Time-Current Curves

Protective Device Coordination

Protective Device Coordination Study-

Description:

- An organized time-current study of protective devices from the utility to a device.
- A comparison of the time it takes protective devices to operate when certain levels of normal or abnormal current pass through them.

Protective Device Coordination

Protective Device Coordination Study-

Objective:

- Determine the characteristics, ratings, and settings of overcurrent protective devices
- Ensure that the minimium, un-faulted load is interrupted when the protective devices isolate a fault or overload anywhere in the system.

Protective Device Coordination

Protective Device Coordination Study-

Results:

- Selection of instrument transformers ratios
- Protective relay characteristics and settings
- Fuse ratings
- LV circuit breaker ratings, characteristics, and settings.

Protective Device Coordination

Protective Device Coordination Study-

Frequency:

- This study should be revised as new protective are added or as existing devices are modified.
- At a minimum, it is recommended that this study be performed every 5 years.

Protective Device Coordination

Protective Device Coordination Study-

Frequency:

- This study should be revised as new protective are added or as existing devices are modified.
- At a minimum, it is recommended that this study be performed every 5 years.

OSHA 1910.334
Use of Equipment

(b) Electric power and lighting circuits.

(1) Routine opening and closing of circuits. Load rated switches, circuit breakers, or other devices specifically designed as disconnecting means shall be used for the opening, reversing, or closing of circuits under load conditions. Cable connectors not of the load break type, fuses, terminal lugs, and cable splice connections may not be used for such purposes, except in an emergency.

OSHA 1910.334

Use of Equipment

(b) Electric power and lighting circuits.

(2) Reclosing circuits after protective device operation. After a circuit is de-energized by a circuit protective device, the circuit protective device, **the circuit may not be manually reenergized until it has been determined that the equipment and circuit can be safely energized**. The repetitive manual reclosing of circuit breakers or reenergizing circuits through replaced fuses is prohibited.

Note: When it can be determined from the design of the circuit and the overcurrent devices involved that the automatic operation of a device was caused by an overload rather than a fault condition, no examination of the circuit or connected equipment is needed before the circuit is reenergized.

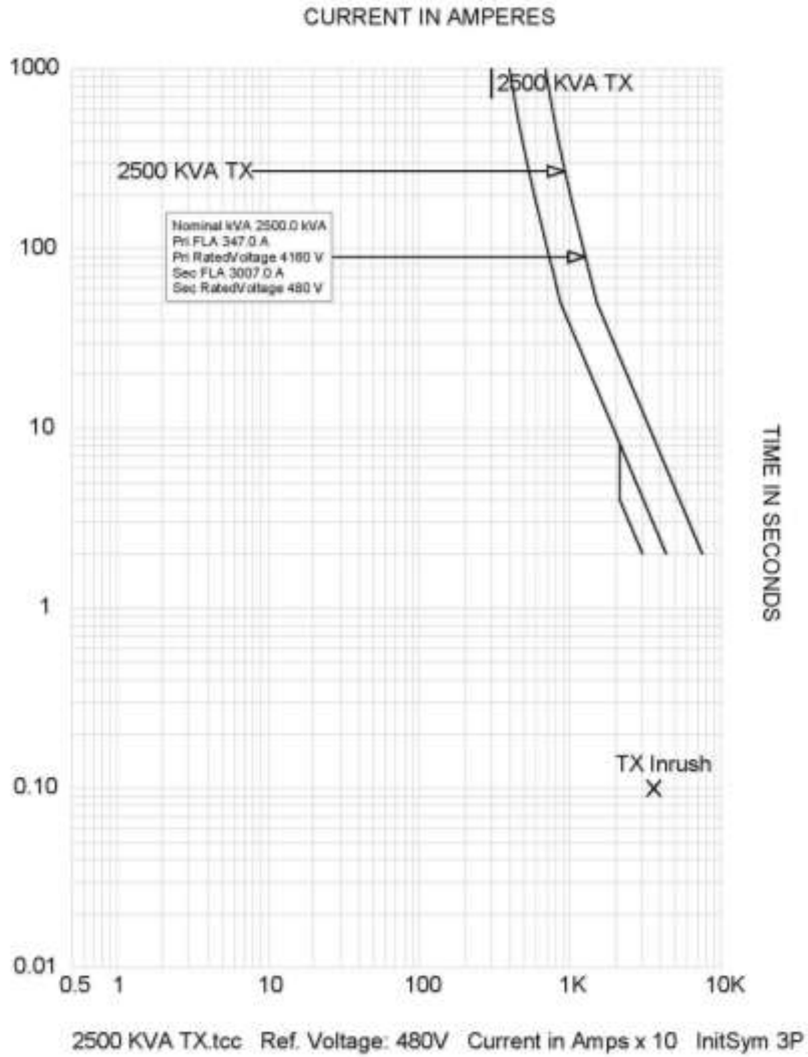
OSHA 1910.334

Use of Equipment

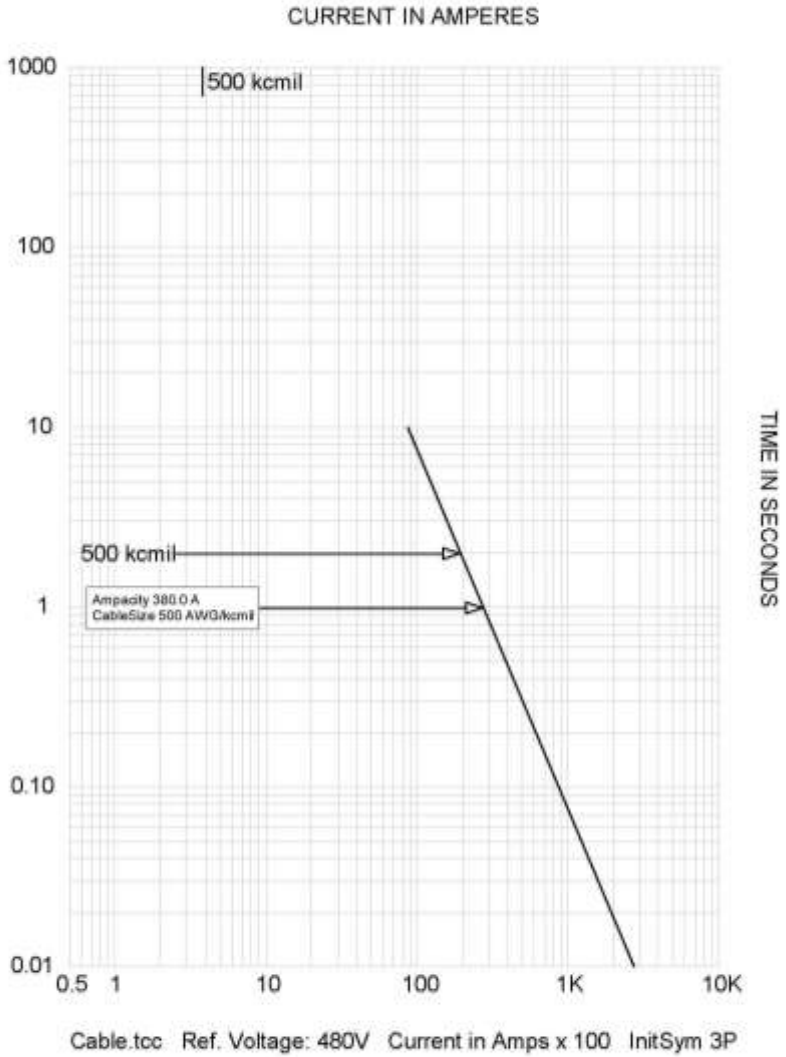
(b) Electric power and lighting circuits.

(3) Overcurrent protection modification. **Overcurrent protection of circuits and conductors may not be modified, even on a temporary basis**, beyond that allowed by 1910.304(e), the installation safety requirements for overcurrent protection.

Time-Current Curves Transformers

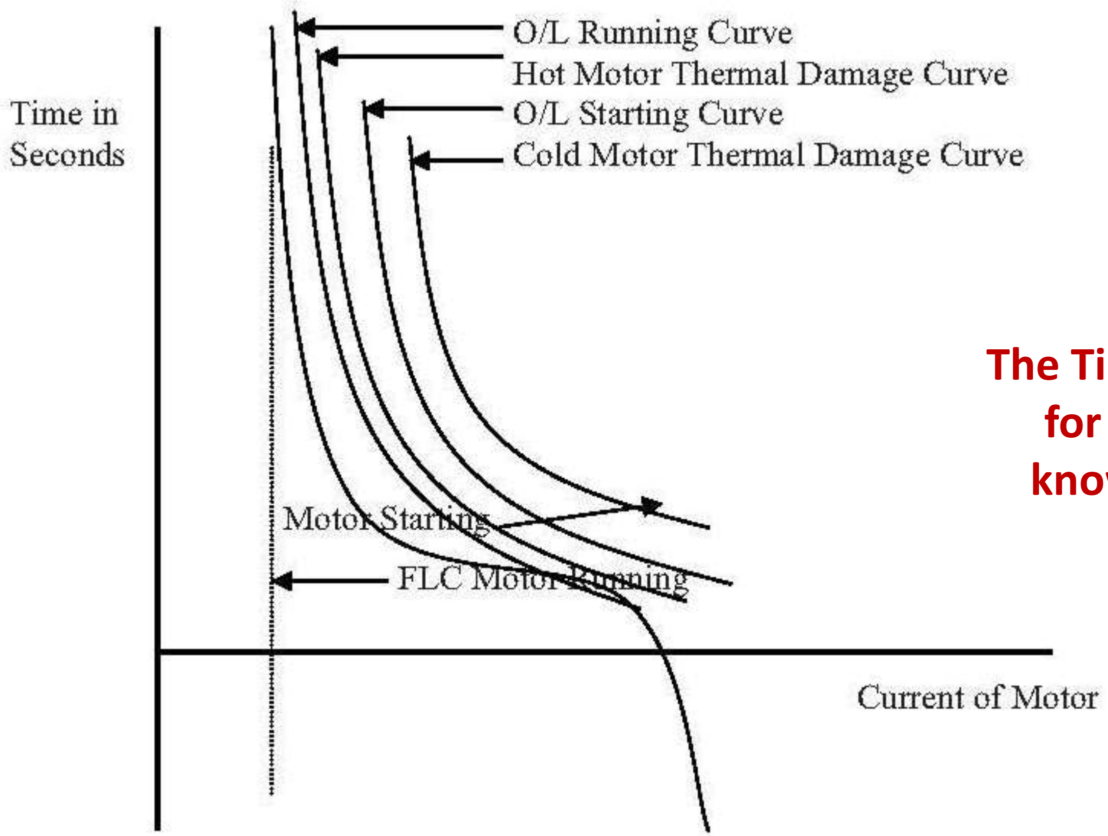


Time-Current Curves
Cables



The Time-Current Curves for cables are also known as "Damage" curves.

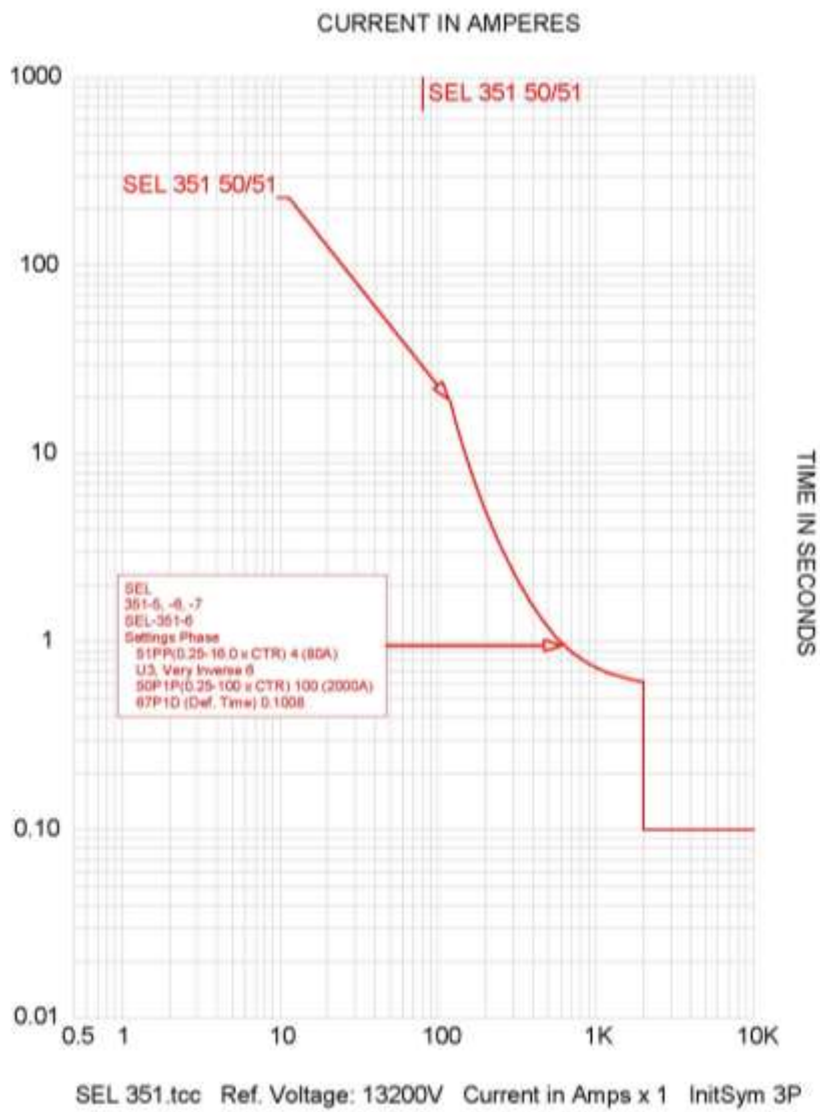
Time Current Curves
Motor



Cold and Hot Thermal Damage Curves

The Time-Current Curves for motors are also known as "Damage" curves.

Time-Current Curves
Protective Relays

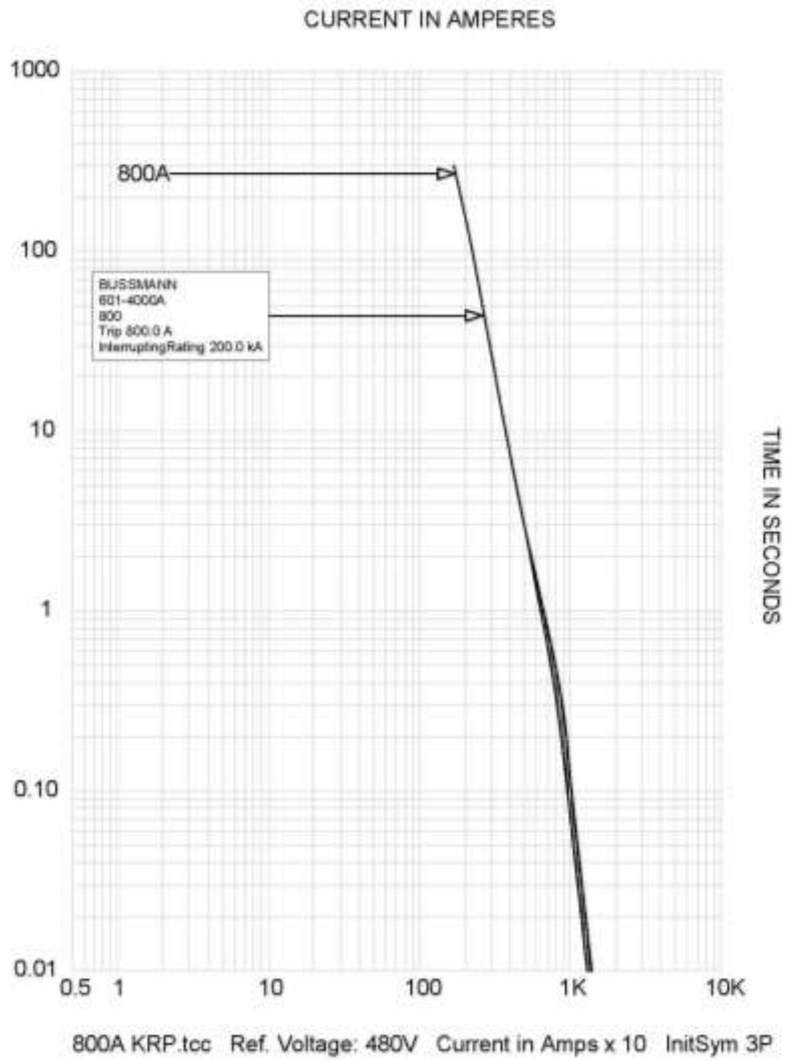


50 – Instantaneous Overcurrent Relay

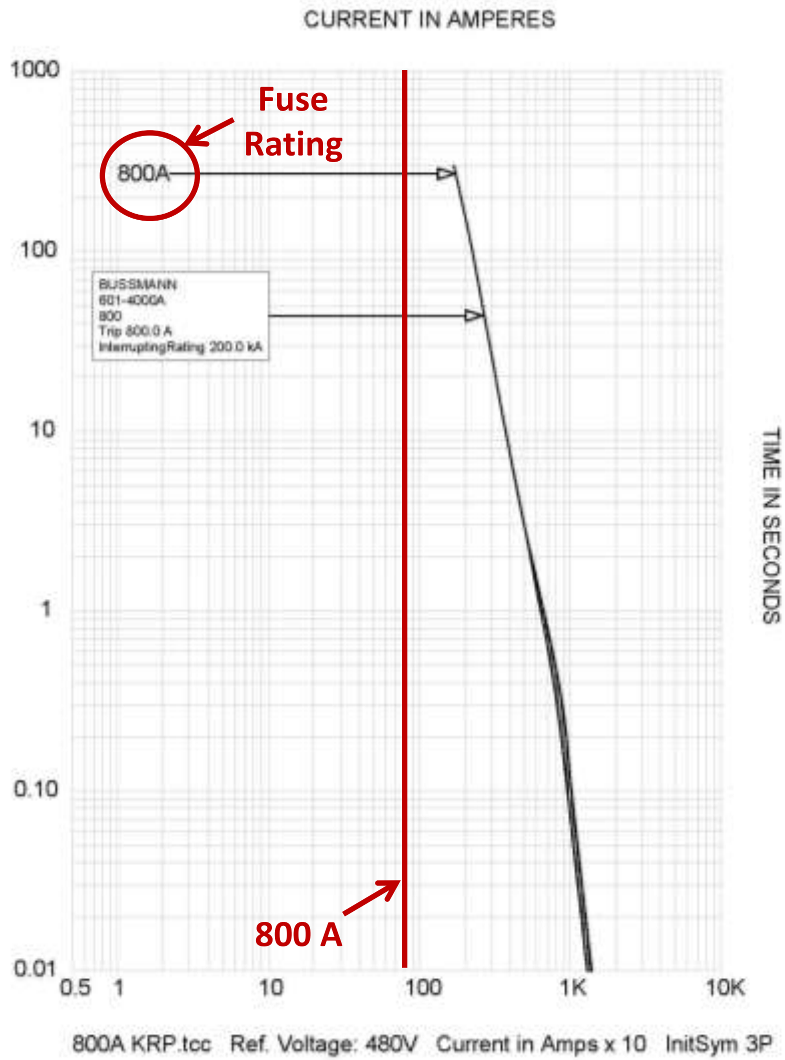
51 – AC Time Overcurrent Relay

67 – AC Directional Overcurrent Relay

Time-Current Curves
Fuses



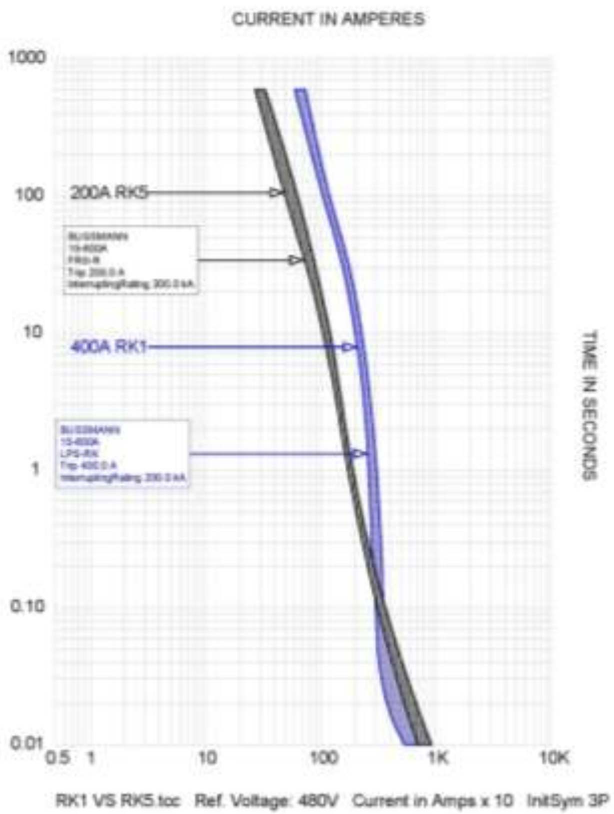
Time-Current Curves
Fuses

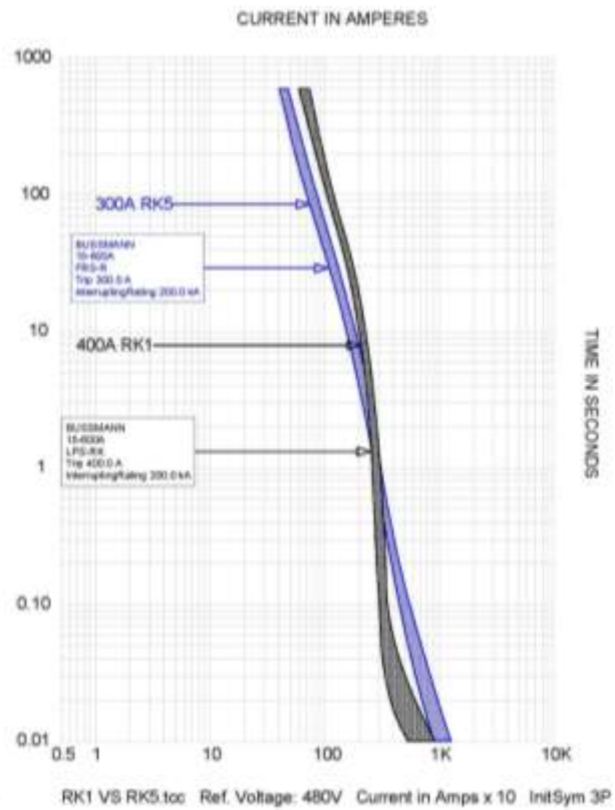


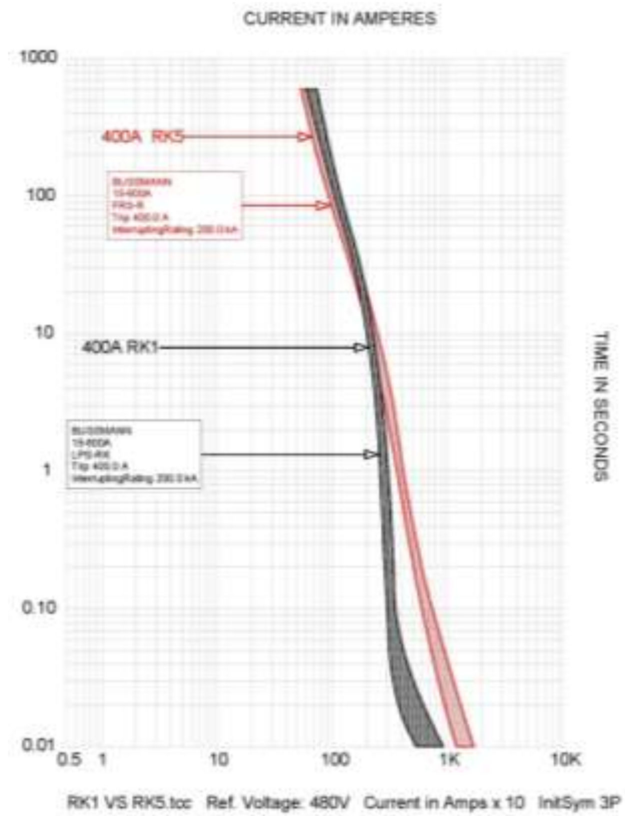
What would cause a fuse to blow?

1. **Inappropriate Sizing**
2. **Inappropriate Type for application**
3. **Fault**

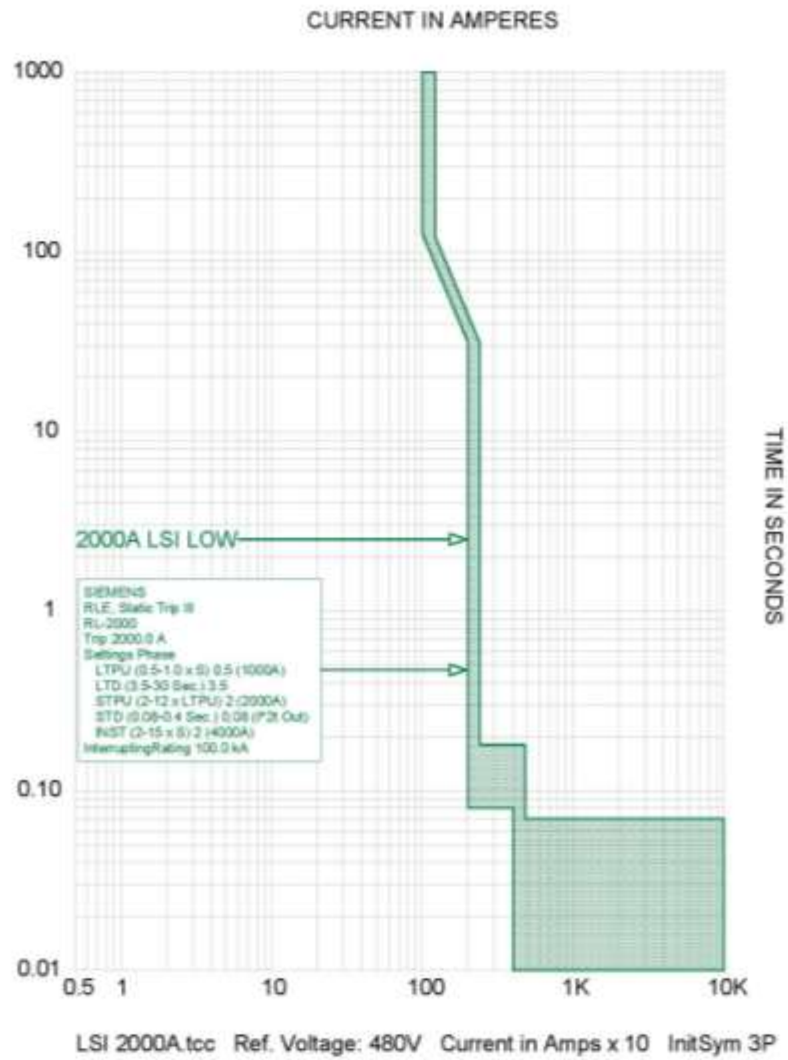
Time-Current Curves
Fuses



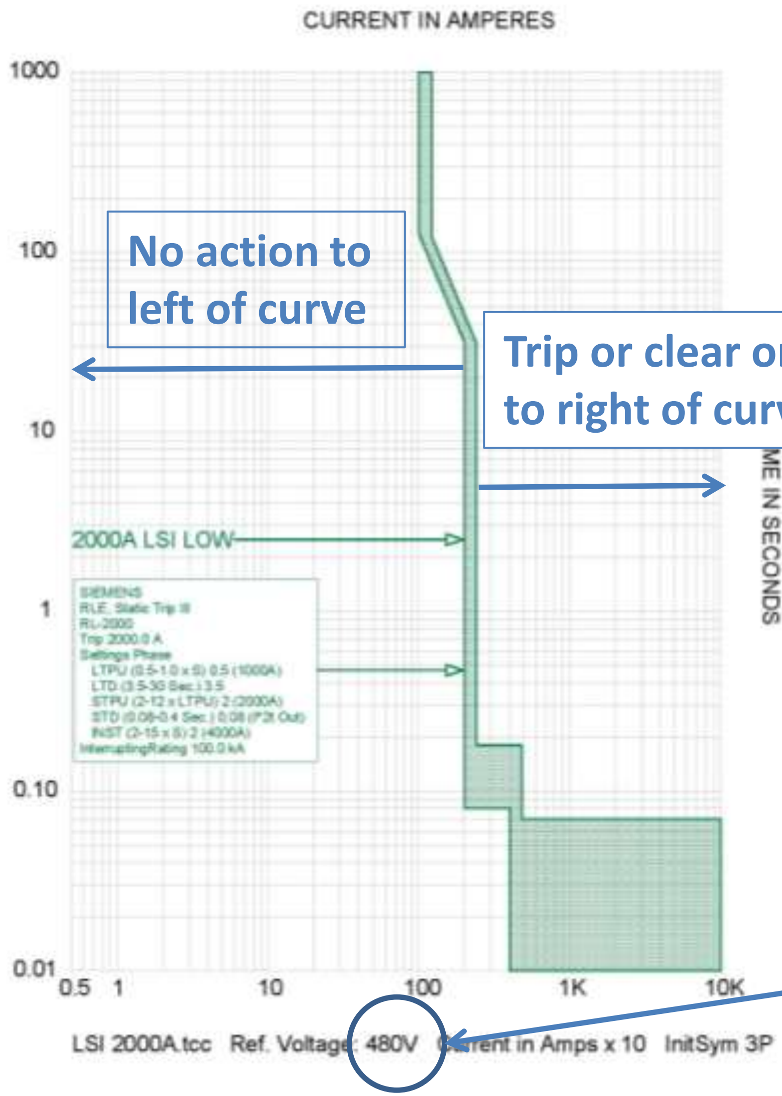




Time-Current Curves
Circuit Breakers



Time-Current Curves
Circuit Breakers

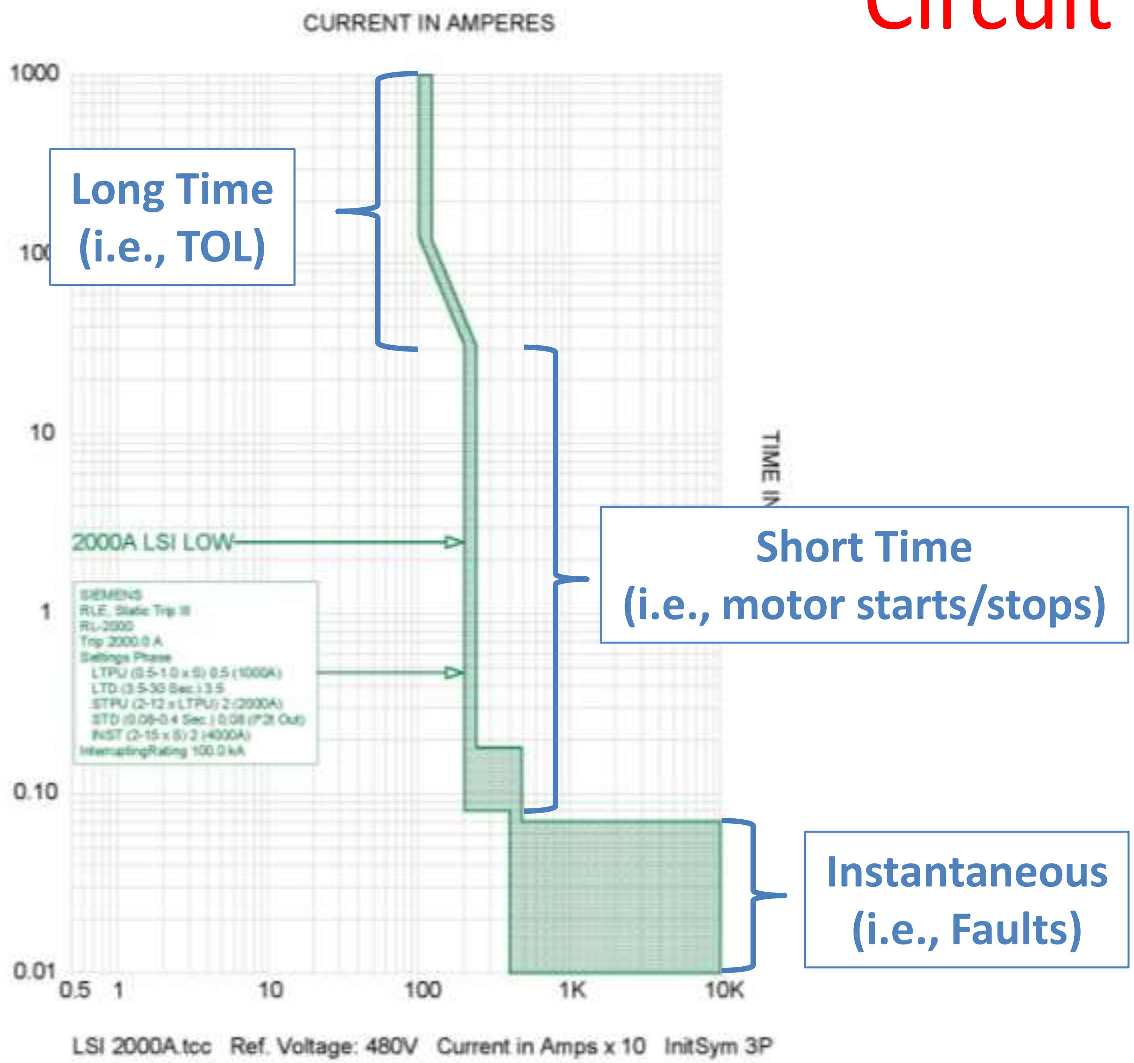


No action to left of curve

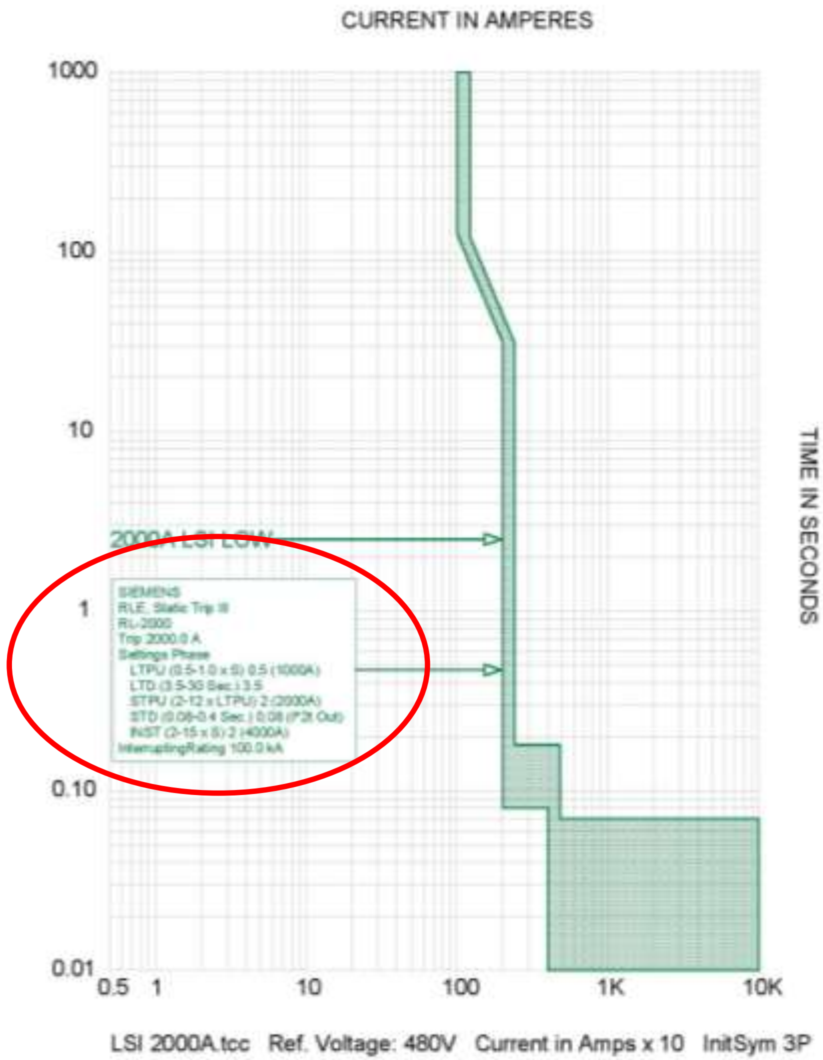
Trip or clear on and to right of curve

All devices should be considered at same voltage

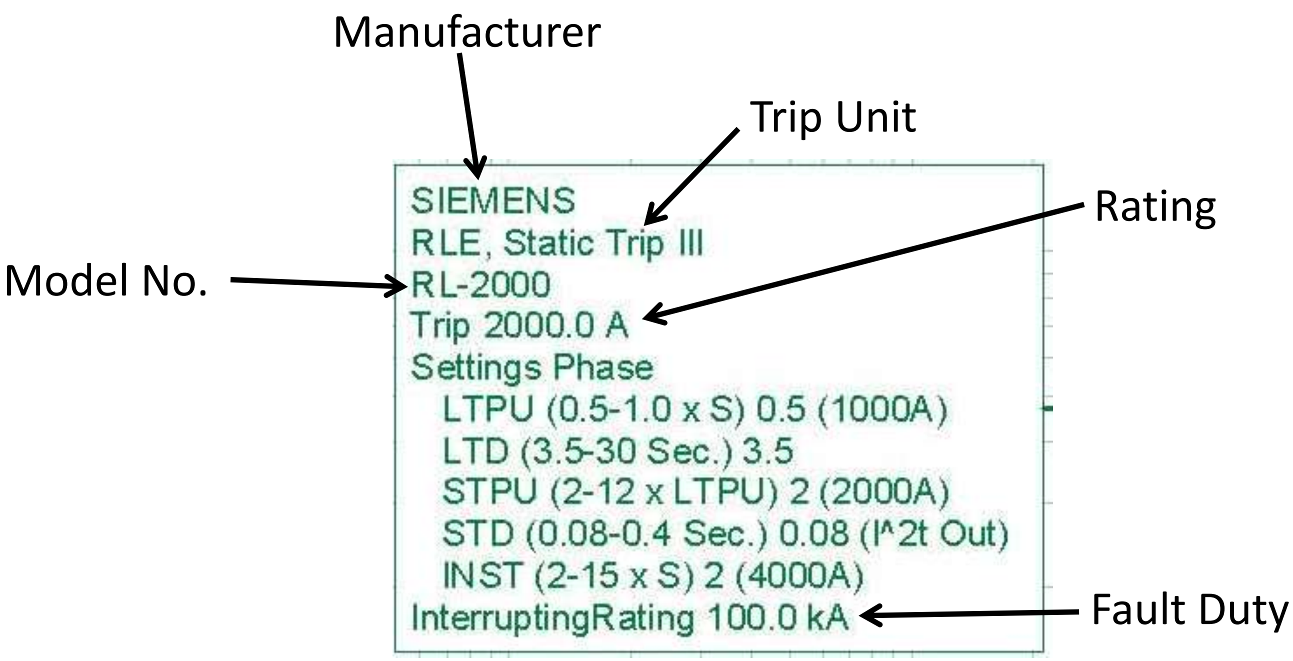
Time-Current Curves
Circuit Breakers



Time-Current Curves
Circuit Breakers



Time-Current Curves
Circuit Breakers



Time-Current Curves
Circuit Breakers

SIEMENS
RLE, Static Trip III
RL-2000
Trip 2000.0 A
Settings Phase
  LTPU (0.5-1.0 x S) 0.5 (1000A)
  LTD (3.5-30 Sec.) 3.5
  STPU (2-12 x LTPU) 2 (2000A)
  STD (0.08-0.4 Sec.) 0.08 (I^2t Out)
  INST (2-15 x S) 2 (4000A)
InterruptingRating 100.0 kA

Available Settings

LTPU – Long Time Pickup
LTD - Long Time Delay
} L

STPU – Short Time Pickup
STD – Short Time Delay
} S

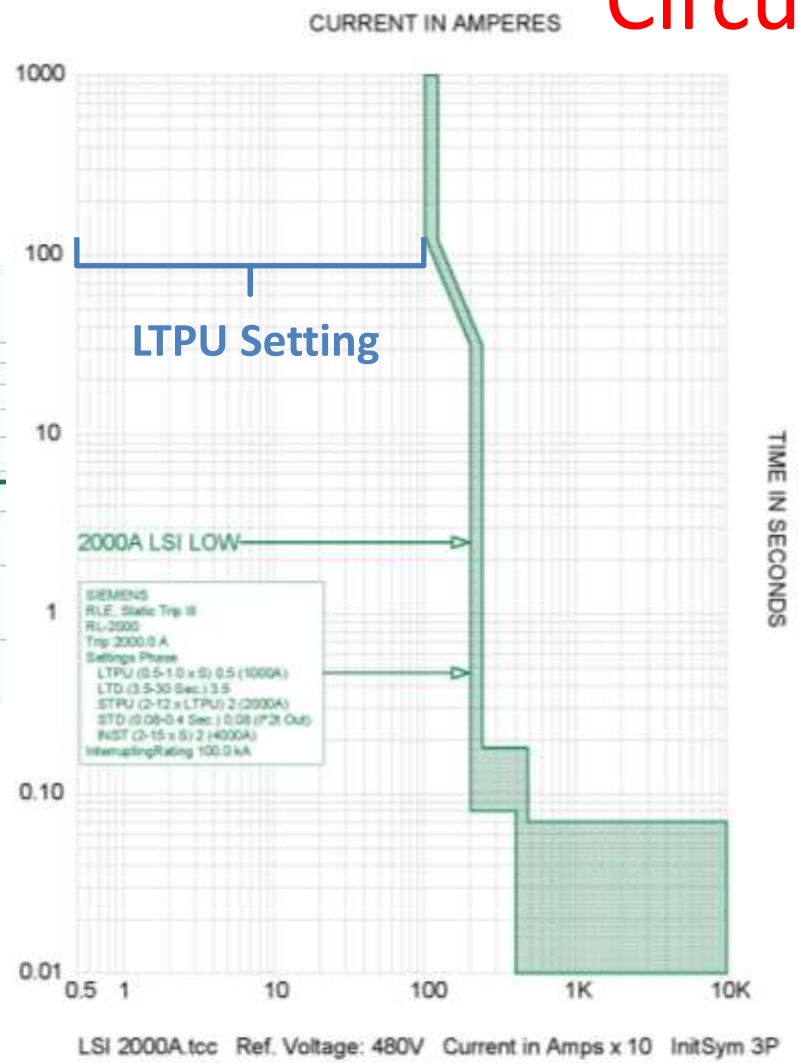
INST – Instantaneous
} I

GF – Ground Fault
GFD – Ground Fault Delay
} G

Time-Current Curves
Circuit Breakers

SIEMENS
RLE, Static Trip III
RL-2000
Trip 2000.0 A
Settings Phase
- LTPU (0.5-1.0 x S) 0.5 (1000A)
- LTD (3.5-30 Sec.) 3.5
- STPU (2-12 x LTPU) 2 (2000A)
- STD (0.08-0.4 Sec.) 0.08 (I^2t Out)
- INST (2-15 x S) 2 (4000A)

InterruptingRating 100.0 kA



Time-Current Curves
Circuit Breakers

SIEMENS
RLE, Static Trip III
RL-2000
Trip 2000.0 A
Settings Phase
  LTPU (0.5-1.0 x S) 0.5 (1000A)
  LTD (3.5-30 Sec.) 3.5
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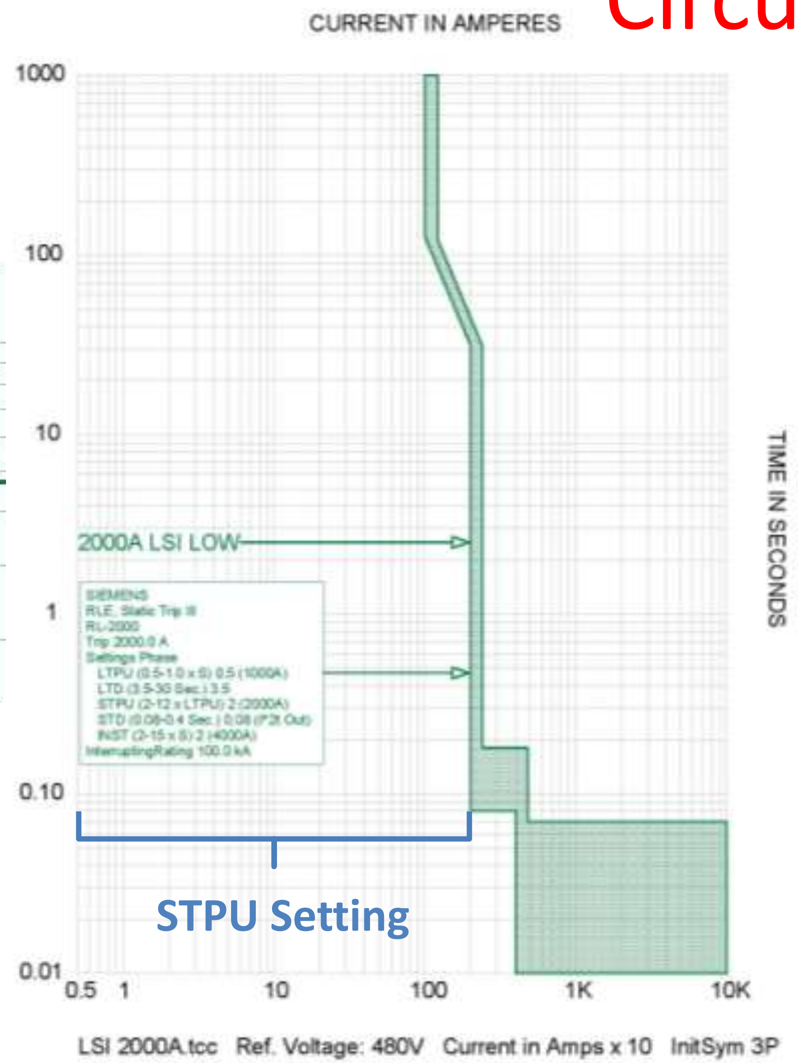
  STD (0.08-0.4 Sec.) 0.08 (I^2t Out)
  INST (2-15 x S) 2 (4000A)
InterruptingRating 100.0 kA



Time-Current Curves
Circuit Breakers

SIEMENS
RLE, Static Trip III
RL-2000
Trip 2000.0 A
Settings Phase
- LTPU (0.5-1.0 x S) 0.5 (1000A)
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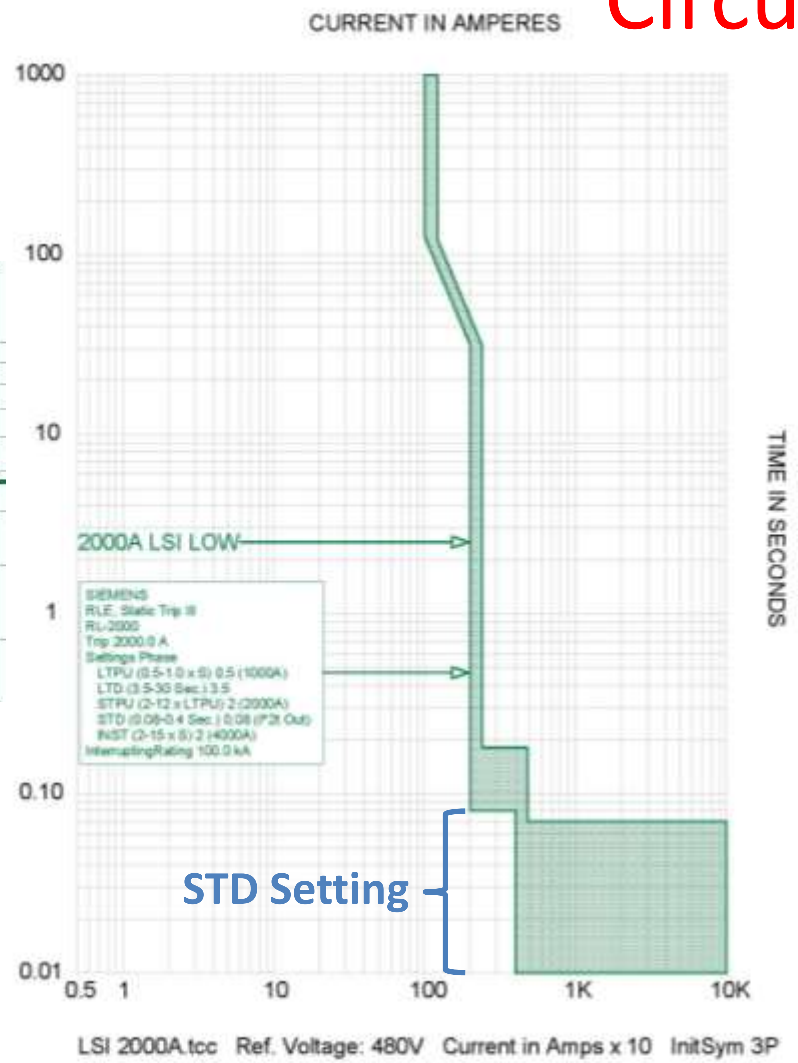
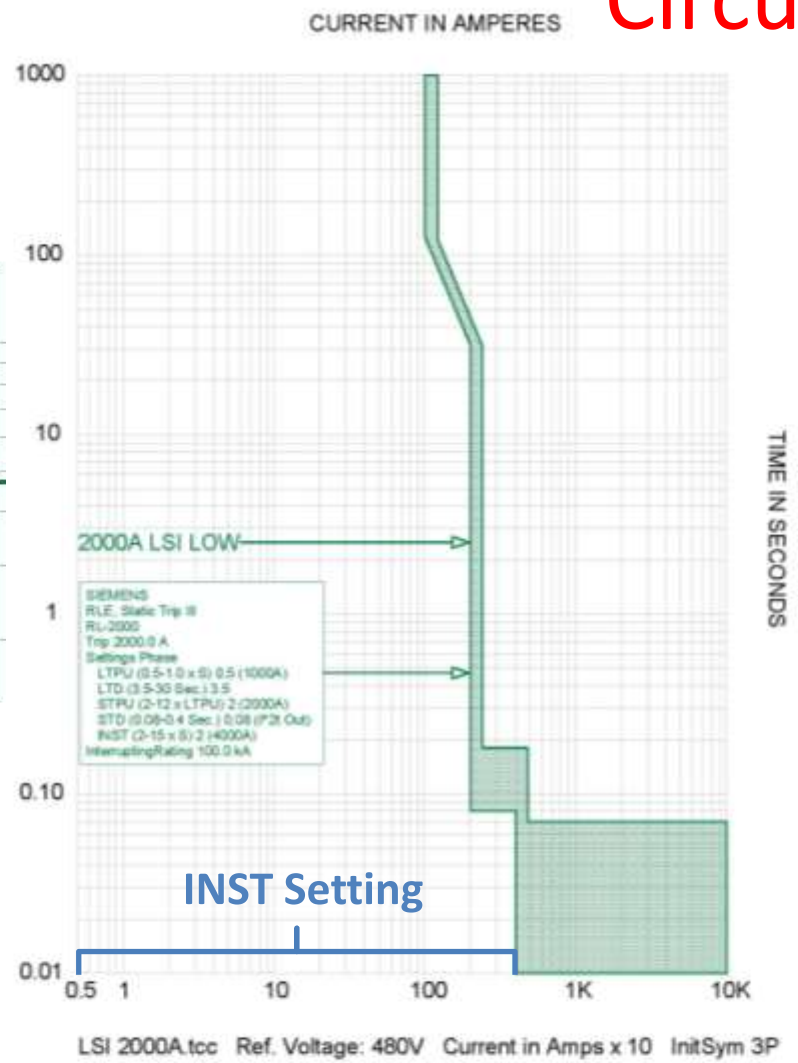
- STD (0.08-0.4 Sec.) 0.08 (I^2t Out)
- INST (2-15 x S) 2 (4000A)

InterruptingRating 100.0 kA

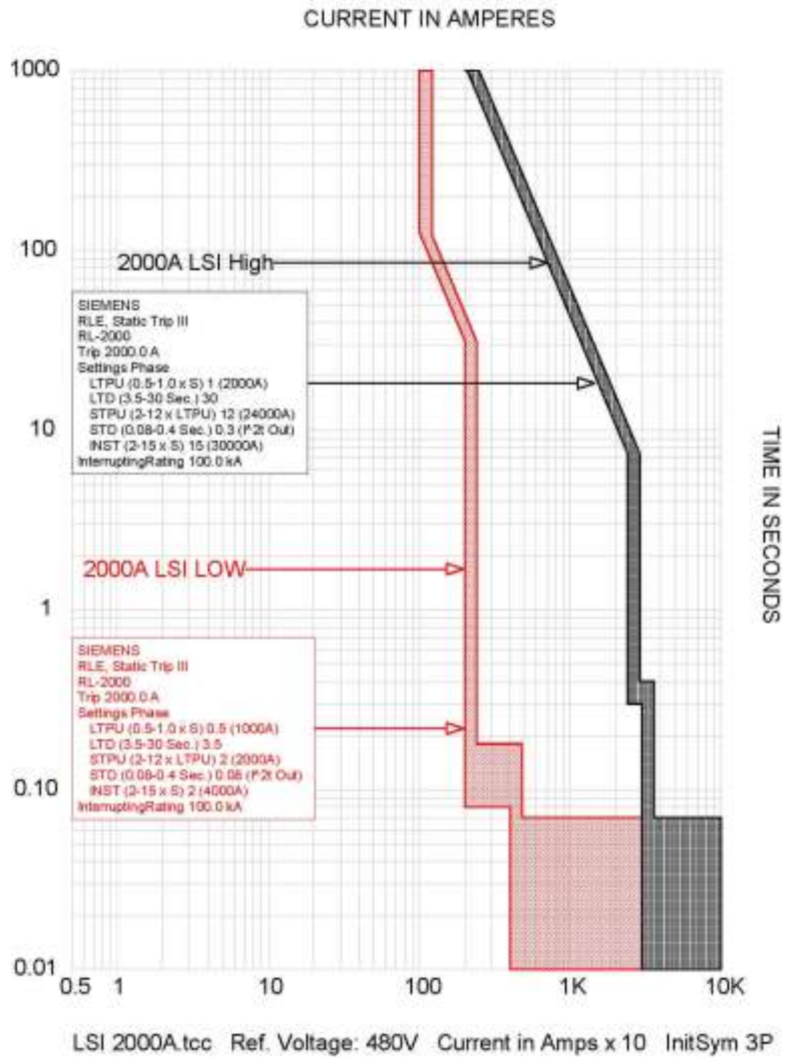


Time-Current Curves
Circuit Breakers

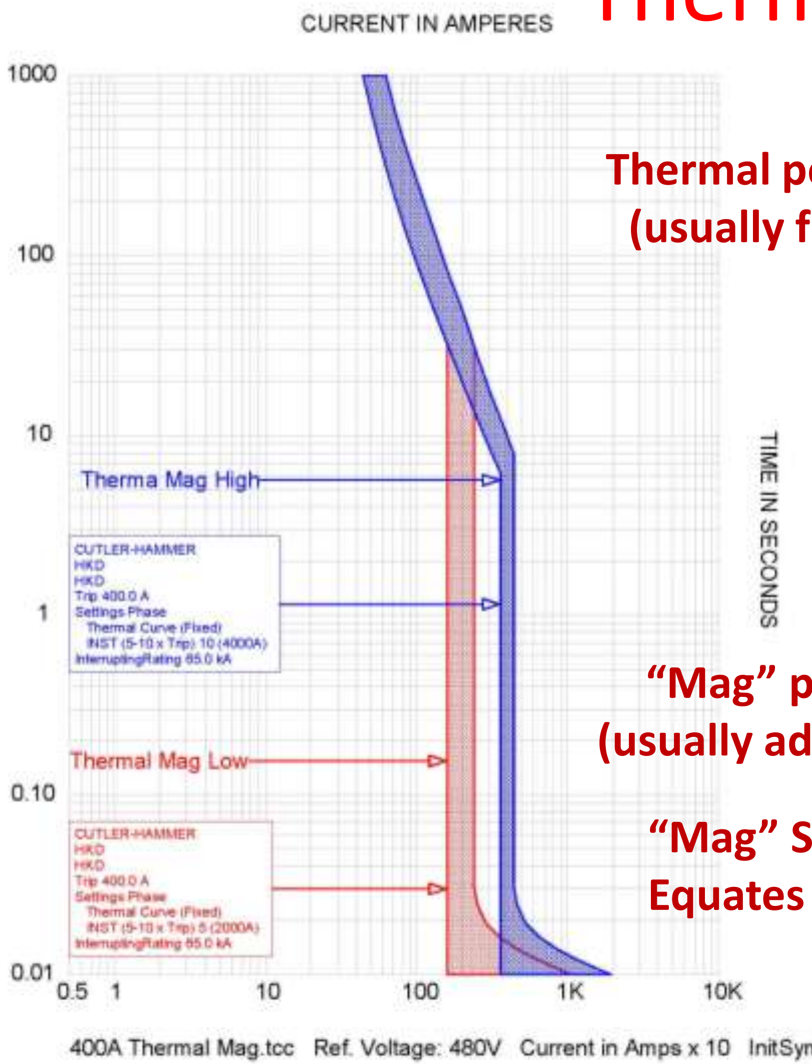
SIEMENS
RLE, Static Trip III
RL-2000
Trip 2000.0 A
Settings Phase
LTPU (0.5-1.0 x S) 0.5 (1000A)
LTD (3.5-30 Sec.) 3.5
STPU (2-12 x LTPU) 2 (2000A)
STD (0.08-0.4 Sec.) 0.08 (I^2t Out)
INST (2-15 x S) 2 (4000A)
InterruptingRating 100.0 kA



Time-Current Curves
Circuit Breakers



Time-Current Curves Thermal-Mag Breakers

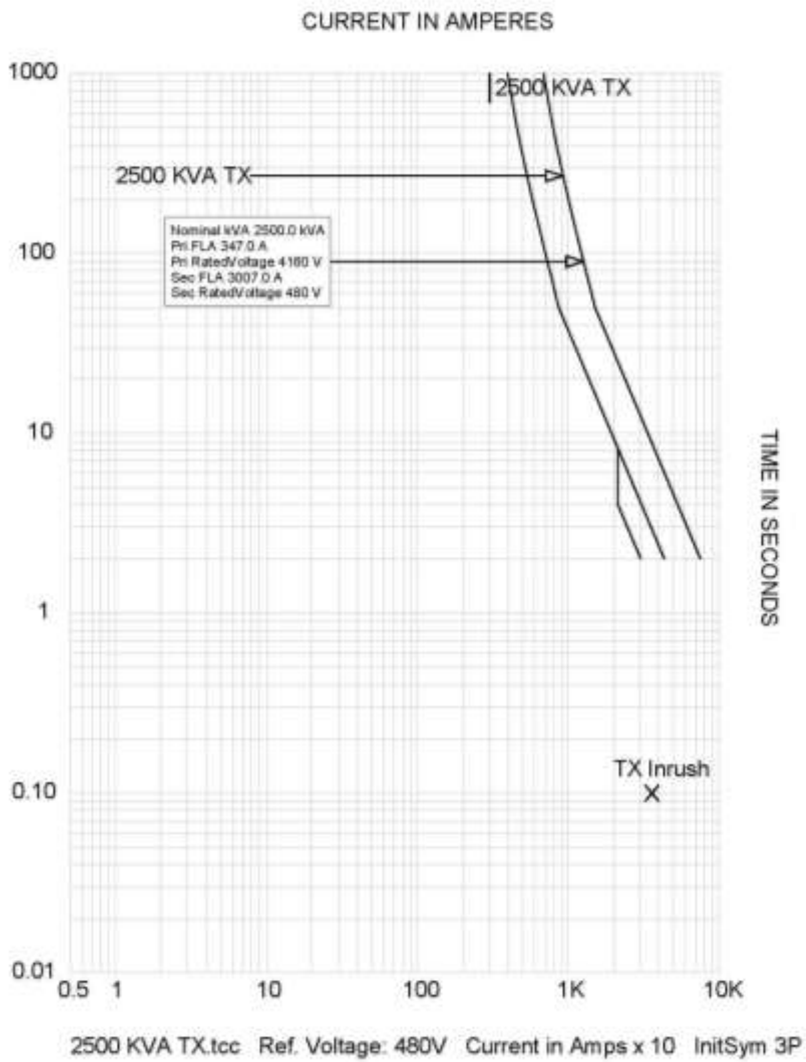


Thermal portion (usually fixed)

“Mag” portion (usually adjustable)

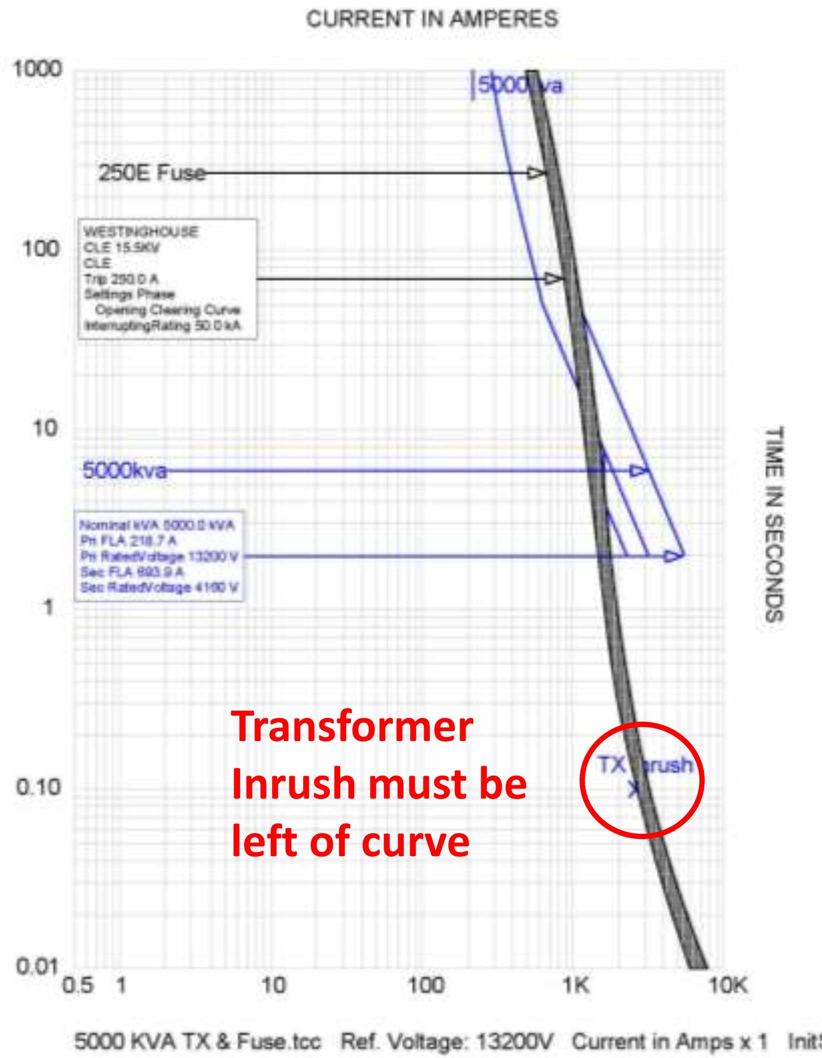
“Mag” Setting – Equates to INST

Time-Current Curves
Transformers



	Transformer	
Protection Point	**< 2500 kVA**	**> 2500 kVA**
ANSI	17.6 x I_{fl} x 58%	16.6 x I_{fl} x 58%
Inrush (for 0.1 sec)	8 x I_{fl}	12 x I_{fl}
NEC Rule (6 x I_{fl})	6 x I_{fl}	6 x I_{fl}

Time-Current Curves Transformers



Time Current Curves
Motor Protection

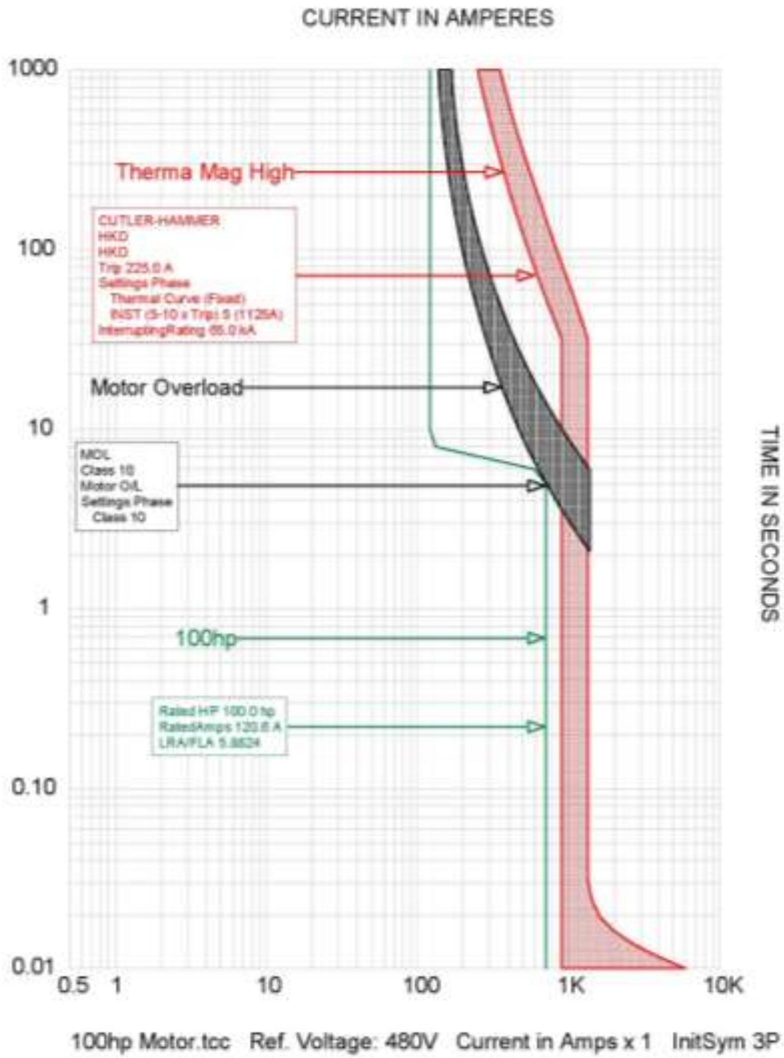
Table 430.52 Maximum Rating or Setting of Motor Branch-Circuit Short-Circuit and Ground-Fault Protective Devices

	Percentage of Full-Load Current			
Type of Motor	Nontime Delay Fuse[1]	Dual Element (Time-Delay) Fuse[1]	Instantaneous Trip Breaker	Inverse Time Breaker[2]
Single-phase motors	300	175	800	250
AC polyphase motors other than wound-rotor	300	175	800	250
Squirrel cage — other than Design B energy-efficient	300	175	800	250
Design B energy-efficient	300	175	1100	250
Synchronous[3]	300	175	800	250
Wound rotor	150	150	800	150
Direct current (constant voltage)	150	150	250	150

Note: For certain exceptions to the values specified, see 430.54.
[1]The values in the Nontime Delay Fuse column apply to Time-Delay Class CC fuses.
[2]The values given in the last column also cover the ratings of nonadjustable inverse time types of circuit breakers that may be modified as in 430.52(C)(1), Exception No. 1 and No. 2.
[3]Synchronous motors of the low-torque, low-speed type (usually 450 rpm or lower), such as are used to drive reciprocating compressors, pumps, and so forth, that start unloaded, do not require a fuse rating or circuit-breaker setting in excess of 200 percent of full-load current.

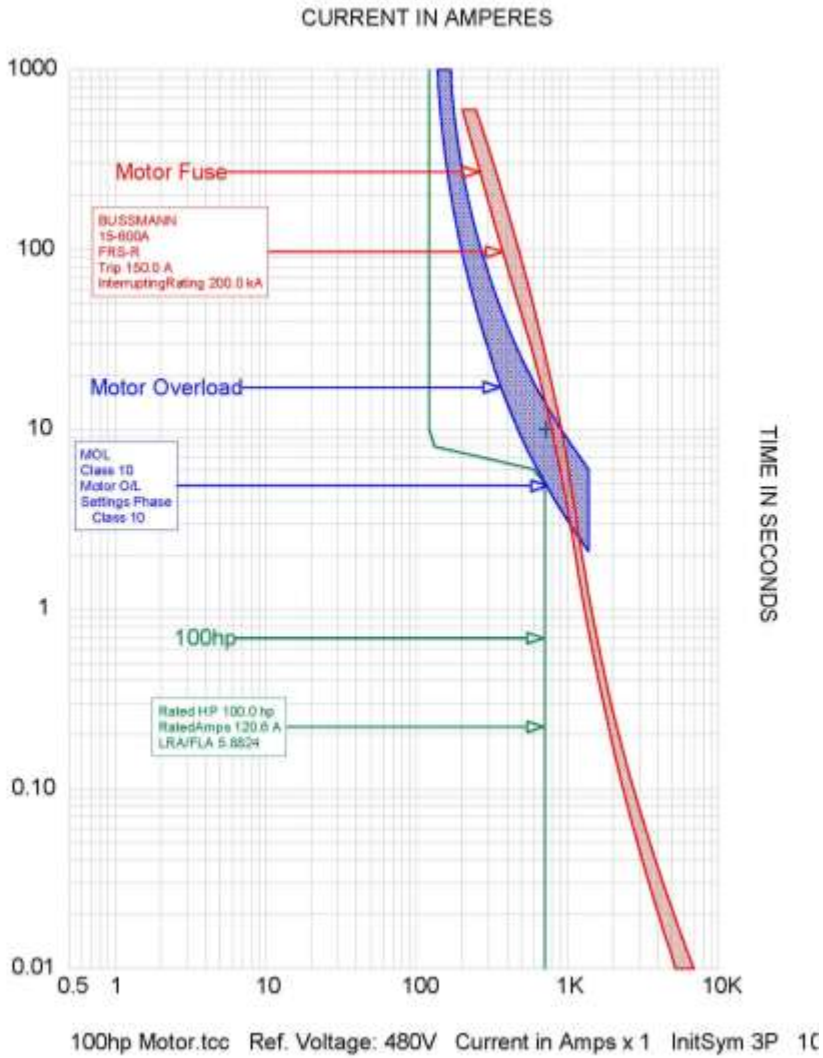
Refer to NEC Article 430.52, "Rating or Setting for Individual Motor Circuit" and manufacturer recommendations for determining appropriate motor protection.

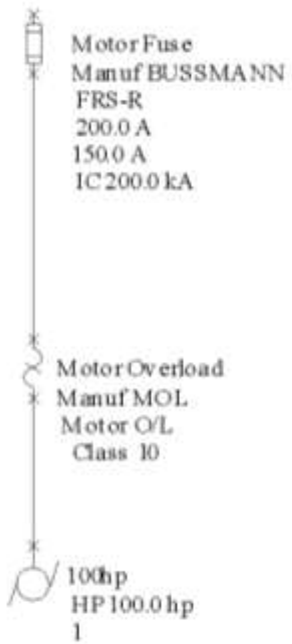
Time Current Curves
Motor Protection



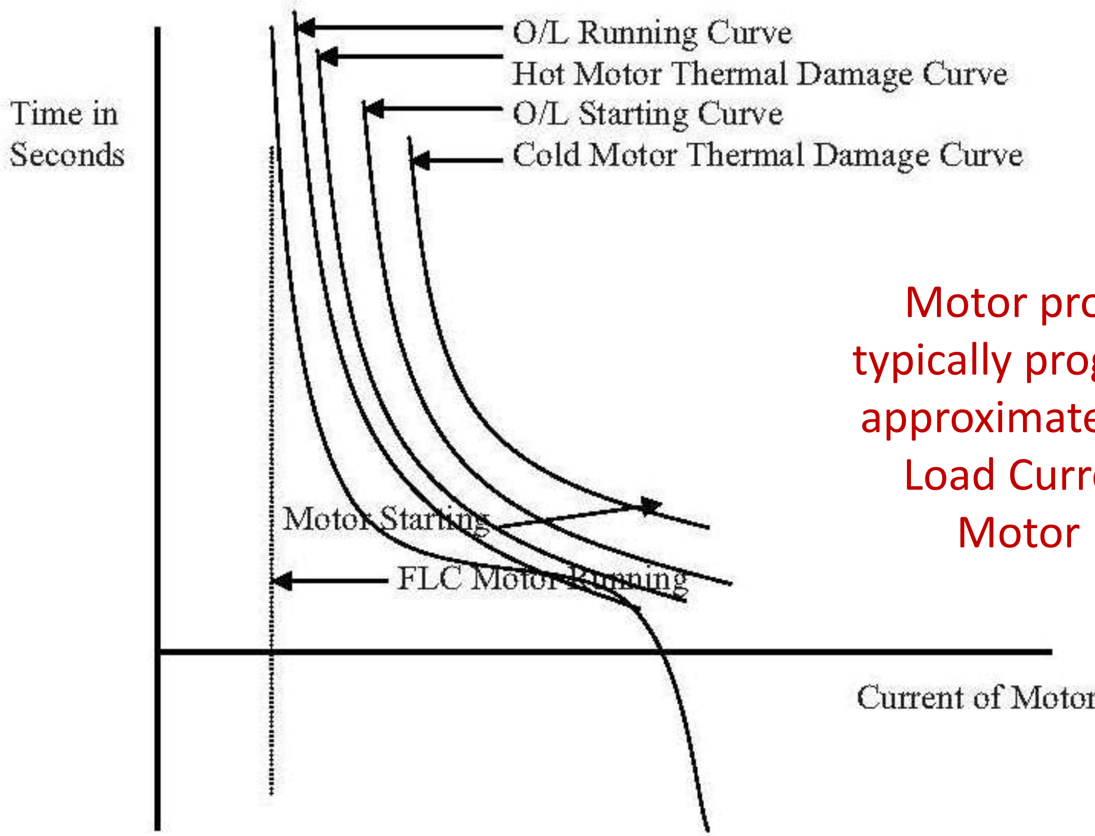
Time Current Curves

Motor Protection





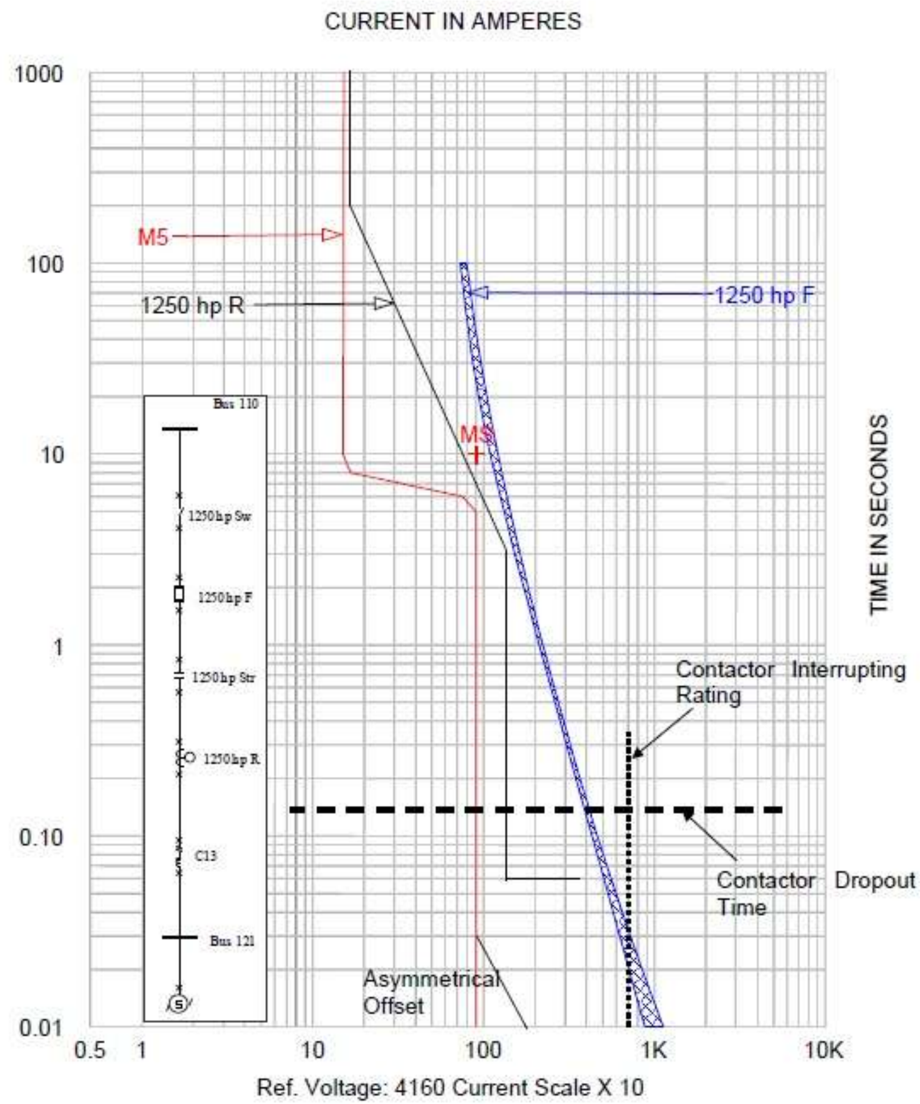
Time Current Curves
Motor Protection



Cold and Hot Thermal Damage Curves

Motor protection relays are typically programmed to operate approximately halfway between Load Current Curve and the Motor Damage Curve.

Time Current Curves
Motor Protection



Questions or Comments?

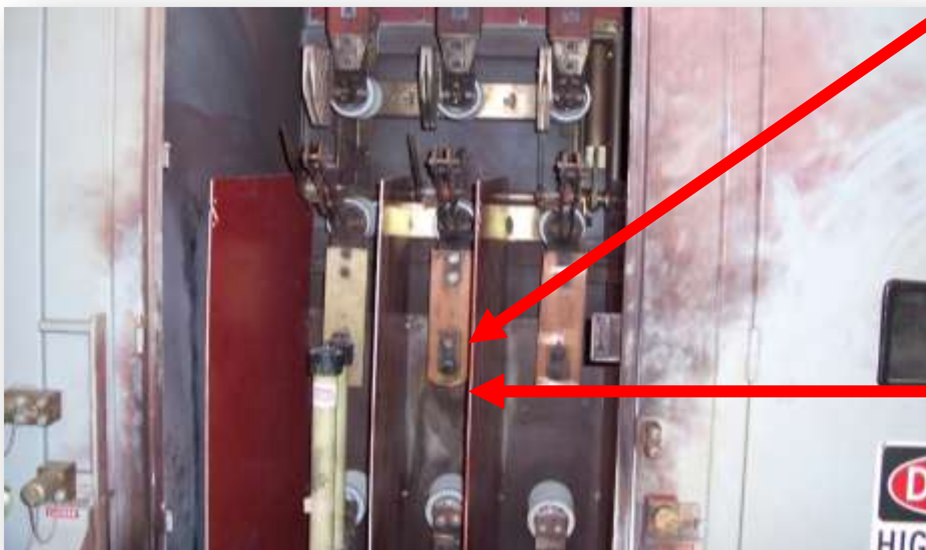
Troubleshooting

Troubleshooting Tools:

- Design Information:
  - One-Line Diagrams
  - Time-Current Curves
  - Manufacturer Literature
  - Operating History
- Maintenance Information:
  - Visual Inspection
  - IR Surveys
  - Oil Sample Reports
  - UE/PD Surveys
  - Testing Data Sheets
  - Protective Relays
  - Power Monitors

Troubleshooting

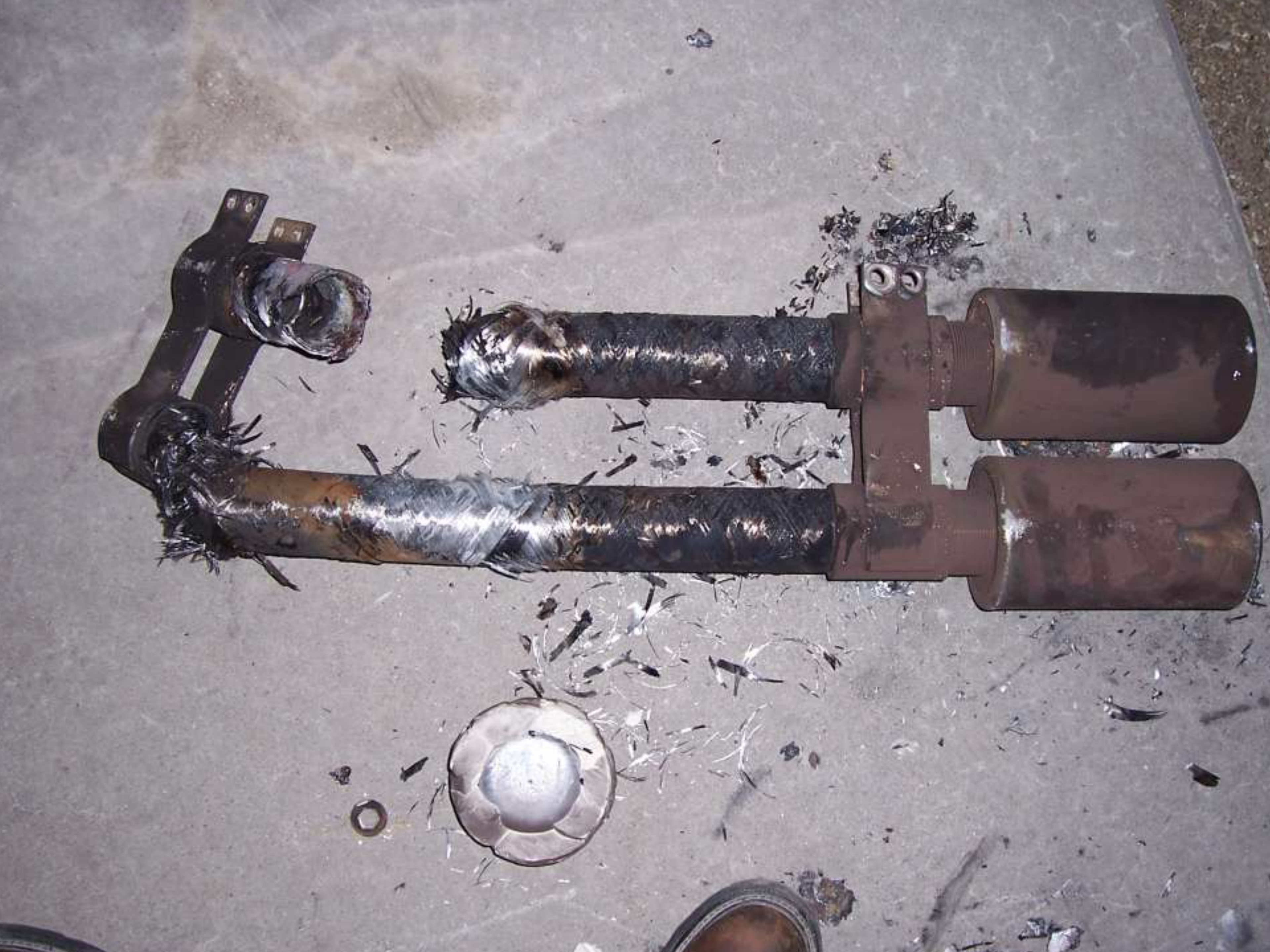
- Scheduled PM Overdue (Needed Cleaning)
- High Humidity compounded problem
- Expulsion Type Fuse failed to operate correctly



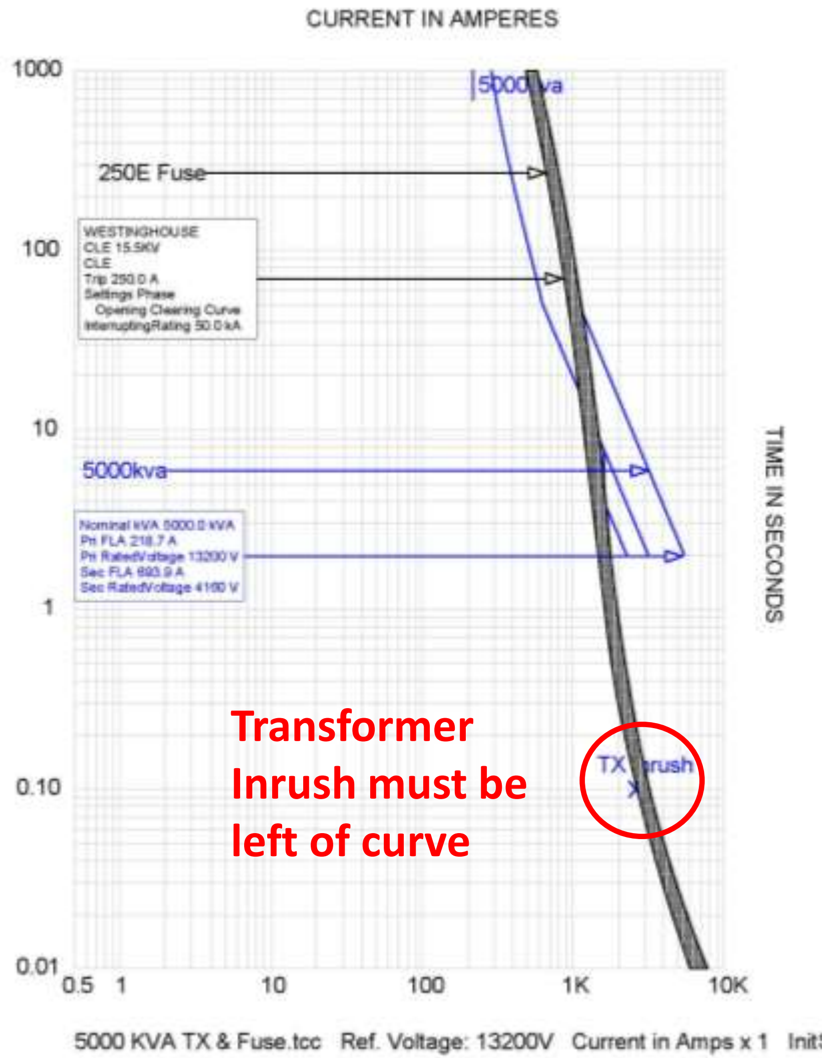

A
B
C
HIG
CLOSED


WARNING


VOLTAGE
OUT



Time-Current Curves
Transformers



Troubleshooting

Control Power Transformer (CPT)

Breaker Trip:

Cause - Rodent

Troubleshooting

High Resistance Fuse Extenuating Circumstances:

- Inadequate spare parts
- Production pressure

Note: First indication provided through IR Survey.

Troubleshooting

HV Bushing Repair Required

- Jumpers undersized
- Heating resulted in gasket failure
- Oil contamination resulted in flashover at bushing.

Note: First indication provided through IR Survey.

Troubleshooting

TABLE 100.18

Thermographic Survey
Suggested Actions Based on Temperature Rise

Temperature difference (ΔT) based on comparisons between similar components under similar loading.	Temperature difference (ΔT) based upon comparisons between component and ambient air temperatures.	Recommended Action
1° C – 3° C	1° C – 10° C	Possible deficiency; warrants investigation
4° C – 15° C	11° C – 20° C	Indicates probable deficiency; repair as time permits
------	21° C – 40° C	Monitor until corrective measures can be accomplished
>15° C	>40° C	Major discrepancy; repair immediately

Temperature specifications vary depending on the exact type of equipment. Even in the same class of equipment (i.e., cables) there are various temperature ratings. Heating is generally related to the square of the current; therefore, the load current will have a major impact on ΔT. In the absence of consensus standards for ΔT, the values in this table will provide reasonable guidelines.

An alternative method of evaluation is the standards-based temperature rating system as discussed in Section 8.9.2, Conducting an IR Thermographic Inspection, *Electrical Power Systems Maintenance and Testing* by Paul Gill, PE, 1998.

It is a necessary and valid requirement that the person performing the electrical inspection be thoroughly trained and experienced concerning the apparatus and systems being evaluated as well as knowledgeable of thermographic methodology.

Troubleshooting

HV Insulated Bus

Insulation Tracking
(Carbon Treeing)

Troubleshooting

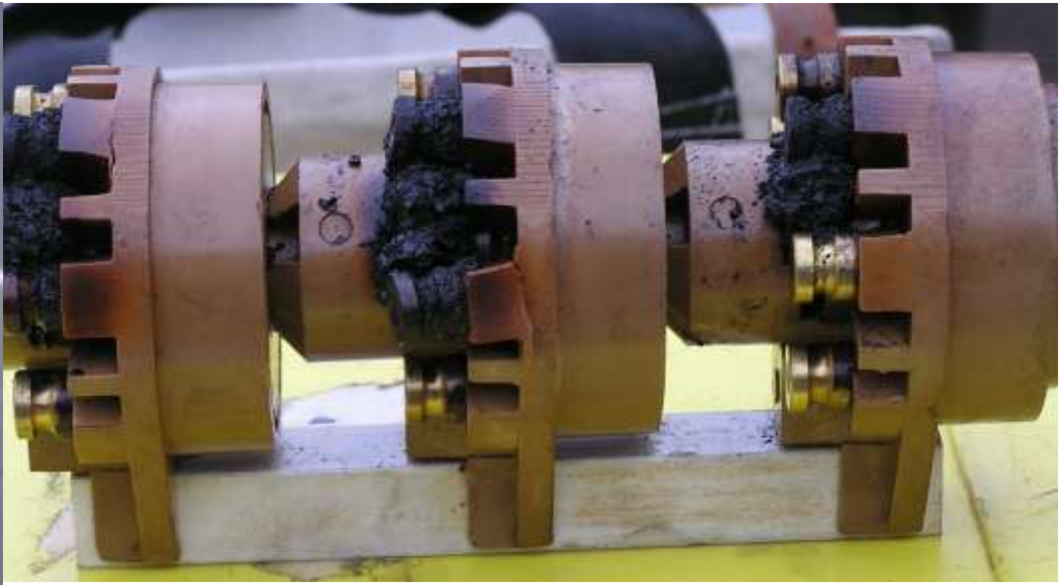
HV Jumper Cable

Insulation Tracking
(Corona Damage Due to Improper Installation)

Troubleshooting

Tap Changer

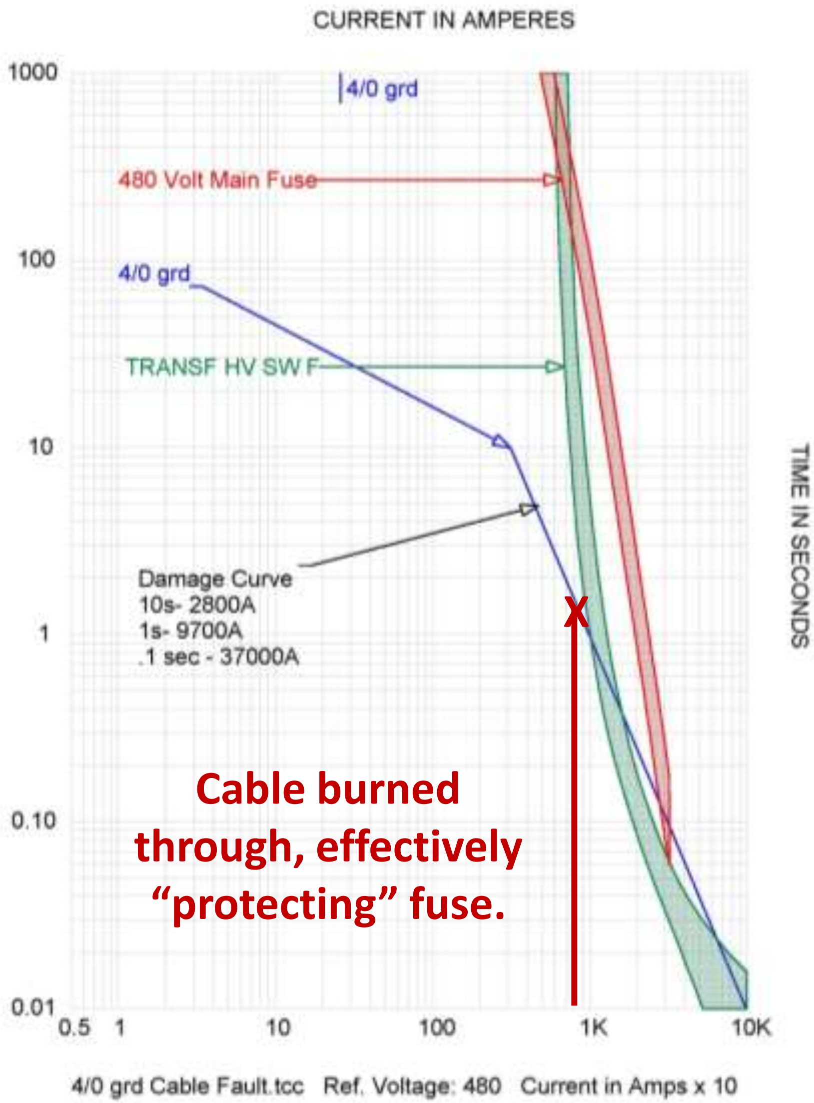
Eminent Connection Failure



Note: First indication provided through Oil Sampling.


LUFKIN®
12FT
®
WHITE CLAD TAPE
W9212

Troubleshooting

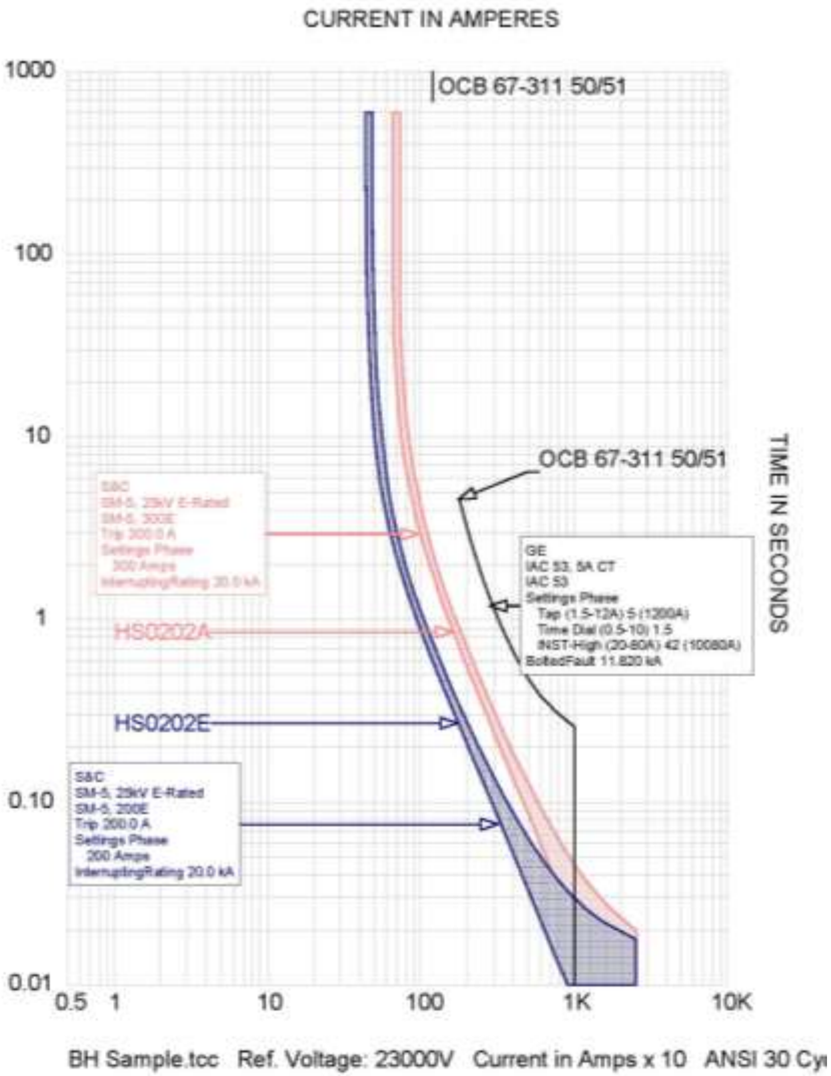


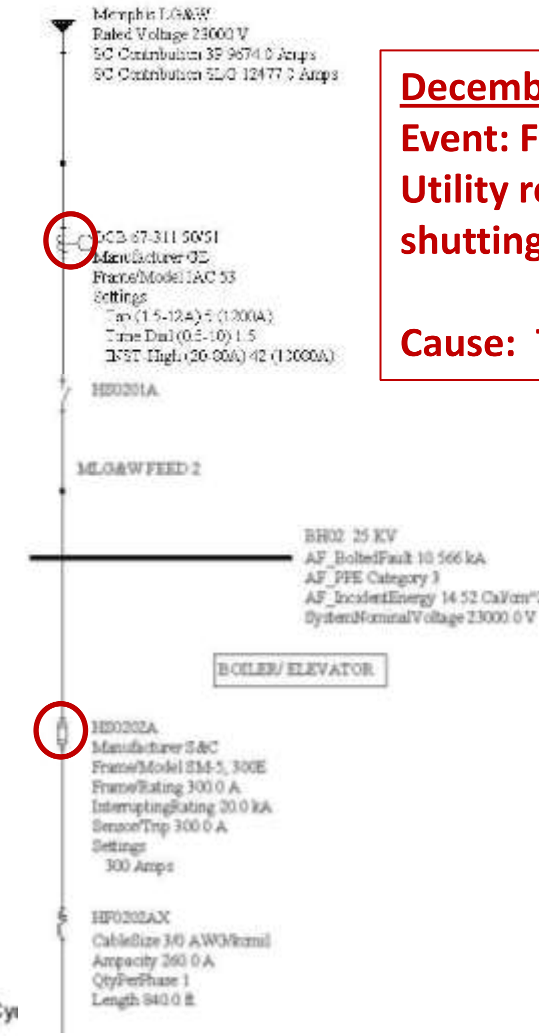
October 2007

Event: Fault (~8,000A) resulted in switchgear lineup burning without fuses clearing.

Cause: Only one of nine 4/0 ground cables was connected.

Troubleshooting

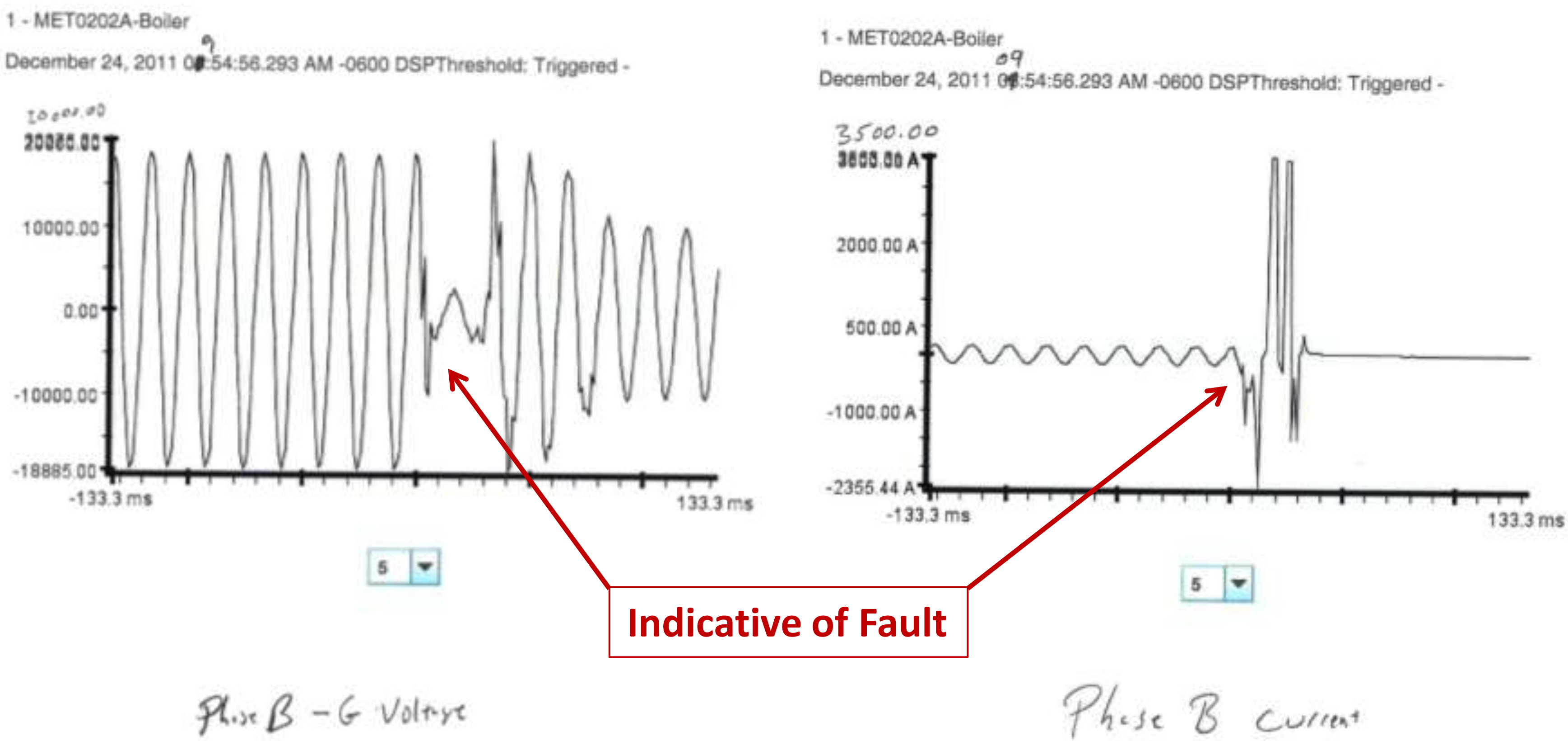




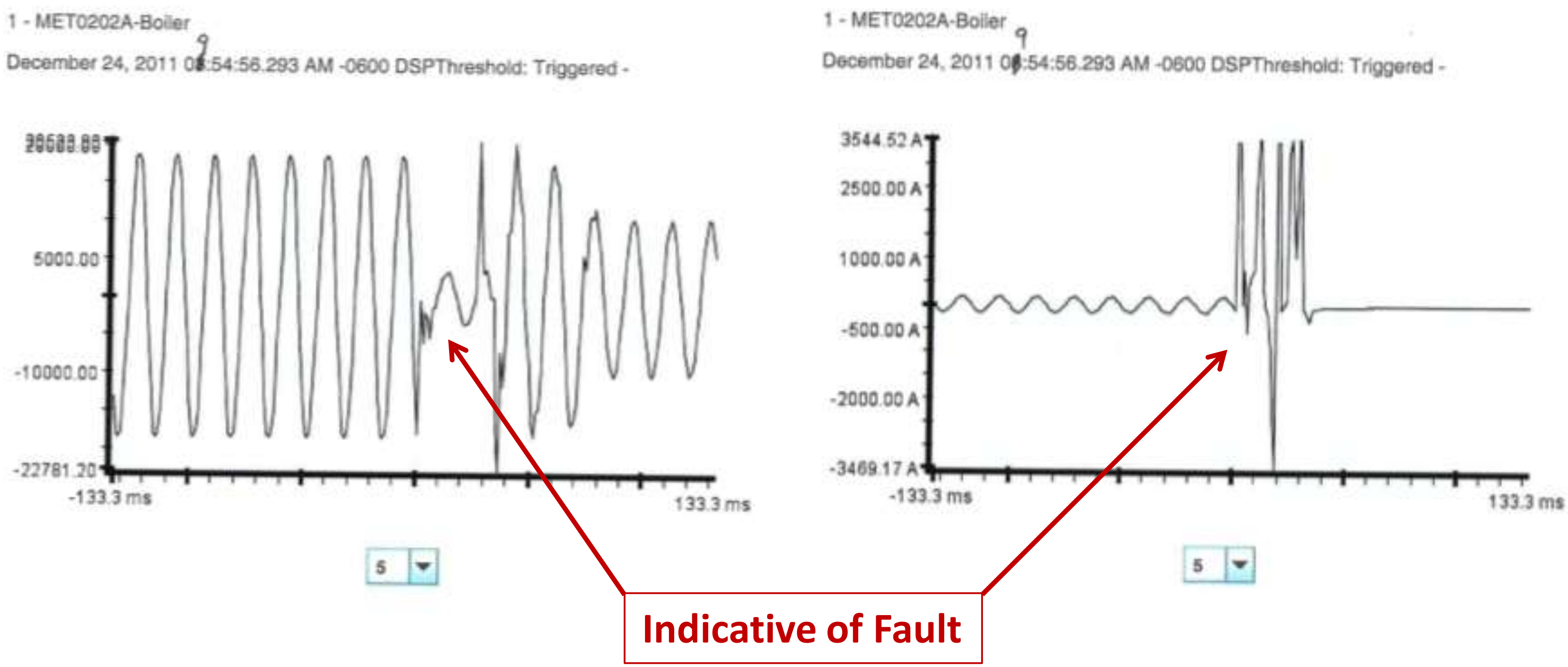
<u>December 2011</u>
Event: Fuse (HS0202A) and Utility relay (50/51) cleared, shutting plant down.

Cause: TBD.

Troubleshooting



Troubleshooting



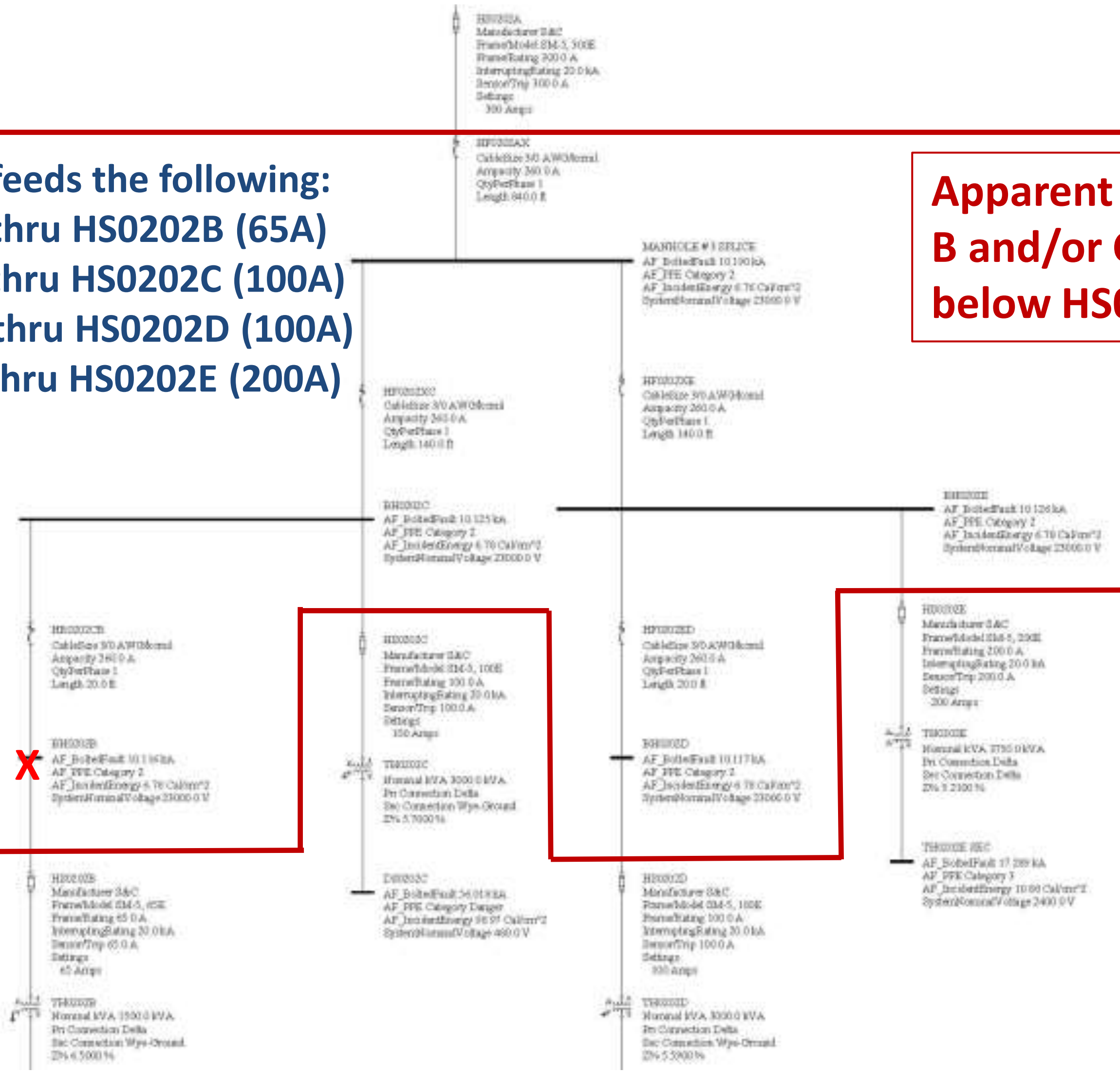
Phase C - G voltage

Phase C current

Troubleshooting

HS0202A feeds the following:
TH0202B thru HS0202B (65A)
TH0202C thru HS0202C (100A)
TH0202D thru HS0202D (100A)
TH0202E thru HS0202E (200A)

Apparent fault on B and/or C phase below HS0202A



OSHA 1910.334
Use of Equipment

(b) Electric power and lighting circuits.

(2) Reclosing circuits after protective device operation. After a circuit is de-energized by a circuit protective device, the circuit protective device, **the circuit may not be manually reenergized until it has been determined that the equipment and circuit can be safely energized**. The repetitive manual reclosing of circuit breakers or reenergizing circuits through replaced fuses is prohibited.

Note: When it can be determined from the design of the circuit and the overcurrent devices involved that the automatic operation of a device was caused by an overload rather than a fault condition, no examination of the circuit or connected equipment is needed before the circuit is reenergized.

Troubleshooting

Questions or Comments?