Advances in Medium Voltage Power Distribution

FFI

Ferrie, Franzmann Industries

Outline

- MV Overview
- Relay Protection Overview
- Operator Safety
- Kirk Key Interlocking
- Maintainability
- Main Tie Main Auto Transfer Schemes
- Paralleling Switchgear
- Applicable Codes and Standards

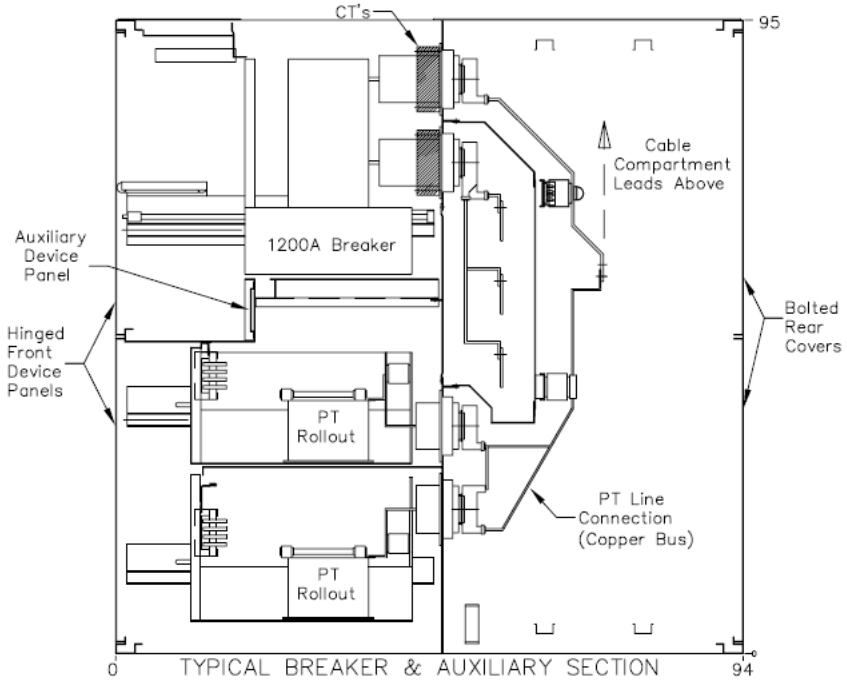
MV Overview

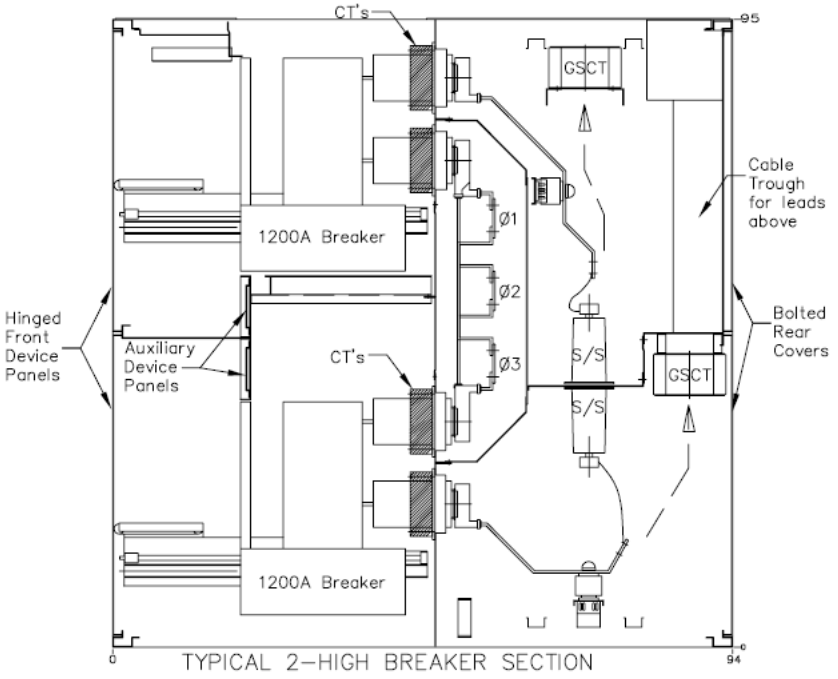
- What is MV Switchgear?
  - Terms: Breakers, PTs, CTs, Bus Size, BIL, kA, LIS, Metering Section, transition section, pull section
  - Metal-Clad
  - Metal-enclosed
  - IEC
  - ANSI
  - UL/cUL
- Configuration

Terms

- Breakers
- PTs
- CTs
- Ground CT
- Surge Arrester
- Bus Size
- BIL
- kA
- LIS
- Metering Section
- Transition section
- Pull section
- NEMA 1
- NEMA 3R Non- walk-in

ANSI Standard





Standard Gear

Standard Features

- Manual Racking
- Breaker Control Switch w/ indicating lights at front of gear
- Local Operation only
- Overcurrent Protection through separate relay
- Heaters

Optional Features/Accessories

- Power Meter
- Breaker Test Cabinet
- Breaker Test Jumper
- Remote Racking
- Remote Control Cabinet
- Arc Flash Mitigation
- 3 Cycle Breaker
- Maintenance Switch (ARMS)
- Portable Breaker Operator
- Remote Operation
- Direct Roll-out
- Ground & Test Device

SPECS

- Voltage Class: 5kV, 15kV, 38kV
- Short Circuit: 25kA, 31.5kA, 40kA, 50kA, 63kA
- BIL: 60kV, 95kV, 150kV, 170KV
- Amperage: 1200A, 2000A, 3000A, 4000A
- Enclosure: NEMA 1, 3R non walk-in, Sheltered Aisle, in PDC
- Paint system, material of enclosure

NEMA 3R Non Walk-in

NEMA 3R Shelter Aisle

NEMA 1 Indoor SWGR in PDC

SWGR BLDG with MV Swgr and Cable Tray Routing

Bus

Relay Protection

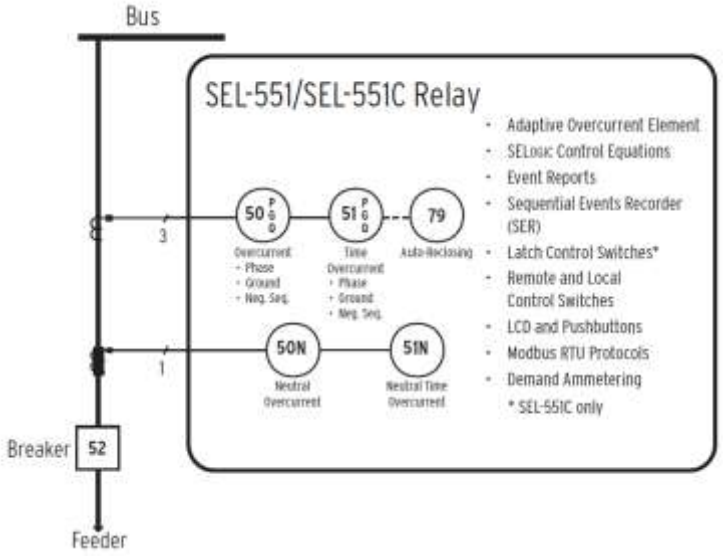
- Basic 50/51
- Voltage Protection
- Line Protection
- Transformer/generator differential
- Bus differential

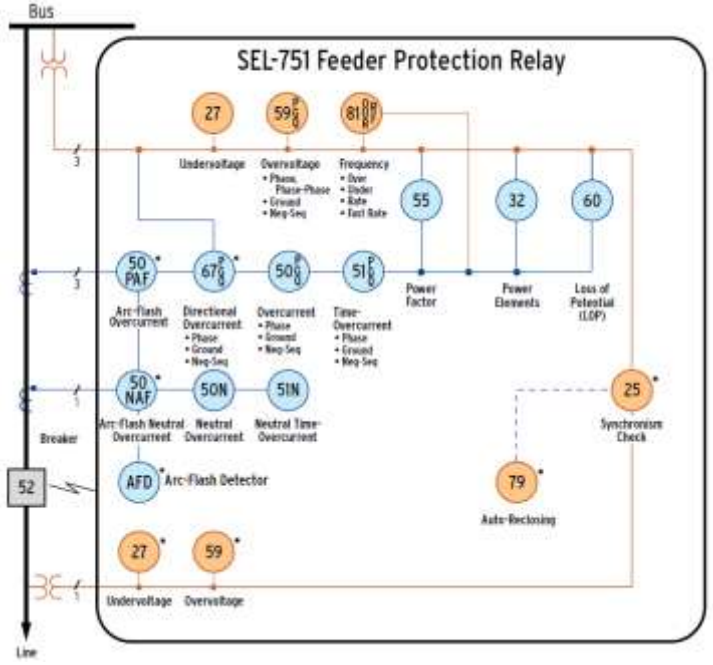
ESSMETRON


EN INST A B C N RS LO
FAULT TYPE
79
TARGET RESET METER EVENTS STATUS OTHER SET CNTRL EXIT
LAMP TEST CANCEL SELECT
SEL–551
OVERCURRENT RELAY
RECLOSING RELAY
SEL
SCHWEITZER ENGINEERING LABORATORIES
PULLMAN WASHINGTON USA


SEL
SEL-751
FEEDER PROTECTION RELAY
SEL-751
FEEDER RELAY
AUX 1
AUX 2
AUX 3
AUX 4
LOCK
CLOSE
TRIP


ARC SENSE
AST
TECHNOLOGY

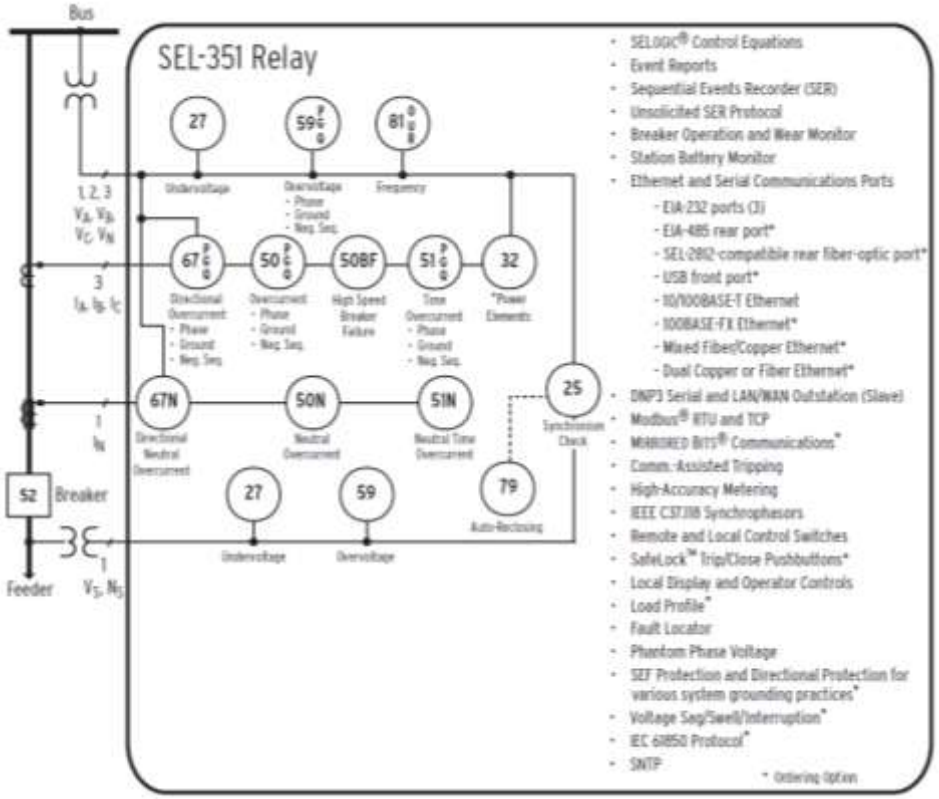

Bus
SEL-551/SEL-551C Relay
50 P G Q
51 P G Q
79
Overcurrent
- Phase
- Ground
- Neg. Seq.
Time Overcurrent
- Phase
- Ground
- Neg. Seq.
Auto-Reclosing
50N
51N
Neutral Overcurrent
Neutral Time Overcurrent
3
1
Breaker
52
Feeder
- Adaptive Overcurrent Element
- SELogic Control Equations
- Event Reports
- Sequential Events Recorder (SER)
- Latch Control Switches*
- Remote and Local Control Switches
- LCD and Pushbuttons
- Modbus RTU Protocols
- Demand Ammetering
* SEL-551C only


Bus
SEL-751 Feeder Protection Relay
27
59 P G Q
81 O U F
Undervoltage
Overvoltage
- Phase, Phase-Phase
- Ground
- Neg-Seq
Frequency
- Over
- Under
- Rate
- Fast Rate
55
32
60
50 PAF
67 P G Q
50 P G Q
51 P G Q
Arc-Flash Overcurrent
Directional Overcurrent
- Phase
- Ground
- Neg-Seq
Overcurrent
- Phase
- Ground
- Neg-Seq
Time-Overcurrent
- Phase
- Ground
- Neg-Seq
Power Factor
Power Elements
Loss of Potential (LOP)
50 NAF
50N
51N
Arc-Flash Neutral Overcurrent
Neutral Overcurrent
Neutral Time-Overcurrent
25
Synchronism Check
Breaker
52
AFD
Arc-Flash Detector
79
Auto-Reclosing
27
59
Undervoltage
Overvoltage
3
1
Line

ESSMETRON

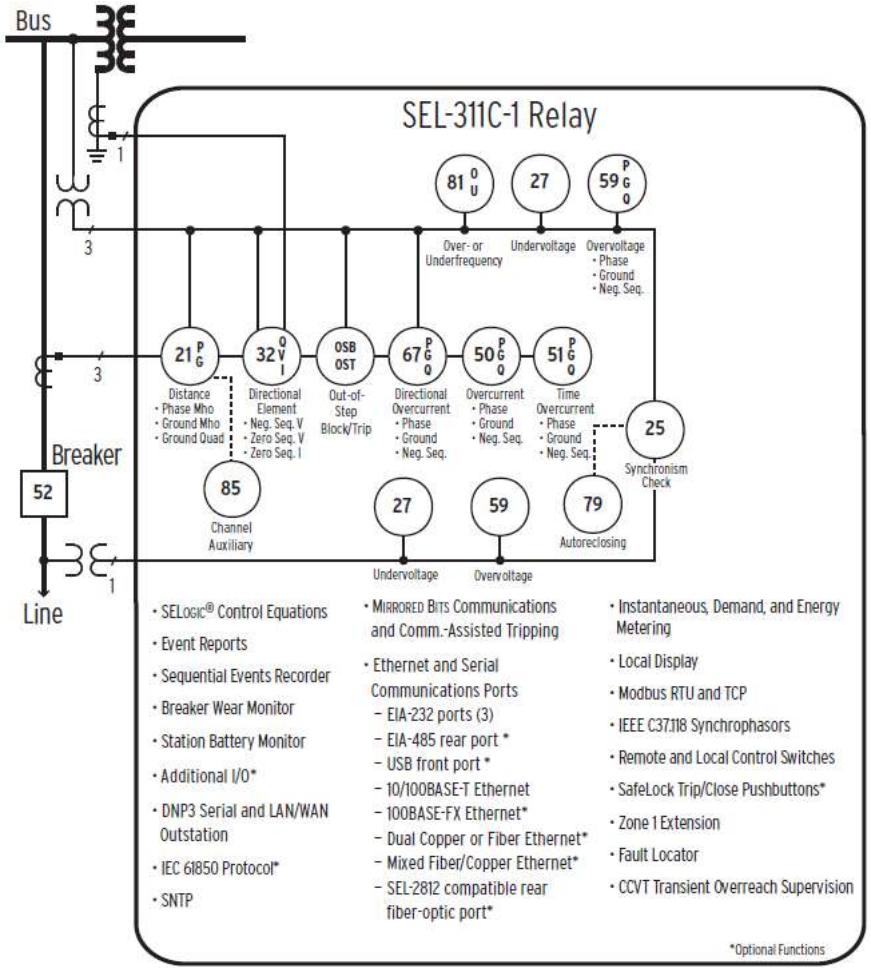

SEL-351
BREAKER
OPEN
TRIP
CLOSED
CLOSE


SEL-351S
IA= 0 IB= 0
IC= 0 IG= 0
GROUND ENABLED
RECLOSE ENABLED
REMOTE ENABLED
ALT. SETTINGS
LOCK
HOT LINE TAG
AUX 1
AUX 2
AUX 3
AUX 4
OPEN
CLOSED
BREAKER
TRIP
CLOSE


SEL-351 Relay
Bus
27
59
81
Undervoltage
Overvoltage
- Phase
- Ground
- Neg. Seq.
Frequency
1, 2, 3
VA, VB, VC, VN
67
50
50BF
51
32
Directional Overcurrent
- Phase
- Ground
- Neg. Seq.
Overcurrent
- Phase
- Ground
- Neg. Seq.
High Speed Breaker Failure
Time Overcurrent
- Phase
- Ground
- Neg. Seq.
"Power Elements
3
IA, IB, IC
67N
50N
51N
25
Directional Neutral Overcurrent
Neutral Overcurrent
Neutral Time Overcurrent
Synchronism Check
1
IN
52
Breaker
27
59
79
Auto-Reclosing
Undervoltage
Overvoltage
1
VS, NS
Feeder
SELOGIC® Control Equations
Event Reports
Sequential Events Recorder (SER)
Unsolicited SER Protocol
Breaker Operation and Wear Monitor
Station Battery Monitor
Ethernet and Serial Communications Ports
- EIA-232 ports (3)
- EIA-485 rear port*
- SEL-2812-compatible rear fiber-optic port*
- USB front port*
- 10/100BASE-T Ethernet
- 100BASE-FX Ethernet*
- Mixed Fiber/Copper Ethernet*
- Dual Copper or Fiber Ethernet*
DNP3 Serial and LAN/WAN Outstation (Slave)
Modbus® RTU and TCP
MIRRORED BITS® Communications*
Comm.-Assisted Tripping
High-Accuracy Metering
IEEE C37.118 Synchrophasors
Remote and Local Control Switches
SafeLock™ Trip/Close Pushbuttons*
Local Display and Operator Controls
Load Profile*
Fault Locator
Phantom Phase Voltage
SEF Protection and Directional Protection for various system grounding practices*
Voltage Sag/Swell/Interruption*
IEC 61850 Protocol*
SNTP
* Ordering Option

ESSMETRON


SEL-311C
SEL
SPT ENABLED
RECLOSE ENABLED
REMOTE ENABLED
ALT. SETTINGS
LOCK
BREAKER CLOSED
BREAKER OPEN
OPEN
CLOSED
BREAKER
TRIP
CLOSE


Bus
Breaker
52
Line
SEL-311C-1 Relay
81 O U
Over- or Underfrequency
27
Undervoltage
59 P G Q
Overvoltage
• Phase
• Ground
• Neg. Seq.
21 P G
Distance
• Phase Mho
• Ground Mho
• Ground Quad
32 Q V I
Directional Element
• Neg. Seq. V
• Zero Seq. V
• Zero Seq. I
OSB OST
Out-of-Step Block/Trip
67 P G Q
Directional Overcurrent
• Phase
• Ground
• Neg. Seq.
50 P G Q
Overcurrent
• Phase
• Ground
• Neg. Seq.
51 P G Q
Time Overcurrent
• Phase
• Ground
• Neg. Seq.
25
Synchronism Check
85
Channel Auxiliary
27
Undervoltage
59
Overvoltage
79
Autoreclosing
• SELogic® Control Equations
• Event Reports
• Sequential Events Recorder
• Breaker Wear Monitor
• Station Battery Monitor
• Additional I/O*
• DNP3 Serial and LAN/WAN Outstation
• IEC 61850 Protocol*
• SNTP
• Mirrored Bits Communications and Comm.-Assisted Tripping
• Ethernet and Serial Communications Ports
– EIA-232 ports (3)
– EIA-485 rear port *
– USB front port *
– 10/100BASE-T Ethernet
– 100BASE-FX Ethernet*
– Dual Copper or Fiber Ethernet*
– Mixed Fiber/Copper Ethernet*
– SEL-2812 compatible rear fiber-optic port*
• Instantaneous, Demand, and Energy Metering
• Local Display
• Modbus RTU and TCP
• IEEE C37.118 Synchrophasors
• Remote and Local Control Switches
• SafeLock Trip/Close Pushbuttons*
• Zone 1 Extension
• Fault Locator
• CCVT Transient Overreach Supervision
*Optional Functions

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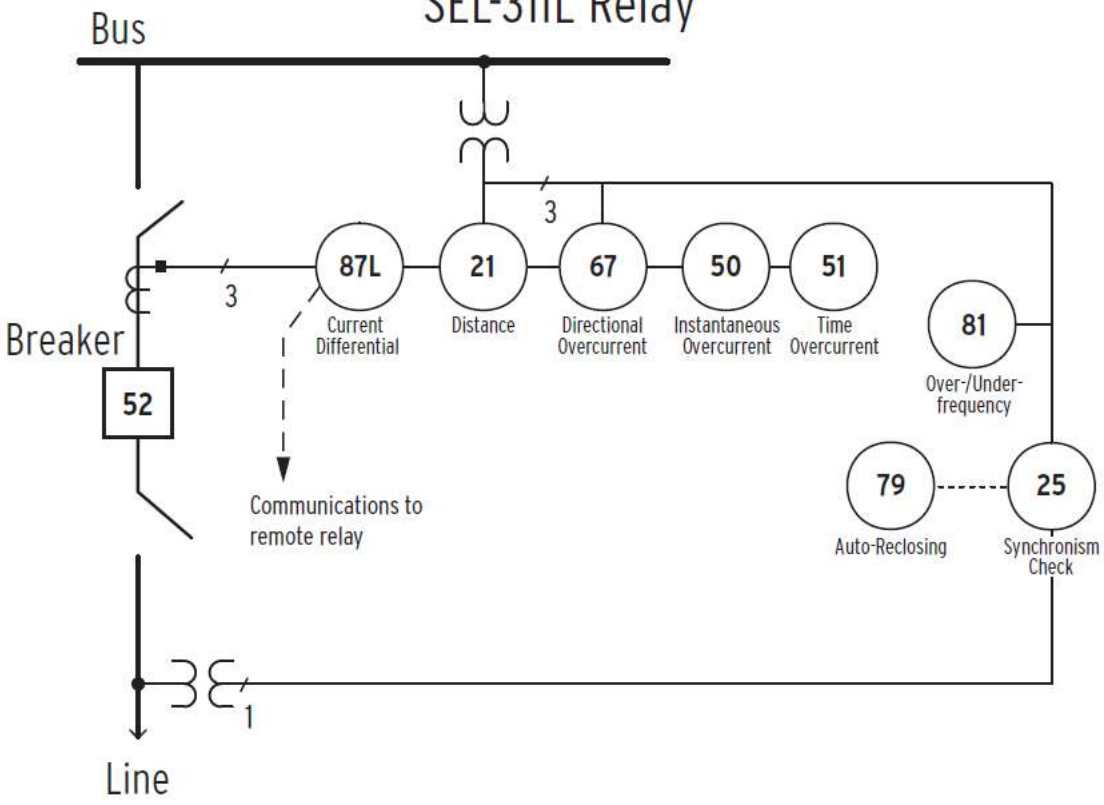
SEL-311L Relay



- Advanced SELogic® Control Equations
- Event Reports With Oscillography
- Sequential Events Recorder
- Breaker Wear Monitor
- Station Battery Monitor
- DNP3 Level 2 Slave Protocol*
- Mirrored Bits® Communications and Advanced Scheme Logic
- Synchrophasors
- Remote and Local Control Switches
- Local Display
- Fault Locator
- CCVT Transient Overreach

*Optional Function

ESSMETRON

SEL-700G0, SEL-700G1

Basic to Comprehensive Protection

Small, Medium, and Large Generators

SEL-700GT

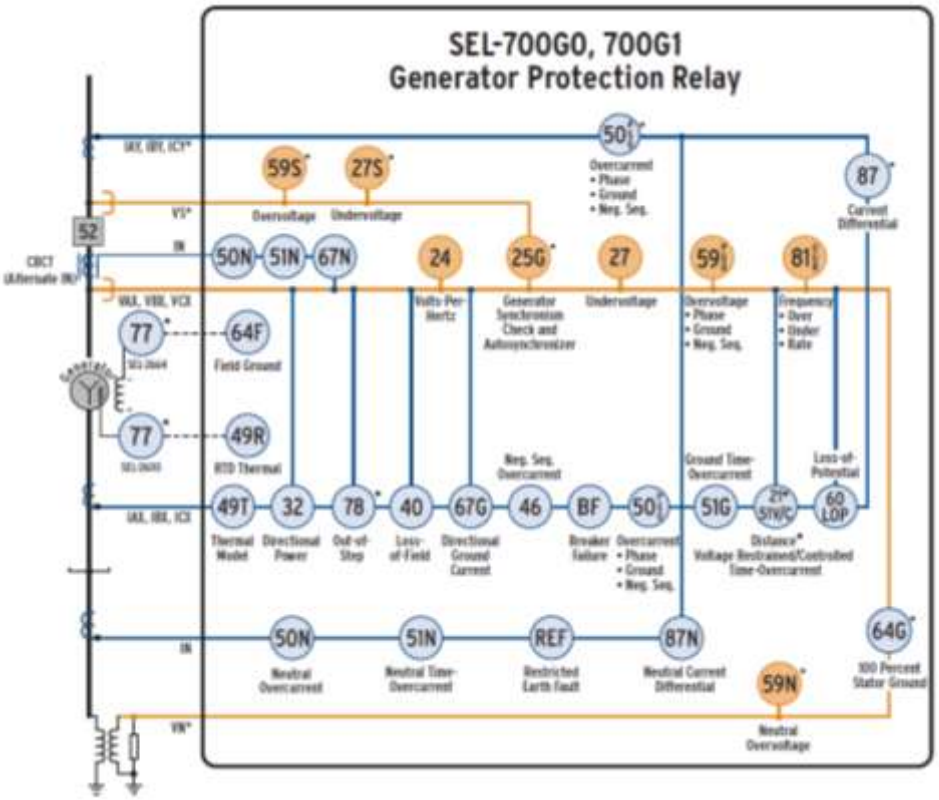
Intertie Protection

Intertie and Generator

SEL-700GW

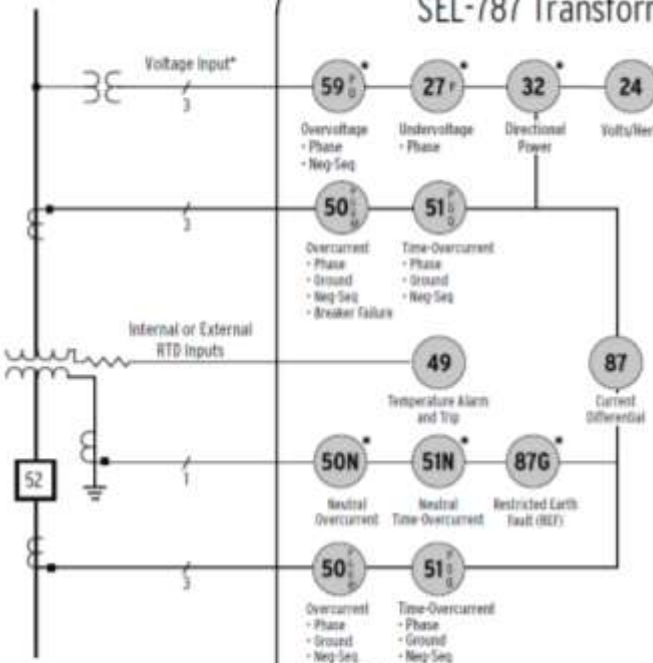
Basic Dual Feeder Overcurrent Protection

Wind Generator



ESSMETRON

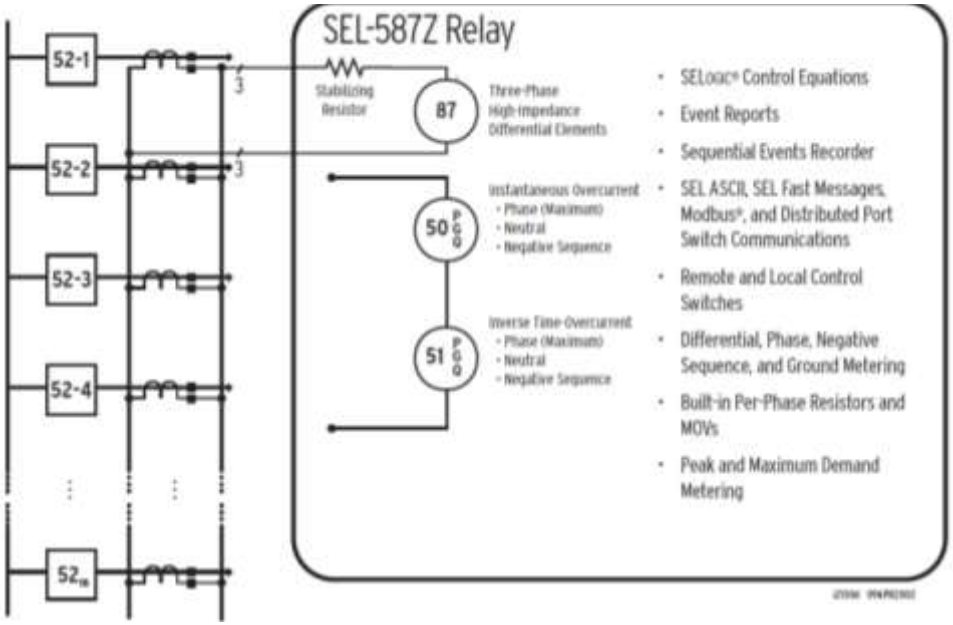
SEL-787 Transformer Protection Relay



- Sequential Events Recorder
- Event Reports
- SEL ASCII, Ethernet*, Modbus TCP*, IEC 61850*, DNP3 LAN/WAN*, DNP3 Serial*, Modbus RTU, Telnet, FTP, SNTP*, and DeviceNet™ Communications*
- Synchrophasor Data and IEEE C37.118 Compliant Protocol
- Front-Panel LED Programmable Targets
- Two Inputs and Three Outputs Standard
- I/O Expansion*–Additional Contact Inputs, Contact Outputs, Analog Inputs, Analog Outputs, and RTD Inputs
- Single or Dual Ethernet Copper or Fiber-Optic Communications Port*
- Battery-Backed Clock, IRIG-B Time Synchronization
- Instantaneous Metering
- Programmable Pushbuttons and LED Indicators
- Through-Fault Monitoring
- Advanced SELOGIC Control Equations
- 32 Programmable Display Messages
- MIRRORED BITS Communications
- Transformer Thermal Monitoring

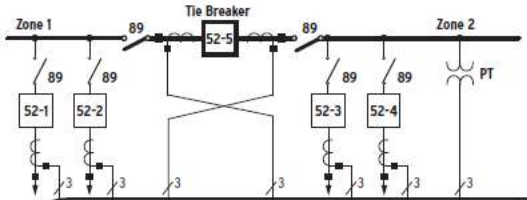
* Optional Functions

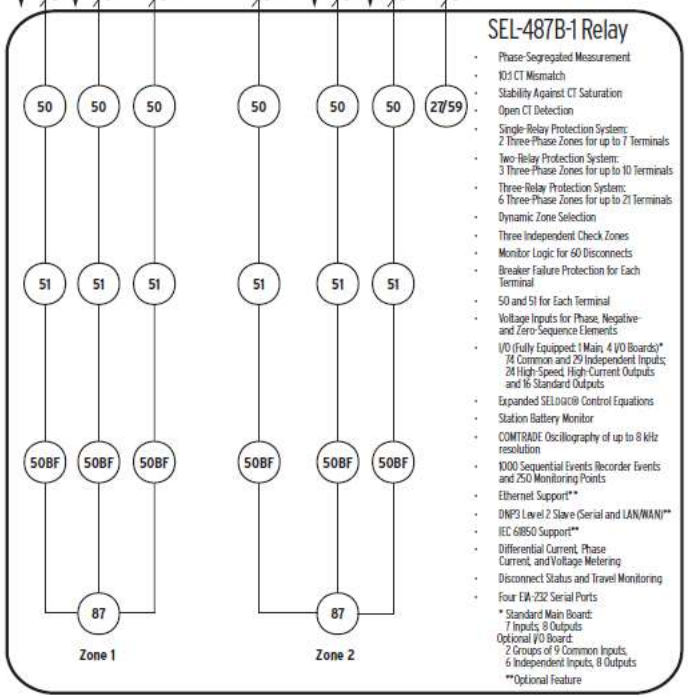
ESSMETRON



SEL-587Z Relay

- SELOGIC® Control Equations
- Event Reports
- Sequential Events Recorder
- SEL ASCII, SEL Fast Messages, Modbus®, and Distributed Port Switch Communications
- Remote and Local Control Switches
- Differential, Phase, Negative Sequence, and Ground Metering
- Built-in Per-Phase Resistors and MOVs
- Peak and Maximum Demand Metering





SEL-487B-1 Relay

- Phase-Segregated Measurement
- 10:1 CT Mismatch
- Stability Against CT Saturation
- Open CT Detection
- Single-Relay Protection System: 2 Three-Phase Zones for up to 7 Terminals
- Two-Relay Protection System: 3 Three-Phase Zones for up to 10 Terminals
- Three-Relay Protection System: 6 Three-Phase Zones for up to 21 Terminals
- Dynamic Zone Selection
- Three Independent Check Zones
- Monitor Logic for 60 Disconnects
- Breaker Failure Protection for Each Terminal
- 50 and 51 for Each Terminal
- Voltage Inputs for Phase, Negative- and Zero-Sequence Elements
- I/O (Fully Equipped: 1 Main, 4 I/O Boards)* 74 Common and 29 Independent Inputs; 24 High-Speed, High-Current Outputs and 16 Standard Outputs
- Expanded SELOGIC® Control Equations
- Station Battery Monitor
- COMTRADE Oscillography of up to 8 kHz resolution
- 1000 Sequential Events Recorder Events and 250 Monitoring Points
- Ethernet Support**
- DNP3 Level 2 Slave (Serial and LAN/WAN)**
- IEC 61850 Support**
- Differential Current, Phase Current, and Voltage Metering
- Disconnect Status and Travel Monitoring
- Four EIA-232 Serial Ports

* Standard Main Board: 7 Inputs, 8 Outputs
Optional I/O Board: 2 Groups of 9 Common Inputs, 6 Independent Inputs, 8 Outputs

**Optional Feature

Operator Safety

- Remote Racking
- ARMS Switch
- 3 cycle breaker
- Arc Flash Mitigation
- Remote Operation/ Control Panel
- Ground & Test Device
- Ground Studs/Neon Glow Tubes
- Kirk Key Interlock
- Shutters
- Lockout/Tagout

Arc Flash

NFPA 70 E TABLE 130.2 (C)

NOMINAL SYSTEM VOLTAGE RANGE	LIMITED APPROACH BOUNDARY	LIMITED APPROACH BOUNDARY	RESTRICTIVE APPROACH BOUNDARY	PROHIBITIVE APPROACH BOUNDARY
PHASE TO PHASE	EXPOSED MOVABLE CONDUCTOR	EXPOSED FIXED CIRCUIT	INCLUDES INADVERTENT MOVEMENT ADDER	INCLUDES REDUCED INADVERTENT MOVEMENT ADDER
LESS THAN 50 V	NOT SPECIFIED	NOT SPECIFIED	NOT SPECIFIED	NOT SPECIFIED
50 TO 300 V	10 FEET 0 INCH	3 FEET 6 INCH	AVOID CONTACT	AVOID CONTACT
301 TO 750 V	10 FEET 0 INCH	3 FEET 6 INCH	1 FEET 0 INCH	0 FEET 1 INCH
751 TO 15 KV	10 FEET 0 INCH	5 FEET 0 INCH	2 FEET 2 INCH	0 FEET 7 INCH
15.1 TO 36 KV	10 FEET 0 INCH	6 FEET 0 INCH	2 FEET 7 INCH	0 FEET 10 INCH
	DISTANCE IN FEET AND INCHES OF THE ENERGIZED PART FROM THE PERSONNEL			

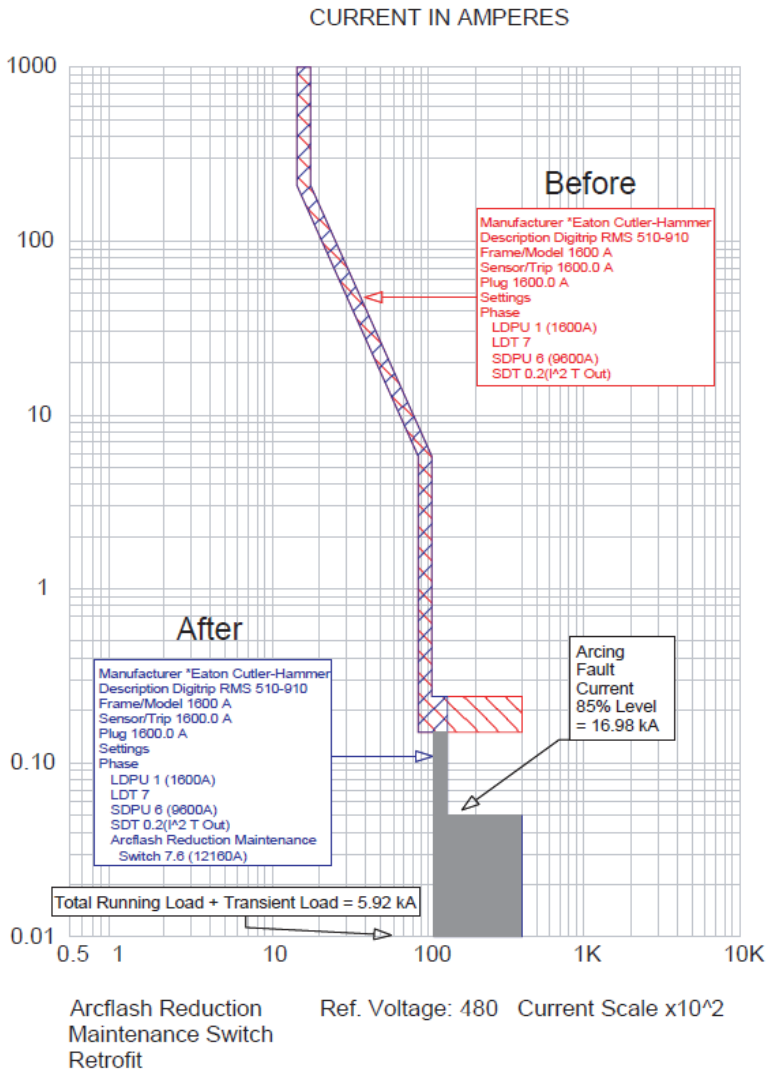
Determining PPE Hazard Risk Category

Category	Cal/cm²	Clothing
0	1.2	Untreated cotton
1	5	Flame retardant (FR) shirt and FR pants
2	8	Cotton underwear, FR shirt, and FR pants
3	25	Cotton underwear, FR shirt, FR pants, and FR coverall
4*	40	Cotton underwear, FR shirt, FR pants, and double-layer switching coat and pants

*Output category for personal protective equipment (PPE).
Source: NFPA 70E, Table 3-3.9.3

Remote Racking

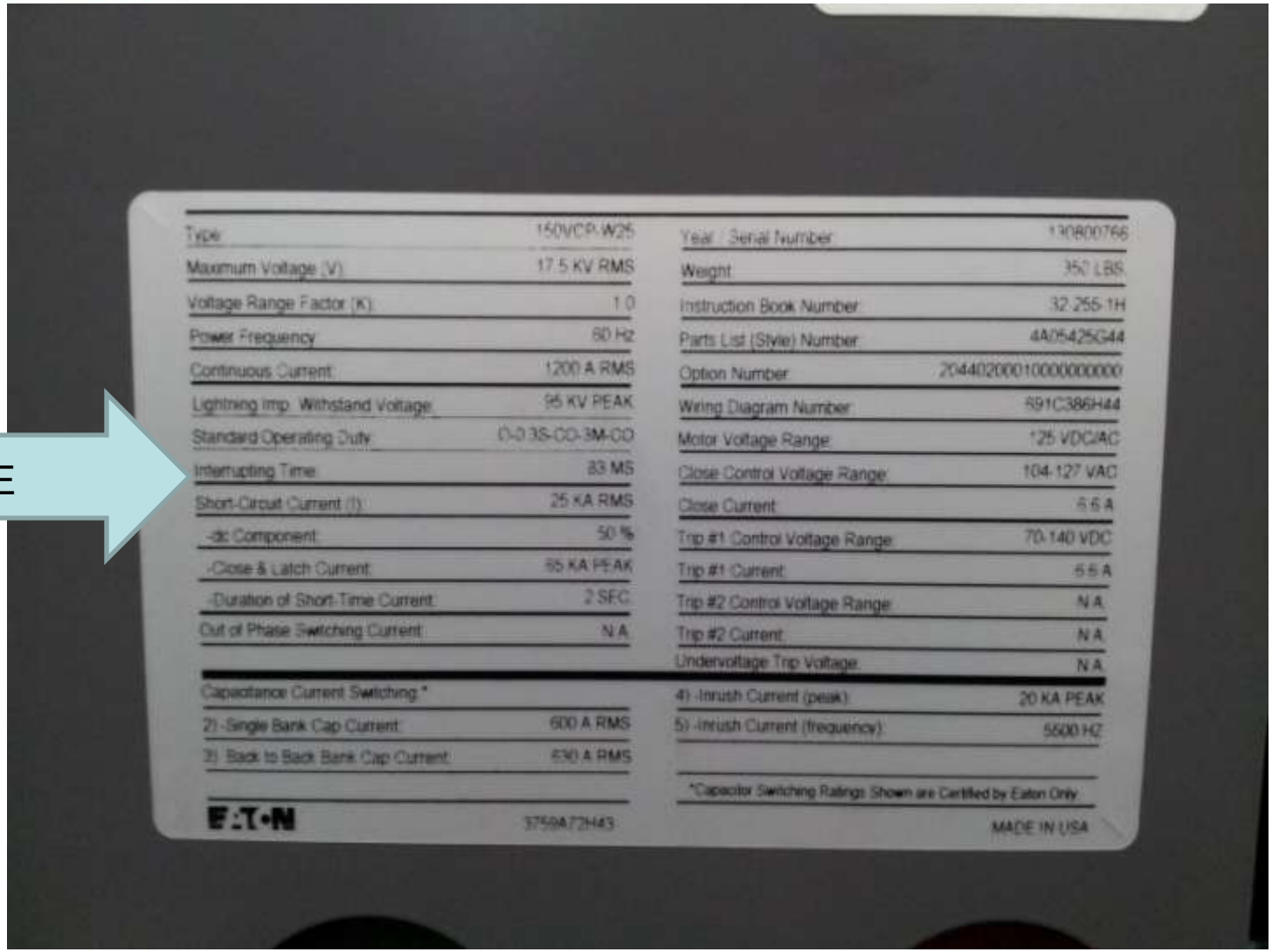
ARMS Switch



Energy Reducing Maintenance Switch	Bolted Fault Current (kA)	Arcing Fault Current (kA)	Clearing Time (ms)	Incident Energy (cal/cm2)
Inactive	40	19.98	240	10.7
Active	40	19.98	50	2.23

3 cycle breaker

5 CYCLE

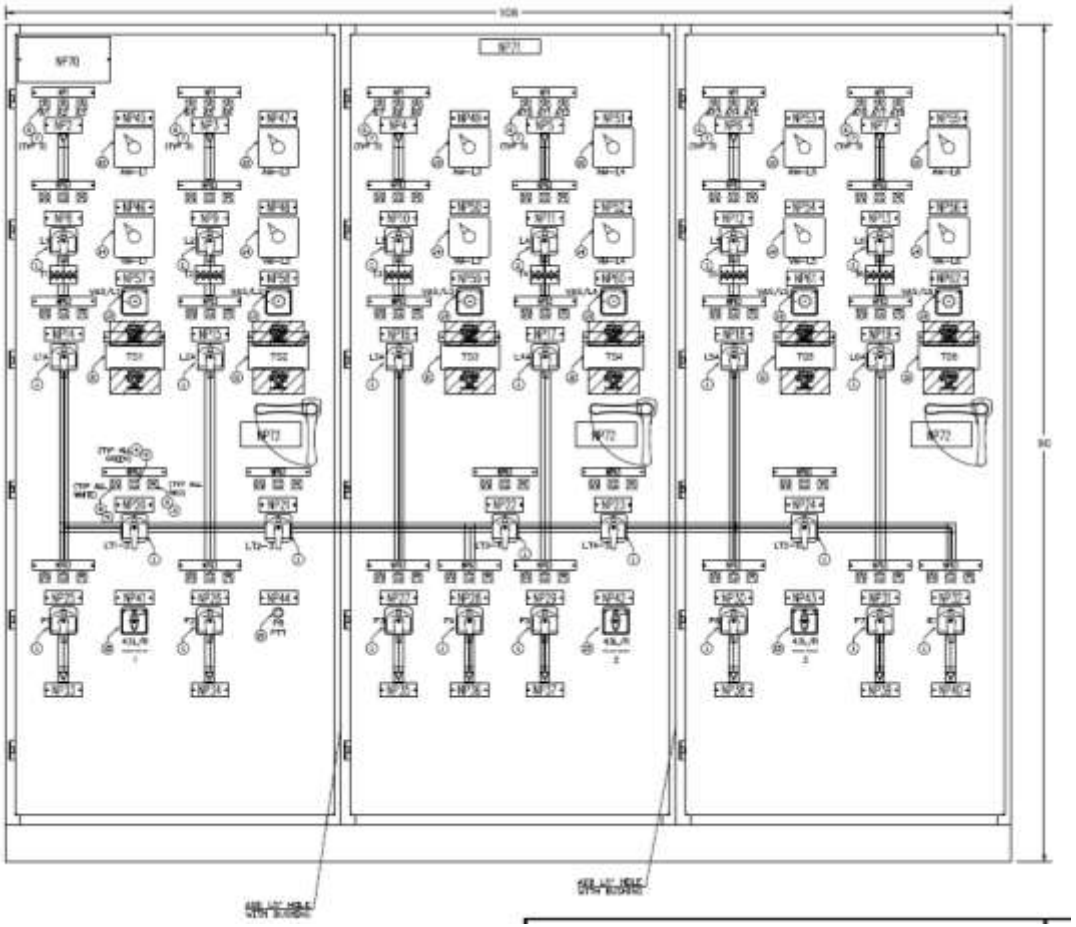


Type	150VCP-W25
Maximum Voltage (V)	17.5 KV RMS
Voltage Range Factor (K)	1.0
Power Frequency	60 Hz
Continuous Current	1200 A RMS
Lightning Imp. Withstand Voltage	95 KV PEAK
Standard Operating Duty	O-0.3S-CO-3M-CO
Interrupting Time	83 MS
Short-Circuit Current (I)	25 KA RMS
-dc Component	50 %
-Close & Latch Current	65 KA PEAK
-Duration of Short-Time Current	2 SEC
Out of Phase Switching Current	N.A.
Capacitance Current Switching *	
2) -Single Bank Cap Current	600 A RMS
3) -Back to Back Bank Cap Current	630 A RMS
EATON	3759A72H43

Year / Serial Number	13080076G
Weight	350 LBS.
Instruction Book Number	32.255.1H
Parts List (Style) Number	4A05425G44
Option Number	2044020001000000000
Wiring Diagram Number	591C386H44
Motor Voltage Range	125 VDC/AC
Close Control Voltage Range	104-127 VAC
Close Current	6.6 A
Trip #1 Control Voltage Range	70-140 VDC
Trip #1 Current	6.6 A
Trip #2 Control Voltage Range	N.A.
Trip #2 Current	N.A.
Undervoltage Trip Voltage	N.A.
4) -Inrush Current (peak)	20 KA PEAK
5) -Inrush Current (frequency)	5500 HZ
*Capacitor Switching Ratings Shown are Certified by Eaton Only	
MADE IN USA	

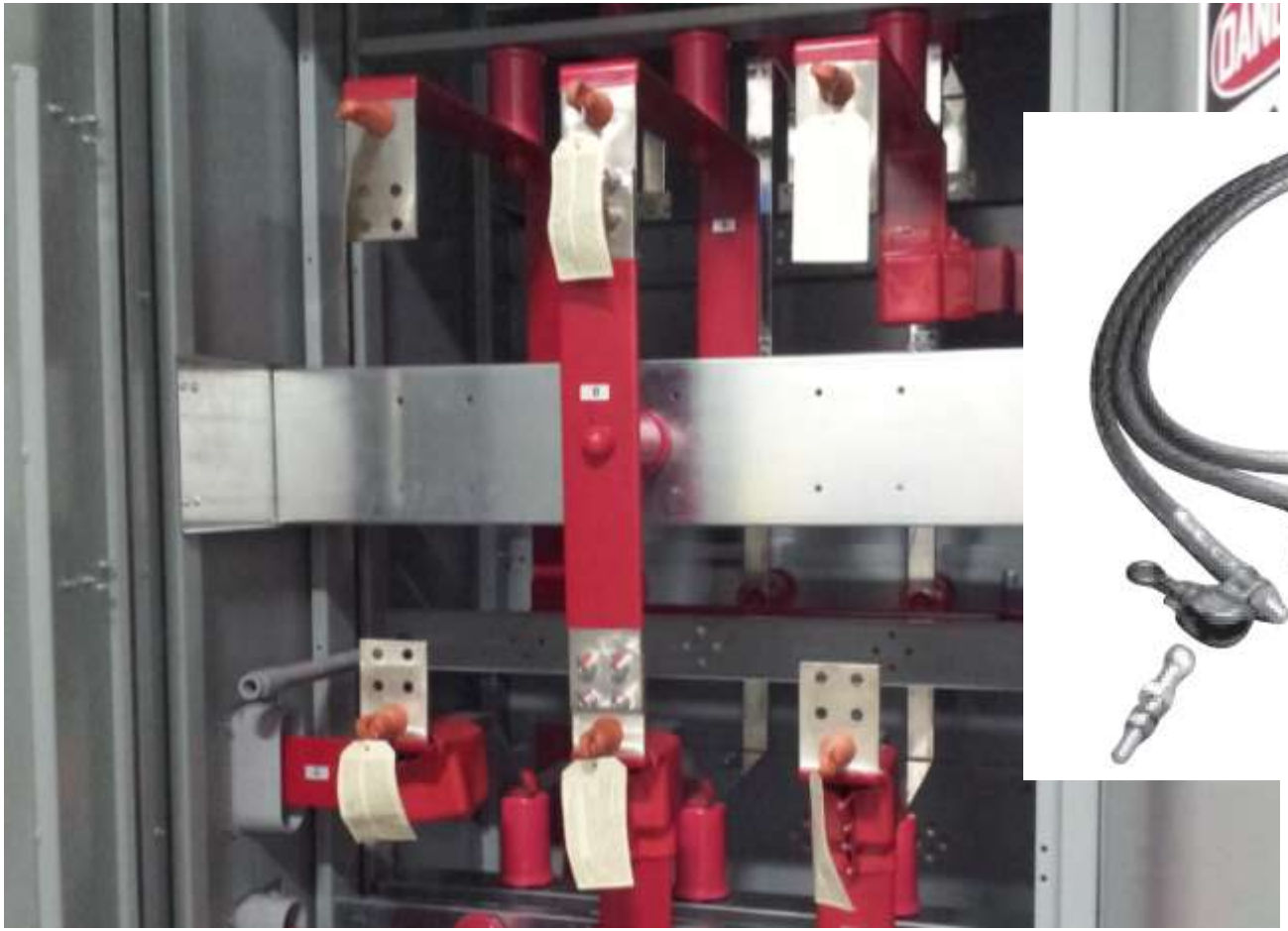
Arc Flash Mitigation

Remote Operation/ Control Panel



G&T Device

Ground Studs



Kirk Key Interlocking

Shutters

Lockout/tagout

Maintainability

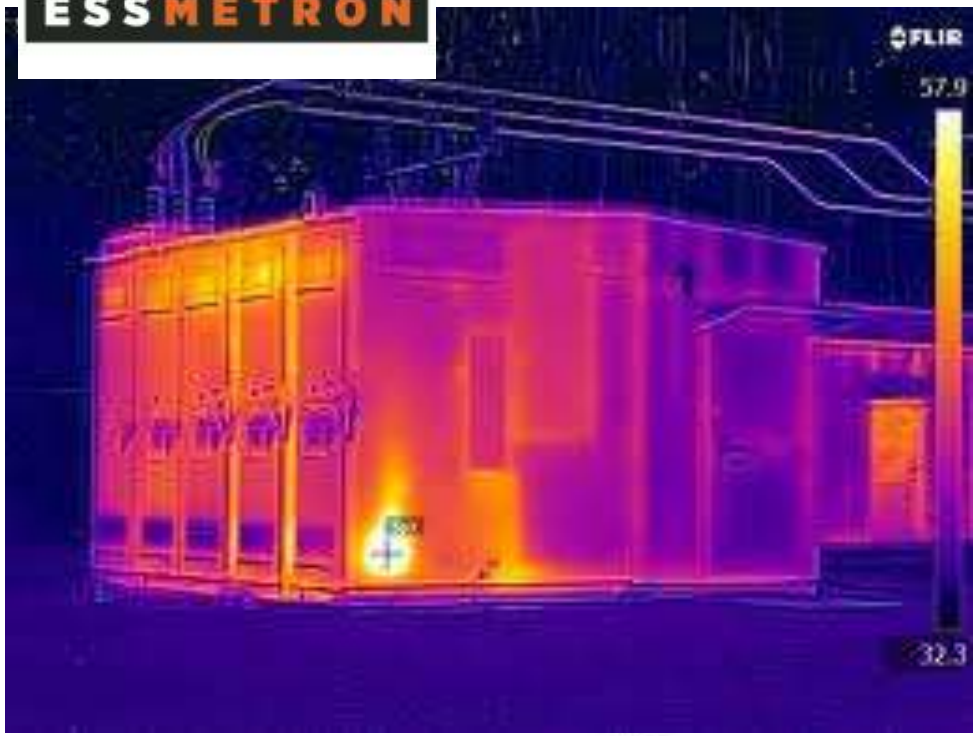
- Ammeters for Space heaters
- Breaker Test Cabinets
- Split Plug Jumpers
- IR windows
- Partial Discharge Monitors

Breaker Accessories

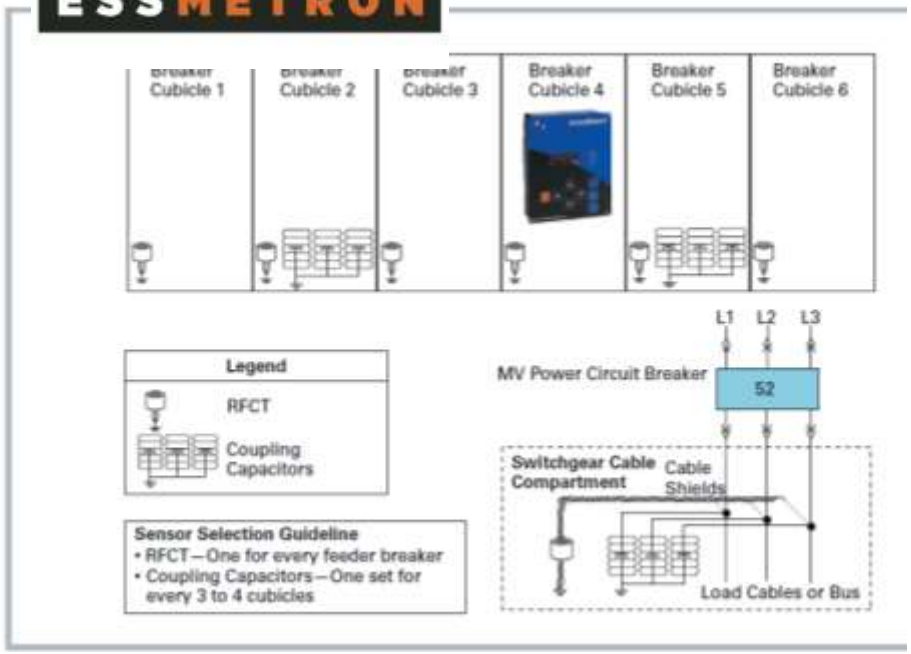
Breaker Test Cabinet

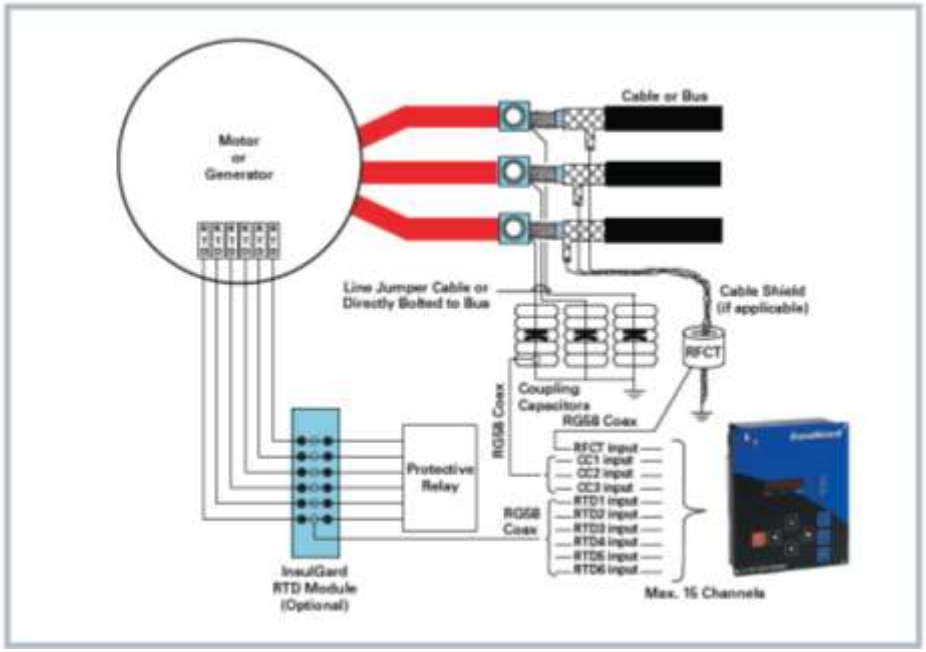
Split Plug Jumper

Infrared Window



PDM Monitor





1

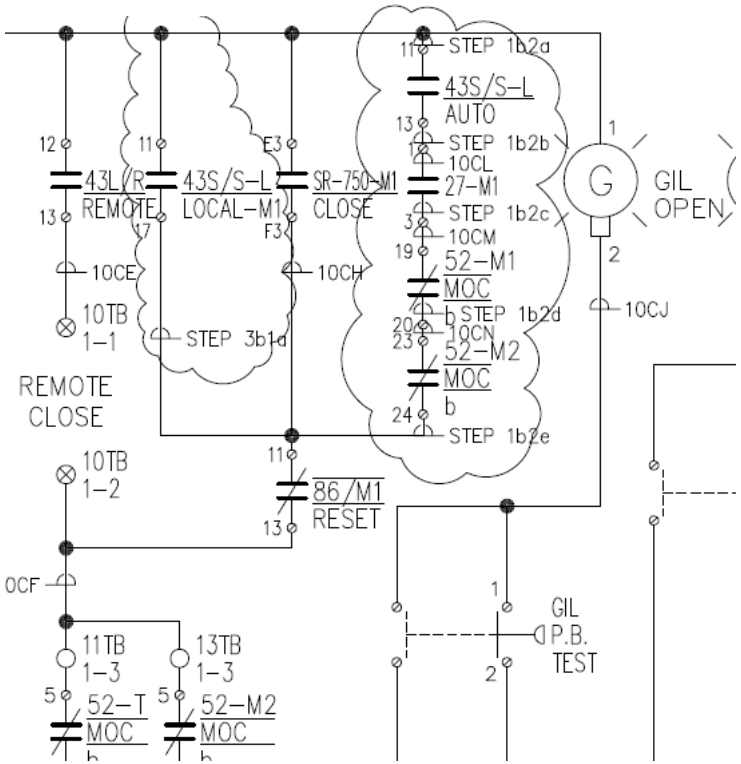
2

3

Main Tie Main Auto Transfer

- Closed/Open Transition
- Through Relays
- Through PLC
- Scheme example

MTM Scheme Example



MAIN-TIE-MAIN INTERLOCKING AND TRANSFER PROCEDURE

BASIC OPERATION

1. BREAKER 52-M1 IS CLOSED TO SUPPLY POWER TO BUS # 1 FDR. BKR'S.
2. BREAKER 52-M2 IS CLOSED TO SUPPLY POWER TO BUS # 2 FDR. BKR'S.
3. TIE BKR. 52-T IS OPEN AND MECHANICAL INTERLOCKS WITH 52-M1 & M2 BREAKERS. TIE BKR. 52-T CANNOT BE CLOSED UNLESS 52-M1 OR 52-M2 IS OPEN.

TO TRANSFER BUS # 2 TO BKR. 52-M1

1. OPEN BKR. 52-M2
2. CLOSE TIE BKR. 52-T

REVERSE SEQUENCE TO RESTORE SERVICE.

LOAD ON BUS # 1 CAN BE SUPPLIED THROUGH BKR. 52-M2 IN A SIMILAR MANNER.

AUTO TRANSFER MODE (CONTROLLED BY 43S/S-R LOCATED IN MIMIC CONTROL PANEL BUILT BY OTHERS)

SCENARIO 1:

52-M1=CLOSE, 52-M2=OPEN, 52-T=CLOSE, 43S/S-R=AUTO

LOSS OR UNDERVOLTAGE SENSED BY SR-750/M1 WILL OPEN 52-M1 & 52-T, CLOSE 52-M2, AND RE-CLOSE 52-T.

SCENARIO 2:

52-M1=OPEN, 52-M2=CLOSE, 52-T=CLOSE, 43S/S-R=AUTO

LOSS OR UNDERVOLTAGE SENSED BY SR-750/M2 WILL OPEN 52-M2 & 52-T, CLOSE-52-M1 AND RE-CLOSE 52-T.

SCENARIO 3:

52-M1=CLOSE, 52--M2=CLOSE, 52-T=OPEN, 43S/S-R=AUTO

LOSS OR UNDERVOLTAGE SENSED BY SR-750/M1 WILL OPEN 52-M1 AND CLOSE 52-T

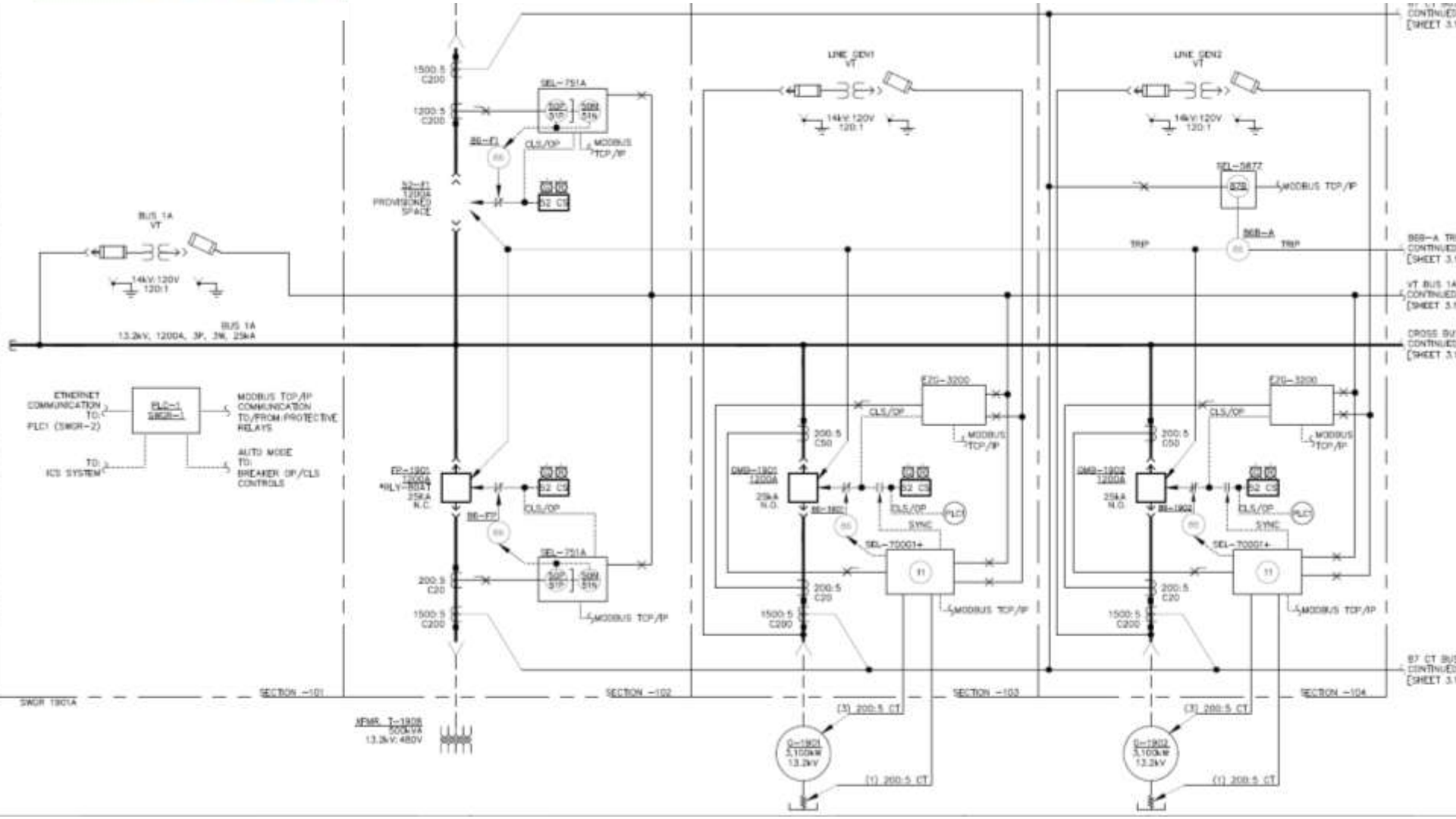
LOSS OR UNDERVOLTAGE SENSED BY SR-750/M2 WILL OPEN 52-M2 AND CLOSE 52-T

SCENARIO 4:

43S/S-R=MANUAL

BREAKER OPERATION IS CONTROLLED MANUALLY THROUGH CONTROL SWITCHES AT MIMIC CONTROL PANEL BUILT BY OTHERS.

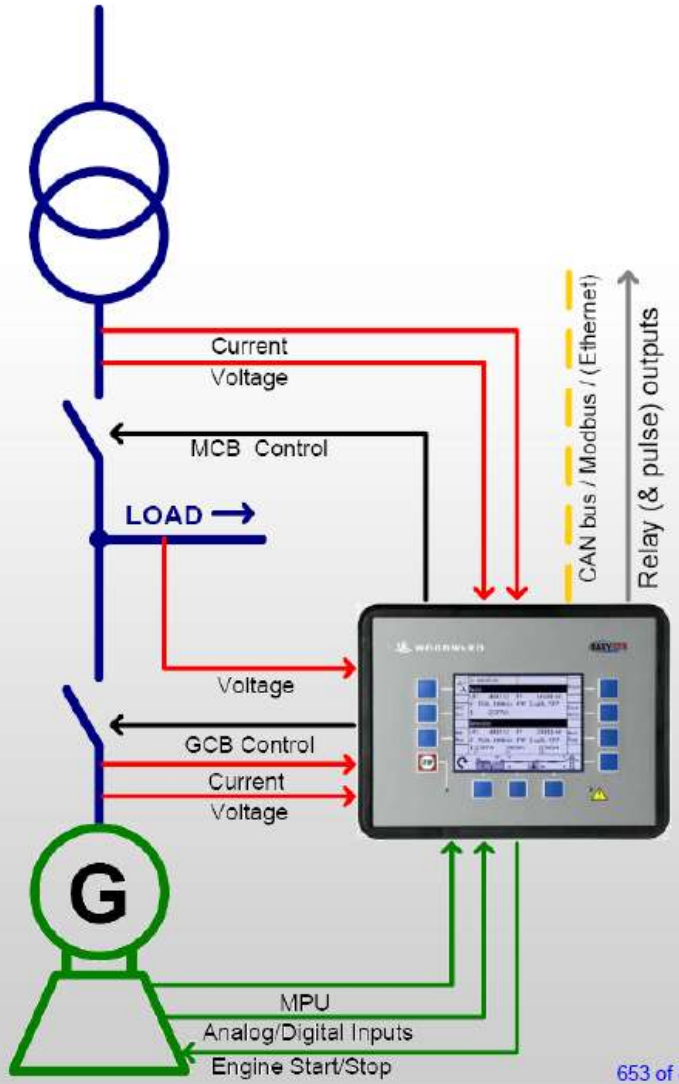
Paralleling SWGR



Application

Single Unit Mains Parallel

- Engine start / stop
- Generator protection
- AMF (auto mains failure)
- Generator control
- Frequency / active power
- Voltage / power factor
- Parallel to mains
- Full Generator Breaker Control
- Full Mains Breaker Control



Applicable Codes and Standards

- ANSI C37.20.2
  - Standard for MV Switchgear
  - Governs ratings and required testing
- NEC

Thank you!