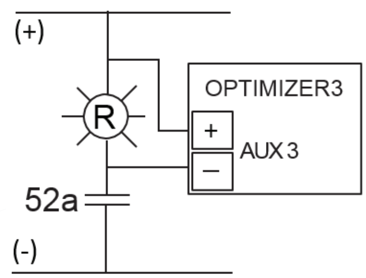
Closing Coil Input Polarity = Positive



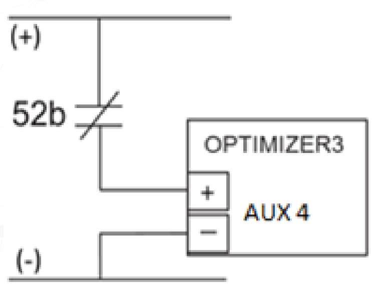
Recommended Connection
R.L./52a Input Polarity = Negative



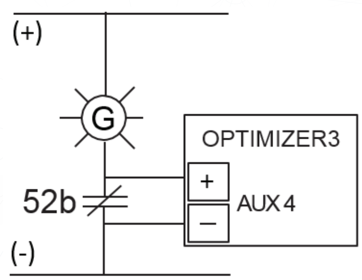
Alternate Connection
R.L./52a Input Polarity = Positive



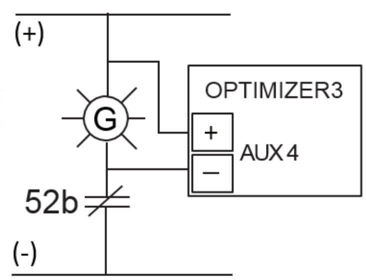
Alternate Connection
R.L./52a Input Polarity = Negative



Recommended Connection
G.L./52b Input Polarity = Positive



Alternate Connection
G.L./52b Input Polarity = Negative



Alternate Connection
G.L./52b Input Polarity = Positive

MODE 6

Figure 57 – Selecting Input Mode 6

Circuit Breaker Monitor		
	Power System Frequency	60 Hz
	Bushing CT Turn Ratio - n:1	240
	Current Transducer Rating	100 A
	Fault Detect Threshold	2000 amps
	Input Mode	3 (Continuous A, No B Input) 4 (Opening Coil, With B Input) 5 (Opening Coil, Closing Coil, With A and B Input) 6 (2 Opening Coils, With A and B Input) 7 (2 Opening Coils, Closing Coil, With A and B Input)
	Stroke Length	45 mm
	Red Light/52A Input Select	3
	Green Light/52B Input Select	4
	Opening Coil 1 Select	1
	Opening Coil 2 Select	2
	Red Light/52A Input Polarity	Negative
	Green Light/52B Input Polarity	Positive
	Opening Coil 1 Polarity	Positive
	Opening Coil 2 Polarity	Positive
	Operation Number Increments On	Open
	A Input Delay	-9 ms
	Contact Wear Mode	I²×T
	Contact Life Danger Limit	300,000,000 A² × sec
	Contact Life Warning Limit	0 %
	Arcing Time Limit	16 ms
	Interrupting Time Limit	0 ms
	Opening Time Limit	0 ms
	Opening Travel Time Limit	0 ms
	Closing Travel Time Limit	0 ms
	Operations Count Limit	300
	Fault Interrupt Count Limit	100
	Non-Fault Interrupt Count Limit	200
	No Operations Limit	500 days
	Restrike Alarm	Disabled
	CT Failure Alarm	Enabled

This choice monitors two Opening Coils, the 52a and 52b auxiliary switches. Mode 6 assumes that no connection to the Closing Coil is possible. Because of this, Closing Time is not measured.

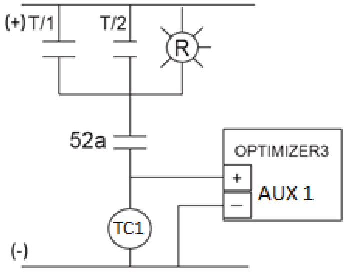
The first Opening Coil to be energized is identified. The Optimizer3 registers an Open operation and records the time duration of the Opening Coil pulse. The start is the protective relay closing the trip circuit. The end is the opening of the 52A auxiliary switch, modified by the A Input Delay, which begins the Contact Duty measurement. This time duration is named Opening Time, given in milliseconds. The Opening Time measurement is modified by the A Input Delay.

The Opening Travel Time is defined by the time duration beginning with the falling edge of the Opening coil pulse (52a auxiliary switch opening) and ending with 52b auxiliary switch closing. This segment of time is recorded and reported as Opening Travel Time, given in milliseconds. Opening Travel Time is the actual measurement and is not modified by the A Input Delay.

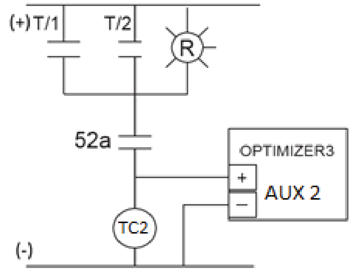
When the 52b transitions from closed to open, the monitor registers a Close operation and records the time duration until the 52a closes. This time duration is called Closing Travel Time, given in milliseconds.

NOTE: Examples shown in the following diagrams (Figure 58).

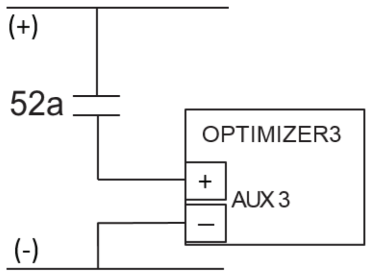
Figure 58 – Connection Options for Input Mode 6



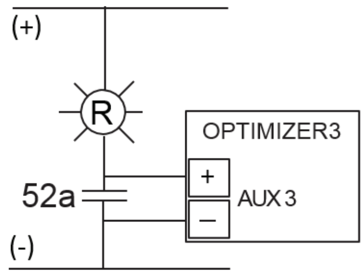
Opening Coil 1 Input Polarity = Positive



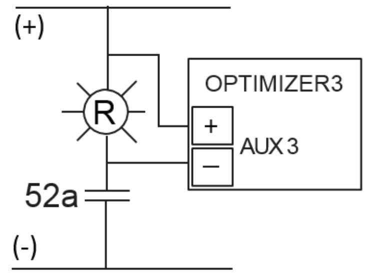
Closing Coil 2 Input Polarity = Positive



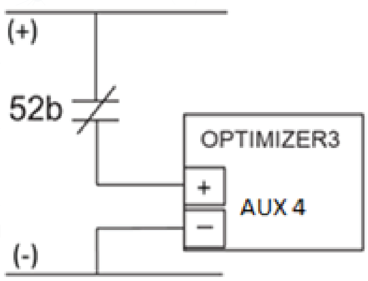
Recommended Connection
R.L./52a Input Polarity = Negative



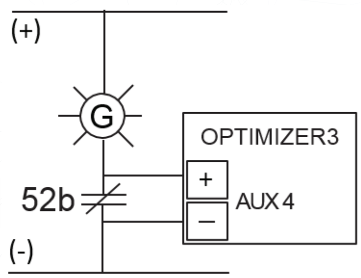
Alternate Connection
R.L./52a Input Polarity = Positive



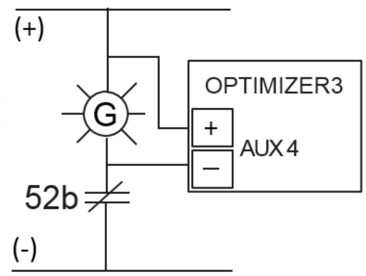
Alternate Connection
R.L./52a Input Polarity = Negative



Recommended Connection
G.L./52b Input Polarity = Positive



Alternate Connection
G.L./52b Input Polarity = Negative



Alternate Connection
G.L./52b Input Polarity = Positive

MODE 7

This choice monitors two Opening Coils, the Closing Coil, the 52a and 52b auxiliary switches. The first Opening Coil to be energized is identified. The Optimizer3 registers an Open operation and records the time duration of the Opening Coil pulse. The start is the protective relay closing the trip circuit. The end is the opening of the 52A auxiliary switch, modified by the A Input Delay, which begins the Contact Duty measurement. This time duration is named Opening Time, given in milliseconds. The Opening Time measurement is modified by the A Input Delay.

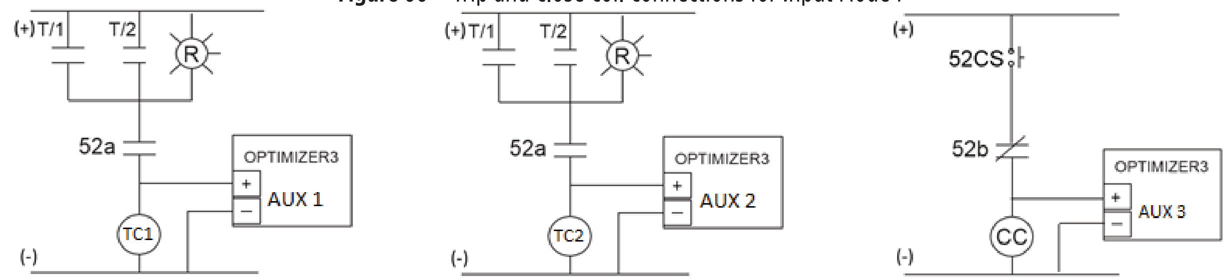
The time duration from 52a auxiliary switch opening to 52b auxiliary switch closing is reported as Opening Travel Time, given in milliseconds. Opening Travel Time is the actual measurement and is not modified by the A Input Delay.

When the Closing Coil is energized, the monitor registers a Close operation. The time duration from Closing Coil energization to 52b auxiliary switch opening is reported as Closing Time, given in milliseconds. The time duration from 52b auxiliary switch opening to 52a auxiliary switch closing is reported as Closing Travel Time, given in milliseconds. Closing Travel Time is the actual measurement and is not modified by the A Input Delay. Total Closing Time is the sum of the Closing Time and Closing Travel Time measurements.

Figure 59 – Selecting Input Mode 7

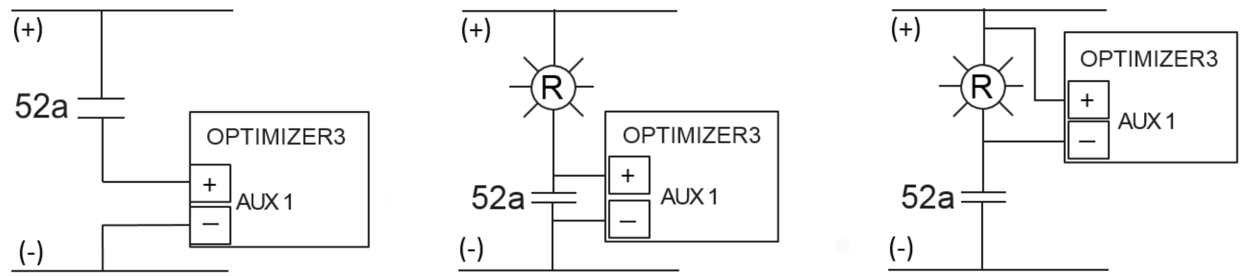
Circuit Breaker Monitor	Power System Frequency	60 Hz
	Bushing CT Turn Ratio - n:1	240
	Current Transducer Rating	100 A
	Fault Detect Threshold	2000 amps
	Input Mode	3 (Continuous A, No B Input) 4 (Opening Coil, With B Input) 5 (Opening Coil, Closing Coil, With A and B Input) 6 (2 Opening Coils, With A and B Input) 7 (2 Opening Coils, Closing Coil, With A and B Input)
	Stroke Length	45 mm
	Red Light/52A Input Select	4
	Green Light/52B Input Select	5
	Opening Coil 1 Select	1
	Opening Coil 2 Select	2
	Closing Coil Select	3
	Red Light/52A Input Polarity	Negative
	Green Light/52B Input Polarity	Positive
	Opening Coil 1 Polarity	Positive
	Opening Coil 2 Polarity	Positive
	Closing Coil Polarity	Positive
	Operation Number Increments On	Open
	A Input Delay	-9 ms
	Contact Wear Mode	$I^2 \times T$
	Contact Life Danger Limit	300,000,000 $A^2 \times$ sec
	Contact Life Warning Limit	0 %
	Arcing Time Limit	16 ms
	Interrupting Time Limit	0 ms
	Opening Time Limit	0 ms
	Closing Time Limit	0 ms
	Opening Travel Time Limit	0 ms
	Closing Travel Time Limit	0 ms
	Total Closing Time Limit	0 ms
	Operations Count Limit	300
	Fault Interrupt Count Limit	100
	Non-Fault Interrupt Count Limit	200

Figure 60 – Trip and Close Coil Connections for Input Mode 7



Opening Coil 1 Input Polarity = Positive | Opening Coil 2 Input Polarity = Positive | Closing Coil Input Polarity = Positive

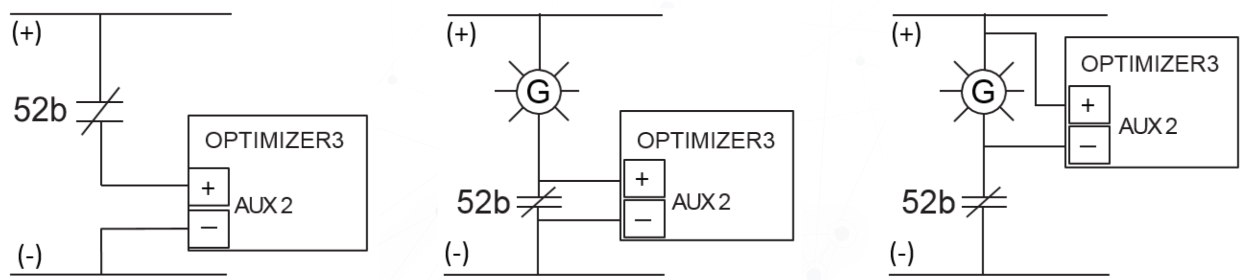
Figure 61 – Connection Option for Input Mode 7.



Recommended Connection
R.L./52a Input Polarity = Negative

Alternate Connection
R.L./52a Input Polarity = Positive

Alternate Connection
R.L./52a Input Polarity = Negative



Recommended Connection
G.L./52b Input Polarity = Positive

Alternate Connection
G.L./52b Input Polarity = Negative

Alternate Connection
G.L./52b Input Polarity = Positive

VELOCITY & AVERAGE VELOCITY MEASUREMENTS

The Optimizer3 will report the Opening Velocity (modes 1,4,5,6,7) and Closing Velocity (modes 1,5,6,7) during Trip and Close operations. The Last 10 Opening and Closing Velocity measurements are averaged to provide the Average Opening Velocity and Average Closing Velocity.

During a Trip operation, the Opening Velocity measurement is calculated by dividing the main contact stroke distance by the Open Travel Time. During a Close operation, the Closing Velocity measurement is calculated by dividing the main contact stroke distance by the Close Travel Time.

The average velocity is an important measurement from the standpoint of trend. The absolute value may not exactly agree with an off-line time-travel test. An off-line time travel test will calculate the velocity as the main contact travels through the arcing zone. The arcing zone may be defined by different end points than are assumed by the Optimizer3. The Optimizer3 calculates the opening velocity from 52A assertion to 52B assertion. The velocity calculation can be manipulated slightly by adjusting the stroke distance. The breaker instruction book will have information on the timing of the breaker operations.

Careful study of the Open and Close Illustrations shows the total contact stroke of 85 mm. The Optimizer3 begins the timer at the start of the Opening Coil pulse. The 52a auxiliary switch opens at 11mS. The 52b auxiliary switch closes at 33 mS. The approximate locations of 52A and 52B assertions are 128 mm and 43 mm, giving a stroke of 85 mm from 52A opening to 52B closing.

Figure 62 – Opening Travel Chart

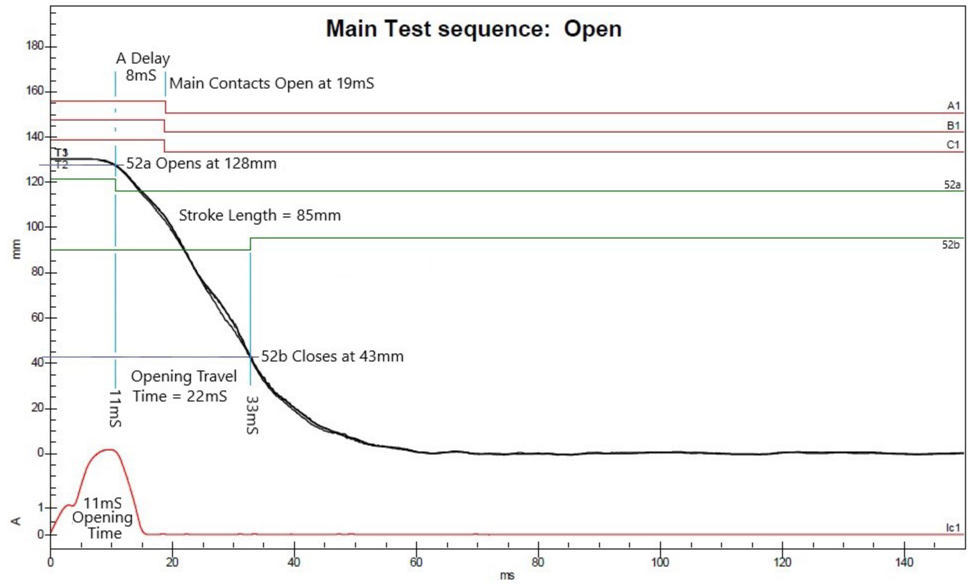
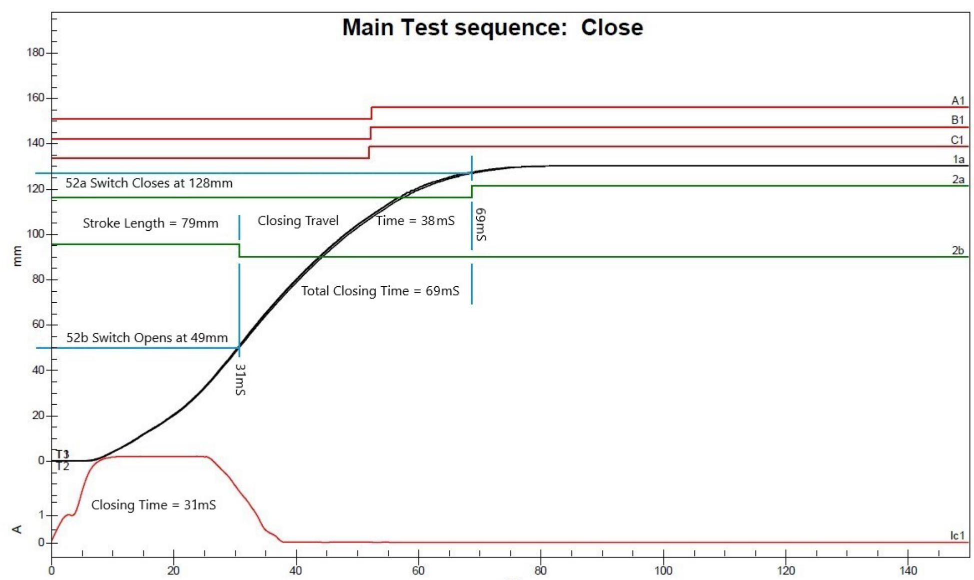


Figure 63 – Close Travel Chart



For this breaker, the approximate value of 82 mm for stroke is used as a Configuration setting in the Optimizer3. This is the average of the strokes found in the Opening and Close Travel Charts (85 mm + 79 mm)/2 = 82 mm.

For some test operations, the following data is produced:

Figure 64 – Open and Close Travel Data

Report ID	Date/Time	Type	Operation Number	Open Coil	Open Type	Open Time	Open Travel Time	Close Time	Close Travel Time	Total Closing Time	Open Velocity	Close Velocity
22	Mar 15, 2022, 5:01:35PM	Open	177	1	Non Fault	11	27				3.04	
21	Mar 15, 2022, 5:01:19PM	Close						30	38	68		2.16
20	Mar 15, 2022, 5:01:12PM	Open	176	2	Non Fault	12	26				3.15	
19	Mar 15, 2022, 5:00:57PM	Close						31	39	69		2.10
18	Mar 15, 2022, 5:00:48PM	Open	175	1	Non Fault	11	26				3.15	
17	Mar 15, 2022, 4:45:45PM	Close						31	38	69		2.16
16	Mar 15, 2022, 4:45:18PM	Open	174	1	Non Fault	11	26				3.15	
15	Mar 15, 2022, 4:44:45PM	Close						30	38	68		2.16

The Optimizer3 divides 82 mm stroke by 26 mS Opening Travel Time to get 3.15 millimeters per millisecond (or meters per second).

The Optimizer3 divides 82 mm stroke by 33 mS Closing Travel Time to get 2.16 millimeters per millisecond (or meters per second).

The breaker instruction book gives a calculation of 3 meters per second for an open operation and 2 meters per second for a close operation. The Optimizer3 gives a very good approximation of the Opening and Closing Velocities.

CURRENT AND VOLTAGE LOGGING

The Optimizer3 is continuously monitoring its power supply voltage and the phase currents.

- Every two hours, the power supply voltage and the phase currents are logged in the database.
- Each day, the minimum, maximum and average power supply voltage and phase currents are calculated and logged in the database.
- As the Optimizer3 monitors the phase currents, while the breaker's main contacts are interrupting a fault, the highest measured current value for each phase is recorded as Peak Current (Φ A,B,C). The Peak Current is measured only during the Arc Time. The time duration of the Peak Current is not recorded – only its amplitude. This is a different measurement than the I^2T but occurs during the same (Arc) time period.

This data is available for download from the Export page. Choose the items for download from the Available Data list, set the desired Date Range and then click the Export button at the bottom of the page.

- Average Power Supply Voltages are downloaded by clicking "Voltage Monitor Continuous Metrics" and selecting "Supply Voltage" instead of a sensor.
- Average Phase Currents are downloaded by clicking "Circuit Breaker Current History".
- Peak Phase Currents are downloaded by clicking "Phase X Peak Current".

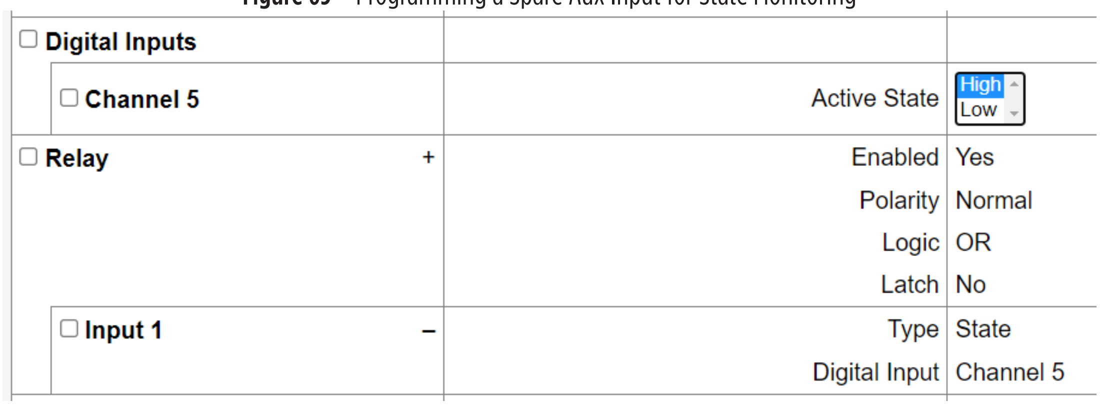
USE OF AUX INPUTS FOR CONTROL CIRCUIT STATUS MONITORING

AUX Inputs left unused for Modes 1-6 may be used for voltage on/off status monitoring of any DC control circuit node. High and Low voltage status may be monitored. After the Mode is saved, unused AUX inputs will be available in the Digital Input cell. They may be configured as active-high or active-low. The Off/On threshold is approximately 35 volts DC.

The AUX Input can drive the relay output only. There is no visibility for the status of AUX Inputs used this way on web pages or through DNP. The relay status is visible as a DNP point so if no other parameter is configured to assert the relay, then the status of the AUX Input may be known by the status of the relay DNP point

For instance, if Mode 6 is selected and saved and AUX Inputs defined, the remaining unused AUX Inputs will show in the Digital Input cell. From the Configuration Page:

Figure 65 – Programming a Spare Aux Input for State Monitoring

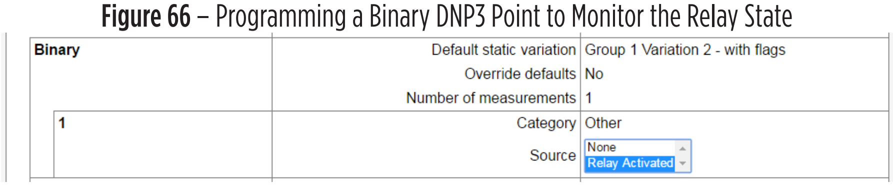


Digital Inputs			
Channel 5		Active State	High / Low
Relay	+	Enabled	Yes
		Polarity	Normal
		Logic	OR
		Latch	No
Input 1	–	Type	State
		Digital Input	Channel 5

NOTE: To configure a Binary DNP point to report the relay state:

- Category = "Other"
- Source = "Relay Activated"

Figure 66 – Programming a Binary DNP3 Point to Monitor the Relay State



Binary	Default static variation	Group 1 Variation 2 - with flags
	Override defaults	No
	Number of measurements	1
1	Category	Other
	Source	None / Relay Activated

DNP3.0

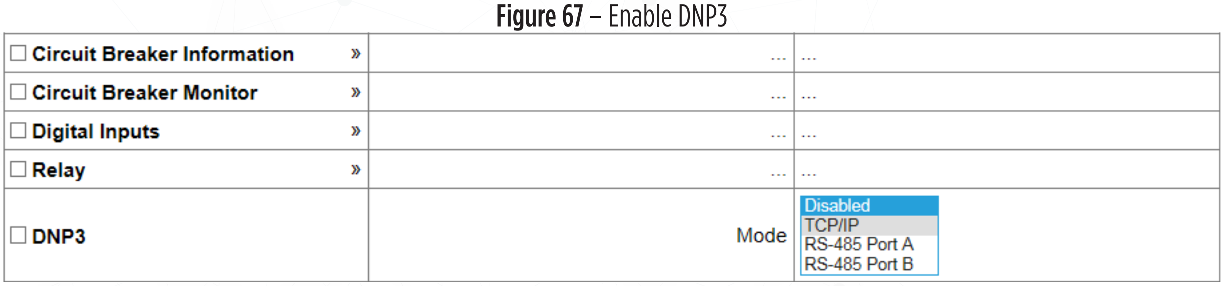
Refer to the Optimizer3 DNP3 Device Profile Document (000-0321) for details on the Optimizer3's DNP3 implementation and a complete DNP3 Points List.

It is recommended that some planning and preparation be made before programming the Optimizer3 DNP3 section. Review the DNP3 Point List and decide what information from which sensors and which phases will be retrieved through DNP3. Program the Sensors, SF_6 Gas Monitor and Circuit Breaker Monitor sections first, before programming the DNP3 section.

PROGRAMMING FOR DNP3

There are two operating modes for DNP3 communication, Ethernet (TCP/IP) and Serial RS-485 (Port A or B). They can be selected by clicking the word "Disabled". A pull-down menu will appear, where the selection can be made

Figure 67 – Enable DNP3



Once the selection is made, the DNP3 setup menu will appear. The desired number of Binary, Analog and Counter points can be programmed.

Figure 68 – Set Number of DNP3 Points

☐ DNP3	Mode	TCP/IP
	TCP/IP Port	20000
	TCP/IP Communication Timeout	60 min
	Slave Address	10
	Master Address	1
	Enable Unsolicted Messages	No
	Enable Time Synchronization	No
	Enable Units Conversion	No
	Logging Level	Normal
☐ Binary	Default static variation	Group 1 Variation 2 - with flags
	Override defaults	No
	Number of measurements	1
☐ 1	Category	Any
	Source	None
☐ Analog	Default static variation	Group 30 Variation 1 - 32-bit with flags
	Override defaults	No
	Number of measurements	**Enter Value Here** 0 ... 200
☐ Counter	Default static variation	Group 20 Variation 1 - 32-bit with flags
	Override defaults	No
	Number of measurements	3
☐ 1	Category	Any
	Source	None
☐ 2	Category	Any
	Source	None
☐ 3	Category	Any
	Source	None

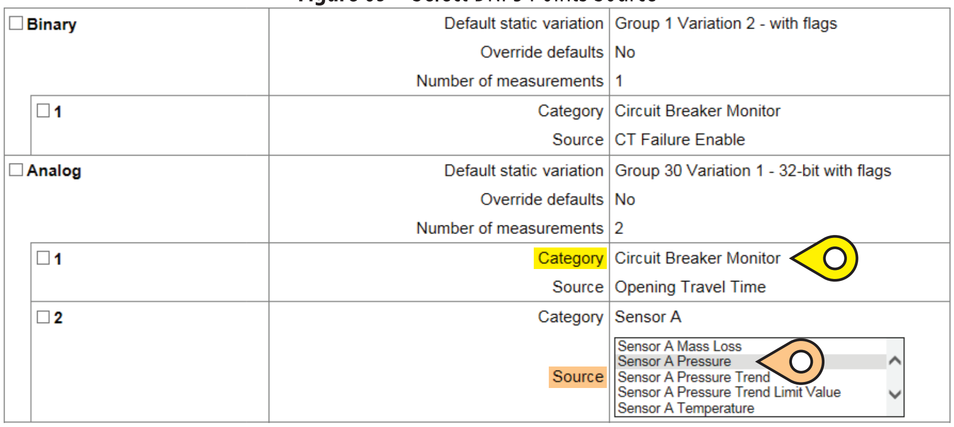
When the number is entered, pre-numbered rows will appear below each section. The number of the row is the DNP Point Index number. The number of points can be changed at any time in the programming process. Points can be added as needed by changing the "Number of Measurements".

Choose the category, from which the DNP3 point will be selected from the following catagories.

- Any
- Circuit Breaker Monitor
- Circuit Breaker Monitor Phase (A,B,C)
- Other
- Sensor (1,2,3,4,5,A,B,C)

Once the category has been chosen, the Source can be selected from the pull-down menu. The items available in the menu will vary depending upon the program settings for the Sensors, the SF_6 Gas Monitor and Circuit Breaker Monitor. If you don't find the item you want in the pull-down menu, double-check your programming in these sections.

Figure 69 – Select DNP3 Points Source



DNP3 BEHAVIOR

FLAG BEHAVIOR

The Online and Restart quality flag bits are used to indicate the status of DNP3 analog points.

- When the system is restarted or powered on, the Restart bit is asserted.
- When a valid sensor input is provided (no sensor errors), the Online flag is asserted, and restart is de-asserted.
- When a sensor error occurs, the Online flag is de-asserted.

VALUE BEHAVIOR

Under error-free conditions, each DNP3 analog point value is updated when the deadband value is exceeded. In the case of a sensor error, the previous value prior to the error remains as the analog point value and the DNP3 flag changes to offline. When the restart quality flag is asserted, the analog point value is set to 0.

TIME STAMPS

The time stamp is updated each time the DNP3 point value is updated using the system time of the Optimizer3. The Optimizer3 system time can be synchronized with an NTP server or from a DNP3 master . The NTP server's IP address is specified in the Configuration Page, in the Date/Time group, 'NTP Servers' option. Multiple NTP servers can be used by placing a space between the addresses. To enable time synchronization from a DNP3 master, set 'Enable Time Synchronization' to 'Yes' in the DNP3 configuration menu. The 'Time Synchronization Interval' can be set from this menu.

UNITS CONVERSION

The Optimizer3 reports DNP3 values in Metric units (grams per liter, BAR, Celsius, liters, grams, meters) regardless of the units chosen in System Preferences, unless the “Enable Units Conversion” is enabled. If enabled, the DNP3 values will be reported in the units chosen in the system Preferences.

Figure 70 – Enable DNP3 Units Conversion

☐ **DNP3**	Mode	TCP/IP
	TCP/IP Port	20000
	TCP/IP Communication Timeout	60 min
	Slave Address	10
	Master Address	1
	Enable Unsolicited Messages	No
	Enable Time Synchronization	No
	Enable Units Conversion	Yes / No
	Logging Level	Normal

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