Protective and Predictive Relays

Contents

Specifications

See Eaton's *Product Specification Guide*, available on CD or on the Web.

CSI Format: 2010

Digitrip 3000	**Section 16903, Paragraph 2.04.A**
FP-4000	**Section 16903, Paragraph 2.04.B**
FP-5000	**Section 16903, Paragraph 2.04.C**
FP-6000	**Section 16903, Paragraph 2.04.D**
MP-3000	**Section 16903, Paragraph 2.02.E**
MP-4000	**Section 16903, Paragraph 2.02.F**
MD-3000	**Section 16903, Paragraph 2.02.G**
DP-300	**Section 16903, Paragraph 2.04.K**
VR-300	**Section 16903, Paragraph 2.04.H**
EDR-3000	**Section 16903, Paragraph 2.04.E**
EDR-4000	**Section 16903, Paragraph 2.04.F**
EDR-5000	**Section 16903, Paragraph 2.04.G**
EMR-3000	**Section 16903, Paragraph 2.02.C**
EMR-4000	**Section 16903, Paragraph 2.02.D**
ETR-4000	**Section 16903, Paragraph 2.04.L**
EGR-4000	**Section 16903, Paragraph 2.04.I**
Universal RTD Module	**Section 16901, Paragraph 2.04.A**
InsulGard	**Sections 16950A, 16950C, 16950D Paragraph 2.03.A**

Selection Chart

Table 4.0-1. Selection Chart

Device Name		Feeder Protection						
Description	**IEEE Device Number**	**DT-3000**	**FP-4000**	**FP-5000**	**FP-6000**	**EDR-3000**	**EDR-4000**	**EDR-5000**
								
Page Number		**Page 4.1-1**	**Page 4.1-11**	**Page 4.1-16**	**Page 4.1-21**	**Page 4.1-27**	**Page 4.1-31**	**Page 4.1-38**
Protection Functions								
Phase inst. OC	50	■	■	■	■	■	■	■
Phase TOC	51	■	■	■	■	■	■	■
Ground inst. OC (measured)	50G	■	■	■	■	■	■	■
Ground TOC (measured)	51G	■	■	■	■	■	■	■
Phase directional control ①	67			■	■			■
Ground directional control ②	67N			■	■			■
Phase voltage restrained OC	51VR			■	■		■	■
No. of curves (ANSI/IEC/thermal)		11	10	10	10	11	11	11
Zone interlocking		■	■	■	■	■	■	■
Thermal overload	49				■			
Locked rotor	49S/51				■			
Jam/stall	51R				■			
Undervoltage	27		■	■	■		■	■
Current unbalance	46		■	■	■		■	■
Negative sequence voltage	47		■	■	■		■	■
Power factor	55		■	■	■		■	■
Overvoltage	59		■	■	■		■	■
Frequency (over/under)	81		■	■	■		■	■
Vector surge	78V						■	■
Rate of change	81R						■	■
Forward/reverse VARs	32V				■			■
Differential	87	■ ③	■ ③	■ ③	■ ③	■ ③	■ ③	■ ③
Forward/reverse power	32			■	■			■
Sync check	25			■	■			■
Reclosing	79				■	■	■	■
Loss of potential block	LOP			■	■		■	■
Cold load pickup				■	■		■	■
Breaker failure	50BF		■	■	■	■	■	■
2nd harmonic restrain								
5th harmonic restrain								
4th harmonic restrain								
Ground differential	87GD							
Generator unbalance	46G							
Loss of excitation	40							
Volts/hertz	24							
100% stator ground fault	27TN/59N							

① The 50 and 51 protective functions can be controlled for reverse, forward or both directional protection.
② The 50N, 51N, 50G and 51G protective functions can be controlled for reverse, forward or both directional protection.
③ 87B using zone selective interlocking.

4

Table 4.0-1. Selection Chart (Continued)

Device Name		Feeder Protection						
Description	**IEEE Device Number**	**DT-3000**	**FP-4000**	**FP-5000**	**FP-6000**	**EDR-3000**	**EDR-4000**	**EDR-5000**
								
Page Number		**Page 4.1-1**	**Page 4.1-11**	**Page 4.1-16**	**Page 4.1-21**	**Page 4.1-27**	**Page 4.1-31**	**Page 4.1-38**
Control Functions								
Remote open/close		■	■	■	■	■	■	■
Programmable I/O		■	■	■	■	■	■	■
Programmable logic control			■	■	■		■	■
Multiple settings groups			4	4	4	4	4	4
Number of starts limit								
Starts per hour								
Time between starts								
Emergency override								
Reduced voltage starting								
Trip lock out	86	■	■	■	■	■	■	■
Metering Functions								
Amperes		■	■	■	■	■	■	■
Ampere demand		■	■	■	■	■	■	■
Volts			■	■	■		■	■
Phase angle (current and voltage)			■	■	■		■	■
Positive, negative and zero sequence			■	■	■	■	■	■
Watts			■	■	■		■	■
Watt demand			■	■	■		■	■
Watthour			■	■	■		■	■
VARs			■	■	■		■	■
VAR demand			■	■	■		■	■
VAR-hour			■	■	■		■	■
VA			■	■	■		■	■
VA demand			■	■	■		■	■
VA-hour			■	■	■		■	■
Frequency			■	■	■		■	■
Trending (load profile)			■	■	■		■	■
Minimum/maximum recording			■	■	■	■	■	■
Monitoring Functions								
Trip circuit monitor			■	■	■	■	■	■
Breaker wear			■	■	■	■	■	■
Failure to trip			■	■	■	■	■	■
Oscillography			■	■	■	■	■	■
Sequence of events			■	■	■	■	■	■
Trip target data		■	■	■	■	■	■	■
Clock			■	■	■	■	■	■
Number of starts					■			
Acceleration time					■			
RTD temperature					■			
Hottest RTD					■			

Table 4.0-1. Selection Chart (Continued)

Device Name		Feeder Protection						
Description	**IEEE Device Number**	**DT-3000**	**FP-4000**	**FP-5000**	**FP-6000**	**EDR-3000**	**EDR-4000**	**EDR-5000**
								
Page Number		**Page 4.1-1**	**Page 4.1-11**	**Page 4.1-16**	**Page 4.1-21**	**Page 4.1-27**	**Page 4.1-31**	**Page 4.1-38**
Communications								
Local human machine interface		■	■	■	■	■	■	■
Remote communication port RS-232			■	■	■	■	■	■
RS-485			■	■	■	■	■	■
Ethernet copper						■	■	■
Frequency shift key		■	■	■	■			
Addressable protocols		■	■	■	■		■	■
INCOM		■	■	■	■			
Modbus-RTU			■	■	■	■	■	■
Modbus-TCP						■	■	■
IEC-61850		■	■	■	■	■	■	■
Construction								
Panel-mount case		■	■	■	■	■	■	■
Drawout		Optional	■	Optional	Optional	Removable terminals	Removable terminals	Removable terminals
Operating temperature range		–30°–55°C	–40°– 60°C	–40°–60°C	–40°–60°C	–40°–60°C	–40°–60°C	–40°–60°C
Power supply options		120–240 Vac	48–125 Vac/Vdc	48–125 Vac/Vdc	48–125 Vac/Vdc	19–300 Vdc	19–300 Vdc	19–300 Vdc
		24–250 Vdc	100–240 Vac/Vdc	100–240 Vac/Vdc	100–240 Vac/Vdc	40–250 Vac	40–250 Vac	40–250 Vac
AC current inputs		■	■	■	■	■	■	■
AC voltage inputs			■	■	■		■	■
Wye PTs			■	■	■		■	■
Delta/open delta PTs			■	■	■		■	■
Binary inputs		■	■	■	■	■	■	■
Alarm outputs		2 Form C	2 Form C	2 Form C	2 Form C	1 Form C	1 Form C	1 Form C
Trip outputs		2	5	5	5	3	10	■
Analog outputs								■
Analog inputs								
Local display			■	■	■	■	■	■
LEDs (local targets)		■	■	■	■	■	■	■
Standards								
ANSI		■	■	■	■	■	■	■
IEC		■	■	■	■	■	■	■
UL		■	■	■	■	■	■	■
CE		DT-3030 only	■	■	■	■	■	■
CSA		■	■	■	■	■	■	■

Table 4.0-1. Selection Chart (Continued)

Device Name		Motor Protection		
Description	**IEEE Device Number**	**C306 Bimetallic OLR**	**C440/*XT* Solid-State OLR**	**C441 Solid-State OLR**
				
Page Number		**Page 4.2-1**	**Page 4.2-1**	**Page 4.2-5**
Protection Functions				
Motor Protection				
Thermal overload protection	49	Bi-metallic	Microprocessor-based	Microprocessor-based
Trip class		■ 10 or 20 Selectable via heater packs	■ 10A, 10, 20, 30 Selectable via DIP switches	■ 5–30 Selectable via user interface
Adjustable FLA		■ Adjustable via dial (range approx.1.6:1)	■ Adjustable via dial (range 5:1)	■ Adjustable via user interface (range 9:1 and 18:1)
Locked rotor/stall current	49S/51	■	■	■
Phase loss—current	46		Selectable on/off (90% setting)	Selectable on/off (60% setting)
Phase imbalance	46		Selectable on/off (50% setting)	Adjustable (0–30% setting), off
Ground fault	51N		Fixed at 50% of FLA setting	Programmable threshold, and alarm or trip mode
Jam/current level protection	50			Instantaneous and adjustable
Phase reversal	47			■
Load Protection				
Undercurrent				■
Low power (kW)				■
High power (kW)				■
Voltage Protection				
Overvoltage	59			■
Undervoltage	27			■
Voltage imbalance	47			■
Voltage phase loss	47			■
Power-up delay				■
Control Functions				
Manual reset		■	■	■
Automatic reset		■	■	■
Electronic remote reset			■	■
Network command reset			■	■
Output Contacts				
NO contacts		1	1 B600	1 B300 (Form A or Form C)
NC contacts		1	1 B600	1 B300 (Form B or Form C)
Ground fault shunt relay ①				1 B300 (Form A)
Independently programmable contacts ①				■
Control Power				
Self (line) powered			■	■
Separate 24 Vdc supply			■	
Separate 120 Vac supply				■
Metering Functions (via Local Display)				
Amperes				
Individual phase				■
Average				■
Current imbalance %				■
Voltage				
Individual phase				■
Average				■
Voltage imbalance %				■

① Depends on the catalog number ordered.

Table 4.0-1. Selection Chart (Continued)

Device Name		Motor Protection		
Description	**IEEE Device Number**	**C306 Bimetallic OLR**	**C440/*XT* Solid-State OLR**	**C441 Solid-State OLR**
				
Page Number		**Page 4.2-1**	**Page 4.2-1**	**Page 4.2-5**
Metering Functions (via Local Display) (continued)				
Kilowatts				■
Power factor				■
Trip status				■
Diagnostics (10 fault queue)				■
Overload indication				■
Thermal capacity				■
Frequency				■
Run hours				■
Ground fault current				■
Monitoring Functions (via Communications)				
Overload indication		■	■	■
Operating LED			■	■
Trip status		■	■	■
Configured settings			■	■
Thermal memory (time until reset)			■	■
Thermal capacity			■	■
Ground fault current			■	■
Frequency			■	■
Motor starts				■
Motor run hours				■
Power motor kW				■
Power factor				■
Current				
Individual Phase I rms			■	■
Average Phase I rms			■	■
Current imbalance %			■	■
Voltage				
Individual Phase V rms				■
Average Phase V rms				■
Voltage imbalance %				■
Fault Indication				
Overload			■	■
Phase loss			■	■
Phase imbalance			■	■
Ground fault			■	■
Phase reversal				■
Jam/stall/current level				■
Undercurrent				■
Low power				■
High power				■
Voltage imbalance				■
Undervoltage				■
Overvoltage				■

Table 4.0-1. Selection Chart (Continued)

Device Name		Motor Protection		
Description	**IEEE Device Number**	**C306 Bimetallic OLR**	**C440/*XT* Solid-State OLR**	**C441 Solid-State OLR**
				
Page Number		**Page 4.2-1**	**Page 4.2-1**	**Page 4.2-5**
Communications				
Modbus RTU RS-485			■	■
Modbus RTU with I/O			■	■
DeviceNet with I/O			■	■
PROFIBUS with I/O			■	■
EtherNet/IP with I/O			■	■
Modbus TCP with I/O			■	■
Mounting				
Panel mounting		■	■	■
Contactor mounting		■	■	
DIN rail mounting		■	■	
Optional remote mounted display				■
Standards				
UL		■	■	■
CSA		■	■	■
CE		■	■	■
NEMA		■	■	■
IEC			■	■
RoHS			■	■

4

Table 4.0-1. Selection Chart (Continued)

Device Name		Motor Protection				Differential Protection		Transformer Protection	Generator Protection	Voltage Protection
Description	IEEE Device Number	MP-3000	MP-4000	EMR-3000	EMR-4000	MD-3000	DP-300	ETR-4000	EGR-4000	VR-300
										
Page Number		Page 4.2-11	Page 4.2-17	Page 4.2-22	Page 4.2-29	Page 4.3-1	Page 4.3-3	Page 4.3-6	Page 4.3-12	Page 4.4-1
Protection Functions										
Phase inst. OC	50	■	■	■	■			■	■	
Phase TOC	51			■	■			■	■	
Ground inst. OC (measured)	50G	■	■	■	■			■	■	
Ground TOC (measured)	51G			■	■			■	■	
Phase directional control ①	67								■	
Ground directional control ②	67N								■	
Phase voltage restrained OC	51VR								■	
No. of curves (ANSI/IEC/thermal)				11	11			11	11	
Zone interlocking				■	■			■	■	
Thermal overload	49	■	■	■	■			■	■	
Locked rotor	49S/51	■	■	■	■					
Jam/stall	51R	■	■	■	■					
Undervoltage	27		■		■				■	■
Current unbalance	46	■	■	■	■				■	
Negative sequence voltage	47		■		■				■	■
Power factor	55		■		■				■	
Overvoltage	59		■		■				■	■
Frequency (over/under)	81		■		■				■	■
Vector surge	78V				■				■	
Rate of change	81R				■				■	
Forward/reverse VARs	32V				■				■	
Differential	87			■ ③	■ ③	■ ④	■ ⑤	■ ③⑥	■ ③	
Forward/reverse power	32		■		■				■	
Sync check	25								■	■
Reclosing	79									
Loss of potential block	LOP				■				■	
Cold load pickup								■	■	
Breaker failure	50BF	■	■	■	■			■	■	■
2nd harmonic restrain							■	■		
5th harmonic restrain							■	■		
4th harmonic restrain								■		
Ground differential	87GD							■		
Generator unbalance	46G								■	
Loss of excitation	40								■	
Volts/hertz	24								■	
100% stator ground fault	27TN/59N								■	

① The 50 and 51 protective functions can be controlled for reverse, forward or both directional protection.
② The 50N, 51N, 50G and 51G protective functions can be controlled for reverse, forward or both directional protection.
③ 87B using zone selective interlocking.
④ 87M or 87G (motor or generator differential).
⑤ 87M, 87T or 87G (motor, transformer or generator differential).
⑥ 87T (transformer differential).

Table 4.0-1. Selection Chart (Continued)

Device Name		Motor Protection				Differential Protection		Transformer Protection	Generator Protection	Voltage Protection
Description	IEEE Device Number	MP-3000	MP-4000	EMR-3000	EMR-4000	MD-3000	DP-300	ETR-4000	EGR-4000	VR-300
										
Page Number		Page 4.2-11	Page 4.2-17	Page 4.2-22	Page 4.2-29	Page 4.3-1	Page 4.3-3	Page 4.3-6	Page 4.3-12	Page 4.4-1
Control Functions										
Remote open/close		(Trip only)	■	■	■	■		■	■	
Programmable I/O		■	■	■	■	■		■	■	
Programmable logic control					■				■	
Multiple settings groups				4	4			4	4	
Number of starts limit		■	■	■	■					
Starts per hour		■	■	■	■					
Time between starts		■	■	■	■					
Emergency override		■	■	■	■					
Reduced voltage starting		■	■	■	■					
Trip lock out	86	■	■	■	■			■	■	
Metering Functions										
Amperes		■	■	■	■	■	■ ①	■	■	
Ampere demand			■	■	■			■	■	
Volts			■		■				■	■
Phase angle (current and voltage)			■		■			Current only	■	
Positive, negative and zero sequence			■	■	■			■	■	
Watts			■		■				■	
Watt demand			■		■				■	
Watthour			■		■				■	
VARs			■		■				■	
VAR demand			■		■				■	
VAR-hour			■		■				■	
VA			■		■				■	
VA demand			■		■				■	
VA-hour			■		■				■	
Frequency			■		■				■	■
Trending (load profile)				■	■				■	
Minimum/maximum recording		Max. only	■	■	■			■	■	
Monitoring Functions										
Trip circuit monitor				■	■			■	■	
Breaker wear				■	■			■	■	
Failure to trip		■	■	■	■			■	■	
Oscillography				■	■			■	■	
Sequence of events		■	■	■	■			■	■	
Trip target data		■	■	■	■	■		■	■	
Clock		■	■	■	■			■	■	
Number of starts		■	■	■	■					
Acceleration time		■	■	■	■					
RTD temperature		■	■	■	■			■	■	
Hottest RTD		■	■	■	■			■	■	

① Differential and restrain current only.

4

Table 4.0-1. Selection Chart (Continued)

Device Name		Motor Protection				Differential Protection		Transformer Protection	Generator Protection	Voltage Protection
Description	**IEEE Device Number**	**MP-3000**	**MP-4000**	**EMR-3000**	**EMR-4000**	**MD-3000**	**DP-300**	**ETR-4000**	**EGR-4000**	**VR-300**
										
Page Number		**Page 4.2-11**	**Page 4.2-17**	**Page 4.2-22**	**Page 4.2-29**	**Page 4.3-1**	**Page 4.3-3**	**Page 4.3-6**	**Page 4.3-12**	**Page 4.4-1**
Communications										
Local human machine interface		■	■	■	■	■		■	■	
Remote communication port RS-232				■	■			■	■	
RS-485				■	■			■	■	
Ethernet copper				■	■			■	■	
Frequency shift key		Optional	Optional						■	
Addressable protocols		■	■	■	■				■	
INCOM		■	■						■	
Modbus-RTU		■	■	■	■			■	■	
Modbus-TCP				■	■			■	■	
IEC-61850		■	■	■	■	■	■	■	■	■
Construction										
Panel-mount case		■	■	■	■	■	■	■		■
Drawout		Optional	Optional	Removable terminals	Removable terminals	Optional		Removable terminals	Removable terminals	
Operating temperature range		–20° to 60°C	–20° to 60°C	–40° to 60°C	–40° to 60°C	–30° to 55°C	20° to 70°C	–40° to 60°C	–40° to 60°C	–20° to 70°C
Power supply options		120–240 Vac	120–240 Vac	19–300 Vdc	19–300 Vdc	120–240 Vac	40–250 Vac	19–300 Vdc	19–300 Vdc	40–250 Vac
				40–250 Vac	40–250 Vac	24–250 Vdc	90–250 Vdc	40–250 Vac	40–250 Vac	90–250 Vdc
AC current inputs		■	■	■	■	■		■	■	■
AC voltage inputs			■		■				■	■
Wye PTs			■		■				■	■
Delta/open delta PTs			■		■				■	■
Binary inputs		■	■	■	■	■	■	■	■	■
Alarm outputs		1 Form C	1 Form C	1 Form C	1 Form C	2 Form C	1 NO	1 Form C	1 Form C	1 Form C
Trip outputs		■	■	3	■	■	■	■	■	■
Analog outputs		■	■	■	■				■	
Analog inputs									■	
Local display		■	■	■	■	■	■	■	■	■
LEDs (local targets)		■	■	■	■	■	■	■	■	■
Standards										
ANSI		■	■	■	■	■	■	■	■	■
IEC		■	■	■	■	■	■	■	■	■
UL		■	■	■	■	■	■	■	■	■
CE				■	■			■	■	
CSA		■	■	■	■	■		■	■	

Digitrip 3000 Feeder Protection Relay

Digitrip 3000 Front View

General Description

Eaton's Digitrip® 3000 protective relay is a multi-function, microprocessor-based overcurrent relay designed for both ANSI and IEC applications. It is a panel-mounted, self-contained unit that operates from either AC or DC control power. The Digitrip 3000 is available in an optional quick-release drawout case for panel-flush mounting. For AC control power applications, an optional Dual-Source Power Supply (DSPS) is recommended. See **Page 4.1-6** for details. The Digitrip 3000 design provides true rms sensing of each phase and ground current. Only one unit is required for each three-phase circuit. Current monitoring and operator selectable protective functions are integral to each relay.

The Digitrip 3000 relay operates from the 5A secondary output of standard current transformers. Current transformer ratio information is quickly programmed into the unit via settings. This enables the relay to display metered current in primary amperes.

The Digitrip 3000 features a user-friendly operator panel to monitor, program and test the relay. Operating parameters and troubleshooting information are displayed in the two highly visible display windows. In addition, all data and information can be communicated to a host computer equipped with the appropriate software. A "Communication Trip" and "Communication Close" control command can also be initiated by a host computer with an authorized access code.

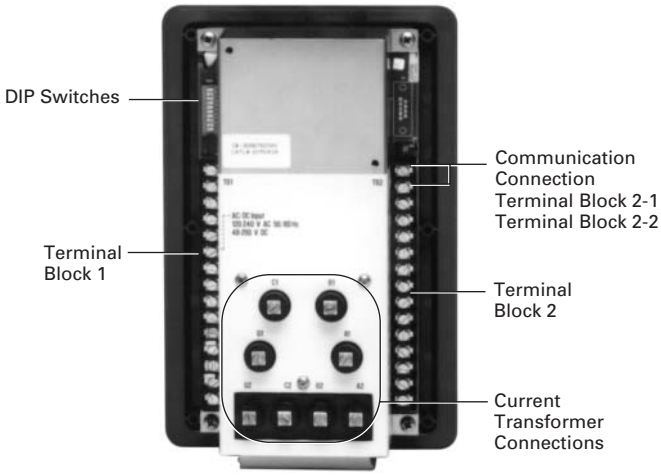
Features

General

- ANSI or IEC applications
- User-friendly front panel
- Non-volatile memory
- View settings any time
- Set CT ratios
- Metered currents in primary amperes
- Individual phase targeting of fault
- Integral test mode (phase and ground)
- Program and test mode security access cover with meter seal provision
- Continuous internal circuitry self-testing
- Programmable lockout/self reset after trip
- Relay failure alarm contact
- Trip alarm contact
- Optional Dual-Source Power Supply (DSPS), see **Page 4.1-6**
- Optional quick-release drawout case, see **Page 4.1-8**

Table 4.1-1. Catalog Numbers

Description	Catalog Number
Digitrip 3000	**DT3000**
Digitrip 3000 drawout relay	**DT3001**
Digitrip 3000 drawout inner chassis	**DT3001-IC**
Digitrip 3000 drawout outer case	**DT3001-OC**
Digitrip 3000 with 120 Vac dual-source power supply	**DT3010**
Digitrip 3000 with 240 Vac dual-source power supply	**DT3020**
Digitrip 3000 with 24/48 Vdc power supply and CE mark	**DT3030**
Digitrip 3000 with 24/48 Vdc power supply and CE mark in drawout case	**DT3031**



Digitrip 3000 Rear View

System Protection

- True rms sensing of each phase and ground current
- Selectable curve shapes: ANSI, IEC or thermal curves
- Phase overcurrent protection per time-current curve
- Independent ground fault protection per time-current curve
- Time overcurrent reset time delay
- Ground element capable of residual, zero sequence or external source connections
- Instantaneous phase and ground OC
- Short delay phase and ground OC
- Selectable true making current release (discriminator)
- Configurable trip outputs
- Zone selective interlocking (phase and ground) for bus protection and reduced arc flash energy

Information and Data Delivery

- Displays individual phase currents
- Displays ground current
- Displays magnitude and phase of current causing trip
- Displays peak demand current for each phase and ground since last reset
- Displays current transformer ratio
- Indicates cause of trip (time or instantaneous)
- Data/information transmission
- Provides breaker "Open" or "Close" status to a remote location via Eaton's PowerNet™

Application Description

General

The Digitrip 3000 microprocessor-based relay provides reliable three-phase and ground overcurrent protection for all voltage levels. It can be used for any application where instantaneous and/or time overcurrent protection is required. It is most commonly used as primary feeder circuit protection, as in **Figure 4.1-1**.

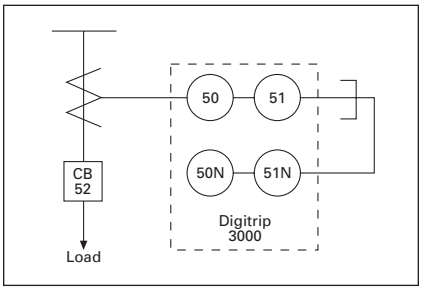


Figure 4.1-1. Primary Feeder Protection

The Digitrip 3000 may be applied as the transformer primary protection or as backup to the differential protection, as in **Figure 4.1-2**.

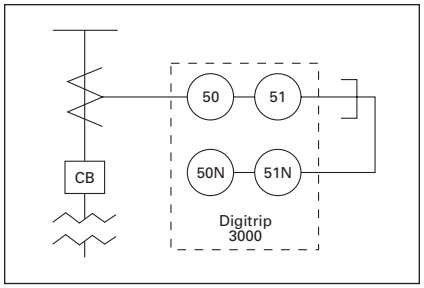


Figure 4.1-2. Transformer Protection

The Digitrip 3000 may be connected to the secondary side of a delta-wye grounded transformer with the ground element connected to a separate CT in the neutral connection of the transformer. With this connection, a lower CT ratio and a pickup setting can be used to provide more sensitive ground fault protection especially for resistance grounded systems (see **Figure 4.1-3**).

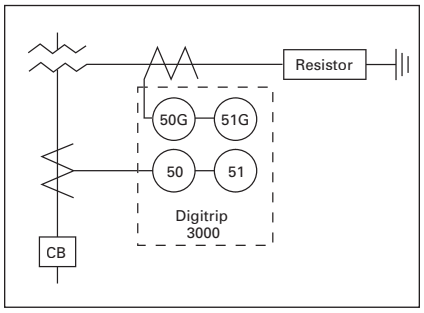


Figure 4.1-3. Transformer Secondary Protection with Ground CT Connection

The Digitrip 3000 relay has special provisions for connection in a *Zone Interlocking Scheme* that can be used for bus protection or to improve protection coordination in a tight or close system. Zone interlocking is described in more detail on **Page 4.1-4**.

Time Overcurrent Reset

The Digitrip 3000 includes time delay reset characteristic for the time overcurrent functions. This improves the overcurrent protection response to arcing fault conditions. The current during an arcing fault may vary above and below the pickup level. The time above pickup will accumulate until trip occurs.

Overcurrent Protection

The Digitrip 3000 provides complete three-phase and ground protection with separate elements and settings. The relay can be used with CT ratios from 5/5 to 5000/5. The CT ratio can be set independently for phase and ground, allowing the ground element to be connected in either the residual or the separate ground CT configuration as in **Figure 4.1-4** and **Figure 4.1-5**.

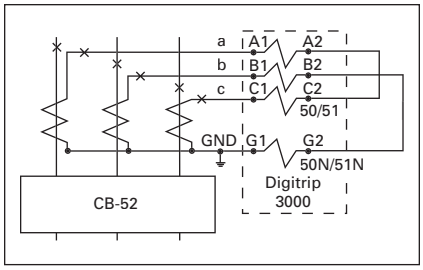


Figure 4.1-4. Residual Ground Connections

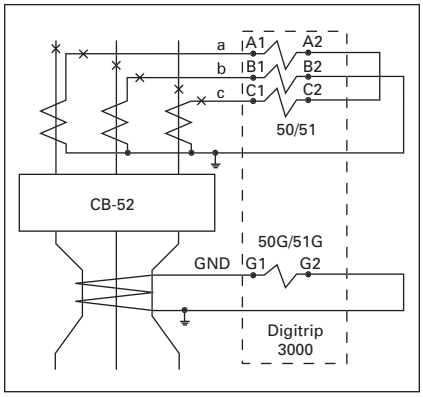


Figure 4.1-5. Separate Zero Sequence Ground CT Connections

The phase and ground overcurrent characteristics are defined by six parameters.

① Curve shape

② Overcurrent pickup

③ Time multiplier or dial

④ Short delay pickup

⑤ Short delay time

⑥ Instantaneous pickup

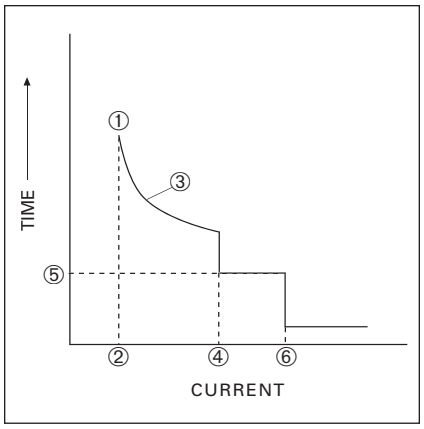


Figure 4.1-6. Phase or Ground Overcurrent Characteristics

Phase Curve Shape

The Digitrip 3000 includes the thermal, ANSI and IEC family of curves, which make it easy to coordinate with any conventional protection scheme. The user can select Moderately Inverse, Very Inverse, Extremely Inverse or Definite Time characteristics. The thermal curves It, I^2t, I^4t and flat slopes can also be selected.

Phase Time Overcurrent Protection

Time overcurrent (overload and fault) protection is defined by the current pickup setting and time multiplier.

Phase Short Time Protection

Short time (fault) protection responds to short-circuit conditions. It is similar to the Phase Long Time Protection in that current and time settings are offered. It differs, however, in two ways: (1) "NONE" is a Short Delay Pickup setting that, if selected, will disable the Phase Short Time Protection, and (2) a slope selection is not available for the time line.

Instantaneous Protection

Instantaneous (short-circuit) protection reacts to high level fault currents. If "NONE" is selected for the instantaneous setting, the instantaneous trip function is disabled and a true making current release (discriminator) function is provided. If selected, the discriminator is functional for 10 cycles and will trip the breaker instantaneously, if the fault current is above 11 times (I_n).

Ground Fault Protection

The ground fault protection function is a composite of the ground:

- Ground curve shape
- Time overcurrent and pickup time settings
- Short delay current and time settings
- Instantaneous setting

A "NONE" setting selection disables that characteristic of the ground fault protection.

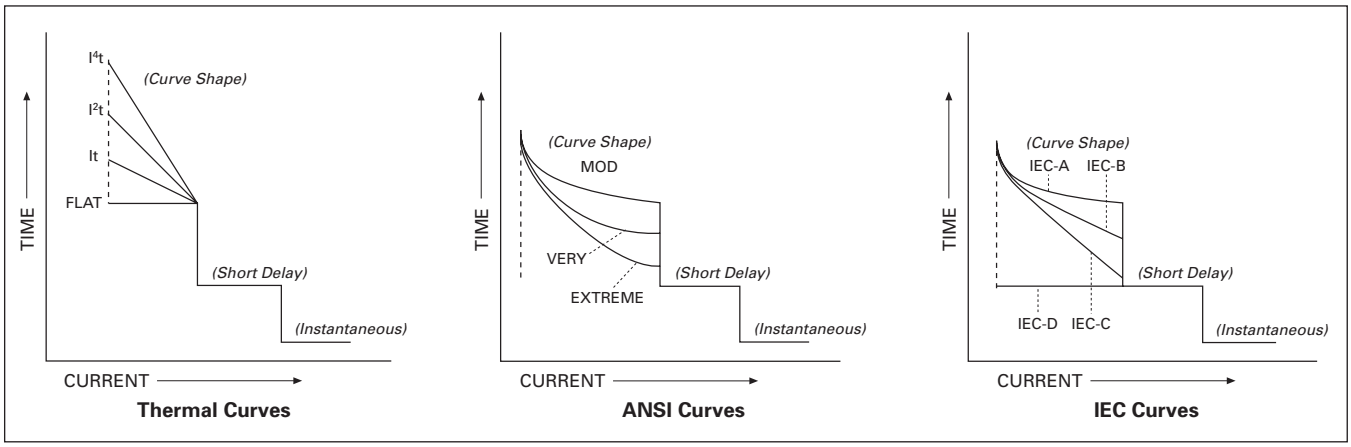


Figure 4.1-7. Digitrip 3000 Selective Curve Types

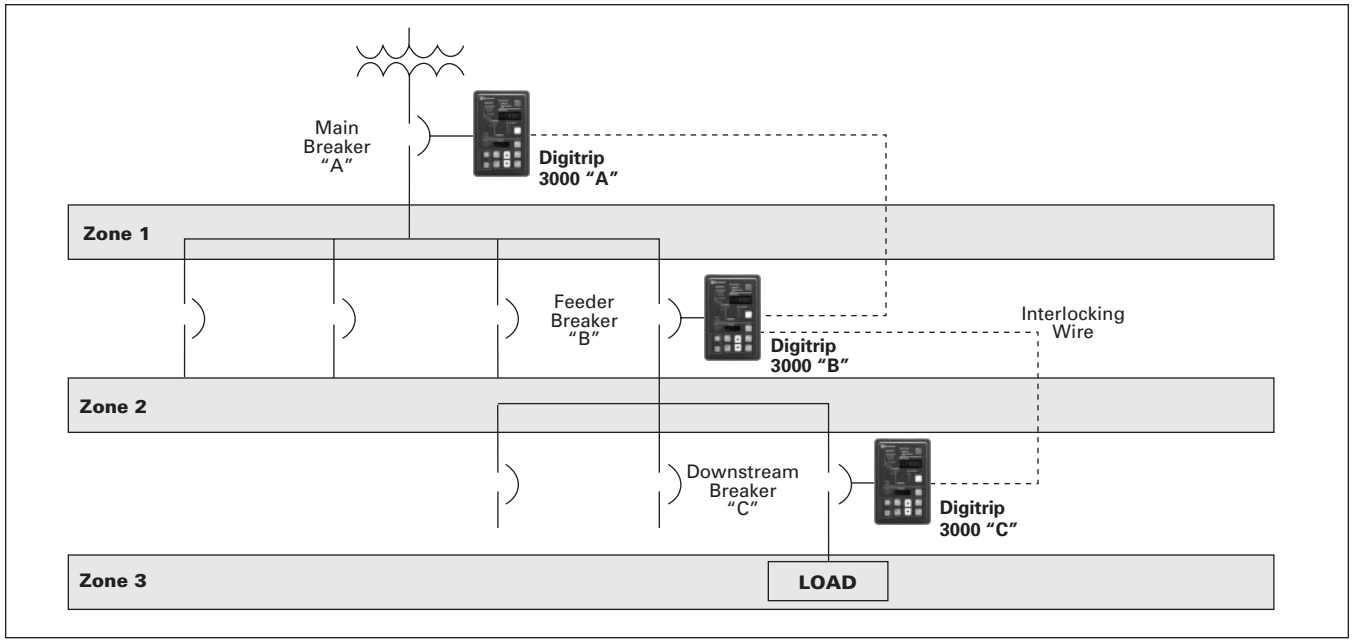


Figure 4.1-8. Sample Zone Selective Interlocking System

Zone Selective Interlocking (Phase and Ground)

Zone selective interlocking is a protection function to minimize equipment damage resulting from a phase fault or a ground fault in an area where long time and/or short time delay is in use.

When the "Ground Zone Interlocking" feature is used, an immediate trip is initiated when the fault is in the breaker's zone of protection, and no restraining signal received regardless of its preset time delay. When the "Phase Zone Interlocking" feature is used, the time overcurrent and short delay phase elements work as follows. The short delay phase element will initiate an immediate trip when the fault is in the breaker's zone of protection, and no restraining signal received regardless of its preset time delay. The time overcurrent phase element will initiate an immediate trip when the fault is in the breaker's zone of protection, and no restraining signal received regardless of its preset time delay only when the current being sensed by the Digitrip 3000 exceeds 300% (3 x I_n) of the current transformer rating.

Upstream Digitrip 3000 protected breakers are restrained from tripping immediately by an interlocking signal from the downstream Digitrip 3000 relay. This interlocking signal requires only a pair of wires from the downstream breaker to the upstream breaker. It provides standard coordinated tripping when the fault is located outside the zone of protection.

In the sample zone interlocking system shown above, circuit breakers A, B and C are equipped with Digitrip 3000 overcurrent relays.

Fault Location Zone 3

Note: For the phase time overcurrent element, the current sensed by the Digitrip 3000 must exceed 300% (3 x I_n) for the zone selective interlocking to initiate an immediate trip signal.

If a fault occurs at a point in Zone 3, the Digitrip 3000 of Downstream Breaker C senses the fault and sends a restraining signal to the upstream Digitrip 3000 of Feeder Breaker B. Having received this signal, the Digitrip 3000 of Feeder Breaker B withholds its trip command. As a result, only Downstream Breaker C is tripped.

Fault Location Zone 2

Note: For the phase time overcurrent element, the current sensed by the Digitrip 3000 must exceed 300% (3 x I_n) for the zone selective interlocking to initiate an immediate trip signal.

If a fault occurs at a point in Zone 2, the Digitrip 3000 of Feeder Breaker B senses the fault and sends a restraining signal to the upstream Digitrip 3000 of Main Breaker A.

The Digitrip 3000 of the Downstream Breaker C does not see this fault because it is situated on the downstream side of the fault. As a result, the Digitrip 3000 of Downstream Breaker C does not send a restraining signal to the Digitrip 3000 of Feeder Breaker B.

Because it did not receive a restraining signal from the Digitrip 3000 of Downstream Breaker C, the Digitrip 3000 of Feeder Breaker B identifies that the fault is in Zone 2 and immediately trips Feeder Breaker B, regardless of its time setting.

Fault Location Zone 1

Note: For the phase time overcurrent element, the current sensed by the Digitrip 3000 must exceed 300% (3 x I_n) for the zone selective interlocking to initiate an immediate trip signal.

If a fault occurs in Zone 1, no restraining signal is received by the Digitrip of Main Breaker A. As a result, Main Breaker A is immediately tripped by its Digitrip overcurrent relay, regardless of its time setting.

Technical Data and Specifications

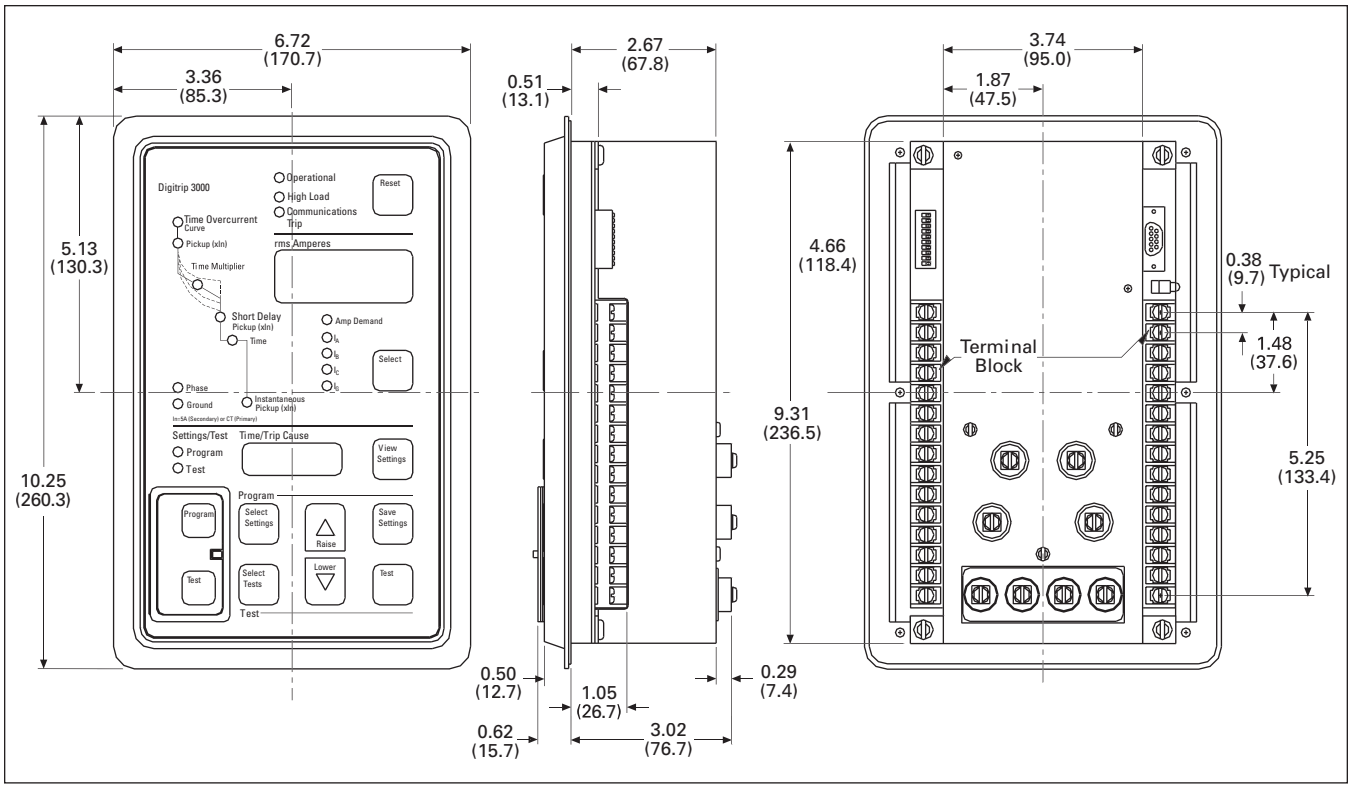


Figure 4.1-9. Digitrip 3000 Fixed Mount—Dimensions in Inches (mm)

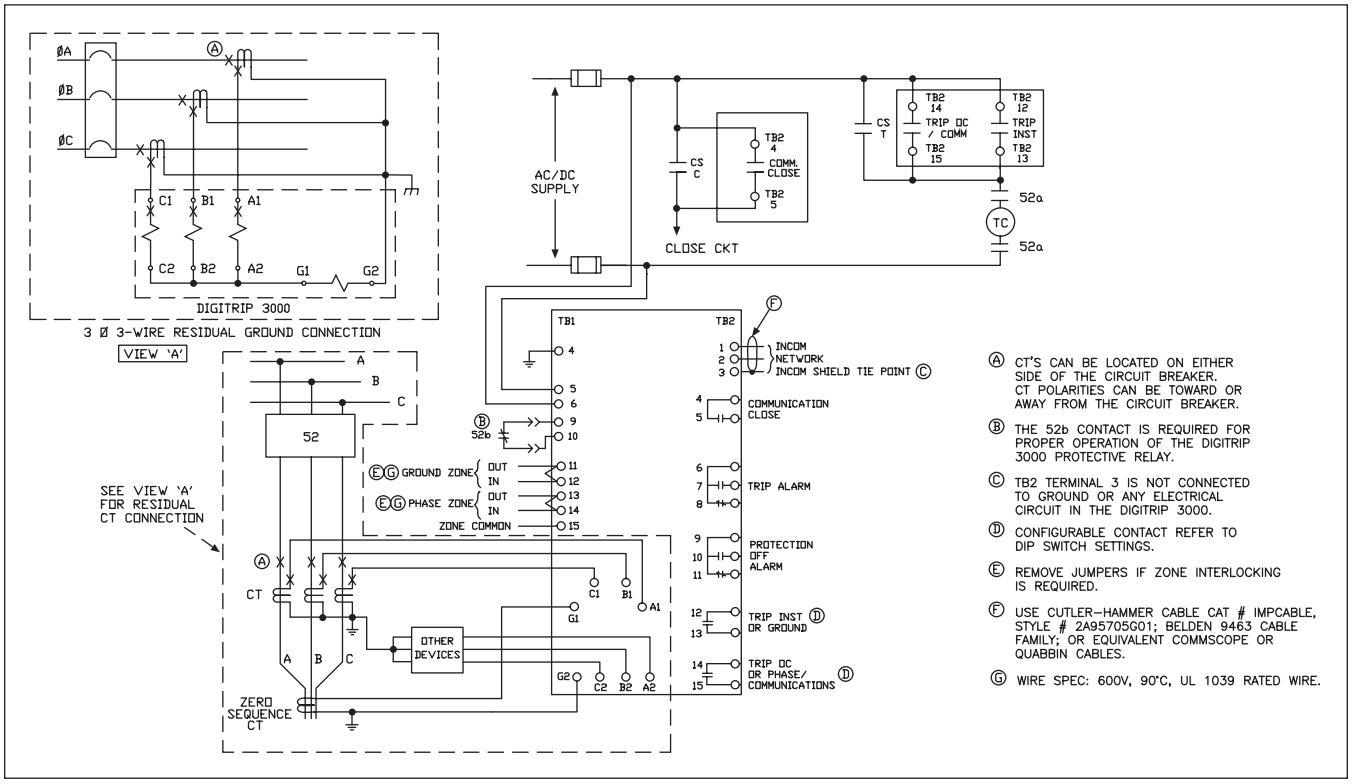


Figure 4.1-10. Digitrip 3000 Typical Schematic and Wiring Diagram

Digitrip 3000 Relay with Dual-Source Power Supply

Digitrip 3000 with Dual-Source Power Supply

General Description

Eaton's Digitrip 3000 with Dual-Source Power Supply (DSPS) is a microprocessor-based feeder overcurrent protective relay designed for AC auxiliary power applications. The DSPS versions, Digitrip 3010 and Digitrip 3020, include an integral power supply module that:

- Powers the relay from nominal 120 Vac, 50/60 Hz (Digitrip 3010 model) or 240 Vac, 50/60 Hz (Digitrip 3020 model) auxiliary power, which is normally connected and available
- Operates solely from the main current transformers (CTs) during a fault if the normally connected auxiliary AC voltage is not available, like an electromechanical relay or an electronic "self-powered" relay
- The transition from external auxiliary AC power to current power is smooth with no time delay

The CT powering capability is critical for tripping if the AC auxiliary supply or its fuses fail prior to the fault; or if the fault itself collapses, the supply voltage at the critical moment when tripping is needed.

The Digitrip 3000 with Dual-Source Power Supply design offers significant performance and reliability benefits over the electromechanical or "self-powered" relays. It provides a full-time metering display, remote communications and self-monitoring functions. In addition, there is no calibration required. The burden is lower than most electromechanical and solid-state self-powered relays.

The Digitrip 3000 with DSPS provides long-term, robust, maintenance-free performance, which can't be achieved with an energy-storing uninterruptible power supply (UPS). The DSPS will operate anytime there is a fault even after an extended power outage.

Functional Description

The Dual-Source Power Supply contains one AC voltage transformer and three AC current transformers. The AC voltage transformer is used to supply nominal AC control power to the unit. The current transformers are used to power the unit from the line current. Normally, the unit will operate from the AC auxiliary power. Because this voltage is usually obtained from the system containing the circuit that the relay is protecting, a fault on the protected line could cause the AC voltage to drop below an acceptable operating level. Below approximately 70V for Digitrip 3010 or 140V for Digitrip 3020, the DSPS switches over to current powering. All three current transformer secondaries are connected in series to supply this power. The DSPS will supply enough power to operate the Digitrip 3000 overcurrent relay in the tripped state with currents greater than 1.8 per unit rated secondary current, or 9A, in a single-phase. The DSPS will operate with three-phase currents in a tripped state with currents greater than 1.2 per unit or 6A rated secondary current.

Note: There will be no effect to the Digitrip 3000 relay trip time accuracy when the Dual-Source Power Supply switches from normal AC voltage to fault-current power.

Technical Data and Specifications

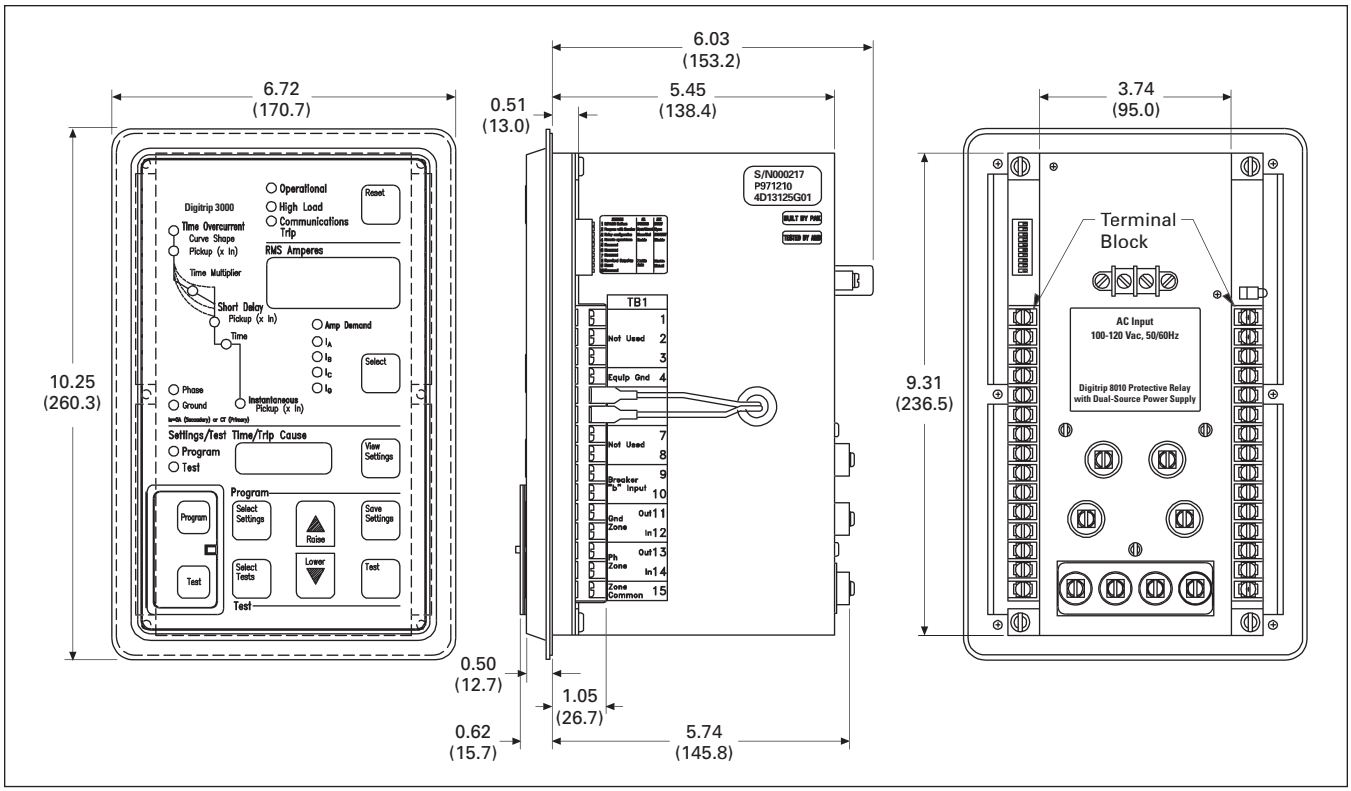


Figure 4.1-11. Digitrip 3010/3020 Dual-Source Power Supply—Dimensions in Inches (mm)

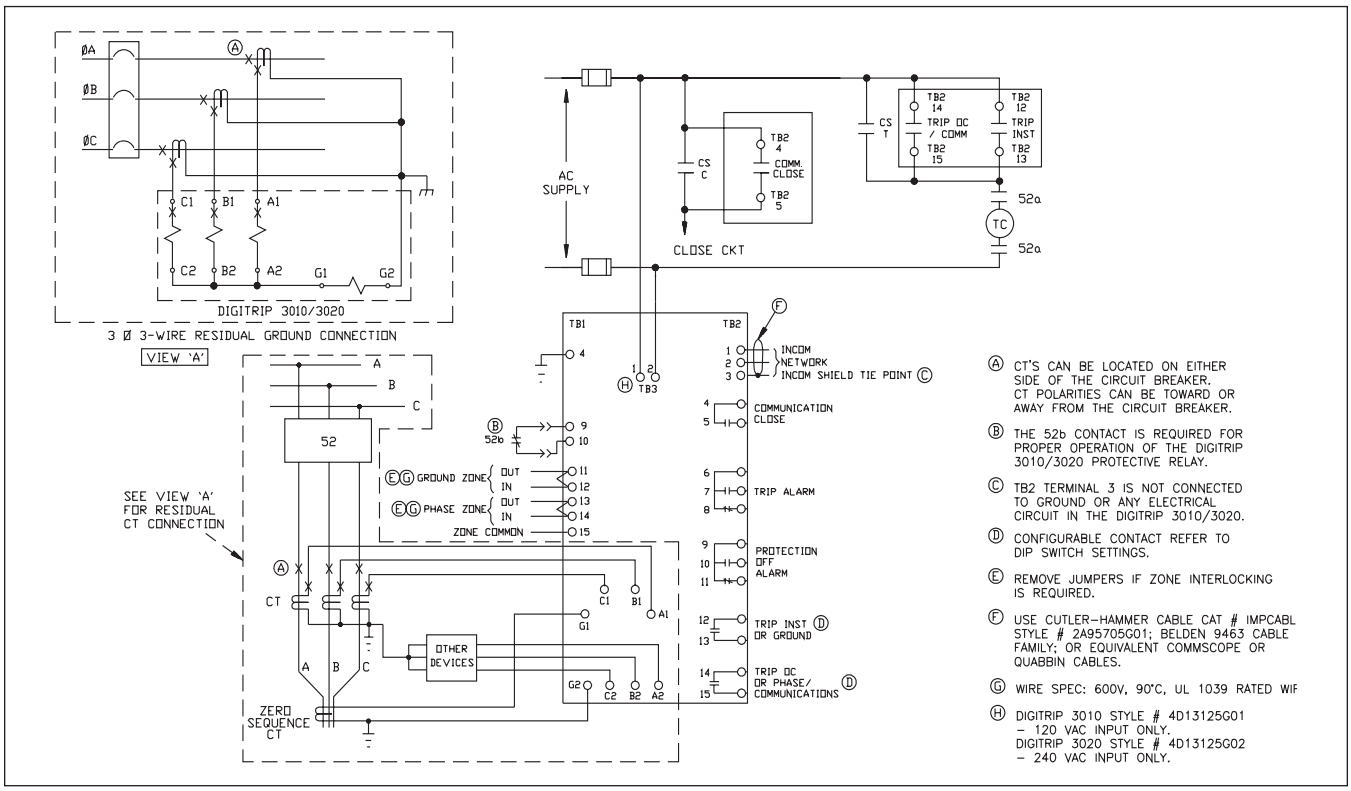


Figure 4.1-12. Digitrip 3010/3020 Typical Schematic and Wiring Diagram

Digitrip 3000—Drawout Case Option

Digitrip 3000 Drawout Relay

General Description

The quick-release Drawout Case option permits easy removal and replacement of the protective unit without disruption of the wiring. The CT circuits are self-shorting with make-before-break operation on removal. All voltage inputs, discrete inputs and contact outputs are disconnected while maintaining security against false tripping.

The terminal blocks feature a two-stage disconnect operation. Removal of the Eaton's Digitrip 3000 Inner Chassis will disconnect the trip circuits and short the CT secondaries before the unit control power is disconnected. Upon insertion of the Inner Chassis, the control power connections are made before the trip circuits are activated. **This feature provides added security against false tripping.**

4

Technical Data and Specifications

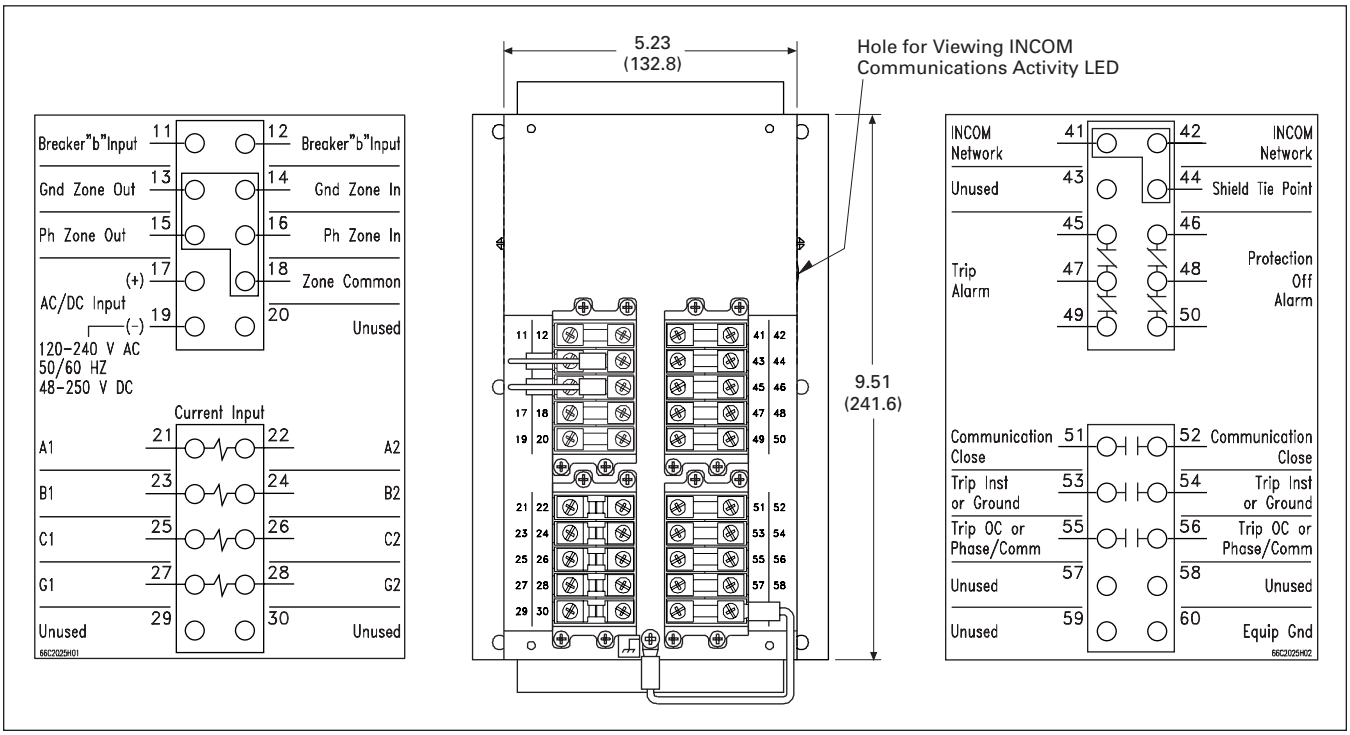


Figure 4.1-13. Rear View of Digitrip 3000 Drawout Outer Case—Terminal Layout

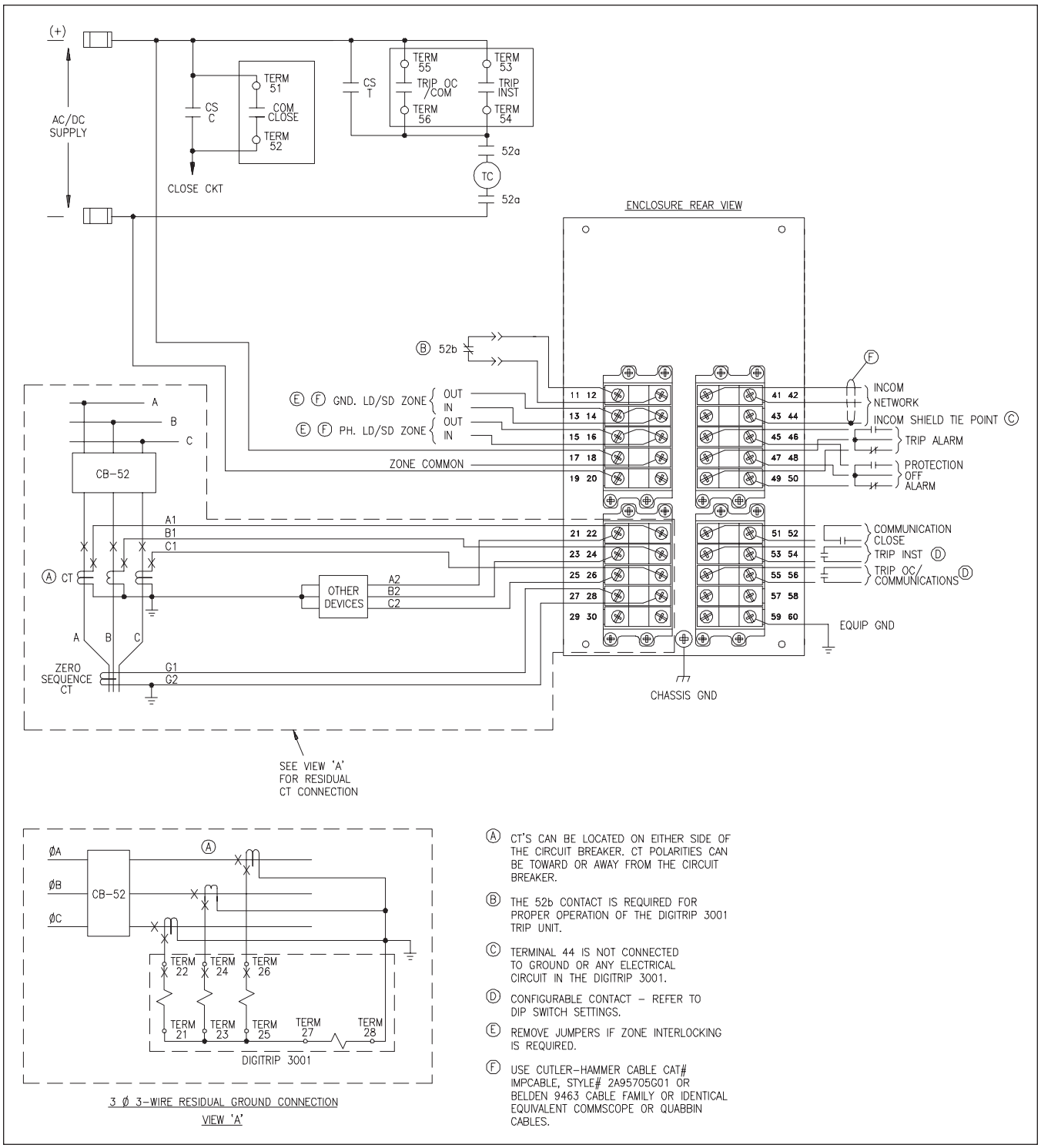


Figure 4.1-14. Digitrip 3000 Drawout Relay Typical Schematic and Wiring Diagram

Standards, Certifications and Ratings

Table 4.1-2. Digitrip 3000 Specifications

Current Inputs

CTs:	5A secondary
CT burden:	<0.004 ohm ①
	<0.1 VA at rated current (5A)
I_n:	5A (secondary) or CT (primary)
Momentary:	100 x I_n for 1 second

CT (Primary) Settings Available

Phase and ground:	5/10/25/50/75/100/ 150/200/250/200/ 250/300/400/500/ 600/630/800/1000/ 1200/1250/1500/ 1600/2000/2400/ 2500/3000/3200/ 4000/5000

Input Voltage DT-30XX

Nominal:	22 to 250 Vdc 120 to 240 Vac 50/60 Hz
Operating range:	28 to 280 Vdc 90 to 254 Vac 50/60 Hz

Power consumption:

24 Vdc	48 Vdc	125 Vdc	250 Vdc	120 Vdc	240 Vac
10W	10W	10W	10W	10 VA	18 VA

DT	3010	3020	3030
Nominal: operating range:	120 Vac 70–132 Vac	240 Vac 140–264 Vac	24/48 Vdc —
Power consumption:	15 VA	15 VA	—

Trip and Communications Close Output Contacts

- Make 30A for 0.25 seconds
- 0.25A break at 250 Vdc
- 5A break at 120/240 Vac
- Meets ANSI C37.90, paragraph 6.7

Environment

Operating temperature:	–30°C to +55°C
Operating humidity:	0% to 95% Relative humidity (noncondensing)
Storage temperature:	–40°C to +70°C

Auxiliary Alarm Contacts

5A continuous
5A break at 120/240 Vac

Tests

Dielectric strength:	Current inputs: 3000 Vac for 1 minute phase to phase
Seismic test:	Meets requirements for UBC® and California Building Code Zone 4 ZPA = 3.5
Standards:	ANSI C37.90, C37.90.1, C37.90.2 IEC 255 UL 1053

Phase and Ground Time-Current Curves

Thermal:	It (moderately inverse) I^2t (very inverse) I^4t (extremely inverse) FLAT (definite time)
ANSI: (per ANSI C37.112, 1996)	Moderately inverse Very inverse Extremely inverse
IEC: (per IEC 255-3, 1989)	IEC-A (moderately inverse) IEC-B (very inverse) IEC-C (extremely inverse) IEC-D (definite time)

Phase Overcurrent Pickup Ranges

Inverse time overcurrent setting:	(0.2 to 2.2) x I_n (28 settings)
Short delay setting:	(1 to 11) x I_n, None (25 settings)
Instantaneous setting:	(1 to 25) x I_n, None (30 settings)

Ground Overcurrent Pickup Ranges

Inverse time Overcurrent setting:	0.1 to 2.0) x I_n, None (26 settings)
Short delay setting:	(1 to 11) x I_n, None (25 settings)
Instantaneous setting:	(1 to 25) x I_n, None (30 settings)

Time Delay Settings

Inverse time overcurrent time multiplier:	It, I^2t, I^4t Curve: 0.2 to 40 (47 settings) FLAT: 0.2 to 2 (21 settings) ANSI (all): 0.1 to 5.0 (50 settings) IEC (all): 0.025 to 1.00 (40 settings)
Short delay time:	0.05 to 1.5 sec (22 settings)

Current Monitoring

True rms sensing:	Three-phase and ground
Display accuracy:	±1% of full scale [I_n] from 0.04 x I_n to 1 x I_n ±2% of full scale [I_n] from 1 x I_n to 2 x I_n
Ampere demand:	Average demand over 5 minute sampling window
High load:	85% of inverse time overcurrent setting

Timing Accuracy ②

Inverse time overcurrent time:	±10% at >1.5 x pickup
Short delay time:	±50 ms
Standards:	ANSI C37.90 IEC 255 UL 1053

Communications

PowerNet compatible:	Built-in INCOM
Baud rate:	1200 or 9600 baud

① Refer to Burden Curves for Digitrip 3010/3020.
② For Ground Pickup < 0.2pu; Time Tolerance ± 15%.

FP-4000
Feeder Protection Relay

FP-4000 Relay

General Description

Eaton's FP-4000 feeder protection relay is a multi-functional, microprocessor-based relay for feeder circuits of all voltage levels. It may be used as primary protection for main, feeder and tie circuit breaker applications and transformers, and as backup protection for high voltage lines and differential protection.

The FP-4000 feeder protection relay provides complete current and voltage protection and metering. The relay has four current inputs rated for 5A or 1A and four voltage inputs. Three of the voltage inputs are to be connected to the three-phase power voltage for voltage protection and for metering. They can be connected in wye-ground, delta or open delta configuration. The fourth voltage is for independent single-phase undervoltage/overvoltage protection.

The multiple settings groups can be used for arc flash mitigation when an alternate settings group, set to have instantaneous elements only, is activated using a selector switch and the programmable I/O in the FP-4000.

An integral keypad and display is provided for direct user programming and for retrieval of data. LEDs provide quick indication of relay status. A front port is provided for direct computer connection. An INCOM communication port on the back of the relay is standard for local area networking. Optional communication ports and protocols are available.

The FP-4000 feeder protection relay includes programmable logic functions. Six gates and timers may be defined and arranged for customized applications. Flash memory is used for the programming and all settings are stored in nonvolatile memory. The relay allows for four preprogrammed setting groups that can be activated through software or contact input.

The FP-4000 feeder protection relay has a mass memory for data storage and a real-time clock with 1 ms time resolution. The relay will log 100 sequence of event records, detailed trip logs, minimum/maximum values, load profiles, breaker wear information and oscillography data.

The FP-4000 feeder protection relay has eight programmable binary inputs, five normally opened heavy-duty outputs and one Form C signal relay.

Features

Protection

- Phase overcurrent:
  - Two-stage instantaneous with timers (50P-1 and 50P-2)
  - Inverse time overcurrent (51P-1)
  - 10 standard curves
  - Instantaneous or time delay reset
- Two independent ground overcurrent elements (one measured-IX and one calculated IR):
  - Two-stage instantaneous with timers (50X-1 and 50X-2) (50R-1, 50R-2)
  - Inverse time overcurrent (51X, 51R)
  - 10 standard curves
  - Instantaneous or time delay reset
- Breaker failure (50BF)
- Phase unbalance negative sequence overcurrent (46)
- Phase voltage unbalance and sequence protection (47)
- Under/overvoltage (27/59)
- Under/overfrequency (81U/81O)
- Power factor (55)
- Zone interlocking for bus protection (87B)

Metering

- Amperes: positive, negative and zero sequence
- Ampere demand
- Volts: positive, negative and zero sequence
- Phase angles
- Volt-amperes and VA demand
- Watts and kW demand
- kWh (forward, reverse, net)
- VARs and kVAR demand
- kVARh (lead, leg and net)
- Power factor
- Frequency
- % THD V and I
- Magnitude THD V and I
- Minimum/maximum recording
- Trending (load profile over time)

Monitoring

- Trip coil monitor
- Close coil monitor
- Breaker wear (accumulated interrupted current)
- Oscillography (up to 16 events)
- Fault data logs (up to 16 events)
- Sequence of events report (up to 100 events)
- Clock (1 ms time stamping)

Communication

- Local HMI
- Password protected
- Addressable
- Local communication port
- Remote communication port:
  - FSK
  - RS-232
  - RS-485
- Protocols:
  - INCOM
  - Modbus
- Configuration software

Control Functions

- Remote open/close
- Programmable I/O
- Programmable logic gates and timers
- Multiple setting groups
- Bus transfer logic

Table 4.1-3. Catalog Numbering Selection

FP4 2 01 - 0 1

Current Range	Packaging	Control Voltage	Communications
2 = 5A **3** = 1A	**1** = Fixed case	**0** = 48–125 Vac/dc **1** = 100–240 Vac/dc	**0** = INCOM **1** = Modbus

Protection Functions

Eaton's FP-4000 feeder protection relay has been designed for maximum user flexibility and simplicity. The base relay includes all the standard current and voltage protection and metering functions.

Overcurrent Protection

The FP-4000 feeder protection relay provides complete three-phase and ground overcurrent protection. There are two independent ground overcurrent elements. The first ground element "X" uses the independently measured ground (or neutral) current from a separate current-sensing input. The second ground element "R" uses a calculated $3I_O$ current obtained from the sum of the three-phase currents. This calculated current could be used for either the neutral or ground current in a three-phase, four-wire system.

Each of the phase and ground over-current elements provides three protection functions. Each element contains an inverse-time overcurrent (51) function and two instantaneous overcurrent (50) functions with adjustable timers.

Inverse-Time Characteristics

There are 10 user-selectable inverse-time overcurrent curve characteristics. The user can select from the ANSI, IEC or thermal curve families and can select instantaneous or time delay reset characteristics.

Breaker Failure

The FP-4000 feeder protection relay includes a breaker failure (50BF, 62BF) function that can be initiated from either an internal or an external trip signal. This is an independent element that can be used to operate a lockout relay or to trip an upstream breaker. The timer must be longer than the breaker operating time and the protective function reset times.

Voltage Protection

The FP-4000 feeder protection relay has four voltage-input circuits. There is a three-phase set designated as Main Voltage (M) and a single-phase voltage circuit designated as Auxiliary Voltage (A). Both include undervoltage (27) and overvoltage (59) protection. The three-phase voltage protection can be set to operate on a single-phase, two out of three phases, or all three-phase logic. The Main VTs also provide phase voltage unbalance/reversal (47 negative sequence) protection. Each element has an independent threshold set point and an adjustable time delay.

Flexible Phase Rotation

The FP-4000 feeder protection relay can be applied on either an A-B-C or an A-C-B phase rotation. A user setting permits correct operation and indication of the actual system configuration.

Frequency Protection

The FP-4000 relay provides under/over frequency (81U/81O) protection on the Main VT inputs. Each element has an independent threshold set point and adjustable time delay.

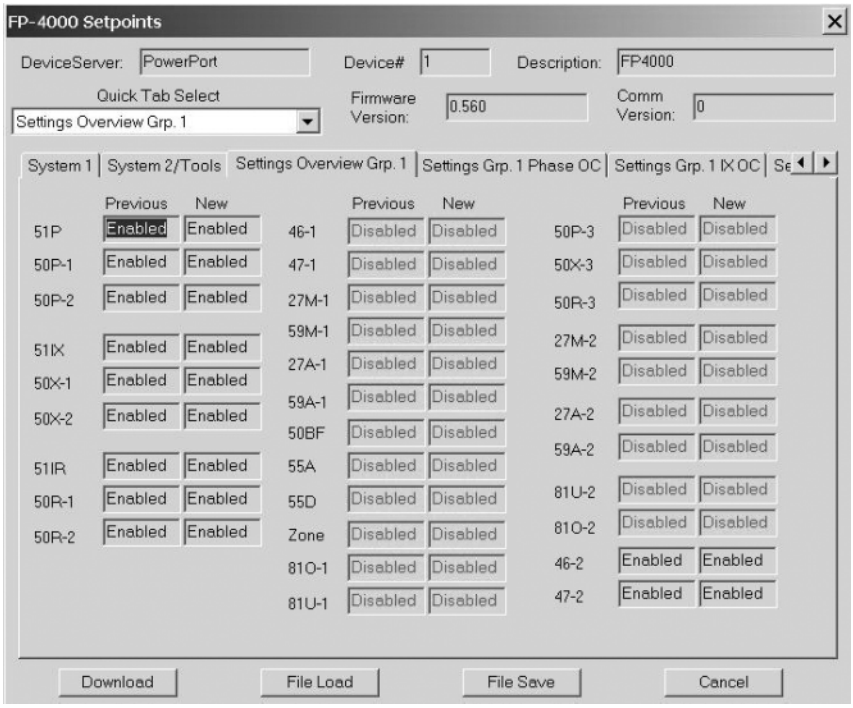
Metering

The FP-4000 feeder protection relay provides complete and accurate metering of the voltages, currents, frequency, power, power factor and energy. Information is available on the individual phase magnitude, angles and the symmetrical component values of positive, negative and zero sequence current and voltage.

The FP-4000 feeder protection relay includes a programmable demand feature and stores the maximum demand of current, kW, kVAR and kVA since last reset. The demand is user-configurable for fixed or sliding window, the time interval is adjustable and the demand interval can be synchronized to a demand pulse.

Energy usage direction and net values are given for kWh, kVARh and kVAh. The relay monitors, logs and time stamps minimum and maximum values for current, voltage, watts, VARs, VA, power factor and frequency.

The FP-4000 feeder protection relay has metered set points that can be used to activate an output for an alarm, control or trip function. For example, you might want to close a contact to insert a capacitor bank if the power factor is less than 0.9 lagging or provide an alarm if the demand is greater than a preset value.



PowerPort and PowerNet Protection Overview Screen

Loading Profile

The FP-4000 feeder protection relay has memory available to store metered data on a predetermined interval. The log holds data from 1024 time sample intervals. This information can be retrieved and plotted with a PC to show the loading profile of a given circuit over a period of time. For example, if the time interval is set for 15 minutes, then the relay will store a metered data profile over an approximate 10-day period.

Sequence of Events Records

The FP-4000 feeder protection relay records a maximum of 100 events associated with the relay. An event is classified as a change of state as detected by the relay. These include relay pickups, dropouts, trips, contact closure, alarms, setting changes and self-diagnostic failures. Each event is date and time stamped to a 1 ms resolution. The events are stored in an FIFO in chronological order.

Trip Log

The FP-4000 feeder protection relay will store a maximum of 16 trip records in an FIFO trip log. Each trip record will be date and time stamped to a 1 ms resolution and reference an event number associated with oscillographic and sequence of event data. The trip log record will include information on the type of fault, protection elements that operated, fault location, and currents and voltages at the time of the fault.

Waveform Capture

The FP-4000 feeder protection relay provides oscillography-recording capabilities. The relay will record all voltage and current signals along with the binary signals of pickup, trip, logic and contact closures. The FP-4000 relay can record 16 records of 16 cycles of data. Fewer records of longer duration can be selected and recorded. The waveform capture is initiated by a trip, pickup, external contact, front panel interface or through the remote communications port.

Programmable Logic

The FP-4000 feeder protection relay provides six logic gates and timers that the user can customize for special or unique applications. Each gate can be assigned a logic function of either AND, OR, NAND or NOR. Each gate can have a maximum of four input signals and each input signal can be required to be a NOT. Input signals can be external inputs received via the binary inputs or internal values associated with the protection, alarm or metering set points. Each gate has a unique output assignment and designation that can be used as the input to another gate. There are six independent timers that have adjustable pickup and dropout delay settings.

Integral User Interface

The front panel user interface has a 4.00 x 20.00-inch (101.6 x 508.0 mm) alphanumeric vacuum fluorescent display for wide angle viewing in all light conditions. LEDs provide quick and easy visual display of power on, mode of operation, alarm and trip indication. Pushbuttons are provided for operation mode selection, scrolling through data and settings. A security door restricts access to the program and test modes. In addition, the relay settings and test functions can be password protected.

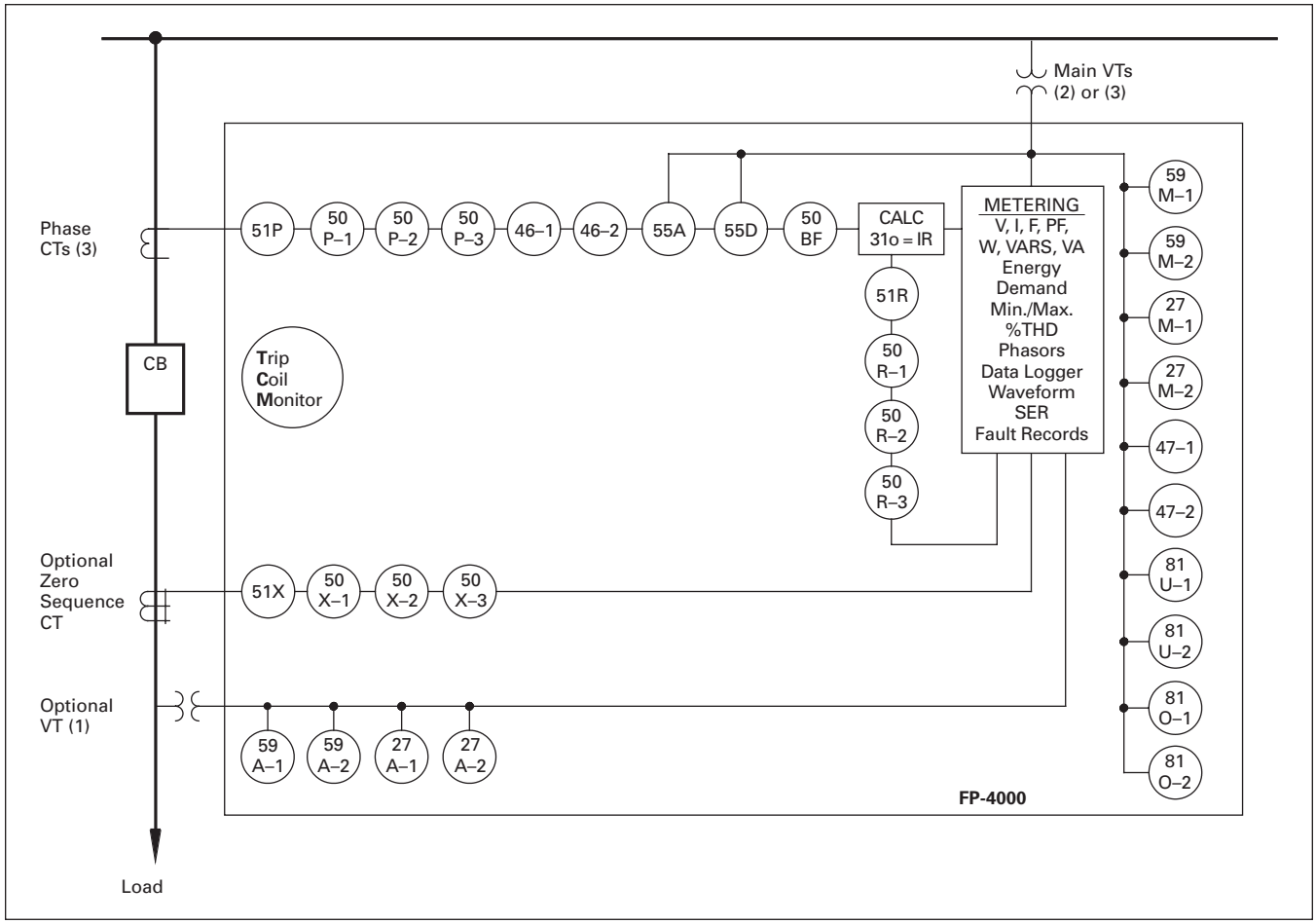


Figure 4.1-15. FP-4000 Relay Typical One-Line Diagram

Programmable I/O

The FP-4000 feeder protection relay provides five heavy-duty, trip-rated, normally open contacts and two Form C auxiliary contacts. Two trip rated contacts are fitted with a circuit continuity feature for monitoring the trip or close circuits. One Form C contact is dedicated to the relay failure alarm function and is operated in a normally energized (failsafe) mode. There are eight user-configurable discrete inputs that accept a dry contact. Each input and output is user-programmable for maximum application flexibility.

Communication Software

Eaton provides two types of communication software. The first is PowerPort. It runs on a PC or laptop for easy access to a single relay to change set points or configuration, and to view metered values and stored data. PowerPort is free and can be downloaded from the Eaton Web site at **www.eaton.com**.

The second package is PowerNet. PowerNet is a power management software package that is designed for continuous, remote monitoring of many devices. It provides all the functionality of PowerPort plus additional functions such as billing, trending and graphics. Contact your local Eaton representative for more information on PowerNet software.

Transview

Transview is a COMTRADE file viewer that is required in addition to the PowerNet waveform client to view FP-4000 waveforms. Users can view individual voltage and current waveforms, as well as phasers and digital input/output and internal protection functions such as undervoltage and current unbalance.

Standards, Certifications and Ratings

Table 4.1-4. FP-4000 Specifications

Compliance

UL Recognized, File # E154862
UL 1053 (1994) Recognized
ANSI C37.90 (1989)
EN 55011 (1991)
EN 61000-6-2 (1999)

Emission Tests

EN 55011 (1991):	Group 1 Class A (CISPR-11, Class A)
FCC 47 CFR Chapter 1:	Part 15 Subpart b Class A

Immunity Tests

ANSI C37.90.1 (1989):	Surge withstand capability
ANSI C37.90.2 (1995):	EMI immunity to 35 V/m
EN 61000-4-2 (1995):	ESD rating of 8 kV
EN 61000-4-3 (1997):	Radiated EM field at 10 V/m
EN 61000-4-4 (1995):	Fast transient burst at 2 kV
EN 61000-4-5 (1995):	Surge immunity test
EN 61000-4-6 (1996):	Conducted RF at 10 V/m
EN 61000-4-11 (1994):	Voltage dips and variations

Control Power

Control voltage:	48–125 Vac/dc 100–240 Vac/dc
Operating voltage:	55–264 Vac 38–300 Vdc
Interruption ride-through time:	20 cycle interruption of nominal AC supply
Power consumption:	20 VA maximum

Current Inputs

Nominal (I_n):	1A or 5A
CT rating:	2 x I_n continuous 50 x I_n for 1 second
CT burdens:	< 0.25 VA at 5A (nominal) < 0.05 VA at 1A (nominal)

Voltage Inputs

Nominal:	120 Vac
Operating range:	69–150 Vac
Burden:	<0.015 at 120 Vac 1 megaohm

Metering Accuracy

Phase current:	±0.5% or ±0.025A from 0.02 to 20.0 per unit fully offset current waveform
Ground current:	±0.5% of full scale (I_n) from 0.02 to 2.0 per unit fully offset current waveform
Phase voltage:	±0.5% or ±0.2V from 0–160 Vac
Frequency measurement accuracy:	±0.02 Hz
Phase angle:	±1°
Power metering accuracy:	±1.5%
Metering accuracy temperature range:	0°C to 50°C
Temperature range:	±5% for operation below 0°C and above 50°C

Metering Accuracy (Continued)

Input signal Frequency necessary for accurate operation:	60 Hz nominal, 57–63 Hz (±5%) 50 Hz nominal, 47–53 Hz (±5%)
Clock accuracy:	Free running ±1 Minute/month at 25°C

Clock automatically updated by PowerNet host when present.

Protective Functions

Phase and Ground Overcurrent Protection (50/51)

Inverse time over-current characteristics 51, 51N, 51G:	Moderate, very, extremely, IECA, IECB, IECC, It, I^2t, I^4t, flat
Inverse time over-current pick-up ranges 51, 51N, 51G:	0.1 to 4.0 per unit in 0.01 steps
Inverse time over-current multipliers 51, 51N, 51G:	0.05 to 10.0 in 0.01 steps
Inverse time delay range 51, 51N, 51G:	0 to 9999 cycles in 1 cycle steps
Instantaneous over-current pickup ranges 50, 50N, 50G:	0.1 to 20.0 per unit in 0.01 steps
Pick-up accuracy 50/51:	±1% (at 0.1–2 per unit)
time accuracy 51, 51N, 51G:	±3% or ±30 ms

Voltage Unbalance (47)

Threshold (minimum voltage) 1 to 100V in 1V steps.

% V2/V1:	4 to 40% in 1% Steps
Time delay:	0 to 9999 cycles in 1 cycle steps

Current Unbalance (46)

Threshold (minimum current) 0.1 to 20.0 per unit in 0.01 steps.

% I2/I1:	4 to 40% in 1% steps
Time delay:	0 to 9999 cycles in 1 cycle steps

Under/Overvoltage Protection (27/59)

Pickup range:	10 to 150V in 1V steps
Time delay:	0 to 9999 cycles in 1 cycle steps

Under/Overfrequency Protection (81U/810)

Pickup range:	45 to 65 Hz in 0.01 Hz steps
Time delay:	0 to 9999 cycles in 1 cycle steps

Breaker Failure Protection (50BF)

Pickup range:	0.1 to 5.0 per unit in 0.01 steps
Time delay:	0 to 9999 cycles in 1 cycle steps

Power Factor (55)

Trigger/Reset Threshold:	0.5 lag to 0.5 lead in 0.01 steps
Time delay:	0 to 1000 seconds in 1 second steps

Discrete Inputs

Number of contact inputs:	8
Rating:	48 Vdc wetting voltage provided with internal ground only

Output Contacts

Number of output contacts: Five Form A and Two Form C

Rating of Output Contacts

Momentary:	Make 30A AC/DC for 0.25 seconds Break 0.25A at 250 Vdc (resistive) Break 5A at 120 Vac
Continuous:	5A at 120 Vac 5A at 30 Vdc

Logic and Control Functions

Six programmable logic gates for AND, OR, NAND, NOR operation
Two latching (flip/flop) gates
Six timer gates provide on/off delays

INCOM Communications

Baud rate:	9600 fixed
Maximum distance:	10,000 feet (3048m)
Protocol:	INCOM

RS-485 Communication, Rear Panel

Baud rate:	9.2k, 9.6k
Protocol:	Modbus RTU

RS-232 Communication, Front Panel

Baud rate:	38.4k, 19.2k, 9.6k
Connector standard 9-pin subminiature, three-wire protocol:	INCOM

Environmental Ratings

Operating temperature:	–40°C to +60°C (–40°F to +140°F) product tested to +85°C
Storage temperature:	–40°C to +85°C (–40°F to +185°F)
Humidity:	5% to 95% relative humidity (noncondensing)
Altitude:	0 to 6350 feet (0 to 2500m) above mean sea level

Dimensions

Behind Panel

Height:	10.15 inches (257.9 mm)
Width:	7.62 inches (193.5 mm)
Depth:	7.48 inches (190.0 mm)

In Front of Panel

Height:	10.15 inches (257.9mm)
Width:	7.62 inches (193.5 mm)
Depth:	0.62 inches (15.7 mm)

Weight

9.0 lbs (4.1 kg)

FP-5000
Feeder Protection Relay

FP-5000 Relay

General Description

Eaton's FP-5000 feeder protection relay is a multi-functional, microprocessor-based relay for feeder circuits of all voltage levels. It may be used as primary protection for main, feeder and tie circuit breaker applications, transformers and as backup protection for high voltage lines and differential protection.

The FP-5000 feeder protection relay provides complete current and voltage protection and metering in a single, compact drawout case. The relay has four current inputs rated for 5A or 1A and four voltage inputs. Three of the voltage inputs are to be connected to the three-phase power voltage for voltage protection and for metering. They can be connected in wye-ground, delta or open delta configuration. The fourth voltage is for independent single-phase undervoltage/overvoltage protection.

The multiple settings groups can be used for arc flash mitigation when an alternate settings group, set to have instantaneous elements only, is activated using a selector switch and the programmable I/O in the FP-5000.

An integral keypad and display is provided for direct user programming and retrieval of data. LEDs provide quick indication of relay status. A front port is provided for direct computer connection. An INCOM communication port on the back of the relay is standard for local area networking. Optional communication ports and protocols are available.

The FP-5000 feeder protection relay includes programmable logic functions. Six gates and timers may be defined and arranged for customized applications. Flash memory is used for the programming and all settings are stored in nonvolatile memory. The relay allows for four preprogrammed setting groups that can be activated through software or contact input.

The FP-5000 feeder protection relay has a mass memory for data storage and a real-time clock with 1 ms time resolution. The relay will log 100 sequence of event records, detailed trip logs, minimum/maximum values, load profiles, breaker wear information and oscillography data.

The FP-5000 feeder protection relay has eight programmable binary inputs, five normally opened heavy-duty outputs and one Form C signal relay. It can be powered from 48 Vdc to 125 Vdc or 120 Vac to auxiliary power.

Features

Protection

- Phase overcurrent (forward, reverse or both):
  - Two-stage instantaneous with timers (50P-1 and 50P-2)
  - Two Inverse time overcurrent (51P-1 and 51P-2)
  - Directional current (67)
  - 10 standard curves
  - Instantaneous or time delay reset
  - Voltage restrained time overcurrent (51VR)
- Two independent ground directional overcurrent elements (one measured-IX and one calculated IR):
  - Two-stage instantaneous with timers (50X-1 and 50X-2) (50R-1, 50R-2)
  - Inverse time overcurrent (51X, 51R)
  - Ground directional polarizing (67N)
    - 3 V_o, I_{pol}, negative sequence
  - 10 standard curves
  - Instantaneous or time delay reset
- Breaker failure (50BF)
- Phase unbalance negative sequence overcurrent (46)
- Phase voltage unbalance and sequence protection (47)
- Under/overvoltage (27/59)
- Under/overfrequency (81U/81O)
- Reverse/forward power (32-1, 32-2)
- Sync check (25)
- Power factor (55)
- Zone interlocking for bus protection (87B)

Metering

- Amperes: positive, negative and zero sequence
- Ampere demand
- Volts: positive, negative and zero sequence
- Phase angles
- Volt-amperes and VA demand
- Watts and kW demand
- kWh (forward, reverse, net)
- VARs and kVAR demand
- kVARh (lead, leg and net)
- Power factor
- Frequency
- % THD V and I
- Magnitude THD V and I
- Minimum/maximum recording
- Trending (load profile over time)

Monitoring

- Trip coil monitor
- Close coil monitor
- Breaker wear (accumulated interrupted current)
- Oscillography (up to 16 events)
- Fault data logs (up to 16 events)
- Sequence of events report (up to 100 events)
- Clock (1 ms time stamping)

Communication

- Local HMI
- Password protected
- Addressable
- Local communication port
- Remote communication port:
  - FSK
  - RS-232
  - RS-485
- Protocols:
  - INCOM
  - Modbus
- Configuration software

Control Functions

- Remote open/close
- Programmable I/O
- Programmable logic gates and timers
- Multiple setting groups
- Bus transfer logic
- Cold load pickup
- Loss of potential (PT blown fuses)

Table 4.1-5. Catalog Numbering Selection

FP5 2 00 - 0 1

Current Range	Packaging	Control Voltage	Communications
2 = 5A **3** = 1A	**0** = Drawout **1** = Fixed case	**0** = 48–125 Vac/dc **1** = 100–240 Vac/dc	**0** = INCOM **1** = Modbus

Protection Functions

Eaton's FP-5000 feeder protection relay has been designed for maximum user flexibility and simplicity. The base relay includes all the standard current and voltage protection, and metering functions.

Directional Overcurrent Protection

The FP-5000 feeder protection relay provides complete three-phase and ground directional overcurrent protection. There are two independent ground overcurrent elements. The first ground element "X" uses the independently measured ground (or neutral) current from a separate current-sensing input. The second ground element "R" uses a calculated $3I_o$ current obtained from the sum of the three-phase currents. This calculated current could be used for either the neutral or ground current in a three-phase, four-wire system.

Each of the phase and ground overcurrent elements provides three protection functions. Each element contains an inverse-time overcurrent (51) function and two instantaneous overcurrent (50) functions with adjustable timers.

Phase direction is a function used to supervise all phase current elements (50, 51). A quadrature voltage is compared to a corresponding phase current to establish the direction of the fault. This function is selectable to operate in the forward, reverse or both directions.

Ground direction is used to supervise ground current elements and is accomplished by using ground, negative sequence or residual currents supervised by zero or positive sequence voltages or ground current. This function is selectable to operate in forward, reverse or both directions.

Voltage Restrained Overcurrent

Voltage restraint reduces the overcurrent pickup level (51P-2). This modification of the pickup overcurrent level is compared to the corresponding phase input voltage. The FP-5000 uses the simple linear model below to determine the effective pickup value.

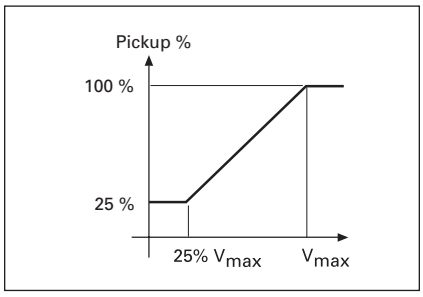


Figure 4.1-16. Voltage Restraint Coil Pickup Characteristics

Sync Check

The sync check function is provided for double-ended power source applications. The sync check monitors voltage magnitude, phase angle and slip frequency between the bus and line. It also incorporates breaker close time, dead bus dead line, dead bus live line and live bus live line features.

Reverse Power

Reverse power provides control for power flowing through a feeder. There are two elements to be configured: operate in forward or reverse; or, under or over power conditions. Reverse power is typically applied to generator or motor applications while under power is generally applied to load or generation loss.

Inverse-Time Characteristics

There are 10 user-selectable inverse-time overcurrent curve characteristics. The user can select from the ANSI, IEC or thermal curve families and can select instantaneous or time delay reset characteristics.

Breaker Failure

The FP-5000 feeder protection relay includes a breaker failure (50BF, 62BF) function that can be initiated from either an internal or external trip signal. This is an independent element that can be used to operate a lockout relay or trip an upstream breaker. The timer must be longer than the breaker operating time and the protective function reset times.

Voltage Protection

The FP-5000 feeder protection relay has four voltage-input circuits. There is a three-phase set designated as Main Voltage (M) and a single-phase voltage circuit designated as Auxiliary Voltage (A). Both include undervoltage (27) and overvoltage (59) protection. The three-phase voltage protection can be set to operate on a single-phase, two out of three phases, or all three-phase logic. The Main VTs also provide phase voltage unbalance/reversal (47 negative sequence) protection. Each element has an independent threshold set point and adjustable time delay.

Flexible Phase Rotation

The FP-5000 feeder protection relay can be applied on either an A-B-C or A-C-B phase rotation. A user setting permits correct operation and indication of the actual system configuration.

Frequency Protection

The FP-5000 relay provides under/over frequency (81U/81O) protection on the Main VT inputs. Each element has an independent threshold set point and adjustable time delay.

4

Metering

The FP-5000 feeder protection relay provides complete and accurate metering of the voltages, currents, frequency, power, power factor and energy. Information is available on the individual phase magnitude, angles and the symmetrical component values of positive, negative and zero sequence current and voltage.

The FP-5000 feeder protection relay includes a programmable demand feature and stores the maximum demand of current, kW, kVAR and kVA since last reset. The demand is user-configurable for fixed or sliding window, the time interval is adjustable and the demand interval can be synchronized to a demand pulse.

Energy usage direction and net values are given for kWh, kVARh and kVAh. The relay monitors, logs and time stamps minimum and maximum values for current, voltage, watts, VARs, VA, power factor and frequency.

The FP-5000 feeder protection relay has metered set points that can be used to activate an output for an alarm, control or trip function. For example, you might want to close a contact to insert a capacitor bank if the power factor is less than 0.9 lagging or provide an alarm if the demand is greater than a preset value.

Loading Profile

The FP-5000 feeder protection relay has memory available to store metered data on a predetermined interval. The log holds data from 1024 time sample intervals. This information can be retrieved and plotted with a PC to show the loading profile of a given circuit over a period of time. For example, if the time interval is set for 15 minutes, then the relay will store a metered data profile over an approximate 10-day period.

Sequence of Events Records

The FP-5000 feeder protection relay records a maximum of 100 events associated with the relay. An event is classified as a change of state as detected by the relay. These include relay pickups, dropouts, trips, contact closure, alarms, setting changes and self-diagnostic failures. Each event is date and time stamped to a 1 ms resolution. The events are stored in an FIFO in chronological order.

Trip Log

The FP-5000 feeder protection relay will store a maximum of 16 trip records in an FIFO trip log. Each trip record will be date and time stamped to a 1 ms resolution and reference an event number associated with oscillographic and sequence of event data. The trip log record will include information on the type of fault, protection elements that operated, fault location, and currents and voltages at the time of the fault.

Waveform Capture

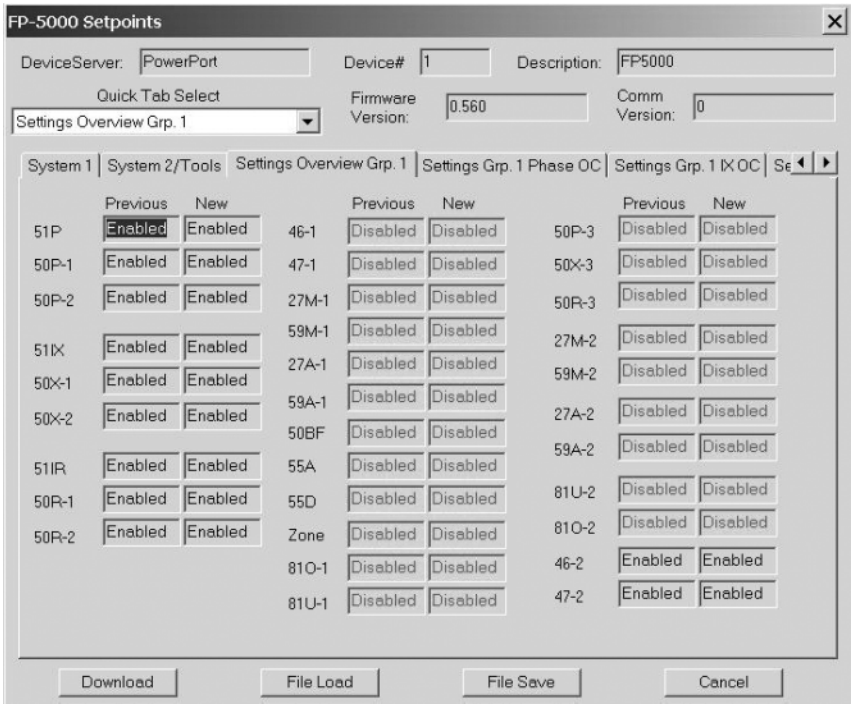
The FP-5000 feeder protection relay provides oscillography-recording capabilities. The relay will record all voltage and current signals along with the binary signals of pickup, trip, logic and contact closures. The FP-5000 relay can record 16 records of 16 cycles of data. Fewer records of longer duration can be selected and recorded. The waveform capture is initiated by a trip, pickup, external contact, front panel interface or through the remote communications port.

Programmable Logic

The FP-5000 feeder protection relay provides six logic gates and timers that the user can customize for special or unique applications. Each gate can be assigned a logic function of either AND, OR, NAND or NOR. Each gate can have a maximum of four input signals and each input signal can be required to be a NOT. Input signals can be external inputs received via the binary inputs or internal values associated with the protection, alarm or metering set points. Each gate has a unique output assignment and designation that can be used as the input to another gate. There are six independent timers that have adjustable pickup and dropout delay settings.

Integral User Interface

The front panel user interface has a 4 x 20-inch (101.6 x 508.0 mm) alpha-numeric vacuum fluorescent display for wide angle viewing in all light conditions. LEDs provide quick and easy visual display of power on, mode of operation, alarm and trip indication. Pushbuttons are provided for operation mode selection, scrolling through data and settings. A security door restricts access to the program and test modes. In addition, the relay settings and test functions can be password protected.



FP-5000 Set Point Overview

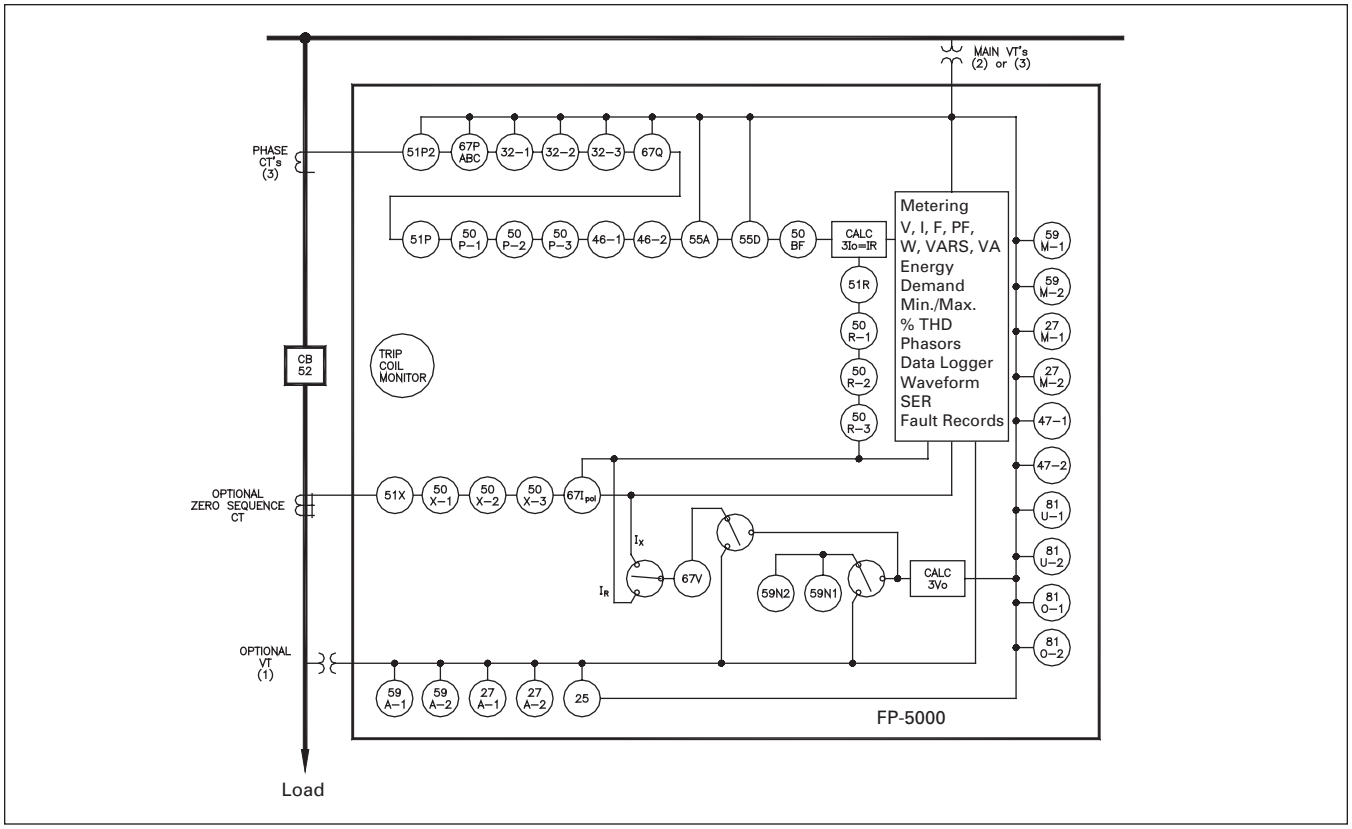


Figure 4.1-17. FP-5000 Relay Typical One-Line Diagram

Programmable I/O

The FP-5000 feeder protection relay provides five heavy-duty, trip-rated, normally open contacts and two Form C auxiliary contacts. Two trip rated contacts are fitted with a circuit continuity feature for monitoring the trip or close circuits. One Form C contact is dedicated to the relay failure alarm function and is operated in a normally energized (failsafe) mode. There are eight user-configurable discrete inputs that accept a dry contact. Each input and output is user-programmable for maximum application flexibility.

Communication Software

Eaton provides two types of communication software. The first is PowerPort. It runs on a PC or laptop for easy access to a single relay to change set points or configuration and to view metered values and stored data. PowerPort is free and can be downloaded from the Eaton Web site at **www.eaton.com**.

The second package is PowerNet. PowerNet is a power management software package that is designed for continuous, remote monitoring of many devices. It provides all the functionality of PowerPort plus additional functions such as billing, trending and graphics. Contact your local Eaton representative for more information on PowerNet software.

Transview

Transview is a COMTRADE file viewer that is required in addition to the PowerNet waveform client to view FP-5000 waveforms. Users can view individual voltage and current waveforms, as well as phasers and digital input/output and internal protection functions such as undervoltage and current unbalance.

Standards, Certifications and Ratings

Table 4.1-6. FP-5000 Specifications

Compliance

UL Recognized, File # E154862
UL 1053 (1994) Recognized
ANSI C37.90 (1989)
EN 55011 (1991)
EN 61000-6-2 (1999)

Emission Tests

EN 55011 (1991):	Group 1 Class A (CISPR-11, Class A)
FCC 47 CFR Chapter 1:	Part 15 Subpart b Class A

Immunity Tests

ANSI C37.90.1 (1989):	Surge withstand capability
ANSI C37.90.2 (1995):	EMI immunity to 35 V/m
EN 61000-4-2 (1995):	ESD rating of 8 kV
EN 61000-4-3 (1997):	Radiated EM field at 10 V/m
EN 61000-4-4 (1995):	Fast transient burst at 2 kV
EN 61000-4-5 (1995):	Surge immunity test
EN 61000-4-6 (1996):	Conducted RF at 10 V/m
EN 61000-4-11 (1994):	Voltage dips and variations

Control Power

Control voltage:	48–250 Vdc 100–240 Vac
Operating voltage:	55–264 Vac 38–300 Vdc
Interruption ride-through time:	20 cycle interruption of nominal AC supply
Power consumption:	20 VA maximum

Current Inputs

Nominal (I_n):	1A or 5A
CT rating:	2 x I_n continuous 50 x I_n for 1 second
CT burdens:	< 0.25 VA at 5A (nominal) < 0.05 VA at 1A (nominal)

Voltage Inputs

Nominal:	120 Vac
Operating range:	69–150 Vac
Burden:	<0.015 at 120 Vac 1 megaohm

Metering Accuracy

Phase current:	±0.5% or ±0.025A from 0.02 to 20.0 per unit fully offset current waveform
Ground current:	±0.5% of full scale (I_n) from 0.02 to 2.0 per unit fully offset current waveform
Phase voltage:	±0.5% or ±0.2V from 0–160 Vac
Frequency measurement Accuracy:	±0.02 Hz
Phase angle:	±1°
Power metering accuracy:	±1.5%
Metering accuracy temperature range:	0ºC to 50ºC
Temperature range:	±5% for operation below 0ºC and above 50ºC

Metering Accuracy (Continued)

Input signal frequency necessary for accurate operation:	60 Hz nominal, 57–63 Hz (±5%) 50 Hz nominal, 47–53 Hz (±5%)
Clock accuracy:	Free running ±1 Minute/month at 25ºC

Clock automatically updated by PowerNet host when present.

Protective Functions

Phase and Ground Overcurrent Protection (50/51)

Inverse time over-current characteristics 51, 51N, 51G:	Moderate, very, extremely, IECA, IECB, IECC, It, I^2t, I^4t, Flat
Inverse time over-current pickup ranges 51, 51N, 51G:	0.1 to 4.0 per unit in 0.01 steps
Inverse time over-current multipliers 51, 51N, 51G:	0.05 to 10.0 in 0.01 steps
Inverse time delay range 51, 51N, 51G:	0 to 9999 cycles in 1 cycle steps
Instantaneous over-current pickup ranges 50, 50N, 50G:	0.1 to 20.0 per unit in 0.01 steps
Pickup accuracy 50/51:	±1% (at 0.1–2 per unit)
Time accuracy 51, 51N, 51G:	±3% or ±30 ms
Directional 67, 67N, 67G:	Reverse overcurrent—same data as above for reverse

Voltage Unbalance (47)

Threshold (Minimum Voltage) 1 to 100V in 1V steps.

% V2/V1:	4 to 40% in 1% steps
Time delay:	0 to 9999 cycles in 1 cycle steps

Current Unbalance (46)

Threshold (minimum current) 0.1 to 20.0 per unit in 0.01 steps.

% I2/I1:	4 to 40% in 1% steps
Time delay:	0 to 9999 cycles in 1 cycle steps

Under/Overvoltage Protection (27/59)

Pickup range:	10 to 150V in 1 volt steps
Time delay:	0 to 9999 cycles in 1 cycle steps

Under/Overfrequency Protection (81U/810)

Pickup range:	45 to 65 Hz in 0.01 Hz steps
Time delay:	0 to 9999 cycles in 1 cycle steps

Breaker Failure Protection (50BF)

Pickup range:	0.1 to 5.0 per unit in 0.01 steps
Time delay:	0 to 9999 cycles in 1 cycle steps

Power Protection (32)

Forward/reverse over/under

Pickup accuracy:	±1.0%
Trip time accuracy:	0 to 12 cycles or 0.1% whichever is greater

Sync Check (25)

Phase angle:	1 to 60°
Slip frequency:	0.1 to 2 Hz
Voltage differential:	1 to 100V
Breaker close time:	0 to 9999 cycles

Power Factor (55)

Trigger/reset threshold:	0.5 lag to 0.5 lead in 0.01 steps
Time delay:	0 to 1000 seconds in 1 second steps

Discrete Inputs

Number of contact inputs:	8
Rating:	48 Vdc wetting voltage provided with internal ground only

Output Contacts

Number of output contacts: Five Form A and Two Form C

Rating of Output Contacts

Momentary:	Make 30A AC/DC for 0.25 seconds Break 0.25A at 250 Vdc (resistive) Break 5A at 120 Vac
Continuous:	5A at 120 Vac 5A at 30 Vdc

Logic and Control Functions

Six programmable logic gates for AND, OR, NAND, NOR operation
Two latching (flip/flop) gates
Six timer gates provide on/off delays

INCOM Communications

Baud rate:	9600 fixed
Maximum distance:	10,000 feet (3048m)
Protocol:	INCOM

RS-485 Communication, Rear Panel

Baud rate:	9.2k, 9.6k
Protocol:	Modbus RTU

RS-232 Communication, Front Panel

Baud rate:	38.4k, 19.2k, 9.6k
Connector standard nine-pin subminiature, three-wire protocol:	INCOM

Environmental Ratings

Operating temperature:	–40ºC to +60ºC (–40ºF to +140ºF) product tested to +85ºC
Storage temperature:	–40ºC to +85ºC (–40ºF to +185ºF)
Humidity:	5% to 95% Relative humidity (noncondensing)
Altitude:	0 to 6350 feet (0 to 2500m) above mean sea level

Dimensions

Behind Panel

Height:	6.70 inches (170.2 mm)
Width:	5.30 inches (134.6 mm)
Depth:	6.90 inches (175.3 mm)

In Front of Panel

Height:	11.34 Inches (288.0 mm)
Width:	7.72 Inches (196.1 mm)
Depth:	0.80 Inches (20.3 mm)

Weight

12.5 lbs (5.7 kg)

FP-6000
Feeder Protection Relay

FP-6000 Relay

General Description

Eaton's FP-6000 feeder protection relay is a multi-functional, microprocessor-based relay for feeder circuits of all voltage levels. It may be used as a reclosing relay; primary protection on feeders, mains and tie circuit breaker applications; or as backup protection for transformers, high voltage lines and differential protection.

The FP-6000 feeder protection relay provides complete current, voltage and power protection and metering in a single, compact drawout case. The relay has four current inputs rated 5A or 1A and four voltage inputs. Three of the voltage inputs are to be connected to the three-phase power voltage for voltage protection and for metering. They can be connected in wye-ground or open delta configuration. The fourth voltage is for independent single-phase undervoltage/overvoltage protection.

The FP-6000 is the only relay in its class that offers a flexible yet simple reclosing protection. Its compact design makes it ideal for pole-mounted recloser controls.

The multiple settings groups can be used for arc flash mitigation when an alternate settings group, set to have instantaneous elements only, is activated using a selector switch and the programmable I/O in the FP-6000.

An integral keypad and display is provided for direct user programming and retrieval of data. LEDs provide quick indication of relay status.

A front port is provided for direct computer connection. An INCOM communication port on the back of the relay is standard for local area networking. Optional communication ports and protocols are available.

The FP-6000 feeder protection relay includes programmable logic functions. Six gates and timers may be defined and arranged for customized applications. Programmable logic control functions make the FP-6000 relay ideally suited for main-tie-main and main 1/main 2 transfer schemes. Flash memory is used for the programming and all settings are stored in nonvolatile memory. The relay allows for four preprogrammed setting groups that can be activated through software or contact input.

The FP-6000 feeder protection relay has a mass memory for data storage and a real-time clock with 1 ms time resolution. The relay will log 100 sequence of event records, detailed trip logs, minimum/maximum values, load profiles, breaker wear information and oscillography data.

The FP-6000 feeder protection relay has eight programmable binary inputs, five normally opened heavy-duty outputs and one Form C signal relay. It can be powered from 48 Vdc to 250 Vdc or 120 Vac to 240 Vac auxiliary power.

Features

Protection

- Phase overcurrent (forward, reverse or both):
  - Two-stage instantaneous with timers (50P-1 and 50P-2)
  - Two Inverse time overcurrent (51P-1 and 51P-2)
  - Directional current (67)
  - 10 standard curves
  - Instantaneous or time delay reset
  - Voltage restrained time overcurrent (51VR)
- Two independent ground directional overcurrent elements (one measured-IX and one calculated IR):
  - Two-stage instantaneous with timers (50X-1 and 50X-2) (50R-1, 50R-2)
  - Inverse time overcurrent (51X, 51R)
  - Ground directional polarizing (67N)
  - 3 Vo, Ipol, negative sequence
  - 10 standard curves
  - Instantaneous or time delay reset
- Breaker failure (50BF)
- Phase unbalance negative sequence overcurrent (46)
- Phase voltage unbalance and sequence protection (47)
- Under/overvoltage (27/59)
- Under/overfrequency (81U/81O)
- Reverse/forward power (32-1, 32-2, 32-3)
- Reverse/forward VARs (32V-1, 32V-2, 32V-3)
- Thermal Protection (49DT, 49MT, 49DA, 49MA)
- Sync check (25)
- Power factor (55)
- Zone interlocking for bus protection (87B)

Metering

- Amperes: positive, negative and zero sequence
- Ampere demand
- Volts: positive, negative and zero sequence
- Phase angles
- Volt-amperes and VA demand
- Watts and kW demand
- kWh (forward, reverse, net)
- VARs and kVAR demand
- kVARh (lead, leg and net)
- Power factor
- Frequency
- % THD V and I
- Magnitude THD V and I
- Minimum/maximum recording
- Trending (load profile over time)
- RTD temperatures

Monitoring

- Trip coil monitor
- Close coil monitor
- Breaker wear (accumulated interrupted current)
- Oscillography (up to 16 events)
- Fault data logs (up to 16 events)
- Sequence of events report (up to 100 events)
- Clock (1 ms time stamping)

Communication

- Local HMI
- Password protected
- Addressable
- Local communication port
- Remote communication port:
  - FSK
  - RS-232
  - RS-485
- Protocols:
  - INCOM
  - Modbus
- Configuration software

4

Table 4.1-7. FP-6000 Catalog Numbering Selection

FP6 2 00 - 0 1

Current Range	Packaging	Control Voltage	Communications Protocol
2 = 5A **3** = 1A	**0** = Drawout	**0** = 48–125 Vac/dc **1** = 100–240 Vac/dc	**0** = INCOM **1** = Modbus RTU

Control Functions

- Remote open/close
- Programmable I/O
- Programmable logic gates and timers
- Multiple setting groups
- Bus transfer logic
- Cold load pickup
- Loss of potential (PT blown fuses)
- Autoreclose function (79)
- Auto zone coordination

Protection Functions

Eaton's FP-6000 feeder protection relay has been designed for maximum user flexibility and simplicity. The base relay includes all of the standard current and voltage protection and metering functions.

Directional Overcurrent Protection

The FP-6000 feeder protection relay provides complete three-phase and ground directional overcurrent protection. There are two independent ground overcurrent elements. The first ground element "X" uses the independently measured ground (or neutral) current from a separate current-sensing input. The second ground element "R" uses a calculated 3Io current obtained from the sum of the three-phase currents. This calculated current could be used for either the neutral or ground current in a three-phase, four-wire system.

Each of the phase and ground overcurrent elements provides three protection functions. Each element contains an inverse-time overcurrent (51) function and two instantaneous overcurrent (50) functions with adjustable timers.

Phase direction is a function used to supervise all phase current elements (50, 51). A quadrature voltage is compared to a corresponding phase current to establish the direction of the fault. This function is selectable to operate in the forward, reverse or both directions.

Ground direction is used to supervise ground current elements and is accomplished by using ground, negative sequence or residual currents supervised by zero or positive sequence voltages or ground current. This function is selectable to operate in forward, reverse or both directions.

Voltage Restrained Overcurrent

Voltage restraint reduces the overcurrent pickup level (51P-2). This modification of the pickup overcurrent level is compared to the corresponding phase input voltage. The FP-6000 uses the simple linear model below to determine the effective pickup value.

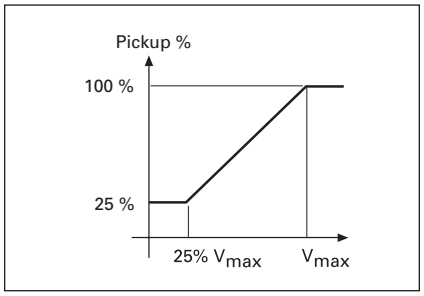


Figure 4.1-18. Voltage Restraint Coil Pickup Characteristics

Sync Check

The sync check function is provided for double-ended power source applications. The sync check monitors voltage magnitude, phase angle and slip frequency between the bus and line. It also incorporates breaker close time, dead bus dead line, dead bus live line and live bus live line features.

Reverse Power

Reverse power provides control for power flowing through a feeder. There are three elements to be configured: operate in forward or reverse; or, under or over power conditions. Reverse power is typically applied to generator or motor applications while under power is generally applied to load or generation loss.

Reverse VARs

Reverse VARs can be used to detect loss of excitation in synchronous machines. There are three elements to be configured: operate in forward or reverse; or, under or over VARs conditions.

Thermal Protection

The FP-6000 has a fiber optic port to communicate to URTD, which is offered separately and is able to provide 11 direct temperature measurements. With URTD connected to the relay, the FP-6000 is able to provide fan control, and temperature-related overload alarm, and trip functions. Each RTD can be assigned to some dedicated spots, such as windings, rotor bearing, load bearing, top oil and user-defined spots.

Inverse-Time Characteristics

There are 10 user-selectable inverse-time overcurrent curve characteristics. The user can select from the ANSI, IEC or thermal curve families and can select instantaneous or time delay reset characteristics.

Breaker Failure

The FP-6000 feeder protection relay includes a breaker failure (50BF, 62BF) function that can be initiated from either an internal or external trip signal. This is an independent element that can be used to operate a lockout relay or to trip an upstream breaker. The timer must be longer than the breaker operating time and the protective function reset times.

Voltage Protection

The FP-6000 feeder protection relay has four voltage-input circuits. There is a three-phase set designated as Main Voltage (M) and a single-phase voltage circuit designated as Auxiliary Voltage (A). Both include undervoltage (27) and overvoltage (59) protection. The three-phase voltage protection can be set to operate on a single-phase, two out of three phases, or all three-phase logic. The Main VTs also provide phase voltage unbalance/reversal (47 negative sequence) protection. Each element has an independent threshold set point and adjustable time delay.

Flexible Phase Rotation

The FP-6000 feeder protection relay can be applied on either an A-B-C or A-C-B phase rotation. A user setting permits correct operation and indication of the actual system configuration.

Frequency Protection

The FP-6000 relay provides under/over frequency (81U/81O) protection on the Main VT inputs. Each element has an independent threshold set point and adjustable time delay.

Autoreclosing Logic

The FP-6000 provides a four shot-recloser scheme. Autoreclosing is normally used by the utilities in their distribution and transmission lines, but it can be used in commercial and industrial applications with long overhead lines. Nearly 85% of the faults that occur on overhead lines are transient in nature. Tripping of a circuit breaker normally clears a transient fault and reclosing of the circuit breaker restores power back to the circuit.

Metering

The FP-6000 feeder protection relay provides complete and accurate metering of the voltages, currents, frequency, power, power factor, energy and RTD temperatures. Information is available on the individual phase magnitude, angles and the symmetrical component values of positive, negative and zero sequence current and voltage.

The FP-6000 feeder protection relay includes a programmable demand feature and stores the maximum demand of current, kW, kVAR and kVA since last reset. The demand is user configurable for fixed or sliding window, the time interval is adjustable and the demand interval can be synchronized to a demand pulse.

Energy usage direction and net values are given for kWh, kVARh and kVAh. The relay monitors, logs and time stamps minimum and maximum values for current, voltage, watts, VARs, VA, power factor and frequency.

The FP-6000 feeder protection relay has metered set points that can be used to activate an output for an alarm, control or trip function. For example, you might want to close a contact to insert a capacitor bank if the power factor is less than 0.9 lagging or provide an alarm if the demand is greater than a preset value.

Loading Profile

The FP-6000 feeder protection relay has memory available to store metered data on a predetermined interval. The log holds data from 1024 time sample intervals. This information can be retrieved and plotted with a PC to show the loading profile of a given circuit over a period of time. For example, if the time interval is set for 15 minutes, then the relay will store a metered data profile over an approximate 10-day period.

Sequence of Events Records

The FP-6000 feeder protection relay records a maximum of 100 events associated with the relay. An event is classified as a change of state as detected by the relay. These include relay pickups, dropouts, trips, contact closure, alarms, setting changes and self-diagnostic failures. Each event is date and time stamped to a 1 ms resolution. The events are stored in an FIFO in chronological order.

Trip Log

The FP-6000 feeder protection relay will store a maximum of 16 trip records in an FIFO trip log. Each trip record will be date and time stamped to a 1 ms resolution and reference an event number associated with oscillographic and sequence of event data. The trip log record will include information on the type of fault, protection elements that operated, fault location and currents and voltages at the time of the fault.

Waveform Capture

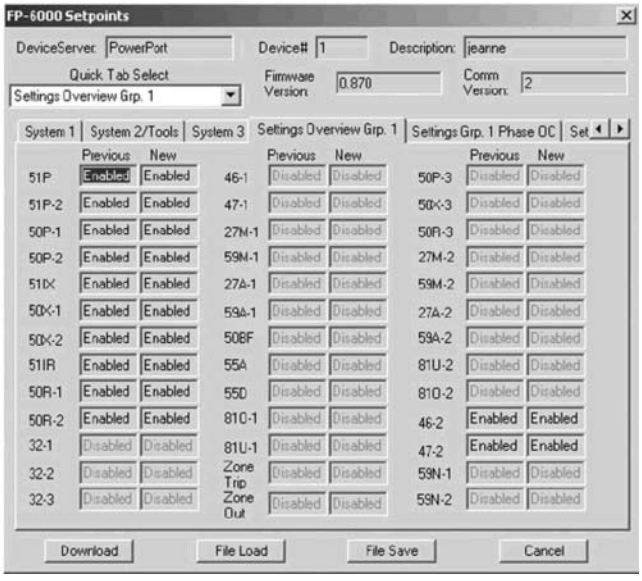
The FP-6000 feeder protection relay provides oscillography-recording capabilities. The relay will record all voltage and current signals along with the binary signals of pickup, trip, logic and contact closures. The FP-6000 relay can record 16 records of 16 cycles of data. Fewer records of longer duration can be selected and recorded. The waveform capture is initiated by a trip, pickup, external contact, front panel interface or through the remote communications port.

Programmable Logic

The FP-6000 feeder protection relay provides six logic gates and timers that the user can customize for special or unique applications. Each gate can be assigned a logic function of either AND, OR, NAND or NOR. Each gate can have a maximum of four input signals and each input signal can be required to be a NOT. Input signals can be external inputs received via the binary inputs or internal values associated with the protection, alarm or metering set points. Each gate has a unique output assignment and designation that can be used as the input to another gate. There are six independent timers that have adjustable pickup and dropout delay settings.

Integral User Interface

The front panel user interface has a 4 x 20-inch (101.6 x 508.0 mm) alpha-numeric vacuum fluorescent display for wide angle viewing in all light conditions. LEDs provide quick and easy visual display of power on, mode of operation, alarm and trip indication. Pushbuttons are provided for operation mode selection, scrolling through data and settings. A security door restricts access to the program and test modes. In addition, the relay settings and test functions can be password protected.



FP-6000 Set Point Overview

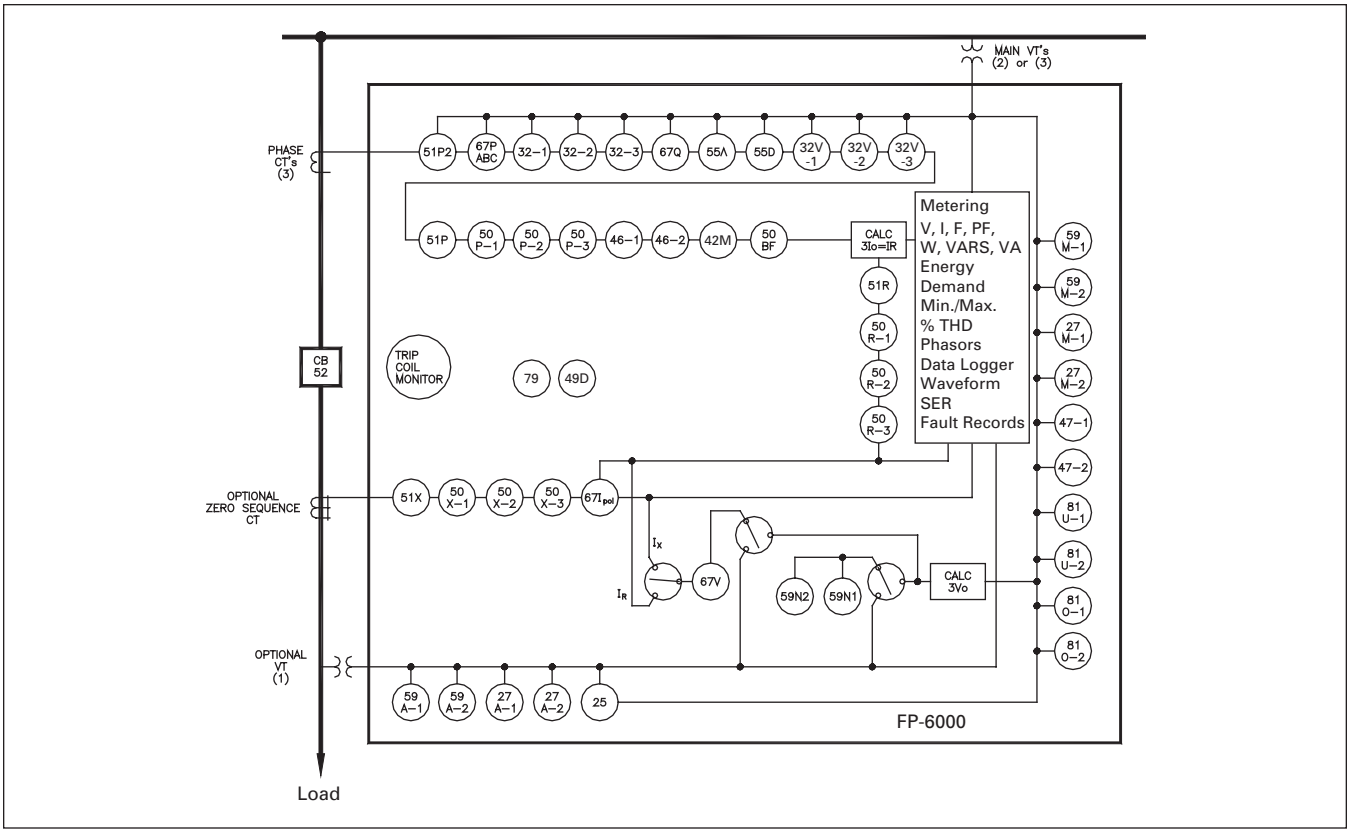


Figure 4.1-19. FP-6000 Relay Typical One-Line Diagram

Programmable I/O

The FP-6000 feeder protection relay provides five heavy-duty, trip-rated, normally open contacts and two Form C auxiliary contacts. Two trip rated contacts are fitted with a circuit continuity feature for monitoring the trip or close circuits. One Form C contact is dedicated to the relay failure alarm function and is operated in a normally energized (failsafe) mode. There are eight user-configurable discrete inputs that accept a dry contact. Each input and output is user-programmable for maximum application flexibility.

Communication Software

Eaton provides two types of communication software. The first is PowerPort. It runs on a PC or a laptop for easy access to a single relay to change set points or configuration, and to view metered values and stored data. PowerPort is free and can be downloaded from the Eaton Web site at **www.eaton.com**.

The second package is Power Xpert Software. Power Xpert Software is a power management software package that is designed for continuous, remote monitoring of many devices. It provides all the functionality of PowerPort plus additional functions such as billing, trending and graphics. Contact your local Eaton representative for more information on Power Xpert Software.

Standards, Certifications and Ratings

Table 4.1-8. FP-6000 Specifications

Compliance

UL Recognized, File # E154862 (FP6200-00 5A CT model only)
UL 1053 (1994) Recognized
ANSI C37.90 (1989)
EN 55011 (1991)
EN 61000-6-2 (1999)

Emission Tests

EN 55011 (1991):	Group 1 Class A (CISPR-11, Class A)
FCC 47 CFR Chapter 1:	Part 15 Subpart b Class A

Immunity Tests

ANSI C37.90.1 (1989):	Surge withstand capability
ANSI C37.90.2 (1995):	EMI immunity to 35 V/m
EN 61000-4-2 (1995):	ESD rating of 8 kV
EN 61000-4-3 (1997):	Radiated EM field at 10 V/m
EN 61000-4-4 (1995):	Fast transient burst at 2 kV
EN 61000-4-5 (1995):	Surge immunity test
EN 61000-4-6 (1996):	Conducted RF at 10 V/m
EN 61000-4-8:	Power frequency magnetic field immunity
EN 61000-4-11 (1994):	Voltage dips and variations

Principal Parameters

	Range	Accuracy
Current (amperes) Ia, Ib, Ic, Ir, Ix	0.02 to 20 per unit	at < 2 + CT rating: ±0.5% of CT rating at > 2 + CT rating: ±0.5% of reading
Sequence currents	0.02 to 20 per unit	±1% of nominal
Main voltage	0 to 160V	±0.5% of nominal ±0.2V
Sequence voltages	0 to 160V	±1% of nominal
Auxiliary voltage	0 to 250V	±1% of nominal
Phase angle for I and V	0 to 360°	±1° at nominal voltage
System frequency	45 to 65 Hz	±0.02 Hz
Ampere demand	0.02 to 20 per unit	±0.5%
Watt demand	0 to 4000 MW	±1.0% FS for PF = unity ①
		±1.5% FS for PF = –0.5 to 0.5 ①
Watts	0 to 4000 MW	
Watthours	0 to 999.999 MWh	
VAR demand	0 to 4000 MVAR	±1.5% FS for PF = –0.5 to 0.5 ①
VARs	0 to 4000 MVAR	
VAR-hours	0 to 999.999 MVARh	
VA demand	0 to 4000 MVA	±1% FS ①
VA	0 to 4000 MVA	
VA-hours	0 to 999,999 MVAh	
Apparent power factor	–1 to +1	±0.02 for load currents above 20% rated
Displacement power factor	–1 to +1	±0.02 for load currents above 20% rated
Total harmonic distortion	0 to 9999 ±1%	
Other metering accuracy	±1%	

① FS (full scale) = 3 x CT rating x nominal L-N voltage.

Control Power

Control voltage:	48–125 Vdc 100–120 Vac 100–250 Vdc 100–240 Vac
Operating voltage:	38–150 Vdc 55–132 Vac 80–308 Vdc 55–264 Vac
Interruption ride-through time:	83 ms at 120V, 60 Hz AC 250 ms at 110 Vdc/ 300 ms at Vac
Power consumption:	20 VA maximum 22 VA maximum

Current Inputs

CT ratings:	2 x I_n at 5A continuous 3 x I_n at 1A continuous 80 x I_n at 5A for 1 second 100 x I_n at 1A for 1 second
CT burdens:	< 0.25 VA at 5A (nominal) < 0.05 VA at 1A (nominal)

Voltage Inputs

Nominal:	0–120 Vac line to common
Operating range:	0–144 Vac (+20%) Line to common
Burden:	1 megaohm input

Metering Accuracy

Input Signal Frequency Necessary for Accurate Operation:	60 Hz nominal, 57–63 Hz (5%) 50 Hz nominal, 47–53 Hz (5%)
Frequency measuring accuracy:	±0.02 Hz
Clock accuracy:	Free running ±1 minute/month at 25°C (77°F) Automatically updated by PowerNet host when present

Protective Functions

Phase and Ground Overcurrent Protection

Inverse characteristics:	Moderate, very, extremely, IECA, IECB, IECC, It, I^2t, I^4t, flat
TOC (51) pickup range:	0.02 to 4.0 per unit in 0.01 steps
Time multipliers:	0.05 to 10.0 in 0.01 steps
IOC (50) pickup range:	0.1 to 20.0 per unit in 0.01 steps
Pickup accuracy:	±1% (at 0.1 to 2 per unit)
Time delay:	0 to 9999 cycles in 1 cycle steps
Time accuracy:	±3% or ±30 ms

Directional (67, 67N, 67G): forward, reverse or both

Voltage Unbalance (47)

Threshold (minimum voltage):	1 to 100V in 1 volt steps
% V2/V1:	2 to 40% in 1% steps
Time delay:	0 to 9999 cycles in 1 cycle steps

Current Unbalance (46)

Threshold (minimum current):	0.1 to 20.0 per unit in 0.01 steps
% I2/I1:	2 to 40% in 1% steps
Time delay:	0 to 9999 cycles in 1 cycle steps

Under/Overvoltage Protection (27/59)

Pickup range:	10 to 150V in 1 volt steps
Time delay:	0 to 9999 cycles in 1 cycle steps

Neutral Voltage Protection (59N)

Source:	calculated, measure
Criterion:	phasor, rms
Pickup range:	5 to 250V in 1V steps
Time delay:	0 to 9999 cycles in 1 cycle steps

Under/Overfrequency Protection (81U/O)

Pickup range:	45 to 65 Hz in 0.01 Hz steps
Time delay:	0 to 9999 cycles in 1 cycle steps

Breaker Failure Protection (50BF)

Pickup range:	0.02 to 5.0 per unit in 0.01 steps
Time delay:	0 to 9999 cycles in 1 cycle steps

Power Factor (55)

Trigger/reset threshold:	–0.5 to 1 lag; 0.5 to 0.99 lead in 0.01 steps
Time delay:	0 to 1000 seconds in 1 second steps

Protective Functions (continued)

Power Protection (32)

Direction:	forward/reverse
Criterion:	over/under
Pickup range:	0.02 to 4 pu

Note: 1pu = 3 x CT secondary rating x VT secondary rating for wye; the square root of 3 x VT secondary rating x CT secondary rating for open delta.

Pickup accuracy:	±1.0%
Trip time accuracy:	0 to 2 cycles or 0.1%, whichever is greater

VAR Protection (32V)

Direction:	forward/reverse
Criterion:	over/under
Pickup range:	0.02 to 4 pu

Note: 1pu = 3 x CT secondary rating x VT secondary rating for wye; the square root of 3 x VT secondary rating x CT secondary rating for open delta.

Pickup accuracy:	±1.0%
Trip time accuracy:	0 to 2 cycles or 0.1%, whichever is greater

Thermal Protection (49)

Pickup range:	0 to 199°C or 0 to 390°F
Time delay:	0.1 to 3500 seg

Sync Check (25)

Phase angle:	1 to 60°
Slip frequency:	0.1 to 2 Hz
Voltage differential:	1 to 100V
Breaker close time:	0 to 9999 cycles

Discrete Inputs

Number of contact inputs:	8
Rating:	48 Vdc wetting voltage provided with internal ground only

Output Contacts

Number of contact inputs:	5 Form A and 2 Form C

Standards, Certifications and Ratings (Continued)

Table 4.1-8. FP-6000 Specifications (Continued)

Rating of Output Contacts

Momentary:	Make 30A AC/DC for 0.25 seconds Break 0.25A at 250 Vdc (resistive) Break 5A at 120/240 Vac
Continuous:	5A at 120/240 Vac 5A at 30 Vdc

Logic and Control Functions

Six programmable logic gates for AND, OR, NAND, NOR operation

Two latching (flip/flop) gates

Six timer gates provide on/off delays

INCOM Communications

Baud rate:	9600 fixed
Maximum distance:	10,000 feet (3048m)
Protocol:	INCOM

RS-232 Communication, Front Panel

Baud rate:	38.4k, 19.2k, 9.6k
Connector standard:	9-pin subminiature, 3-wire
Protocol:	INCOM

RS-485 Communication, Rear Panel

Baud rate:	19.2k, 9.6k
Protocol:	Modbus RTU

Environmental Ratings

Operating temperature:	–40ºC to +60ºC (–40ºF to +140ºF)
Storage temperature:	–40ºC to +85ºC (–40ºF to +185ºF)
Humidity:	5% to 95% relative humidity (noncondensing)
Altitude:	0 to 6350 feet (0 to 2500m) Above Mean Sea Level

Dimensions

Behind Panel

Height:	6.70 inches (170.2 mm)
Width:	5.30 inches (134.6 mm)
Depth:	6.90 inches (175.3 mm)

In Front of Panel

Height:	11.34 inches (288.0 mm)
Width:	7.72 inches (196.1 mm)
Depth:	0.80 inches (20.3 mm)

Weight

12.5 lbs (5.7 kg)

EDR-3000 Distribution Relay

EDR-3000 Relay

General Description

The EDR-3000 protective relay is a multifunction, microprocessor-based overcurrent relay designed for both ANSI and IEC applications. It is a panel-mounted, self-contained unit that operates from either AC or DC control power. The EDR-3000 design provides true rms and fundamental sensing of each phase and ground current. Only one unit is required for each three-phase circuit.

Current monitoring and operator selectable protective functions are integral to each relay. The EDR-3000 relay operates from the 5A or 1A secondary output of standard current transformers. Current transformer ratio information is quickly programmed into the unit via settings. This enables the relay to display metered current in primary amperes, secondary amperes or per unit values. The EDR-3000 features a user-friendly operations panel to monitor and to program the relay. Operating parameters and trouble-shooting information are displayed in the 128 x 64 LCD display. In addition, all data and information can be communicated to a host computer equipped with PowerPort-E™. A "Communication Trip" and "Communication Close" control command can also be initiated by a host computer.

Application Description

General

The EDR-3000 microprocessor-based relay provides reliable three-phase and ground overcurrent protection for all voltage levels. It can be used for any application where instantaneous and/or time overcurrent protection is required. It is most commonly used as primary feeder circuit protection, as in **Figure 4.1-20**.

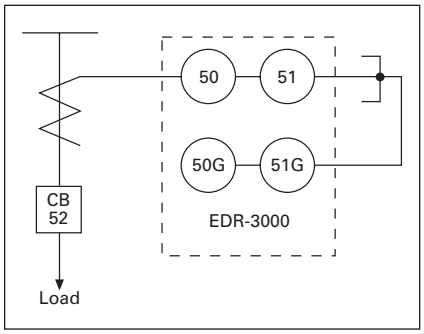


Figure 4.1-20. Primary Feeder Circuit Protection

The EDR-3000 may be applied as the transformer primary protection or as backup to the differential protection, as in **Figure 4.1-21**.

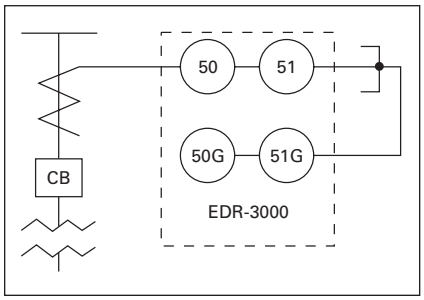


Figure 4.1-21. Transformer Overcurrent Protection

The EDR-3000 may be connected to the secondary side of a delta-wye grounded transformer with the ground element connected to a separate CT in the neutral connection of the transformer. With this connection, a lower CT ratio and a pickup setting can be used to provide more sensitive ground fault protection especially for resistance grounded systems (see **Figure 4.1-22**).

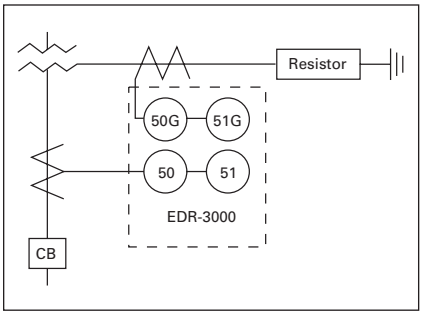


Figure 4.1-22. Transformer Secondary Protection with Neutral CT Connection

The EDR-3000 relay has special provisions for connection in a zone interlocking scheme that can be used for bus protection or to improve protection coordination in a tight or close system. Zone interlocking is described in the following sections. In addition, the EDR-3000 has multiple setting groups that can be used to reduce arc flash hazard with instantaneous elements.

Overcurrent Protection

The EDR-3000 provides complete three-phase and ground protection with separate elements and settings. The relay can be used with CT ratios from 1 to 50,000 for 1A models and 1 to 10,000 for 5A models. The CT ratio can be set independently for phase and ground, allowing the ground element to be connected in either the residual or the separate ground CT configuration, as in **Figure 4.1-23** and **4.1-24**.

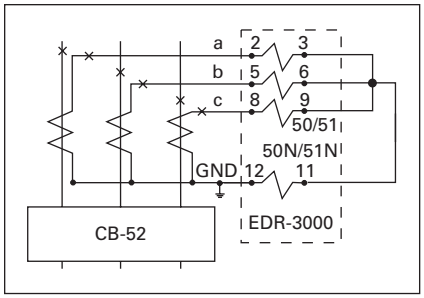


Figure 4.1-23. Residual Ground Connection

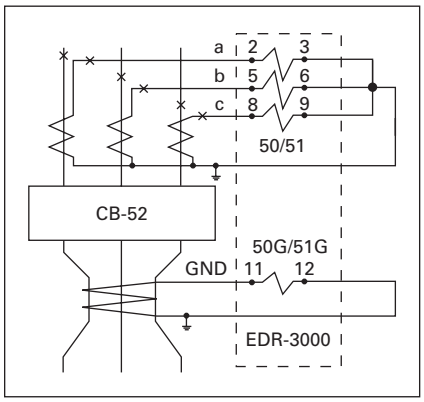


Figure 4.1-24. Separate Zero Sequence Ground CT Connection

Zone Selective Interlocking (Phase and Ground)

Zone selective interlocking is a protection function to minimize equipment damage resulting from a phase or a ground fault in an area where long time and/or short time delay is in use.

When the "Ground Zone Interlocking" feature is used, an immediate trip is initiated when the fault is in the breaker's zone of protection, regardless of its preset time delay. When the "Phase Zone Interlocking" feature is used, the time overcurrent elements work as follows. The instantaneous phase element will initiate an immediate trip when the fault is in the breaker's zone of protection, regardless of its preset time delay. For the time overcurrent phase element, the current sensed by the EDR-3000 must exceed 1.5 times the pickup setting for the zone selective interlocking to initiate an immediate trip signal when the fault is in the breaker's zone of protection.

Upstream EDR-3000 protected breakers are restrained from tripping immediately by an interlocking signal from the downstream EDR-3000 relay. This interlocking signal requires only a pair of wires from the downstream breaker to the upstream breaker. It provides standard coordinated tripping when the fault is located outside the zone of protection. In the sample zone interlocking system shown in **Figure 4.1-26**, circuit breakers A, B and C are equipped with EDR-3000 overcurrent relays.

Table 4.1-9. Catalog Numbering Selection for EDR-3000 Distribution Relay Removable Terminals

EDR-3000 A 0 B A 1

Hardware Option 1	Hardware Option 2	Communication Options	Conformal Coating Options	Mounting Options
A = Four digital inputs, four outputs, removable terminals	**0** = Phase current 5A/1A, ground current 5A/1A, power supply range: 19–300 Vdc 40–250 Vac	**B** = Modbus-RTU (RS-485)	**A** = None	**0** = Standard mount
B = Eight digital inputs, six outputs, removable terminals, trip coil monitor ①		**I** = Modbus-TCP (RJ-45)	**B** = Conformal coated circuit boards	**1** = Projection panel mount
C = Four digital inputs, four outputs, removable terminals, zone interlocking ① and IRIG-B ①				

① Consult factory for the availability of eight digital inputs, six outputs, trip coil monitor, zone interlocking, IRIG-B and Modbus-TCP.

Fault Location Zone 3

If a fault occurs at a point in Zone 3, the EDR-3000 of downstream breaker C senses the fault and sends a restraining signal to the upstream EDR-3000 of feeder breaker B. Having received this signal, the EDR-3000 of feeder breaker B withholds its trip command. As a result, only downstream breaker C is tripped.

Fault Location Zone 2

If a fault occurs at a point in Zone 2, the EDR-3000 of feeder breaker B senses the fault and sends a restraining signal to the upstream EDR-3000 of main breaker A. The EDR-3000 of the downstream breaker C does not see this fault because it is situated on the downstream side of the fault. As a result, the EDR-3000 of downstream breaker C does not send a restraining signal to the EDR-3000 of feeder breaker B. Because it did not receive a restraining signal from the EDR-3000 of downstream breaker C, the EDR-3000 of feeder breaker B identifies that the fault is in Zone 2 and immediately trips feeder breaker B, regardless of its time setting.

Fault Location Zone 1

If a fault occurs in Zone 1, no restraining signal is received by the Digitrip of main breaker A. As a result, main breaker A is immediately tripped by its EDR-3000 overcurrent relay, regardless of its time setting.

Note: For the time overcurrent phase element, the current sensed by the EDR-3000 must exceed 1.5 times the pickup setting for the zone selective interlocking to initiate an immediate trip signal when the fault is in the breaker's zone of protection.

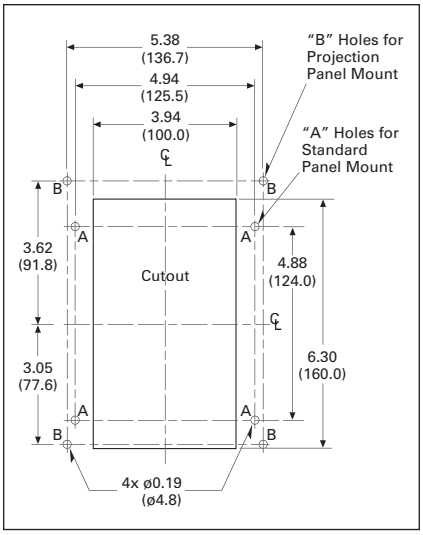


Figure 4.1-25. Drilling Pattern

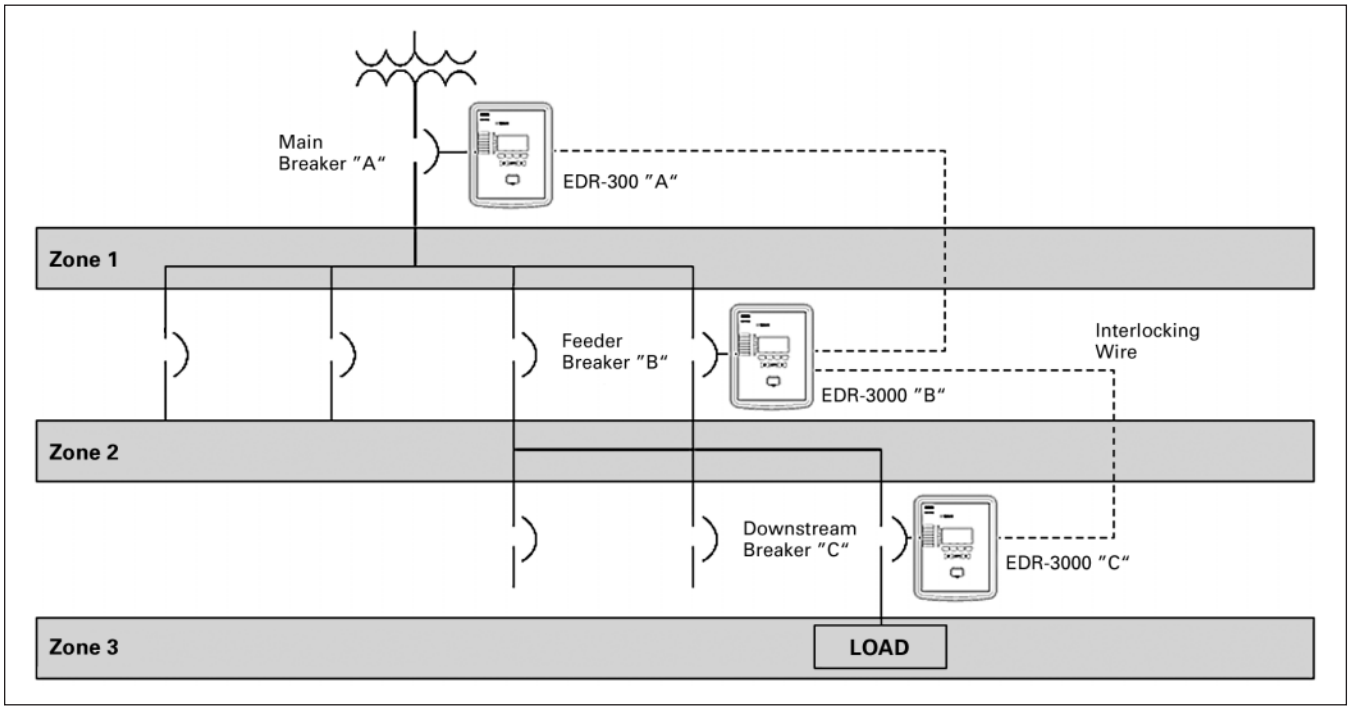


Figure 4.1-26. Sample Zone Selective Interlocking System

Standards, Certifications and Ratings

Table 4.1-10. EDR-3000 Specifications

Voltage Supply

Aux. voltage:	19–300 Vdc/40–250 Vac
Buffer time in case of supply failure:	≥ 50 ms at minimal aux. voltage communication is permitted to be interrupted

Max. permissible making current:
18A peak value for <0.25 ms
12A peak value for <1 ms
The voltage supply must be protected b a fuse of:
2.5A time-lag miniature fuse 5.0 x 20.0 mm (approx. 0.20 in. x 0.08 in) according to IEC 60127
3.5A time-lag miniature fuse 6.3 x 32.0 mm (approx. 0.25 in. x 1.25 in) according to UL 248-14

Power Consumption

Power supply range:	19–300 Vdc: 6W idle mode/ 8W max. power 40–250 Vac: 6W idle mode/ 8W max. power (for frequencies of 40–70 Hz)
Power consumption:	Phase current inputs at I_n = 1A burden = 0.15 mVA at I_n = 5A burden = 0.15 mVA
Ground current input:	at I_n = 1A burden = 0.35 mVA at I_n = 5A burden = 0.35 mVA

Digital Inputs

Max. input voltage:	300 Vdc/270 Vac
Input current:	<4 mA
Reaction time:	<20 ms
Fallback time:	<30 ms (safe state of the digital inputs)
4 Switching thresholds:	Un = 24 Vdc, 48 Vdc, 60 Vdc, 110 Vac/dc, 230 Vac/dc
Un = 24 Vdc	
Switching threshold 1 ON:	Min. 19.2 Vdc
Switching threshold 1 OFF:	Max. 9.6 Vdc
Un = 48V/60 Vdc	
Switching threshold 2 ON:	Min. 42.6 Vdc
Switching threshold 2 OFF:	Max. 21.3 Vdc
Un = 110/120 Vac/dc	
Switching threshold 3 ON:	Min. 88.0 Vdc/88.0 Vac
Switching threshold 3 OFF:	Max. 44.0 Vdc/44.0 Vac
Un = 230/240 Vac/dc	
Switching threshold 4 ON:	Min. 184 Vdc/184 Vac
Switching threshold 4 OFF:	Max. 92 Vdc/92 Vac
Terminals:	Screw-type terminal

Binary Output Relays

Continuous current:	5A AC/DC
Switch-on current:	25A AC/DC for 4s
Max. breaking current:	5A AC up to 125V AC
5A DC up to 50V (resistive)	
0.2A DC at 300V	
Max. switching voltage:	250 Vac/300 Vdc
Switching capacity:	2000 VA
Contact type:	1 changeover contact
Terminals:	Screw-type terminals

Front Interface RS-232

Baud rates:	115,200 Baud
Handshake:	RTS and CTS
Connection:	Nine-pole D-Sub plug

RS-485

Master/slave:	Slave
Connection:	Six screw-clamping terminals RM 3.5 mm (138 MIL) (terminating resistors internal)

Climatic Environmental Conditions

Storage temperature:	–25°C up to +70°C (–13°F to +158°F)
Operating temperature:	–20°C up to +60°C (–4°F to +140°F)
Permissible humidity at Ann. average:	<75% rel. (on 56d up to 95% rel.)
Permissible installation altitude:	<2000m (6561.67 ft) above sea level If 4000m (13,123.35 ft) altitude applies, a changed classification of the operating and test voltages may be necessary.

EDR-4000 Distribution Protection Relay

EDR-4000 Distribution Protection Relay

General Description

Eaton's EDR-4000 distribution protection relay is a multi-functional, microprocessor-based relay for feeder circuits of all voltage levels. It may be used as a primary protection on feeders, mains and tie circuit breaker applications; or as backup protection for transformers, high voltage lines and differential protection. The relay is most commonly used on medium voltage switchgear applications.

The EDR-4000 feeder protection relay provides complete current, voltage, frequency protection and metering in a single, compact case. The relay has four current inputs rated for either 5A or 1A and four voltage inputs. Three of the voltage inputs are to be connected to the three-phase power voltage for voltage protection and for metering. They can be connected in wye-ground or open delta configuration. The fourth voltage is for independent single-phase undervoltage/overvoltage protection, or ground protection for an ungrounded system.

The Maintenance Mode password protected soft key, can be used for arc flash mitigation to change to an alternate settings group, set to have instantaneous elements only. The multiple setting groups can also be changed, via communications or a digital input.

An integral keypad and display is provided for direct user programming and retrieval of data without the need of a computer. 14 programmable LEDs provide quick indication of relay status.

A front port is provided for direct computer connection. An RS-485 communication port on the back is standard for local area networking using Modbus-RTU. An optional Ethernet port and protocols are available.

The EDR-4000 distribution protection relay includes programmable logic functions*. Logic gates and timers may be defined and arranged for customized applications. Programmable logic control functions make the EDR-4000 relay ideally suited for main-tie-main and main 1/main 2 transfer schemes. Flash memory is used for the programming and all settings are stored in nonvolatile memory. The relay allows for four preprogrammed setting groups that can be activated through software or contact input.

Flash memory is used for the programming and all settings are stored in nonvolatile memory. The relay allows for four preprogrammed setting groups that can be activated through software, the display or a contact input.

The EDR-4000 distribution protection relay has a mass memory for data storage and a real-time clock with 1 ms time resolution. The relay will log 300 sequence of event records, 20 detailed trip logs, minimum/maximum values, load profiles, breaker wear information and oscillography data.

The EDR-4000 has eight programmable binary inputs, two normally opened and eight Form C heavy-duty outputs and one Form C signal alarm relay. It can be powered from 19 Vdc to 300 Vdc or 40 Vac to 250 Vac auxiliary power.

Features

Protection

- Phase overcurrent elements:
  - Three instantaneous elements with timers (50P[1], 50P[2] and 50P[3])
  - Three inverse time overcurrent elements (51P[1], 51P[2] and 51P[3])
  - 11 standard curves
  - Instantaneous or time delay reset
  - 51P[2] and 51P[3] can be voltage restrained
- Ground overcurrent elements:
  - Two instantaneous measured elements with timers (50X[1] and 50X[2])
  - Two instantaneous calculated elements with timers (50R[1] and 50R[2])
  - Two inverse time overcurrent measured elements (51X[1] and 51X[2])
  - Two inverse time overcurrent calculated elements (51R[1] and 51R[2])
  - 11 standard curves
  - Instantaneous or time delay reset
- Breaker failure (50BF)
- Phase unbalance negative sequence overcurrent (46[1], 46[2])
- Phase voltage unbalance and sequence protection (47[1], 47[2])
- Main three-phase under/overvoltage (27M[1], 27M[2], 59M[1], 59M[2])
- Auxiliary single-phase under/overvoltage (27A[1], 27A[2], 59A[1], 59A[2])
- Ground fault overvoltage relay (59N[1], 59N[2])
- Six frequency elements that can be assigned to: overfrequency, underfrequency, rate of change or vector surge (81[1], 81[2], 81[3], 81[4], 81[5], 81[6])
- Apparent and displacement power factor (55A[1], 55A[2], 55D[1], 55D[2])
- Zone interlocking for bus protection (87B)
- Switch onto fault protection
- Cold load pickup
- Zone interlocking for bus protection (87B)

Metering

- Amperes: positive, negative and zero sequence
- Ampere demand
- Volts: positive, negative and zero sequence
- Phase angles
- Volt-amperes and VA demand
- Watts and kW demand
- kWh (forward, reverse, net)
- VARs and kVAR demand
- kVARh (lead, leg and net)
- Power factor
- Frequency
- % THD V and I
- Magnitude THD V and I
- Minimum/maximum recording
- Trending (load profile over time)

Monitoring

- Trip coil monitor
- Breaker wear primary and secondary (accumulated interrupted current)
- Oscillography (6000 cycles total)
- Fault data logs (up to 20 events)
- Sequence of events report (up to 300 events)
- Clock (1 ms time stamping)

Communication

- Local HMI
- Password protected
- Addressable
- IRIG-B
- Local communication port
- Remote communication port:
  - RS-232
  - RS-485
- Protocols:
  - Modbus-RTU
  - Modbus-TCP (optional)
- Configuration software

Control Functions

- Breaker open/close
- Remote open/close
- Programmable I/O
- Programmable Logic
- Programmable LEDs
- Multiple setting groups
- Cold load pickup
- CT supervision

4

Table 4.1-11. Catalog Numbering Selection for EDR-4000 Distribution Relay Removable Terminals

EDR-4000 A 0 B A 1

Hardware Option 1	Hardware Option 2	Communication Options	Conformal Coating Options	Mounting Options
A = Eight digital inputs, 11 outputs, removable terminals, zone interlocking	**0** = Phase current 5A/1A, ground current 5A/1A, power supply range: 19–300 Vdc 40–250 Vac	**B** = Modbus-RTU (RS-485)	**A** = None	**0** = Standard mount
B = Eight digital inputs, 11 outputs, removable terminals, zone interlocking and large display ①	**1** = Phase current 5A/1A, sensitive ground current 0.5A/0.1A, power supply range: 19–300 Vdc 40–250 Vac ①	**1** = Modbus-RTU + Modbus-TCP	**B** = Conformal coated circuit boards	**1** = Projection panel mount

① Consult factory for the availability of sensitive ground and large display.

Protection and Control Functions

Eaton's EDR-4000 distribution protection relay has been designed for maximum user flexibility and simplicity. The base relay includes all the standard current and voltage protection and metering functions.

Overcurrent Protection

The EDR-4000 distribution protection relay provides complete three-phase and ground overcurrent protection. There are eight independent ground overcurrent elements. The ground elements "X" use the independently measured ground (or neutral) current from a separate current-sensing input. The ground elements "R" use a calculated 3Io residual current obtained from the sum of the three-phase currents. This calculated current could be used for either the neutral or ground current in a three-phase, four-wire system. Each of the phase and ground overcurrent elements can be selected to operate based on fundamental or rms current.

Voltage Restrained Overcurrent

Voltage restraint reduces the overcurrent pickup level (51P[2] and 51P[3]). This modification of the pickup overcurrent level is compared to the corresponding phase input voltage. The EDR-4000 uses the simple linear model below to determine the effective pickup value.

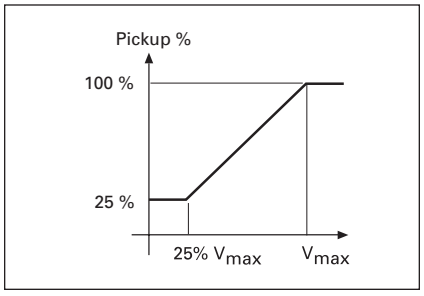


Figure 4.1-27. Voltage Restraint Coil Pickup Characteristics

Inverse-Time Characteristics

There are 11 user-selectable inverse-time overcurrent curve characteristics. The user can select from the ANSI, IEC or thermal curve families, and can select instantaneous or time delay reset characteristics.

Breaker Failure

The EDR-4000 distribution protection relay includes a breaker failure (50BF, 62BF) function that can be initiated from either an internal or an external trip signal. This is an independent element that can be used to operate a lockout relay or to trip an upstream breaker. The timer must be longer than the breaker operating time and the protective function reset times.

Voltage Protection

The EDR-4000 distribution protection relay has four voltage-input circuits. There is a three-phase set designated as Main Voltage (M) and a single-phase voltage circuit designated as Auxiliary Voltage (A). Both include undervoltage (27) and overvoltage (59) protection. The three-phase voltage protection can be set to operate on a single-phase, two out of three phases, or all three-phase logic. The Main VTs also provide phase voltage unbalance/reversal (47 negative sequence) protection. Each element has an independent threshold set point and adjustable time delay.

Ground Voltage Protection

In high impedance grounded systems, ground fault protection is provided by the detection of zero sequence voltage (3Vo) in the neutral of the transformer by an overvoltage element (59N) connected to the secondary of the distribution grounding transformer, or in the secondary of a wye-broken delta transformer used when the neutral is not accessible or in delta system. In the EDR-4000, we can measure this zero sequence voltage through the 4th voltage input; the 59N element has to be desensitized for 3rd harmonic voltages that can be present in the system under normal operation.

Flexible Phase Rotation

The EDR-4000 distribution protection relay can be applied on either an A-B-C or A-C-B phase rotation. A user setting permits correct operation and indication of the actual system configuration.

Frequency Protection

The EDR-4000 relay provides six frequency elements than can be used to detect under/over frequency, rate of change, and a vector surge (decoupling of two systems) protection on the Main VT inputs. Each element has an independent threshold set point and adjustable time delay.

Maintenance Mode

The Maintenance Mode can improve safety by providing a simple and reliable method to reduce fault clearing time and lower incident energy levels at energized panels. The Maintenance Mode allows the user to switch to more sensitive settings via a password protected soft key, communication or via a digital Input while maintenance work is being performed at an energized panel or device. The more sensitive settings provide greater security for maintenance personnel and helps to reduce the possibility of injury.

Monitoring and Metering

Sequence of Events Records

The EDR-4000 protection relay records a maximum of 300 events associated with the relay. An event is classified as a change of state as detected by the relay. These include relay pickups, dropouts, trips, contact closure, alarms, setting changes and self-diagnostic failures. Each event is date and time stamped to a 1 ms resolution. The events are stored in an FIFO log in chronological order.

Trip Log

The EDR-4000 protection relay will store a maximum of 20 trip records in an FIFO trip log. Each trip record will be date and time stamped to a 1 ms resolution. The trip log record will include information on the type of fault, protection elements that operated, fault location, and currents and voltages at the time of the fault.

Waveform Capture

The EDR-4000 transformer protection relay provides oscillography-recording capabilities. The relay will record all measured signals along with the binary signals of pickup, trip, logic and contact closures. The ETR-4000 relay can record up to 6000 cycles of data. The number of records is proportional to the size of each record; the maximum size per record is 600 cycles. The waveform capture is initiated by up to eight different triggers; it can also be generated manually through the display or via communications.

Integral User Interface

The front panel user interface has a 128 x 64 pixel LCD display with background illumination for wide angle viewing in all light conditions. 17 programmable LEDs provide quick and easy visual display of power on, mode of operation, alarm and trip indication. Soft keys are provided for operation mode selection, scrolling through data and settings. In addition, the relay settings and test functions are password protected.

Programmable I/O

The EDR-4000 distribution protection relay provides heavy-duty, trip-rated, two normally open and eight Form C contacts. Two isolated inputs can be used for monitoring the trip circuit. One Form C contact is dedicated to the relay failure alarm function and is operated in a normally energized (fail-safe) mode. There are eight user-configurable discrete inputs that accept a wet contact and can operate through a wide range of power. Each input and output is user-programmable for maximum application flexibility.

Programmable Logic

The EDR-4000 distribution protection relay provides logic gates and timers that the user can customize for special or unique applications. Each gate can be assigned a logic function of either AND, OR, NAND or NOR. Each gate can have a maximum of four input signals and each input signal can be required to be a NOT. Input signals can be external inputs received via the binary inputs or internal values associated with the protection, alarm or metering set points. Each gate has a unique output assignment and designation that can be used as the input to another gate. There are 24 independent timers that have adjustable pickup and dropout delay settings.

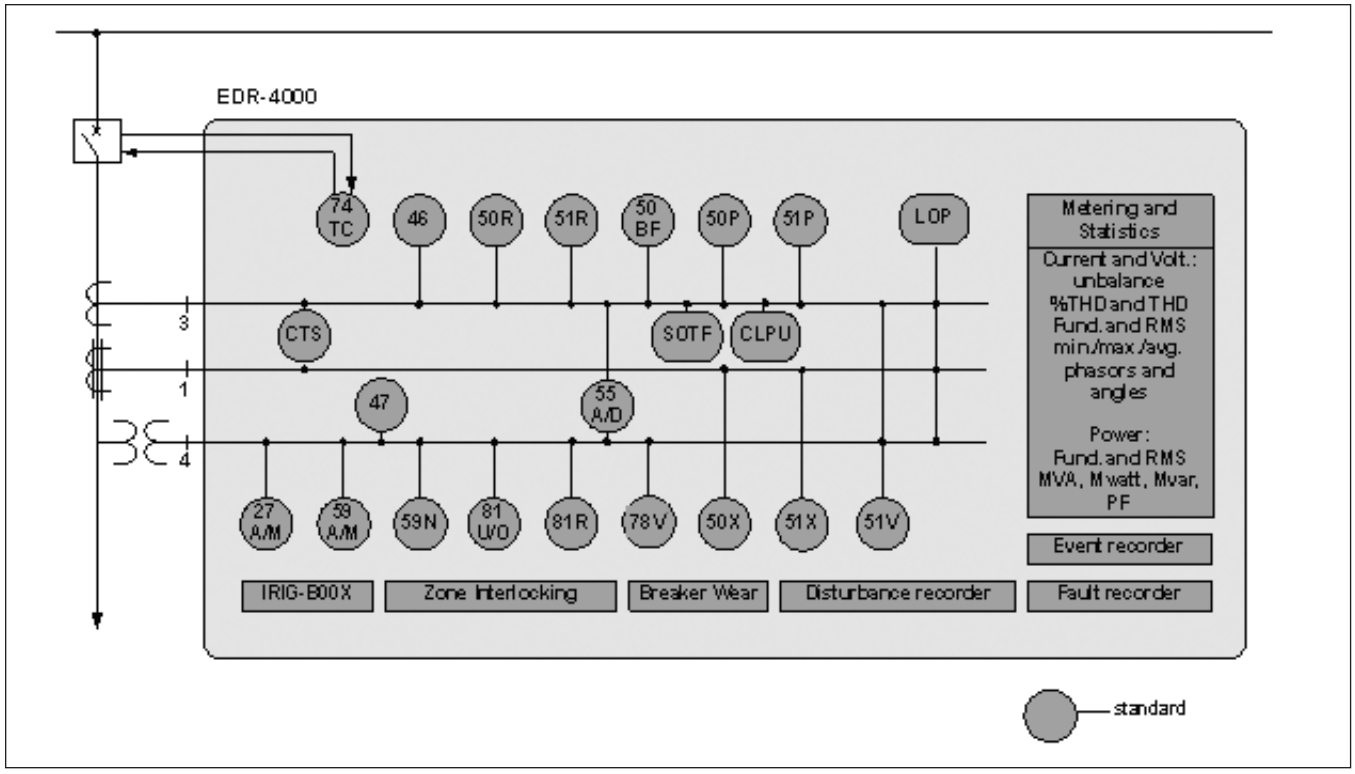


Figure 4.1-28. Typical One-Line Diagram

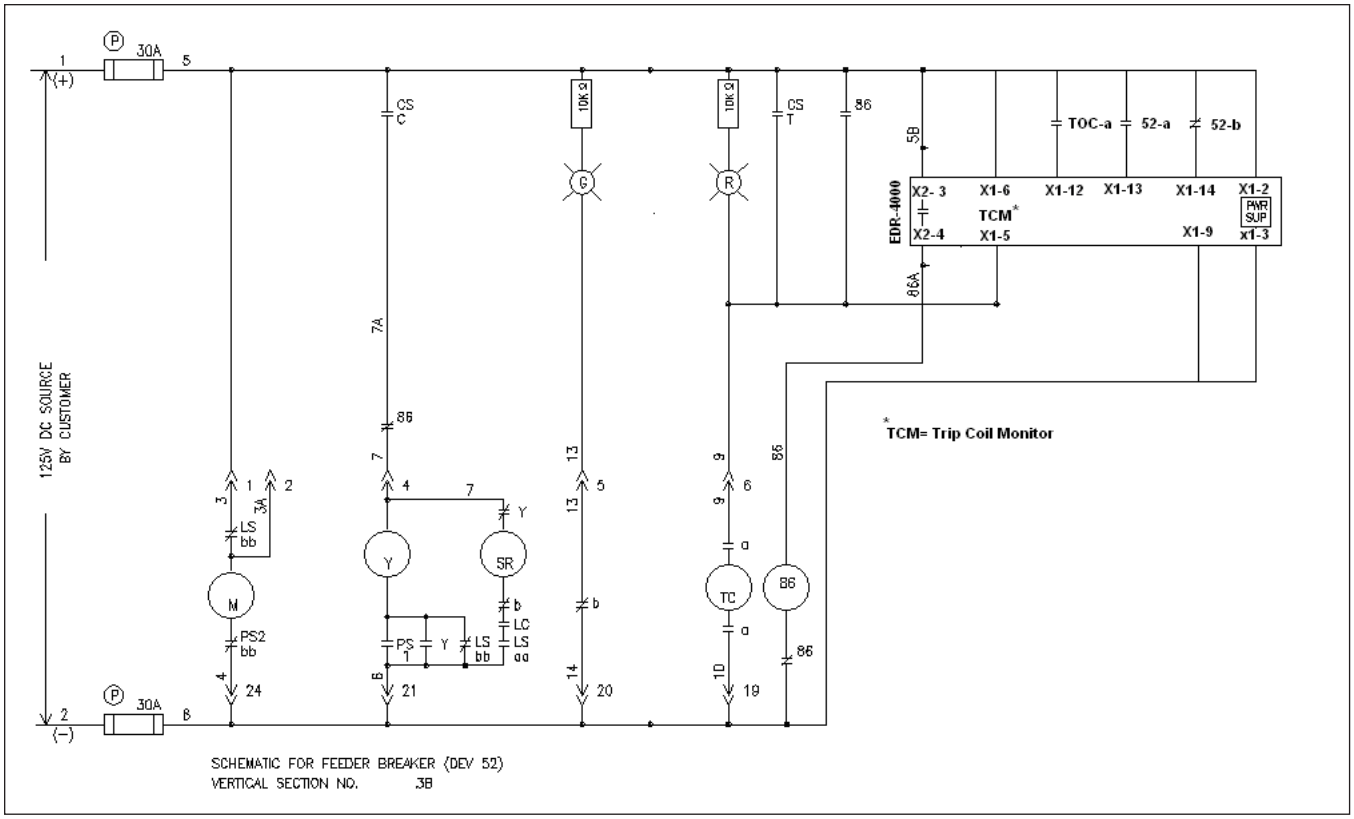


Figure 4.1-29. Typical Control Diagram

4

Communication Software

Eaton provides two types of communication software. The first is PowerPort-E. It runs on a PC or a laptop for easy access to a single relay to change set points or configuration and to view metered values and stored data. PowerPort-E is free and can be downloaded from the Eaton Web site at **www.eaton.com/pr**.

The second package is Power Xpert® Software. Power Xpert Software is a power management software package that is designed for continuous, remote monitoring of many devices. It provides additional functions such as billing, trending and graphics. Contact your local Eaton representative for more information on Power Xpert Software.

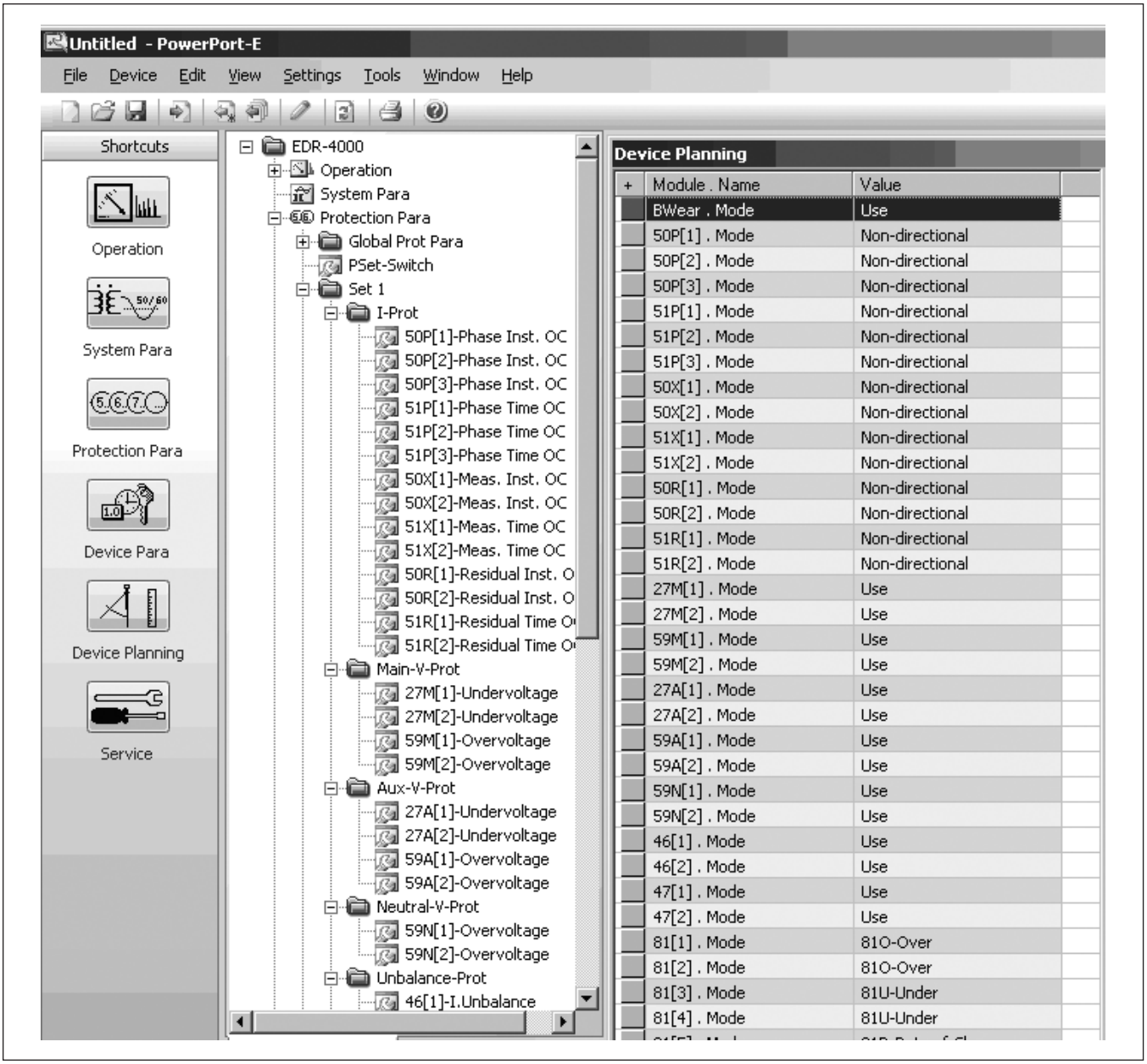


Figure 4.1-30. PowerPort-E EDR-4000 Device Planning

Standards, Certifications and Ratings

Table 4.1-12. EDR-4000 Specifications

Voltage Supply

Aux. voltage:	24–270 Vdc/48–230 Vac (–20%/+10%)
Buffer time in case of supply failure:	≥ 50 ms at minimal aux. voltage interrupted communication is permitted

Max. permissible making current:
18A peak value for <0.25 ms
12A peak value for <1 ms
The voltage supply must be protected by a fuse of:
2.5A time-lag miniature fuse 5.0 x 20.0 mm (approx. 0.20 in. x 0.80 in) according to IEC 60127
3.5A time-lag miniature fuse 6.3 x 32.0 mm (approx. 0.25 in. x 1.25 in) according to UL 248-14

Power Consumption

Power supply range:	24–270 Vdc: 7W idle mode/ approx. 13W max. power 48–230 Vac: 7 VA idle mode/ approx. 13 VA max. power (for frequencies of 40–70 Hz)
Power consumption:	Phase current inputs at I_n = 1A, S = 0.15 mVA at I_n = 5A, S = 0.15 mVA
Ground current input:	at I_n = 1A, S = 0.35 mVA at I_n = 5A, S = 0.35 mVA

Digital Inputs

Max. input voltage:	300 Vdc/259 Vac
Input current:	<4 mA
Reaction time:	<20 ms
Fallback time:	<30 ms (safe state of the digital inputs)
Switching thresholds:	Un = 24 Vdc, 48 Vdc, 60 Vdc, 110 Vac/dc, 230 Vac/dc
Un = 24 Vdc	
Switching threshold 1 ON:	Min. 19.2 Vdc
Switching threshold 1 OFF:	Max. 9.6 Vdc
Un = 48V/60 Vdc	
Switching threshold 2 ON:	Min. 42.6 Vdc
Switching threshold 2 OFF:	Max. 21.3 Vdc
Un = 110/120 Vac/dc	
Switching threshold 3 ON:	Min. 88.0 Vdc/88.0 Vac
Switching threshold 3 OFF:	Max. 44.0 Vdc/44.0 Vac
Un = 230/240 Vac/dc	
Switching threshold 4 ON:	Min. 184 Vdc/184 Vac
Switching threshold 4 OFF:	Max. 92 Vdc/92 Vac
Terminals:	Screw-type terminal

Relay Outputs

Continuous current:	5A AC/DC
Max. make current:	25A AC/25A DC up to 30V for 4s 30A/230 Vac according to ANSI IEEE Std. C37.90-2005 30A/250 Vac according to ANSI IEEE Std. C37.90-2005
Max. breaking current:	5A AC up to 125 Vdc 5A DC up to 30V (resistive) 0.3A DC at 300V
Max. switching voltage:	250 Vac/250 Vdc
Switching capacity:	1250 VA
Contact type:	Form C or normally open contact
Terminals:	Screw-type terminals

Zone Interlocking

NOTICE: ONLY FOR ZONE INTERLOCK TRIPPING OUTPUTS (ZONE INTERLOCK, SEMI-CONDUCTOR OUTPUT): 5 Vdc, <2 mA FOR CONNECTION TO ELECTRONIC INPUTS ONLY.

Zone out:	
Output voltage (high):	4.75 to 5.25 Vdc
Output voltage (low):	0.0 to +0.5 Vdc
Zone in:	
Nominal input voltage:	+5 Vdc
Max. input voltage:	+5.5 Vdc
Switching threshold ON:	Min. 4.0 Vdc
Switching threshold OFF:	Max. 1.5 Vdc
Galvanic isolation:	2.5 kV AC (to ground and other IO)
Connection:	Screw-type terminals (twisted pair)

Front Interface RS-232

Baud rates:	115,200 Baud
Handshake:	RTS and CTS
Connection:	Nine-pole D-Sub plug

RS-485

Master/slave:	Slave
Connection:	Six screw-clamping terminals RM 3.5 mm (138 MIL) (terminating resistors internal)

Climatic Environmental Conditions

Storage temperature:	–30°C to +70°C (–22°F to +158°F)
Operating temperature:	–20°C up to +60°C (–4°F to +140°F)
Permissible humidity at Ann. average:	<75% rel. (on 56d up to 95% rel.)
Permissible installation altitude:	<2000m (6561.67 ft) above sea level If 4000m (13,123.35 ft) altitude applies a changed classification of the operating and test voltages may be necessary.

4

EDR-5000 Distribution Protection Relay

EDR-5000 Distribution Protection Relay

General Description

Eaton's EDR-5000 distribution protection relay is a multi-functional, microprocessor-based relay for feeder circuits of all voltage levels. It may be used as a primary protection on feeders, mains and tie circuit breaker applications; or as backup protection for transformers, high voltage lines and differential protection. The relay is most commonly used on medium voltage switchgear applications.

The EDR-5000 distribution protection relay provides complete current, voltage and frequency protection, and metering in a single, compact case. The relay has four current inputs rated for either 5A or 1A and four voltage inputs. Three of the voltage inputs are to be connected to the three-phase power voltage for voltage protection and for metering. They can be connected in wye-ground or open delta configuration. The fourth voltage is for independent single-phase undervoltage/overvoltage protection, or ground protection for an ungrounded system.

The Maintenance Mode password protected soft key, can be used for arc flash mitigation to change to an alternate settings group, set to have instantaneous elements only. The multiple setting groups can also be changed, via communications or a digital input.

An integral keypad and display is provided for direct user programming and retrieval of data without the need of a computer. 14 programmable LEDs provide quick indication of relay status.

A front port is provided for direct computer connection. An RS-485 communication port on the back is standard for local area networking using Modbus-RTU. An optional Ethernet port and protocols are available.

The EDR-5000 distribution protection relay includes programmable logic functions. Logic gates and timers may be defined and arranged for customized applications. Programmable logic control functions make the EDR-5000 relay ideally suited for main-tie-main and main 1/main 2 transfer schemes.

Flash memory is used for the programming, and all settings are stored in nonvolatile memory. The relay allows for four preprogrammed setting groups that can be activated through software, the display or a contact input.

The EDR-5000 distribution protection relay has mass memory for data storage and a real-time clock with 1 ms time resolution. The relay will log 300 sequence of event records, 20 detailed trip logs, minimum/maximum values, load profiles, breaker wear information and oscillography data.

The EDR-5000 has eight programmable binary inputs, two normally opened and eight Form C heavy-duty outputs and one Form C signal alarm relay. It can be powered from 19 Vdc to 300 Vdc or 40 Vac to 250 Vac auxiliary power.

Features

Protection

- Phase overcurrent elements:
  - Three instantaneous elements with timers (50P[1], 50P[2] and 50P[3])
  - Three inverse time overcurrent elements (51P[1], 51P[2] and 51P[3])
  - 11 standard curves
  - Instantaneous or time delay reset
  - Voltage restraint (51P[2] and 51P[3])
  - Directional control (all elements)
- Ground overcurrent elements:
  - Two instantaneous measured elements with timers (50X[1] and 50X[2])
  - Two instantaneous calculated elements with timers (50R[1] and 50R[2])
  - Two inverse time overcurrent measured elements (51X[1] and 51X[2])
  - Two inverse time overcurrent calculated elements (51R[1] and 51R[2])
  - 11 standard curves
  - Instantaneous or time delay reset
  - Directional control (all elements)
- Breaker failure (50BF)
- Phase unbalance negative sequence overcurrent (46[1], 46[2])
- Phase voltage unbalance and sequence protection (47[1], 47[2])
- Main three-phase under/overvoltage (27M[1], 27M[2], 59M[1], 59M[2])
- Auxiliary single-phase under/overvoltage (27A[1], 27A[2], 59A[1], 59A[2])
- Ground fault overvoltage relay (59N[1], 59N[2])
- Six frequency elements that can be assigned to: overfrequency, underfrequency, rate of change or vector surge (81[1], 81[2], 81[3], 81[4], 81[5], 81[6])
- Apparent and displacement power factor (55A[1], 55A[2], 55D[1], 55D[2])
- Forward and reverse watts (32[1], 32[2])
- Forward and reverse VARs (32V[1], 32V[2])
- Sync check (25)
- Autoreclosing (79)
- Zone interlocking for bus protection (87B)
- Switch onto fault protection
- Cold load pickup

Metering

- Amperes: positive, negative and zero sequence
- Ampere demand
- Volts: positive, negative and zero sequence
- Phase angles
- Volt-amperes and VA demand
- Watts and kW demand
- kWh (forward, reverse, net)
- VARs and kVAR demand
- kVARh (lead, leg and net)
- Power factor
- Frequency
- % THD V and I
- Magnitude THD V and I
- Minimum/maximum recording
- Sync values
- Trending (load profile over time)

Monitoring

- Trip coil monitor
- Breaker wear primary and secondary (accumulated interrupted current)
- Oscillography (6000 cycles total)
- Fault data logs (up to 20 events)
- Sequence of events report (up to 300 events)
- Clock (1 ms time stamping)

Communication

- Local HMI
- Password protected
- Addressable
- IRIG-B
- Local communication port
- Remote communication port:
  - RS-232
  - RS-485
- Protocols:
  - Modbus-RTU
  - Modbus-TCP (optional)
- Configuration software

Control Functions

- Breaker open/close
- Remote open/close
- Programmable I/O
- Programmable logic
- Programmable LEDs
- Multiple setting groups
- Cold load pickup
- CT supervision

4

Table 4.1-13. Catalog Numbering Selection for EDR-5000 Distribution Relay Removable Terminals

EDR-5000 A 0 B A 1

Hardware Option 1	Hardware Option 2	Communication Options	Conformal Coating Options	Mounting Options
A = Eight digital inputs, 11 outputs, removable terminals, zone interlocking	**0** = Phase current 5A/1A, ground current 5A/1A, power supply range: 19–300 Vdc 40–250 Vac	**B** = Modbus-RTU (RS-485)	**A** = None	**0** = Standard mount
B = Eight digital inputs, 11 outputs, removable terminals, zone interlocking and large display ①	**1** = Phase current 5A/1A, sensitive ground current 0.5A/0.1A, power supply range: 19–300 Vdc 40–250 Vac ①	**H** = IEC-61850 (Goose)	**B** = Conformal coated circuit boards	**1** = Projection panel mount
		1 = Modbus-RTU + Modbus-TCP		

① Consult factory for the availability of sensitive ground and large display.

Protection and Control Functions

The Eaton's EDR-5000 distribution protection relay has been designed for maximum user flexibility and simplicity. The base relay includes all the standard current and voltage protection and metering functions.

Directional Overcurrent Protection

The EDR-5000 distribution protection relay provides complete three-phase and ground directional overcurrent protection. There are eight independent ground overcurrent elements. The ground elements "X" use the independently measured ground (or neutral) current from a separate current-sensing input. The ground elements "R" uses a calculated 3Io residual current obtained from the sum of the three-phase currents. This calculated current could be used for either the neutral or ground current in a three-phase, four-wire system. Each of the phase and ground overcurrent elements can be selected to operate based on fundamental or rms current.

Phase direction is a function used to supervise all phase current elements (50, 51). A quadrature voltage is compared to a corresponding phase current to establish the direction of the fault. This function is selectable to operate in the forward, reverse or both directions.

Ground direction is used to supervise ground current elements and is accomplished by using ground, negative sequence or residual currents supervised by zero, negative or positive sequence voltages or ground current. This function is selectable to operate in forward, reverse or both directions.

Voltage Restrained Overcurrent

Voltage restraint reduces the overcurrent pickup level (51P[2], 51P[3]). This modification of the pickup overcurrent level is compared to the corresponding phase input voltage. The EDR-5000 uses the simple linear model below to determine the effective pickup value.

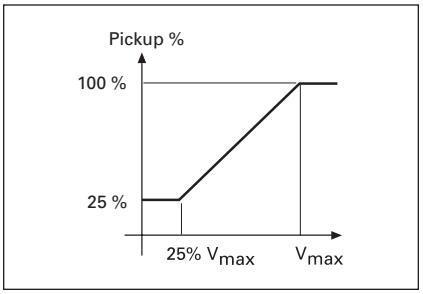


Figure 4.1-31. Voltage Restraint Coil Pickup Characteristics

Sync Check

The sync check function is provided for double-ended power source applications. The sync check monitors voltage magnitude, phase angle and slip frequency between the bus and the line. It also incorporates breaker close time, dead bus dead line, dead bus live line, and live bus live line features.

Reverse Power

Reverse power provides control for power flowing through a feeder. There are three elements to be configured: operate in forward or reverse; or, under or over power conditions. Reverse power is typically applied to generator or motor applications while under power is generally applied to load or generation loss.

Reverse VARs

Reverse VARs can be used to detect loss of excitation in synchronous machines. There are three elements to be configured: operate in forward or reverse; or, under or over VARs conditions.

Inverse-Time Characteristics

There are 11 user-selectable inverse-time overcurrent curve characteristics. The user can select from the ANSI, IEC or thermal curve families, and can select instantaneous or time delay reset characteristics.

Breaker Failure

The EDR-5000 distribution protection relay includes a breaker failure (50BF, 62BF) function that can be initiated from either an internal or external trip signal. This is an independent element that can be used to operate a lockout relay or to trip an upstream breaker. The timer must be longer than the breaker operating time and the protective function reset times.

Voltage Protection

The EDR-5000 distribution protection relay has four voltage-input circuits. There is a three-phase set designated as Main Voltage (M) and a single-phase voltage circuit designated as Auxiliary Voltage (A). Both include undervoltage (27) and overvoltage (59) protection. The three-phase voltage protection can be set to operate on a single-phase, two out of three phases, or all three-phase logic. The Main VTs also provide phase voltage unbalance/reversal (47 negative sequence) protection. Each element has an independent threshold set point and adjustable time delay.

Ground Voltage Protection

In high impedance grounded systems, ground fault protection is provided by the detection of zero sequence voltage (3Vo) in the neutral of the transformer by an overvoltage element (59N) connected to the secondary of the distribution grounding transformer, or in the secondary of a wye-broken delta transformer used when the neutral is not accessible or in delta system. In the EDR-5000, we can measure this zero sequence voltage through the 4th voltage input; the 59N element has to be desensitized for 3rd harmonic voltages that can be present in the system under normal operation.

Flexible Phase Rotation

The EDR-5000 distribution protection relay can be applied on either an A-B-C or A-C-B phase rotation. A user setting permits correct operation and indication of the actual system configuration.

Frequency Protection

The EDR-5000 relay provides six frequency elements than can be used to detect under/over frequency, rate of change, and a vector surge (decoupling of two systems) protection on the Main VT inputs. Each element has an independent threshold set point and adjustable time delay.

Autoreclosing Logic

The EDR-5000 provides a six shot-recloser scheme. Autoreclosing is normally used by the utilities in their distribution and transmission lines, but it can be used in commercial and industrial applications with long overhead lines. Nearly 85% of the faults that occur on overhead lines are transient in nature. Tripping of a circuit breaker normally clears a transient fault and reclosing of the circuit breaker restores power back to the circuit.

Maintenance Mode

The Maintenance Mode can improve safety by providing a simple and reliable method to reduce fault clearing time and lower incident energy levels at energized panels. The Maintenance Mode allows the user to switch to more sensitive settings via a password protected soft key, communication or via a digital input while maintenance work is being performed at an energized panel or device. The more sensitive settings provide greater security for maintenance personnel and help to reduce the possibility of injury.

Monitoring and Metering

Sequence of Events Records

The EDR-5000 protection relay records a maximum of 300 events associated with the relay. An event is classified as a change of state as detected by the relay. These include relay pickups, dropouts, trips, contact closure, alarms, setting changes and self-diagnostic failures. Each event is date and time stamped to a 1 ms resolution. The events are stored in an FIFO log in chronological order.

Trip Log

The EDR-5000 protection relay will store a maximum of 20 trip records in an FIFO trip log. Each trip record will be date and time stamped to a 1 ms resolution. The trip log record will include information on the type of fault, protection elements that operated, fault location and currents and voltages at the time of the fault.

Waveform Capture

The EDR-5000 distribution protection relay provides oscillography-recording capabilities. The relay will record all measured signals along with the binary signals of pickup, trip, logic and contact closures. The EDR-5000 relay can record up to 6000 cycles of data. The number of records is proportional to the size of each record; the maximum size per record is 600 cycles. The waveform capture is initiated by up to eight different triggers; it can also be generated manually through the display or via communications.

Integral User Interface

The front panel user interface has a 128 x 64 pixel LCD display with background illumination for wide angle viewing in all light conditions. 17 programmable LEDs provide quick and easy visual display of power on, mode of operation, alarm and trip indication. Soft keys are provided for operation mode selection, scrolling through data and settings. In addition, the relay settings and test functions are password protected.

Load Profiling/Trending

The EDR-5000 relay automatically records selected quantities into non-volatile memory every 5, 10, 15, 30 or 60 minutes, depending on the trending report setting.

Programmable I/O

The EDR-5000 distribution protection relay provides heavy-duty, trip-rated, two normally open and eight Form C contacts. Two isolated inputs can be used for monitoring the trip circuit. One Form C contact is dedicated to the relay failure alarm function and is operated in a normally energized (failsafe) mode. There are eight user-configurable discrete inputs that accept a wet contact and can operate through a wide range of power. Each input and output is user-programmable for maximum application flexibility.

Programmable Logic

The EDR-5000 distribution protection relay provides logic gates and timers that the user can customize for special or unique applications. Each gate can be assigned a logic function of either AND, OR, NAND or NOR. Each gate can have a maximum of four input signals and each input signal can be required to be a NOT. Input signals can be external inputs received via the binary inputs or internal values associated with the protection, alarm or metering set points. Each gate has a unique output assignment and designation that can be used as the input to another gate. There are 24 independent timers that have adjustable pickup and dropout delay settings.

4

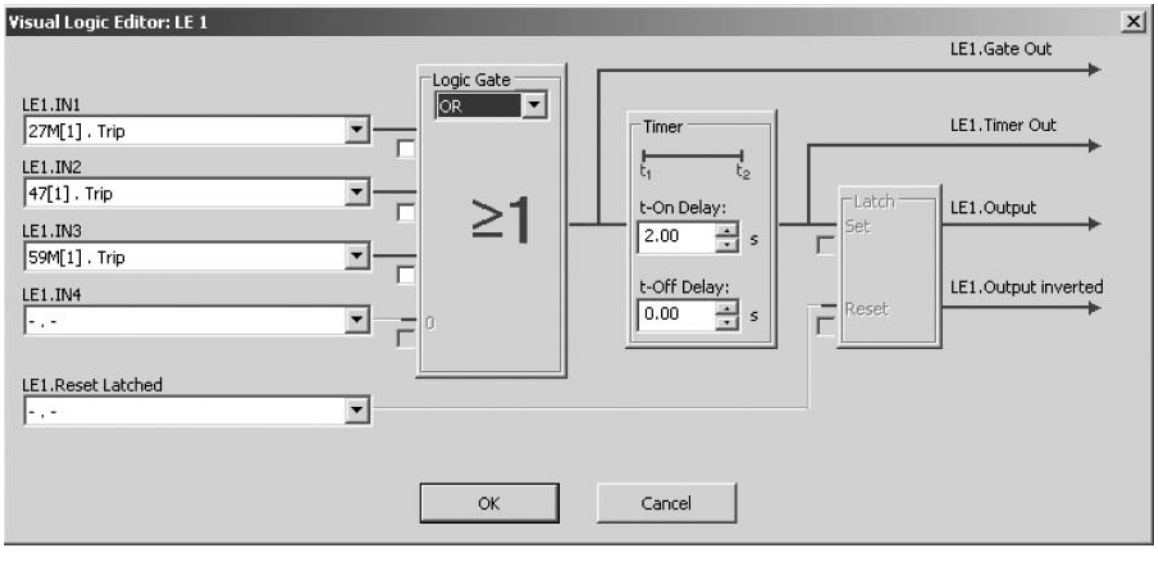


Figure 4.1-32. Visual Logic Editor

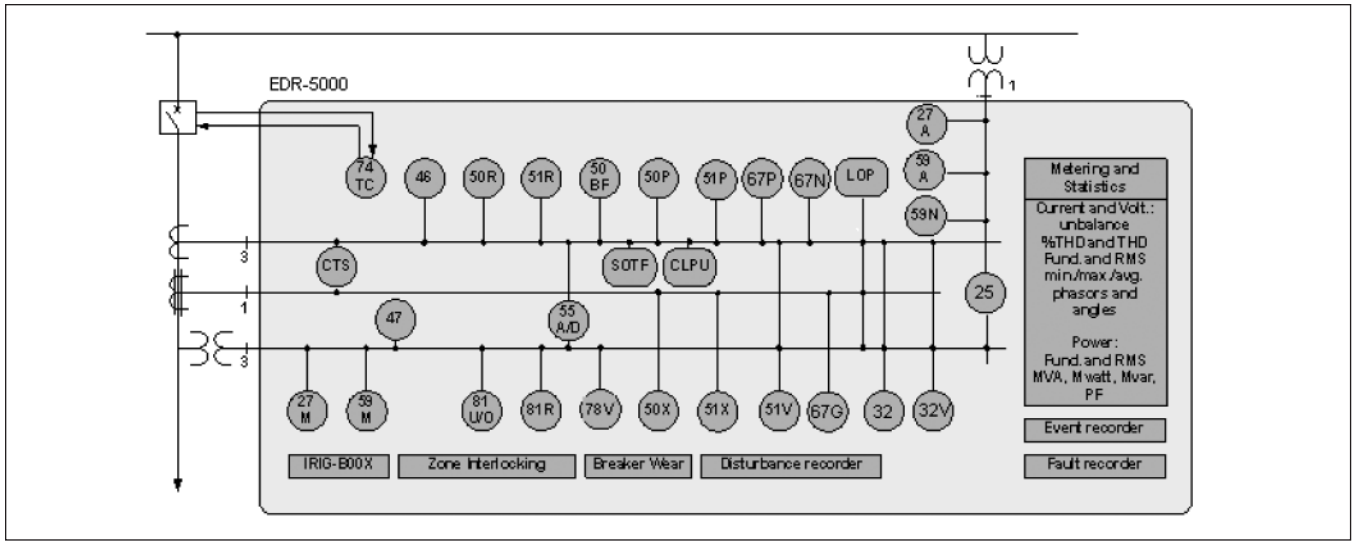


Figure 4.1-33. Typical One-Line Diagram

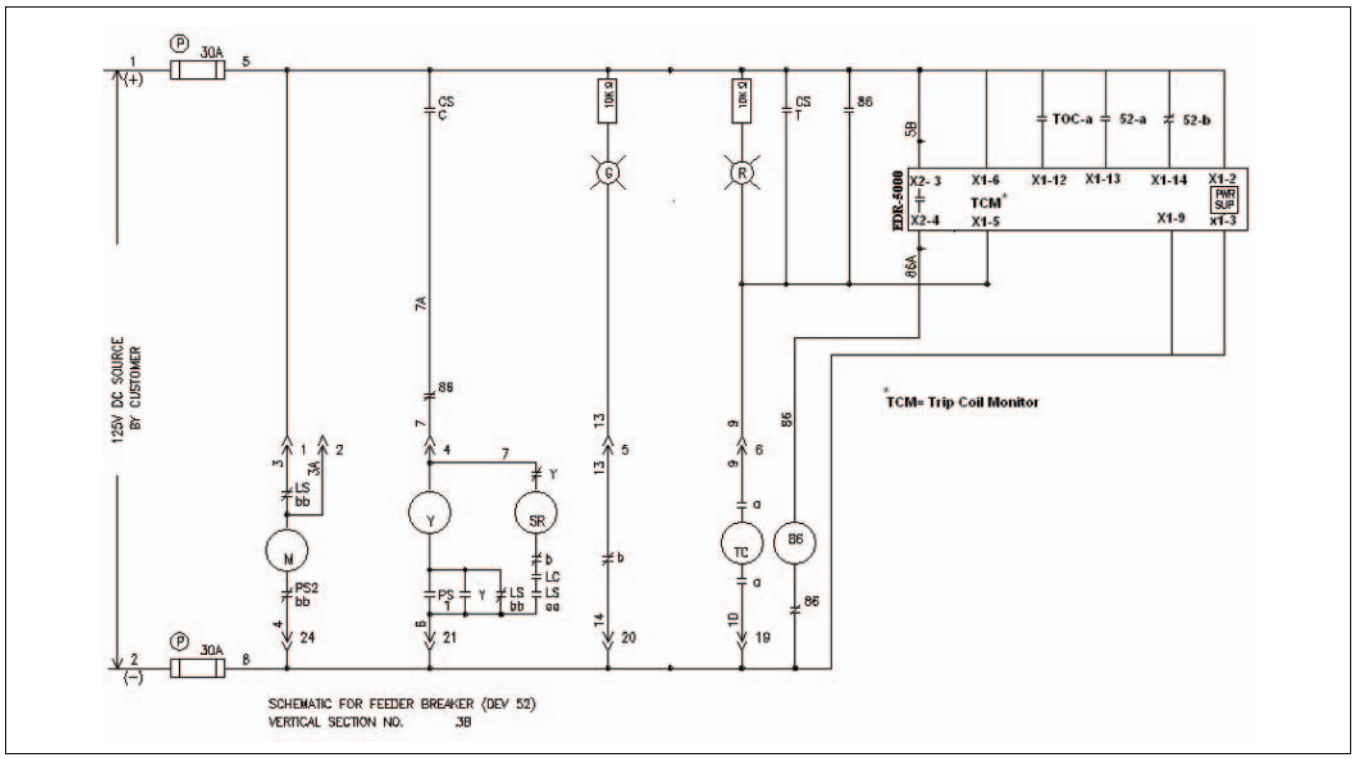


Figure 4.1-34. Typical Control Diagram

Communication Software

Eaton provides two types of communication software. The first is PowerPort-E. It runs on a PC or laptop for easy access to a single relay to change set points or configuration and to view metered values and stored data. PowerPort-E is free and can be downloaded from the Eaton Web site at **www.eaton.com/pr**.

The second package is Power Xpert Software. Power Xpert Software is a power management software package that is designed for continuous, remote monitoring of many devices. It provides additional functions such as billing, trending and graphics. Contact your local Eaton representative for more information on Power Xpert Software.

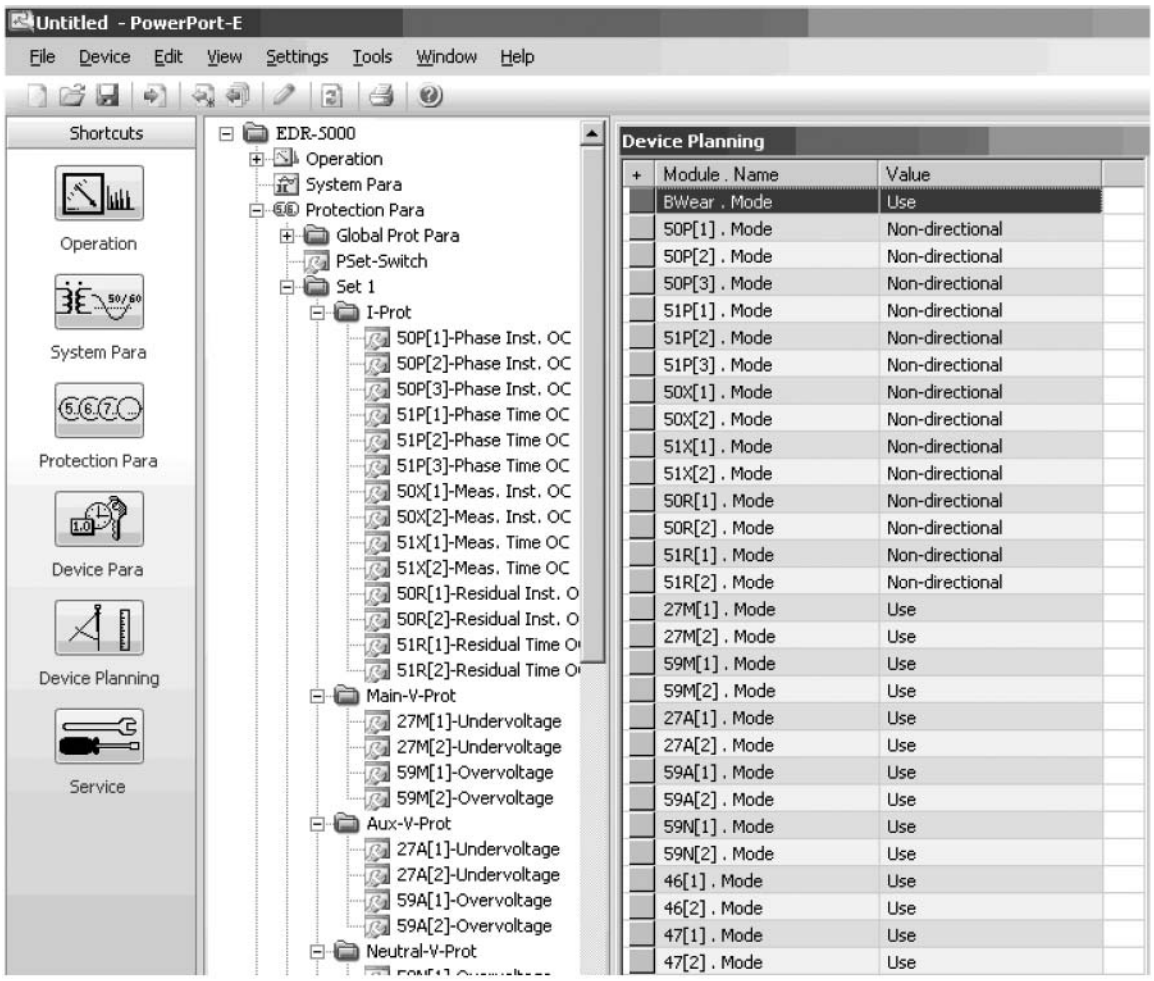


Figure 4.1-35. PowerPort-E EDR-5000 Device Planning

Standards, Certifications and Ratings

Table 4.1-14. EDR-5000 Specifications

Voltage Supply

Aux. voltage:	24–270 Vdc/48–230 Vac (–20%/+10%)
Buffer time in case of supply failure:	≥50 ms at minimal aux. voltage interrupted communication is permitted

Max. permissible making current:
18A peak value for 0.25 ms
12A peak value for 1 ms
The voltage supply must be protected by a fuse of:
2.5A time-lag miniature fuse 5.0 x 20.0 mm (approx. 0.20 in. x 0.80 in) according to IEC 60127
3.5A time-lag miniature fuse 6.3 x 32.0 mm (approx. 0.25 in. x 1.25 in) according to UL 248-14

Power Consumption

Power supply range:	24–270 Vdc: 7W idle mode/ approx. 13W max. power 48–230 Vac: 7 VA idle mode/ approx. 13 VA max. power (for frequencies of 40–70 Hz)
Power consumption:	Phase current inputs at I_n = 1A, S = 0.15 mVA at I_n = 5A, S = 0.15 mVA
Ground current input:	at I_n = 1A, S = 0.35 mVA at I_n = 5A, S = 0.35 mVA

Digital Inputs

Max. input voltage:	300 Vdc/259 Vac
Input current:	<4 mA
Reaction time:	<20 ms
Fallback time:	<30 ms (safe state of the digital inputs)
Switching thresholds:	Un = 24 Vdc, 48 Vdc, 60 Vdc, 110 Vac/dc, 230 Vac/dc
Un = 24 Vdc	
Switching threshold 1 ON:	Min. 19.2 Vdc
Switching threshold 1 OFF:	Max. 9.6 Vdc
Un = 48V/60 Vdc	
Switching threshold 2 ON:	Min. 42.6 Vdc
Switching threshold 2 OFF:	Max. 21.3 Vdc
Un = 110/120 Vac/dc	
Switching threshold 3 ON:	Min. 88.0 Vdc/88.0 Vac
Switching threshold 3 OFF:	Max. 44.0 Vdc/44.0 Vac
Un = 230/240 Vac/dc	
Switching threshold 4 ON:	Min. 184 Vdc/184 Vac
Switching threshold 4 OFF:	Max. 92 Vdc/92 Vac
Terminals:	Screw-type terminal

Relay Outputs

Continuous current:	5A AC/DC
Max. make current:	25A AC/25A DC up to 30V for 4s 30A/230 Vac according to ANSI IEEE Std. C37.90-2005 30A/250 Vac according to ANSI IEEE Std. C37.90-2005
Max. breaking current:	5A AC up to 125 Vdc 5A DC up to 30V (resistive) 0.3A DC at 300V
Max. switching voltage:	250 Vac/250 Vdc
Switching capacity:	1250 VA
Contact type:	Form C or normally open contact
Terminals:	Screw-type terminals

Zone Interlocking

NOTICE: ONLY FOR ZONE INTERLOCK TRIPPING OUTPUTS (ZONE INTERLOCK, SEMI-CONDUCTOR OUTPUT): 5 Vdc, <2 mA FOR CONNECTION TO ELECTRONIC INPUTS ONLY.

Zone out:	
Output voltage (high):	4.75 to 5.25 Vdc
Output voltage (low):	0.0 to +0.5 Vdc
Zone in:	
Nominal input voltage:	+5 Vdc
Max. input voltage:	+5.5 Vdc
Switching threshold ON:	Min. 4.0 Vdc
Switching threshold OFF:	Max. 1.5 Vdc
Galvanic isolation:	2.5 kV AC (to ground and other IO)
Connection:	Screw-type terminals (twisted pair)

Front Interface RS-232

Baud rates:	115,200 Baud
Handshake:	RTS and CTS
Connection:	Nine-pole D-Sub plug

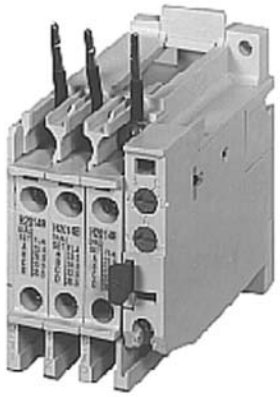
RS-485

Master/slave:	Slave
Connection:	Six screw-clamping terminals RM 3.5 mm (138 MIL) (terminating resistors internal)

Climatic Environmental Conditions

Storage temperature:	–30°C to +70°C (–22°F to +158°F)
Operating temperature:	–20°C up to +60°C (–4°F to +140°F)
Permissible humidity at Ann. average:	<75% rel. (on 56d up to 95% rel.)
Permissible installation altitude:	<2000m (6561.67 ft) above sea level If 4000m (13,123.35 ft) altitude applies, a changed classification of the operating and test voltages may be necessary.

Freedom Overload Relays



32A Overload—C306DN3B

General Description

C306 Overload Relays are designed for use with CE or CN non-reversing and reversing contactors. Four sizes are available for overload protection up to 144A.

Features

- Selectable manual or automatic reset operation
- Interchangeable heater packs adjustable ±24%to match motor FLA and calibrated for use with 1.0 and 1.15 service factor motors. Heater packs for 32A overload relay will mount in 75A overload relay—useful in derating applications such as jogging
- Class 10 or 20 heater packs
- Load lugs built into relay base
- Bimetallic, ambient compensated operated. Trip free mechanism
- Electrically isolated NO-NC contacts (pull RESET button to test). (Electrical ratings see tables in Volume 5—Motor Control and Protection, CA08100006E, Tab 33, Section 33.1)
- Overload trip indication
- Shrouded or fingerproof terminals to reduce possibility of electrical shock

Standards and Certifications

- Meets UL 508 single-phasing requirements
- UL listed, CSA certified, NEMA compliance and CE mark

Reference

Refer to Volume 5—Motor Control and Protection, CA08100006E, Tab 33, Section 33.1 for additional product information.

C440/*XT* Electronic Overload Relay

C440/XT Electronic Overload Relay

General Description

Eaton's electronic overload relay (EOL) is the most compact, high-featured, economical product in its class. Designed on a global platform, the new EOL covers the entire power control spectrum including NEMA, IEC and DP contactors. The NEMA and DP versions are offered with the C440 designation while the IEC offering has the ***XT*** designation. The electronic design provides reliable, accurate and value driven protection and communications capabilities in a single compact device. It is the flexible choice for any application requiring easy-to-use, reliable protection.

Eaton has a long history of innovations and product development in motor control and protection, including both traditional NEMA, as well as IEC control. It was from this experience that the C440 was developed, delivering new solutions to meet today's demands.

C440 is a self-powered electronic overload relay available up to 100A as a self contained unit. With external CTs, C440 can protect motor up to 1500 FLA. Available add-on accessories include remote reset capability and communication modules with I/O for DeviceNet, PROFIBUS, and Modbus.

Features and Benefits

Features

- Reliable, accurate, electronic motor protection
- Easy to select, install and maintain
- Compact size
- Flexible, intelligent design
- Global product offering—available with NEMA, IEC and DP power control

Size/Range

- Broad FLA range (0.33–1500A)
- Selectable trip class (10A, 10, 20, 30)
- Direct mounting to NEMA, IEC and DP contactors
- Most compact electronic overload in its class

Motor Control

- Two B600 alarm (NO) and fault (NC) contacts
- Test/Trip button

Motor Protection

- Thermal overload
- Phase loss
- Selectable (ON/OFF) phase imbalance
- Selectable (ON/OFF) ground fault

User Interface

- Large FLA selection dial
- Trip status indicator
- Operating mode LED
- DIP switch selectable trip class, phase imbalance and ground fault
- Selectable Auto/Manual reset

Feature Options

- Remote reset
  - ❑ 120 Vac
  - ❑ 24 Vac
  - ❑ 24 Vdc
- Tamper-proof cover
- Communications modules
  - ❑ Modbus RTU RS-485
  - ❑ DeviceNet with I/O
  - ❑ PROFIBUS with I/O
  - ❑ Modbus RTU with I/O (Q4 2010)
  - ❑ Ethernet IP (planned)

4

Benefits

Reliability and Improved Uptime

- C440 provides the users with peace of mind knowing that their assets are protected with the highest level of motor protection and communication capability in its class
- Extends the life of plant assets with selectable motor protection features such as trip class, phase imbalance and ground fault
- Protects against unnecessary downtime by discovering changes in your system (line/load) with remote monitoring capabilities
- Status LED provides added assurance that valuable assets are protected by indicating the overload operational status

Flexibility

- Available with NEMA, IEC and DP contactors
- Improves return on investment by reducing inventory carrying costs with wide FLA adjustment (5:1) and selectable trip class
- Design incorporates built-in ground fault protection thus eliminating the need for separate CTs and modules
- Flexible communication with optional I/O enables easy integration into plant management systems for remote monitoring and control
- Available as an open component and in enclosed control and motor control center assemblies

Monitoring Capabilities

- Individual phase currents rms
- Average three-phase current rms
- Thermal memory
- Fault indication (overload, phase loss, phase imbalance, ground fault)

Safety

- IP 20 rated terminal blocks
- Available in Eaton's industry leading FlashGard MCCs
- Tested to the highest industry standards such as UL, CSA, CE and IEC
- RoHS compliant

Standards and Certifications

- UL
- CSA
- CE
- NEMA
- IEC/EN 60947 VDE 0660
- ISO 13849-1 (EN954-1)
- RoHS
- ATEX directive 94/9/EC
- Equipment Group 2, Category 2

Table 4.2-1. Electronic Overload Education

Description	Definition	Cause	Effect if not Protected	C440/*XT* Protection
Motor Protection				
Thermal overload	Overload is a condition in which current draw exceeds 115% of the full load amperage rating for an inductive motor.	• An increase in the load or torque that is being driven by the motor. • A low voltage supply to the motor causes the current to go high to maintain the power needed. • A poor power factor causing above normal current draw.	• Increase in current draw leads to heat and insulation breakdown, which can cause system failure. • Increase in current can increase power consumption and waste valuable energy.	• Thermal trip behavior is defined by UL, CSA and IEC standards. • Trip class is settable from 10A, 10, 20, 30
Ground fault	A line to ground fault.	A current leakage path to ground.	An undetected ground fault can burn through multiple insulation windings, ultimately leading to motor failure, not to mention risk to equipment or personnel	Fixed protective setting that takes the starter offline if ground fault current exceeds 50% of the FLA dial setting, i.e., if the FLA dial is set to 12A, the overload relay will trip if the ground current exceeds 6A.
Imbalanced phases (voltage and current)	Uneven voltage or current between phases in a three-phase system.	When a three-phase load is powered with a poor quality line, the voltage per phase may be imbalanced.	Imbalanced voltage causes large imbalanced currents and as a result this can lead to motor stator windings being overloaded, causing excessive heating, reduced motor efficiency and reduced insulation life.	Fixed protective setting that takes the starter offline if a phase drops below 50% of the other two phases.
Phase loss—current (single-phasing)	One of the three-phase voltages is not present.	Multiple causes, loose wire, improper wiring, grounded phase, open fuse, etc.	Single-phasing can lead to unwanted motor vibrations in addition to the results of imbalanced phases as listed above.	Fixed protective setting that takes the starter offline if a phase drops below 50% of the other two phases.

Modbus Communication Module

The Modbus module combined with an expansion module and a communication adapter provide Modbus communication capability to the C440 electronic overload relay.

Modbus Communication Module

Features and Benefits

- The Modbus communication module is capable of baud rates up to 115K
- The Modbus address and baud rate configuration can be easily changed using the HMi user interface
- Modbus address and baud rate are set via convenient DIP switches; LEDs are provided to display Modbus traffic
- Configuration with common Modbus configuration tools
- Terminals
  - Unique locking mechanism provides for easy removal of the terminal block with the field wiring installed
  - Each terminal is marked for ease of wiring and troubleshooting
- Selectable I/O assemblies
  - 4IN/2OUT
  - Signal types include 24 Vdc I/O and 120 Vac I/O
  - Each I/O module is optically isolated between the field I/O and the network adapter to protect the I/O and communication circuits from possible damage due to transients and ground loops
  - Input Module features a user-definable input debounce, which limits the effects of transients and electrical noise
  - Output Module supports a user-definable safe state for loss of communication; hold last state, ON or OFF

DeviceNet Communication Modules

The DeviceNet Communication Module provides monitoring and control for the C440 overload relay from a single DeviceNet node. These modules also offer convenient I/O in two voltage options, 24 Vdc and 120 Vac.

DeviceNet Communication Module

Features and Benefits

- Communication to DeviceNet uses only one DeviceNet MAC ID
- Configuration
  - DeviceNet MAC ID and Baud rate are set via convenient DIP switches with an option to set from the network
  - Advanced configuration available using common DeviceNet tools
- Terminals
  - Unique locking mechanism provides for easy removal of the terminal block with the field wiring installed
  - Each terminal is marked for ease of wiring and troubleshooting
- Selectable I/O assemblies
  - 4IN/2OUT
  - Signal types include 24 Vdc I/O and 120 Vac I/O
  - Each I/O module is optically isolated between the field I/O and the network adapter to protect the I/O and communication circuits from possible damage due to transients and ground loops
  - Input Module features a user-definable input debounce, which limits the effects of transients and electrical noise
  - Output Module supports a user-definable safe state for loss of communication; hold last state, ON or OFF
- Combined status LED

PROFIBUS Communication Modules

The PROFIBUS module combined with an expansion module and a communication adapter provide Modbus communication capability to the C440 electronic overload relay.

PROFIBUS Communication Module

Features and Benefits

- The PROFIBUS communication module is capable of baud rates up to 12 Mb
- PROFIBUS address is set via convenient DIP switches; LEDs are provided to display PROFIBUS status
- Intuitive configuration with common PROFIBUS configuration tools
- Terminals
  - Unique locking mechanism provides for easy removal of the terminal block with the field wiring installed
  - Each terminal is marked for ease of wiring and troubleshooting
- Selectable I/O assemblies
  - 4IN/2OUT
  - Signal types include 24 Vdc I/O and 120 Vac I/O
  - Each I/O module is optically isolated between the field I/O and the network adapter to protect the I/O and communication circuits from possible damage due to transients and ground loops
  - Input Module features a user-definable input debounce, which limits the effects of transients and electrical noise
  - Output Module supports a user-definable safe state for loss of communication; hold last state, ON or OFF

Technical Data and Specifications

Table 4.2-2. Electronic Overload Relays up to 1500A

Description	Specification	
	45 mm	**55 mm**
Electrical Ratings		
Operating voltage (three-phase) and frequency	690 Vac (60/50 Hz)	690 Vac (60/50 Hz)
FLA Range		
	0.33–1.65A 1–5A 4–20A 9–45A	20–100A
Use with Contactors		
XT IEC frames	B, C, D	F, G
Freedom NEMA sizes	00, 0, 1, 2	3
Trip Class		
	10A, 10, 20, 30 Selectable	10A, 10, 20, 30 Selectable
Motor Protection		
Thermal overload setting	1.05 x FLA: does not trip 1.15 x FLA: overload trip	1.05 x FLA: does not trip 1.15 x FLA: overload trip
Feature		
Phase loss	Fixed threshold 50%	Fixed threshold 50%
Phase imbalance (selectable: enable/disable)	Fixed threshold 50%	Fixed threshold 50%
Ground fault (selectable: enable/disable)	50% of FLA dial setting >150% = 2 sec >250% = 1 sec	50% of FLA dial setting >150% = 2 sec >250% = 1 sec
Reset	Manual/automatic	Manual/automatic
Indicators		
Trip status	Orange flag	Orange flag
Mode LED	One flash: Overload operating properly Two flashes: Current is above FLA dial setting—pending trip	One flash: Overload operating properly Two flashes: Current is above FLA dial setting—pending trip
Options		
Remote reset	Yes	Yes
Reset bar	Yes	Yes
Communication expansion module	Yes	Yes
Communication adapter	Yes	Yes
Capacity		
Load terminals Terminal capacity	 12–10 AWG (4–6 mm^2) 8–6 AWG (6–16 mm^2)	 6–1 AWG (16–50 mm^2)
Tightening torque	20–25 lb-in (2.3–2.8 Nm) 25–30 lb-in (2.8–3.4 Nm)	25–30 lb-in (2.8–3.4 Nm)
Input, auxiliary contact and remote reset terminals Terminal capacity	 2 x (18–12) AWG	 2 x (18–12) AWG
Tightening torque	5.3 lb-in (0.8–1.2 Nm)	5.3 lb-in (0.8–1.2 Nm)
Voltages		
Insulation voltage U_i (three-phase)	690 Vac	690 Vac
Insulation voltage U_i (control)	500 Vac	500 Vac
Rated impulse withstand voltage	6000 Vac	6000 Vac
Overvoltage category/pollution degree	III/3	III/3

C441 Overload Relays

C441 Motor Insight Overload and Monitoring Relay

General Description

Eaton's C441 Motor Insight®, the first product in the Intelligent Power Control Solutions family, is a highly configurable motor, load and line protection device with power monitoring, diagnostics and flexible communications allowing the customer to save energy, optimize their maintenance schedules and configure greater system protection, thus reducing overall costs and downtime.

C441 Motor Insight is available in either a line-powered or 120 Vac control powered design, capable of monitoring voltages up to 660 Vac. Each of these units is available in a 1–9A or a 5–90A FLA model. With external CTs, Motor Insight can protect motors up to 540A FLA. Available add-on accessories include communication modules for Modbus®, DeviceNet™ and PROFIBUS®, all with I/O options. For ease-of-use and operator safety, C441 Motor Insight offers a remote display that mounts easily with two 30 mm knockouts.

Features and Benefits

Features

Size/Range

- Broad FLA range of 1–540A
- Selectable trip class (5–30)
- Four operating voltage options
  - Line-powered from 240 Vac, 480 Vac, 600 Vac
  - Control-powered from 120 Vac

Motor Control

- Two output relays
  - One B300 Form C fault relay and one B300 ground fault shunt relay
  - Other relay configurations are available, including one Form A and one Form B SPST (fault and auxiliary relays), allowing programmable isolated relay behavior and unique voltages
- One external remote reset terminal
- Trip status indicator

Motor Protection

- Thermal overload
- Jam protection
- Current imbalance
- Current phase loss
- Ground fault
- Phase reversal

Load Protection

- Undercurrent
- Low power (kW)
- High power (kW)

Line Protection

- Overvoltage
- Undervoltage
- Voltage imbalance
- Voltage phase loss

Monitoring Capabilities

- Current—average and phase rms
- Voltage—average and phase rms
- Power—motor kW
- Power factor
- Frequency
- Thermal capacity
- Run hours
- Ground fault current
- Current imbalance %
- Voltage imbalance %
- Motor starts
- Motor run hours

Options

- Type 1, 12 remote display
- Type 3R remote display kit
- Communication modules
  - Modbus
  - Modbus with I/O
  - DeviceNet with I/O
  - PROFIBUS with I/O
  - Modbus TCP with I/O (contact product line)
  - Ethernet IP (contact product line)

Benefits

Reliability and Improved Uptime

- Advanced diagnostics allows for quick and accurate identification of the root source of a motor, pump or power quality fault; reducing trouble-shooting time and the loss of productivity, reducing repeat faults due to misdiagnosis, and increasing process output and profitability
- Provides superior protection of motors and pumps before catastrophic failure occurs
- Increases profitability with greater process uptime and throughput, reduced costs per repair, reduced energy consumption and extended equipment life
- Adjustments to overload configuration can be made at any time

Safety

- IP20 rated terminal blocks
- Terminal blocks are set back from the display to reduce operator shock hazard
- Remote display (optional) does not require that the operator open the panel to configure the device

Flexibility

- Communications modules
  - Offered in a variety of configurations
  - External snap-on modules provide support for multiple communications protocols
- Advanced power, voltage and current monitoring capabilities
- Communications modules and remote display can be used simultaneously
- Highly configurable fault and reset characteristics for numerous applications
- Fully programmable isolated fault and auxiliary relays

Ease of Use

- Bright LED display with easy-to-understand setting and references
- Powered from line voltage or 120 Vac control power
- Remote display powered from base unit
- Full word descriptions and units on user interface

Standards and Certifications

- cULus listed NKCR, NKCR7, 508
- UL 1053 applicable sections for ground fault detection
- CSA certified (Class 3211-02)
- CE
- NEMA
- IEC EN 60947-4-1
- RoHS

Table 4.2-3. Advanced Overload Education

Description	Definition	Source	Result	C441 Motor Insight Protection
Motor Protection				
Thermal overload	Overload is a condition in which current draw to a motor exceeds 115% of the full load amperage rating over a period of time for an inductive motor.	An increase in the load or torque that is being driven by the motor. A low voltage supply to the motor would cause the current to go high to maintain the power needed. A poor power factor would cause above normal current draw.	Increase in current draw. Current leads to heat and insulation breakdown, which can cause system failure. Additionally, an increase in current can increase power consumption and waste valuable energy.	Thermal trip behavior is defined by UL, CSA and IEC standards. Trip class is settable from 5–30 by 1 Provides power factor monitoring and low voltage protection features.
Jam	Jam is similar to thermal overload in that it is a current draw on the motor above normal operating conditions.	Mechanical stall, interference, jam or seizure of the motor or motor load.	The motor attempts to drive the load, which has more resistive force due to the mechanical interference. In order to drive the load, the motor draws an abnormal amount of current, which can lead to insulation breakdown and system failure.	Provides a configurable Jam setting that is active during "motor run state" to avoid nuisance trips. Trip Threshold 150–400% of FLA. Trip Delay 1–20 seconds.
Ground fault	A line to ground fault.	A current leakage path to ground.	An undetected ground fault can burn through multiple insulation windings, ultimately leading to motor failure.	Motor Insight has ground fault protection capability down to 0.15 amps estimated from the existing three-phase CTs using the residual current method. That is, the three-phase current signals should sum to zero unless a ground fault (GF) condition is present. In the case of a GF, Motor Insight can alarm, trip the starter, or trip an alternative relay that can be used to shunt trip a breaker or light up a warning light. GF current can also be monitored in real-time through the advanced monitoring capabilities. **Note:** GF settable thresholds vary with motor FLA. 0.15A may not be available in all cases.
Imbalanced phases (voltage and current)	Uneven voltage or currents between phases in a three-phase system.	When a three-phase load is powered with a poor quality line, the voltage per phase may be imbalanced.	Imbalanced voltage causes large imbalanced currents and as a result this can lead to motor stator windings being overloaded, causing excessive heating, reduced motor efficiency and reduced insulation life.	Provides two protection settings that address this problem. The user can choose to set current imbalance thresholds or voltage imbalance thresholds, each of which can trip the starter. Additionally, both of these may be monitored through Motor Insight's advanced monitoring capabilities, allowing the customer to notice in real-time when and where a condition is present.
Phase loss—current (single-phasing)	One of the three-phase current is not present.	Multiple causes, loose wire, improper wiring, grounded phase, open fuse, etc.	Single-phasing can lead to unwanted motor vibrations in addition to the results of imbalanced phases as listed above.	Fixed protective setting that takes the starter offline if a phase drops below 60% of the other two phases.
Phase rotation (phase-reversal)	Improper wiring, leading to phases being connected to the motor improperly.	A miswired motor. Inadvertent phase-reversal by the utility.	Phase-reversal can cause unwanted directional rotation of a motor. In the event that the load attached to the motor can only be driven in one direction, the result could be significant mechanical failure and/or injury to an operator.	Configurable phase protection, allowing the user to define the phase sequencing intended for that application. If no phase sequence is required, the user has the ability to disable this feature.
Frequency variance	When line frequency is inconsistent.	Malfunctioning alternator speed regulator, or poor line quality caused by an overload of a supply powered by individual sources.	Variations in frequency can cause increases in losses, decreasing the efficiency of the motor. In addition, this can result in interference with synchronous devices.	Advanced monitoring capabilities allow the user to monitor frequency in real-time.

Table 4.2-3. Advanced Overload Education (Continued)

Description	Definition	Source	Result	C441 Motor Insight Protection
Load Protection				
Undercurrent or low power	Average rms current provided to the motor falls below normal operating conditions.	Undercurrent is usually associated with a portion of the user's load disappearing. Examples of this would be a broken belt, a dry-pump (low suction head) or a dead-headed centrifugal pump.	If undercurrent goes undetected, a mechanical failure can and has occurred. In the case of a pump, running a pump dry or running a pump in a dead-headed condition can cause excessive heating, damaging expensive seals and breaking down desired fluid properties.	Motor Insight has two protection settings to detect this: undercurrent and low power. Low power is a more consistent way of ensuring detection as power is linear with motor load, where as current is not. An unloaded motor may draw 50% of its rated current, but the power draw will be less than 10% of rated power due to a low power factor.
High power	The motor load is drawing more power than it should at normal operating conditions.	This is typical of batch processing applications where several ingredients flow into a mixer. When a substance's consistency changes and viscosity increases from what is expected, the motor may use more power to blend the mixture. Out-of-tolerance conditions can be detected using the High Power and Low Power settings.	If a high-power fault goes undetected, the result may be a batch of material that does not meet specification.	Monitors the three-phase real power. If the real power value is estimated above the set threshold for the set length of time, a fault is detected and the overload will trip the starter. Additionally, power can be monitored in real-time.
Line Protection				
Overvoltage	When the line voltage to the motor exceeds the specified rating.	Poor line quality.	An overvoltage condition leads to a lower than rated current draw and a poor power factor. A trip limit of 110% of rated voltage is recommended. Overvoltage can also lead to exceeding insulation ratings.	Monitors the maximum rms value of the three-phase voltages. If the rms value rises above the set threshold for the set length of time, a fault is detected and the overload can trip the starter or send and display an alarm of the condition. All line-related faults have an "alarm-no-trip" mode.
Undervoltage	When the line voltage to the motor is below the specified rating.	Poor line quality.	An undervoltage condition leads to excessive current draw. This increases the heating of the motor windings and can shorten insulation life. A trip limit set to 90% of rated voltage is recommended.	Monitors the minimum rms value of the three-phase voltages. If the rms value drops below the set threshold for the set length of time, a fault is detected and the overload can trip the starter or send and display an alarm of the condition. All line-related faults have an "alarm-no-trip" mode.
Power-up delay	Allows for starting motors and loads in a deliberate fashion.	When there is a power failure, or power cycle, multiple loads come online simultaneously.	Multiple loads starting simultaneously can cause sags affecting the operation of devices that may prevent successful startup. If power is lost to a motor driving a pump, it may be necessary to delay a restart to allow the pump to come to a complete stop to prevent starting a motor during backspin.	Configurable to delay closing the fault relay on power-up. For each Motor Insight controlling a motor, a different setting can be programmed, helping to maintain the integrity of your line power.

Accessories

Modbus Communication Module

The C441 Motor Insight Modbus Communication Module is a side-mounted device providing Modbus communication capability to the C441 Motor Insight overload relay.

The Modbus Communication Module with I/O provides communication, monitoring and control for the C441 Motor Insight overload relay.

Features and Benefits

- The Modbus communication module is capable of baud rates up to 115K
- The Modbus address and baud rate configuration can be easily changed using the Motor Insight user interface (C441M only)
- Modbus address and baud rate are set via convenient DIP switches (C441N and C441P); LEDs are provided to display Modbus traffic
- Configuration with common Modbus configuration tools
- Terminals
  - Unique locking mechanism provides for easy removal of the terminal block with the field wiring installed
  - Each terminal is marked for ease of wiring and troubleshooting
- Selectable I/O assemblies
  - 4IN/2OUT
  - Signal types include 24 Vdc I/O and 120 Vac I/O
  - Each I/O module is optically isolated between the field I/O and the network adapter to protect the I/O and communication circuits from possible damage due to transients and ground loops
  - Input Module features a user-definable input debounce, which limits the effects of transients and electrical noise
  - Output Module supports a user-definable safe state for loss of communication; hold last state, ON or OFF

Table 4.2-4. Modbus Communication Module

Description		I/O	Catalog Number
 Modbus Module	Modbus Communication Module	None	**C441M**
 Modbus with I/O Module	Modbus Communication Module 4IN/2OUT	120 Vac	**C441N**
	Modbus Communication Module 4IN/2OUT	24 Vdc	**C441P**

DeviceNet Communication Modules

The DeviceNet Communication Module provides monitoring and control for the Motor Insight overload relay from a single DeviceNet node. These modules also offer convenient I/O in two voltage options, 24 Vdc and 120 Vac.

Features and Benefits

- Communication to DeviceNet uses only one DeviceNet MAC ID
- Configuration
  - DeviceNet MAC ID and Baud rate are set via convenient DIP switches with an option to set from the network
  - Advanced configuration available using common DeviceNet tools
- Terminals
  - Unique locking mechanism provides for easy removal of the terminal block with the field wiring installed
  - Each terminal is marked for ease of wiring and troubleshooting
- Selectable I/O assemblies
  - 4IN/2OUT
  - Signal types include 24 Vdc I/O and 120 Vac I/O
  - Each I/O module is optically isolated between the field I/O and the network adapter to protect the I/O and communication circuits from possible damage due to transients and ground loops
  - Input Module features a user-definable input debounce, which limits the effects of transients and electrical noise
  - Output Module supports a user-definable safe state for loss of communication; hold last state, ON or OFF
- Combined status LED

Table 4.2-5. DeviceNet Modules

	Description	I/O	Catalog Number
 DeviceNet Module	DeviceNet Communication Module	120 Vac	**C441K**
	DeviceNet Communication Module	24 Vdc	**C441L**

PROFIBUS Communication Module

The C441 Motor Insight PROFIBUS Communication Module is a side-mounted device providing PROFIBUS communication capability to the C441 Motor Insight overload relay.

The PROFIBUS Communication Module with I/O provides communication, monitoring and control for the C441 Motor Insight overload relay.

Features and Benefits

- The PROFIBUS communication module is capable of baud rates up to 12 Mb
- PROFIBUS address is set via convenient DIP switches (C441Q and C441S); LEDs are provided to display PROFIBUS status
- Intuitive configuration with common PROFIBUS configuration tools
- Terminals
  - Unique locking mechanism provides for easy removal of the terminal block with the field wiring installed
  - Each terminal is marked for ease of wiring and troubleshooting
- Selectable I/O assemblies
  - 4IN/2OUT
  - Signal types include 24 Vdc I/O and 120 Vac I/O
  - Each I/O module is optically isolated between the field I/O and the network adapter to protect the I/O and communication circuits from possible damage due to transients and ground loops
  - Input Module features a user-definable input debounce, which limits the effects of transients and electrical noise
  - Output Module supports a user-definable safe state for loss of communication; hold last state, ON or OFF

Table 4.2-6. PROFIBUS Communication Module

Description		I/O	Catalog Number
 PROFIBUS with I/O Module	PROFIBUS Communication Module 4IN/2OUT	120 Vac	**C441S**
	PROFIBUS Communication Module 4IN/2OUT	24 Vdc	**C441Q**

4

Approximate Dimensions in Inches (mm)

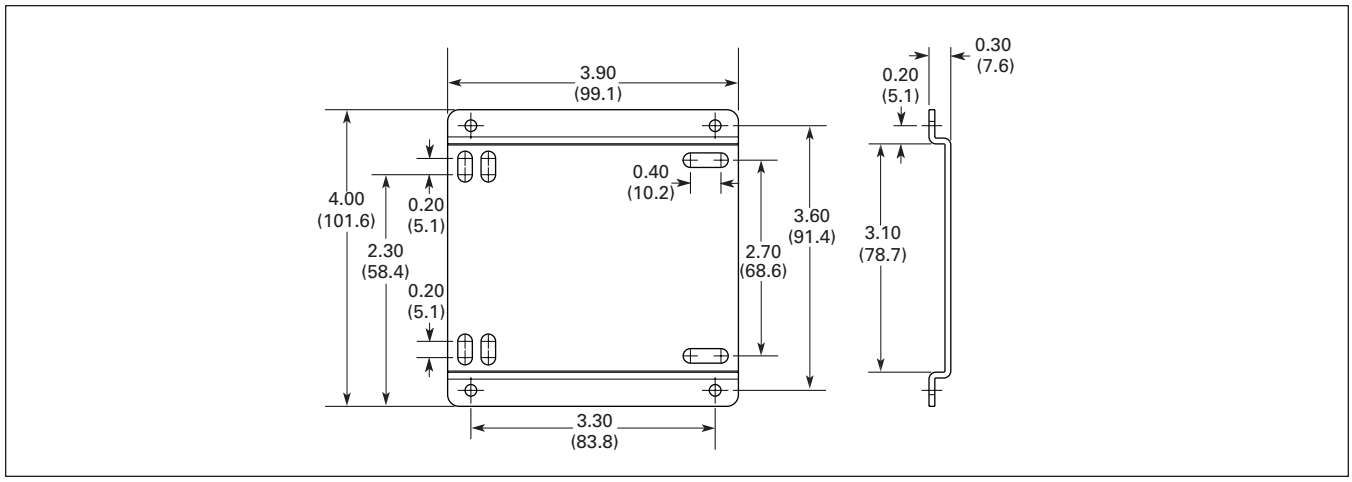


Figure 4.2-1. C441 Motor Insight Conversion Plate

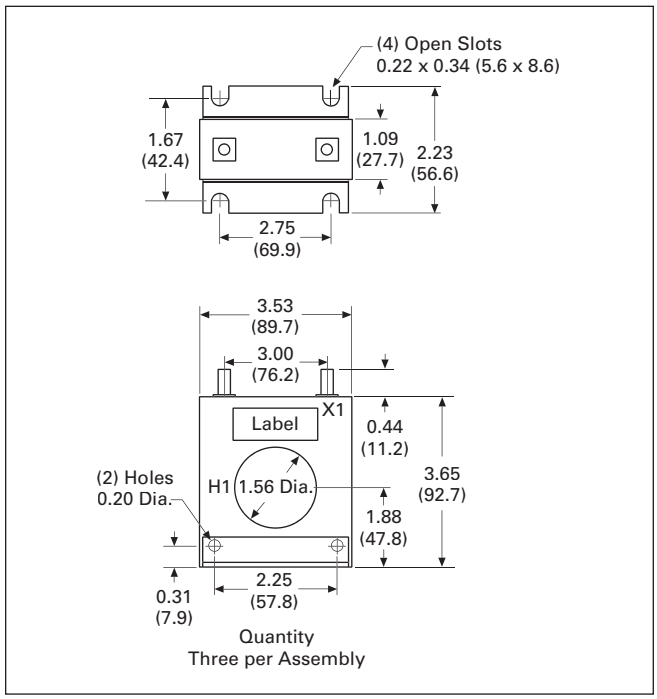


Figure 4.2-2. Applicable for C441CTKIT150, C441CTKIT300 and C441CTKIT600

MP-3000
Motor Protection Relay

MP-3000 Motor Protection Relay

General Description

Eaton's MP-3000 motor protection relay is a multi-functional microprocessor-based protective relay for the protection of any size motor at all voltage levels. It is most commonly applied on medium voltage starters and on critical or larger motors. The MP-3000 relay is a current only device that provides complete and reliable motor protection, monitoring and starting control functions.

The MP-3000 motor protection relay is available in either a fixed mount, semi-flush case or in a semi-flush quick-release drawout case. Both housings are compact and fit a standard IQ cutout.

The optional quick-release drawout case features two-stage contact disconnection and self-shorting CT circuit terminals. A spare self-shorting terminal pair is available for use as relay removal alarm or for continuous motor operation (non-failsafe mode) on relay removal. The optional communication module is externally mounted on the fixed mount case and internally mounted in the drawout case.

The MP-3000 motor protection relay has three phase and one ground current inputs. Both a 5A and 1A version are available. The ground protection and metering functions can be used with either a zero sequence ground CT or from the residual connection of the phase CTs. The zero sequence ground CT provides greater ground fault sensitivity than the residual connection. The relay is programmable for 60 Hz or 50 Hz operation.

The MP-3000 motor protection relay has two discrete inputs, four Form C (1NO and 1NC) contacts and one 4 to 20 mA analog output. The relay provides maximum user flexibility to configure the I/O. All inputs and outputs (except for the trip output) are user-programmable. In addition, the relay has 10 LEDs for the indication of protection on, program mode, monitor mode, view setting mode, history mode, log mode, trip, alarm, auxiliary 1 and auxiliary 2 operation. A test page in the program mode provides display indication of the discrete input states and testing of the output relays, target LEDs and analog circuit.

A user-friendly operator interface and display provides quick access to the settings, monitored values, motor history and operational logs. Large LED alphanumeric character display provides easy viewing from any angle in any light. Simple keypad operation provides quick and easy navigation through all settings and stored data. The program mode and emergency override buttons are access restricted via a latched cover which can be sealed if required. An integrated help function provides an online description display of functions, abbreviations and operations.

Optimum Motor Protection

The MP-3000 motor protection relay has been designed for maximum motor operation and protection. It permits running the motor as close to its design limits while protecting it against excessive heating and damaging overload conditions. The MP-3000 field proven protection algorithms were developed based on motor designs and operating parameters for optimum operation and protection while minimizing nuisance tripping.

The MP-3000 motor protection relay uses a protection algorithm and measurement technique based on proven positive and negative (unbalance) sequence current sampling and true rms calculations.

Features

General

- Microprocessor-based
- Self diagnostics
- User-friendly interface
- Large LED display
- Built-in help program
- Built-in test mode
- LED mode and target indication
- Remote communications
- Programmable discrete inputs
- Programmable outputs

Protection

- I^2t overload protection (49/51)
- Locked rotor (49S/51)
- Ultimate trip current (51)
- Negative sequence phase unbalance (46)
- Instantaneous overcurrent (50)
- Ground fault protection (50G)
- RTD trip and alarm with URTD module (49/38)
- Underload trip (37)
- Starts per time (66)
- Jam or stall (51R)
- Auto or manual reset (86)
- Failsafe or non-failsafe trip modes

Alarming

- Ground fault
- I^2t overload
- Jam/stall
- Underload
- Phase unbalance

Control

- Transition for reduced voltage starts:
  - Transition on current level
  - Transition on time
  - Transition on current level or time
  - Transition on current level and time
- Incomplete sequence monitoring
- Permits number of cold starts
- Limits number of starts per time
- Time between starts
- Anti-backspin time delay
- Mechanical load shedding
- Zero speed switch for long acceleration motors
- Motor stop input for synchronous motor applications
- Remote trip input
- Differential trip input
- Emergency override

Monitoring Functions

- Motor currents:
  - Average current (I ave)
  - Individual phase and ground current in primary amperes
  - % of full load
  - % phase unbalance
- RTD temperatures:
  - Individual winding
  - Motor bearing
  - Load
  - Auxiliary temperatures
- Motor conditions:
  - % of I^2t thermal bucket
  - Time before start
  - Remaining starts allowed
  - Oldest start time

History

- Motor history:
  - Operational counter
  - Run time
  - Highest starting and running currents
  - Highest % phase unbalance
  - Maximum winding, bearing and load RTD temperatures
  - Number of emergency overrides
- Trip history (number of trips):
  - Ground faults
  - Overloads
  - Instantaneous overcurrent
  - JAM
  - Underload
  - Phase unbalance
  - RTDs
  - Phase reversal
  - Incomplete sequence
  - Remote, differential
  - Communication
  - Starts exceeded
  - Time between starts
  - Transition
- Alarms history (number of alarms):
  - Ground faults
  - Overloads
  - JAM
  - Underload
  - Phase unbalance
  - RTDs
  - Starts exceeded
- Total history (record which cannot be reset):
  - Total trips
  - Run time
  - Operations count

Logging

- Log book (chronological list of last 100 events with date and time stamp)
- Event log (detailed information of last 20 trips and alarms with date and time stamp)
- Start log (data on most recent four starts with date and time stamp)

User Interface

The MP-3000 motor protection relay has a user-friendly interface that makes it easy to retrieve important information or make setting changes. LEDs provide visual indication of display and keypad mode. The push-buttons are clearly labeled and quickly access the desired information.

Protection Functions

The MP-3000 motor protection relay provides protection against motor overloads, short circuits and abnormal operating conditions.

I^2t Overload

Motor overloads are typically limited by the rotor thermal capabilities but the measuring quantities are from the stator. This requires accurate measurements and good motor thermal models to provide reliable protection.

The MP-3000 motor protection relay uses a field proven measurement and motor thermal protection model. The relay samples the current waveforms 36 times per cycle providing accurate measurements of the positive and negative sequence currents. The negative sequence component of current causes greater heating effect on the rotor and has a greater impact on the thermal model in the relay. This same algorithm has been used to protect thousands of motors since 1984.

The MP-3000 motor protection relay overload protection is easy to set and apply. Simply input motor nameplate information and CT ratios and the characteristic is automatically set.

When using the MP-3000 motor protection relay, it is recommended that the ratio of CT primary rating to the motor full load amperes (CT Pri/Motor FLA) is selected to fall between 0.25 and 1.5. The thermal model adapts its tripping characteristics if RTDs are connected.

Instantaneous Overcurrent

The MP-3000 motor protection relay provides an instantaneous phase overcurrent function to trip the motor for high fault current levels. This function can be disabled and has an adjustable time delay on starting to avoid nuisance tripping on inrush.

Phase Unbalance Protection

Motor supply circuits are often fed through fuses and can be run with a single-phase fuse blown. The motor may still see three-phase voltage but will only have current on two phases, referred to as single-phasing the motor. The MP-3000 motor protection relay measures the current unbalance and can be used to alarm or trip the motor before damage occurs. Pickup, start and run timers and a separate alarm setting are provided.

Ground Fault Protection

A separate circuit measures ground fault current. A ground CT is recommended for more sensitive protection against winding fault ground. The relay ground circuit can be connected residually from the three-phase CTs. The ground fault protection has pickup and time delay set points or can be disabled.

JAM Protection

The user-selectable JAM function protects motors that are running against a sudden mechanical jam or stall condition. The common application is on motors used on crushers, chippers or conveyors. It detects an increase of motor current to a level above full load. Pickup, start and run timers and a separate alarm setting are provided.

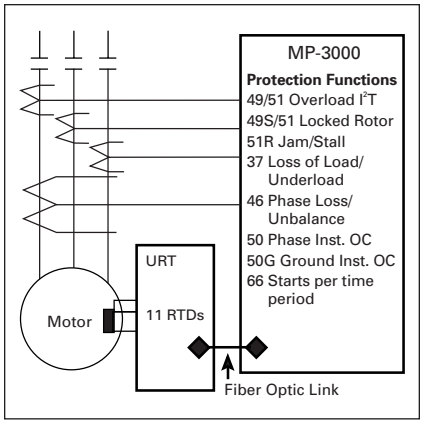


Figure 4.2-3. MP-3000 Motor Protection Relay Functions

Underload Protection

The user-selectable underload function is used to detect the loss of load on the motor. Coupling failure is a common cause for loss of load. Pickup, start and run timers and a separate alarm setting are provided.

Reduced Voltage Starting

Eaton's MP-3000 motor protection relay provides a transition and incomplete sequence function for reduced voltage starting. The user can select to transition based on the current level or on time.

Anti-Backspin

For certain applications, for example, pumping fluid up a pipe, the motor may be driven backward for a period of time after it stops. The MP-3000 relay provides an anti-backspin timer to prevent starting the motor while it is spinning in the reverse direction. The timer begins counting from the moment a stop is declared by the relay.

Start Control Timers

Motors typically have limits to the number of cold starts, hot starts, starts per time period and time between starts that are permitted without damage. The MP-3000 motor protection relay incorporates these timers to prevent starting the motor beyond its capabilities.

Load Shedding

The MP-3000 motor protection relay provides a mechanical load shedding feature that can be used to control an upstream process. The load shedding function closes a contact on an overload condition to control an upstream process from adding more load until the overload condition is gone.

Emergency Override

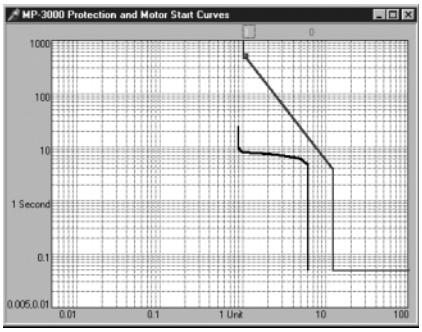
The MP-3000 motor protection relay has a user-programmable feature that will let the operator reset the start control timers and thermal overload bucket. This function is intended for use in emergency conditions only and may result in motor damage or failure.

Long Acceleration Motors

Large motors with high inertia loads may experience starting currents that exceed the locked rotor current and time. The MP-3000 motor protection relay has logic and provisions for a zero speed switch input to differentiate between a stall and start condition. If the motor is spinning then the relay will not trip on the normal locked rotor time allowing the motor to start.

Remote/Differential Trip

One of the binary inputs can be programmed to accept a contact input from a separate differential relay, such as the MD-3000 or other device to trip the motor. This provides local and remote target information and uses the trip contacts of the MP-3000 motor protection relay. It will also record and log the motor information at the time of the trip.



Motor Starting Profile Time/Current Chart

Motor Starting Profile

The MP-3000 relay records the average current of the motor for the last two starts. This information is available over the communications port. The motor current can then be plotted and compared to the motor overload protection curve. Available in PowerPort or the PowerNet Event Viewer Client.

4

Product Selection

Table 4.2-7. MP-3000

Description	Catalog Number
MP-3000 drawout, 5A with RS-232 MP-3000 drawout, INCOM, 5A with RS-232 MP-3000 drawout, Modbus, 5A with RS-232	**MP3011** **MP3012** **MP3013**
MP-3000 drawout, DeviceNet, 5A with RS-232 MP-3000 drawout, 1A with RS-232 MP-3000 drawout, INCOM, 1A with RS-232	**MP3014** **MP3111** **MP3112**
MP-3000 drawout, Modbus, 1A with RS-232 MP-3000 drawout, DeviceNet, 1A with RS-232 MP-3000 fixed case, 5A with RS-232	**MP3113** **MP3114** **MP3010**
MP-3000 fixed case, INCOM, 5A with RS-232 MP-3000 fixed case, Modbus, 5A with RS-232 MP-3000 fixed case, DeviceNet, 5A with RS-232	**MP3010-INCOM** **MP3010MODBUS** **MP3010DEVICEN**
MP-3000 fixed case, 1A with RS-232 MP-3000 fixed case, INCOM, 1A with RS-232 MP-3000 fixed case, Modbus, 1A with RS-232	**MP3110** **MP3110-INCOM** **MP3110MODBUS**
MP-3000 fixed case, DeviceNet, 1A with RS-232 MP-3000 fixed case, INCOM, 5A with RS-232, URTD MP-3000 fixed case, Modbus, 5A with RS-232, URTD	**MP3110DEVICEN** **MP3010VPI** **MP3010VPM**
MP-3000 fixed case, DeviceNet, 5A with RS-232, URTD MP-3000 fixed case, INCOM, 1A with RS-232, URTD MP-3000 fixed case, Modbus, 1A with RS-232, URTD MP-3000 fixed case, DeviceNet, 1A with RS-232, URTD	**MP3010VPD** **MP3110VPI** **MP3110VPM** **MP3110VPD**

Technical Data and Specifications

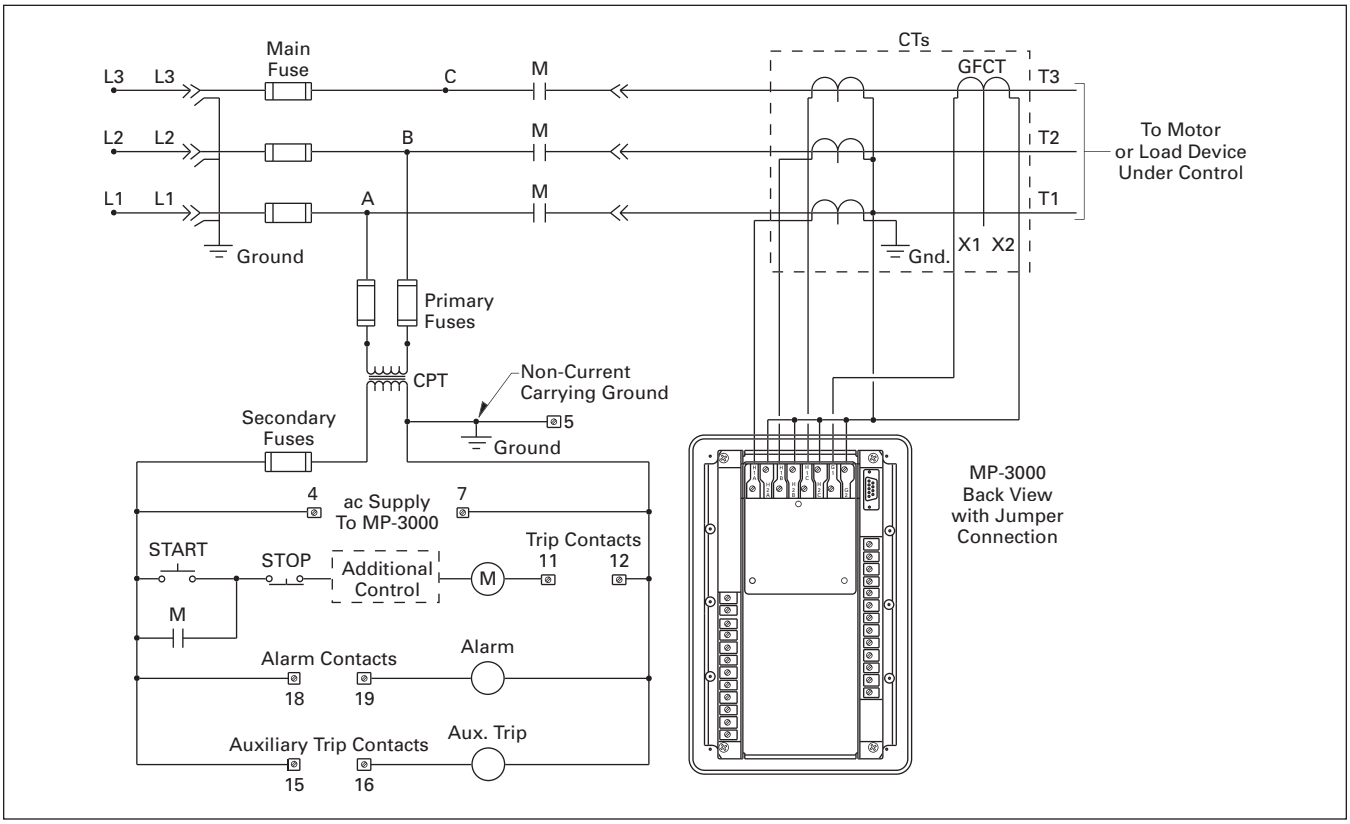


Figure 4.2-4. MP-3000 Wiring

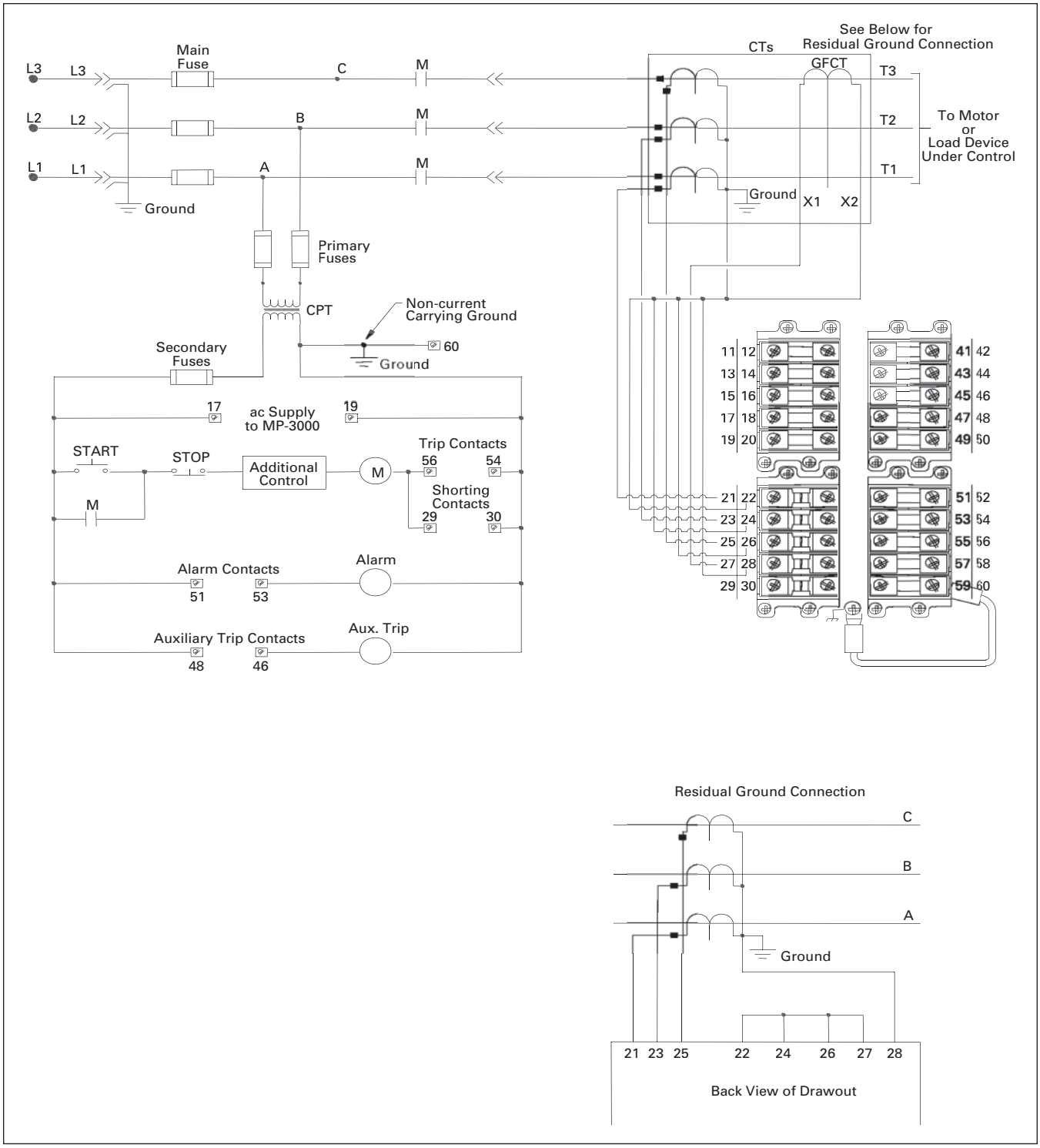


Figure 4.2-5. MP-3000 Drawout Typical CT Circuits and Motor Control Wiring

Standards, Certifications and Ratings

Table 4.2-8. MP-3000 Specifications

Control Power

Nominal rating:	120 Vac or 240 Vac (+10%, –25%)
Frequency:	50 or 60 Hz
Power use:	20 VA maximum URTD: 6 VA maximum IPONI: 1 VA maximum
Operating range:	120 Vac: 90–132 Vac 240 Vac: 180–264 Vac
Ride through time:	30 cycles at nominal Vac

Current Inputs

Nominal (I_n):	1A or 5A
CT rating:	2 x I_n continuous 40 x I_n for 1 second
Phase burden:	VA at I_n
Ground burden:	VA at I_n
Saturation:	x I_n

Metering Accuracy

Phase current:	±1% of I_n (5%–100%)
Ground current:	±1.5% of I_n (0%–55%)

Discrete Inputs

Number of inputs:	2 Programmable
Rating:	1.2 VA at 120 Vac Maximum OFF = 36 Vac Minimum ON = 86 Vac

Output Contacts

Number of outputs:	4 Form C, Programmable
Momentary:	Make 30A AC/DC for 0.25 second
(Resistive)	Break 0.25A at 250 Vdc Break 5A at 120/240 Vac
Continuous:	5A at 120/240 Vac 5A at 30 Vdc

Analog Output

Rating:	± 4 to 20 mA Programmable
Maximum load:	1K ohm
Accuracy:	1%

Motor Overload Protection (I^2t)

Full load amperes:	10 to 3000A
Locked rotor current:	300% to 1200% FLA
Locked rotor time:	1 to 120 seconds
Ultimate trip current:	85% to 150% FLA
Phase CT ratio:	10 to 4000: I_n
Ground CT ratio:	10 to 4000: I_n
Timing accuracy:	± 2.5% or ±30 ms For I > 1.1x U.T.C.

Trip Setting Range

Ground fault (GF):	Off, 2% to 55% CT ratio
GF Start and run time delay:	2 to 60 cycles
Timer accuracy:	±20 ms
Instantaneous O.C.:	Off, 300% to 1600% FLA
IOC start time delay:	0 to 60 cycles
Timer accuracy:	±20 ms
JAM trip:	Off, 100% to 1200% FLA
Underload trip:	Off, 1% to 90% FLA
Phase unbalance trip:	Off, 4% to 40% I_{neg}/I_{pos} 0 to 1200 seconds

JAM, Underload and Phase Unbalance Time Delay

Start delay timers:	0 to 120 seconds
Run delay timers:	0 to 240 seconds
Timer accuracy:	±0.5% +100 ms

Alarm Setting Range

Ground fault:	Off, 2% to 75% CT ratio
Overload I^2t:	Off, 60% to 99% I^2t
JAM:	Off, 100% to 1200% FLA
Underload:	Off, 1% to 90% FLA
Phase unbalance:	Off, 4% to 40% I_{neg}/I_{pos}
Run delay timers:	0 to 240 seconds

Logging

Log book:	100 events
Log event:	20 trips and alarms
Log start:	Last 4 starts
Start profile:	Last start (communication only)
History records:	Motor, trips, alarms and permanent records

Start Control Functions

Starts per time:	Off, 1 to 10 starts
Time for starts per time:	Off, 1 to 240 minutes
Time between starts:	Off, 1 to 240 minutes
Number of cold starts:	1 to 5 starts
Motor transition current:	10% to 300% FLA
Time for transition:	0 to 1200 seconds
Inc. sequence timer:	Off, 1 to 240 seconds
Long acceleration timer:	Off, 1 to 1200 seconds
Anti-backspin timer:	Off, 1 to 3600 minutes

Clock

Accuracy:	±1 minute/month at 25°C

Communications

DPONI

Type:	5-wire
Baud rate:	500K, 250K, 125K, Auto
Protocol:	DeviceNet
Functions:	Read/write set points Read metered values Read trip/alarms Read events/history View starting profile

IPONI

Type:	2-wire, FSK
Baud rate:	1200 or 9600 baud
Protocol:	INCOM
Functions:	Read/write set points Read metered values Read trip/alarms Read events/history View starting profile

MPONI

Type:	5-wire, 485
Baud rate:	1200 or 9600 baud
Protocol:	Modbus RTU
Functions:	Read/write set points Read metered values Read trip/alarms Read events/history View starting profile

Environmental Ratings

Operating:	Temperature: –20°C to +60°C
Storage:	Temperature: –45°C to +85°C
Humidity:	0% to 95% (noncondensing)

Dimensions in Inches (mm)

Height:	10.25 (260.4)
Width:	6.72 (170.7)
Depth:	3.70 (94.0)
Weight:	7 lbs (3 kg)

UL Recognized

File Number E154862
UL 1053
ANSI C37.90, C37.90.1, C37.90.2
CSA

MP-4000 Motor Protection Relay with Voltage Inputs

MP-4000 Motor Protection Relay

General Description

Eaton's MP-4000 motor protection relay is a multi-functional micro-processor-based protective relay for the protection of any size motor at all voltage levels. It is most commonly applied on medium voltage starters and on critical or larger motors. The MP-4000 relay provides complete and reliable motor protection, monitoring and starting control functions.

The MP-4000 motor protection relay is available in either a fixed mount, semi-flush case or in a semi-flush quick-release drawout case.

The optional quick-release drawout case features two-stage contact disconnection and self-shorting CT circuit terminals. A spare self-shorting terminal pair is available for use as relay removal alarm or for continuous motor operation (non-failsafe mode) on relay removal. The optional communication module is externally mounted on the fixed mount case and internally mounted in the drawout case.

The MP-4000 motor protection relay has three phase and one ground current inputs. The MP-4000 also has three voltage inputs. Both a 5A and 1A version are available. The ground protection and metering functions can be used with either a zero sequence ground CT or from the residual connection of the phase CTs. The zero sequence ground CT provides greater ground fault sensitivity than the residual connection. The relay is programmable for 60 Hz or 50 Hz operation.

The MP-4000 motor protection relay has two discrete inputs, four Form C (1NO and 1NC) contacts and one 4 to 20 mA analog output. The relay provides maximum user flexibility to configure the I/O. All inputs and outputs (except for the trip output) are user-programmable. In addition, the relay has 10 LEDs for the indication of protection on, program mode, monitor mode, view setting mode, history mode, log mode, trip, alarm, auxiliary 1 and auxiliary 2 operation. A test page in the program mode provides display indication of the discrete input states and testing of the output relays, target LEDs and analog circuit.

A user-friendly operator interface and display provides quick access to the settings, monitored values, motor history and operational logs. Large LED alphanumeric character display provides easy viewing from any angle in any light. Simple keypad operation provides quick and easy navigation through all settings and stored data. The program mode and emergency override buttons are access restricted via a latched cover which can be sealed if required. An integrated help function provides an online description display of functions, abbreviations and operations.

Optimum Motor Protection

The MP-4000 motor protection relay has been designed for maximum motor operation and protection. It permits running the motor as close to its design limits while protecting it against excessive heating and damaging overload conditions. The MP-4000 field proven protection algorithms were developed based on motor designs and operating parameters for optimum operation and protection while minimizing nuisance tripping.

The MP-4000 motor protection relay uses a protection algorithm and measurement technique based on proven positive and negative (unbalance) sequence current sampling and true rms calculations.

Features

General

- Microprocessor-based
- Self diagnostics
- User-friendly interface
- Large LED display
- Built-in help program
- Built-in test mode
- LED mode and target indication
- Remote communications
- Programmable discrete inputs
- Programmable outputs

Protection

- I^2t overload protection (49/51)
- Locked rotor (49S/51)
- Ultimate trip current (51)
- Undervoltage (27)
- Overvoltage (59)
- Under power (32)
- Negative sequence phase unbalance (46)
- Negative sequence voltage unbalance (47)
- Instantaneous overcurrent (50)
- Ground fault protection (50G)
- RTD trip and alarm with URTD module (49/38)
- Underload trip (37)
- Power factor (55)
- Starts per time (66)
- Jam or stall (51R)
- Auto or manual reset (86)
- Failsafe or non-failsafe trip modes

Alarming

- Ground fault
- I^2t overload
- Jam/stall
- Underload
- Phase unbalance
- Voltage unbalance

4

General Description—MP-4000

Control

- Transition for reduced voltage starts:
  - ❑ Transition on current level
  - ❑ Transition on time
  - ❑ Transition on current level or time
  - ❑ Transition on current level and time
- Incomplete sequence monitoring
- Permits number of cold starts
- Limits number of starts per time
- Time between starts
- Anti-backspin time delay
- Mechanical load shedding
- Zero speed switch for long acceleration motors
- Motor stop input for synchronous motor applications
- Remote trip input
- Differential trip input
- Emergency override

Monitoring Functions

- Metering
- RTD temperatures:
  - ❑ Individual winding
  - ❑ Motor bearing
  - ❑ Load
  - ❑ Auxiliary temperatures
- Motor conditions:
  - ❑ % of I^2t thermal bucket
  - ❑ Time before start
  - ❑ Remaining starts allowed
  - ❑ Oldest start time

History

- Motor history:
  - ❑ Operational counter
  - ❑ Run time
  - ❑ Highest starting and running currents
  - ❑ Highest % current unbalance
  - ❑ Highest % voltage unbalance
  - ❑ Highest starting and running voltages
  - ❑ Maximum winding, bearing and load RTD temperatures
  - ❑ Number of emergency overrides
- Trip history (number of trips):
  - ❑ Ground faults
  - ❑ Overloads
  - ❑ Instantaneous overcurrent
  - ❑ JAM
  - ❑ Underload
  - ❑ Phase unbalance
  - ❑ Voltage unbalance
  - ❑ Overvoltage
  - ❑ Undervoltage
  - ❑ Overfrequency
  - ❑ Underfrequency
  - ❑ Under power
  - ❑ Power factor
  - ❑ RTDs
  - ❑ Phase reversal
  - ❑ Incomplete sequence
  - ❑ Remote, differential
  - ❑ Communication
  - ❑ Starts exceeded
  - ❑ Time between starts
  - ❑ Transition
- Alarms history (number of alarms):
  - ❑ Ground faults
  - ❑ Overloads
  - ❑ JAM
  - ❑ Underload
  - ❑ Current unbalance
  - ❑ Voltage unbalance
  - ❑ Overvoltage
  - ❑ Undervoltage
  - ❑ Overfrequency
  - ❑ Underfrequency
  - ❑ Under power
  - ❑ Power factor
  - ❑ RTDs
  - ❑ Starts exceeded
- Total history (record which cannot be reset):
  - ❑ Total trips
  - ❑ Run time
  - ❑ Operations count

Logging

- Log book (chronological list of last 100 events with date and time stamp)
- Event log (detailed information of last 20 trips and alarms with date and time stamp)
- Start log (data on most recent four starts with date and time stamp)

User Interface

The MP-4000 motor protection relay has a user-friendly interface that makes it easy to retrieve important information or make setting changes. LEDs provide visual indication of display and keypad mode. The push-buttons are clearly labeled and quickly access the desired information.

Protection Functions

The MP-4000 motor protection relay provides protection against motor overloads, short circuits and abnormal operating conditions.

I^2t Overload

Motor overloads are typically limited by the rotor thermal capabilities but the measuring quantities are from the stator. This requires accurate measurements and good motor thermal models to provide reliable protection.

The MP-4000 motor protection relay uses a field-proven measurement and motor thermal protection model. The relay samples the current waveforms 36 times per cycle providing accurate measurements of the positive and negative sequence currents. The negative sequence component of current causes greater heating effect on the rotor and has a greater impact on the thermal model in the relay. This same algorithm has been used to protect thousands of motors since 1984.

The MP-4000 motor protection relay overload protection is easy to set and apply. Simply input motor nameplate information and CT ratios and the characteristic is automatically set.

When using the MP-4000 motor protection relay, it is recommended that the ratio of CT primary rating to the motor full load amperes (CT Pri/Motor FLA) is selected to fall between 0.25 and 1.5. The thermal model adapts its tripping characteristics if RTDs are connected.

Instantaneous Overcurrent

The MP-4000 motor protection relay provides an instantaneous phase overcurrent function to trip the motor for high fault current levels. This function can be disabled and has an adjustable time delay on starting to avoid nuisance tripping on inrush.

Product Selection

Table 4.2-9. MP-4000 Ordering Information

Description	Catalog Number
MP-4000 drawout, 5A with RS-232	**MP4011**
MP-4000 drawout, INCOM, 5A with RS-232	**MP4012**
MP-4000 drawout, Modbus, 5A with RS-232	**MP4013**
MP-4000 drawout, DeviceNet, 5A with RS-232	**MP4014**
MP-4000 drawout, 1A with RS-232	**MP4111**
MP-4000 drawout, INCOM, 1A with RS-232	**MP4112**
MP-4000 drawout, Modbus, 1A with RS-232	**MP4113**
MP-4000 drawout, DeviceNet, 1A with RS-232	**MP4114**
MP-4000 fixed case, 5A with RS-232	**MP4010**
MP-4000 fixed case, INCOM, 5A with RS-232	**MP4010INCOM**
MP-4000 fixed case, Modbus, 5A with RS-232	**MP4010MODBUS**
MP-4000 fixed case, DeviceNet, 5A with RS-232	**MP4010DEVICEN**
MP-4000 fixed case, 1A with RS-232	**MP4110**
MP-4000 fixed case, INCOM, 1A with RS-232	**MP4110INCOM**
MP-4000 fixed case, Modbus, 1A with RS-232	**MP4110MODBUS**
MP-4000 fixed case, DeviceNet, 1A with RS-232	**MP4110DEVICEN**
MP-4000 fixed case, INCOM, 5A with RS-232, URTD	**MP4010VPI**
MP-4000 fixed case, Modbus, 5A with RS-232, URTD	**MP4010VPM**
MP-4000 fixed case, DeviceNet, 5A with RS-232, URTD	**MP4010VPD**
MP-4000 fixed case, INCOM, 1A with RS-232, URTD	**MP4110VPI**
MP-4000 fixed case, Modbus, 1A with RS-232, URTD	**MP4110VPM**
MP-4000 fixed case, DeviceNet, 1A with RS-232, URTD	**MP4110VPD**

Technical Data and Specifications

Current Unbalance Protection

Motor supply circuits are often fed through fuses and can be run with a single-phase fuse blown. The motor may still see three-phase voltage but will only have current on two phases, referred to as single-phasing the motor. The MP-4000 motor protection relay measures the current unbalance and can be used to alarm or trip the motor before damage occurs. Pickup, start and run timers and a separate alarm setting are provided.

4

Voltage Unbalance Protection

The MP-4000 will calculate negative sequence voltage from three-phase voltages. The presence of negative sequence voltage identifies either a phase unbalance or reverse phase rotation condition. The MP-4000 provides both alarm and trip functionality.

Ground Fault Protection

A separate circuit measures ground fault current. A ground CT is recommended for more sensitive protection against winding fault ground. The relay ground circuit can be connected residually from the three-phase CTs. The ground fault protection has pickup and time delay set points or can be disabled.

Frequency Protection

The MP-4000 provides over/under protection on the Main VT inputs. Each element has an independent threshold and time delay.

Voltage Protection

The MP-4000 voltage protection can be used to generate a trip or alarm if the voltage exceeds (overvoltage 59) a specified threshold for a specific time delay or drops below (undervoltage 27) a specified threshold for a specified time delay. Voltage elements can act on one, two or three phases.

Power Factor

The power factor function in the MP-4000 can be used for many applications. For a synchronous motor, it can be used to indicate field loss. The power factor protection can generate a trip or alarm when the power factor falls between specified thresholds.

JAM Protection

The user-selectable JAM function protects motors that are running against a sudden mechanical jam or stall condition. The common application is on motors used on crushers, chippers or conveyors. It detects an increase of motor current to a level above full load. Pickup, start and run timers and a separate alarm setting are provided.

Underload Protection

The user-selectable underload function is used to detect the loss of load on the motor. Coupling failure is a common cause for loss of load. Pickup, start and run timers and a separate alarm setting are provided.

Reduced Voltage Starting

Eaton's MP-4000 motor protection relay provides a transition and incomplete sequence function for reduced voltage starting. The user can select to transition based on the current level or on time.

Anti-Backspin

For certain applications, for example, pumping fluid up a pipe, the motor may be driven backward for a period of time after it stops. The MP-4000 relay provides an anti-backspin timer to prevent starting the motor while it is spinning in the reverse direction. The timer begins counting from the moment a stop is declared by the relay.

Start Control Timers

Motors typically have limits to the number of cold starts, hot starts, starts per time period and time between starts that are permitted without damage. The MP-4000 motor protection relay incorporates these timers to prevent starting the motor beyond its capabilities.

Load Shedding

The MP-4000 motor protection relay provides a mechanical load shedding feature that can be used to control an upstream process. The load shedding function closes a contact on an overload condition to control an upstream process from adding more load until the overload condition is gone.

Emergency Override

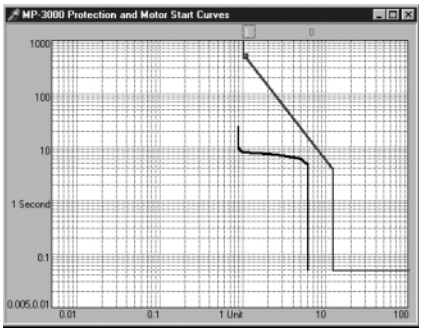
The MP-4000 motor protection relay has a user-programmable feature that will let the operator reset the start control timers and thermal overload bucket. This function is intended for use in emergency conditions only and may result in motor damage or failure.

Long Acceleration Motors

Large motors with high inertia loads may experience starting currents that exceed the locked rotor current and time. The MP-4000 motor protection relay has logic and provisions for a zero speed switch input to differentiate between a stall and start condition. If the motor is spinning then the relay will not trip on the normal locked rotor time allowing the motor to start.

Remote/Differential Trip

One of the binary inputs can be programmed to accept a contact input from a separate differential relay, such as the MD-3000, or other device to trip the motor. This provides local and remote target information and uses the trip contacts of the MP-4000 motor protection relay. It will also record and log the motor information at the time of the trip.



Motor Starting Profile Time/Current Chart

Motor Starting Profile

The MP-4000 relay records the average current of the motor for the last two starts. This information is available over the communications port. The motor current can then be plotted and compared to the motor overload protection curve. Available in PowerPort or the PowerNet Event Viewer Client.

Standards, Certifications and Ratings

Table 4.2-10. MP-4000 Specifications

Control Power

Nominal rating:	120 Vac or 240 Vac (+10%, –25%)
Frequency:	50 or 60 Hz
Power use:	20 VA maximum URTD: 6 VA maximum IPONI: 1 VA maximum
Operating range:	120 Vac: 90–132 Vac 240 Vac:180–264 Vac
Ride through time:	30 cycles at nominal Vac

Current Inputs

Nominal (I_n):	1A or 5A
CT rating:	2 x I_n continuous 40 x I_n for 1 second
Phase burden:	VA at I_n
Ground burden:	VA at I_n
Saturation:	x I_n

Voltage Inputs

Nominal rating:	120 Vac
Operating range:	69 to 150 Vac
Burden:	2 VA

Metering Accuracy

Phase current:	±1% of I_n (5%–100%)
Ground current:	±1.5% of I_n (0%–55%)

Discrete Inputs

Number of Inputs:	2 Programmable
Rating:	1.2 VA at 120 Vac Maximum OFF = 36 Vac Minimum ON = 86 Vac

Output Contacts

Number of outputs:	4 Form C, Programmable
Momentary:	Make 30A AC/DC for 0.25 second
(Resistive)	Break 0.25A at 250 Vdc Break 5A at 120/240 Vac
Continuous:	5A at 120/240 Vac 5A at 30 Vdc

Analog Output

Rating:	±4 to 20 mA Programmable
Maximum load:	1K ohm
Accuracy:	1%

Motor Overload Protection (I^2t)

Full load amperes:	10 to 3000A
Locked rotor current:	300% to 1200% FLA
Locked rotor time:	1 to 120 seconds
Ultimate trip current:	85% to 150% FLA
Phase CT ratio:	10 to 4000: I_n
Ground CT ratio:	10 to 4000: I_n
Timing accuracy:	± 2.5% or ±30 ms For I > 1.1x U.T.C.

Trip Setting Range

Ground fault (GF):	Off, 2% to 55% CT Ratio
GF Start and run time delay:	2 to 60 cycles
Timer accuracy:	± 20 ms
Instantaneous O.C.:	Off, 300% to 1600% FLA
IOC Start time delay:	0 to 60 cycles
Timer accuracy:	±20 ms
JAM trip:	Off, 100% to 1200% FLA
Underload trip:	Off, 1% to 90% FLA
Current unbalance trip:	Off, 4% to 40% I_{neg}/I_{pos} 0 to1200 seconds
Voltage unbalance (47)	
Threshold:	OFF, 1 to 100V
% V2/V1:	4% to 40%
Time delay:	0 to 1200 seconds
Under/overvoltage (27/59)	
Pickup range:	OFF, 10 to 150V
Time delay:	0 to 1200 seconds
Under/overfrequency (81U/81O)	
Pickup range:	Off, 15 to 60 Hz
Time delay:	0 to 60 seconds
Power protection (32)	
Threshold:	OFF, 0.06 to 0.90 *FLA *VT
Time delay:	0 to 1200 seconds
Power factor (55)	
Threshold:	OFF, 0.05 to 0.99
Time delay:	0 to 60 seconds

JAM, Underload and Phase Unbalance Time Delay

Start Delay timers:	0 to 120 seconds
Run Delay timers:	0 to 240 seconds
Timer accuracy:	±0.5% + 100 ms

Alarm Setting Range

Ground fault:	Off, 2% to 75% CT Ratio
Overload I^2t:	Off, 60% to 99% I^2t
JAM:	Off, 100% to 1200% FLA
Underload:	Off, 1% to 90% FLA
Phase unbalance:	Off, 4% to 40% I_{neg}/I_{pos}
Run Delay timers:	0 to 240 seconds

Logging

Log book:	100 events
Log event:	20 trips and alarms
Log start:	Last 4 starts
Start profile:	Last start (communication only)
History records:	Motor, trips, alarms and permanent records

Start Control Functions

Starts per time:	Off, 1 to 10 starts
Time for starts per time:	Off, 1 to 240 minutes
Time between starts:	Off, 1 to 240 minutes
No. of cold starts:	1 to 5 starts
Motor transition current:	10% to 300% FLA
Time for transition:	0 to 1200 seconds
Inc. sequence timer:	Off, 1 to 240 seconds
Long acceleration timer:	Off, 1 to 1200 seconds
Anti-Backspin Timer:	Off, 1 to 3600 minutes

Clock

Accuracy:	±1 minute/month at 25°C

Communications

DPONI

Type:	5-wire
Baud rate:	500K, 250K, 125K, Auto
Protocol:	DeviceNet
Functions:	Read/write set points Read metered values Read trip/alarms Read events/history View starting profile

IPONI

Type:	2-wire, FSK
Baud rate:	1200 or 9600 baud
Protocol:	INCOM
Functions:	Read/write set points Read metered values Read trip/alarms Read events/history View starting profile

MPONI

Type:	5-wire, 485
Baud rate:	1200 or 9600 baud
Protocol:	Modbus RTU
Functions:	Read/write set points Read metered values Read trip/alarms Read events/history View starting profile

Environmental Ratings

Operating:	Temperature: –20°C to +60°C
Storage:	Temperature: –45°C to +85°C
Humidity:	0% to 95% (noncondensing)

Dimensions in Inches (mm)

Height:	10.25 (260.4)
Width:	6.72 (170.7)
Depth:	3.70 (94.0)
Weight:	7 lbs (3 kg)

UL Recognized

File Number E154862
UL 1053
ANSI C37.90, C37.90.1, C37.90.2
CSA

EMR-3000
Motor Protection Relay

EMR-3000

General Description

Eaton's EMR-3000 motor protection relay is a multifunctional microprocessor-based protective relay for the protection of any size motor at all voltage levels. It is most commonly applied on medium voltage or larger motors. The MP-3000 relay is a current only device that provides complete and reliable motor protection, monitoring and starting control functions.

The EMR-3000 motor protection relay has removable terminal blocks, and it has Modbus-RTU communications as standard; and an optional Ethernet port for Modbus-TCP communications.

The EMR-3000 motor protection relay has three-phase and one ground current inputs. It can be used with either 5A or 1A CTs. The ground protection can be used with either a zero sequence ground CT or from the residual connection of the phase CTs. The zero sequence ground CT provides greater ground fault sensitivity than the residual connection. The unit is user programmable for 60 Hz or 50 Hz operation.

The Maintenance Mode password protected soft key, can be used for arc flash mitigation to change to an alternate settings group, set to have instantaneous elements only. The multiple setting groups can also be changed, via communications or a digital input. Flash memory is used for the programming and all settings are stored in nonvolatile memory.

An integral keypad and display is provided for direct user programming and retrieval of data without the need of a computer. 14 programmable LEDs provide quick indication of relay status.

A front port is provided for direct computer connection. An RS-485 communication port on the back is standard for local area networking using Modbus-RTU. An optional Ethernet port and protocols are available.

The EMR-3000 motor protection relay has mass memory for data storage and a real-time clock with 1 ms time resolution. The relay will log 300 sequence of event records, 20 detailed trip logs, minimum/maximum values, load profiles, the five latest start profiles, motor trending, breaker wear information and oscillography data.

The EMR-3000 motor protection relay has four discrete inputs and one fiber optic input, one Form C and two NO programmable contacts, and one Form C healthy contact. It also has an optional 4–20 mA analog output or zone interlocking card. The relay provides maximum user flexibility to configure the I/O. All inputs and outputs (except the healthy output) are user-programmable. The unit also counts with a test mode to force outputs and simulate currents, to facilitate the commissioning of the unit. It can be powered from 19 Vdc to 300 Vdc or 40 Vac to 250 Vac auxiliary power.

Features, Benefits and Functions

- Microprocessor-based protection with monitoring and control for medium voltage motors
- Integral test function reduces maintenance time and expense
- Zone selective interlocking improves coordination and tripping time, and saves money compared to a traditional bus differential scheme
- Reduce troubleshooting time and maintenance costs—Trip and event recording in non-volatile memory provides detailed information for analysis and system restoration. 6000 cycles of waveform capture aids in post fault analysis (viewable using PowerPort-E software)
- Minimum replacement time—Removable terminal blocks ideal in industrial environments
- Front RS-232 port and PowerPort-E software provides local computer access and user-friendly windows based interface for relay settings, configuration and data retrieval
- Breaker open/close from relay faceplate or remotely via communications
- Fast and easy troubleshooting, improved maintenance procedures and increased device security. Provides detailed traceability for system configuration changes
- Relays self-diagnostics and reporting improves uptime and troubleshooting
- Breaker trip circuit monitoring improves the reliability of the breaker operation

Features

Protection

- Thermal protection (49/51)
  - Locked rotor protection (49S/51)
- Phase overcurrent elements:
  - Two instantaneous elements with timers (50P[1], 50P[2] and 50P[3])
  - Three inverse time overcurrent elements (51P[1], 51P[2] and 51P[3])
  - 11 standard curves
  - Instantaneous or time delay reset
- Ground overcurrent elements:
  - Two instantaneous measured elements with timers (50X[1] and 50X[2])
  - Two instantaneous calculated elements with timers (50R[1] and 50R[2])
  - Two inverse time overcurrent measured elements (51X[1] and 51X[2])
  - Two inverse time overcurrent calculated elements (51R[1] and 51R[2])
  - 11 standard curves
  - Instantaneous or time delay reset
- Jam or Stall protection (50J[1] and 50J[2])
- Phase unbalance negative sequence overcurrent (46[1] and 46[2])
- Underload protection (37[1], 37[2], 37[3])
- Temperature protection with optional URTD (49/38)
- Stars per hour (66)
- Lockout protection (86)
- Breaker failure (50BF)
- Zone interlocking for bus protection (87B)

Metering

- Amperes: positive, negative and zero sequence
- Ampere demand
- Phase angles
- Frequency
- % THD I
- Magnitude THD I
- Minimum/maximum recording
- Phase angles
- Temperature with remote URTD module

Monitoring

- Trip coil monitor
- Breaker wear primary and secondary (accumulated interrupted current)
- Oscillography (6000 cycles total)
- Fault data logs (up to 20 events)
- Sequence of events report (up to 300 events)
- Trending (load profile over time)
- Motor history
- Records the last five motor start profiles
- Motor start trending
- CT supervision
- Clock (1 ms time stamping)

Communication

- Local HMI
- Password protected
- Addressable
- IRIG-B
- Local communication port
- Remote communication port:
  - RS-232
  - RS-485
- Protocols:
  - Modbus-RTU
  - Modbus-TCP (optional)
- Configuration software

Control Functions

- Transition for reduced voltage starts
- Incomplete sequence delay
- Permits numbers of cold starts
- Limits numbers of starts per hour
- Anti-backspin time delay
- Mechanical load shedding
- Zero speed switch for long acceleration motors
- Motor stop inputs
- Remote trip input
- Differential trip input
- Emergency override
- Breaker/Contactor open-close/ stop-start
- Remote open-close (stop-start)
- Programmable I/O
- Programmable LEDs
- Multiple setting groups

Protection and Control Functions

Eaton's EMR-3000 motor protection relay has been designed for maximum motor operation and protection. It permits running the motor close to its design limits while protecting it against excessive heating and damaging overload conditions. The EMR-3000 field-proven protection algorithms were developed based on motor designs and operating parameters for optimum operation and protection while minimizing nuisance tripping. The EMR-3000 motor protection relay uses a protection algorithm and measurement technique based on proven positive and negative (unbalance) sequence current sampling and true rms calculations.

Intel-I-Trip (I^2t) Overload Protection

The EMR-3000 motor relay features the exclusive Eaton Intel-I-Trip intelligent overload protection system. Intel-I-Trip develops custom overload curves simply from motor nameplate data. Intel-I-Trip protects motors from potentially damaging overload and abnormal operating conditions. The Intel-I-Trip intelligent overload protection feature uses field-proven measurement techniques and a motor thermal protection model. The EMR-3000 motor relay's unique measurement technique samples the current waveforms 36 times per cycle, providing accurate measurements of the positive and negative sequence currents. The negative sequence current causes a greater heating effect on the rotor and has a greater impact on the thermal model in the relay. Intel-I-Trip uses these measurements in its motor model to safely protect the motor against the heating effects of these currents.

The motor thermal model is analogous to a bucket that is being filled and drained at the same time. The fill rate is dependent on the motor currents and the drain is based on motor design principles. The size of the bucket is equivalent to the thermal capacity associated with the mass of the motor. Intel-I-Trip integrates these rates and will issue a trip when the thermal capacity is filled.

Intel-I-Trip features adaptive trip characteristics that adjust the trip times based on measured motor temperature when RTDs are used.

Instantaneous Overcurrent

The EMR-3000 motor protection relay provides an instantaneous phase overcurrent function to trip the motor for high fault current levels and to save the fuses. This function can be disabled and has an adjustable time delay on starting to avoid nuisance tripping on inrush.

Phase Unbalance Protection

Motor supply circuits are often fed through fuses and can be run with a single-phase fuse blown, referred to as single-phasing the motor. The EMR-3000 motor protection relay measures the current unbalance and can be used to alarm or trip the motor before damage occurs. Pickup, start and run timers, and a second element for alarm purposes are provided.

Ground Fault Protection

A separate measuring circuit is used to measure ground current. A ground CT is recommended for more sensitive protection against winding insulation breakdown to ground. The relay ground circuit can be connected residually from the three-phase CTs. The ground fault protection has pickup and time delay set points or can be disabled.

Jam Protection

The user-selectable Jam function protects motors that are running against a sudden mechanical jam or stall condition. The common application is on motors used on crushers, chippers or conveyors. It detects an increase of motor current to a level above full load. Pickup, start and run timers and a second element for alarm purposes are provided.

Underload Protection

The user-selectable underload function is used to detect the loss of load on the motor. Coupling failure is a common cause for loss of load. Pickup, start and run timers, and a second element for alarm purposes are provided.

Reduced Voltage Starting

The EMR-3000 motor protection relay provides a transition and incomplete sequence function for reduced voltage starting. The user can select to transition based on the current level and/or on time.

Antibackspin

The stop function is programmable from 2–20%. For certain applications, such as pumping a fluid up a pipe, the motor may be driven backward for a period of time after it stops. The EMR-3000 relay provides an antibackspin timer to prevent starting the motor while it is spinning in the reverse direction. The timer begins counting from the moment a stop is declared by the relay.

Start Control Timers

Motors typically have limits to the number of cold starts, starts per hour period, or time between starts that are permitted without damage. The EMR-3000 motor protection relay incorporates these timers to prevent starting the motor beyond its capabilities.

Load Shedding

The EMR-3000 motor protection relay provides a mechanical load shedding feature that can be used to control an upstream process. The load-shedding function closes a contact on an overload condition to control an upstream process from adding more load until the overload condition is gone.

Emergency Override

The EMR-3000 motor protection relay has a user-programmable feature that will let the operator reset the start inhibitor timers and thermal overload bucket. This function is intended for use in emergency conditions only, and it may result in motor damage or failure.

Long Acceleration Motors

Large motors with a high inertia may experience starting currents that exceed the locked rotor current and time. The EMR-3000 motor protection relay has logic and provisions for a zero speed switch input to differentiate between a stall and start condition. If the motor is spinning, then the relay will not trip on the normal locked rotortime allowing the motor to start.

Remote/Differential Trip

The digital inputs can be programmed to accept a contact input from a separate differential relay or other device to trip the motor. This provides local and remote target information and uses the trip contacts of the EMR-3000 motor protection relay. It will also record and log the motor information at the time of the trip.

Breaker Failure or Stuck Contactor

The EMR-3000 motor protection relay includes a breaker failure (50BF, 62BF) function that can be initiated from either an internal or external trip signal. This is an independent element that can be used to operate a lockout relay or trip an upstream breaker. The timer must be longer than the breaker operating time and the protective function reset times.

Flexible Phase Rotation

The EMR-3000 motor protection relay can be applied on either an A-B-C or A-C-B phase rotation. A user setting permits correct operation and indication of the actual system configuration.

Maintenance Mode

The Maintenance Mode can improve safety by providing a simple and reliable method to reduce fault clearing time and lower incident energy levels at energized panels. The Maintenance Mode allows the user to switch to more sensitive settings via a password protected soft key, communication or via a digital Input while maintenance work is being performed at an energized panel or device. The more sensitive settings provide greater security for maintenance personnel and help to reduce the possibility of injury.

Monitoring and Metering

Sequence of Events Records

The EMR-3000 protection relay records a maximum of 300 events associated with the relay. An event is classified as a change of state as detected by the relay. These include relay pickups, dropouts, trips, contact closure, alarms, setting changes and self-diagnostic failures. Each event is date and time stamped to a 1 ms resolution. The events are stored in a FIFO in chronological order.

Trip Log

The EMR-3000 protection relay will store a maximum of 20 trip records in a FIFO trip log. Each trip record will be date and time stamped to a 1 ms resolution. The trip log record will include information on the type of fault, protection elements that operated, fault location, and currents and voltages at the time of the fault.

Waveform Capture

The EMR-3000 motor protection relay provides oscillography-recording capabilities. The relay will record all measured signals along with the binary signals of pickup, trip, logic and contact closures. The EMR-3000 relay can record up to 6000 cycles of data. The number of records is proportional to the size of each record; the maximum size per record is 600 cycles. The waveform capture is initiated by up to eight different triggers; it can also be generated manually through the display or via communications.

Integral User Interface

The front panel user interface has a 128 x 64 pixel LCD display with background illumination for wide angle viewing in all light conditions. Seven programmable LEDs provide quick and easy visual display of power on, mode of operation, alarm and trip indication. Soft keys are provided for operation mode selection, scrolling through data and settings. In addition, the relay settings and test functions are password protected.

Starting Profiles

The EMR-3000 records the average current versus time for the last five starting cycles. This information is available via the communications port through PowerPort-E.

Motor Statistics

For each motor start, the EMR-300 stores a motor start report and adds this data to the motor statistics buffer. With the motor statistics you can track motor start data for the past 18 30-day periods. For each 30-day interval, the relay records the following information:

- The date the interval began
- The total number of starts in the interval
- The averages of the following quantities:
  - Motor start time
  - Start % rotor thermal capacity used
  - Maximum start current

Load Profiling/Trending

The EMR-3000 relay automatically records selected quantities into non-volatile memory every 5, 10, 15, 30 or 60 minutes, depending on the trending report setting.

Programmable I/O

The EMR-3000 motor protection relay provides heavy-duty, trip rated, 2NO and one Form C contacts. One isolated inputs can be used for monitoring the trip circuit. One Form C contact is dedicated to the relay failure alarm function and is operated in a normally energized (failsafe) mode. There are 4 eight user-configurable discrete inputs that accept a wet contact and can operate through a wide range of power. Each input and output is user-programmable for maximum application flexibility.

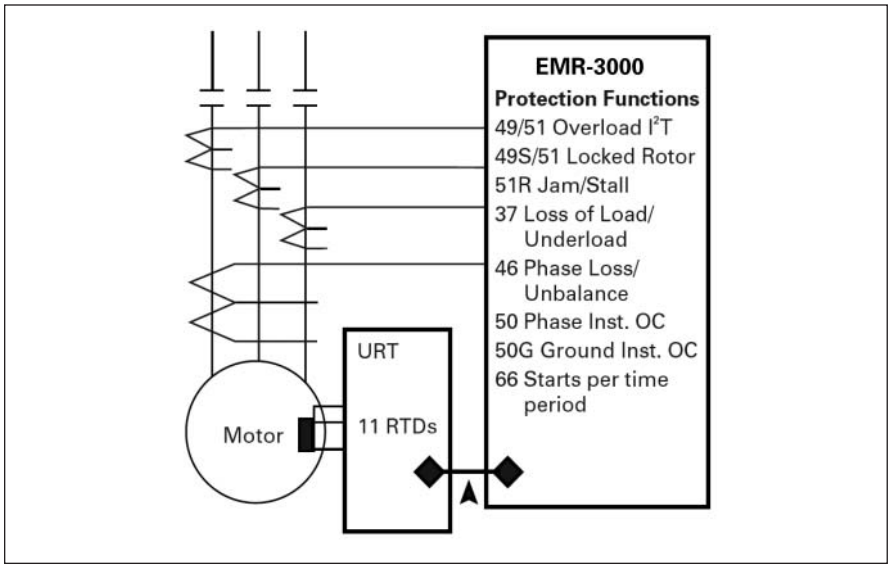


Figure 4.2-6. Typical One-Line Diagram

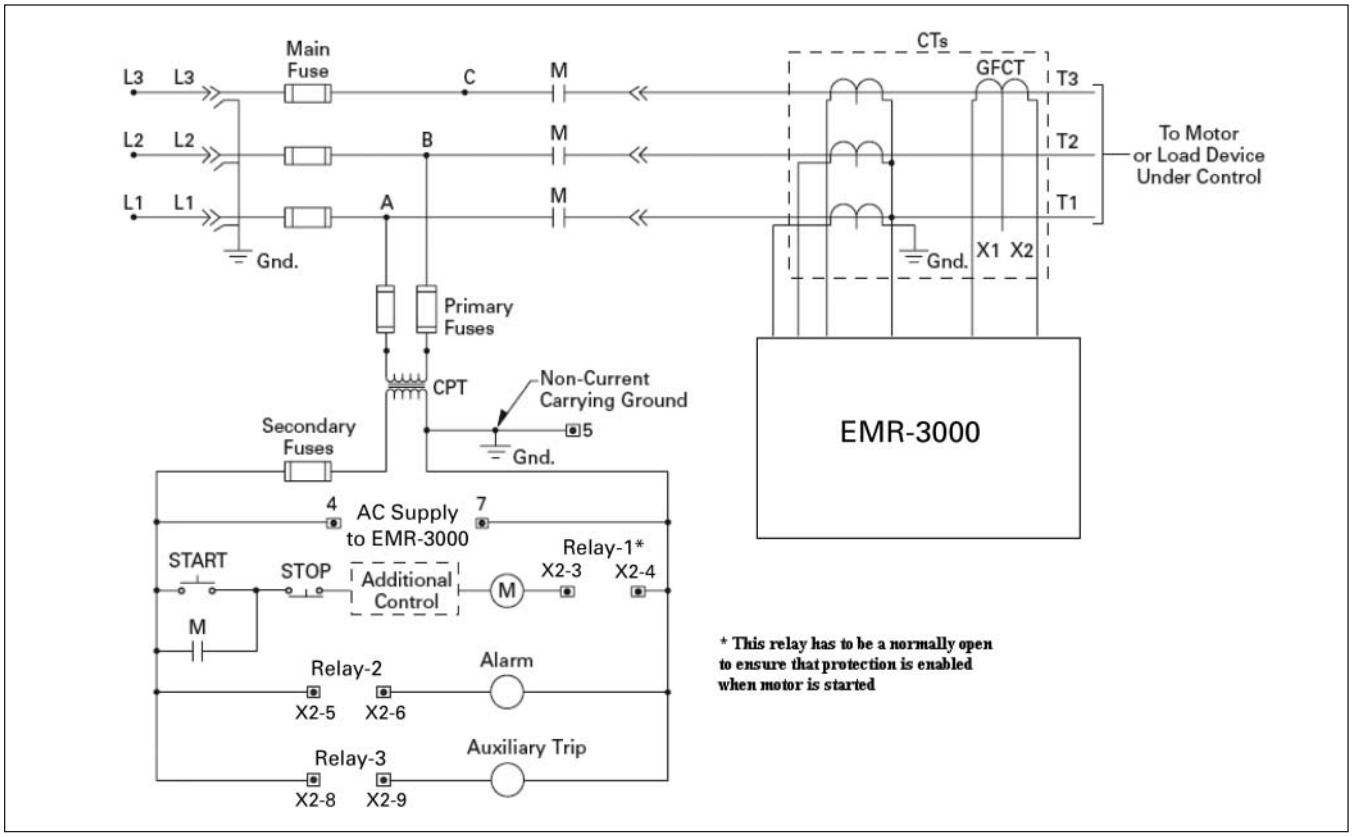


Figure 4.2-7. Typical Control Diagram

4

Communication Software

Eaton provides two types of communication software. The first is PowerPort-E. It runs on a PC or laptop for easy access to a single relay to change set points or configuration and to view metered values and stored data. PowerPort-E is free and can be downloaded from the Eaton Web site at www.eaton.com/pr.

The second package is Power Xpert Software. Power Xpert Software is a power management software package that is designed for continuous, remote monitoring of many devices. It provides additional functions such as billing, trending and graphics. Contact your local Eaton representative for more information on Power Xpert Software.

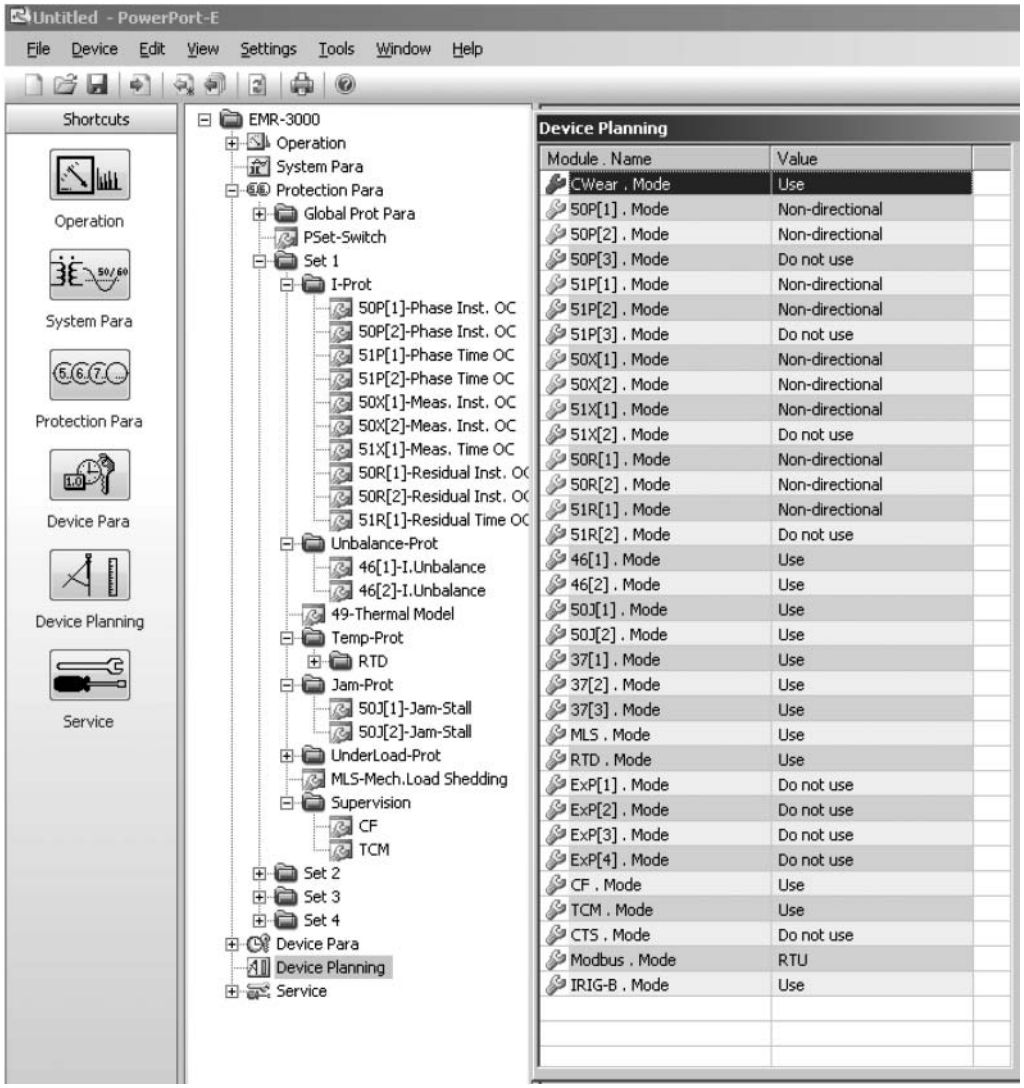


Figure 4.2-8. PowerPort-E EMR-3000 Device Planning

Table 4.2-11. Catalog Numbering Selection for EMR-3000 Motor Relay Removable Terminals

EMR-3000 A 0 B A 1

Hardware Option 1	Hardware Option 2	Communication Options	Conformal Coating Options	Mounting Options
A = Four digital inputs, four outputs, removable terminals, one 4–20 mA analog output, URTD interface, IRIG-B small display	**0** = Phase current 5A/1A, ground current 5A/1A, power supply range: 19–300 Vdc 40–250 Vac	**B** = Modbus-RTU (RS-485)	**A** = None	**0** = Standard mount
B = Four digital inputs, four outputs, removable terminals, zone interlocking, URTD interface, IRIG-B, small display	**1** = Phase current 5A/1A, sensitive ground current, 0.5A/0.1A, power supply range: 19–300 Vdc 40–250 Vac ①	**I** = Modbus-RTU (RS-485) + Modbus-TCP (RJ-45)	**B** = Conformal coated circuit boards	**1** = Projection panel mount

① Consult factory for the availability of sensitive ground.

4

Standards, Certifications and Ratings

Table 4.2-12. EMR-3000 Specifications

Voltage Supply

Aux. voltage:	19–300 Vdc/40–250 Vac
Buffer time in case of supply failure:	≥50 ms at minimal aux. voltage communication is permitted to be interrupted

Max. permissible making current:
18A peak value for 0.25 ms
12A peak value for 1 ms

The voltage supply must be protected by a fuse of:
2.5A time-lag miniature fuse 5.0 x 20.0 mm (approx. 0.20 in. x 0.80 in) according to IEC 60127
3.5A time-lag miniature fuse 6.3 x 32.0 mm (approx. 0.25 in. x 1.25 in) according to UL 248-14

Power Consumption

Power supply range:	19–300 Vdc: 6W idle mode/ 8W max. power 40–250 Vac: 6W idle mode/ 8W max. power (for frequencies of 40–70 Hz)
Power consumption:	Phase current inputs at I_n = 1A burden = 0.15 mVA at I_n = 5A burden = 0.15 mVA
Ground current input:	at I_n = 1A burden = 0.35 mVA at I_n = 5A burden = 0.35 mVA

Digital Inputs

Max. input voltage:	300 Vdc/270 Vac
Input current:	<4 mA
Reaction time:	<20 ms
Fallback time:	<30 ms (safe state of the digital inputs)
4 switching thresholds:	Un = 24 Vdc, 48 Vdc, 60 Vdc, 110 Vac/dc, 230 Vac/dc
Un = 24 Vdc	
Switching threshold 1 ON:	Min. 19.2 Vdc
Switching threshold 1 OFF:	Max. 9.6 Vdc
Un = 48V/60 Vdc	
Switching threshold 2 ON:	Min. 42.6 Vdc
Switching threshold 2 OFF:	Max. 21.3 Vdc
Un = 110/120 Vac/dc	
Switching threshold 3 ON:	Min. 88.0 Vdc/88.0 Vac
Switching threshold 3 OFF:	Max. 44.0 Vdc/44.0 Vac
Un = 230/240 Vac/dc	
Switching threshold 4 ON:	Min. 184 Vdc/184 Vac
Switching threshold 4 OFF:	Max. 92 Vdc/92 Vac
Terminals:	Screw-type terminal

Binary Output Relays

Continuous current:	5A AC/DC
Max. make current:	25A AC/25A DC for 4s
Max. breaking current:	5A AC up to 125 Vdc 5A DC up to 30V (resistive) 0.2A DC at 300V
Max. switching voltage:	250 Vac/300 Vdc
Switching capacity:	2000 VA
Contact type:	1 changeover contact
Terminals:	Screw-type terminals

Front Interface RS-232

Baud rates:	115,200 Baud
Handshake:	RTS and CTS
Connection:	Nine-pole D-Sub plug

RS-485

Master/slave:	Slave
Connection:	Six screw-clamping terminals RM 3.5 mm (138 MIL) (terminating resistors internal)

Fiber Optic

Master/slave:	Slave
Connection:	ST-plug

URTD-Interface

Connection:	Versatile link

Climatic Environmental Conditions

Storage temperature:	–25°C up to +70°C (–13°F to 158°F)
Operating temperature:	–20°C up to +60°C (–4°F to 140°F)
Permissible humidity at Ann. average:	<75% rel. (on 56d up to 95% rel.)
Permissible installation altitude:	<2000m (6561.67 ft) above sea level If 4000m (13,123.35 ft) altitude applies, a changed classification of the operating and test voltages may be necessary.

EMR-4000
Motor Protection Relay

EMR-4000

General Description

Eaton's EMR-4000 motor protection relay is a multifunctional microprocessor-based protective relay for the protection of any size motor at all voltage levels. It is most commonly applied on medium voltage or larger motors. The EMR-4000 relay is a current and voltage device that provides complete and reliable motor protection, monitoring, diagnostics, metering and starting control functions.

The EMR-4000 motor protection relay has removable terminal blocks, and it has Modbus-RTU communications as standard; and an optional Ethernet port for Modbus-TCP communications or IEC-61850.

The EMR-4000 motor protection relay provides complete current, voltage and frequency protection in a single compact case. The relay has four current inputs rated for either 5A or 1A and four voltage inputs. Three of the voltage inputs are to be connected to the three-phase power voltage for voltage protection and for metering. They can be connected in wye-ground or open delta configuration. The fourth voltage is for independent single-phase undervoltage/overvoltage protection. The unit is user programmable for 60 Hz or 50 Hz operation.

The Maintenance Mode password protected soft key can be used for arc flash mitigation to change to an alternate settings group, set to have instantaneous elements only. The multiple setting groups can also be changed, via communications or a digital input. Flash memory is used for the programming and all settings are stored in nonvolatile memory.

An integral keypad and display is provided for direct user programming and retrieval of data without the need of a computer. 14 programmable LEDs provide quick indication of relay status.

A front port is provided for direct computer connection. An RS-485 communication port on the back is standard for local area networking using Modbus-RTU. An optional Ethernet port and protocols are available.

The EMR-4000 motor protection relay includes programmable logic functions. Logic gates and timers may be defined and arranged for customized applications. With the programmable logic control functions you can simplify the complexity of your starting schemes by eliminating timers and auxiliary relays. Flash memory is used for the programming and all settings are stored in non-volatile memory. The relay allows for four preprogrammed setting groups that can be activated through software or contact input.

The EMR-4000 motor protection relay has mass memory for data storage and a real-time clock with 1 ms time resolution. The relay will log 300 sequence of event records, 20 detailed trip logs, minimum/maximum values, load profiles, the five latest start profiles, motor trending, breaker/contactor wear information and oscillography data.

The EMR-4000 motor protection relay has eight discrete inputs, one fiber optic input, two Form C and 2NO output programmable contacts, and one Form C healthy contact. It also has four 4–20 mA analog outputs and one zone interlocking card. The relay provides maximum user flexibility to configure the I/O. All inputs and to outputs (except the healthy output) are user-programmable. The unit also counts with a test mode to force outputs and simulate currents, to facilitate the commissioning of the unit. It can be powered from 19 Vdc to 300 Vdc or 40 Vac to 250 Vac auxiliary power.

Features

Protection

- Thermal protection (49/51)
  - Locked rotor protection (49S/51)
- Phase overcurrent elements:
  - Two instantaneous elements with timers (50P[1], 50P[2] and 50P[3])
  - Three inverse time overcurrent elements (51P[1], 51P[2] and 51P[3])
  - 11 standard curves
  - Instantaneous or time delay reset
- Ground overcurrent elements:
  - Two instantaneous measured elements with timers (50X[1] and 50X[2])
  - Two instantaneous calculated elements with timers (50R[1] and 50R[2])
  - Two inverse time overcurrent measured elements (51X[1] and 51X[2])
  - Two inverse time overcurrent calculated elements (51R[1] and 51R[2])
  - 11 standard curves
  - Instantaneous or time delay reset
- Jam or Stall protection (50J[1] and 50J[2])
- Phase unbalance negative sequence overcurrent (46[1] and 46[2])
- Underload protection (37[1], 37[2], 37[3])
- Temperature protection with optional URTD (49/38)
- Stars per hour (66)
- Switch onto fault protection
- Phase voltage unbalance and sequence protection (47[1], 47[2])
- Main three-phase under/overvoltage (27M[1], 27M[2], 59M[1], 59M[2])
- Auxiliary single-phase under/overvoltage (27A[1], 27A[2], 59A[1], 59A[2])
- Six frequency elements that can be assigned to: overfrequency, underfrequency, rate of change or vector surge (81[1], 81[2], 81[3], 81[4], 81[5], 81[6])
- Apparent and displacement power factor (55A[1], 55A[2], 55D[1], 55D[2])
- Forward and reverse watts (32[1], 32[2], 32[3])
- Forward and reverse VARs (32V[1], 32V[2], 32V[3])
- Lockout protection (86)
- Breaker failure (50BF)
- Zone interlocking for bus protection (87B)

Metering

- Amperes: positive, negative and zero sequence
- Volts: positive, negative and zero sequence
- Phase angles
- Volt-amperes and VA demand
- Watts and kW demand
- kWh (forward, reverse, net)
- VARs and kVAR demand
- kVARh (lead, leg and net)
- Power factor
- Frequency
- % THD V and I
- Magnitude THD V and I
- Minimum/maximum recording
- Trending (load profile over time)
- Minimum/maximum recording
- Temperature with remote URTD module

Monitoring

- Trip coil monitor
- Breaker wear primary and secondary (accumulated interrupted current)
- Oscillography (6000 cycles total)
- Fault data logs (up to 20 events)
- Sequence of events report (up to 300 events)
- Trending (load profile over time)
- Motor history
- Records the last five motor start profiles
- Motor start trending
- CT supervision
- VT supervision
- Clock (1 ms time stamping)

Diagnostic

- Broken rotor bar (Beta version)

Communication

- Local HMI
- Password protected
- Addressable
- IRIG-B
- Local communication port
- Remote communication port:
  - RS-232
  - RS-485
- Protocols:
  - Modbus-RTU (optional)
  - Modbus-TCP (optional)
  - IEC-61850 (optional)
- Configuration software

Control Functions

- Transition for reduced voltage starts
- Incomplete sequence delay
- Permits numbers of cold starts
- Limits numbers of starts per hour
- Anti-backspin time delay
- Mechanical load shedding
- Zero speed switch for long acceleration motors
- Motor stop inputs
- Remote trip input
- Differential trip input
- Emergency override
- Breaker/contactor open-close/stop-start
- Remote open-close (stop-start)
- Programmable I/O
- Programmable LEDs
- Programmable logic
- Multiple setting groups

Table 4.2-13. Catalog Numbering Selection for EMR-4000 Motor Relay Removable Terminals

EMR-4000 A 0 B A 1

Hardware Option 1	Hardware Option 2	Communication Options	Conformal Coating Options	Mounting Options
A = Eight digital inputs, five outputs, removable terminals, zone interlocking, URTD interface, IRIG-B, small display **B** = Eight digital inputs, 11 outputs, removable terminals, zone interlocking, URTD interface, IRIG-B, large display ①	**0** = Phase current 5A/1A, ground current 5A1A, power supply range: 19–300 Vdc 40–250 Vac **1** = Phase current 5A/1A, sensitive ground current, 0.5A/0.1A, power supply range: 19–300 Vdc 40–250 Vac ①	**B** = Modbus-RTU (RS-485) **H** = IEC-61850 **I** = Modbus-RTU (RS-485) + Modbus-TCP (RJ-45)	**A** = None **B** = Conformal coated circuit boards	**0** = Standard mount **1** = Projection panel mount

① Consult factory for the availability of sensitive ground, large display and IEC-61850.

4

Protection and Control Functions

Eaton's EMR-4000 motor protection relay has been designed for maximum motor operation and protection. It permits running the motor close to its design limits while protecting it against excessive heating and damaging overload conditions. The EMR-4000 field-proven protection algorithms were developed based on motor designs and operating parameters for optimum operation and protection while minimizing nuisance tripping. The EMR-4000 motor protection relay uses a protection algorithm and measurement technique based on proven positive and negative (unbalance) sequence current sampling and true rms calculations.

Intel-I-Trip (I^2t) Overload Protection

The EMR-4000 motor relay features the exclusive Eaton Intel-I-Trip intelligent overload protection system. Intel-I-Trip develops custom overload curves simply from motor nameplate data. Intel-I-Trip protects motors from potentially damaging overload and abnormal operating conditions. The Intel-I-Trip intelligent overload protection feature uses field proven measurement techniques and a motor thermal protection model. The EMR-4000 motor relay's unique measurement technique samples the current waveforms 36 times per cycle, providing accurate measurements of the positive and negative sequence currents. The negative sequence current causes a greater heating effect on the rotor and has a greater impact on the thermal model in the relay. Intel-I-Trip uses these measurements in its motor model to safely protect the motor against the heating effects of these currents.

The motor thermal model is analogous to a bucket that is being filled and drained at the same time. The fill rate is dependent on the motor currents and the drain is based on motor design principles. The size of the bucket is equivalent to the thermal capacity associated with the mass of the motor. Intel-I-Trip integrates these rates and will issue a trip when the thermal capacity is filled.

Intel-I-Trip features adaptive trip characteristics that adjust the trip times based on measured motor temperature when RTDs are used.

Instantaneous Overcurrent

The EMR-4000 motor protection relay provides an instantaneous phase overcurrent function to trip the motor for high fault current levels and to save the fuses. This function can be disabled and has an adjustable time delay on starting to avoid nuisance tripping on inrush.

Phase Unbalance Protection

Motor supply circuits are often fed through fuses and can be run with a single-phase fuse blown, referred to as single-phasing the motor. The EMR-4000 motor protection relay measures the current and voltage unbalance and either can be used to alarm or trip the motor before damage occurs. The EMR-4000 has two voltage and two current unbalance elements. Pickup, start and run timers are provided for each element.

Ground Fault Protection

A separate measuring circuit is used to measure ground current. A ground CT is recommended for more sensitive protection against winding insulation breakdown to ground. The relay ground circuit can be connected residually from the three-phase CTs. The ground fault protection has pickup and time delay set points or can be disabled.

Jam Protection

The user-selectable jam function protects motors that are running against a sudden mechanical jam or stall condition. The common application is on motors used on crushers, chippers or conveyors. It detects an increase of motor current to a level above full load. Pickup, start and run timers, and a second element for alarm purposes are provided.

Underload/Underpower Protection

The user-selectable underload/underpower function is used to detect the loss of load on the motor. Coupling failure is a common cause for loss of load. Whenever possible, it is better to use underpower to detect loss of load. Three power elements and two underload elements are provided in the relay for tripping and alarm purposes. Pickup, start and run timers are provided for each element.

Frequency Protection

The frequency elements provide the ability to detect when the motor is operating at off-nominal frequencies that can do damage to the process or, to signal to upstream protections or controls to implement load shedding actions.

Power Factor Protection

This protection is used in synchronous motors applications to detect out-of-synchronism conditions.

Undervoltage/Overvoltage Protection

Use the voltage protective functions to detect abnormal system voltage conditions that are potentially hazardous to the motor.

Reduced Voltage Starting

The EMR-4000 motor protection relay provides a transition and an incomplete sequence function for reduced voltage starting. The user can select to transition based on the current level and/or on time.

Antibackspin

The stop function is programmable from 2–20%. For certain applications, such as pumping a fluid up a pipe, the motor may be driven backward for a period of time after it stops. The EMR-4000 relay provides an antibackspin timer to prevent starting the motor while it is spinning in the reverse direction. The timer begins counting from the moment a stop is declared by the relay.

Start Control Timers

Motors typically have limits to the number of cold starts, starts per hour period or time between starts that are permitted without damage. The EMR-4000 motor protection relay incorporates these timers to prevent starting the motor beyond its capabilities.

Load Shedding

The EMR-4000 motor protection relay provides a mechanical load shedding feature that can be used to control an upstream process. The load-shedding function closes a contact on an overload condition to control an upstream process from adding more load until the overload condition is gone.

Emergency Override

The EMR-4000 motor protection relay has a user-programmable feature that will let the operator reset the start inhibitor timers and thermal overload bucket. This function is intended for use in emergency conditions only, and it may result in motor damage or failure.

Long Acceleration Motors

Large motors with a high inertia may experience starting currents that exceed the locked rotor current and time. The EMR-4000 motor protection relay has logic and provisions for a zero speed switch input to differentiate between a stall and start condition. If the motor is spinning, then the relay will not trip on the normal locked rotor time allowing the motor to start.

Remote/Differential Trip

The digital inputs can be programmed to accept a contact input from a separate differential relay or other device to trip the motor. This provides local and remote target information and uses the trip contacts of the EMR-4000 motor protection relay. It will also record and log the motor information at the time of the trip.

Breaker Failure or Stuck Contactor

The EMR-4000 motor protection relay includes a breaker failure (50BF, 62BF) function that can be initiated from either an internal or external trip signal. This is an independent element that can be used to operate a lockout relay or trip an upstream breaker. The timer must be longer than the breaker operating time and the protective function reset times.

Flexible Phase Rotation

The EMR-4000 motor protection relay can be applied on either an A-B-C or A-C-B phase rotation. A user setting permits correct operation and indication of the actual system configuration.

Maintenance Mode

The Maintenance Mode can improve safety by providing a simple and reliable method to reduce fault clearing time and to lower incident energy levels at energized panels. The Maintenance Mode allows the user to switch to more sensitive settings via a password protected soft key, communication or via a digital Input while maintenance work is being performed at an energized panel or device. The more sensitive settings provide greater security for maintenance personnel and help to reduce the possibility of injury.

Diagnostic Features

Broken Rotor Bar (Beta Version)

The EMR-4000 provides advanced motor diagnostics including a broken rotor bar detection function. The broken rotor bar detection is a condition maintenance function that continuously monitors the motor's health while in operation. The advanced Motor Current Signature Analysis (MCSA) continuously analyzes the motor current signature and based on preset algorithms it will determine when a broken rotor bar is present in the motor.

The broken rotor bar function will provide early detection of any rotor problems and advise maintenance personnel of the impending issue, allowing for predictive maintenance of the motor and for prevention of catastrophic motor failures.

By providing early indication of potential rotor problems, serious system issues such as: reduced starting torque, overloads, torque and speed oscillation and bearing wear can be avoided. With the advanced broken rotor bar detection system, advanced warning of impending problems reduces catastrophic failures, maximizing motor life and system uptime.

Monitoring and Metering

Sequence of Events Records

The EMR-4000 protection relay records a maximum of 300 events associated with the relay. An event is classified as a change of state as detected by the relay. These include relay pickups, dropouts, trips, contact closure, alarms, setting changes and self-diagnostic failures. Each event is date and time stamped to a 1 ms resolution. The events are stored in a FIFO in chronological order.

Trip Log

The EMR-4000 protection relay will store a maximum of 20 trip records in a FIFO trip log. Each trip record will be date and time stamped to a 1 ms resolution. The trip log record will include information on the type of fault, protection elements that operated, fault location and currents and voltages at the time of the fault.

Waveform Capture

The EMR-4000 motor protection relay provides oscillography-recording capabilities. The relay will record all measured signals along with the binary signals of pickup, trip, logic and contact closures. The EMR-4000 relay can record up to 6000 cycles of data. The number of records is proportional to the size of each record; the maximum size per record is 600 cycles. The waveform capture is initiated by up to eight different triggers; it can also be generated manually through the display or via communications.

Integral User Interface

The front panel user interface has a 128 x 64 pixel LCD display with background illumination for wide angle viewing in all light conditions. Seven programmable LEDs provide quick and easy visual display of power on, mode of operation, alarm and trip indication. Soft keys are provided for operating mode selection, scrolling through data and settings. In addition, the relay settings and test functions are password protected.

Starting Profiles

The EMR-4000 records the average current versus time for the last five starting cycles. This information is available via the communications port through PowerPort-E.

Motor Statistics

For each motor start, the EMR-3000 stores a motor start report and adds this data to the motor statistics buffer. With the motor statistics you can track motor start data for the past 18 30-day periods. For each 30-day interval, the relay records the following information:

- The date the interval began
- The total number of starts in the interval
- The averages of the following quantities:
  - Motor start time
  - Start % rotor thermal capacity used
  - Maximum start current

Load Profiling/Trending

The EMR-4000 relay automatically records selected quantities into non-volatile memory every 5, 10, 15, 30 or 60 minutes, depending on the trending report setting.

Programmable I/O

The EMR-4000 motor protection relay provides heavy-duty, trip-rated, 2NO and one Form C contacts. One isolated input can be used for monitoring the trip circuit. One Form C contact is dedicated to the relay failure alarm function and is operated in a normally energized (failsafe) mode. There are 4 eight user-configurable discrete inputs that accept a wet contact and can operate through a wide range of power. Each input and output is user-programmable for maximum application flexibility.

Programmable Logic

The EMR-4000 motor protection relay provides logic gates and timers that the user can customize for special or unique applications. Each gate can be assigned a logic function of either AND, OR, NAND or NOR. Each gate can have a maximum of four input signals and each input signal can be required to be a NOT. Input signals can be external inputs received via the binary inputs or internal values associated with the protection, alarm or metering set points. Each gate has a unique output assignment and designation that can be used as the input to another gate. There are 80 independent timers that have adjustable pickup and dropout delay settings.

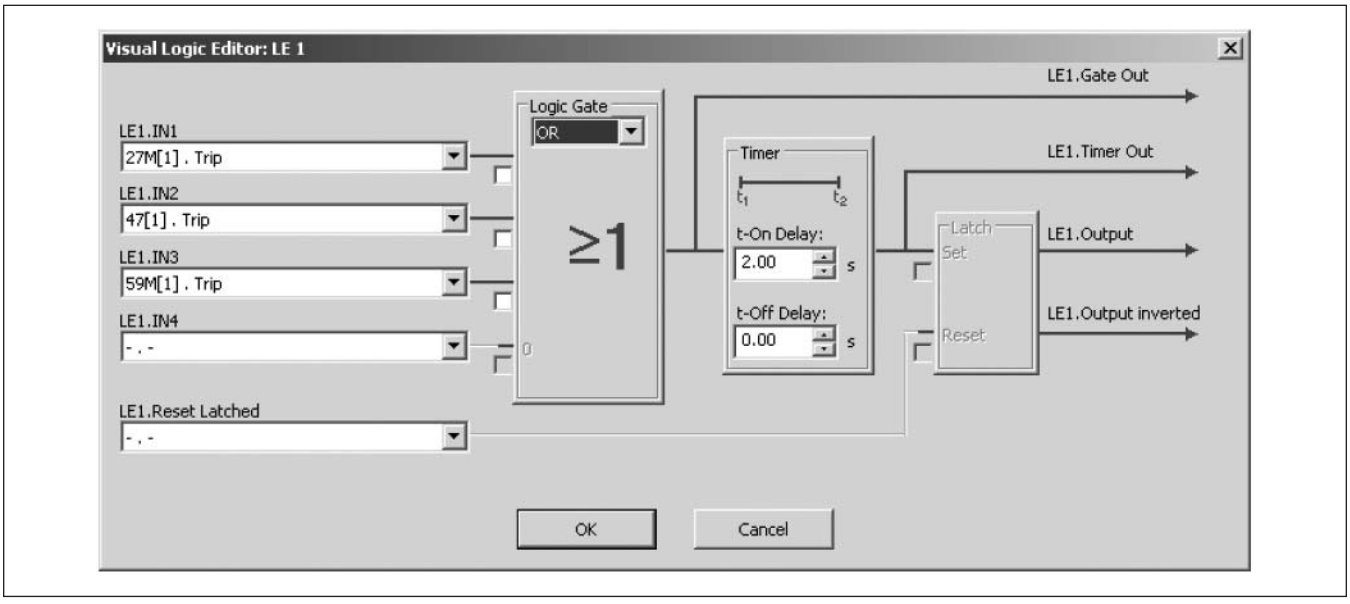


Figure 4.2-9. Visual Logic Editor

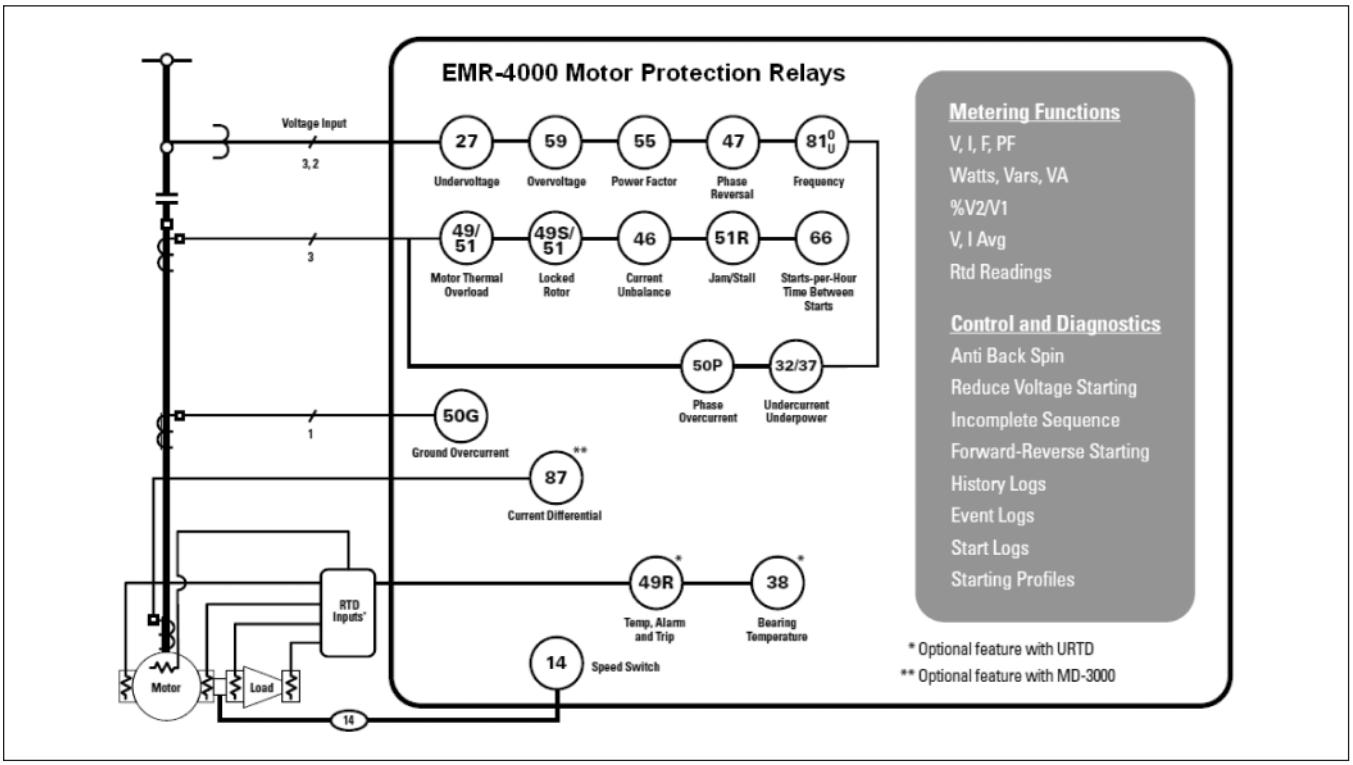


Figure 4.2-10. Typical One-Line Diagram

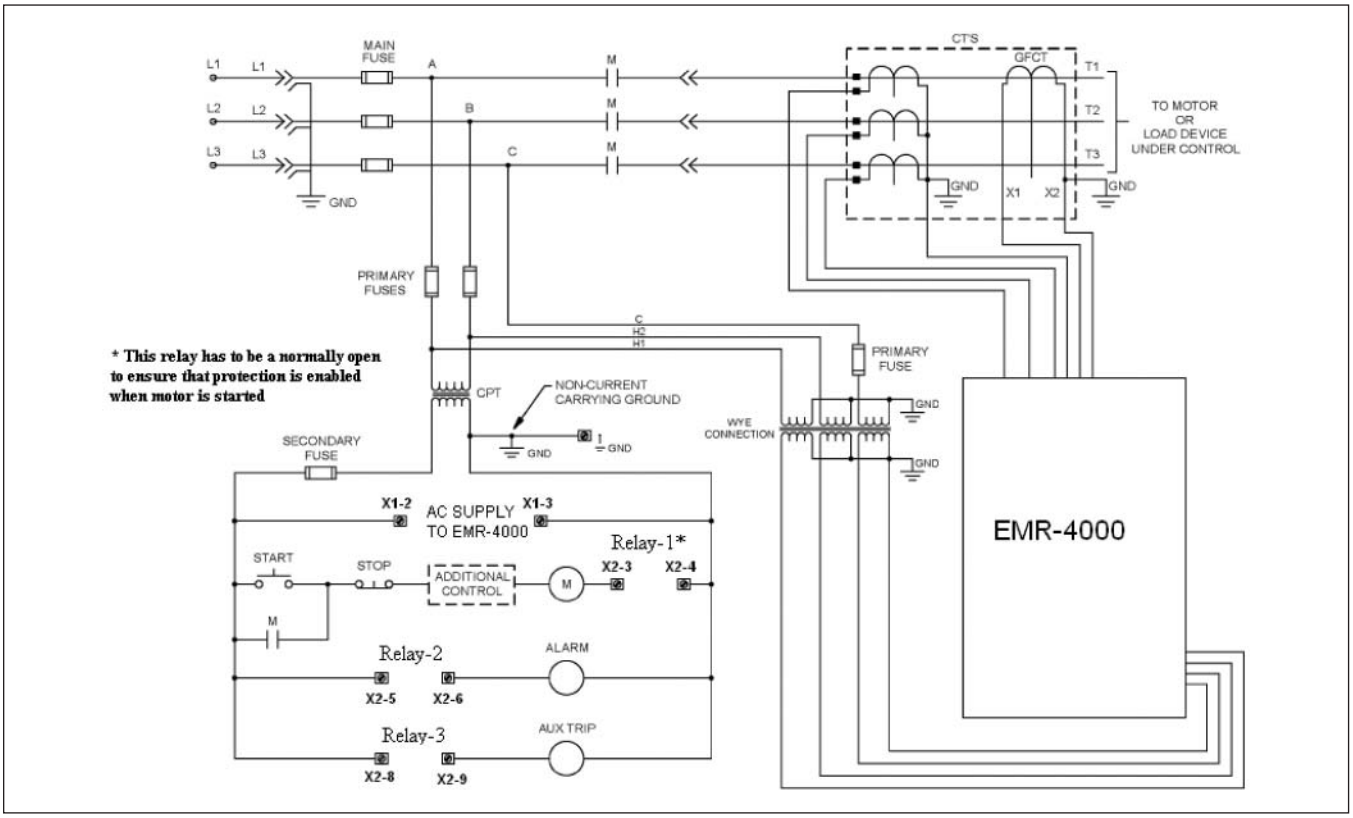


Figure 4.2-11. Typical Control Diagram

Communication Software

Eaton provides two types of communication software. The first is PowerPort-E. It runs on a PC or a laptop for easy access to a single relay to change set points or configuration and to view metered values and stored data. PowerPort-E is free and can be downloaded from the Eaton Web site at **www.eaton.com/pr**.

The second package is Power Xpert Software. Power Xpert Software is a power management software package that is designed for continuous, remote monitoring of many devices. It provides additional functions such as billing, trending and graphics. Contact your local Eaton representative for more information on Power Xpert Software.

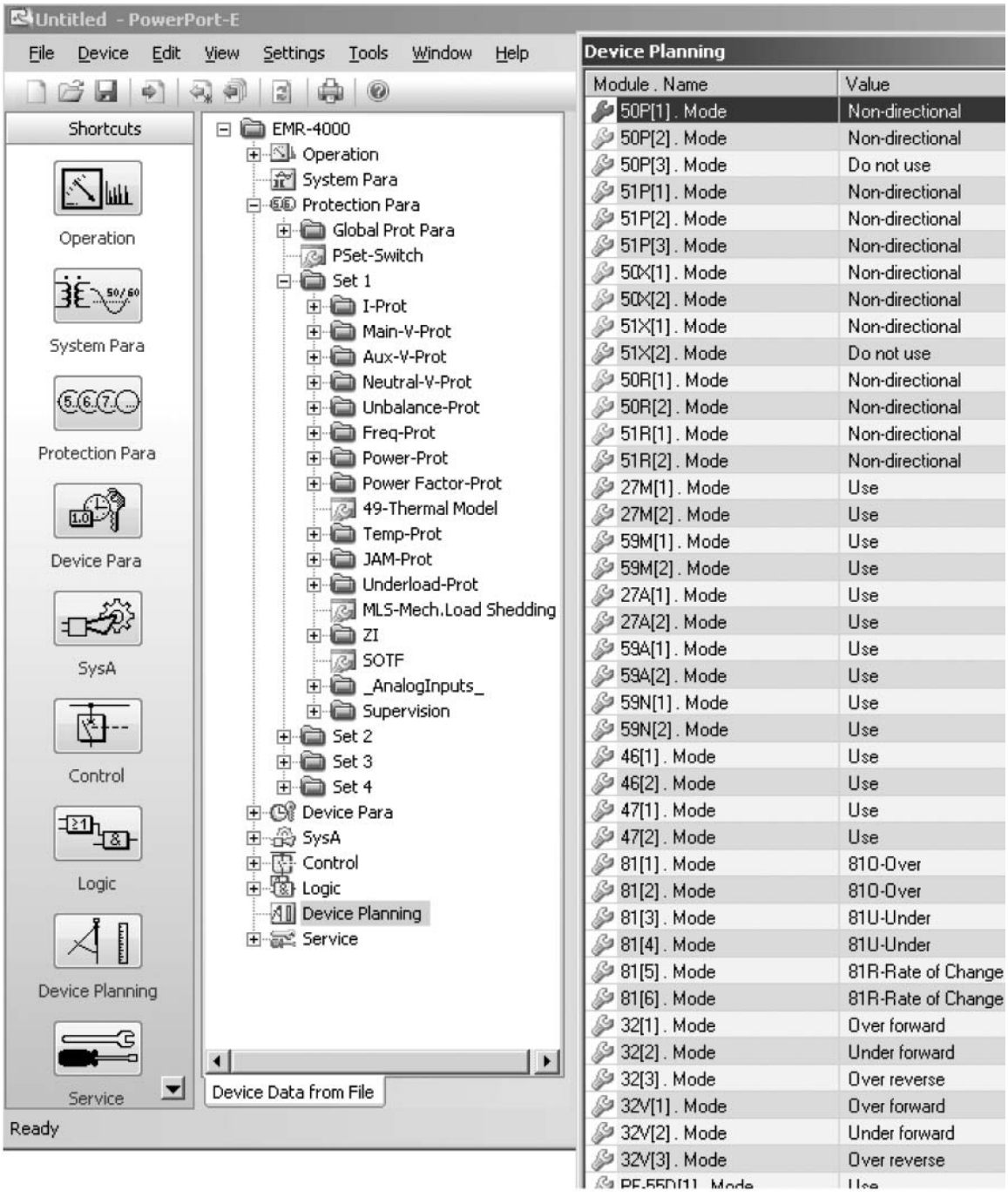


Figure 4.2-12. PowerPort-E EMR-4000 Device Planning

Standards, Certifications and Ratings

Table 4.2-14. EMR-4000 Specifications

Voltage Supply

Aux. voltage:	24–270 Vdc/48–230 Vac (–20%/+10%)
Buffer time in case of supply failure:	≥50 ms at minimal aux. voltage interrupted communication is permitted

Max. permissible making current:
18A peak value for 0.25 ms
12A peak value for 1 ms
The voltage supply must be protected by a fuse of:
2.5A time-lag miniature fuse 5.0 x 20.0 mm (approx. 0.20 in. x 0.80 in) according to IEC 60127
3.5A time-lag miniature fuse 6.3 x 32.0 mm (approx. 0.25 in. x 1.25 in) according to UL 248-14

Power Consumption

Power supply range:	24–270 Vdc: 7W idle mode/ approx. 13W max. power 48–230 Vac: 7 VA idle mode/ approx. 13 VA max. power (for frequencies of 40–70 Hz)
Power consumption:	Phase current inputs at I_n = 1A, S = 0.15 mVA at I_n = 5A, S = 0.15 mVA
Ground current input:	at I_n = 1A, S = 0.35 mVA at I_n = 5A, S = 0.35 mVA

Digital Inputs

Max. input voltage:	300 Vdc/259 Vac
Input current:	<4 mA
Reaction time:	<20 ms
Fallback time:	<30 ms (safe state of the digital inputs)
Switching thresholds:	Un = 24 Vdc, 48 Vdc, 60 Vdc, 110 Vac/dc, 230 Vac/dc
Un = 24 Vdc	
Switching threshold 1 ON:	Min. 19.2 Vdc
Switching threshold 1 OFF:	Max. 9.6 Vdc
Un = 48V/60 Vdc	
Switching threshold 2 ON:	Min. 42.6 Vdc
Switching threshold 2 OFF:	Max. 21.3 Vdc
Un = 110/120 Vac/dc	
Switching threshold 3 ON:	Min. 88.0 Vdc/88.0 Vac
Switching threshold 3 OFF:	Max. 44.0 Vdc/44.0 Vac
Un = 230/240 Vac/dc	
Switching threshold 4 ON:	Min. 184 Vdc/184 Vac
Switching threshold 4 OFF:	Max. 92 Vdc/92 Vac
Terminals:	Screw-type terminal

Relay Outputs

Continuous current:	5A AC/DC
Max. make current:	25A AC/25A DC up to 30V for 4s 30A/230 Vac according to ANSI IEEE Std. C37.90-2005 30A/250 Vac according to ANSI IEEE Std. C37.90-2005
Max. breaking current:	5A AC up to 125 Vdc 5A DC up to 30V (resistive) 0.3A DC at 300V
Max. switching voltage:	250 Vac/250 Vdc
Switching capacity:	1250 VA
Contact type:	Form C or normally open contact
Terminals:	Screw-type terminals

Zone Interlocking

NOTICE: ONLY FOR ZONE INTERLOCK TRIPPING OUTPUTS (ZONE INTERLOCK, SEMI-CONDUCTOR OUTPUT): 5 Vdc, <2 mA FOR CONNECTION TO ELECTRONIC INPUTS ONLY.

Zone out:	
Output voltage (high):	4.75 to 5.25 Vdc
Output voltage (low):	0.0 to +0.5 Vdc
Zone in:	
Nominal input voltage:	+5 Vdc
Max. input voltage:	+5.5 Vdc
Switching threshold ON:	Min. 4.0 Vdc
Switching threshold OFF:	Max. 1.5 Vdc
Galvanic isolation:	2.5 kV AC (to ground and other IO)
Connection:	Screw-type terminals (twisted pair)

Front Interface RS-232

Baud rates:	115,200 Baud
Handshake:	RTS and CTS
Connection:	Nine-pole D-Sub plug

RS-485

Master/slave:	Slave
Connection:	Six screw-clamping terminals RM 3.5 mm (138 MIL) (terminating resistors internal)

Fiber Optic

Master/slave:	Slave
Connection:	ST-plug

URTD-Interface

Connection:	Versatile link

Climatic Environmental Conditions

Storage temperature:	–30°C to +70°C (–22°F to +158°F)
Operating temperature:	–20°C up to +60°C (–4°F to +140°F)
Permissible humidity at Ann. average:	<75% rel. (on 56d up to 95% rel.)
Permissible installation altitude:	<2000m (6561.67 ft) above sea level If 4000m (13,123.35 ft) altitude applies, a changed classification of the operating and test voltages may be necessary.

Universal RTD Module

Universal RTD Module

General Description

Monitors as a stand-alone device or in conjunction with the MP-3000, MP-4000, FP-6000, ETR-4000, EMR-3000, EMR-4000 and EGR-4000 protection relays.

Eaton's Universal RTD Module is an electronic resistance temperature detector designed to monitor as a stand-alone device or in conjunction with the protective relays. The Universal RTD Module can be used to monitor, for example, transformer temperature and relay that information back to a remote computer or programmable controller. When used in conjunction with the motor relays, the Universal RTD Module enhances the unit's motor protection ability. In addition to the FP-6000, ETR-4000, EMR-3000, EMR-4000 and EGR-4000, the Universal RTD Module can be used with the older motor relays such as IQ-1000 II™, MP-3000 and MP-4000.

The Universal RTD Module can be used to monitor as many as 12 RTD inputs—four groups consisting of six motor windings, two motor bearings, two load bearings and two auxiliary. The Universal RTD Module can be programmed to accept any of the following types of RTD inputs: 10 ohm copper, 100 ohm platinum, and 100 and 120 ohm nickel.

The Universal RTD Module transmits information using a fiber optic link, with a maximum distance of 400 feet (122m).

Table 4.2-15. Catalog Numbers

Description	Catalog Number
Universal RTD Module 48–250 AC/DC	**URTDI-01**
Universal RTD Module 24–48 Vdc	**URTDII-02**

Technical Data and Specifications

Dimensions in Inches (mm)

- Height: 7.67 (194.8)
- Width: 4.32 (109.7)
- Depth: 2.00 (50.8)

Communications

Communications to the Power Xpert Software are enabled through Power Xpert Gateway and Modbus-RTU port built into the module.

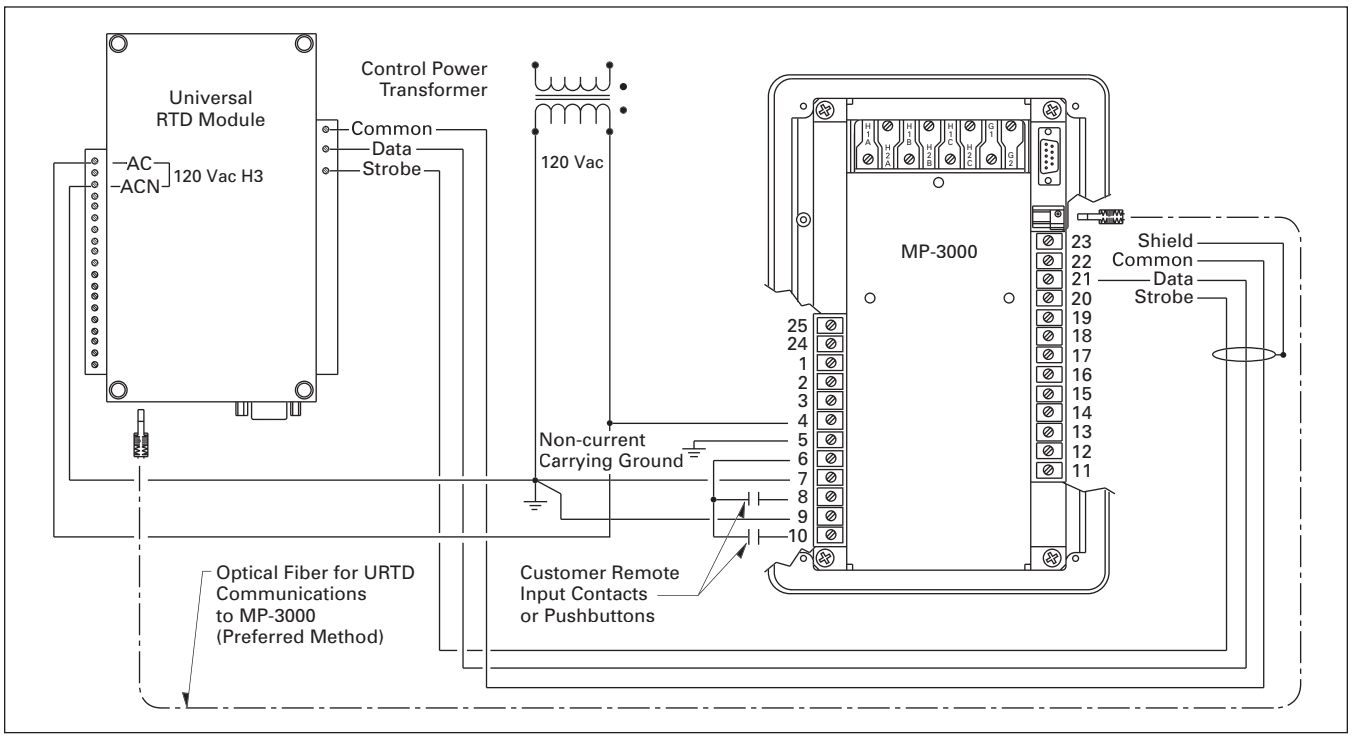


Figure 4.2-13. MP-3000 and URTD Wiring

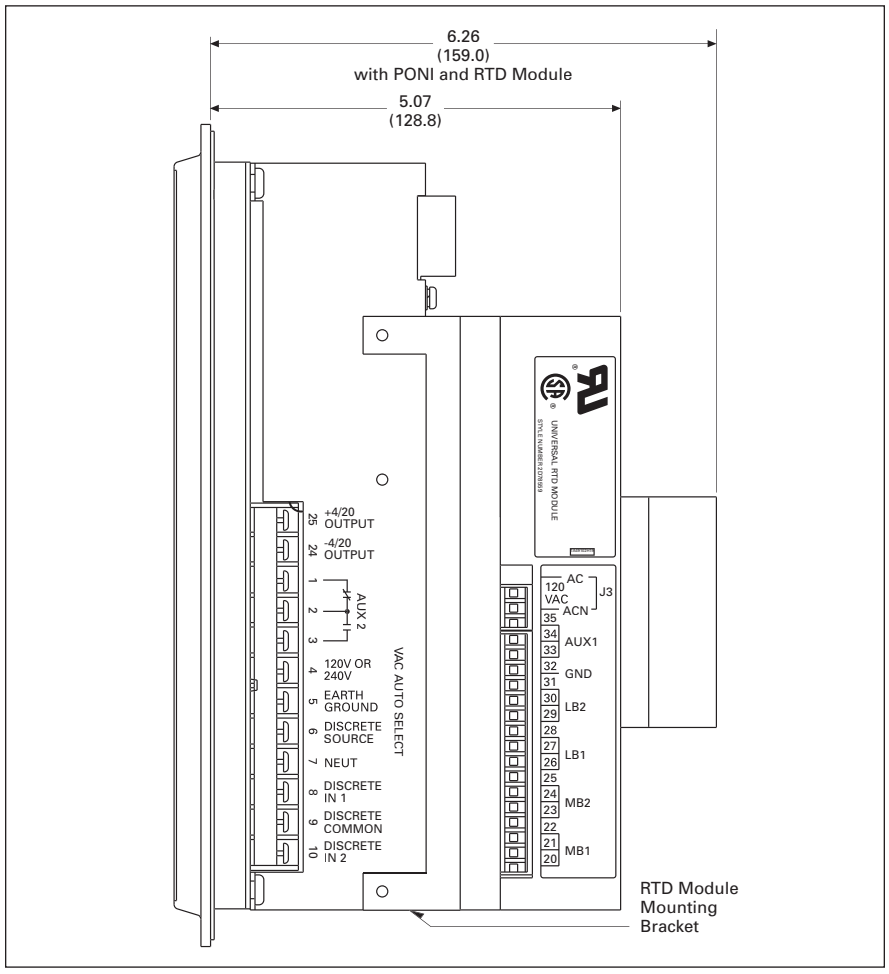


Figure 4.2-14. MP-3000 URTD Mounting—Dimensions in Inches (mm)

RTD Inputs: (Requires URTD Module)

Sensor types: 10 ohm copper
100 ohm nickel
120 ohm nickel
100 ohm platinum

URTD Module Communications

Interface: Fiber optic

Fiber optic cable: Type HFBR-PNS005

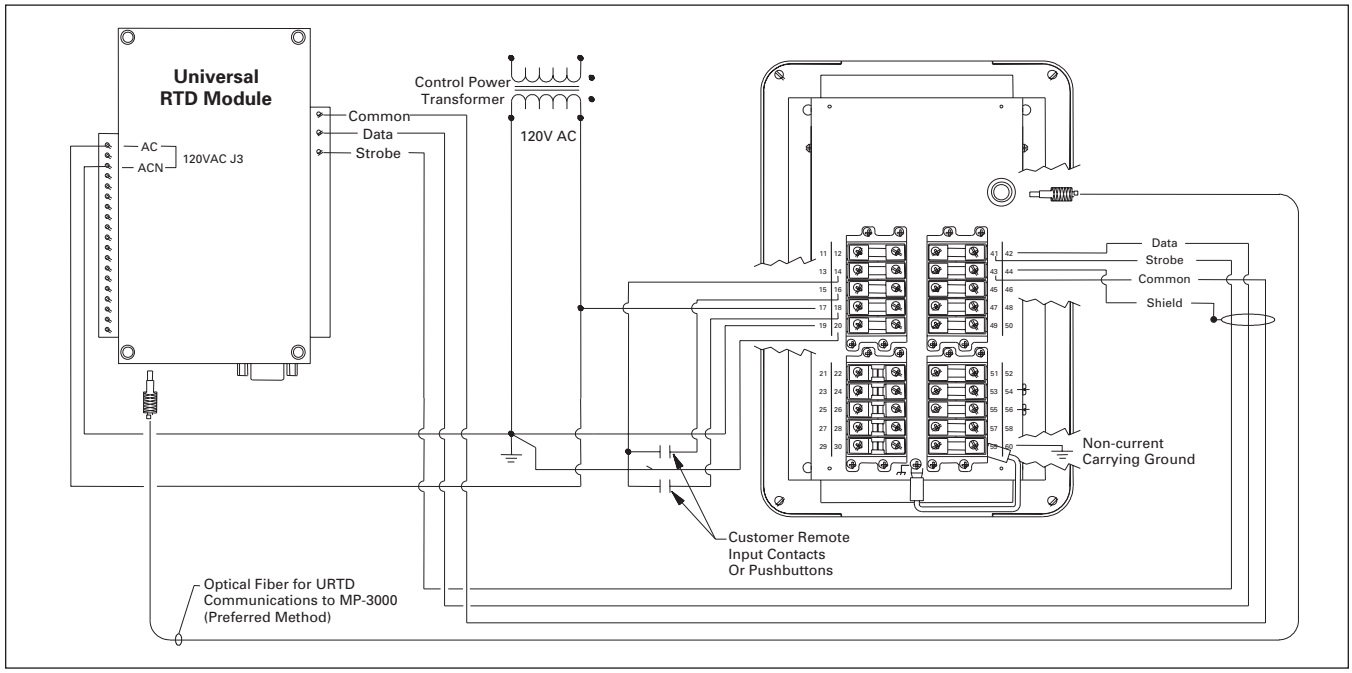


Figure 4.2-15. MP-3000 Drawout Typical AC Supply and URTD Wiring

MD-3000 Motor Differential Relay

MD-3000 Differential Relay

General Description

Eaton's MD-3000 Protective Relay is a microprocessor-based sensitive three-phase instantaneous OC relay designed for both ANSI and IEC applications. The MD-3000 is suitable for use as a motor or generator self-balancing differential protection relay.

The MD-3000 Relay operates from the 5A secondary output of standard current transformers. Current transformer ratio information is quickly programmed into the unit via settings. The MD-3000 features a user-friendly operator panel to monitor, program and test the relay. Operating parameters and trouble-shooting information are displayed in the two display windows.

Application Description

The MD-3000 microprocessor-based relay provides reliable instantaneous trip protection for all voltage levels. It is most commonly used as a motor differential protection relay.

Features

- ANSI and IEC applications
- Phase differential metering
- Monitoring and reporting of magnitude and phase of current causing trip
- Relay failure alarm contact
- Trip alarm contact
- User-friendly front panel
- Non-volatile memory
- View settings any time
- Set CT ratios
- Integral test mode
- Program and test mode security access cover with meter seal provision
- Continuous internal circuitry self-testing
- Programmable lockout/self reset after trip

Table 4.3-1. Catalog Numbers

Description	Catalog Number
Fixed case Drawout	**MD3000** **MD3001**

System Protection

- Instantaneous sensitive phase overcurrent trip

Information and Data Delivery

- Displays current transformer ratio
- Data/information transmission

Wiring Diagram

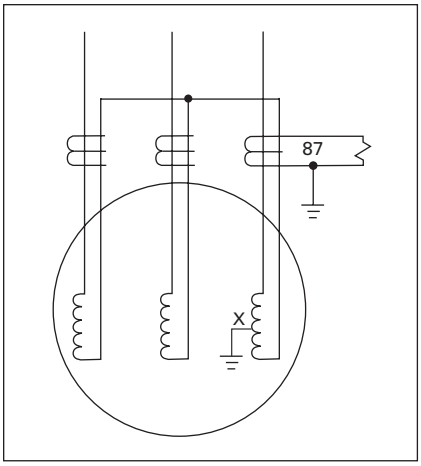


Figure 4.3-1. Self-Balancing Differential Protection

4

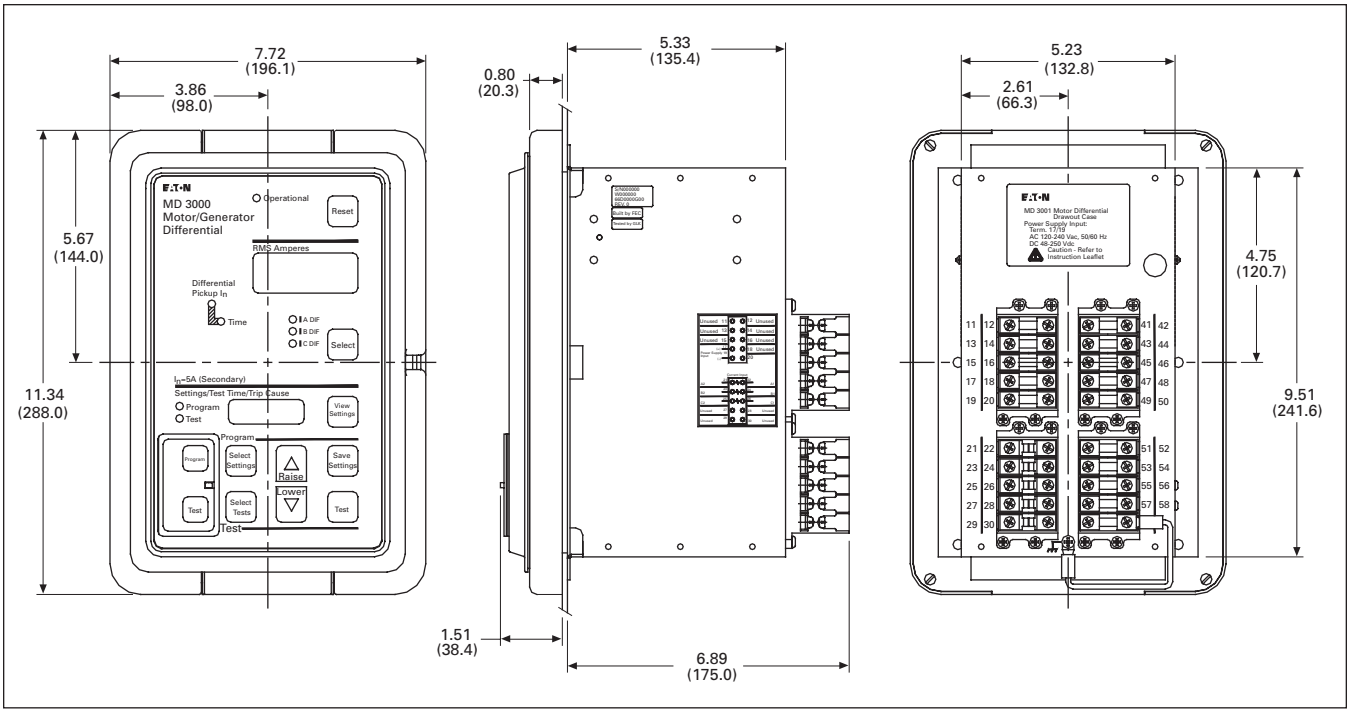


Figure 4.3-2. MD-3000—Dimensions in Inches (mm)

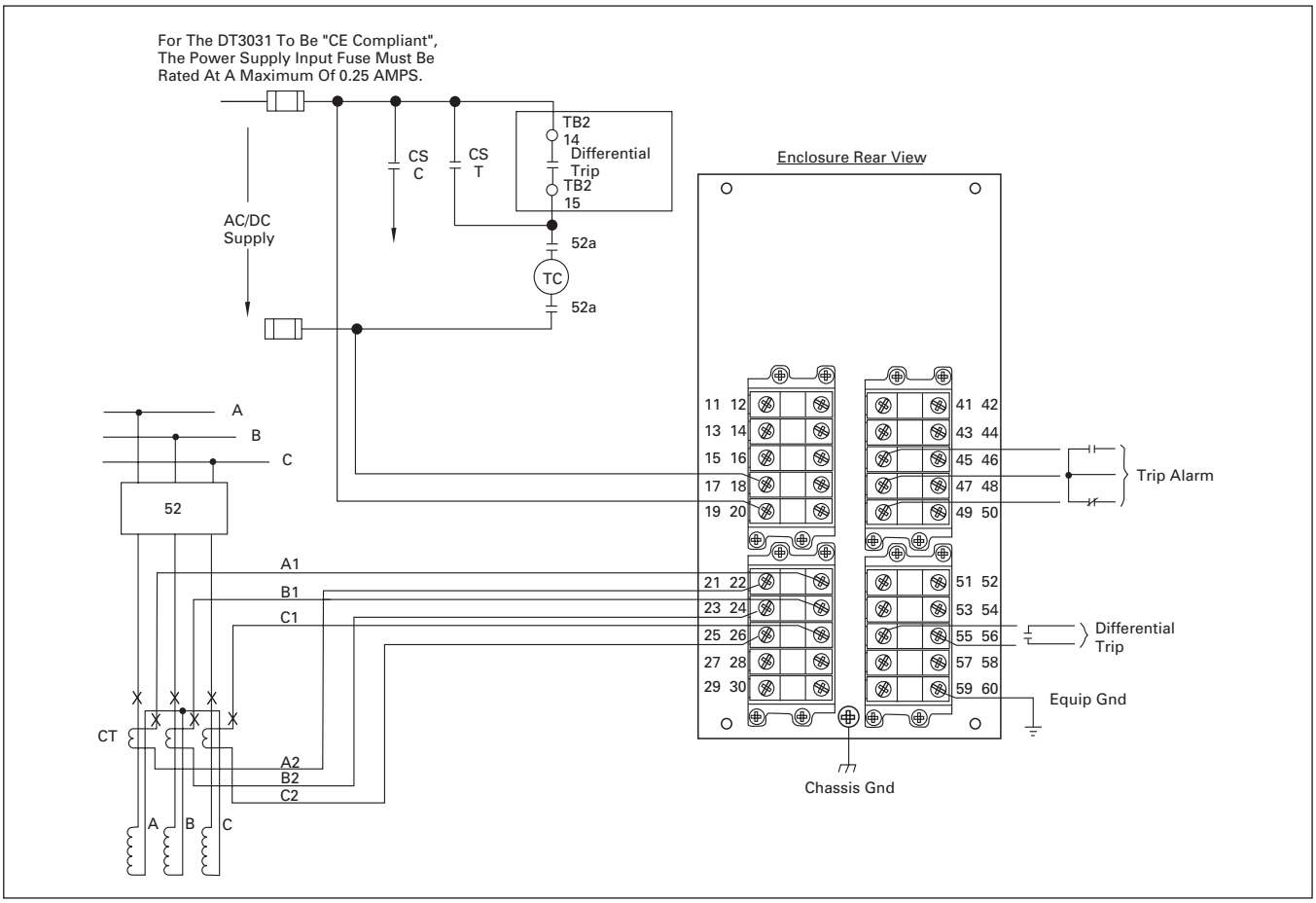


Figure 4.3-3. MD-3000 Wiring Diagram

DP-300 Current Differential Protection Relay

DP-300

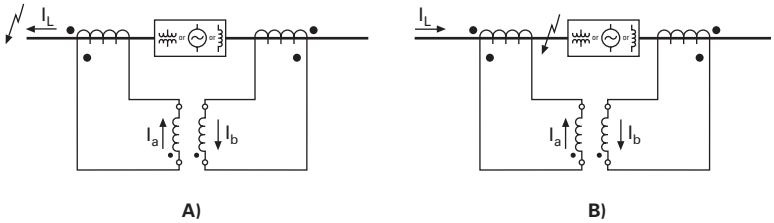
General Description

The DP-300 offers a three-phase current differential protection for generators, motors and two winding transformers.

The current flowing in the individual conductors is measured by means of current transformers installed on both sides of the protection zone. These transformers form the limits of the protection zone. By means of freely configurable relays, the unit will indicate if any of the adjusted fault current limits have been exceeded. The unit counts with a slope characteristic to prevent operation due to CT ratio mismatches, CT ratio errors, CT saturation, and errors because of tap changes.

For transformer applications, the unit has 2nd and 5th harmonic restraints to prevent misoperation in case of inrush currents caused for energization or over excitation of the transformer. When used in transformer applications, the DP-300 allows change to the phase shift of the transformer, without having to change the connection of the external CTs, via selecting the vector group in the display. The different nominal currents of the high and low voltage side of the transformer, as well as the transformer ratio, may be configured. Every measuring point may be set separately. These features permit the DP-300 to be universal in its applications.

The DP-300 permits design simplification of the switchgear cabinet, facilitates the commissioning, ensures the operation of the system, is user friendly, and increases the availability of the system.



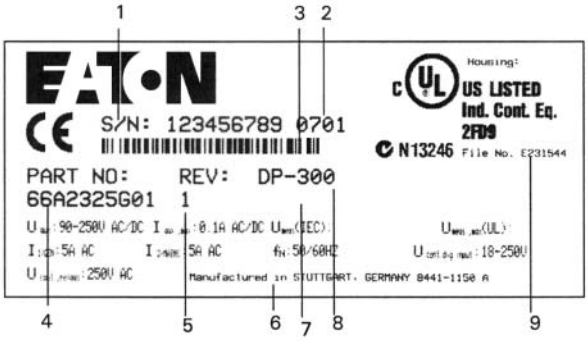
Schematic Circuit Diagrams (Single-Phase Version):
A) Fault Outside the Protection Area
B) Fault Inside the Protection Area

Figure 4.3-4. Protected Area Principle—Fault "A" Outside = No Alarm, Fault "B" Inside = Alarm

Features

- True rms 6 x current measurement, three-phase system on both sides of the protected zone
- Secondary current transformer output available as: /1A or /5A
- Configurable trip set points for:
  - Differential current (Id)
  - Restrain current (Is)
- Configurable delays
- Four alarm relays
- Three discrete inputs (for blocking, acknowledgment and configuration)
- Two-line LC display
- Configurable transformer ratio
- Configurable vector group
- Transformer inrush detection/ suppression
- Individual configuration of the nominal current for the high- and low-voltage side of the transformer
- Configurable transformer ratio separated for currents of high- and low-voltage side of the transformer

Typical Nameplate



1	S/N	Serial Number (Numerical)
2	S/N	Date of Production (YYMM)
3	S/N	Serial Number (Bar Code)
4	P/N	Item Number
5	REV	Item Revision Number
6	Details	Technical Data
7	Type	Description (Long)
8	Type	Description (Short)
9	UL	UL Sign

Figure 4.3-5. Typical DP-300 Nameplate

Technical Data

Table 4.3-2. DP-300 Specifications

Description	Specification
Measurements, Currents—Isolated	
Measured currents (nominal value IN)	5A
Measuring frequency	40.0 to 70.0 Hz
Accuracy	Class 1
Linear measuring range	5.0 x I_n
Maximum power consumption per path	< 0.15 VA
Rated short-time current (1s)	30.0 x I_n
Ambient Conditions	
Voltage supply	90 to 250 Vac/Vdc
Intrinsic consumption	Maximum 10 VA
Ambient temperature storage	–30° to +80°C (–22° to +176°F)
Operational	–20° to +70°C (–4° to +158°F)
Ambient humidity	95%, noncondensing
Maximum altitude	6562 ft (2000m)
Degree of pollution	2
Digital Inputs—Isolated	
Input range ($V_{cont, digital input}$)	Nominal voltage 18 to 250 Vac/dc
Input resistance	Approximately 68K ohms
Relay Outputs—Isolated	
Contact material	AgCdO
Resistive load (GP) ($V_{cont, relay output}$)	AC: 2.00 Aac at 250 Vac DC: 2.00 Adc at 24 Vdc, 0.36 Adc at 125 Vdc, 0.18 Adc at 250 Vdc
Inductive load (PD) ($V_{cont, relay output}$)	AC: B300 DC: 1.00 Adc at 24 Vdc, 0.22 Adc at 125 Vdc, 0.10 Adc at 250 Vdc
Protective Functions	
Operating time	Minimum 100 ms
Differential current	Minimum 10%
Housing	
Type	APRANORM DIN 43 700
Dimensions (W x H x D)	5.67 x 3.78 x 5.20 inches (144 x 96 x 132 mm)
Front panel cutout (W x H)	5.43 [+0.039] x 3.63 [=0.031] inches (138 [+1.0] x 92 [+0.8] mm)
Terminals	Screw-type, terminals depending on connector, 0.00388 $in.^2$ (2.5 mm^2) or 0.00620 $in.^2$ (4.0 mm^2)
Recommended tightening torque	[0.00388 $in.^2$] 4.43 in./lbs/[0.00620 $in.^2$] 5.3 in./lbs ([2.5 mm^2] 0.5 Nm/[4.0 mm^2] 0.6 Nm) Use 60°/75°C (140°/167°F) copper wire only Use Class 1 wire only (or equivalent)
Weight	Approximately 2.2 lbs (1000g)
Housing Protection	
Protection system	IP42 from front with correct mounting IP54 from front with gasket Gasket: P/N 8923-1038) IP20 from back
Front foil	Insulating surface
EMC-Test (CE)	Tested according to applicable EN guidelines
Listings	CE marking; UL listing for ordinary locations, UL/cUL listed, ordinary locations, File No.: E231544
Additional approvals	IEEE C37.90.1 and C37.90.2

Wiring Diagram

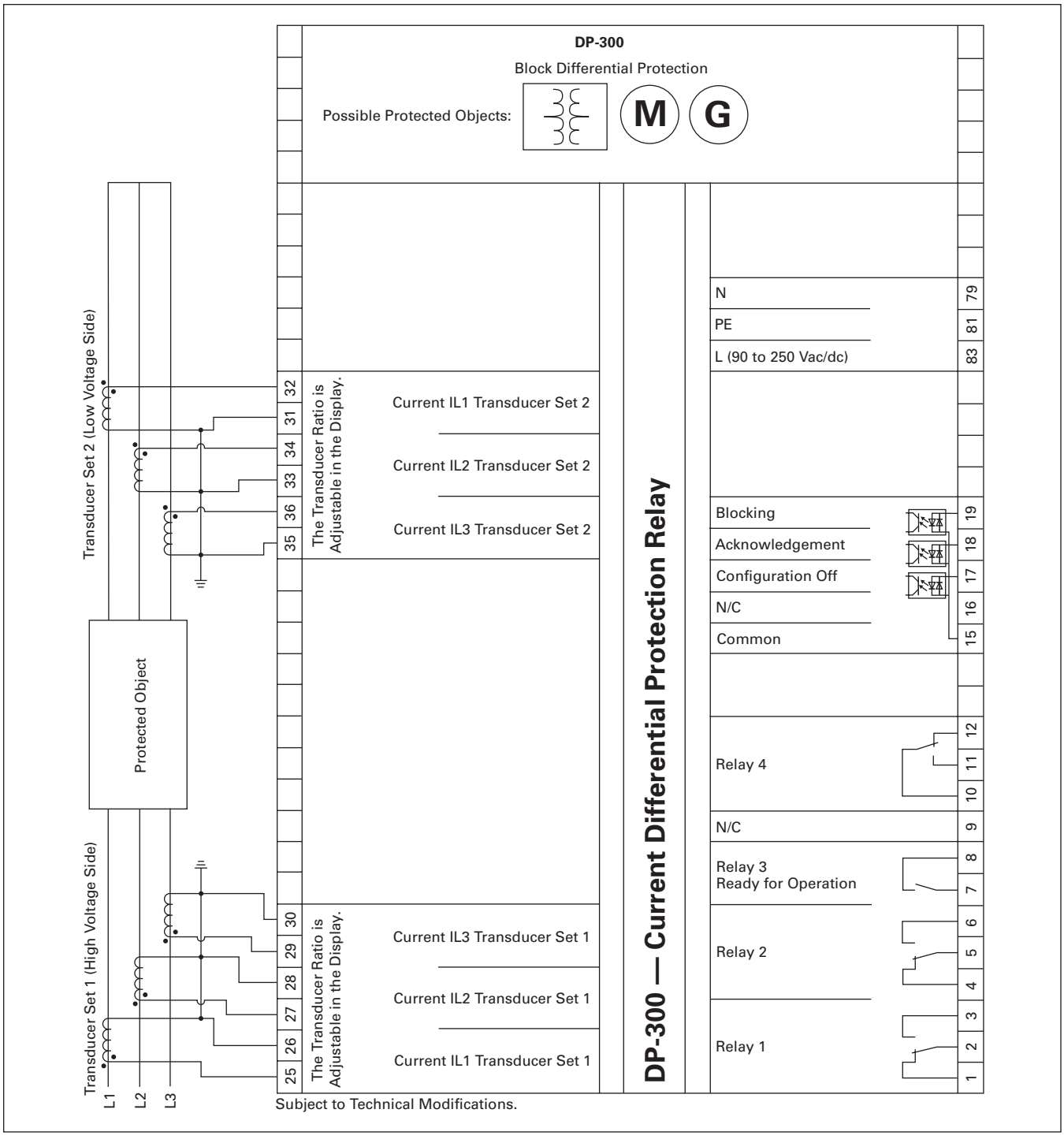


Figure 4.3-6. DP-300 Wiring Diagram

ETR-4000 Transformer Protection Relay

ETR-4000 Transformer Protection Relay

General Description

Eaton's ETR-4000 transformer protection relay is a multi-functional, microprocessor-based relay for two winding transformers of all voltage levels. The ETR-4000 provides phase and ground percentage restrained differential protection using a variable dual slope characteristic with phase, negative, residual and neutral overcurrent elements for backup protection. It can also be used to provide restrained differential protection to large motors and generators.

The ETR-4000 has eight current inputs rated for either 5A or 1A to monitor both sides of the transformers. The CTs can be connected in wye in both sides of the transformer; the relay automatically compensates for the connection of the transformer and for CT mismatch errors.

The Maintenance Mode password protected soft key can be used for arc flash mitigation to change to an alternate settings group, set to have instantaneous elements only.

An integral keypad and display is provided for direct user programming and retrieval of data without the need of a computer. 14 programmable LEDs provide quick indication of relay status.

A front port is provided for direct computer connection. An RS-485 communication port on the back is standard for local area networking using Modbus-RTU. An optional Ethernet port and protocols are available.

Flash memory is used for the programming and all settings are stored in nonvolatile memory. The relay allows for four preprogrammed setting groups that can be activated through software, the display or a contact input.

The ETR-4000 transformer protection relay has a mass memory for data storage and a real-time clock with 1 ms time resolution. The relay will log 300 sequence of events records, 20 detailed trip logs, minimum/maximum values, load profiles, breaker wear information and oscillography data.

The ETR-4000 has eight programmable binary inputs, four normally opened and four Form C heavy-duty outputs and one Form C signal alarm relay. It can be powered from 19 Vdc to 300 Vdc or 40 Vac to 250 Vac auxiliary power.

Features

Protection

- Dual-slope percentage restrained current differential with magnetizing inrush and overexcitation blocking (87R)
- Unrestrained current differential (87H)
- Restricted ground fault/Ground Differential (87GD)
- Phase overcurrent (elements can be assigned to either side of the transformer):
  - ❑ Four instantaneous elements with timers (50P[1], 50P[2], 50P[3] and 50P[4])
  - ❑ Four inverse time overcurrent elements (51P[1], 51P[2], 51P[3] and 51P[4])
  - ❑ 11 standard curves
  - ❑ Inrush blocking
  - ❑ Instantaneous or time delay reset
- Negative sequence phase overcurrent (elements can be assigned to either side of the transformer):
  - ❑ Two inverse time overcurrent elements (51Q[1] and 51Q[2])
  - ❑ 11 standard curves
  - ❑ Instantaneous or time delay reset
- Ground overcurrent (elements can be assigned to either side of the transformer):
  - ❑ Two instantaneous measured elements with timers (50X[1] and 50X[2])
  - ❑ Two instantaneous calculated elements with timers (50R[1] and 50R[2])
  - ❑ Two inverse time overcurrent measured elements (51X[1] and 51X[2])
  - ❑ Two inverse time overcurrent calculated elements (51R[1] and 51R[2])
  - ❑ 11 standard curves
  - ❑ Instantaneous or time delay reset
- Two breaker failure elements (50BF[1] and 50BF[2])
- Phase transformer overload protection (49)
- Switch onto fault protection
- Zone interlocking for bus protection (87B)

Metering

- Amperes: positive, negative and zero sequence
- Ampere demand
- Current phase angles
- % THD I
- Magnitude THD I
- Minimum/maximum recording
- Trending (load profile over time)
- RTD temperatures

Monitoring

- Trip coil monitor for both primary and secondary breakers
- Breaker wear primary and secondary (accumulated interrupted current)
- Oscillography (3600 cycles total)
- Fault data logs (up to 20 events)
- Sequence of events report (up to 300 events)
- Clock (1 ms time stamping)

Communication

- Local HMI
- Password protected
- Addressable
- IRIG-B
- Local communication port
- Remote communication port:
  - ❑ RS-232
  - ❑ RS-485
- Protocols:
  - ❑ Modbus-RTU
  - ❑ Modbus-TCP (optional)
- Configuration software

Control Functions

- Breaker open/close both breakers
- Remote open/close
- Programmable I/O
- Programmable LEDs
- Multiple setting groups
- Cold load pickup
- CT supervision

Table 4.3-3. Catalog Numbering Selection for ETR-4000 Transformer Protection Relay Removable Terminals

ETR-4000 A 0 B A 1

Hardware Option 1	Hardware Option 2	Communication Options	Conformal Coating Options	Mounting Options
A = Eight digital inputs, nine outputs, removable terminals, two zone interlocking, URTD interface, IRIG-B, small display **B** = Four digital inputs, five outputs, removable terminals, IRIG-B, small display ① **C** = Eight digital inputs, five outputs, removable terminals, one zone interlocking, IRIG-B, small display ①	**0** = Phase current 5A/1A, ground current 5A/1A, power supply range: 19–300 Vdc 40–250 Vac **1** = Phase current 5A/1A, sensitive ground current 0.5A/0.1A, power supply range: 19–300 Vdc 40–250 Vac ①	**B** = Modbus-RTU (RS-485) **1** = Modbus-RTU (RS-485) + Modbus-TCP (RJ-45)	**A** = None **B** = Conformal coated circuit boards	**0** = Standard mount **1** = Projection panel mount

① Consult factory for the availability of sensitive ground, four inputs/five outputs and eight inputs/five outputs.

4

Protection Functions

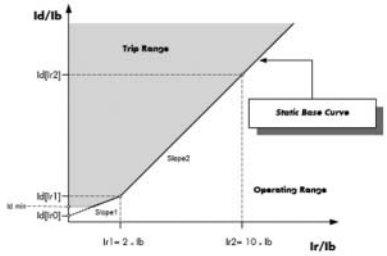
Eaton's ETR-4000 transformer protection relay has been designed for maximum user flexibility and simplicity. The ETR-4000 is suitable for application on small, medium and large two-winding power transformers. Multiple current inputs are used to provide primary protection, control and backup protection of transformers, including current differential, restricted ground differential and overcurrent protection.

Dual-Slope Percent Differential Protection

The primary protective element for transformer protection is the percent differential element, which compares the current entering the primary and leaving the secondary of the transformer. The ETR-4000 has built in compensation for the turns-ratio and the phase shift of the transformer, so it's not necessary to compensate for the transformer connection by the connection of the CTs.

The current differential element looks at the vector difference between the current entering and leaving the zone of protection. If the difference exceeds a pre-determined amount, the element will operate.

The operating characteristic of the percent differential element is a dual-slope characteristic to accommodate for CT saturation and CT errors.

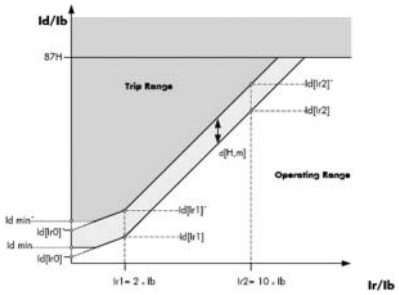


Dual-Slope Operating Characteristics

Harmonic Restraints

There are certain conditions like energizing one side of the transformer with the other side de-energized (inrush currents) or the paralleling of two transformers (sympathetic currents) that can create false differential currents. These differential currents if not recognized can cause a false trip; in the case of inrush conditions or sympathetic currents, the differential current is characterized by a heavy content of 2nd and 4th harmonic currents. The percentage differential element is desensitized either permanently (stationary conditions) or temporarily (transient conditions), whenever the 2nd or 4th harmonic exceed the value programmed into the relay.

Another condition that can create a false differential current is a sudden change of voltage or frequency that can put the transformer in a over-excitation state. In this case there is high content of 5th harmonic currents. The percentage differential element is also desensitized when the 5th harmonic content exceeds a predefined value.



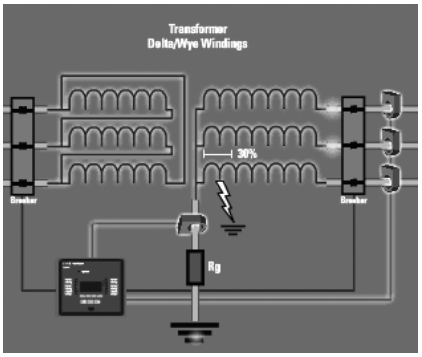
Harmonic Restraints

Unrestrained Differential

An unrestrained differential element is provided for fast tripping on heavy internal faults to limit catastrophic damage to the transformer and to minimize risks to the remainder of the power system.

Restricted Ground Fault

Ground differential protection is applied to transformers having impedance grounded wye windings. It is intended to provide sensitive ground fault detection for low magnitude fault currents, which would not be detected by the main percent differential element.



Restricted Ground Fault

Overcurrent Elements

The ETR-4000 can be used to provide backup for transformer and adjacent power system equipment. Instantaneous overcurrent elements can be used for fast clearing of severe internal or external (through) faults.

Time overcurrent protection elements per winding allow coordinating with the adjacent protection zones and acting as a backup protection. There are 11 user-selectable inverse-time overcurrent curve characteristics. The user can select from the ANSI, IEC or thermal curve families, and can select instantaneous or time delay reset characteristics.

Negative Sequence Overcurrent

Because this element does not respond to balanced load or three-phase faults, the negative-sequence overcurrent element may provide the desired overcurrent protection. This is particularly applicable to delta-wye grounded transformers where only 58% of the secondary p.u. phase-to-ground fault current appears in any one primary phase conductor. Backup protection can be particularly difficult when the wye is impedance grounded.

A negative-sequence element can be used in the primary supply to the transformer and can be set as sensitively as required to protect for secondary phase-to-ground or phase-to-phase faults. This element should be set to coordinate with the low-side phase and ground relays for phase-to-ground and phase-to-phase faults. The negative sequence element must also be set higher than the negative-sequence current due to unbalanced loads.

Breaker Failure

The ETR-4000 transformer protection relay includes two breaker failure (50BF, 62BF) elements that can be initiated from either an internal or external trip signal. These are independent elements that can be used to operate a lockout relay or trip an upstream breaker. The timer must be longer than the breaker operating time and the protective function reset times.

Maintenance Mode

The Maintenance Mode can improve safety by providing a simple and reliable method to reduce fault clearing time and to lower incident energy levels at energized panels. The Maintenance Mode allows the user to switch to more sensitive settings via a password-protected soft key, communication or via a digital Input while maintenance work is being performed at an energized panel or device. The more sensitive settings provide greater security for maintenance personnel and help to reduce the possibility of injury.

Sequence of Events Records

The ETR-4000 protection relay records a maximum of 300 events associated with the relay. An event is classified as a change of state as detected by the relay. These include relay pickups, dropouts, trips, contact closure, alarms, setting changes and self-diagnostic failures. Each event is date and time stamped to a 1 ms resolution. The events are stored in an FIFO in chronological order.

Trip Log

The ETR-4000 protection relay will store a maximum of 20 trip records in an FIFO trip log. Each trip record will be date and time stamped to a 1 ms resolution. The trip log record will include information on the type of fault, protection elements that operated, fault location, and currents and voltages at the time of the fault.

Waveform Capture

The ETR-4000 transformer protection relay provides oscillography-recording capabilities. The relay will record all measured signals along with the binary signals of pickup, trip, logic and contact closures. The ETR-4000 relay can record up to 6000 cycles of data. The number of records is proportional to the size of each record; the maximum size per record is 600 cycles. The waveform capture is initiated by up to eight different triggers; it can also be generated manually through the display or via communications.

Integral User Interface

The front panel user interface has a 128 x 64 pixel LCD display with background illumination for wide angle viewing in all light conditions. 17 programmable LEDs provide quick and easy visual display of power on, mode of operation, alarm and trip indication. Soft keys are provided for operation mode selection, scrolling through data and settings. In addition, the relay settings and test functions are password protected.

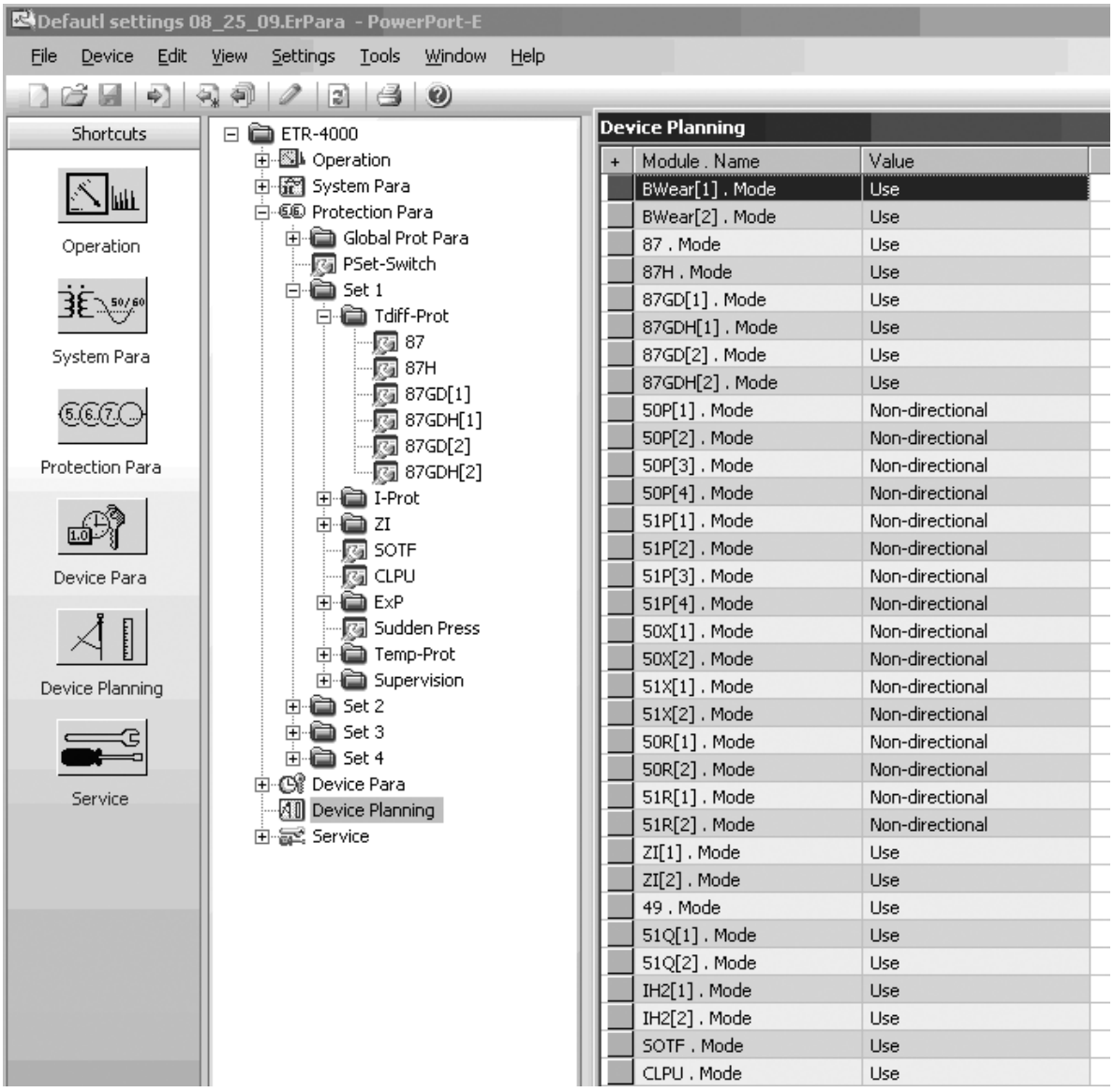


Figure 4.3-7. ETR-4000 Device Planning

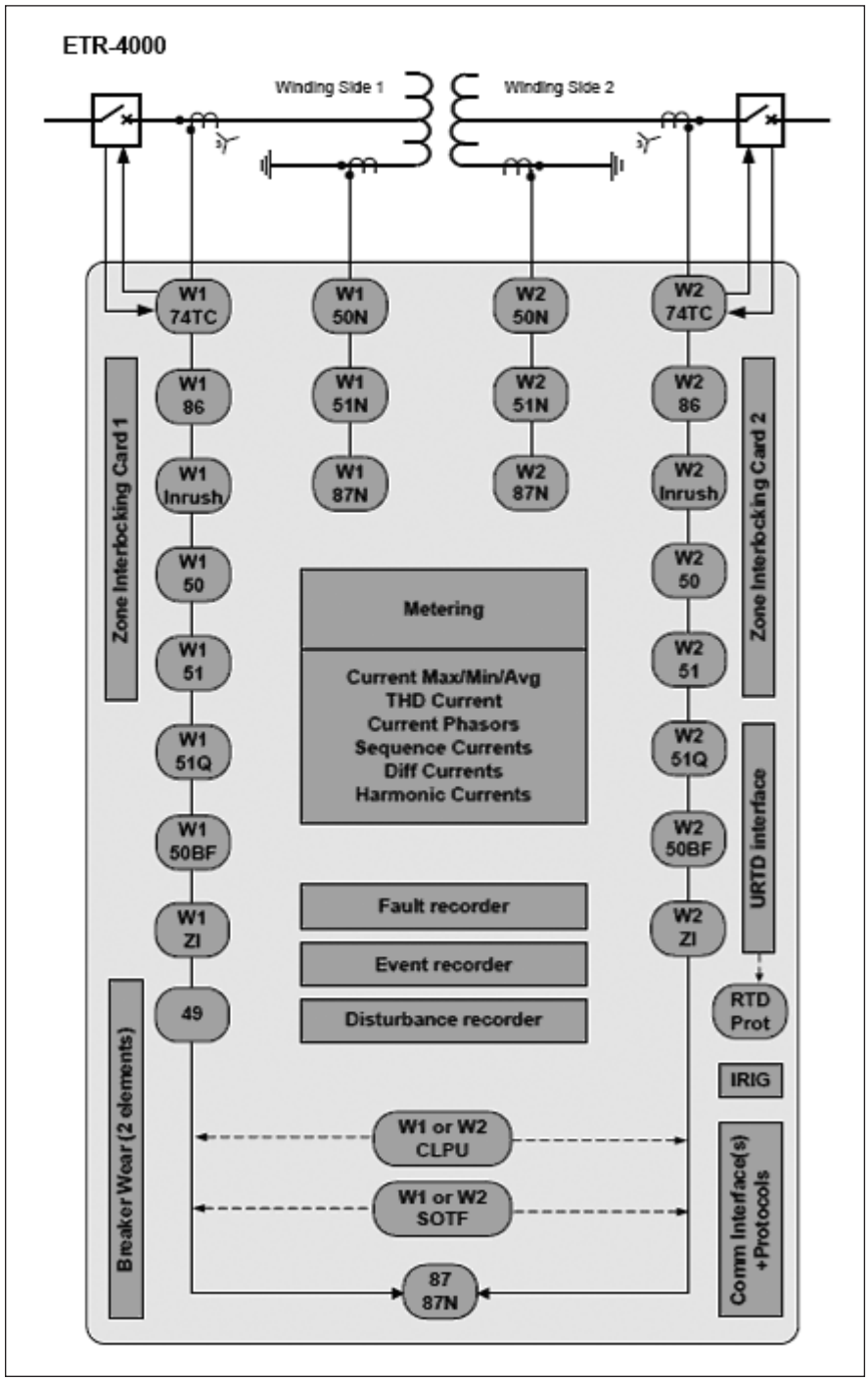


Figure 4.3-8. ETR-4000 Typical One-Line Diagram

Programmable I/O

The ETR-4000 transformer protection relay provides heavy-duty, trip-rated, four normally open and four Form C contacts. Two isolated inputs can be used for monitoring the trip circuits. One Form C contact is dedicated to the relay failure alarm function and is operated in a normally energized (failsafe) mode. There are eight user-configurable discrete inputs that accept a wet contact and can operate through a wide range of power. Each input and output is user-programmable for maximum application flexibility.

Communication Software

Eaton provides two types of communication software. The first is PowerPort-E. It runs on a PC or laptop for easy access to a single relay to change set points or configuration and to view metered values and stored data. PowerPort-E is free and can be downloaded from the Eaton Web site at **www.eaton.com/pr**.

The second package is Power Xpert Software. Power Xpert Software is a power management software package that is designed for continuous, remote monitoring of many devices. It provides additional functions such as billing, trending and graphics. Contact your local Eaton representative for more information on Power Xpert Software.

Standards, Certifications and Ratings

Table 4.3-4. ETR-4000 Specifications

Voltage Supply

Aux. voltage:	24–270 Vdc/48–230 Vac (–20%/+10%)
Buffer time in case of supply failure:	> = 50 ms at minimal aux. voltage interrupted communication is permitted

Max. permissible making current:
18A peak value for 0.25 ms
12A peak value for 1 ms

The voltage supply must be protected by a fuse of:
2.5A time-lag miniature fuse 5.0 x 20.0 mm (approx. 0.20 in. x 0.80 in) according to IEC 60127
3.5A time-lag miniature fuse 6.3 x 32.0 mm (approx. 0.25 in. x 1.25 in) according to UL 248-14

Power Consumption

Power supply range:	24–270 Vdc: 7W idle mode/ approx. 13W max. power 48–230 Vac: 7 VA idle mode/ approx. 13 VA max. power (for frequencies of 40–70 Hz)
Power consumption:	Phase current inputs at I_n = 1A, S = 0.15 mVA at I_n = 5A, S = 0.15 mVA
Ground current input:	at I_n = 1A, S = 0.35 mVA at I_n = 5A, S = 0.35 mVA

Digital Inputs

Max. input voltage:	300 Vdc/259 Vac
Input current:	<4 mA
Reaction time:	<20 ms
Fallback time:	<30 ms (safe state of the digital inputs)
Switching thresholds:	Un = 24 Vdc, 48 Vdc, 60 Vdc, 110 Vac/dc, 230 Vac/dc
Un = 24 Vdc	
Switching threshold 1 ON:	Min. 19.2 Vdc
Switching threshold 1 OFF:	Max. 9.6 Vdc
Un = 48V/60 Vdc	
Switching threshold 2 ON:	Min. 42.6 Vdc
Switching threshold 2 OFF:	Max. 21.3 Vdc
Un = 110/120 Vac/dc	
Switching threshold 3 ON:	Min. 88.0 Vdc/88.0 Vac
Switching threshold 3 OFF:	Max. 44.0 Vdc/44.0 Vac
Un = 230/240 Vac/dc	
Switching threshold 4 ON:	Min. 184 Vdc/184 Vac
Switching threshold 4 OFF:	Max. 92 Vdc/92 Vac
Terminals:	Screw-type terminal

Relay Outputs

Continuous current:	5A AC/DC
Max. make current:	25A AC/25A DC up to 30V for 4s 30A/230 Vac according to ANSI IEEE Std. C37.90-2005 30A/250 Vac according to ANSI IEEE Std. C37.90-2005
Max. breaking current:	5A AC up to 125 Vdc 5A DC up to 30V (resistive) 0.3A DC at 300V
Max. switching voltage:	250 Vac/250 Vdc
Switching capacity:	1250 VA
Contact type:	Form C or normally open contact
Terminals:	Screw-type terminals

Zone Interlocking

NOTICE: ONLY FOR ZONE INTERLOCK TRIPPING OUTPUTS (ZONE INTERLOCK, SEMI-CONDUCTOR OUTPUT): 5 Vdc, <2 mA FOR CONNECTION TO ELECTRONIC INPUTS ONLY.

Zone out:	
Output voltage (high):	4.75 to 5.25 Vdc
Output voltage (low):	0.0 to +0.5 Vdc
Zone in:	
Nominal input voltage:	+5 Vdc
Max. input voltage:	+5.5 Vdc
Switching threshold ON:	Min. 4.0 Vdc
Switching threshold OFF:	Max. 1.5 Vdc
Galvanic isolation:	2.5 kV AC (to ground and other IO)
Connection:	Screw-type terminals (twisted pair)

Front Interface RS-232

Baud rates:	115,200 Baud
Handshake:	RTS and CTS
Connection:	Nine-pole D-Sub plug

RS-485

Master/slave:	Slave
Connection:	Six screw-clamping terminals RM 3.5 mm (138 MIL) (terminating resistors internal)

Fiber Optic

Master/slave:	Slave
Connection:	ST-plug

URTD-Interface

Connection:	Versatile link

Climatic Environmental Conditions

Storage temperature:	–30°C to +70°C (–22°F to +158°F)
Operating temperature:	–20°C up to +60°C (–4°F to +140°F)
Permissible humidity at Ann. average:	<75% rel. (on 56d up to 95% rel.)
Permissible installation altitude:	<2000m (6561.67 ft) above sea level If 4000m (13,123.35 ft) altitude applies, a changed classification of the operating and test voltages may be necessary.

EGR-4000 Generator Protection Relay

EGR-4000 Generator Protection Relay

General Description

Eaton's EGR-4000 generator protection relay is a multi-functional, micro-processor-based relay for small to medium sized generators. It may be used as a primary or backup protection in standby generators, and cogeneration applications.

The EGR-4000 generator protection relay provides voltage controlled, voltage restrained, and standard directional three-phase overcurrent protection, as well as directional phase-residual and independent ground overcurrent protection and breaker failure. Three-phase over-/undervoltage, voltage unbalance, current unbalance, over/under and rate-of-change frequency, vector surge, power factor, directional VARs, directional power, loss of excitation, overexcitation and sync check functions are standard functions.

The EGR-4000 generator relay provides all required protection, control, monitoring and metering for small and medium sized generators in a single, compact case. The relay has four current inputs rated for either 5A or 1A and four voltage inputs. Three of the voltage inputs are to be connected to the three-phase power voltage for voltage protection and for metering. They can be connected in wye-ground or open delta configuration. The fourth voltage is for independent single-phase undervoltage/overvoltage protection, or 100% ground protection for a high resistance grounded generator.

The Maintenance Mode password protected soft key, can be used for arc flash mitigation to change to an alternate settings group, set to have instantaneous elements only. The multiple setting groups can also be changed, via communications or a digital input.

An integral keypad and display is provided for direct user programming and retrieval of data without the need of a computer. 14 programmable LEDs provide quick indication of relay status.

A front port is provided for direct computer connection. An RS-485 and an Ethernet port in the back are optional for local area networking. Optional Modbus-RTU, Modbus-TCP or IEC-61850 protocols are supported.

The EGR-4000 generator protection relay includes programmable logic functions. Logic gates and timers may be defined and arranged for custom-ized applications. Programmable logic control functions make the EGR-4000 very flexible. Flash memory is used for the programming and all settings are stored in nonvolatile memory.

The EGR-4000 generator protection relay has mass memory for data storage and a real-time clock with 1 ms time resolution. The relay will log 300 sequence of event records, 20 detailed trip logs, minimum/maximum values, load profiles, breaker wear information and oscillography data.

The EGR-4000 has eight programmable binary inputs, two analog inputs, two analog outputs, two normally opened and two Form C heavy-duty outputs, and one Form C signal alarm relay. It can be powered from 19 Vdc to 300 Vdc or 40 Vac to 250 Vac auxiliary power.

Features

Protection

- Thermal protection (49/51)
- Phase overcurrent elements:
  - Three instantaneous elements with timers (50P[1], 50P[2] and 50P[3])
  - Three inverse time overcurrent elements (51P[1], 51P[2] and 51P[3])
  - 11 standard curves
  - Instantaneous or time delay reset
  - Voltage restraint (51P[2] and 51P[3])
  - Directional control (all elements)
- Ground overcurrent elements:
  - Two instantaneous measured elements with timers (50X[1] and 50X[2])
  - Two instantaneous calculated elements with timers (50R[1] and 50R[2])
  - Two inverse time overcurrent measured elements (51X[1] and 51X[2])
  - Two inverse time overcurrent calculated elements (51R[1] and 51R[2])
  - 11 standard curves
  - Instantaneous or time delay reset
  - Directional control (all elements)
- Breaker failure (50BF)
- Phase unbalance negative sequence overcurrent (46[1], 46[2])
- Phase voltage unbalance and sequence protection (47[1], 47[2])
- Main three-phase under/overvoltage (27M[1], 27M[2], 59M[1], 59M[2])
- Auxiliary single-phase under/overvoltage (27A[1], 27A[2], 59A[1], 59A[2])
- Ground fault overvoltage relay (59N[1], 59N[2])
- Six frequency elements that can be assigned to: overfrequency, under-frequency, rate of change or vector surge (81[1], 81[2], 81[3], 81[4], 81[5], 81[6])
- Apparent and displacement power factor (55A[1], 55A[2], 55D[1], 55D[2])
- Forward and reverse watts (32[1], 32[2], 32[3])
- Forward and reverse VARs (32V[1], 32V[2], 32V[3])
- Overexcitation, volts-per-hertz (24[1], 24[2])
- 64S, 100% stator ground fault (27TN/ 59N)
- Generator unbalance (46G[1], 46G[2])
- Loss of excitation (40[1],40[2])
- Sync check (25)
- Lockout (86)
- Loss of potential-LOP
- Zone interlocking for bus protection (87B)
- Switch onto fault protection
- Cold load pickup

Metering
- Generator hours of operation
- Amperes: positive, negative and zero sequence
- Ampere demand
- Volts: positive, negative and zero sequence
- Phase angles
- Volt-amperes and VA demand
- Watts and kW demand
- kWh (forward, reverse, net)
- VARs and kVAR demand
- kVARh (lead, leg and net)
- Power factor
- Frequency
- % THD V and I
- Magnitude THD V and I
- Minimum/maximum recording
- Sync values
- Trending (load profile over time)
- Temperature with remote URTD module

Monitoring
- Trip coil monitor
- Breaker wear
- Oscillography (6000 cycles total)
- Fault data logs (up to 20 events)
- Sequence of events report (up to 300 events)
- Clock (1 ms time stamping)

Communication
- Local HMI
- Password protected
- Addressable
- IRIG-B
- Local communication port
- Remote communication port:
  - RS-232
  - RS-485
- Protocols:
  - Modbus-RTU (optional)
  - Modbus-TCP (optional)
  - IEC-61850 (optional)
- Configuration software

Control Functions
- Breaker open/close
- Remote open/close
- Programmable I/O
- Programmable Logic
- Programmable LEDs
- Multiple setting groups
- Cold load pickup
- CT supervision

4

Table 4.3-5. Catalog Numbering Selection for EGR-4000 Generator Relay Removable Terminals

EGR-4000 A 0 B A 1

Hardware Option 1	Hardware Option 2	Communication Options	Conformal Coating Options	Mounting Options
A = Eight digital inputs, five outputs, 2AI +2AO, removable terminals, zone interlocking, URTD interface	**0** = Phase current 5A/1A, ground current 5A/1A, power supply range: 19–300 Vdc 40–250 Vac **1** = Phase current 5A/1A, sensitive ground current 0.5A/0.1A, power supply range: 19–300 Vdc 40–250 Vac	**B** = Modbus-RTU (RS-485) **H** = IEC-61850 (Goose) **I** = Modbus-RTU + Modbus-TCP	**A** = None **B** = Conformal coated circuit boards	**0** = Standard mount **1** = Projection panel mount

Protection and Control Functions

Eaton's EGR-4000 generator protection relay has been designed for maximum user flexibility and simplicity. The EGR-4000 provides comprehensive protection, metering and monitoring of small to medium sized synchronous or induction generators operating at 50 or 60 Hz. The base relay includes all the standard protection and metering functions. Protection features found in the EGR-4000 include:

Directional Overcurrent Protection

The EGR-4000 generation protection relay provides complete three-phase and ground directional overcurrent protection. There are 14 independent ground overcurrent elements. The ground elements "X" use the independently measured ground (or neutral) current from a separate current-sensing input. The ground elements "R" use a calculated 3Io residual current obtained from the sum of the three-phase currents. This calculated current could be used for either the neutral or ground current in a three-phase, four-wire system. Each of the phase and ground overcurrent elements can be selected to operate based on fundamental or rms current.

Ground direction is used to supervise ground current elements and is accomplished by using ground, negative sequence or residual currents supervised by zero, negative or positive sequence voltages or ground current. This function is selectable to operate in forward, reverse or both directions.

Phase direction is a function used to supervise all phase current elements (50, 51). A quadrature voltage is compared to a corresponding phase current to establish the direction of the fault. This function is selectable to operate in the forward, reverse or both directions.

Ground direction is used to supervise ground current elements and is accomplished by using ground, negative sequence or residual currents supervised by zero, negative or positive sequence voltages or ground current. This function is selectable to operate in forward, reverse or both directions.

Voltage Restrained Overcurrent

Voltage restraint reduces the overcurrent pickup level (51P[2], 51P[3]), to protect the distribution system components against excessive damage and to prevent the generator and its auxiliaries from exceeding their thermal limitations. This modification of the pickup overcurrent level is compared to the corresponding phase input voltage. The EGR-4000 uses the simple linear model below to determine the effective pickup value.

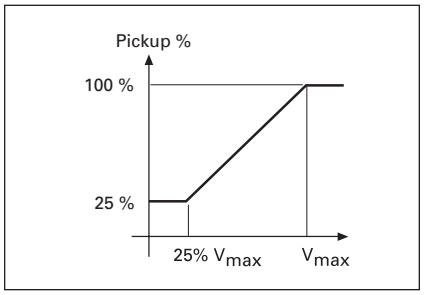


Figure 4.3-9. Voltage Restraint Coil Pickup Characteristics

Sync Check

The sync check function is provided for double-ended power source applications. The sync check monitors voltage magnitude, phase angle and slip frequency between the bus and line. It also incorporates breaker close time, dead bus dead line, dead bus live line and live bus live line features.

Reverse Power

Reverse power provides control for power flowing through a generator. There are three elements to be configured, operate in forward or reverse; or, under or over power conditions. Reverse power is typically applied to prevent generator motoring that can cause damage to the prime mover; while under power is generally applied to load loss and to prevent an overspeed condition that could damage the prime mover.

Reverse VARs

Reverse VARs can be used to detect loss of excitation in synchronous machines. There are three elements to be configured: operate in forward or reverse; or, under or over VARs conditions.

Inverse-Time Characteristics

There are 11 user-selectable inverse-time overcurrent curve characteristics.

The user can select from the ANSI, IEC or thermal curve families, and can select instantaneous or time delay reset characteristics.

Breaker Failure

The EGR-4000 generator protection relay includes a breaker failure (50BF, 62BF) function that can be initiated from either an internal or external trip signal. This is an independent element that can be used to operate a lockout relay or to trip an upstream breaker. The timer must be longer than the breaker operating time and the protective function reset times.

Voltage Protection

The EGR-4000 generator protection relay has four voltage-input circuits. There is a three-phase set designated as Main Voltage (M) and a single-phase voltage circuit designated as Auxiliary Voltage (A). Both include undervoltage (27) and overvoltage (59) protection. The three-phase voltage protection can be set to operate on a single-phase, two out of three phases, or all three-phase logic. The Main VTs also provide phase voltage unbalance/reversal (47 negative sequence) protection. Each element has an independent threshold set point and an adjustable time delay.

100% Ground Stator Protection

In high impedance grounded generators, ground fault protection is provided by the detection of voltage in the neutral of the generator by an overvoltage element (59N) connected to the secondary of the distribution grounding transformer, this overvoltage element has to be desensitized for 3rd harmonic voltages normally present in the generator. Under normal conditions there is no voltage across the secondary of the grounded transformer; when one of the phases goes to ground, voltage appears across the resistor and the overvoltage element operates, indicating a ground conductor. However, the overvoltage element technique described above will protect around 90% to 95% of the winding. The last 5% to 10% is protected by detecting the decayed of the 3rd harmonic voltage using an undervoltage element (27TN) tuned to the 3rd harmonic voltage. In the EGR-4000 we can provide 100% stator ground protection by measuring the zero sequence voltage through the 4th voltage input, and by combining the 59N and 27A elements. The 27A element has to be programmed to operate for 3rd harmonic zero sequence voltages.

Flexible Phase Rotation

The EGR-4000 generator protection relay can be applied on either an A-B-C or an A-C-B phase rotation. A user setting permits correct operation and indication of the actual system configuration.

Frequency Protection

Operation of generators at off-nominal frequencies can have extremely detrimental effects on both the generator itself and the associated prime mover, in particular with steam turbine generators operating below normal frequency. The EGR-4000 relay provides six frequency elements that can be used to detect under/over frequency, rate of change and a vector surge (decoupling of two systems) protection on the Main VT inputs. Each element has an independent threshold set point and an adjustable time delay.

Negative Sequence Protection

Negative sequence overcurrent protection prevents the generators from rotor overheating damage. Unbalanced loads, fault conditions or open phasing will produce a negative sequence current to flow. The unbalanced currents induce double system frequency currents in the rotor, which quickly causes rotor overheating. Serious damage will occur to the generator if the unbalance is allowed to persist. The EGR-4000 provides a negative sequence definite time overcurrent element and a negative sequence timed overcurrent tripping element to ensure that the generator stays within its short-time and continuous negative sequence current rated limits.

Overexcitation Protection

Generator overexcitation occurs when the ratio of voltage versus frequency is too high, and the rotor iron saturates due to high flux density. High flux density results in stray flux in components not designed to carry it, which in turn causes overheating and can potentially damage the generator. This protection is provided through a Volts/Hertz function with a programmable inverse time characteristic.

Loss of Excitation

Loss of field protection or loss of excitation is used to avoid unstable operation, potential loss of synchronism and possible damage to synchronous generators. When a synchronous generator loses its field, the generator can continue to generate power as an induction generator, provided that it can obtain its excitation from the other machines on the system. During this condition, the rotor will quickly overheat due to the slip frequency currents induced in it. Loss of excitation in one machine could jeopardize the operation of other machines beyond their capability and also the stability of the entire system. The EGR-4000 supports the two typical distance relaying schemes used for detecting the loss excitation. The two schemes differ mainly in that scheme 1 uses a negative offset mho element and scheme 2 uses a positive offset mho element with directional unit supervision.

Maintenance Mode

The Maintenance Mode can improve safety by providing a simple and a reliable method to reduce fault clearing time and to lower incident energy levels at energized panels. The Maintenance Mode allows the user to switch to more sensitive settings via a password-protected soft key, communication or via a digital input while maintenance work is being performed at an energized panel or a device. The more sensitive settings provide greater security for maintenance personnel and help to reduce the possibility of injury.

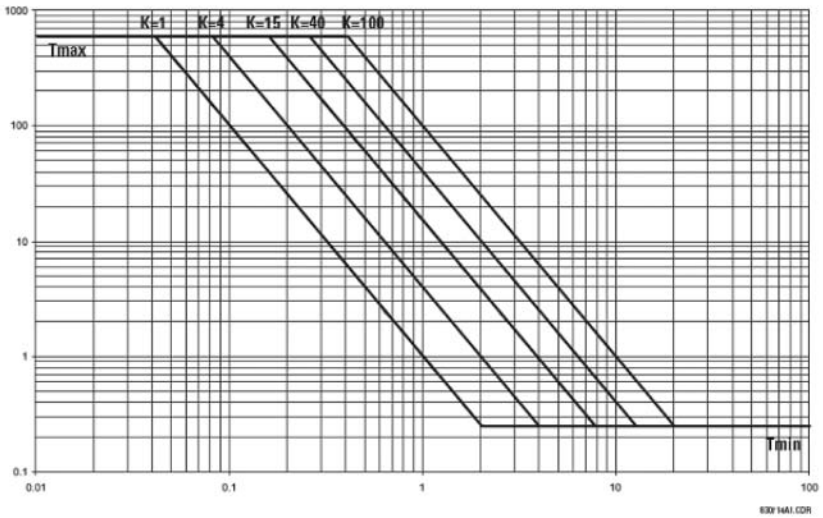


Figure 4.3-10. Negative Sequence Protection

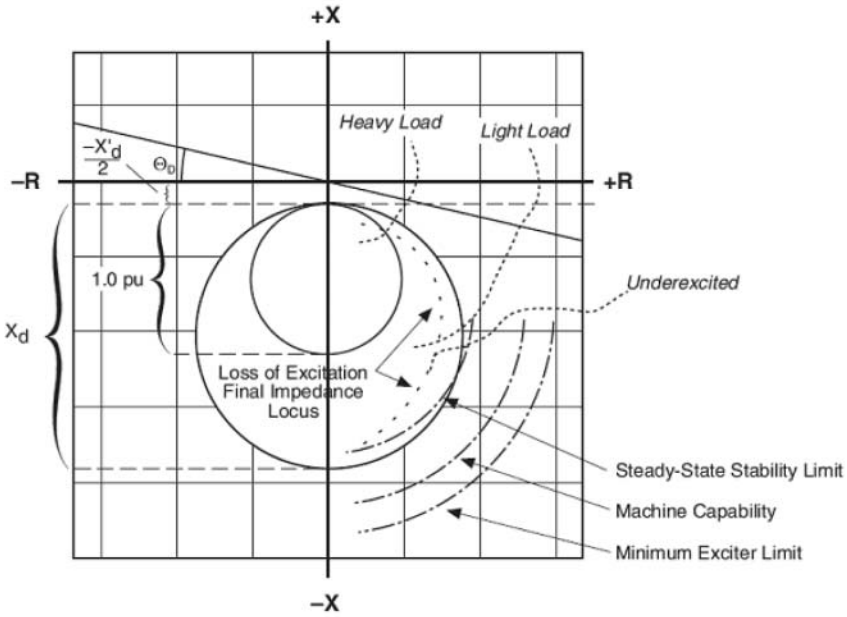


Figure 4.3-11. Loss of Excitation

Monitoring and Metering

Sequence of Events Records

The EGR-4000 generator protection relay records a maximum of 300 events associated with the relay. An event is classified as a change of state as detected by the relay. These include relay pickups, dropouts, trips, contact closure, alarms, setting changes and self-diagnostic failures. Each event is date and time stamped to a 1 ms resolution. The events are stored in an FIFO log in chronological order.

Trip Log

The EGR-4000 protection relay will store a maximum of 20 trip records in an FIFO trip log. Each trip record will be date and time stamped to a 1 ms resolution. The trip log record will include information on the type of fault, protection elements that operated, fault location, and currents and voltages at the time of the fault.

Waveform Capture

The EGR-4000 distribution protection relay provides oscillography-recording capabilities. The relay will record all measured signals along with the binary signals of pickup, trip, logic and contact closures. The EGR-4000 relay can record up to 6000 cycles of data. The number of records is proportional to the size of each record; the maximum size per record is 600 cycles. The waveform capture is initiated by up to eight different triggers; it can also be generated manually through the display or via communications.

Integral User Interface

The front panel user interface has a 128 x 64 pixel LCD display with background illumination for wide angle viewing in all light conditions. 17 programmable LEDs provide quick and easy visual display of power on, mode of operation, alarm and trip indication. Soft keys are provided for operation mode selection, scrolling through data and settings. In addition, the relay settings and test functions are password protected.

Load Profiling/Trending

The EGR-4000 relay automatically records selected quantities into non-volatile memory every 5, 10, 15, 30 or 60 minutes, depending on the trending report setting.

Programmable I/O

The EGR-4000 generator protection relay provides heavy-duty, trip-rated, two normally open and two Form C contacts. Two isolated inputs can be used for monitoring the trip circuit. One Form C contact is dedicated to the relay failure alarm function and is operated in a normally energized (failsafe) mode. There are eight user-configurable discrete inputs that accept a wet contact and can operate through a wide range of power. Each input and output is user-programmable for maximum application flexibility.

The EGR-4000 also has two analog inputs and two analog outputs. The analog inputs are available for providing protection and monitoring of generator bearing vibration. The analog inputs are field programmable to measure transducer signals that operate over a range of 0 to 20 mA, 4 to 20 mA, or 1 to 10V. Two analog outputs are available for signaling the value of measured analog quantities to external process control devices such as PLCs. They can be programmed to operate over a 0 to 20 mA, 4 to 20 mA, or 1 to 10V range. The analog outputs can be configured to signal a representation of most analog quantities measured by the EGR-4000 including current, voltages and RTD temperature.

Programmable Logic

The EGR-4000 generator protection relay provides logic gates and timers that the user can customize for special or unique applications. Each gate can be assigned a logic function of either AND, OR, NAND or NOR. Each gate can have a maximum of four input signals and each input signal can be required to be a NOT. Input signals can be external inputs received via the binary inputs or internal values associated with the protection, alarm or metering set points. Each gate has a unique output assignment and designation that can be used as the input to another gate. There are 24 independent timers that have adjustable pickup and dropout delay settings.

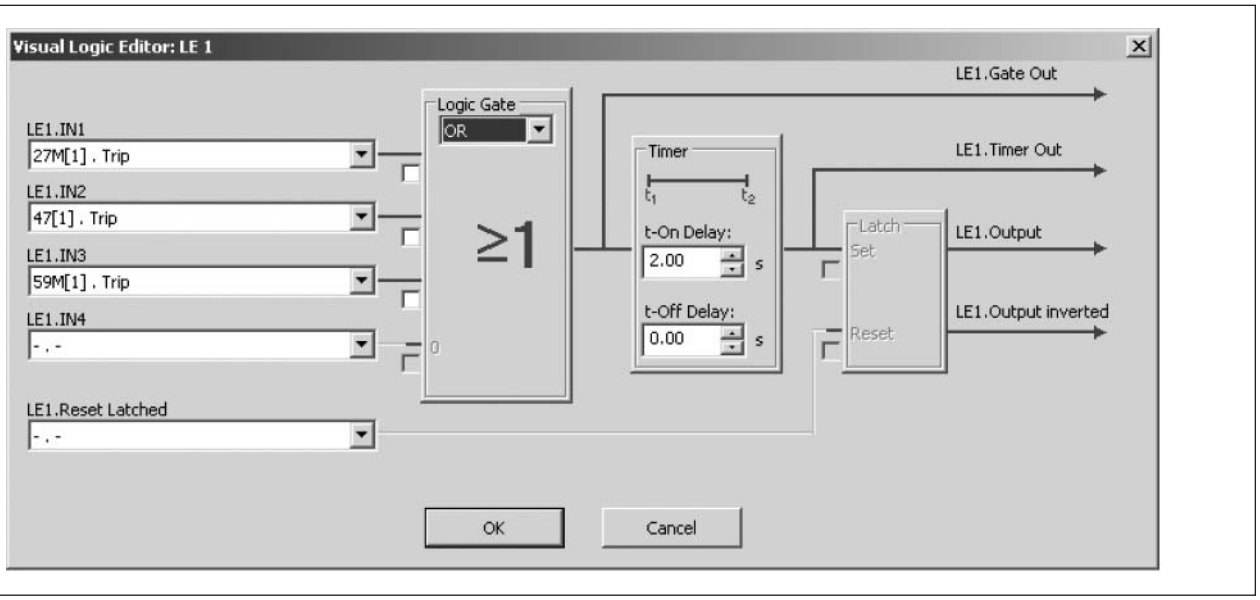


Figure 4.3-12. Visual Logic Editor

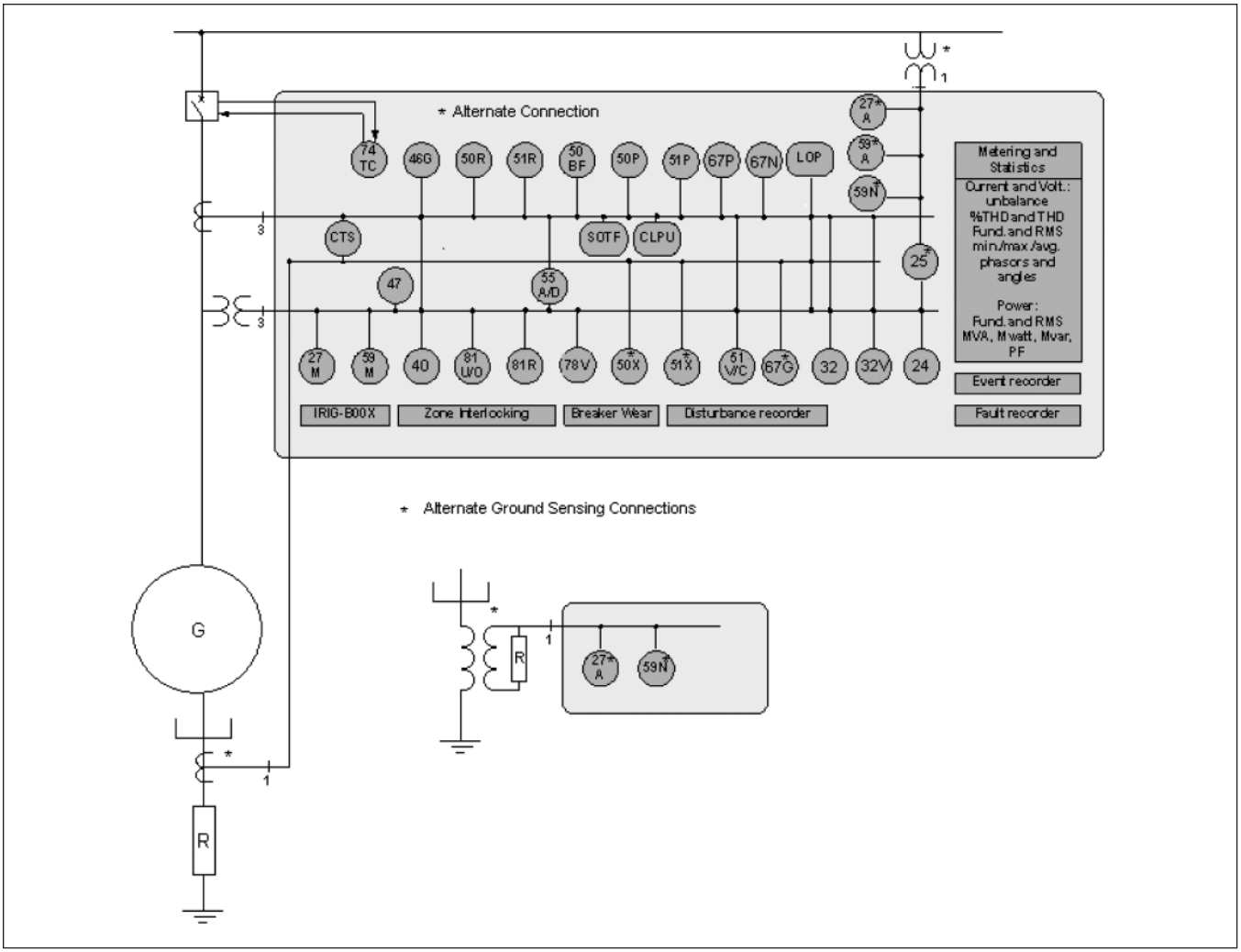


Figure 4.3-13. Typical One-Line Diagram

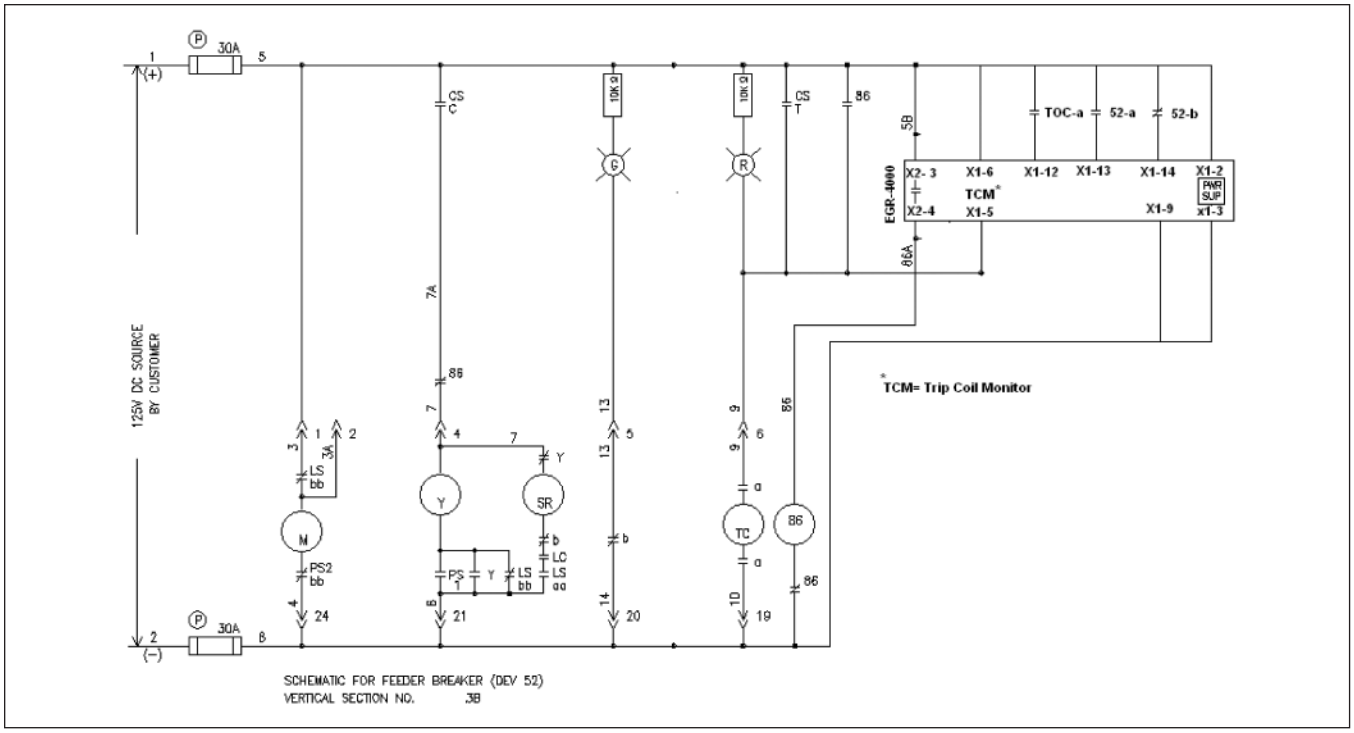


Figure 4.3-14. Typical Control Diagram

4

Communication Software

Eaton provides two types of communication software. The first is PowerPort-E. It runs on a PC or laptop for easy access to a single relay to change set points or configuration, and to view metered values and stored data. PowerPort-E is free and can be downloaded from the Eaton Web site at **www.eaton.com/pr**.

The second package is Power Xpert Software. Power Xpert Software is a power management software package that is designed for continuous, remote monitoring of many devices. It provides additional functions such as billing, trending and graphics. Contact your local Eaton representative for more information on Power Xpert Software.

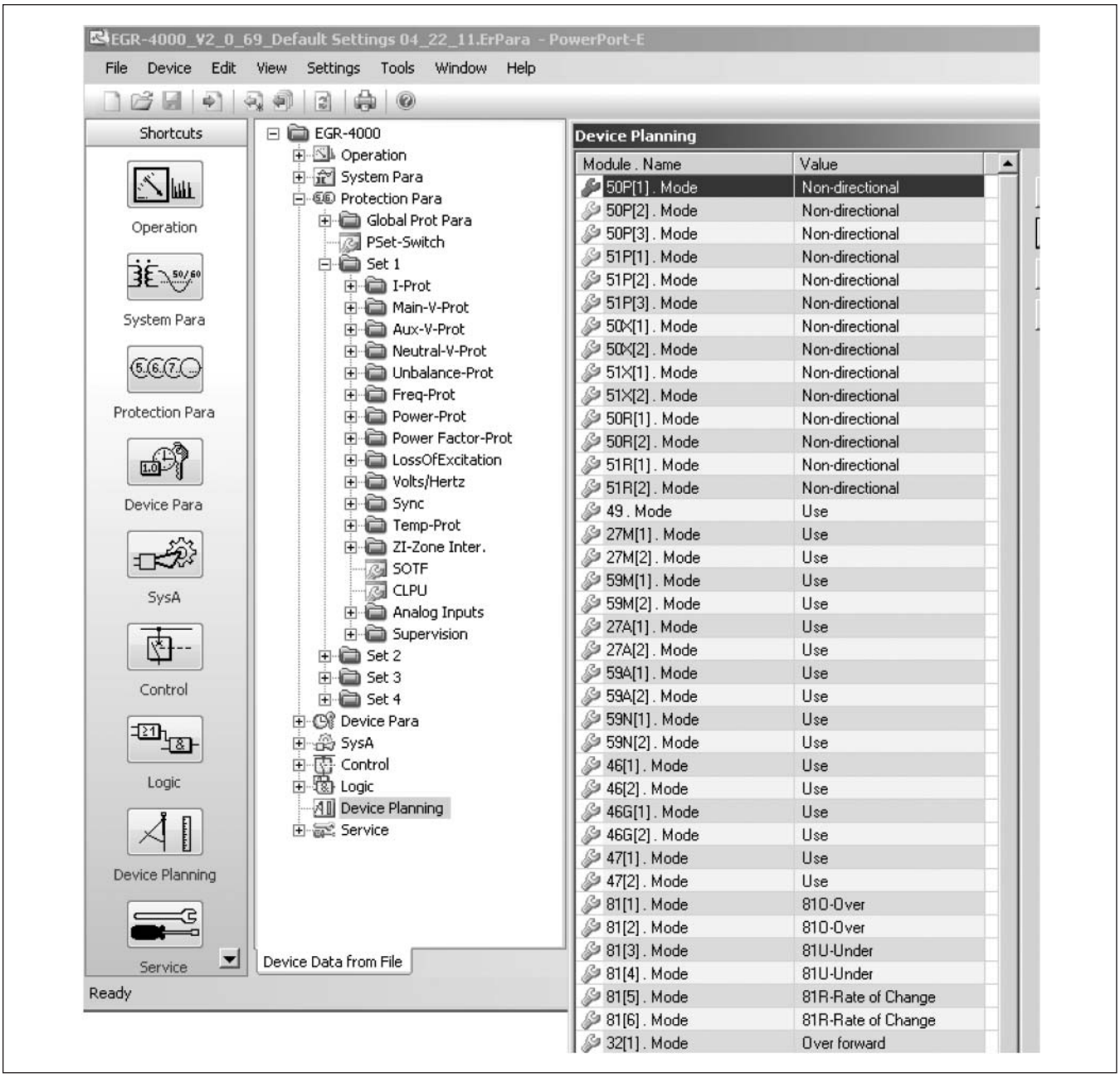


Figure 4.3-15. PowerPort-E EGR-5000 Device Planning

Standards, Certifications and Ratings

Table 4.3-6. EGR-4000 Specifications

Voltage Supply

Aux. voltage:	24–270 Vdc/48–230 Vac (–20%/+10%)
Buffer time in case of supply failure:	≥50 ms at minimal aux. voltage interrupted communication is permitted

Max. permissible making current:
18A peak value for 0.25 ms
12A peak value for 1 ms

The voltage supply must be protected by a fuse of:
2.5A time-lag miniature fuse 5.0 x 20.0 mm (approx. 0.20 in. x 0.80 in) according to IEC 60127
3.5A time-lag miniature fuse 6.3 x 32.0 mm (approx. 0.25 in. x 1.25 in) according to UL 248-14

Power Consumption

Power supply range:	24–270 Vdc: 7W idle mode/ approx. 13W max. power 48–230 Vac: 7 VA idle mode/ approx. 13 VA max. power (for frequencies of 40–70 Hz)
Power consumption:	Phase current inputs at I_n = 1A, S = 0.15 mVA at I_n = 5A, S = 0.15 mVA
Ground current input:	at I_n = 1A, S = 0.35 mVA at I_n = 5A, S = 0.35 mVA

Digital Inputs

Max. input voltage:	300 Vdc/259 Vac
Input current:	<4 mA
Reaction time:	<20 ms
Fallback time:	<30 ms (safe state of the digital inputs)
Switching thresholds:	Un = 24 Vdc, 48 Vdc, 60 Vdc, 110 Vac/dc, 230 Vac/dc
Un = 24 Vdc	
Switching threshold 1 ON:	Min. 19.2 Vdc
Switching threshold 1 OFF:	Max. 9.6 Vdc
Un = 48V/60 Vdc	
Switching threshold 2 ON:	Min. 42.6 Vdc
Switching threshold 2 OFF:	Max. 21.3 Vdc
Un = 110/120 Vac/dc	
Switching threshold 3 ON:	Min. 88.0 Vdc/88.0 Vac
Switching threshold 3 OFF:	Max. 44.0 Vdc/44.0 Vac
Un = 230/240 Vac/dc	
Switching threshold 4 ON:	Min. 184 Vdc/184 Vac
Switching threshold 4 OFF:	Max. 92 Vdc/92 Vac
Terminals:	Screw-type terminal

Relay Outputs

Continuous current:	5A AC/DC
Max. make current:	25A AC/25A DC up to 30V for 4s 30A/230 Vac according to ANSI IEEE Std. C37.90-2005 30A/250 Vac according to ANSI IEEE Std. C37.90-2005
Max. breaking current:	5A AC up to 125 Vdc 5A DC up to 30V (resistive) 0.3A DC at 300V
Max. switching voltage:	250 Vac/250 Vdc
Switching capacity:	1250 VA
Contact type:	Form C or normally open contact
Terminals:	Screw-type terminals

Zone Interlocking

NOTICE: ONLY FOR ZONE INTERLOCK TRIPPING OUTPUTS (ZONE INTERLOCK, SEMI-CONDUCTOR OUTPUT): 5 Vdc, <2 mA FOR CONNECTION TO ELECTRONIC INPUTS ONLY.

Zone out:	
Output voltage (high):	4.75 to 5.25 Vdc
Output voltage (low):	0.0 to +0.5 Vdc
Zone in:	
Nominal input voltage:	+5 Vdc
Max. input voltage:	+5.5 Vdc
Switching threshold ON:	Min. 4.0 Vdc
Switching threshold OFF:	Max. 1.5 Vdc
Galvanic isolation:	2.5 kV AC (to ground and other IO)
Connection:	Screw-type terminals (twisted pair)

Front Interface RS-232

Baud rates:	115,200 Baud
Handshake:	RTS and CTS
Connection:	Nine-pole D-Sub plug

RS-485

Master/slave:	Slave
Connection:	Six screw-clamping terminals RM 3.5 mm (138 MIL) (terminating resistors internal)

Fiber Optic

Master/slave:	Slave
Connection:	ST-plug

URTD-Interface

Connection:	Versatile link

Climatic Environmental Conditions

Storage temperature:	–30°C to +70°C (–22°F to +158°F)
Operating temperature:	–20°C up to +60°C (–4°F to +140°F)
Permissible humidity at Ann. average:	<75% rel. (on 56d up to 95% rel.)
Permissible installation altitude:	<2000m (6561.67 ft) above sea level If 4000m (13,123.35 ft) altitude applies, a changed classification of the operating and test voltages may be necessary.

This page intentionally left blank.

VR-300 Multifunctional Voltage Relay

VR-300

General Description

The VR-300 is an industrial grade protective relay that offers multiple protective features in a single package, ideal for stand-alone protection or for the implementation of transfer schemes.

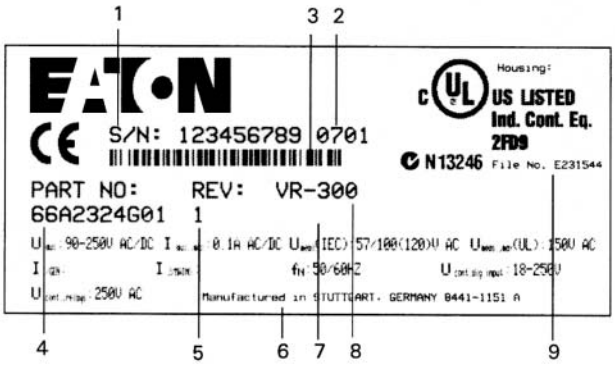
Using a digital processor to measure true rms values enables a high degree of measuring accuracy regardless of harmonics, transients or disturbing pulses.

The compact size and multiple functions of the VR-300 help to simplify switchgear design. The digital display offers a user-friendly interface to set up the unit as well as to monitor the operation and display any alarms.

Features

- Over-/undervoltage monitoring (59/27)
- Over-/underfrequency monitoring (81O/U)
- Voltage asymmetry monitoring (47)
- Sync-check (25)—fixed to relay 3
- Zero voltage monitoring: dead bus start functionality (close CB to dead bus)
- Two configurable relays
- Discrete input for blocking of protective functions or remote acknowledgment

Typical Nameplate



1	S/N	Serial number (numerical)
2	S/N	Date of production (YYMM)
3	S/N	Serial number (Barcode)
4	P/N	Item number
5	REV	Item revision number
6	Details	Technical data
7	Type	Description (long)
8	Type	Description (short)
9	UL	UL sign

Figure 4.4-1. Typical VR-300 Nameplate

4

Technical Data

Table 4.4-1. VR-300 Specifications

Description	Specification
Measuring Voltage	
Standard (V_{rated}) wye/delta	66/115 Vac
Maximum value V_{ph-ph} maximum, (UL/cUL)	Maximum 150 Vac
Rated Voltage $V_{ph-ground}$	50 Vac/2.5 kV
Rated surge voltage	2.5 kV
Measuring frequency	40.0 to 80.0 Hz
Accuracy	Class 1
Linear measuring range	1.3 x V_{rated}
Input resistance	0.21M ohms
Maximum power consumption per path	< 0.15W
Ambient Variables	
Wide range power supply	90 to 250 Vac/Vdc
Intrinsic consumption	Maximum 12 VA
Ambient temperature	Storage: –30° to +80°C (–22° to +176°F) Operational: –20° to +70°C (–4° to +158°F)
Ambient humidity	95%, noncondensing
Maximum altitude	6562 ft (2000m)
Degree of pollution	2
Discrete Inputs—Isolated	
Input range ($V_{cont, discrete input}$)	Rated voltage 18 to 250 Vac/Vdc
Input resistance	Approximately 68K ohms
Relay Outputs—Potential Free	
Contact material	AgCdO
General purpose (GP) ($V_{cont, relay output}$)	AC: 2.00A AC at 250 Vac DC: 2.00A DC at 24 Vdc, 0.22A DC at 125 Vdc, 0.10A DC at 250 Vdc
Pilot duty (PD) ($V_{cont, relay output}$)	AC: B300 DC: 1.00A DC at 24 Vdc, 0.22A DC at125 Vdc, 0.10A DC at 250 Vdc
Housing	
Type	APRANORM DIN 43 700
Dimensions (W x H x D)	3.78 x 2.84 x 5.20 in. (96 x 72 x 132 mm)
Front panel cutout (W x H)	3.62 [+0.03) x 2.68 [+0.03] in. (92 [+0.8] x 68 [+0.7] mm)
Wiring	Screw-type, terminals 0.0039 $in.^2$ (2.5 mm^2)
Recommended tightening torque	0.369 ft/lbs (0.5 Nm). Use 60°/75°C (140°/167°F) copper wire only. Use Class 1 wire only (or equivalent)
Weight	Approximately 2.14 lbs (800g)
Protection	
Protection system	IP42 from front with correct mounting IP54 from front with gasket (gasket: P/N 8923-1036) IP20 from back
Front foil	Insulating surface
EMC-test (CE)	Tested according to applicable EN guidelines
Listings	CE marking; UL listing for ordinary locations, UL/cUL listed, ordinary locations, File No.: E231544
Additional approvals	IEEE C37.90.1 and C37.90.2

Table 4.4-2. Reference Conditions

Measuring Value	Display Range	Accuracy
Frequency		
fL1, fL2, fL3	40.0 to 80.0 Hz	0.05 Hz
Voltage		
VL1, VL2, VL3, VL12, VL23, VL31	0 to 520, 0 to 65 kV	1% ①

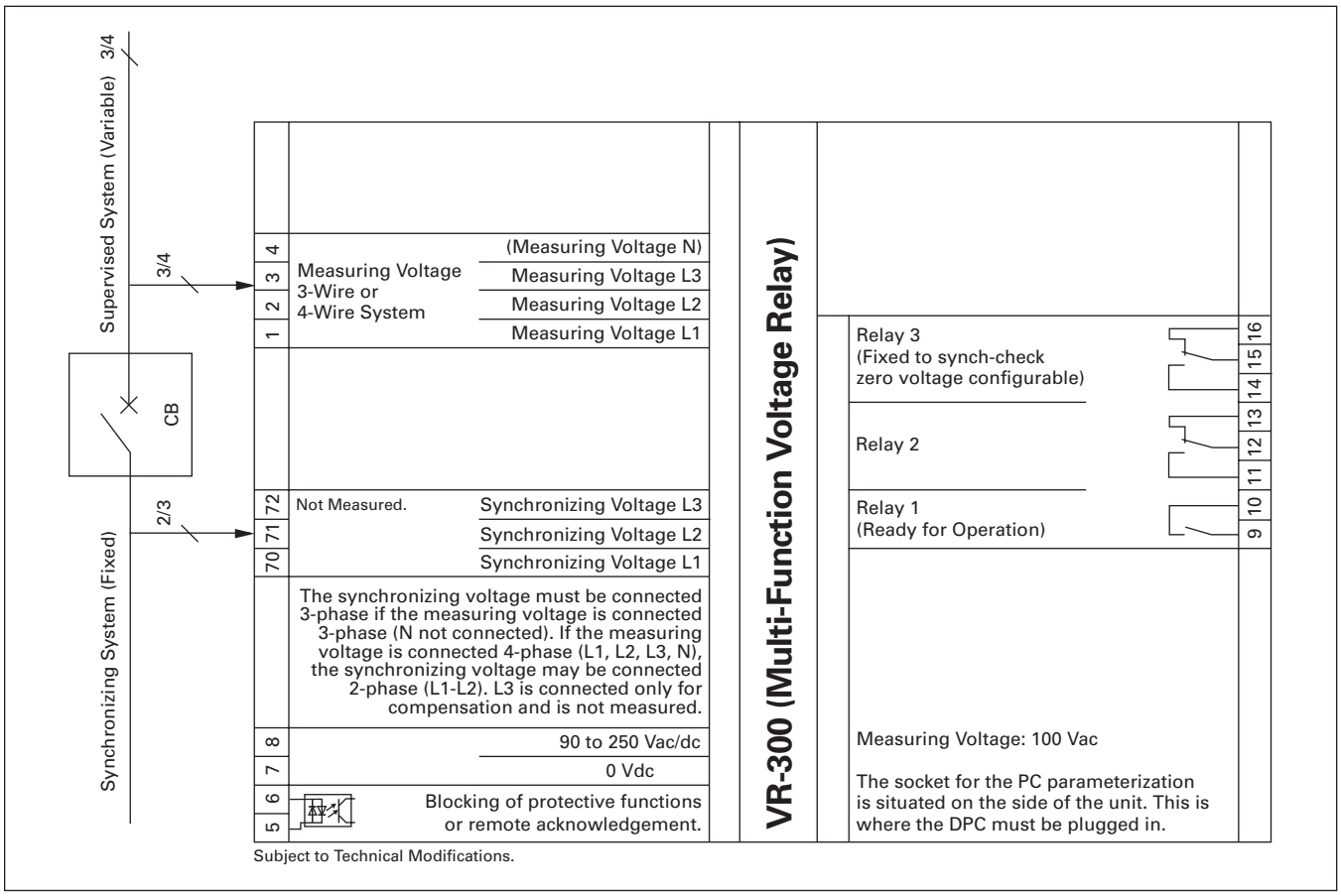
① Accuracy depending on the configured transformer ratio.

Reference Conditions

The data apply to the following reference conditions:

- Input voltage = sinusoidal rated voltage
- Frequency = rated frequency ±2%
- Power supply = rated voltage ±2%
- Power factor cos ϕ = 1
- Ambient temperature 23°C ±2K
- Warm-up period = 20 minutes

Wiring Diagram



Subject to Technical Modifications.

Figure 4.4-2. VR-300 Wiring Diagram

TC-100 Transformer Temperature Controller for Dry-Type Transformers

TC-100

General Description

The TC-100 Transformer Temperature Controller monitors up to three ventilated dry-type transformer windings and one ambient temperature. The TC-100 operates relays by comparing the highest winding temperature to stored set point temperatures and displays four thermocouple inputs, as well as the stored maximum temperature and its associated winding. The unit provides fans, alarm and trip output relays. Up to two fans can be controlled via the TC-100. Each fan operating contact is fuse protected. A yellow LED indicates that fans are on. A fan exerciser turns the fans on automatically at periodic intervals to prevent fan motor seizing (on-time and interval is programmable).

Form C contacts are provided for notification of alarm conditions. A red LED illuminates to indicate that the alarm is actuated. An internal audible alarm also sounds when the unit goes into alarm condition. This audible buzzer can be silenced without canceling the alarm. The alarm and trip relays can be configured as a fail-safe relay (normally energized when the unit is powered up). For example, if the alarm relay was configured as a fail-safe; if supply control power to the TC-100 is interrupted, the alarm relay changes state for notification of this condition. The alarm circuit is also used for notification of an open or a missing thermocouple. If a thermocouple were to open, the alarm relay operates and the corresponding channel will read "-" on the LED display. It is important to note that a failed thermocouple will not cause the device to trip the transformer offline.

Form C contacts are provided to trip the transformer offline if any of the winding temperatures exceed the trip setting. A red LED indicates that the trip relay has actuated.

A test function is provided to: test the digital display and all of the LEDs; simulate over-temperature conditions; and check the internal temperature of the monitor.

A 4–20 mA analog signal is provided for remote indication or for use with SCADA systems.

The TC-100 has built-in monitoring functions and logging functions to help you shed some light on the unknowns of the operation of your transformer. Temperature trending lets you understand the hour of the day that the transformer runs hotter, and modify its loading to extend the life of your transformer; logging information lets you restore the operation of your system faster, by letting you correlate tripping and alarming events to the overall conditions of your system; and fan wear information can be used to perform preventive maintenance to increase the uptime in your transformers.

Features and Benefits

Control

- Thermocouple inputs (E or K type thermocouples)
- Automatic correlation throughout entire temperature range to compensate for thermocouple non-linearity
- Programmable on and off set points
- Alarm relay for remote monitoring
- Trip relay for remote monitoring
- Two fan power relays
- Fan failure detection to start a backup fan or alarm
- Fan exerciser (cycle time and duration) to reduce fan wear
- Fans can be operated automatically or manually

Metering

- Average temperature (all three windings)
- Maximum instantaneous temperature (all three windings)
- Maximum temperature memory per winding
- Fans hours of operation
- Winding 1, Winding 2, Winding 3 and ambient temperature

Monitoring

- Trending
- Fan failure
- Fan wear
- Alarm log
- Trip log
- Test mode
- Detect failed sensors
- Self-diagnostics

Communications

- USB port in the front
- Modbus-RTU communications
- Programming and monitoring software (the unit can be completely programmed through the front of the unit)
- 4–20 mA output for integration with SCADA systems

Hardware

- One trip relay (Form C)
- One alarm relay (Form C)
- Two power fan relays (1 NO each)
- Two digital inputs
- 4–20 mA output for integration with SCADA systems
- Local Alarm 95 db
- Available in semi-flush or hinge panel-mounting versions

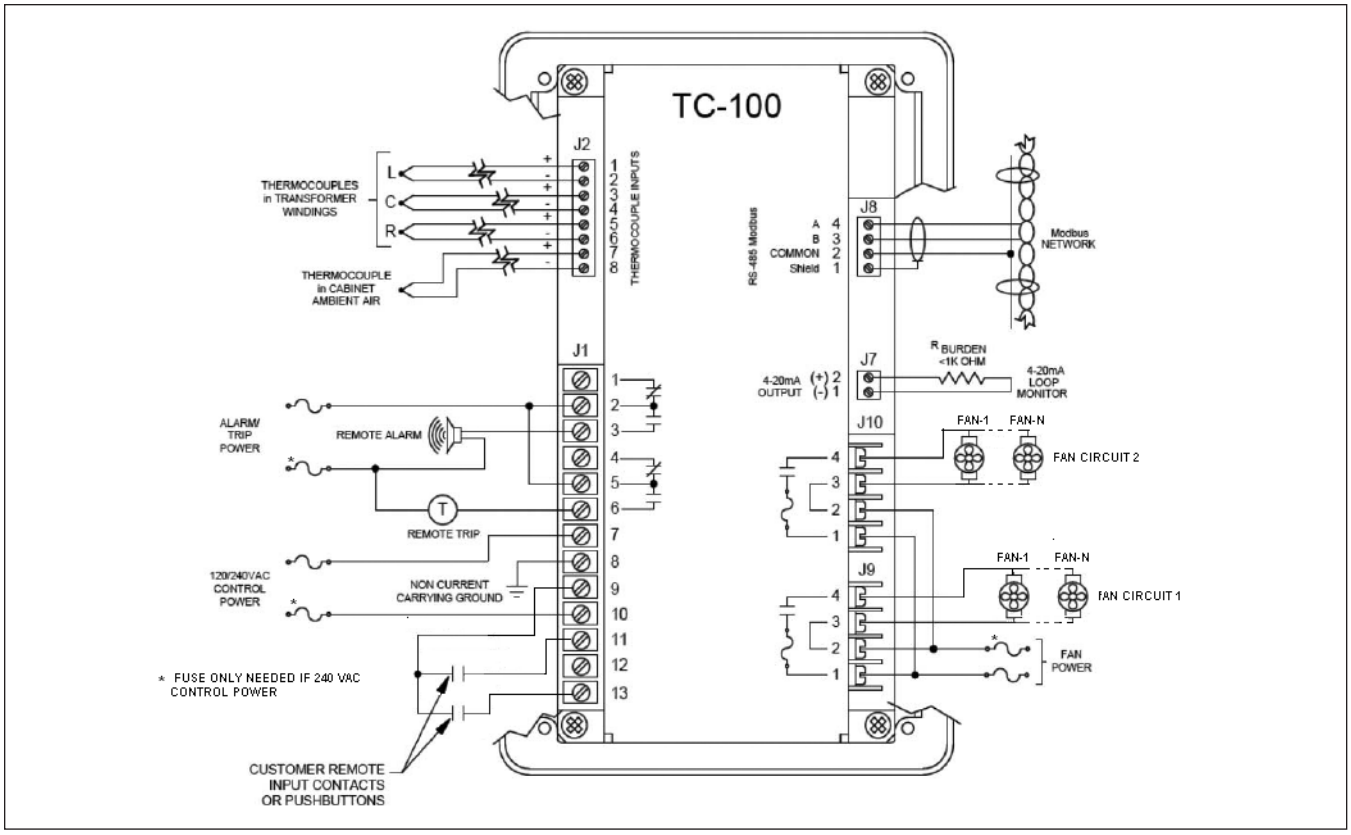


Figure 4.4-3. TC-100 External Wiring Diagram

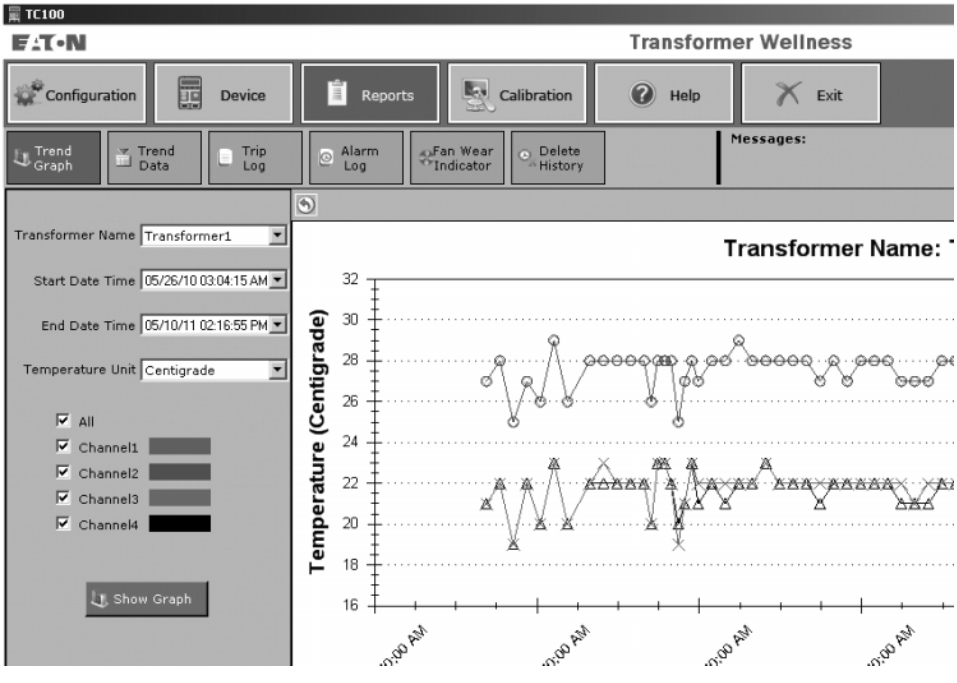


Figure 4.4-4. Programming and Monitoring Software

Technical Data and Specifications

Table 4.4-3. TC-100 Technical Specifications

Description	Specification	
Control Power		
Nominal rating	120 Vac or 240 Vac (+10%, –25%)	
Frequency	50 or 60 Hz	
Power use	15 VA maximum	
Operating range	120 Vac: 90–132 Vac 240 Vac:180–264 Vac	
Ride-through time	20 cycles at nominal Vac	
Environmental		
Operating temperature	–30 to +72ºC	
Storage temperature	–50 to +72ºC	
Relative humidity	0 to 90% (noncondensing)	
Measurement Accuracy		
Temperature	±1ºC ± one count under normal conditions ±2ºC ± one count under extreme conditions Extreme conditions are: Ambient temperature colder than –10ºC Winding to unit temperature greater than 210ºC	
Discrete Inputs		
Number of inputs	Two programmable	
Rating	1.2 VA at 120 Vac Max. OFF = 36 Vac Min. ON = 86 Vac (built in power source available)	
Outputs		
Output fans	Two individually configurable SPST contacts rated 30A at 120/240 Vac, 1 hp at 120 Vac, 2 hp at 240 Vac for each contact	
Output alarm	One SPDT contact rated 10A at 120/240 Vac (resistive) configurable for normal or fail-safe operations	
Output alarm	One SPDT contact rated 10A at 120/240 Vac (resistive) configurable for normal of fail-safe operation	
Remote analog output	4–20 mA into a load of up to 1000 ohms max. proportional to hottest winding temperature ±1%	
EMC		
Immunity	ANSI/IEEE C37.90.1-2002 - Standard Surge Withstand Capability (SWC) tests for protective relays and relay systems ANSI/IEEE C37.90.2-2004, standard withstand capability of relay systems to radiated electromagnetic interference from transceivers	
	EN 61000-4-2 EN 61000-4-3 EN 61000-4-4 EN 61000-4-5 EN 61000-4-6 EN 61000-4-8 EN 61000-4-11	ESD RF Radiated immunity EFT/Burst immunity Surge immunity RF conducted immunity Power frequency magnetic field immunity Voltage variation immunity
Emissions	EN 50011 CISPR-11, Class A CFR 47 FCC Part 15 Subpart B Class A	
Clock		
Accuracy	+/1 1 minute/month at 25ºC	
Logging		
Trend data	100 entries, logging interval programmable from 1 minute to 30 days	
Alarm events	Last 25 alarm events	
Trip events	Last 25 trip events	

Ordering Information

Table 4.4-4. Catalog Ordering Information for TC-100 Transformer Temperature Controller for Dry-Type Transformers

Description	Catalog Number
Barrier cabinet	**TC-100-Barrier**
Controller only (semi flush mounting) TC-100	**TC-100**
Controller with barrier cabinet (hinge front panel)	**TC-101**

InsulGard™

InsulGard

General Description

The InsulGard™ is a continuous partial discharge monitor that can be applied to a variety of medium voltage electrical equipment rated 4 kV to 38 kV. It is commonly applied to motors, generators, switchgear, bus duct, unit substations and cable systems. The InsulGard will monitor the quality of insulation while the equipment is in service under normal operating conditions. Through monitoring, it can ascertain the relative condition of insulation, the deterioration of which is the leading cause of electrical failures.

The InsulGard system consists of sensors and a monitor. The monitor can be used as a stand-alone unit, or it can be wired so that it can remotely upload data to your system or to Eaton diagnostics personnel for analysis. While the sensors vary according to application, they are all designed to detect partial discharges—the foundation of the InsulGard technology and one of the best predictors of insulation breakdown.

The term "partial discharge" is a common name for small electrical discharges (arcs) that typically occur within or between insulation materials—usually across a void in the insulation. Partial discharge is also referred to as corona or surface tracking. The visible evidence of corona presents itself as white, powdery residue, typically found on the end windings of motors or generators. Surface-tracking damage appears as tree-like, jagged lines, typically found on switchgear and bus ducts. Surface tracking stems from a contaminated insulation surface, often started by corona. The small arcing activity on the surface of the insulation contributes to further burning, resulting in additional stress points that promote further deterioration. Both corona and surface tracking are the primary causes of insulation breakdown, which can lead to full discharges and electrical failures. It is important to note that traditional methods of detecting corona and surface-tracking damage require taking equipment offline. It also requires disassembling the equipment—a costly procedure. Moreover, corona and surface tracking damage have to be severe to be visible. The InsulGard system allows you to detect partial discharge while the electrical system is energized. It does so by detecting and analyzing the radio signal frequencies emitted by the partial discharges. More specifically, the InsulGard focuses on the 1 MHz to 20 MHz bandwidth range where the majority of partial-discharge activity can be detected. InsulGard allows predictive analysis and maintenance as opposed to preventive analysis and time-based maintenance.

The detection of partial discharge on equipment can indicate if a problem exists. Even more useful is information that can correlate the signal intensity (measured in milliwatts) associated with partial discharges to various states of insulation degradation on similar equipment. Eaton's Predictive Diagnostics Group has studied numerous cases of partial discharge on rotating equipment and switchgear. The knowledge base accumulated has allowed Eaton to develop guidelines and parameters to help one determine the seriousness (failure-time windows) of the partial-discharge activity that the equipment may be exhibiting. Because it is a continuous, online monitoring system, it is easy to monitor conditions over time.

Eaton's InsulGard is a stand-alone microprocessor-controlled continuous partial discharge monitoring device for a wide range of medium voltage power equipment. It is designed to provide an alarm based on PD characteristics at an early stage of insulation degradation. It measures partial discharges from up to 15 different partial discharge sensors and stores the information in internal memory, alarming users if any set points are exceeded. InsulGard can work with constant 50/60 Hz frequency powered equipment, as well as with variable frequency applications.

Various PD sensor types can be used, depending on the application.

InsulGard has three auxiliary inputs for PD data correlation to additional parameters. One of the inputs is designated for temperature, where the other two are commonly used for load, voltage or humidity depending upon the application. InsulGard has several interfaces that allow for easy implementation into any alarm or SCADA system:

- Three C-form dry relay contacts provide Yellow or Red alarm indication, and the Device Status relay indicates any device malfunction
- 4–20 mA optically isolated output can be configured to represent Partial Discharge Intensity (PDI) or maximum discharge magnitude to any SCADA system
- RS-485 optically isolated interface based on Modbus RTU protocol allows for remote device configuration and data download. InsulGard can be networked with an existing Modbus, allowing for up to 231 addressable devices
- Ethernet port, Web page, FTP or Modbus TCP

Communication protocol includes Modbus, proprietary binary and ASCII text options allowing a software programmer to build InsulGard into a high-level software program using simple text type commands. InsulGard is supplied with database software that allows for automated communication to a device or several devices for data acquisition and analysis. The software allows for either direct network or dialup connection to a device by a regular telephone landline or a cellular connection.

InsulGard has 15 signal inputs (Ch1–Ch15) for partial discharge measurement and a noise input dedicated for noise suppression (Ch16). All 16 inputs have identical conditioning circuits (CC) providing signal isolation, transient suppression and high-pass filtering of the input signals. The frequency band of the InsulGard is from 1 MHz to 20 MHz.

InsulGard acquires PD data in the form of three dimensional phase-resolved pulse height distribution (PRPHD)—PD pulse count as a function of pulse magnitude and 60(50) Hz phase. It has 24 (15°) phase windows and a magnitude dynamic range of about 70 dB, divided in 21 magnitude windows.

The data can be stored in the internal device memory in the form of three-dimensional PRPHD matrixes and/or in the brief form of integral quantities derived from these matrixes. Each record is accompanied by three additional correlation parameters.

Before each measurement, InsulGard performs self-calibration and self-test. If any problem is detected, the status relay dry contacts will open and an appropriate message will appear on the InsulGard display. Loss of power will be indicated in the same way by opening status relay contacts.

InsulGard measures signals from signal inputs sequentially multiplexing them to a single metering channel. Each pulse from each sensor is validated by the allowed pulse width. In the case of non-compliance, InsulGard will not count the pulse.

After each measurement, data from all active signal channels will be compared to alarm thresholds. If any of the Yellow threshold limits are exceeded, the Warning LED will be turned on and the Warning relay dry contacts will close. In the case of a Red level achieved, InsulGard will trigger additional measurement and, if confirmed, an Alarm LED will be turned on and the Alarm relay dry contacts will close. If Red alarm is detected, full measurement data will be stored in the memory.

PD measurements can be performed on a time schedule (up to 50 per day) or in specified time intervals (from 1 minute to 23 hours 59 minutes). Four measurements per day are recommended.

Between scheduled measurements, the “High Alarm” feature is enabled. All signal sensors are connected to a summation unit and further to a separate “High Alarm” channel. InsulGard continuously searches for an appearance of high magnitude pulses and pulse series. Magnitude threshold and repetition in series are configurable. If five events of pulse series were detected between the scheduled measurements, InsulGard will trigger a full PD measurement, and display an alarm, if any.

Full PD measurement by InsulGard involves a measurement of statistical Phase Resolved Partial Discharge Distribution (PRPDD) for every active channel. After each measurement for every active channel, InsulGard calculates PDI, Maximum PD magnitude, PD pulse repetition rate, and trend parameters (rate of PD parameter change). The calculated parameters are compared to alarm set points and alarm status is determined. All calculated and alarm status parameters are stored in the internal memory for each measurement. Additionally, three auxiliary parameters (temperature, % of full load current and operating voltage or humidity) are assigned to the measurement data. PRPDD can, optionally, be stored in the internal memory. There are two modes of PD data storage “Brief” and “Full.”

Full—during this mode PRPDD is stored in the memory with the mentioned above parameters for each active channel and every measurement.

Brief—in order to save a memory, PRPDD can be stored in the memory several times a month. An operator should set a number of days and a measurement number at the current day for storing PRPDD. During the remaining measurements, InsulGard will store the brief version of PD data.

InsulGard has two Megabytes of internal flash memory for data storage allowing for its standalone operation. When the memory is filled, the device starts replacing the oldest data with the latest data. The rate of the memory consumption depends upon a number of active channels, frequency of measurements, and frequency of PRPDD storage. As an example, if all 15 channels are active for measurements four times a day and PRPDD are stored twice a month, the device holds 17 months of the latest PD data in its internal memory. All stored data and settings can be accessed from the keypad, or remotely from a PC.

Alarms

InsulGard has two configurable alarms, Red and Yellow, that connect to two C-form relays. There are two groups of parameters that can generate an alarm. One is if an alarm set point is exceeded (Partial Discharge Intensity (PDI) and its trend or PD pulse magnitude and its trend). One of two, PDI or Magnitude, can be configured for alarm at one time. The same parameter is configured for 4–20 mA interface output automatically. 4–20 mA output provides a signal with the slope of 10% of Red Alarm Threshold per 1mAmp. That means that Red alarm threshold corresponds to 14 mA output.

Alarm set points for PDI are represented in terms of mW. Magnitude is represented in terms of mV.

Trend is set in terms of times per year for both PDI and Magnitude. Alarm on trend is enabled after a training period of 1/3 of the trend-sliding window.

Yellow and Red alarms operate differently. In the case of a Yellow alarm, it will appear on the corresponding relay as received. In the case of a Red alarm, InsulGard will initiate an additional measurement at the time of alarm, and only if confirmed, will indicate the alarm by relay. If the Red alarm is not confirmed, the status of the alarm will be set per the last measurement. If at any measurement the alarm status will be reduced, InsulGard will indicate the reduced alarm status with both an alarm LED reading and relay.

Alarm relays can operate in two modes (configurable). Relays lock in an alarm status received at the last measurements, until the next measurement. Or a relay can operate for a limited configurable time and then open the contacts. At the next measurement, if an alarm status is detected, relays will hold the alarm contacts closed for the same time.

Trend

InsulGard calculates trend of a parameter enabled for alarm. Trend is normalized to the value of the parameter change in times per year. Trend has two alarm thresholds, Yellow and Red, connected to alarm relays and also to the alarm status LED at the front panel of the device. Trend is calculated as a linear approximation of data over specified time interval (default is 18 weeks). This 18-week time window is sliding over time while device monitors partial discharges.

Continuous Watch Feature

Between the scheduled measurements the Continuous Watch feature (“High Alarm”) is initiated. At this time all signal sensors are summarized and connected to the separate High Alarm channel. InsulGard is continuously watching for the events of high magnitude pulses (configurable) and their series. If five series of such events are detected, InsulGard starts full PD measurement and, in the case of Red alarm confirmation, InsulGard indicates this alarm and stores full PD data in the internal device memory.

Schedule

PD measurements can be performed at specified times during a day or time interval basis (configurable). The device is shipped with “time basis” schedule enabled and set to record measurements four times a day. This is sufficient for all common applications.

If necessary, InsulGard can be set to measure up to 50 times per day at scheduled times or in specific time intervals varying from 1 minute to 23 hours 59 minutes.

Technical Data and Specifications

Table 4.5-1. Power Source Specifications

Description	Specification
Applications	HV and MV equipment (motors including VFD), switchgears, generators, bus ducts, cable terminations, transformers, est.)
Mounting options	In NEMA 4X enclosure. On the panel. Door (Flash) mount
Installation category	II
Pollution degree	2
Temperature range	–40°C to +70°C (+85°C without enclosure)
Relative humidity	0%RH–90%RH
Maximum altitude	6562 ft (2000m)
Power source	115V / 230 Vac ±10%
	60 / 50 Hz
Power consumption of device (VA max)	15 VA
Fuse inside InsulGard case: 20 mm, 250 Vac, time lag 5TS type by BEL Inc.	For 115 Vac–5ST200-R (200 mA) For 230 Vac–5ST125-R (125 mA)
Input fuse on the panel (panel mount option): 20 mm, 250 Vac, Fast fuse 5MF type by BEL Inc. (A maximum output current from outlet for 115 Vac–3A)	5MF 3 –R (3 A)
Display	Graphic dot display, two lines
Keypad	Four arrows and four functional keys
LEDs (normal, warning (Alarm 1) or Alarm (Alarm 2) conditions, memory and setting modes	Five LEDs
Approximate Size (Length x Width x Height) and Weight	
Main unit	9.20 x 7.00 x 2.50 inches (23.4 x 17.8 x 6.4 cm), 4.2 lb (1.9 kg)
Door-mount option (main unit with sensor interface board)	9.20 x 7.00 x 4.00 inches (23.4 x 17.8 x 10.2 cm), 4.6 lb (2.1 kg)
Panel-mount option	14.80 x 12.90 x 4.00 inches (37.6 x 32.8 x 10.2 cm), 10.3 lb (4.7 kg)
Enclosure (NEMA 4X) mount option	17.20 x 15.40 x 8.80 inches (43.7 x 39.0 x 22.3 cm), 21.6 lb (9.8 kg)
PD Measurement Parameters	
PD channels	15
Noise channel	1
Continuous watch (high PD activity) channel	1
Basic type of data	Phase-resolved PD distribution
PD channel dynamic range	68 dB
Number of magnitude windows (3.23 dB each)	21
Number of phase windows (15° each)	24
Power frequency at a monitored equipment	3–20 Hz, 20–400 Hz
Synchronization type	Internal and external
Maximum measured pulse repetition rate	367,300 pulses/second at 60 Hz 306,000 pulses/second at 50 Hz
Calculated parameters for each PD channel	Partial discharge intensity (PDI) or maximum pulse magnitude (Q_{max}), Pulse repetition rate (pps), Trend
Alarming parameters	PDI, Q_{max}, Trend
Data record types	Full/Brief
Internal data memory allows for up to 1000 days data storage at four measurements per day	2 MB
Self-test and self-calibration	At powering up and before every measurement
Setup	Configurable from keypad and PC
Allowed RG-58 coaxial cable length to PD sensors	Up to 150 ft (46m)
Auxiliary Inputs	
Input specified for temperature measurement calibrated for 100 ohm platinum RTD sensor	1
Analog inputs specified for current, voltage or humidity measurement	2
USB Host	For future use
Interfaces	
C-form dry-type relays for device status, warning (Alarm 1) and alarm (Alarm 2) PD levels (fully configurable)	3 120 Vac/ 5A 28 Vdc/ 5A For other ratings refer to the relay specification
4–20 mA isolated interface represents highest PDI or max. magnitude as % of the alarm (Alarm 2) threshold	Slope is 1 mA per 10%
RS-485 interface optically isolated (231 addresses)	Communication Protocol: Modbus RTU, binary, text commands
Ethernet	Modbus-TCP, Web page, FTP
USB	PC connection
USB host	For future use

General Notes

The three basic InsulGard packages are Switchgear Applications, Motor Applications and Generator Applications. At the beginning of each section to follow are the basic components typically found in each type of application.

Switchgear Applications

Switchgear Applications have three typical components: InsulGard Switchgear Package, Coupling Capacitor Sensors and RFCT Sensors.

InsulGard Systems for Switchgear Applications are sold as "packages." Packages provide greater value. Standard Equipment with the InsulGard Switchgear Package is shown in **Table 4.5-3**.

Table 4.5-2. Standard Equipment

Description	Quantity
InsulGard	1
Humidity sensor mounted as specified	1
Temperature mounted as specified	1
RS-485 communication port	1
InsulGard software CD	1
Set of instruction manuals	1

Table 4.5-3. InsulGard Switchgear Packages—Order PD Sensors Separately

Description	Catalog Number
Door-mount InsulGard for mounting onto indoor cabinet door cut-out, includes: ■ RS-485 communication port with Modbus RTU protocol ■ Universal communications with USB and Ethernet ports ■ Embedded temperature and humidity sensors ■ InsulGard software CD and one set of instruction manuals	**PD-IG-S-E0**
Back-panel-mount (no enclosure) for installing InsulGard into an existing enclosure, includes: ■ RS-485 communication port with Modbus RTU protocol ■ Universal communications with USB and Ethernet ports ■ Embedded temperature and humidity sensors ■ InsulGard software CD and set of instruction manuals	**PD-IG-S-E1**
InsulGard in NEMA-4X non-metallic enclosure with transparent window, includes: ■ RS-485 communication port with Modbus RTU protocol ■ Universal communications with USB and Ethernet ports ■ External temperature and humidity sensors (PD-SR-TS, PD-SR-HS) ■ InsulGard software CD and set of instruction manuals	**PD-IG-S-E2**

Table 4.5-4. Communication Options

Description	Catalog Number
RS-485-to-USB converter—only required if using RS-485 port for extended length, remote connection to PC USB port	**PD-USB**
Advanced RS-232/485 industrial Modem TD-36485HV (installed on back panel except for door-mounted IG it must be mounted separately)	**PD-MODEM**

Table 4.5-5. Auxiliary (Dynamic) Sensors

Description	Catalog Number
Auxiliary Sensors for InsulGard, BushingGard	
External temperature sensor for InsulGard (TS) Supplied with default cable L = 65 feet	**PD-SR-TS**
External humidity sensor for InsulGard (HS) Supplied with default cable L = 65 feet	**PD-SR-HS**
Load sensor for InsulGard: includes Current Transformer (CT), rated 5A, with ID = 0.50 inches Connect to secondary winding of the motor (or generator) current transformer **Note:** Differential current transformer can't be used Supplied with default cable L = 65 feet	**PD-SR-CT**
Split (Flex)—Core CT rated 500A. Supplied with preinstalled PD-SR-CT. Should be installed on a motor power supply cable for load measurement if the motor/generator current transformer can't be used (Order separately if required)	**PD-SR-CTF**

Note: In switchgear applications, humidity and temperature sensors are installed in the same switchgear cubicle (embedded) with the InsulGard.

Table 4.5-6. Coupling Capacitors Sensors

Description	Catalog Number
InsulGard Partial Discharge Sensors	
IPDS-Integrated partial discharge sensor Set of three 5 kV, 80 pF coupling capacitors with mounting kit Supplied with default RG58 cable L = 65 feet	**PD-SR-IPDS-5**
IPDS-Integrated partial discharge sensor Set of three 7 kV, 80 pF coupling capacitors with mounting kit Supplied with default RG58 cable L = 65 feet	**PD-SR-IPDS-7**
IPDS-Integrated partial discharge sensor Set of three 15 kV, 80 pF coupling capacitors with mounting kit Supplied with default RG58 cable L = 65 feet	**PD-SR-IPDS-15**
IPDS-Integrated partial discharge sensor Set of three 27 kV, 80 pF coupling capacitors with mounting kit Supplied with default RG58 cable L = 65 feet	**PD-SR-IPDS-27**
IPDS-Integrated partial discharge sensor Set of three 38 kV, 80 pF coupling capacitors with mounting kit Supplied with default RG58 cable L = 65 feet	**PD-SR-IPDS-38**

Note: The number of cubicles will determine the number of coupling capacitors required for the project. One set of three coupling capacitors is required for every three vertical structures. The catalog numbered set includes mounting kits, boots, cables and the like.

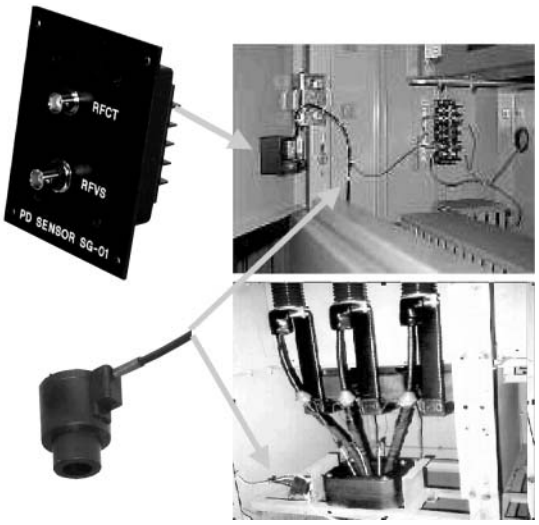
Table 4.5-7. RFCT Sensor

Description	Catalog Number
0.75-inch diameter RFCT, default cable length 65 feet	**PD-SR-RFCT-075**

The number of RFCTs required is determined by what cables the customer wants to protect (to protect secondary cables leaving the switchgear, incoming feeder cables to the main breaker/switch, etc.). There will be one RFCT per cubicle to protect the cabling (even if there are multiple cables per phase).

The length of cable or "sensitivity zone" of protection depends upon the type of cable, the number of splices, and the number of taps. PLIC Type Cable is protected up to maximum of 1500 ft. EPR (rubber composition) distances are shorter with protection up to a maximum of 300 ft.

In figures shown below, the InsulGard is protecting the six vertical section switchgear layout with the two sets of coupling capacitors and is protecting the feeder cables via the RFCTs installed on the power cable shield. An exploded view of the RFCT is also shown.



Typical Installation of RFCT Sensor

Motor Applications

Generally, the Motor Application components list consists of just the InsulGard Package itself. In some applications, the customer may want to monitor the cable feeding the motor. In those cases, one will need to add the line item for the appropriate RFCT.

InsulGard Systems for Motor Applications are sold as "packages." Packages provide greater value. Standard Equipment with the InsulGard Motor Package is shown in **Table 4.5-8**.

Table 4.5-8. Standard Equipment

Description	Quantity
InsulGard	1
NEMA 4X enclosure	1
Set of three coupling capacitors	1
Coupling capacitor mounting kit (cabling, hardware, boots, connectors)	1
RTD module (six inputs)	1
External mount humidity sensor (65 ft cable pigtail included)	1
Temperature sensor (65 ft cable pigtail included)	1
RS-485 communication port	1
InsulGard software CD	1
Set of instruction manuals	1

Table 4.5-9. InsulGard Motor Packages

Description	Catalog Number
InsulGard Motor Kits	
■ Stator RTD number ≤ 8 ■ Motor voltage ≤ 15 kV ■ For motors with Stator RTD number ≥ 9 order additional PD-SR-RTD-6	
InsulGard in NEMA-4X non-metallic enclosure with transparent window, includes: ■ RS-485 communication port with Modbus RTU protocol ■ Universal communications with USB and Ethernet ports ■ One set of coupling capacitors (PD-SR-IPDS-X), X = kV, choose 5, 7 or 17 ■ One RTD-6 sensor board PD-SR-RTD-6 ■ External temperature and humidity sensors (PD-SR-TS, PD-SR-HS) ■ Load sensor CT (PD-SR-CT) ■ InsulGard software CD and set of instruction manuals	**PD-IG-M-E2-A1**
InsulGard in NEMA-4X non-metallic enclosure with transparent window, includes: ■ RS-485 communication port with Modbus RTU protocol ■ Universal communications with USB and Ethernet ports ■ One set of coupling capacitors (PD-SR-IPDS-X), X = kV, choose 5, 7 or 17 ■ One RTD-6 sensor board (PD-SR-RTD-6) ■ External humidity sensor (PD-SR-HS) ■ Load sensor CT (PD-SR-CT) ■ Cable for spare stator RTD for temp sensor input ■ InsulGard software CD and set of instruction manuals	**PD-IG-M-E2-A2**
InsulGard in NEMA-4X non-metallic enclosure with transparent window, includes: ■ RS-485 communication port with Modbus RTU protocol ■ Universal communications with USB and Ethernet ports ■ One set of coupling capacitors (PD-SR-IPDS-X), X = kV, choose 5, 7 or 17 ■ One RTD-6 sensor board PD-SR-RTD-6 ■ External humidity sensor (PD-SR-HS) ■ Split core CT (PD-SR-CTF) ■ Cable for spare stator RTD for temp sensor input ■ InsulGard software CD and set of instruction manuals	**PD-IG-M-E2-A2-CTF**

Table 4.5-10. Communication Options

Description	Catalog Number
RS-485-to-USB converter—only required if using RS-485 port for extended length, remote connection to PC USB port	**PD-USB**
Advanced RS-232/485 industrial Modem TD-36485HV (installed on back panel except for door-mounted IG it must be mounted separately)	**PD-MODEM**

Table 4.5-11. Auxiliary (Dynamic) Sensors

Description	Catalog Number
Auxiliary Sensors for InsulGard, BushingGard	
External temperature sensor for InsulGard (TS) Supplied with default cable L = 65 feet	**PD-SR-TS**
External humidity sensor for InsulGard (HS) Supplied with default cable L = 65 feet	**PD-SR-HS**
Load sensor for InsulGard: includes current transformer (CT), rated 5A, with ID = 0.50-inches Connect to secondary winding of the motor (or generator) current transformer **Note:** Differential current transformer can't be used Supplied with default cable L = 65 feet	**PD-SR-CT**
Split (flex)—core CT rated 500A. Supplied with preinstalled PD-SR-CT. Should be installed on a motor power supply cable for load measurement if the motor/generator current transformer can't be used (Order separately if required)	**PD-SR-CTF**

Note: In most motor applications, the humidity and temperature sensors will be external to the InsulGard Enclosure (typically field mounted in cable termination compartment) and shipped with a 65 foot coaxial pigtail. Mounting in the same cubicle as the InsulGard is not typical for motor applications. Also please indicate if CT input is customer furnished or must be supplied and what type it is/should be.

Table 4.5-12. RFCT Sensor

Description	Catalog Number
0.75-Inch diameter RFCT, default cable length 65 feet	**PD-SR-RFCT-075**

The length of cable or "sensitivity zone" of protection depends upon the type of cable, the number of splices, and the number of taps. PLIC Type Cable is protected up to maximum of 1500 ft. EPR (rubber composition) distances are shorter with protection up to a maximum of 300 ft.

Generator Applications

Typically, the Generator Package components list consists of the InsulGard Package and occasionally additional sets of coupling capacitors. For part numbers of additional sets of coupling capacitors, please see Switchgear Applications Section on **Page 4.5-5**.

InsulGard Systems for Generator Applications are sold as "packages." Packages provide greater value. Standard Equipment with the InsulGard Generator Package is shown in **Table 4.5-13**.

Table 4.5-13. Standard Equipment

Description	Quantity
InsulGard	1
NEMA 4X enclosure	1
Set of three coupling capacitors	1
Coupling capacitor mounting kit (cabling, hardware, boots, connectors)	1
RTD module (six inputs)	2
External mount humidity sensor (65 cable pigtail included)	1
Temperature sensor (65' cable pigtail included)	1
RS-485 communication port	1
InsulGard software CD	1
Set of instruction manuals	1

Table 4.5-14. Generator Packages

Description	Catalog Number
InsulGard Generator Kits (Air-Cooled)—Voltage 27 kV	
InsulGard in NEMA-4X non-metallic enclosure with transparent window, includes: ■ RS-485 communication port with Modbus RTU protocol ■ Universal communications with USB and Ethernet ports ■ One set of coupling capacitors (PD-SR-IPDS-X), X = kV, choose 5, 7 or 17 ■ One RTD-6 sensor board PD-SR-RTD-6 ■ External temperature and humidity sensors (PD-SR-TS, PD-SR-HS) ■ Load sensor CT (PD-SR-CT) ■ InsulGard software CD and set of instruction manuals	**PD-IG-M-E2-A1**
InsulGard in NEMA-4X non-metallic enclosure with transparent window, includes: ■ RS-485 communication port with Modbus RTU protocol ■ Universal communications with USB and Ethernet ports ■ One set of coupling capacitors (PD-SR-IPDS-X), X = kV, choose 5, 7 or 17 ■ One RTD-6 sensor board (PD-SR-RTD-6) ■ External humidity sensor (PD-SR-HS) ■ Load sensor CT (PD-SR-CT) ■ Cable for spare stator RTD for temp sensor input ■ InsulGard software CD and set of instruction manuals	**PD-IG-M-E2-A2**
InsulGard Generator Kits (Air-Cooled)—Voltage 27 kV	
InsulGard in NEMA-4X non-metallic enclosure with transparent window, includes: ■ RS-485 communication port with Modbus RTU protocol ■ Universal communications with USB and Ethernet ports ■ One set of coupling capacitors (PD-SR-IPDS-27) ■ Two RTD-6 sensor boards (PD-SR-RTD-6) ■ Auxiliary sensors set (PD-SR-A1) ■ InsulGard software CD and set of instruction manuals	**PD-IG-GV-E2-A1**
InsulGard in NEMA-4X non-metallic enclosure with transparent window, includes: ■ RS-485 communication port with Modbus RTU protocol ■ Universal communications with USB and Ethernet ports ■ One set of coupling capacitors (PD-SR-IPDS-27) ■ Two RTD-6 sensor boards (PD-SR-RTD-6) ■ Auxiliary sensors set A2 (PD-SR-A2) ■ InsulGard software CD and set of instruction manuals	**PD-IG-GV-E2-A2**
InsulGard Generator Kit (Hydrogen-Cooled)—Voltage ≤ 16 kV	
InsulGard inside NEMA-4X non-metallic enclosure with transparent window, includes: ■ RS-485 communication port with Modbus RTU protocol ■ Universal communications with USB and Ethernet ports ■ One set of coupling capacitors (PD-SR-IPDS-X), X = kV, choose 5, 7 or 17 ■ Two RTD-6 sensor boards (PD-SR-RTD-6) ■ Load sensor CT (PD-SR-CT) ■ Cable for spare stator RTD for temp sensor input ■ InsulGard software CD and set of instruction manuals	**PD-IG-HC-E2-A3**

Table 4.5-15. Communication Options

Description	Catalog Number
RS-485-to-USB converter—only required if using RS485 port for extended length, remote connection to PC USB port	**PD-USB**
Advanced RS232/485 industrial Modem TD-36485HV (installed on back panel except for door-mounted IG it must be mounted separately)	**PD-MODEM**

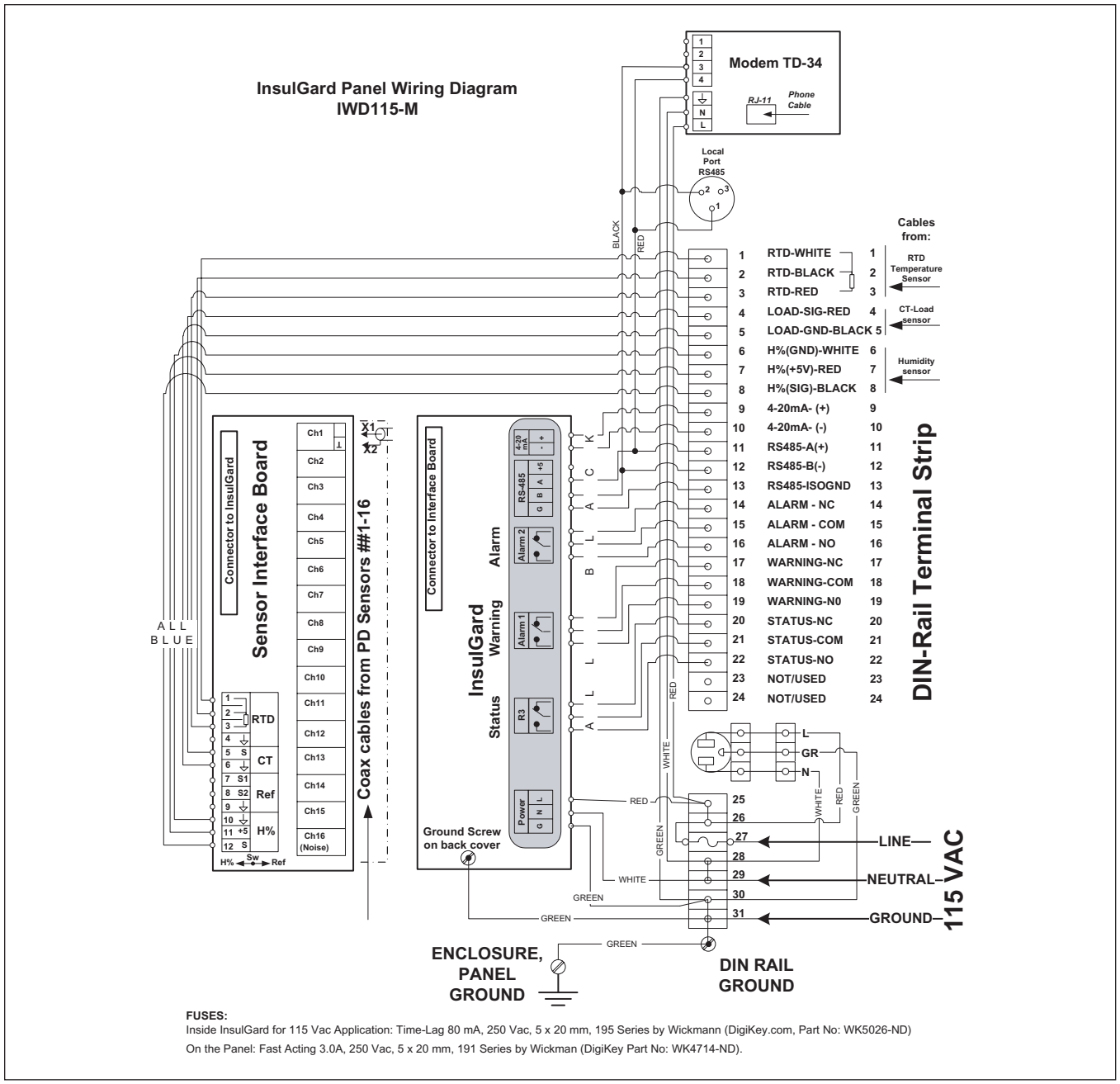
Table 4.5-16. Auxiliary (Dynamic) Sensors

Description	Catalog Number
Auxiliary Sensors for InsulGard, BushingGard	
External temperature sensor for InsulGard (TS) Supplied with default cable L = 65 feet	**PD-SR-TS**
External humidity sensor for InsulGard (HS) Supplied with default cable L = 65 feet	**PD-SR-HS**
Load sensor for InsulGard: includes current transformer (CT), rated 5A, with ID = 0.50-inches Connect to secondary winding of the motor (or generator) current transformer **Note:** Differential current transformer can't be used Supplied with default cable L = 65 feet	**PD-SR-CT**
Split (Flex) - Core CT rated 500A. Supplied with preinstalled PD-SR-CT. Should be installed on a motor power supply cable for Load measurement if the motor/generator current transformer can't be used (Order separately if required)	**PD-SR-CTF**

Note: In most generator applications, the humidity and temperature sensors will be external to the InsulGard enclosure {typically field mounted in cable termination compartment} and shipped with a 65-foot coaxial pigtail. Mounting in the same cubicle as the InsulGard is not typical for generator applications. Also, please indicate if CT input is customer furnished or must be supplied and what type it is/should be.

4

Connection Wiring Diagram



FUSES:
Inside InsulGard for 115 Vac Application: Time-Lag 80 mA, 250 Vac, 5 x 20 mm, 195 Series by Wickmann (DigiKey.com, Part No: WK5026-ND)
On the Panel: Fast Acting 3.0A, 250 Vac, 5 x 20 mm, 191 Series by Wickman (DigiKey Part No: WK4714-ND).

Figure 4.5-1. Typical Connection Diagram

Notes

1. Modem with Power Module are installed if ordered.
2. On motors, an unused RTD can be used as the temperature sensor (wire colors in brackets relate only to TS sensor).
3. In switchgears current sensor (CT) is not used, and if panel is installed without an enclosure, the temperature (TS) and humidity (HS) sensors can be installed directly on the panel. Use a left fitting (hub) on the enclosure for power supply cable and for the cables to the relays (Alarm1&2, R3) and use a right hub for all signal cables.
4. Fuses: Miniature Fuses 5 x 20, 250 Vac, 195 Series by Wickmann (Distributor—DigiKey.com).
5. Fuse inside InsulGard for 120V application—200 mA (DigiKey Part NO: WK5034-ND), for 230 Vac application–80mA (DigiKey Part NO: WK5026-ND). Fuse on a panel: 1.0A (DigiKey Part NO: WK5048-ND).
6. Outlet is not installed for 230 Vac application.