Meeting the NEC® Selective Coordination Requirements

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- NEC® is a trademark of the National Fire Protection Association, Inc.

Agenda

- Definitions
- NEC Code Requirements
- Fuse Selective Coordination
- Breaker Trip Unit Types
- Breaker Selective Coordination
- Procedure to Achieve Selective Coordination
  - Fuses
  - Breakers
- Arc Flash and Selective Coordination
- Examples

Special Thanks

- Square D Company
- Data Bulletin
- "Enhancing Short Circuit Selective Coordination with Low Voltage Breakers"
- http://ecatalog.squared.com/pubs/Circuit%20Protection/0100DB0403.pdf

Special Thanks

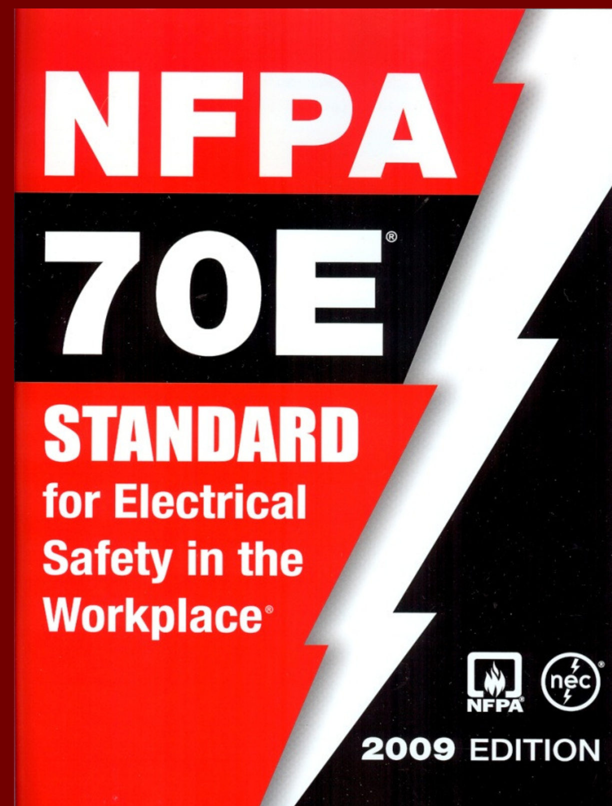
- Cooper Bussmann
- White paper & SPD p21
  - Traces the Codeology for Selective Coordination Requirements
- Papers and Online Voiceover Training Module
- www.CooperBussmann.com

NFPA 70 and NFPA 70E

Primarily Fire Protection

How you built it.

Primarily Personnel Protection



How you work on it.

NEC® 2011

- Chapters 1 through 4:
  - Generally for all electrical installations
  - No selective coordination requirements
- Selective coordination requirements under "special" Chapters
- Chapter 7 Special Conditions
  - Emergency Systems: 700.27
  - Legally Required Standby Systems: 701.27
  - Critical Operations Power Systems: 708.54

Selective Coordination Requirements 2011 NEC®

- Chapter 5 Special Occupancies
- Healthcare Facilities: 517.26 - Essential Electrical Systems
- These special systems supply vital loads essential for life safety, public safety, or national security.
- Reliability more crucial than for systems in Chapter 1-4.

These Special System Requirements

- Separate dedicated Articles in the NEC
  - 700, 701, 708, & 517
- *Minimum* standards
  - Delivering reliable power to life safety loads

These Special System Requirements

- Alternate power sources
- Separate wiring
- Locate wiring to avoid outage due to physical damage
- Testing, maintenance, and record retention
- Automatic transfer switches (ATSs)
- Separate ATSs for load segmenting & shedding

Selective Coordination in the NEC

- 100 Definition: Coordination Selective (2005)
- 517.26 Required for Essential Electrical Systems (2005)
- 620.62 Required for Circuits with multiple Elevators (1993)
- 695.3(C)(3) Power Sources for Fire Pumps in Multi-building Campus Style Complexes (2011)

Selective Coordination in the NEC

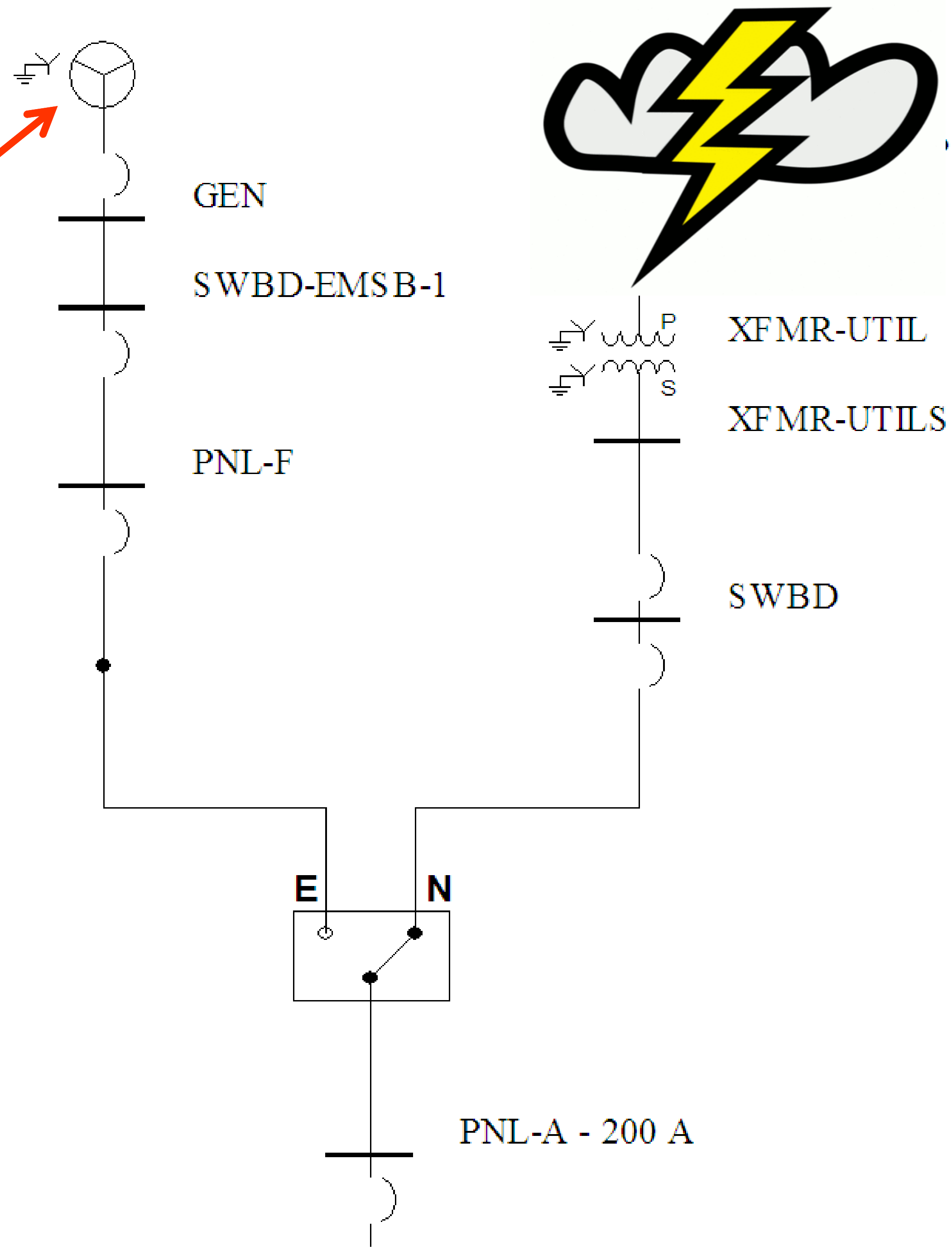
- 700.27 Required for Emergency Systems (2005)
- 701.27 Required for Legally Required Standby Systems (2005)
- 708.54 Required for Critical Operations Power Systems (COPS) (2008)

517.2 Definitions

- Emergency System.
  - A system of circuits and equipment intended to supply alternate power to a limited number of prescribed functions vital to the protection of life and safety.
  - Essential for safety of human life.

- NEC® 700.2 Informational Note:
  - Emergency systems are generally installed in places of assembly where artificial illumination is required for safe exiting and for panic control in buildings subject to occupancy by large numbers of persons....,

– such as hotels, theaters, sports arenas, health care facilities, and similar institutions. Emergency systems may also provide power for such functions as ventilation where essential to maintain life, fire detection and alarm systems, elevators, fire pumps, public safety communications systems, industrial processes where current interruption would produce serious life safety or health hazards, and similar functions.”



Emergency Backup Power

ARTICLE 100 Definitions

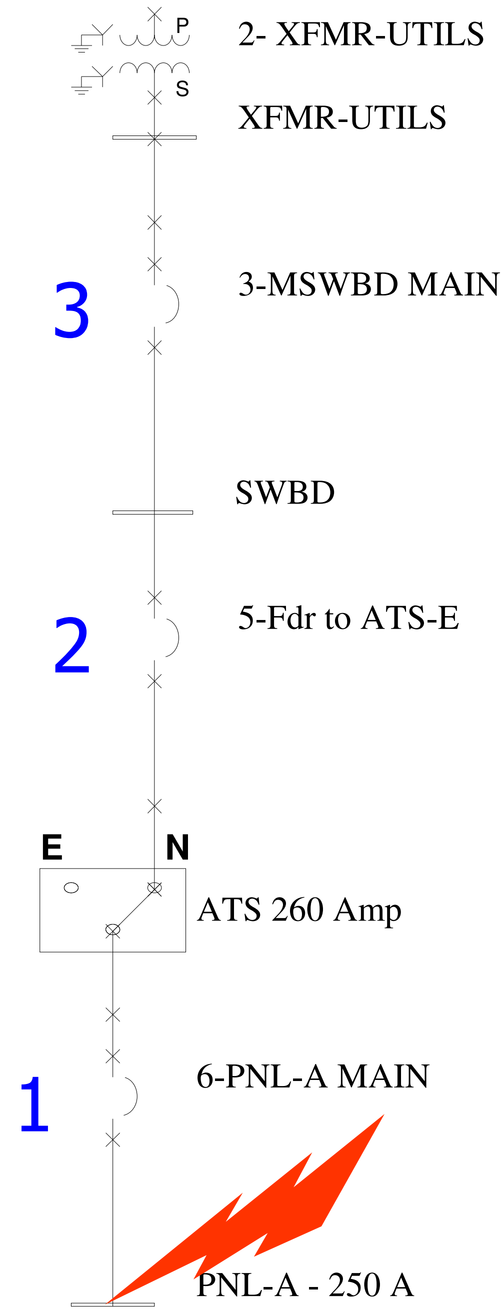
- Coordination (Selective).
  - Localization of an overcurrent condition to restrict outages to the circuit or equipment affected, accomplished by the choice of overcurrent protective devices and their ratings or settings.

240.12 Electrical System Coordination

- Where an orderly shutdown is required to minimize the hazard(s) to personnel and equipment, a system of coordination based on the following two conditions shall be permitted:
  - (1) Coordinated short-circuit protection
  - (2) Overload indication based on monitoring systems or devices

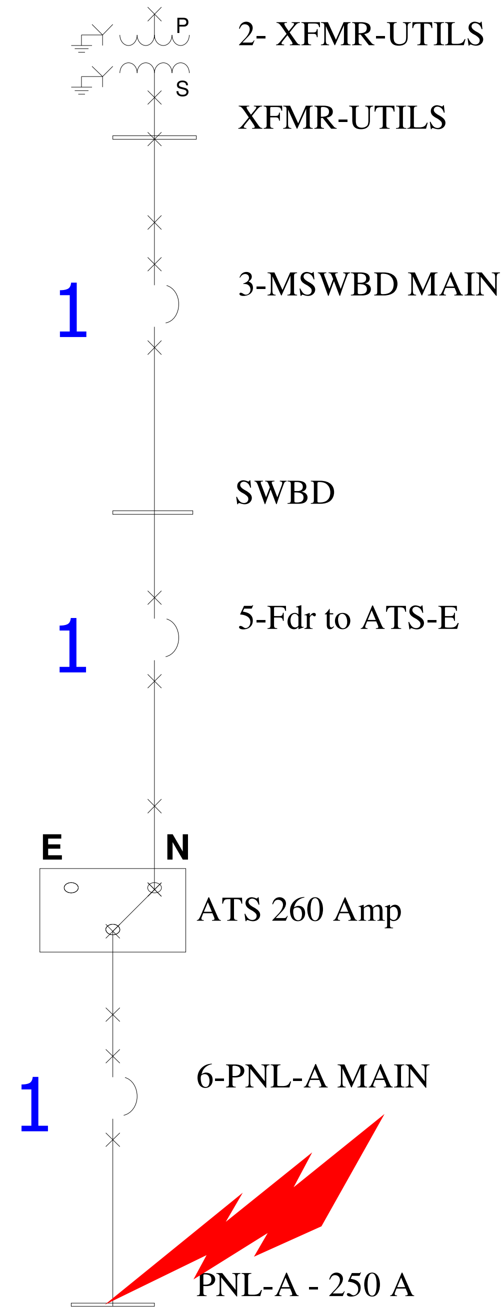
Sample One Line

- Selective Coordination



Sample
One Line

- No Selective Coordination



701.2 Definitions

- Legally Required Standby Systems.
  - Those systems required and so classed as legally required standby by municipal, state, federal, or other codes or by any governmental agency having jurisdiction.
  - These systems are intended to automatically supply power to selected loads (other than those classed as emergency systems) in the event of failure of the normal source.

701.2 Definitions

- Informational Note:
  - Legally required standby systems are typically installed to serve loads, such as heating and refrigeration systems, communications systems, ventilation and smoke removal systems, sewage disposal, lighting systems, and industrial processes, that, when stopped during any interruption of the normal electrical supply, could create hazards or hamper rescue or fire-fighting operations.

517.2 Health Care Facilities Definitions

- Essential Electrical System.
  - A system comprised of alternate sources of power and all connected distribution systems and ancillary equipment, designed to ensure continuity of electrical power to designated areas and functions of a health care facility during disruption of normal power sources, and also designed to minimize disruption within the internal wiring system.

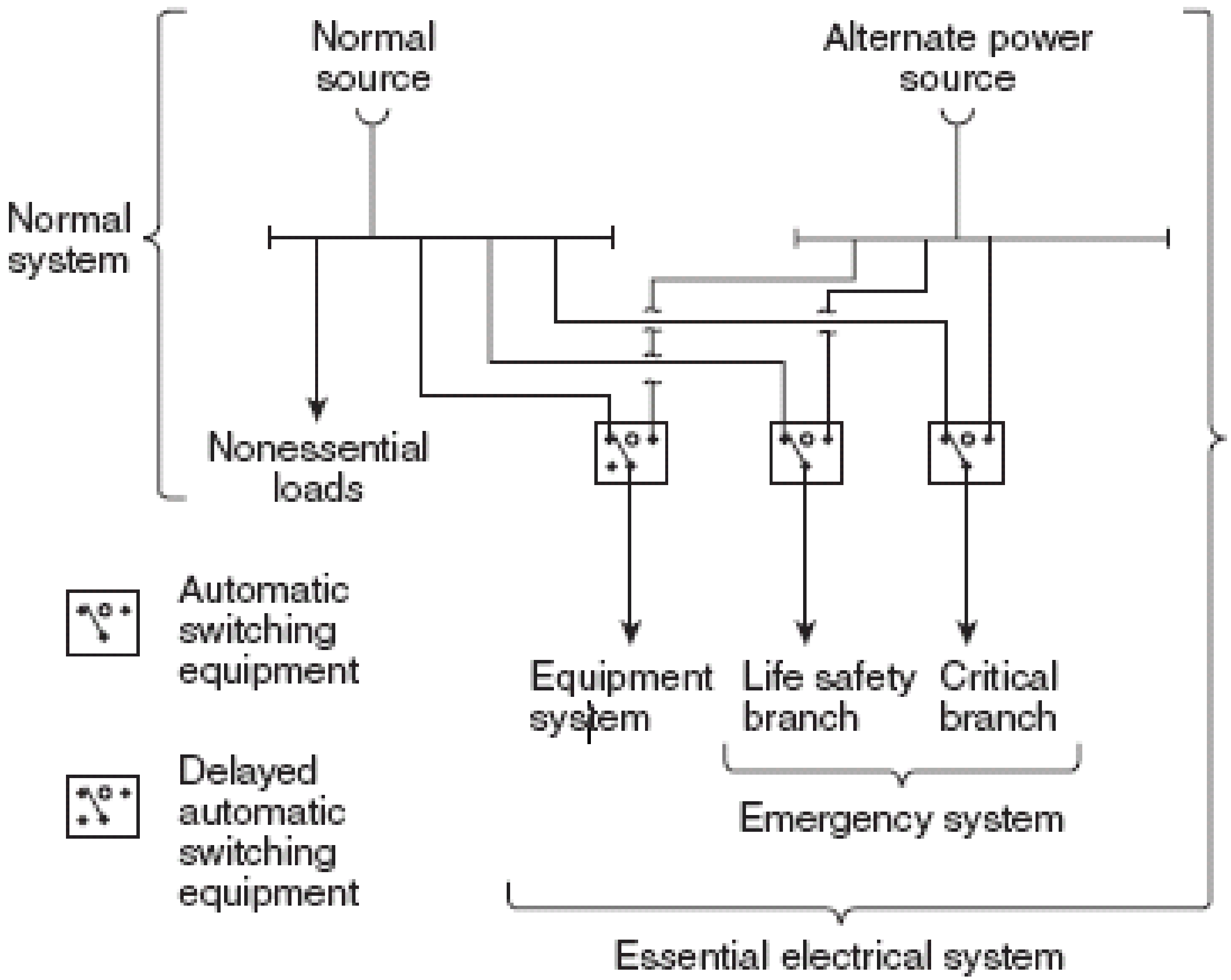
517.2 Health Care Facilities Definitions

- Alternate Power Source.
  - One or more generator sets, or battery systems where permitted, intended to provide power during the interruption of the normal electrical services or the public utility electrical service intended to provide power during interruption of service normally provided by the generating facilities on the premises.

517.2 Health Care Facilities Definitions

- Critical Branch.
  - A subsystem of the emergency system consisting of feeders and branch circuits supplying energy to task illumination, special power circuits, and selected receptacles serving areas and functions related to patient care and that are connected to alternate power sources by one or more transfer switches during interruption of normal power source.

517.30 (A) Essential Electrical System



708.1 Definition

- Critical Operations Power Systems (COPS)
  - (COPS) are those systems so classed by municipal, state, federal, or other codes by any governmental agency having jurisdiction or by facility engineering documentation establishing the necessity for such a system. These systems include but are not limited to power systems, HVAC, fire alarm, security, communications, and signaling for designated critical operations areas.

708.1 Definition

- Critical Operations Power Systems
  - Informational Note No. 1: Critical operations power systems are generally installed in vital infrastructure facilities that, if destroyed or incapacitated, would disrupt national security, the economy, public health or safety; and where enhanced electrical infrastructure for continuity of operation has been deemed necessary by governmental authority."

History & FPN to Mandatory

- 620.62 for elevators since 1993 NEC®
- Fine Print Notes (FPN): non-mandatory
  - Design consideration
  - Unenforceable point of interest
- 2005 NEC® cycle, CMP 13 moved selective coordination from FPN to Requirement
  - Society is changing
  - Building systems evolving
  - Dependency on availability of power for life safety loads

History: FPN to Mandatory

- NEC® Panel 13 Statement:
  - *"The panel agrees that selective coordination of emergency system overcurrent devices with the supply side overcurrent devices will provide for a more reliable emergency system."*

History: FPN to Mandatory

- 700.27 & 701.27: 2005, 2008, & 2011 NEC®
- 708.54 placed in 2008 NEC® by specially created Code Panel with expertise for COPS.
- The requirements in four Articles:
- Minimum standards for circuits supplying a few vital life safety loads

The substantiation for the original (2005) NEC® proposal for Section 700.27

"This article specifically mandates that the emergency circuits be separated from the normal circuits as shown in [Section] 700.9(B)

and that the wiring be specifically located to minimize system hazards as shown in [Section] 700.9(C), all of which reduce the probability of faults, or failures to the system so it will be operational when called upon.

The substantiation for the original (2005) NEC® proposal for Section 700.27

With the interaction of this Article for emergency lighting for egress, it is imperative that the lighting system remain operational in an emergency.

Failure of one component must not result in a condition where a means of egress will be in total darkness as shown in [Section] 700.16….

Selectively coordinated overcurrent protective devices will provide a system that will support all these requirements and principles.

The substantiation for the original (2005) NEC® proposal for Section 700.27

With properly selected overcurrent protective devices, a fault in the emergency system will be localized to the overcurrent protective device nearest the fault, allowing the remainder of the system to be functional…

Due to the critical nature of the emergency system uptime, selective coordination <u>must be mandated</u> for emergency systems.

Problems with this Code Requirement – Circuit Breakers

- Most breakers have an instantaneous trip function.
  - Fixed
  - Adjustable
  - For Faults - Breaker trips instantaneously (no time delay)

Problems with this Code Requirement – Circuit Breakers

- Breakers without an instantaneous trip function are expensive.
- Limited Selective Coordination Testing for Thermal/Magnetic Breakers
- Breakers without instantaneous trips require more costly equipment (i.e. ATSs & Switchgear construction.)
- Limited equipment w/o Instantaneous
- Higher fault current = Increases complexity to selectively coordinate

Problems with this Code Requirement – Circuit Breakers

- Requires larger frame breakers with Solid State Trip units
- Larger Framed Breakers Means Larger Electrical Room - Less rental or usable building space
- Not all trip units function the same way
- Difficult to obtain competitive bids
- Difficult to intermix fuses and circuit breakers

Problems with this Code Requirement - Fuses

- Requires larger equipment than using T/M CBs
- Larger Electrical Room – Less rental or usable building space
- Reduces Levels of downstream equipment
- Fusible Panelboards and Elevator Modules are more expensive than T/M circuit breakers

Reality

Very Expensive to Design and Comply

This new Section of the code will radically change the way we all design emergency and standby power systems.

Real Problem or a Perceived (Paper) Problem?

- On paper, breakers with instantaneous trip units will not coordinate.
- In the real world…is this a problem?
- How many times has this happened at your customers or your facilities?
  - Incorrect trip unit settings do not count
  - Poor maintenance or defective trip units do not count
- FACT: Majority of faults are lower level line to ground faults.

Real Problem or a Perceived (Paper) Problem?

- It is hard to argue cost versus safety!

Real Problem or a Perceived (Paper) Problem?

- For three NEC® cycles, opposition worked to delete or dilute these requirements
  - It has radically changed the way emergency and standby electrical systems are designed.
  - Sometimes, it is extremely difficult to do!
  - For circuit breakers, the higher the available short circuit current (from the utility source) the harder to achieve selective device coordination.
- It can be very expensive to implement!

Why is Selective Device Coordination an Issue? - Ground-Fault Protection

- Code Requires Ground Fault Selective Coordination for Main and Feeders (medical facilities) only.
- Code does not state that Ground Fault Protection Must Coordinate with the Phase Protection.
- Considered a different protection scheme
- Maximum Pickup setting is 1,200 Amperes
- Maximum Time Delay setting is 0.5 sec.

Ground-Fault Protection

- Limited Equipment GF options for fuses
- Many times impossible to prevent overlap with ground fault and phase devices.
- False Sense of Security????
  - – Ignoring selective device coordination between phase and ground fault devices does not increase reliability.
  - – Majority of electrical faults are line to ground faults.

More Problems with the Code

- Modifications or additions to a facility.
  - How far do you go to implement selective coordination?
  - Include the existing and the new equipment?
  - See WAC Rules 296-46B-700 & 701

WAC 296-46B-700 Emergency systems

- 027 Coordination
  - (4) The requirements for selective coordination described in NEC 700.27 are not required where the emergency system was installed prior to June 1, 2006.
  - For new emergency systems that are supplied from an existing emergency system installed prior to June 1, 2006, the new portion of the emergency system must comply with NEC 700.27.

WAC 296-46B-700 Emergency systems

- 027 Coordination
  - The ground fault sensing function of overcurrent protective devices will only be required to selectively coordinate with the ground fault sensing functions of other overcurrent protective devices.

WAC 296-46B-701 Legally required standby systems

- 018 Coordination
  - Uses the same wording as previous.

More Problems with the Code

- Inconsistent requirements and enforcement through out the US.
  - For our customers....AZ, WA, and OR only (so far)
  - City of Seattle and some other AHJs allow overlap in the breaker instantaneous region.
  - Most AHJs only require selective coordination for emergency supply NOT normal (Utility) Supply

Seattle Electrical Code (SEC)

- Selective coordination as required by Articles 620.62, 700.27, 701.18, and 708.54 has been amended by the SEC.
- Fault current calculations provided by a licensed electrical engineer may be selectively coordinated for faults with a duration of 0.1 seconds or longer.

Seattle Electrical Code (SEC)

- The calculations will be required to be wet stamped by a licensed Washington State electrical engineer.
- All other calculations will be required to be calculated to infinity and will not be permitted to utilize adjustable trip breakers to achieve selective coordination.

More Problems with the Code

- Utility Transformer Sizing
  - NEC forces designers to over design a building.
  - Actual load 1st year is less than 50% of the design demand.
  - Utilities size transformers 30 – 50% of the designers demand load.
  - Utility fuse overlaps with downstream mains and feeder breakers.

Resources and Additional Info

- http://www.geindustrial.com/solutions/engineers/selective_coordination.html
- http://www.eaton.com/Electrical/Consultants/SelectiveCoordination/index.htm
- http://www.schneider-electric.us/sites/us/en/customers/consulting-engineer/selective-coordination.page

Resources and Additional Info

- http://www.sea.siemens.com/us/Support/Consulting-Engineers/Pages/SelectiveCoordination.aspx
- http://www1.cooperbussmann.com/2/SelectiveCoordination.html
- http://us.ferrazshawmut.com/resources/articles-white-papers.cfm
- http://us.ferrazshawmut.com/resources/online-training.cfm

Summary

- You must change the way you design circuits for:
  - Emergency
  - Standby
  - Elevators
  - Fire Pumps
- Manufacturers must provide:
  - New Equipment to meet the code
  - Tools (tables, spreadsheets, charts)
  - I^2T Withstand curves for Equipment

Need more Information

- www.powerstudies.com
  - Articles
  - Links
  - Specifications for Power System Studies
    - Short Circuit
    - Protective Device Coordination
    - Arc Flash Hazard
- Low and High Voltage Electrical Safety Training

Questions??

Thank you for your time!

Meeting the NEC Selective Coordination Requirements (Afternoon Session)

Robert E. Fuhr, P.E.

June 23rd, 2011

PowerStudies, Inc.
Maple Valley, WA.

ARTICLE 620 Elevators, Dumbwaiters, Escalators, Moving Walks, Wheelchair Lifts, and Stairway Chair Lifts

- 620.62 Selective Coordination.
  - Where more than one driving machine disconnecting means is supplied by a single feeder, the overcurrent protective devices in each disconnecting means shall be selectively coordinated with any other supply side overcurrent protective devices.

Emergency Systems

- 700.27 Coordination.
  - Emergency system(s) overcurrent devices shall be selectively coordinated with all supply side overcurrent protective devices.
  - "The provisions of this article apply to the electrical safety of the installation, operation, and maintenance"
  - "Essential for safety of human life"

ARTICLE 701 Legally Required Standby Systems

- 701.18 Coordination.
  - Legally required standby system(s) overcurrent devices shall be selectively coordinated with <u>all</u> supply side overcurrent protective devices.

ARTICLE 708.54 Critical Operations Power Systems

- 708.54 Coordination.
  - Critical operations power system(s) overcurrent devices shall be selectively coordinated with all supply side overcurrent protective devices.

ARTICLE 517 Health Care Facilities

- Essential Electrical Systems must meet Section 700 (except as amended by 517)
- Implies that Essential Electrical Systems must be selectively coordinated. (700.27 & 701.18)

ARTICLE 517.17(C) Selectivity

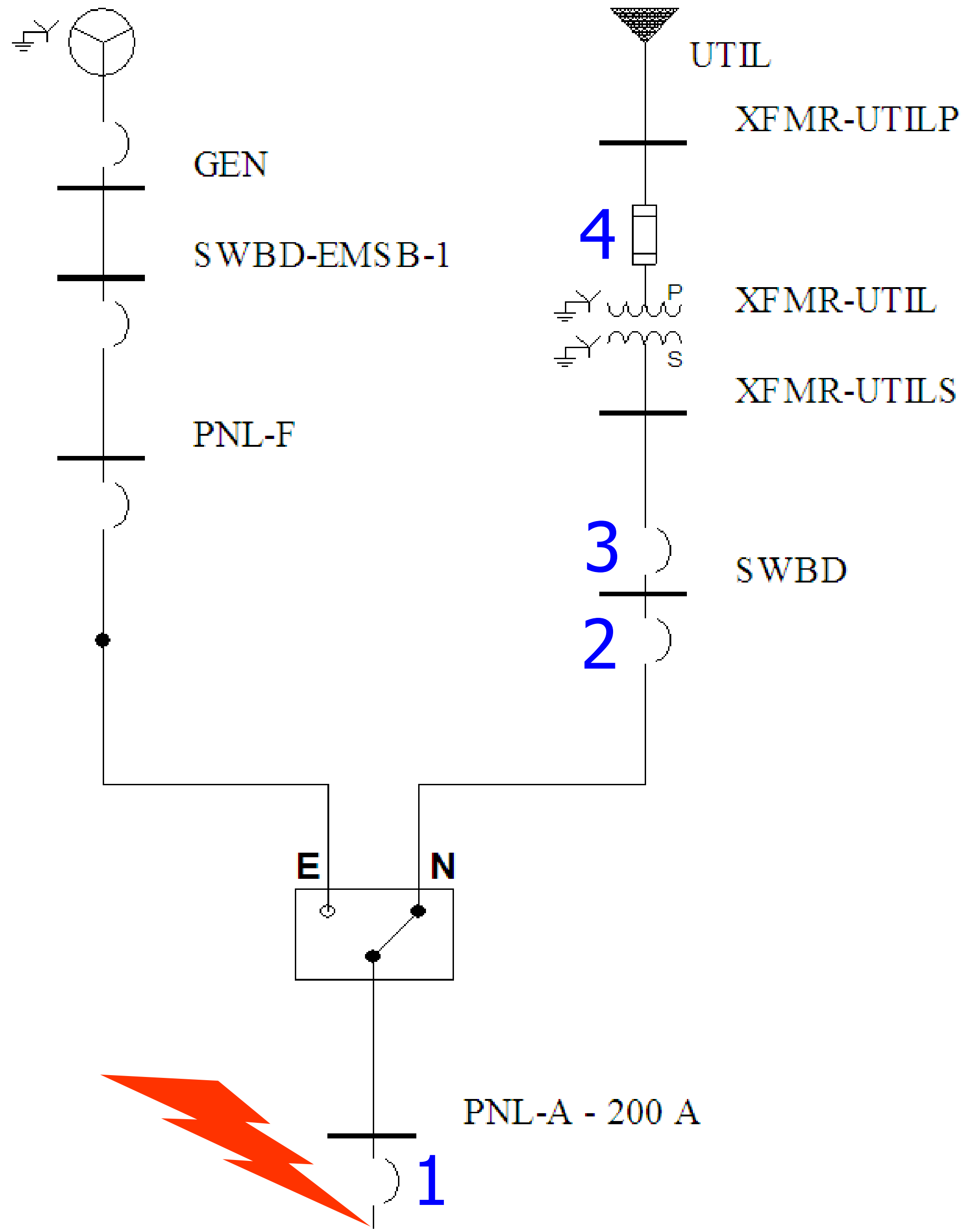
– Ground-fault protection for operation of the service and feeder disconnecting means shall be fully selective such that the feeder device, but not the service device, shall open on ground faults on the load side of the feeder device. Separation of ground-fault protection time-current characteristics shall conform to manufacturer's recommendations and shall consider all required tolerances and disconnect operating time to achieve 100 percent selectivity.

ARTICLE 695 Fire Pumps

- Multi-building Campus-Style Complexes.
- 695.3(C)(3) Selective Coordination.
  - – The overcurrent protective device(s) in each disconnecting means shall be selectively coordinated with any other supply-side overcurrent protective device(s).

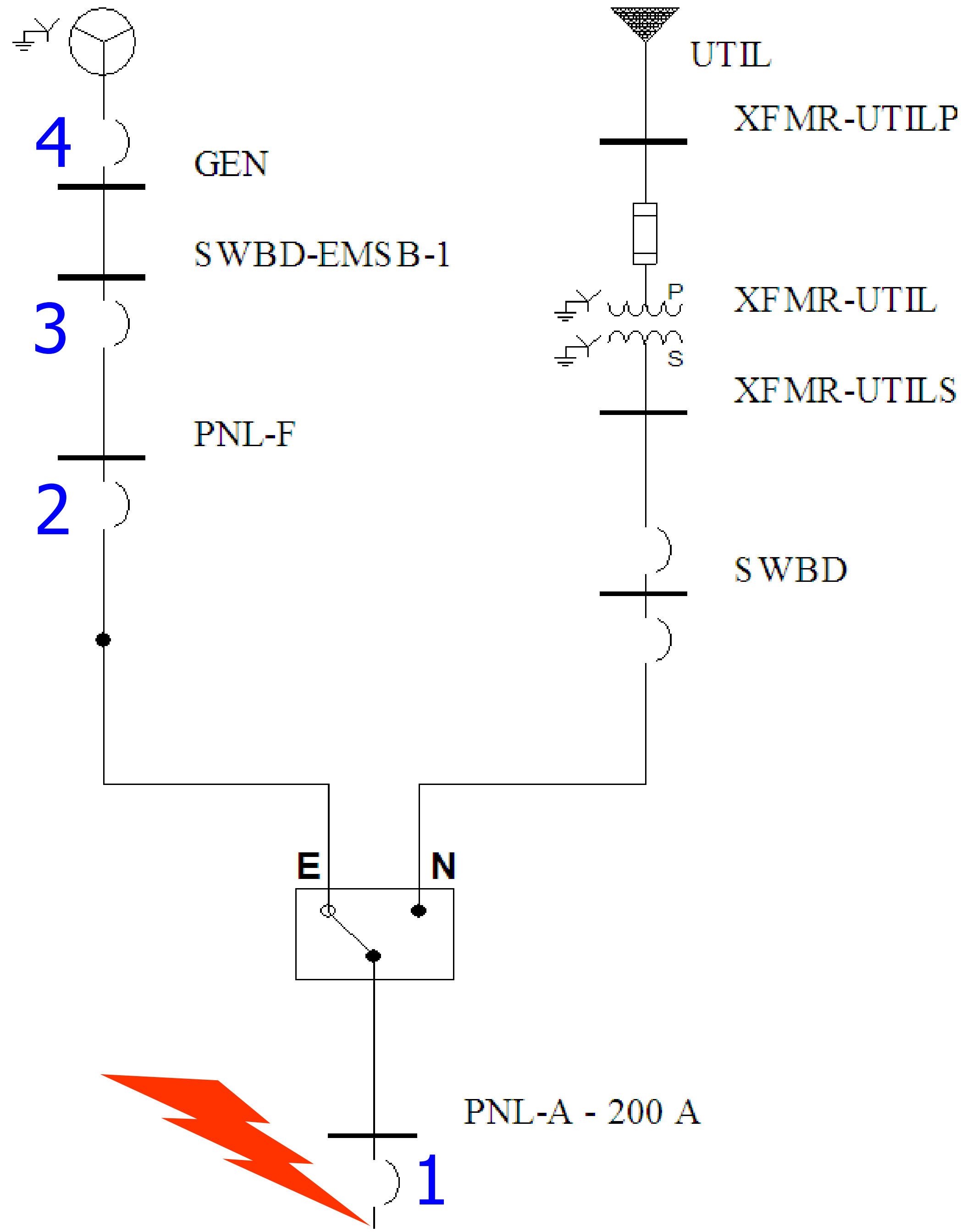
Sample One Line

- Normal Power
- Must be Selectively Coordinated



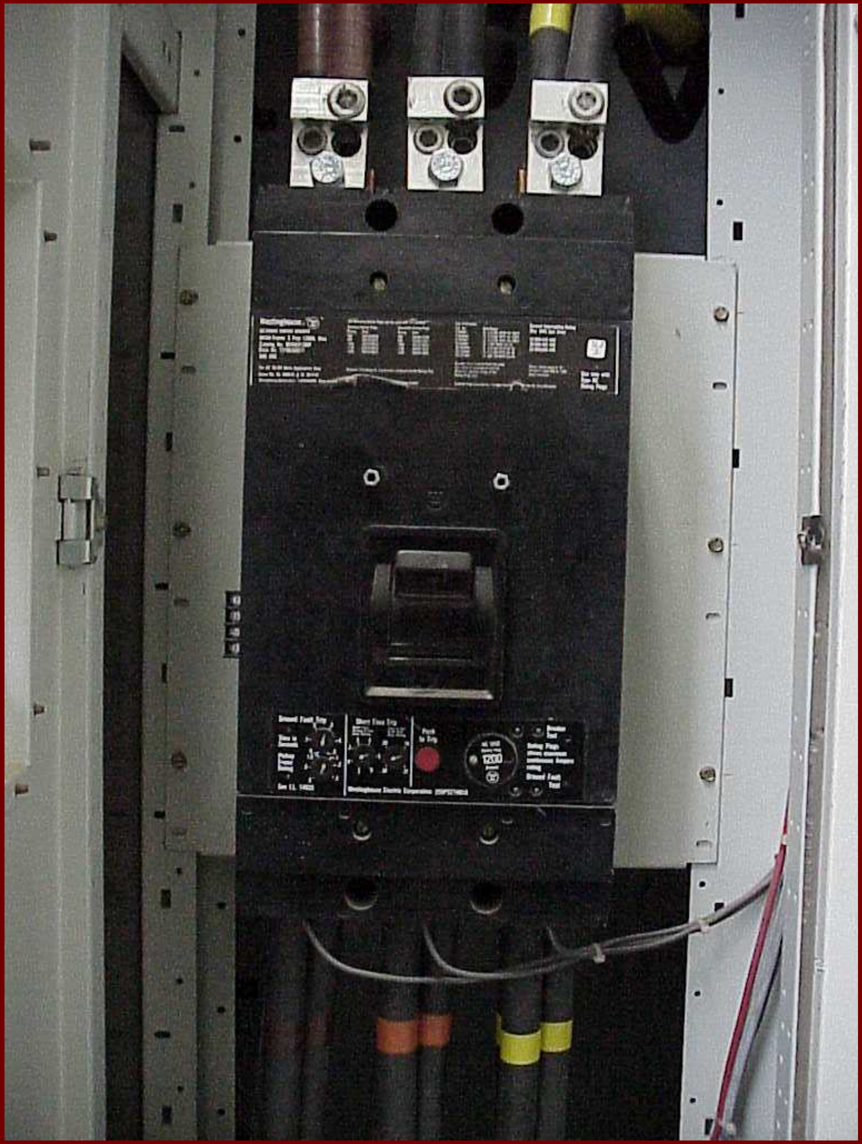
Sample One Line

- Emergency Power
- Must be Selectively Coordinated



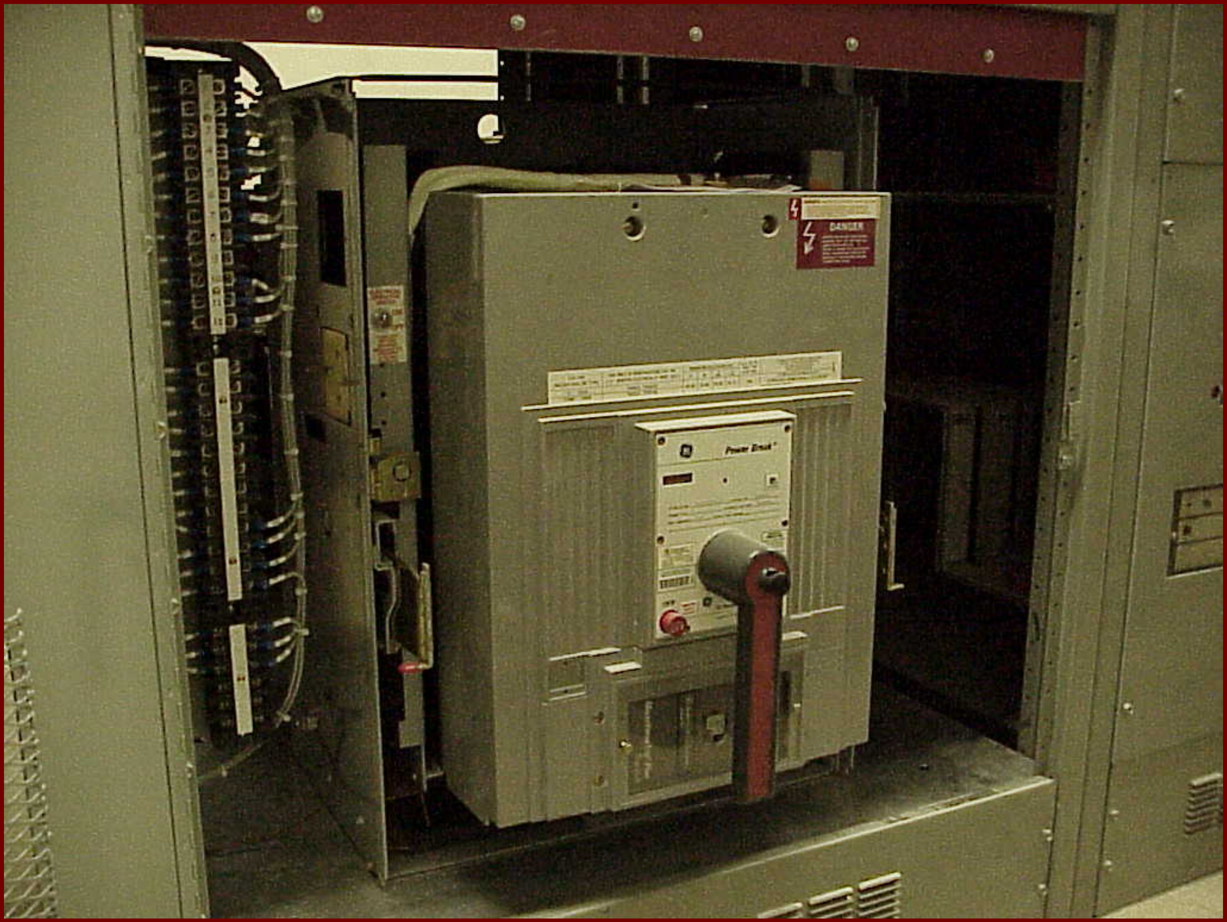
Definitions

- MCCB – Molded Case Circuit Breaker



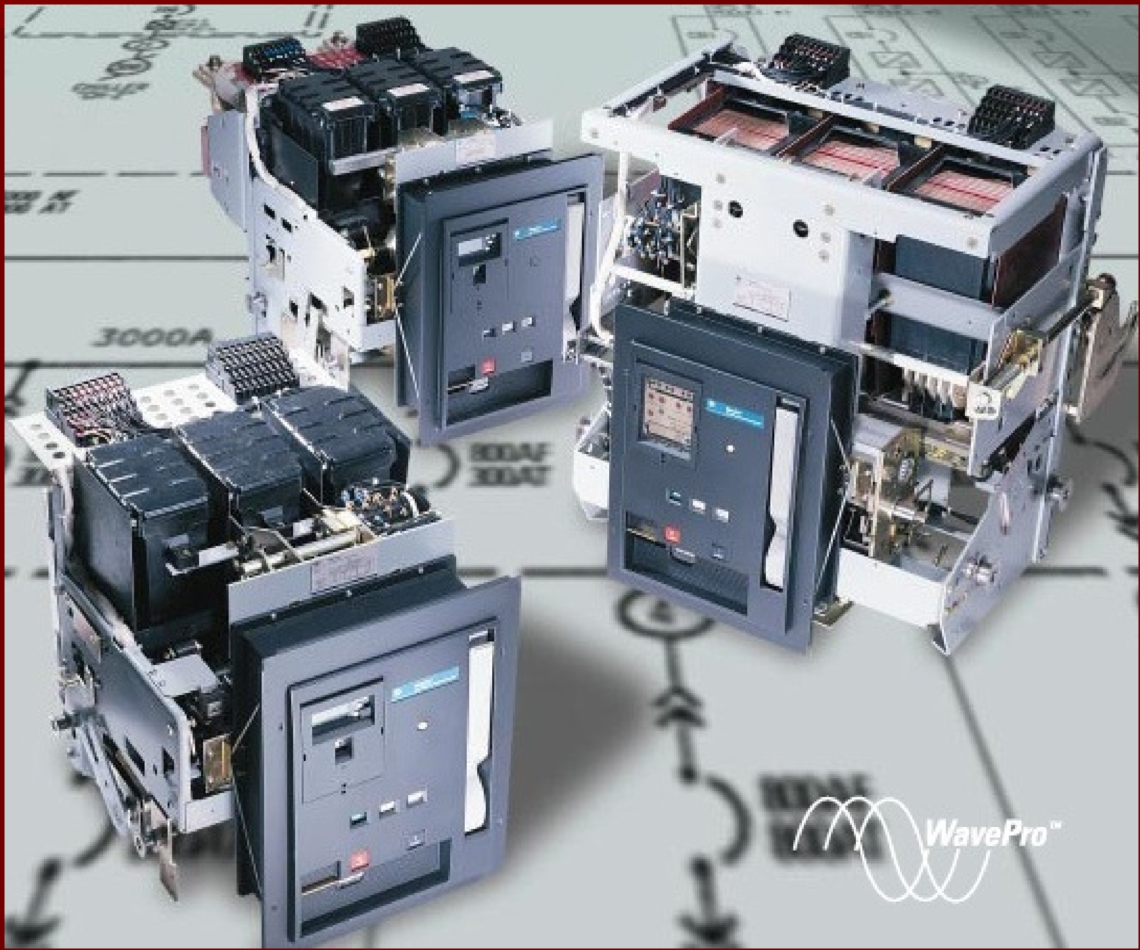
Definitions

- ICCB – Insulated Case Circuit Breaker



Definitions

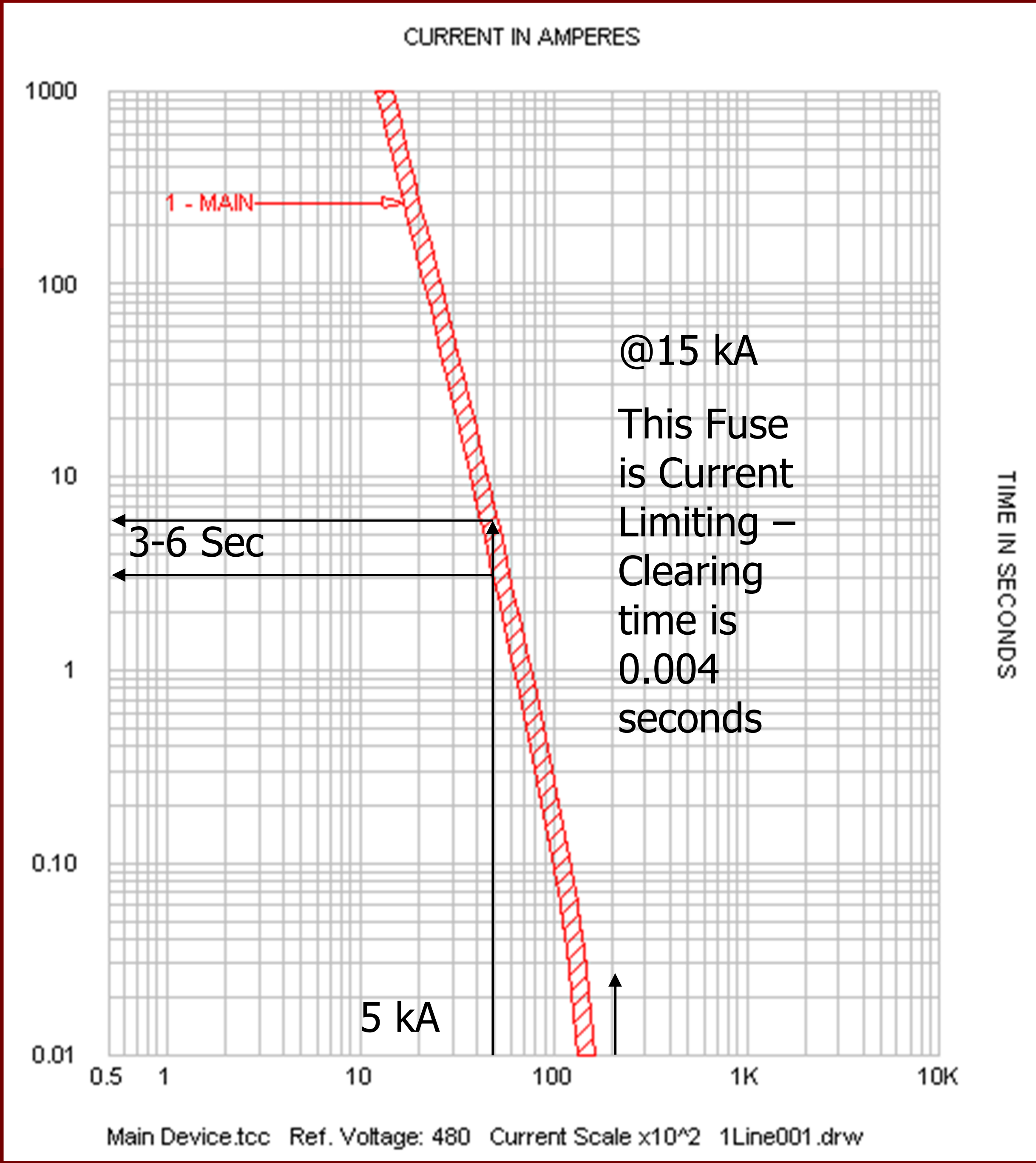
- LVPCB – Low Voltage Power Circuit Breaker



Time Current Curves

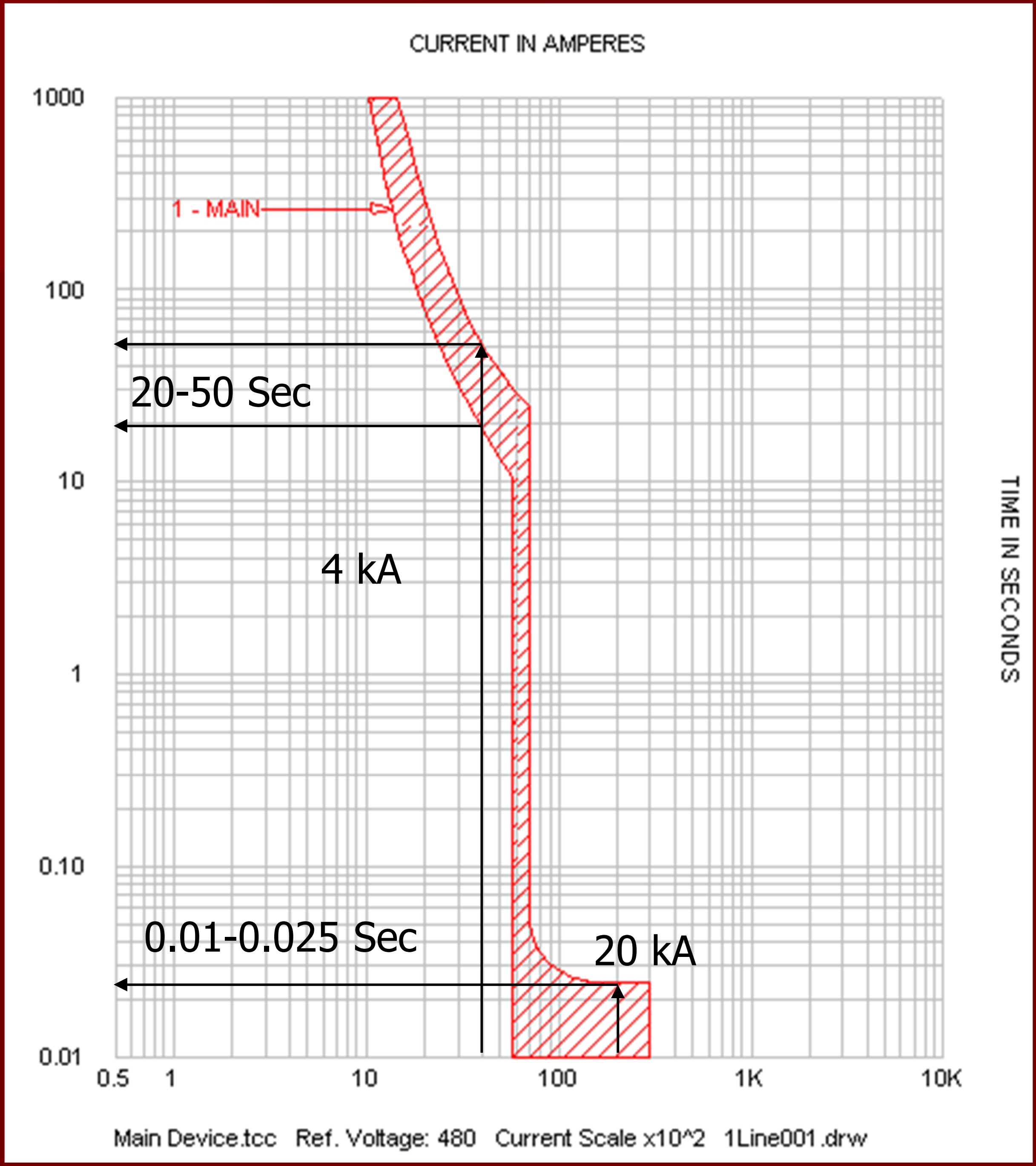
- Time Current Curve (TCC)
- The log-log graph of time versus current.
- Each breaker, fuse, and relay has a time current characteristic curve

Fuse TCC



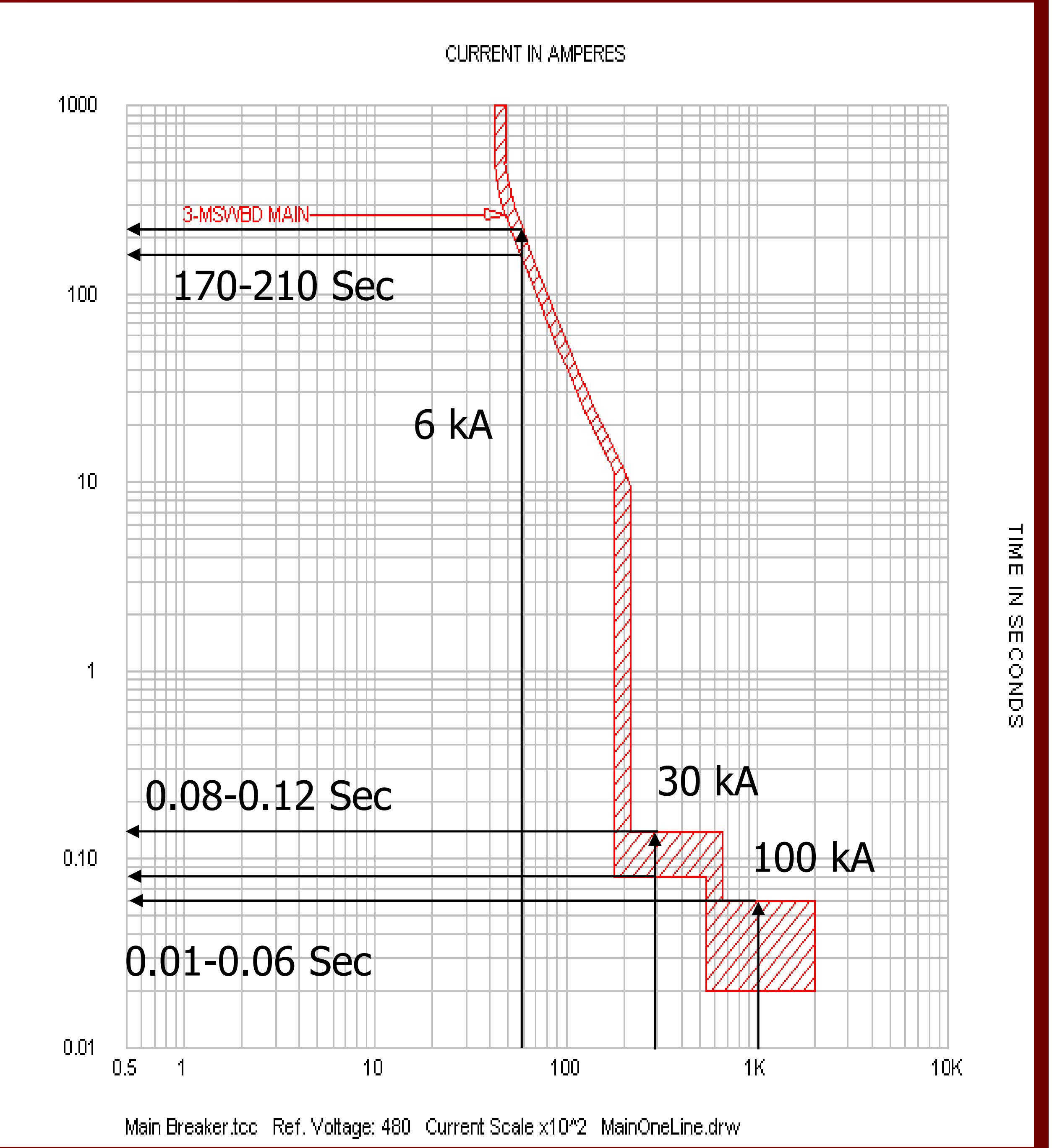
CURRENT IN AMPERES
1000
100
10
1
0.10
0.01
0.5
1
10
100
1K
10K
1 - MAIN
3-6 Sec
5 kA
@15 kA
This Fuse is Current Limiting – Clearing time is 0.004 seconds
TIME IN SECONDS
Main Device.tcc Ref. Voltage: 480 Current Scale x10^2 1Line001.drw

Thermal Magnetic Breaker



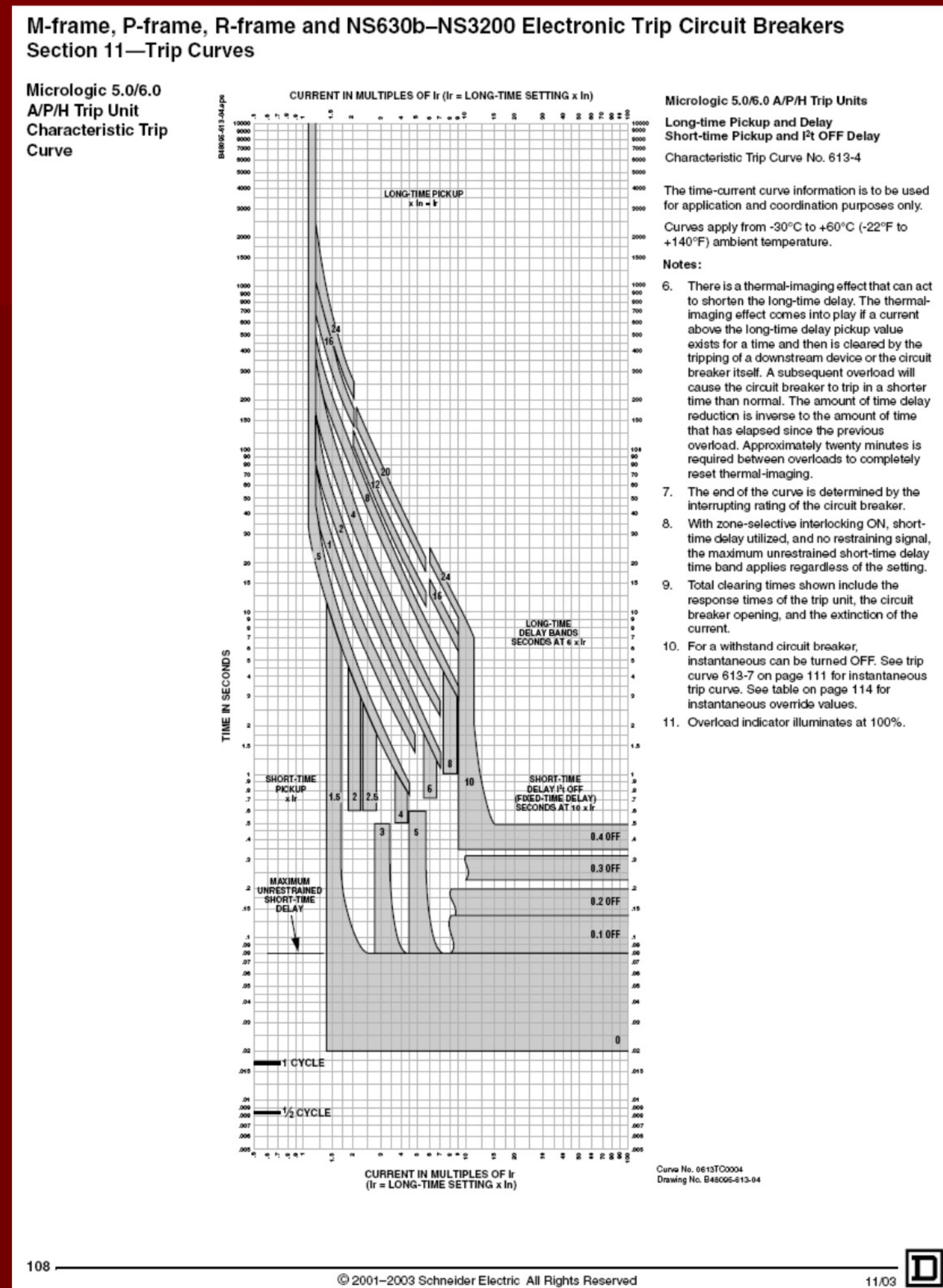
Solid State Trip

- SQ D NW 40H
- 4000 Amp
- Micrologic



Manufacture TCC

- SQ D NW 40H
- 4000 Amp
- Micrologic



M-frame, P-frame, R-frame and NS630b–NS3200 Electronic Trip Circuit Breakers
Section 11—Trip Curves

Micrologic 5.0/6.0 A/P/H Trip Unit Characteristic Trip Curve

Micrologic 5.0/6.0 A/P/H Trip Units

Long-time Pickup and Delay
Short-time Pickup and I²t OFF Delay

Characteristic Trip Curve No. 613-4

The time-current curve information is to be used for application and coordination purposes only.

Curves apply from -30°C to +60°C (-22°F to +140°F) ambient temperature.

Notes:

6. There is a thermal-imaging effect that can act to shorten the long-time delay. The thermal-imaging effect comes into play if a current above the long-time delay pickup value exists for a time and then is cleared by the tripping of a downstream device or the circuit breaker itself. A subsequent overload will cause the circuit breaker to trip in a shorter time than normal. The amount of time delay reduction is inverse to the amount of time that has elapsed since the previous overload. Approximately twenty minutes is required between overloads to completely reset thermal-imaging.
7. The end of the curve is determined by the interrupting rating of the circuit breaker.
8. With zone-selective interlocking ON, short-time delay utilized, and no restraining signal, the maximum unrestrained short-time delay time band applies regardless of the setting.
9. Total clearing times shown include the response times of the trip unit, the circuit breaker opening, and the extinction of the current.
10. For a withstand circuit breaker, instantaneous can be turned OFF. See trip curve 613-7 on page 111 for instantaneous trip curve. See table on page 114 for instantaneous override values.
11. Overload indicator illuminates at 100%.

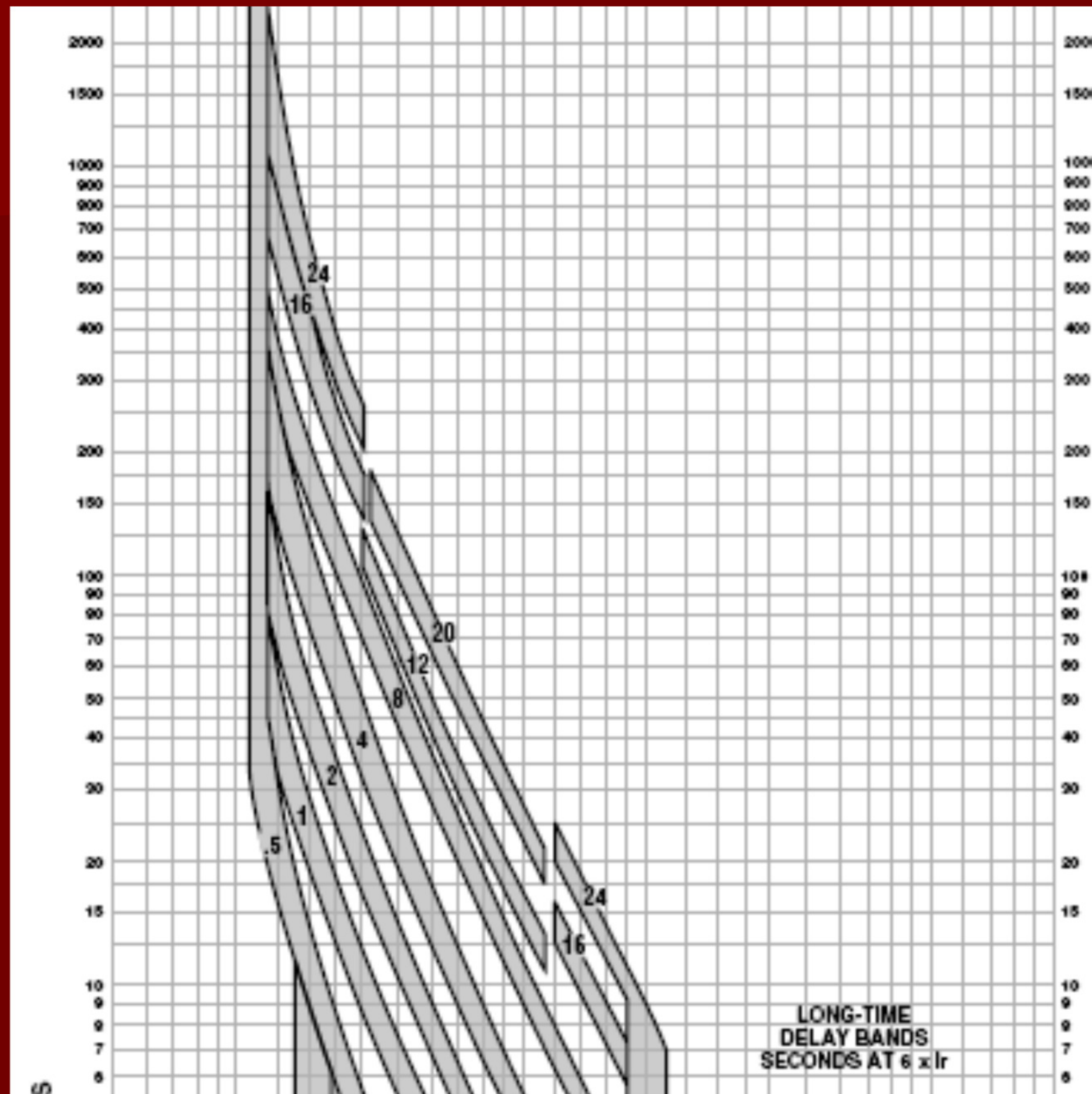
Curve No. 0613TC0004
Drawing No. B48095-613-04

108

11/03

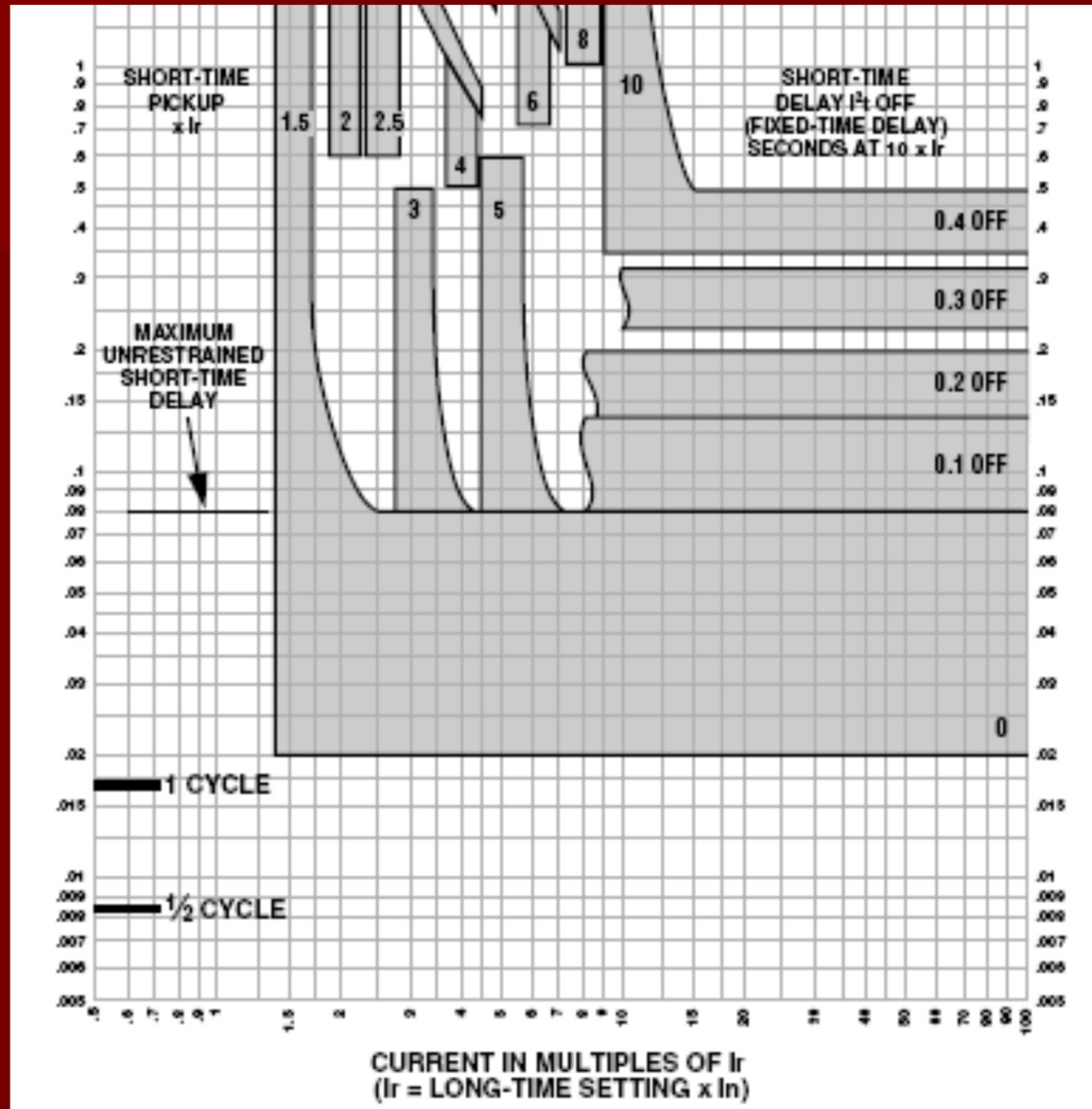
Manufacture TCC

- SQ D NW 40H
- 4000 Amp
- Micrologic



Manufacture TCC

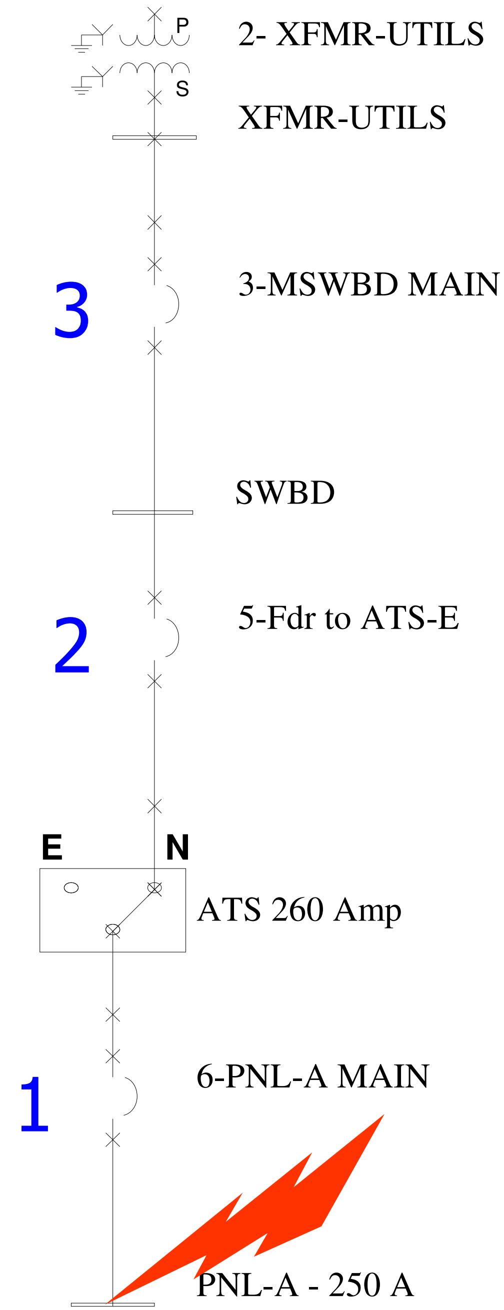
- SQ D NW 40H
- 4000 Amp
- Micrologic



What is Selective Device Coordination

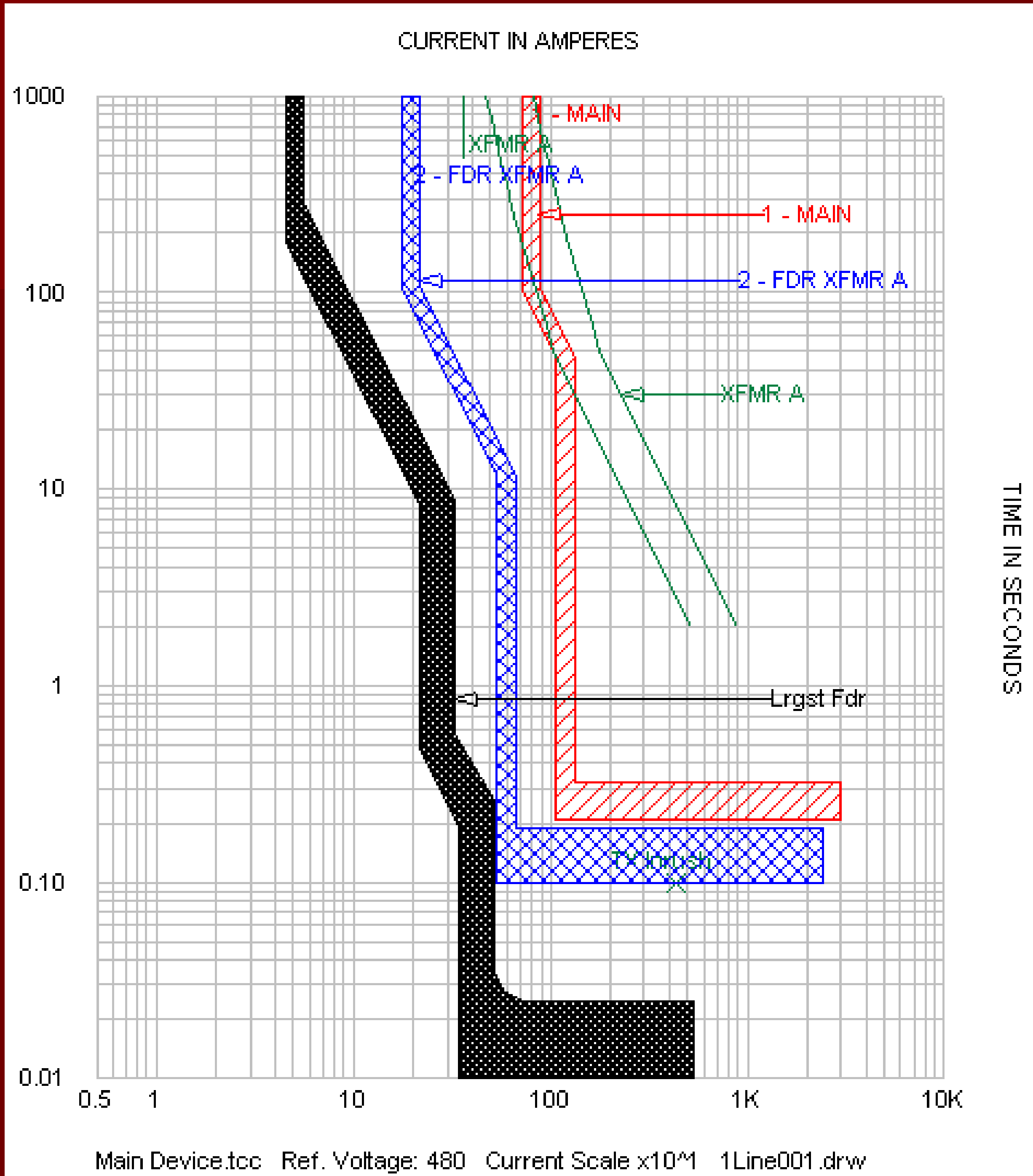
- Devices closest to the fault must operate first.
- Upstream devices trip in sequence
- No overlap on TCCs

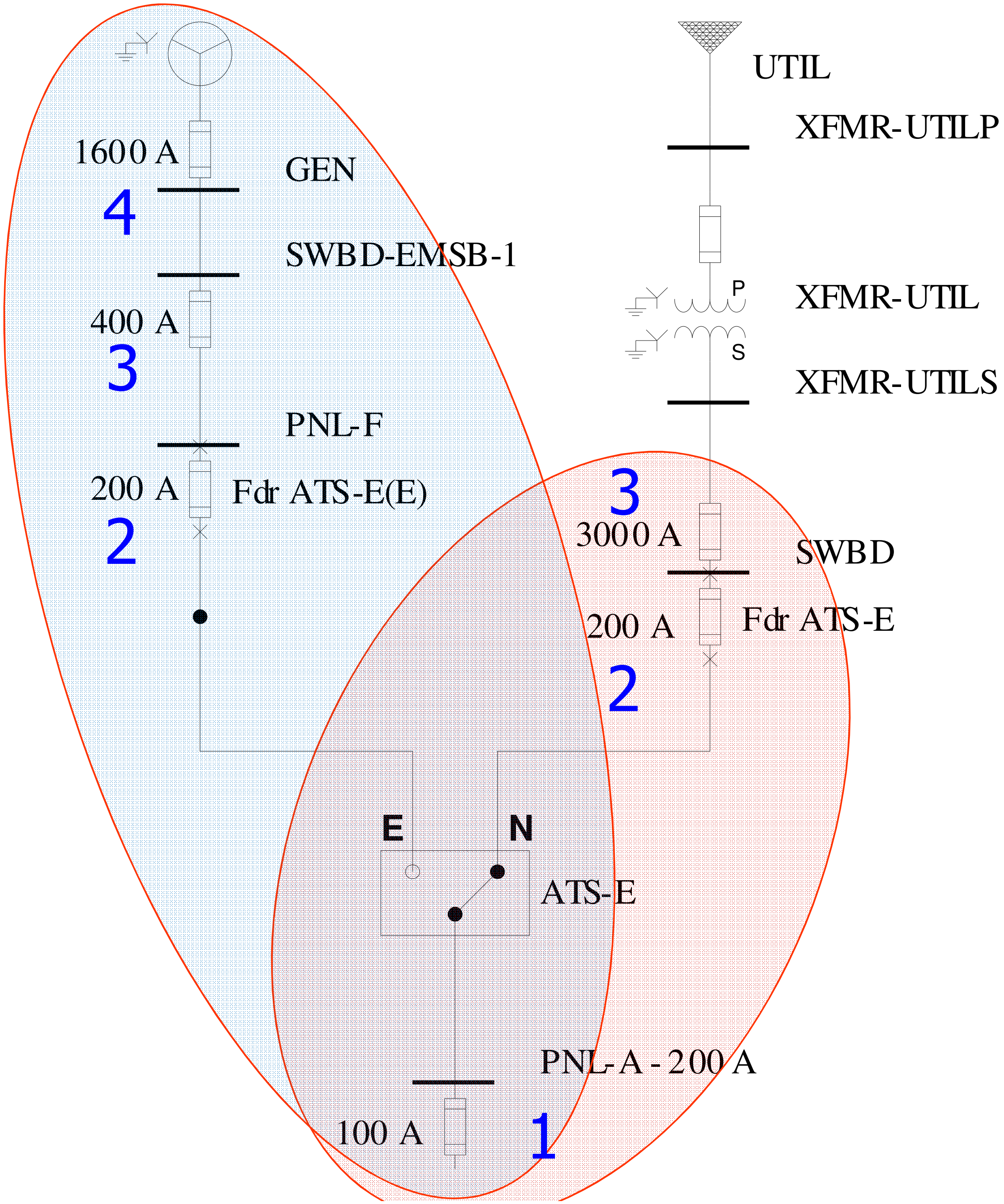
Sample One Line



Selective Coordination Breakers

- Three Breakers in Series
- No Overlap
- Easy Right?

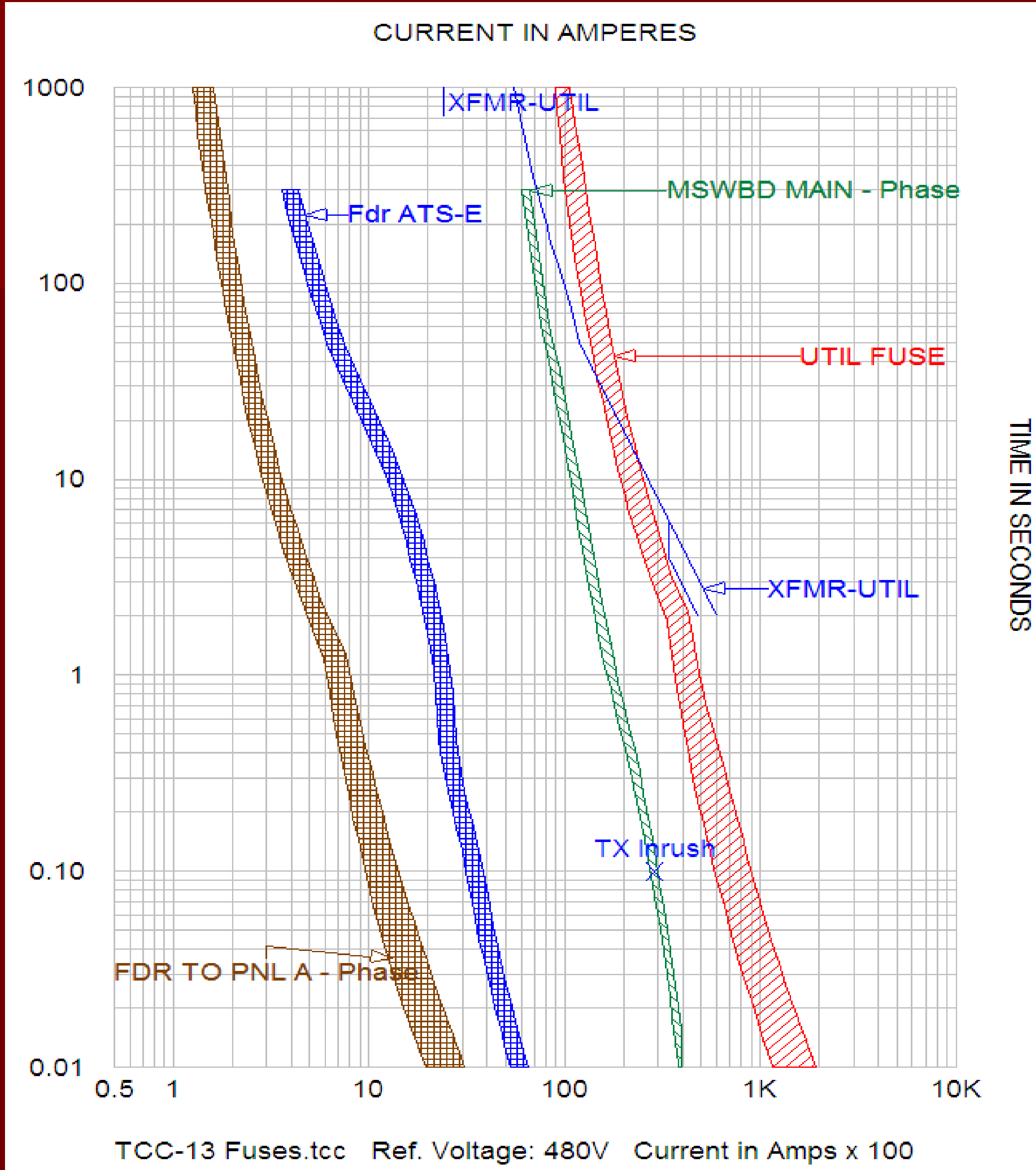




UTIL
XFMR-UTILP
1600 A
GEN
4
SWBD-EMSB-1
400 A
P
XFMR-UTIL
S
3
XFMR-UTILS
PNL-F
200 A
Fdr ATS-E(E)
3
2
3000 A
SWBD
200 A
Fdr ATS-E
2
E
N
ATS-E
PNL-A - 200 A
100 A
1

Selective Coordination Fuses

- No Overlap – Does not guarantee coordination.
- Must use Mfg coordination tables
- Need 2-2.5 ratio



Problems with this Code Requirement - Fuses

- Requires larger equipment than using T/M CBs
- Larger Electrical Room – Less rental or usable building space
- Reduces Levels of downstream equipment
- Fusible Panelboards and Elevator Modules are more expensive than T/M circuit breakers

Problems with this Code Requirement – Circuit Breakers

- Most breakers have an instantaneous trip function.
  - Breaker trips instantaneously (no time delay)
- No Selective Coordination Testing for Thermal/Magnetic Breakers
- Limited equipment w/o Instantaneous
- Higher fault current = Increases complexity to selectively coordinate

Problems with this Code Requirement – Circuit Breakers

- Requires larger frame breakers with Solid State Trip units
- Larger Framed Breakers Means Larger Electrical Room - Less rental or usable building space
- Not all trip units function the same way
- Difficult to obtain competitive bids

Reality

Very Expensive to Design and Comply

This new Section of the code will radically change the way we all design emergency and standby power systems.

Real Problem or a Perceived (Paper) Problem?

- On paper, breakers with instantaneous trip units will not coordinate.
- In the real world…is this a problem?
- How many times has this happened to your customer’s or your facility?
  - Before you answer the question....
  - Incorrect trip unit settings do not count
  - Poor maintenance or defective trip units do not count

Selective Coordination - Fuses

- Fuses have been tested for coordination.
- Relatively easy to select equipment to coordinate.
- Pick Fuses from Manufacturer’s Fuse Selective Coordination Charts

Ferraz-Shawmut

Fuse Selectivity Ratios - 600 and 480 Volt Applications Up to 200,000 RMS Symmetrical Amperes

1600 Ampere Main

600 Ampere Branch

BRANCH FUSE	RATIO* MAIN FUSE A4BQ	A4BY	A4BT	TRS	A6K	A6D	A4J	AJT	A6T
A4BQ	2:1	2:1	2:1	-	-	-	-	-	-
A4BY	-	2.5:1	2:1	-	-	-	-	-	-
A4BT	2.5:1	2.5:1	2:1	-	-	-	-	-	-
TRS	[illegible]	[illegible]	[illegible]	2:1	4:1	4:1	4:1	3:1	4.5:1
A6K	2:1	2:1	1.5:1	1.5:1	2:1	2:1	3:1	2:1	3.5:1
A6D	2:1	2:1	1.5:1	1.5:1	2:1	2:1	3:1	2:1	3.5:1
A4J	2:1	2:1	1.5:1	1.5:1	2:1	2:1	2:1	2:1	3:1
AJT	2:1**	2:1**	2:1	1.5:1	2:1	2:1	2.5:1	2:1	3.5:1
A6T	3:1	2.5:1	2:1	1.5:1	2:1	2:1	2:1	2:1	2.5:1

Fuse Selectivity Ratios - 240 Volt Applications Up to 200,000 RMS Symmetrical Amperes

BRANCH FUSE	RATIO* MAIN FUSE A4BQ	A4BY	A4BT	TR	A2K	A2D	A4J	AJT	A3T
A4BQ	2:1	2:1	2:1	-	-	-	-	-	-
A4BY	-	2.5:1	2:1	-	-	-	-	-	-
A4BT	2.5:1	2.5:1	2:1	-	-	-	-	-	-
TR	4:1	4:1	4:1	1.5:1	4:1	3:1	4:1	3:1	5:1
A2K	2:1	2:1	1.5:1	1.5:1	2:1	1.5:1	2:1	1.5:1	3:1
A2D	2.5:1	2.5:1	2:1	1.5:1	2:1	1:5:1	2:1	2:1	3:1
A4J	2:1	2:1	1.5:1	1.5:1	2:1	1.5:1	2:1	2:1	3:1
AJT	2:1	2:1	2:1	1.5:1	2.5:1	2:1	2.5:1	2:1	3:1
A3T	1.5:1	1.5:1	1.5:1	1.5:1	1.5:1	1.5:1	1.5:1	1.5:1	2:1

*These ratios apply to fuses rated 61-6000A.

**Exception: For AJT450-600 use 2:1 on 480V only, 2.25:1 on 600V.

Bussmann

*** Selectivity Ratio Guide (Line-Side to Load-Side) for Blackout Prevention**

Circuit			Load-Side Fuse										
Current Rating				601-6000A	601-4000A	0-600A			601-6000A	0-600A	0-1200A	0-600A	0-60A
	Type			Time-Delay	Time-Delay	Dual-Element Time-Delay			Fast-Acting	Fast-Acting			Time-Delay
		Trade Name		LOW-PEAK® YELLOW	LIMITRON	LOW-PEAK® YELLOW		FUSETRON®	LIMITRON	LIMITRON	T-TRON®	LIMITRON	SC
		Class		(L)	(L)	(RK1)	(J)	(RK5)	(L)	(RK1)	(T)	(J)	(G)
		Buss® Symbol		**KRP-C_SP**	**KLU**	**LPN-RK_SP LPS-RK_SP**	**LPJ-SP**	**FRN-R FRS-R**	**KTU**	**KTN-R KTS-R**	**JJN JJS**	**JKS**	**SC**
Line-Side Fuse: 601 to 6000A	Time-Delay	LOW-PEAK® YELLOW (L)	**KRP-C_SP**	2:1	2.5:1	2:1	2:1	4:1	2:1	2:1	2:1	2:1	N/A
601 to 4000A	Time-Delay	LIMITRON (L)	**KLU**	2:1	2:1	2:1	2:1	4:1	2:1	2:1	2:1	2:1	N/A
0 to 600A	Dual-Element	LOW-PEAK® YELLOW (RK1)	**LPN-RK_SP LPS-RK_SP**	–	–	2:1	2:1	8:1	–	3:1	3:1	3:1	4:1
		(J)	**LPJ-SP**	–	–	2:1	2:1	8:1	–	3:1	3:1	3:1	4:1
		FUSETRON® (RK5)	**FRN-R FRS-R**	–	–	1.5:1	1.5:1	2:1	–	1.5:1	1.5:1	1.5:1	1.5:1
601 to 6000A	Fast-Acting	LIMITRON (L)	**KTU**	2:1	2.5:1	2:1	2:1	6:1	2:1	2:1	2:1	2:1	N/A
0 to 600A		LIMITRON (RK1)	**KTN-R KTS-R**	–	–	3:1	3:1	8:1	–	3:1	3:1	3:1	4:1
0 to 1200A		T-TRON® (T)	**JJN JJS**	–	–	3:1	3:1	8:1	–	3:1	3:1	3:1	4:1
0 to 600A		LIMITRON (J)	**JKS**	–	–	2:1	2:1	8:1	–	3:1	3:1	3:1	4:1
0 to 60A	Time-Delay	SC (G)	**SC**	–	–	3:1	3:1	4:1	–	2:1	2:1	2:1	2:1

* **Note:** At some values of fault current, specified ratios may be lowered to permit closer fuse sizing. Plot fuse curves or consult with Bussmann®.
General Notes: Ratios given in this Table apply only to Buss® fuses. When fuses are within the same case size, consult Bussmann®.

Fuse not in Chart

- Fuse I^2t is the best tool for assuring coordination
- Total clearing I^2t of the downstream fuse < melting I^2t of the main upstream fuse

Selective Coordination – Fuses

- Most ratios are 2:1 or higher
- Reduces # of Levels of Coordination
- Example – 1600 Ampere Main (6 Levels)
  - Feeder 1 – 800 Ampere
  - Feeder 2 – 400 Ampere
  - Feeder 3 – 200 Ampere
  - Feeder 4 – 100 Ampere
  - Feeder 5 – 50 Ampere
  - Feeder 6 – 25 Ampere

Fused Panelboards

- Bussmann - Coordination Panel Board 30A – 400A Fusible
- Ferraz Shawmut – Coordination Panel

Issues with Fuses

- Upstream Fuses with Downstream Circuit Breakers
  - They have not been tested for Selective Coordination
  - Rare Exception – Fault current is less than the current limiting operation of the fuse.
  - Usually, must use all fuses
- Usually, the fuses must all be the same manufacture.
- Tip#1 – Avoid intermixing fuses and circuit breakers.

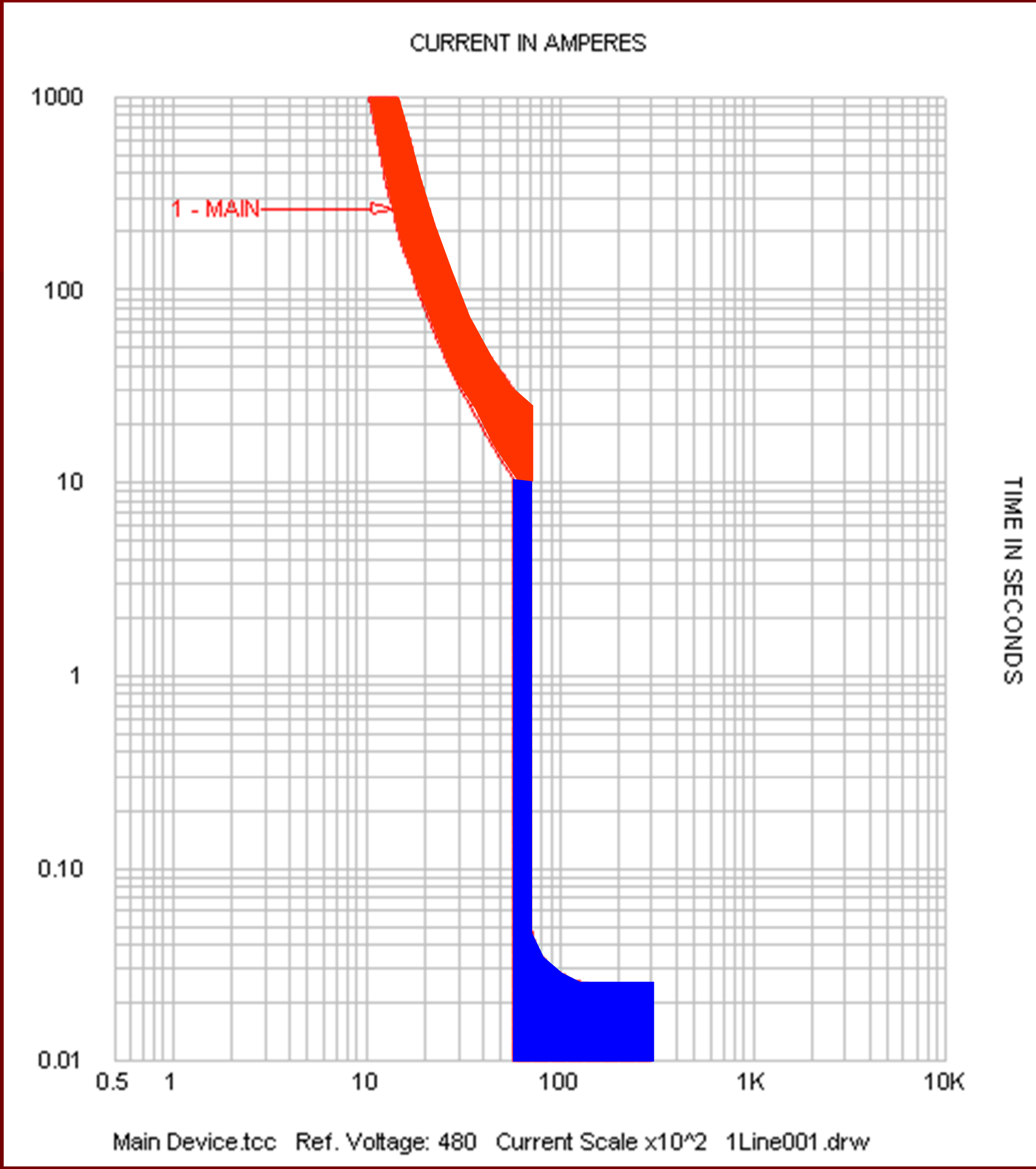
Circuit Breaker Trip Units

- Thermal Magnetic
- Solid State
  - LI (Long Time & Instantaneous)
  - LSI (Long, Short Times & Instantaneous)
  - LS (Long Time and Short Time)
  - G (Ground Fault)
- Not all Solid State Trip Units are alike!!!

Thermal Magnetic Trip Unit

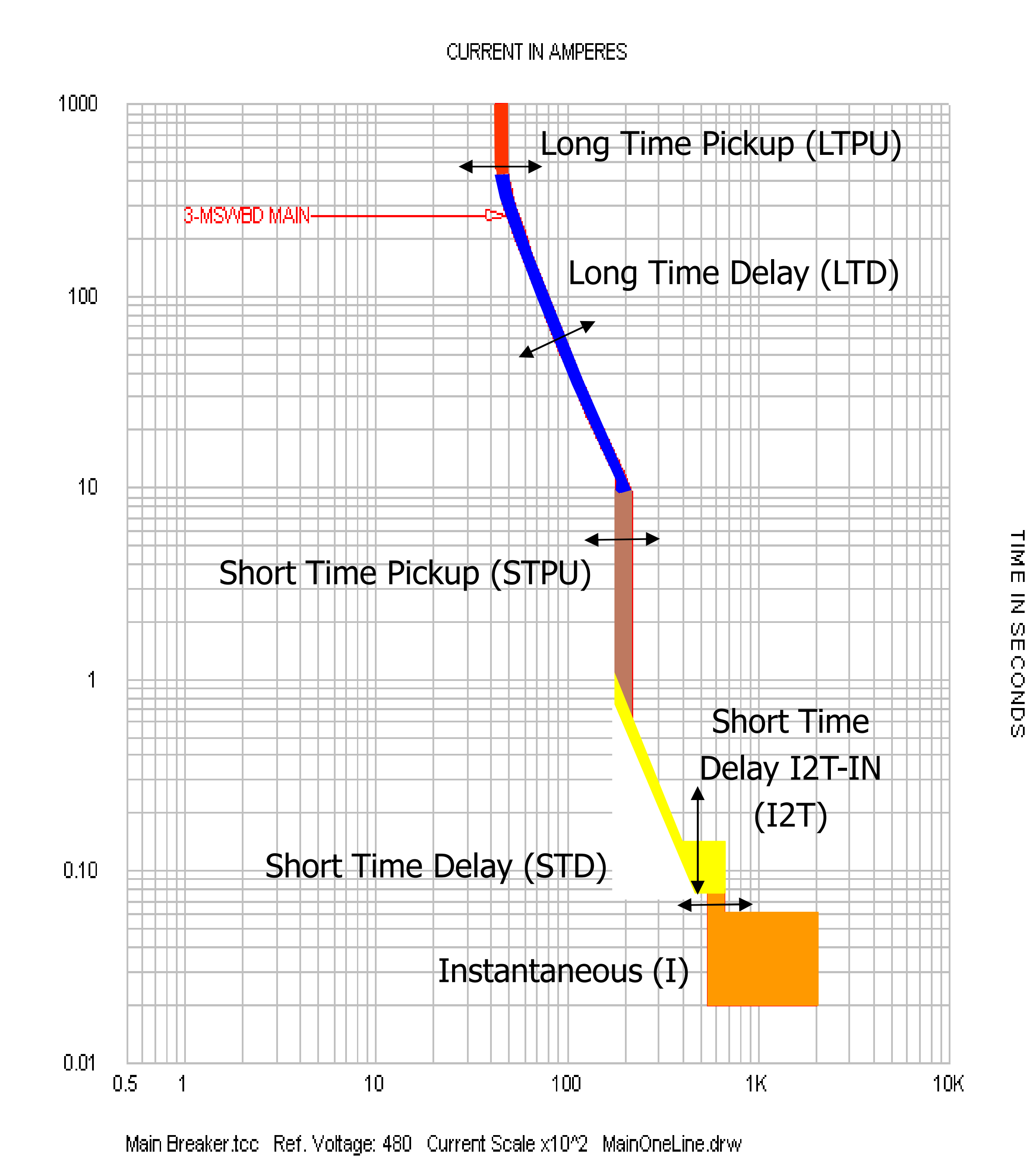
Thermal Magnetic Trip Unit

- Thermal Unit is Fixed
- Instantaneous
  - Fixed
  - Adjustable



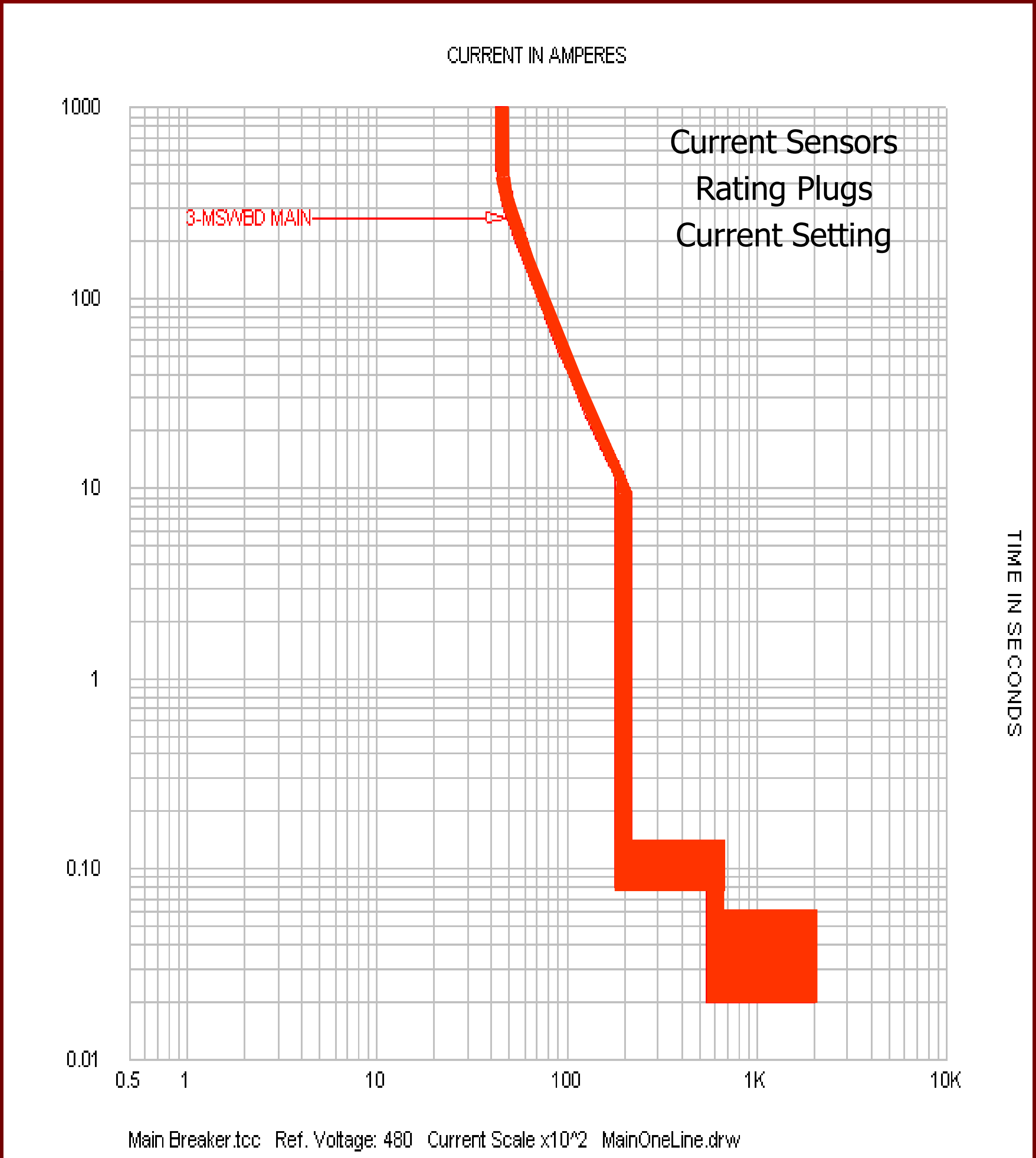
Solid State Trip Unit

- Varies for each Trip Unit!
- Some Functions are Not Adjustable!

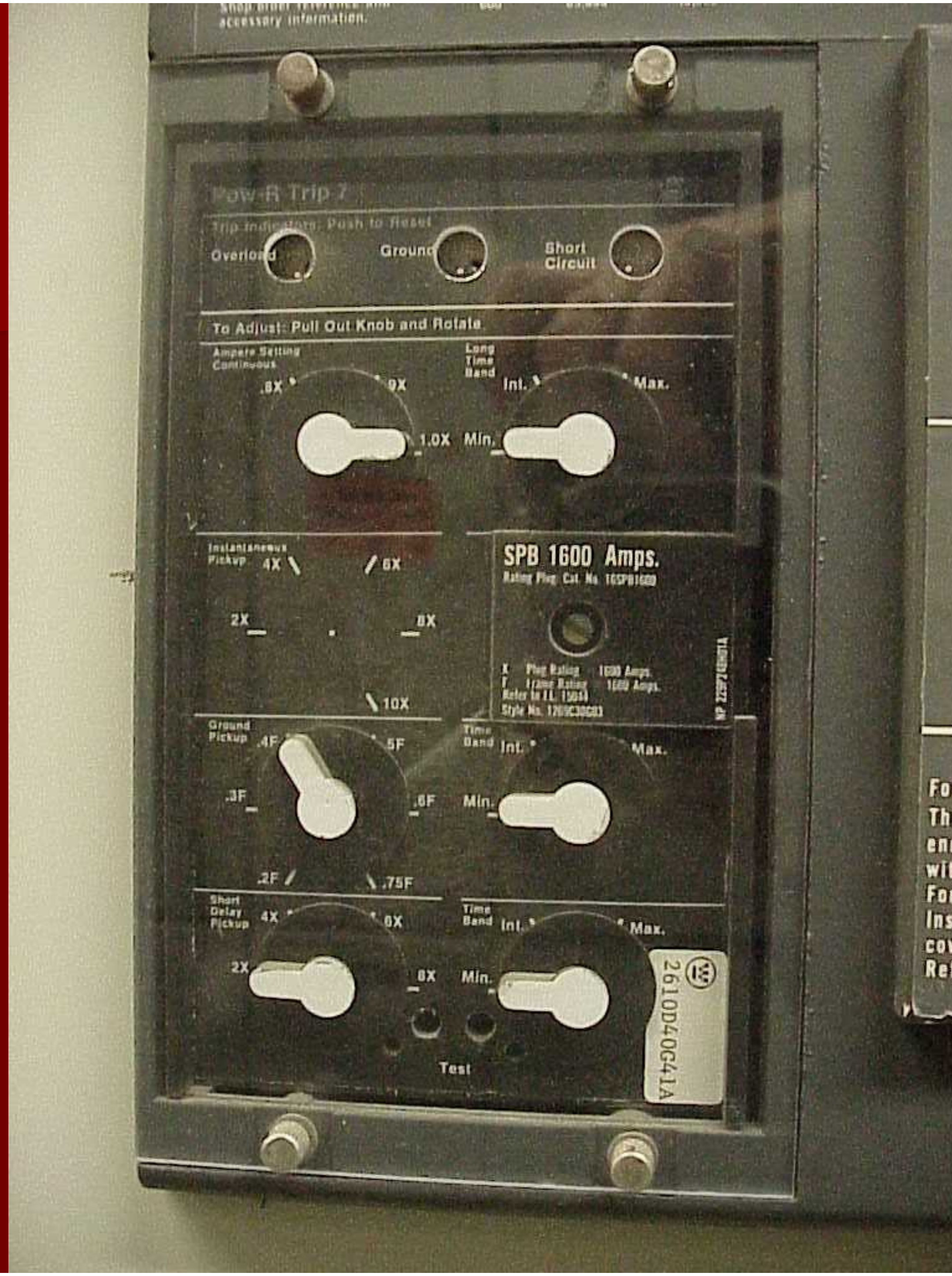


Solid State Trip Unit

- SQ D NW 40H
- 4000 Amp
- Micrologic



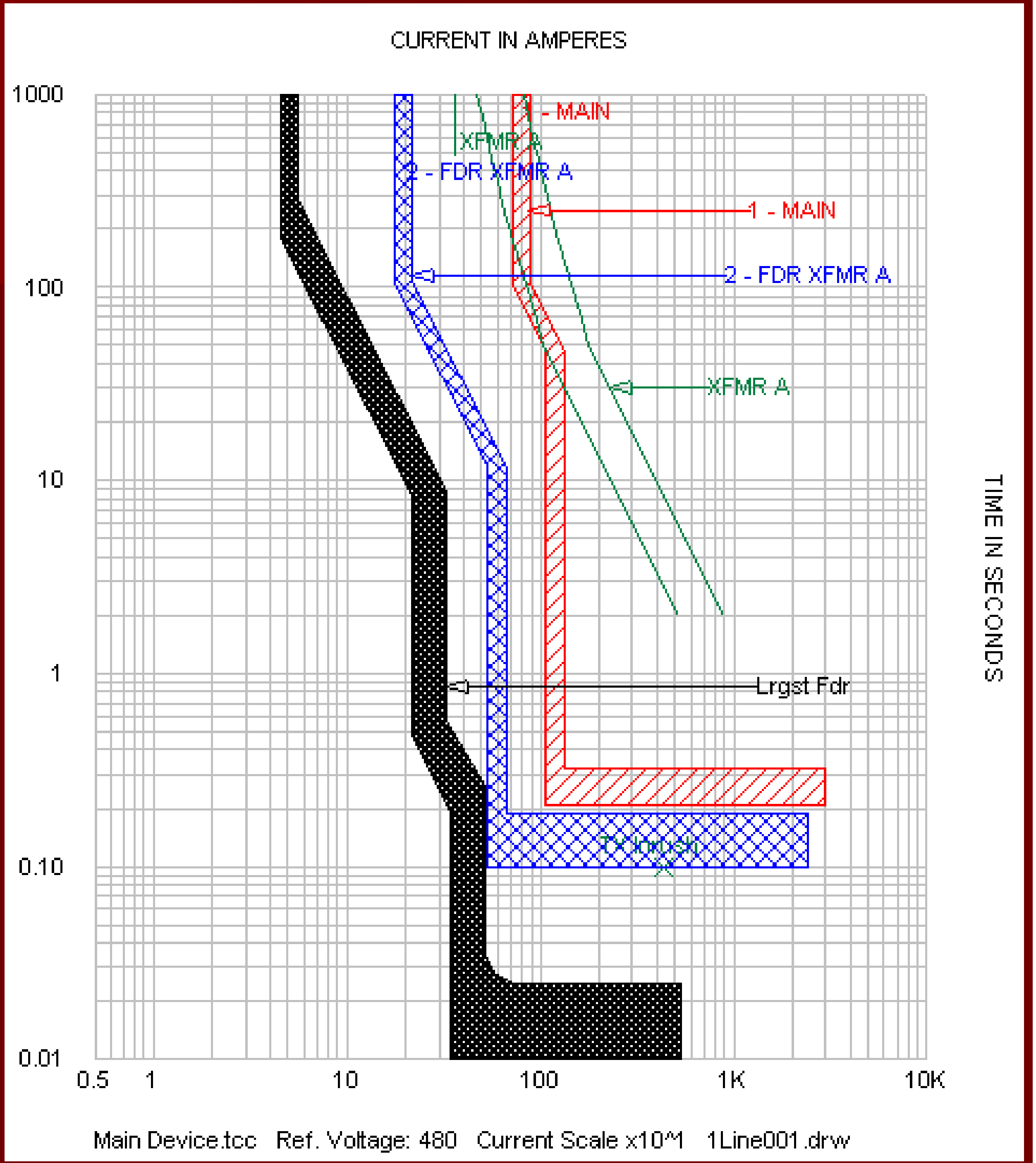
Solid State Trip Unit



Pow-R Trip 7
Overload
Ground
Short Circuit
To Adjust: Pull Out Knob and Rotate
Ampere Setting Continuous
.8X
.9X
1.0X
Long Time Band
Int.
Max.
Min.
Instantaneous Pickup
4X
6X
2X
8X
10X
SPB 1600 Amps.
Ground Pickup
.4F
.5F
.3F
.6F
.2F
.75F
Time Band
Short Delay Pickup
Test
2610D40G41A

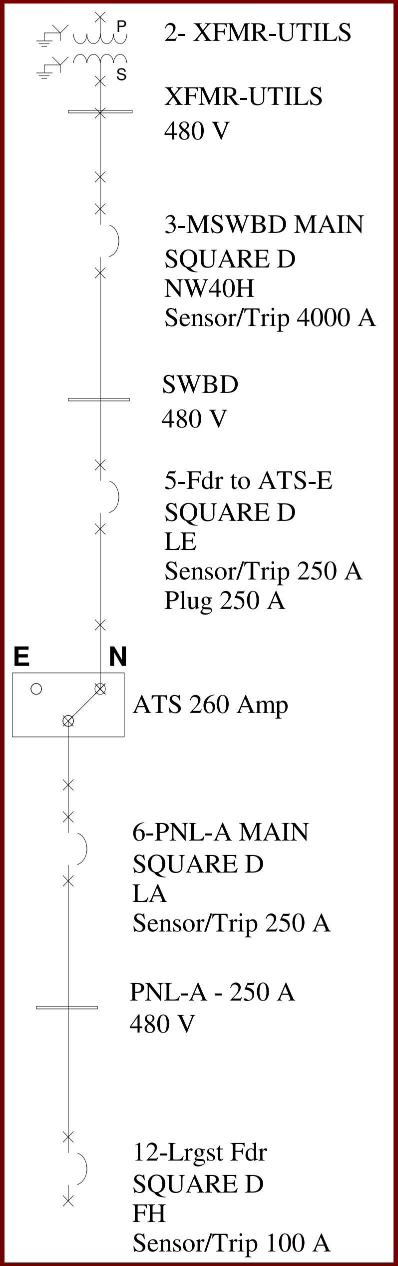
Why is this Difficult?

- Three Breakers in Series
- No Overlap
- Easy Right?



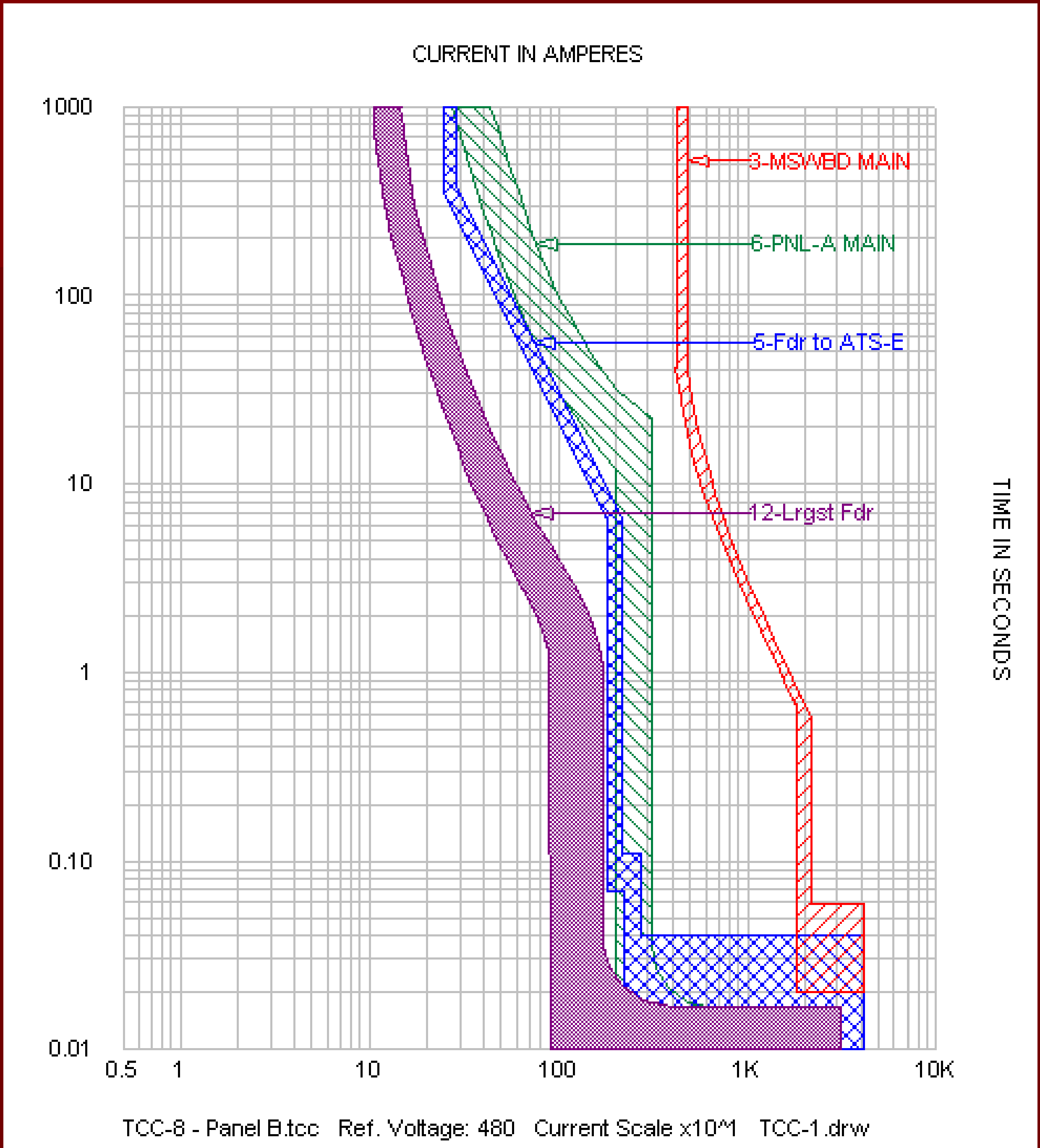
Why is this Difficult?

- SWBD Main
  - SS w/ LI
- Feeder
  - SS w/ LSI
- Panel Main
  - T/M
- Panel Branch
  - T/M



Why is this Difficult?

- Instantaneous Function
- Per UL & NEMA – Required on MCCBs & ICCBs
- LVPCBs – Not Required

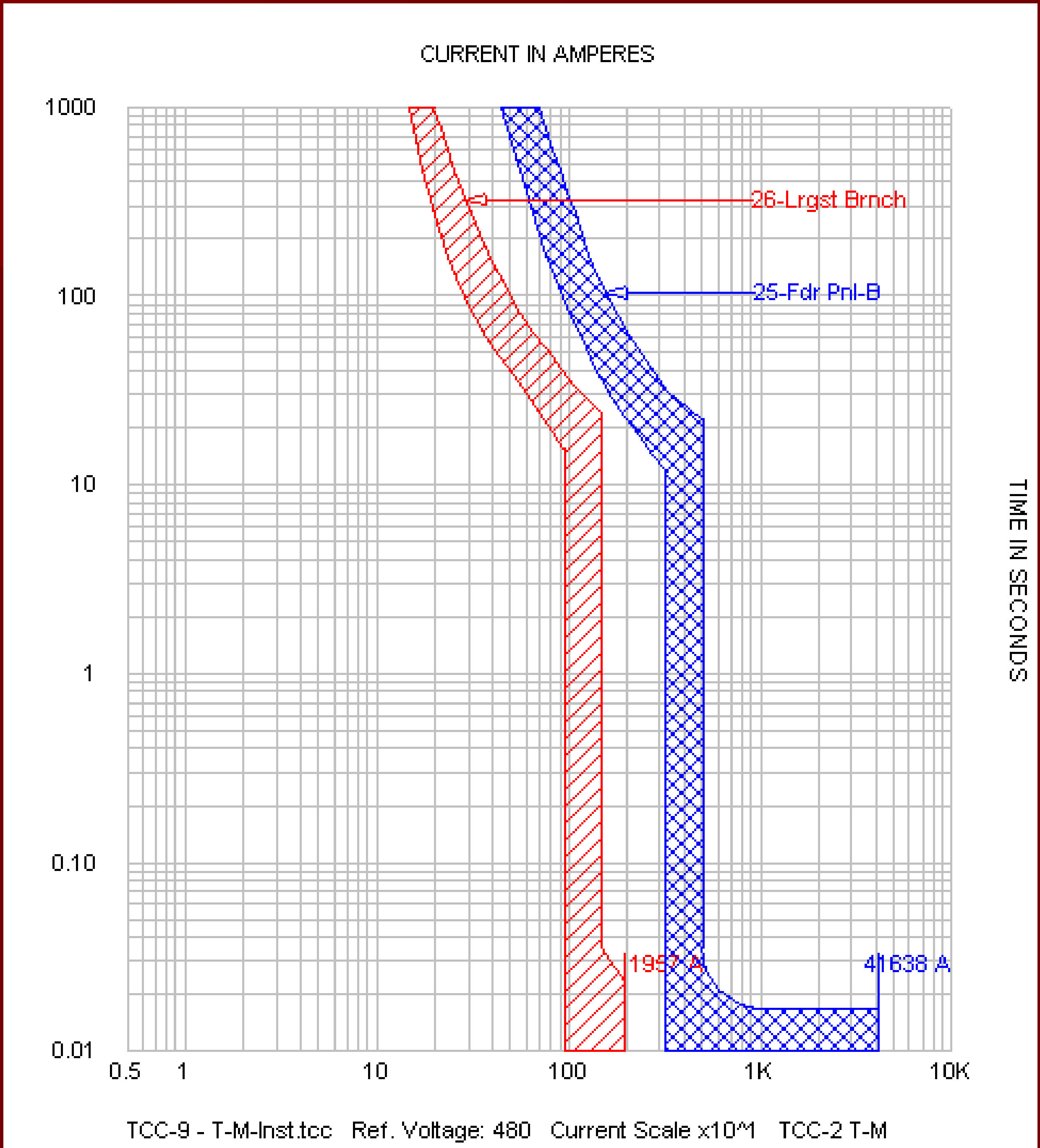


Solution

- Eliminate the Instantaneous Function by:
  - Reducing the fault current
    - Transformers
    - Reactors
    - Long Conductor Lengths
  - Setting Instantaneous above fault current.

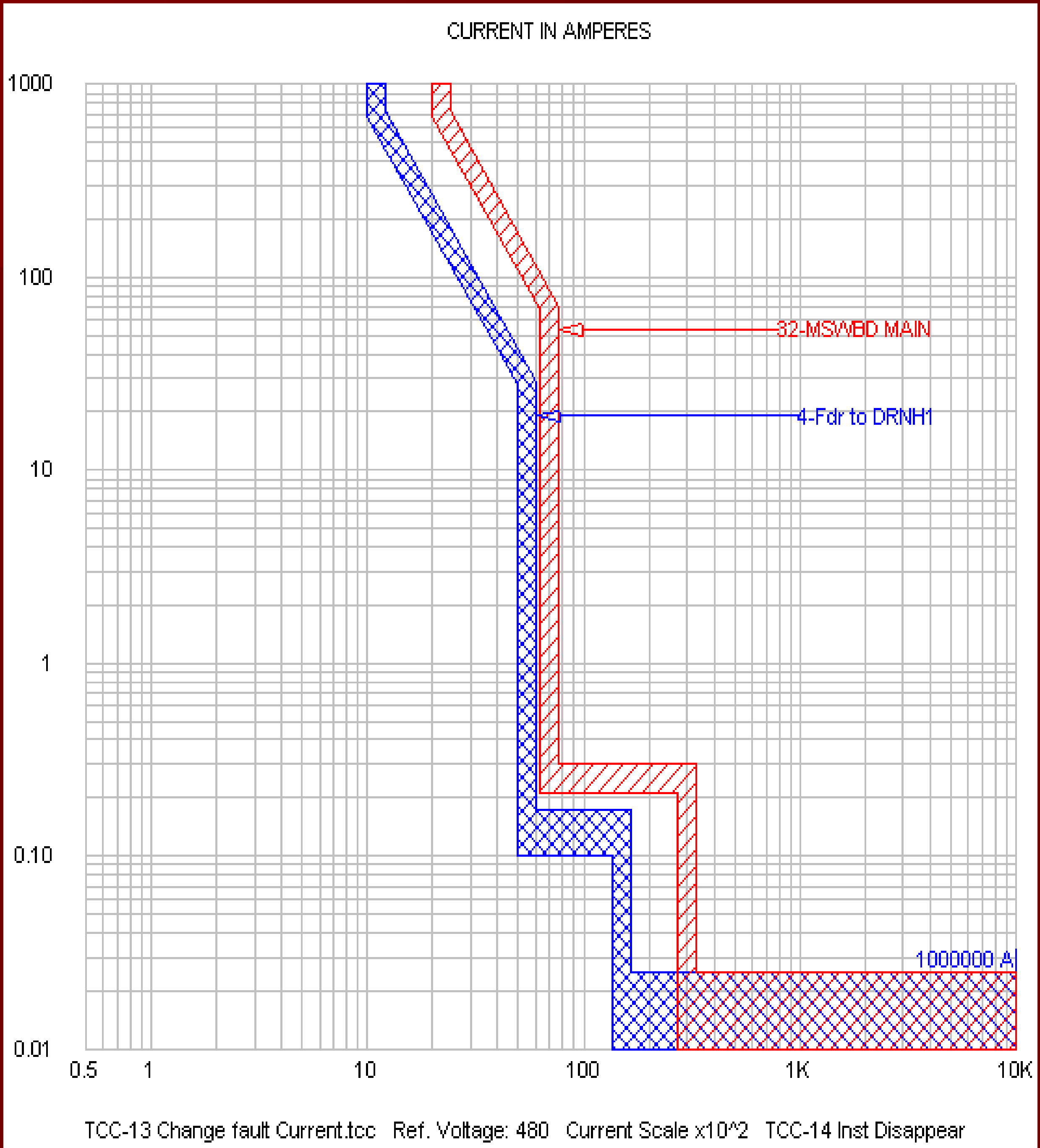
Instantaneous Function – T/M Trip

- Selectively coordinates only if difference in fault current



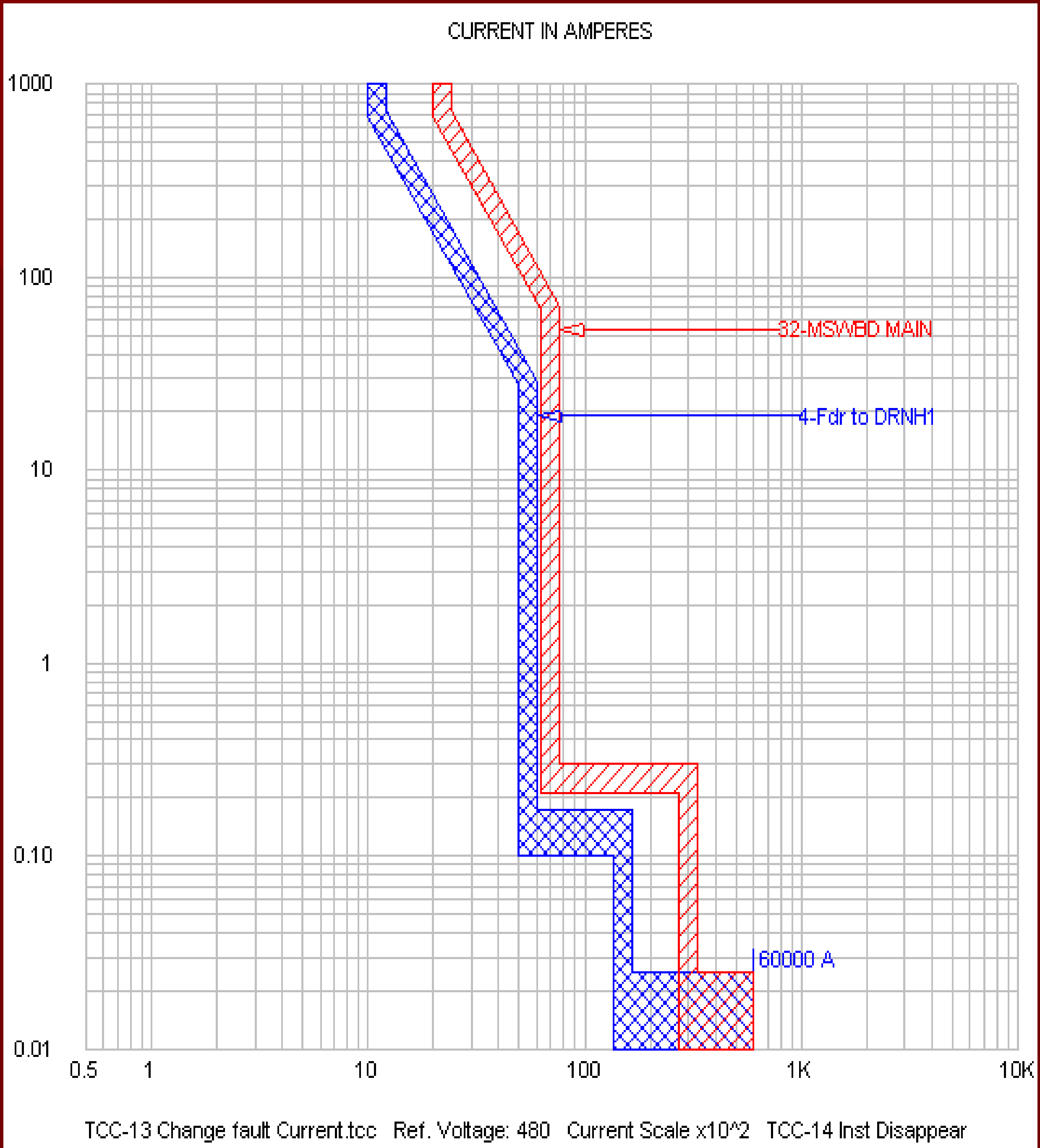
Instantaneous Function – SS Trip

- Instantaneous curve ends at available fault current
- 100,000 Amps



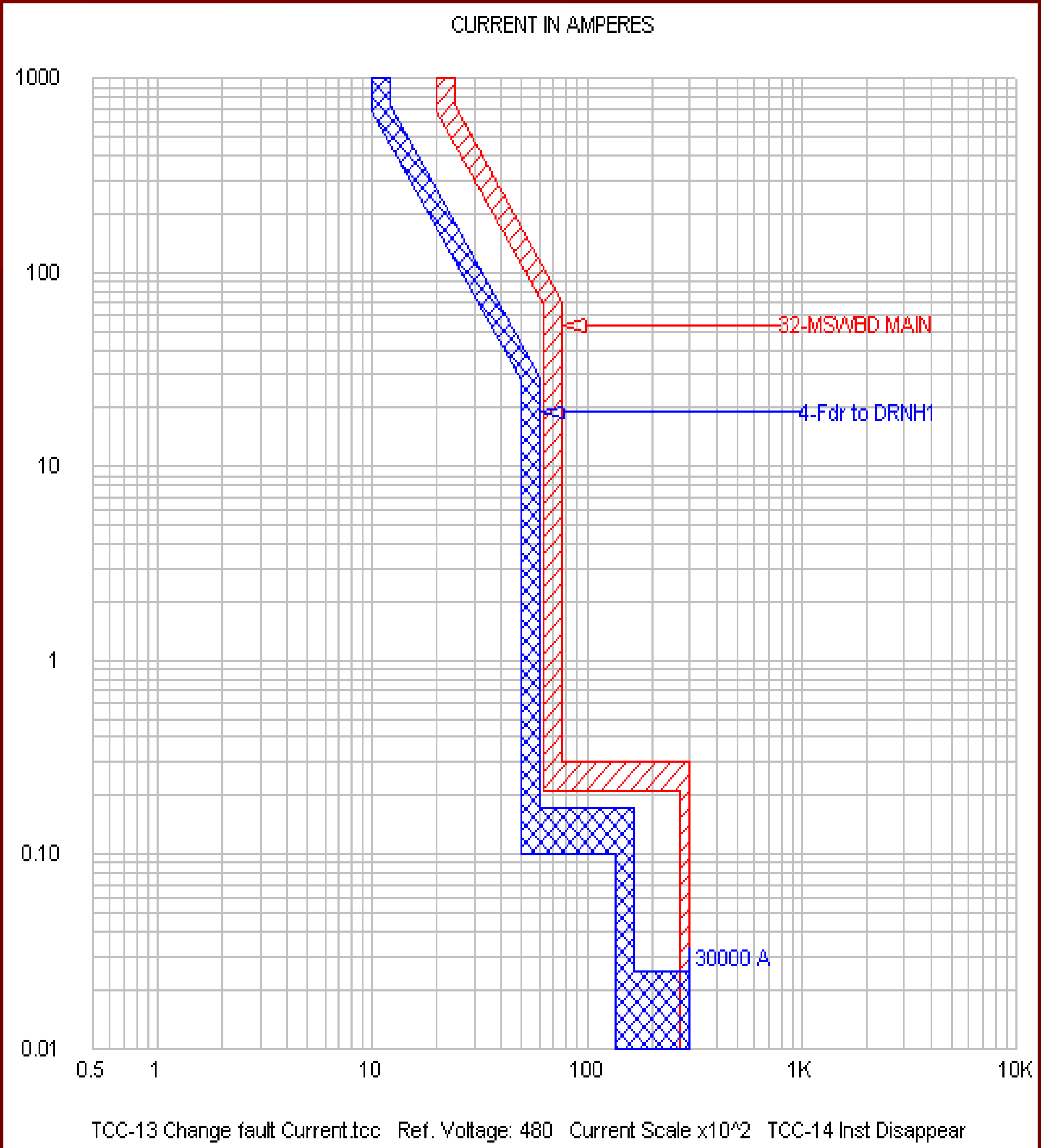
Instantaneous Function – SS Trip

- Instantaneous curve ends at available fault current
- 60,000 Amps



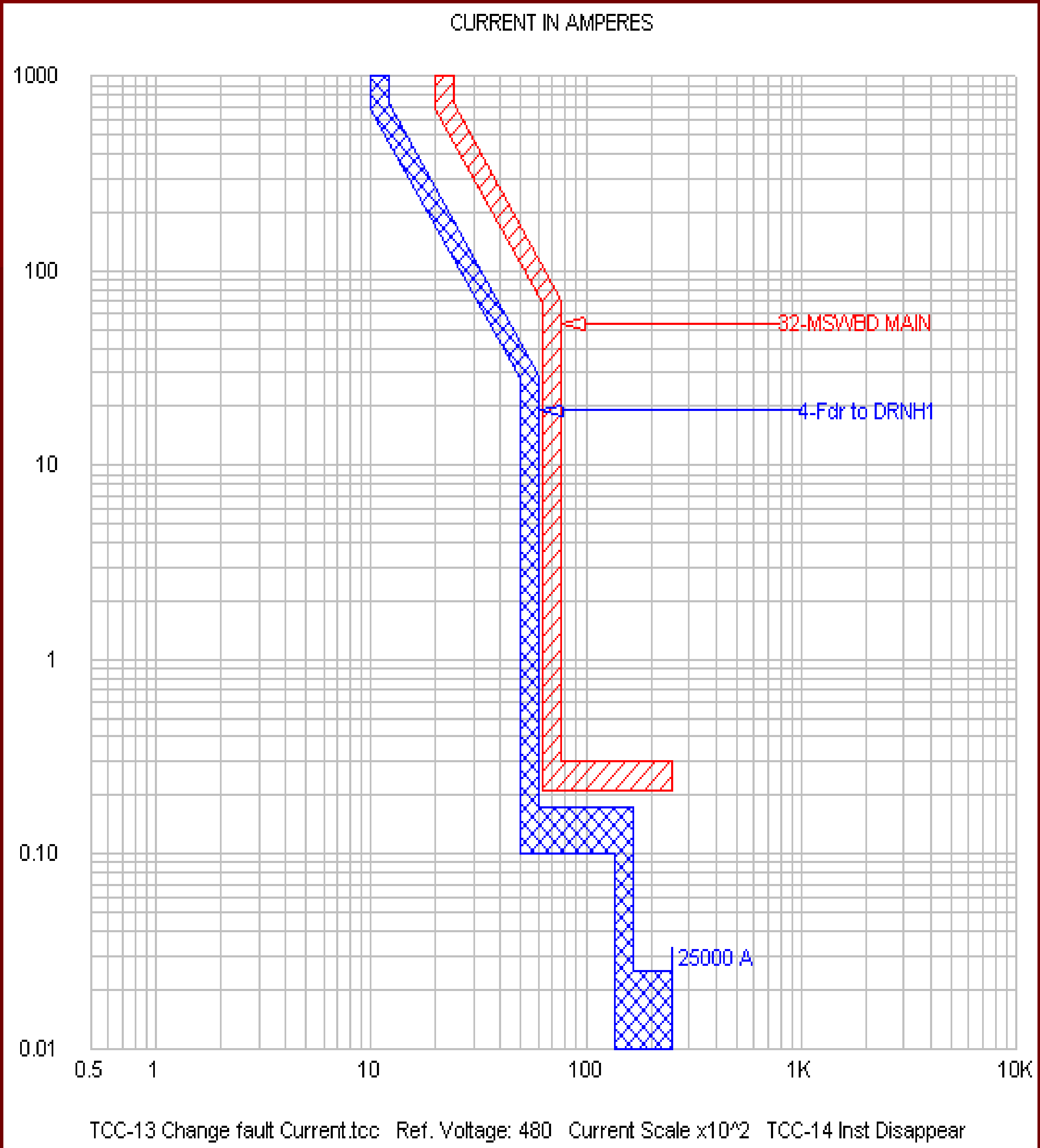
Instantaneous Function – SS Trip

- Instantaneous curve ends at available fault current
- 30,000 Amps



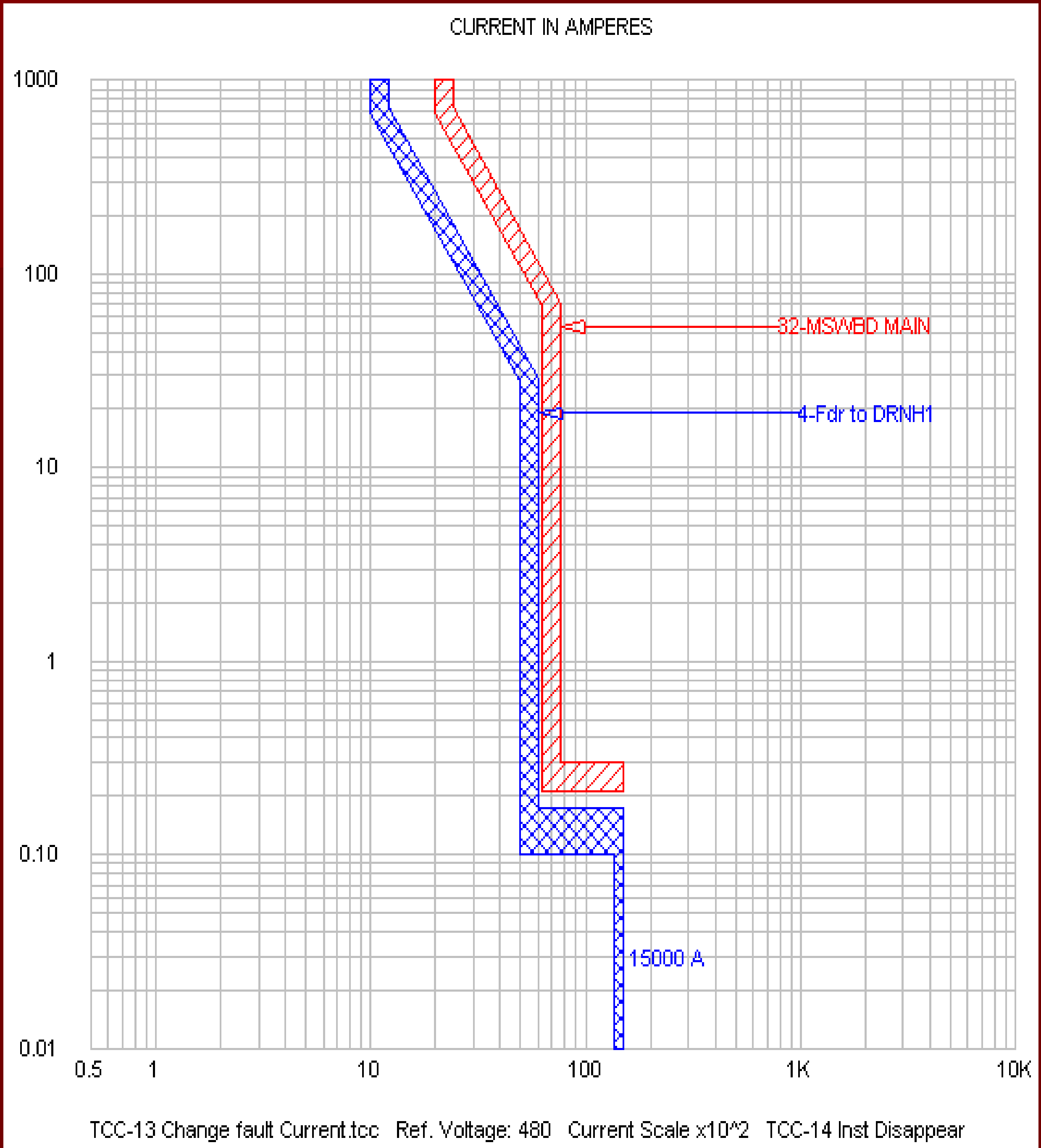
Instantaneous Function – SS Trip

- Instantaneous curve ends at available fault current
- 25,000 Amps



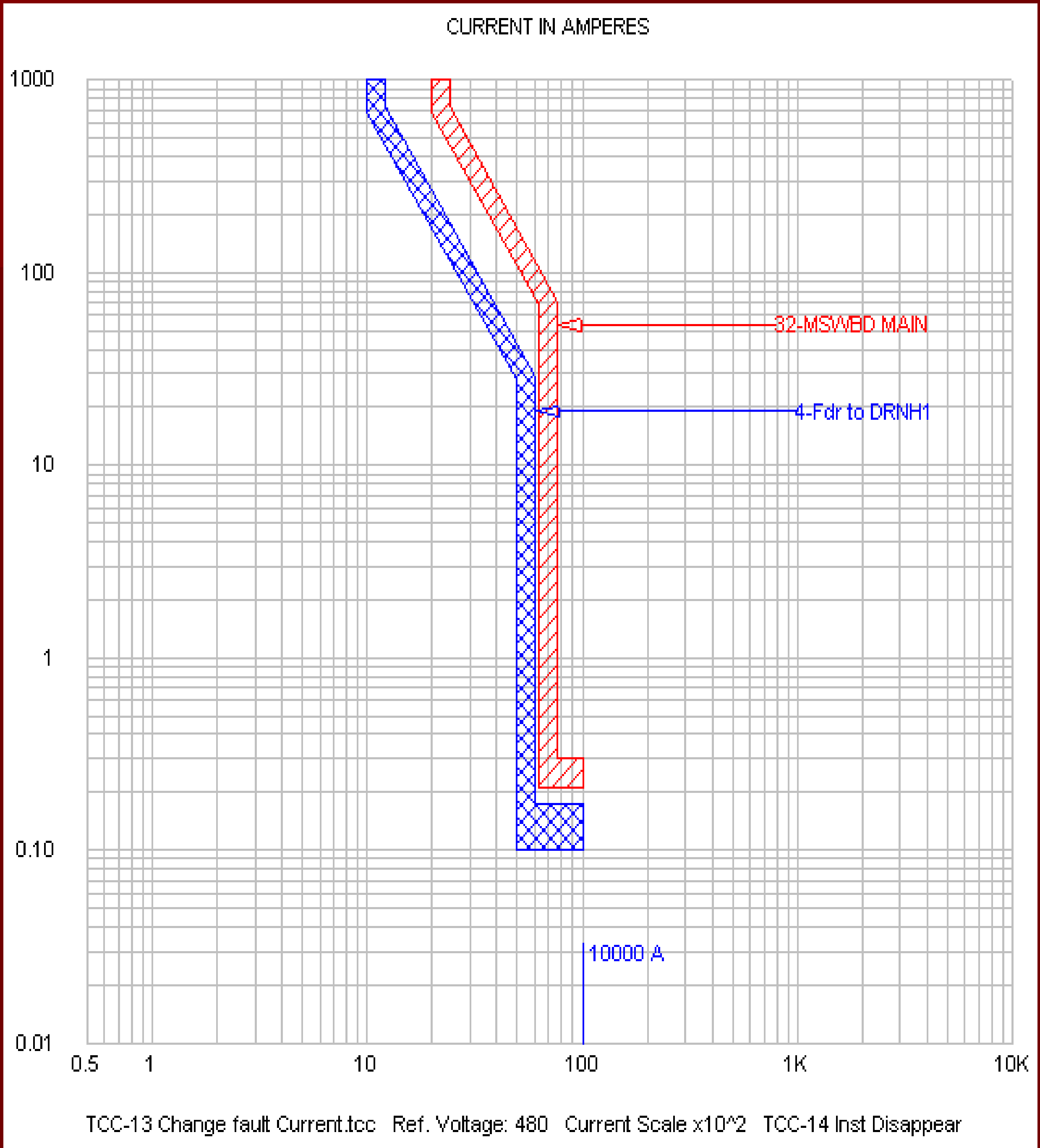
Instantaneous Function – SS Trip

- Instantaneous curve ends at available fault current
- 15,000 Amps



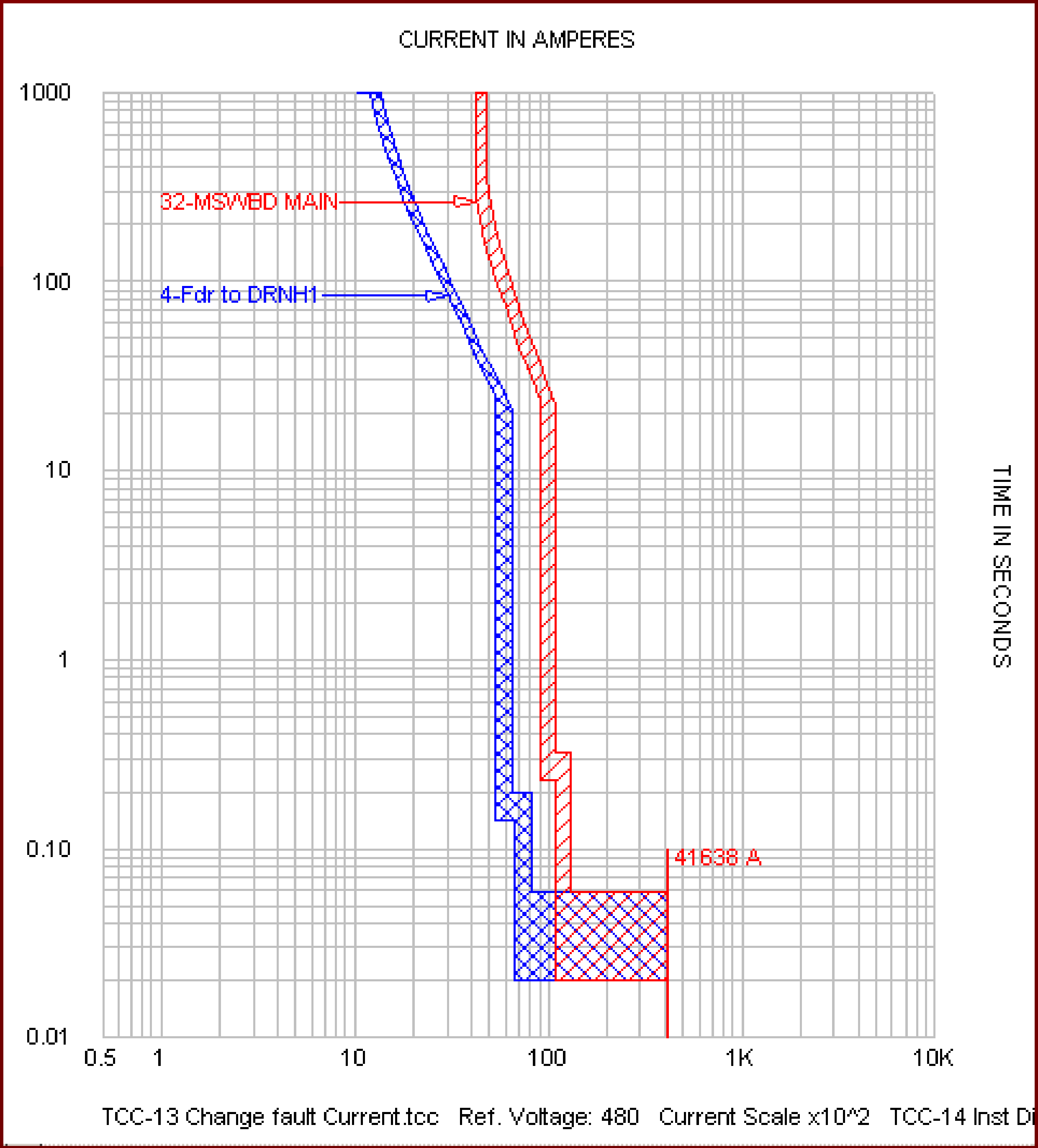
Instantaneous Function – SS Trip

- Instantaneous curve ends at available fault current
- 10,000 Amps



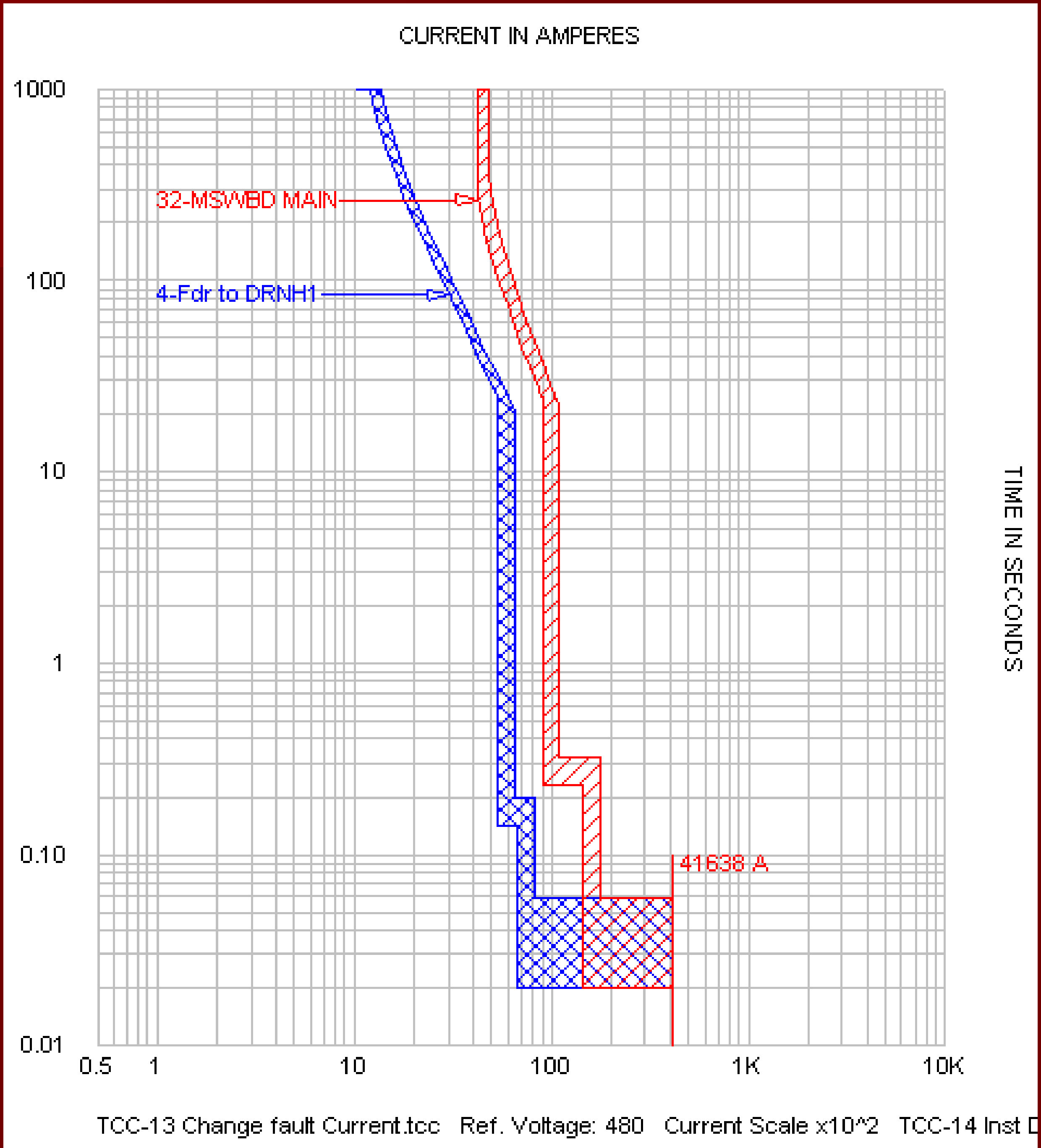
Instantaneous Function – SS Trip

- Adjust Instantaneous curve above the available fault current
- 3X



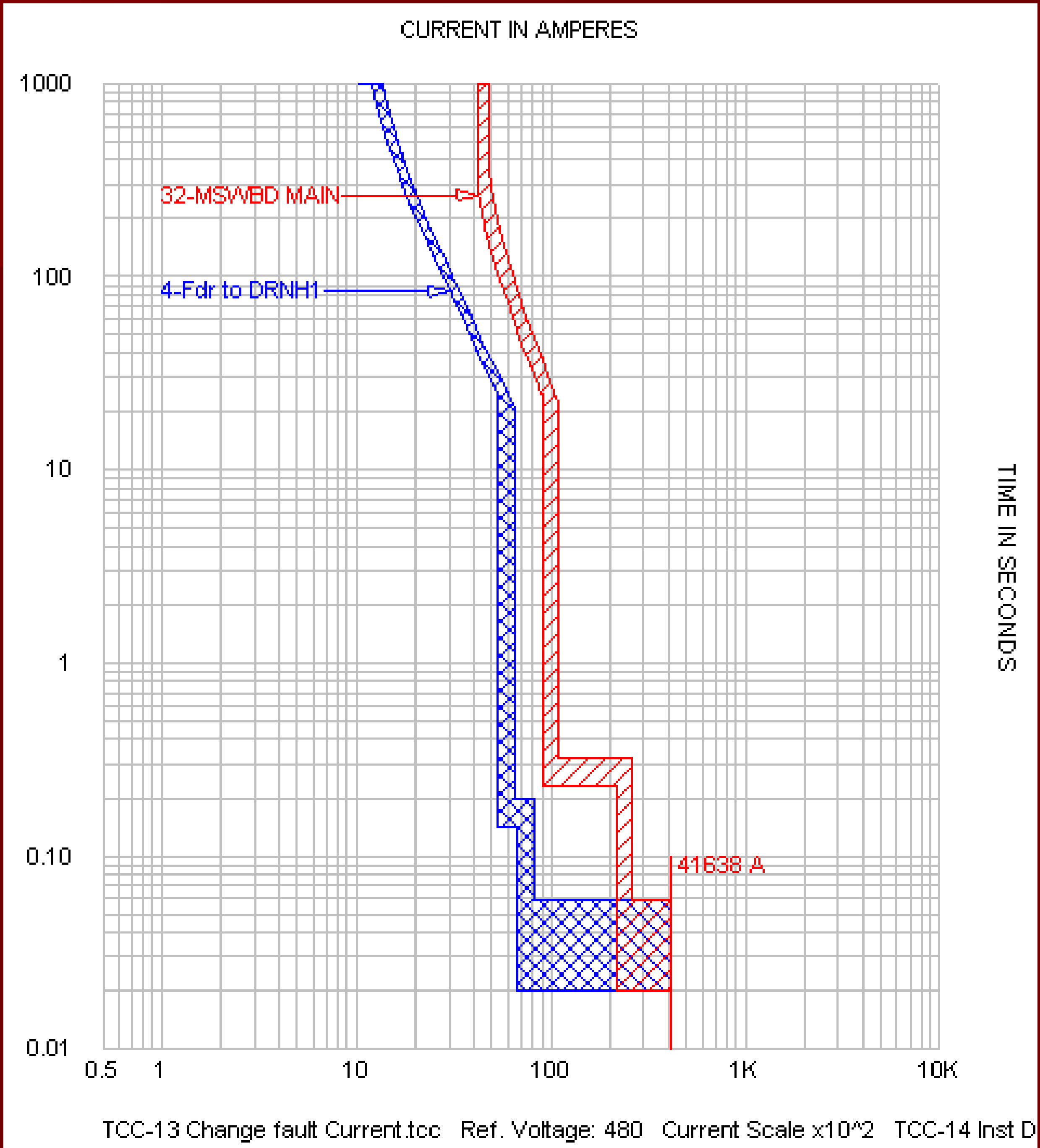
Instantaneous Function – SS Trip

- Adjust Instantaneous curve above the available fault current
- 4X



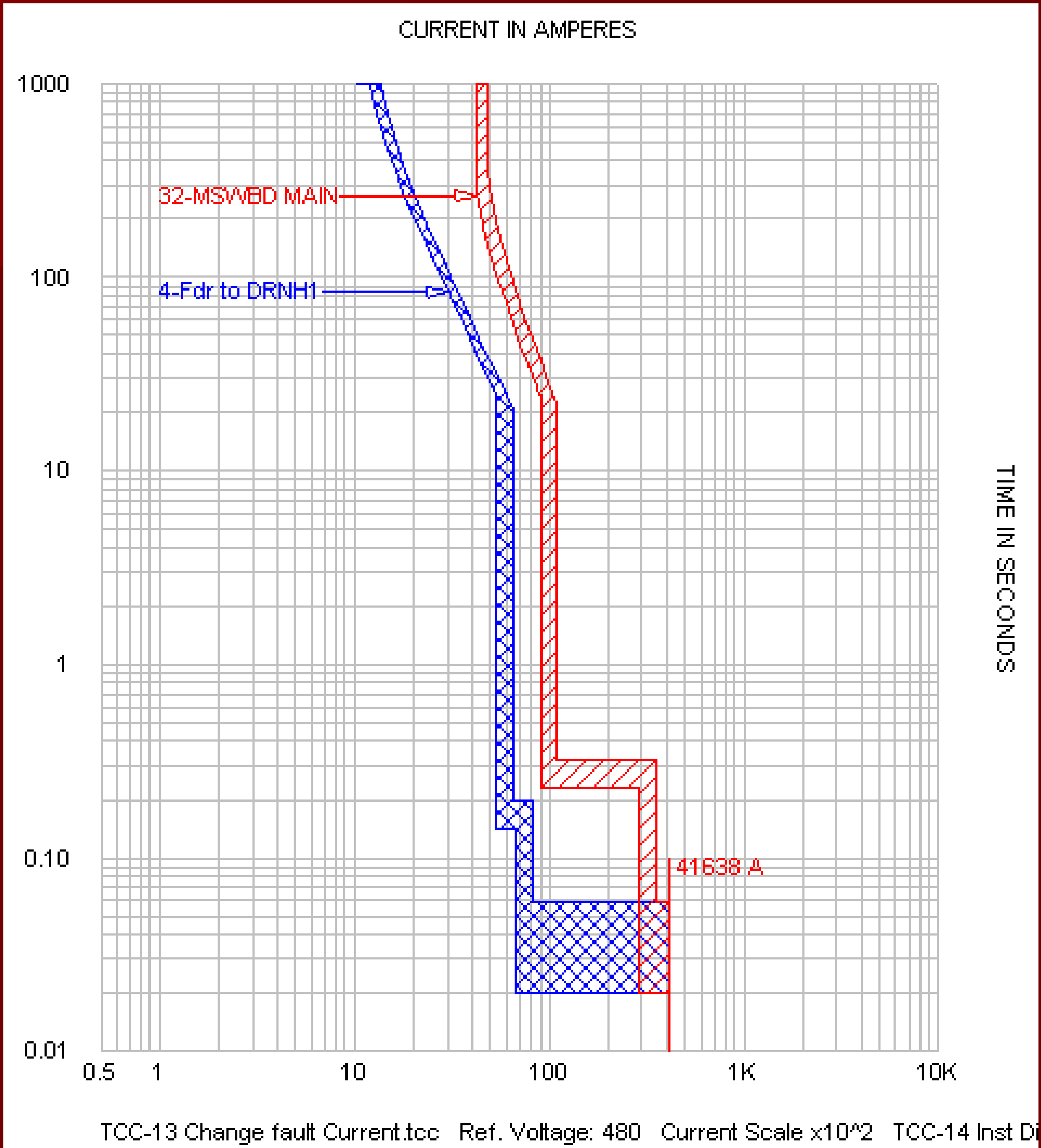
Instantaneous Function – SS Trip

- Adjust Instantaneous curve above the available fault current
- 6X



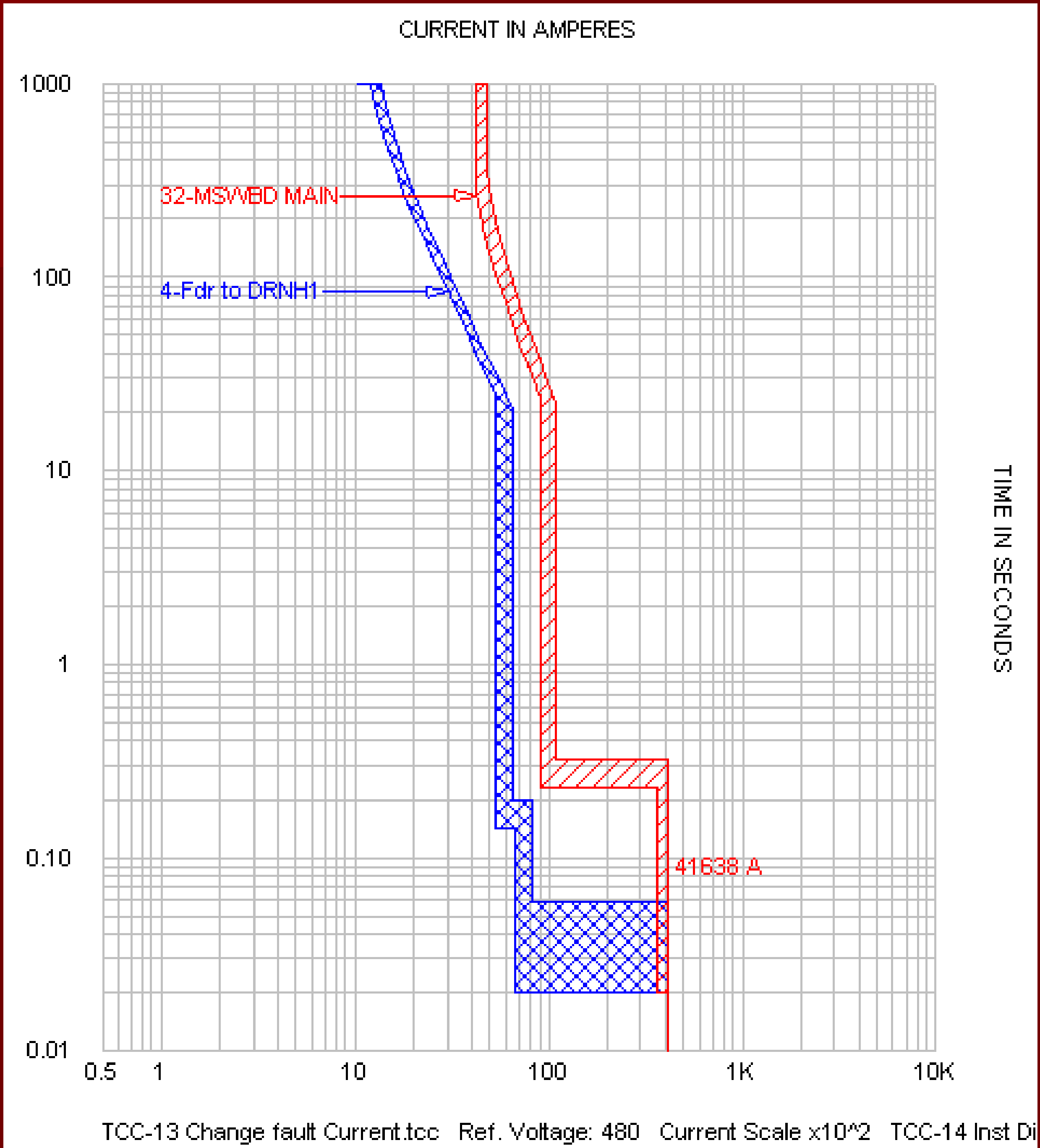
Instantaneous Function – SS Trip

- Adjust Instantaneous curve above the available fault current
- 8X



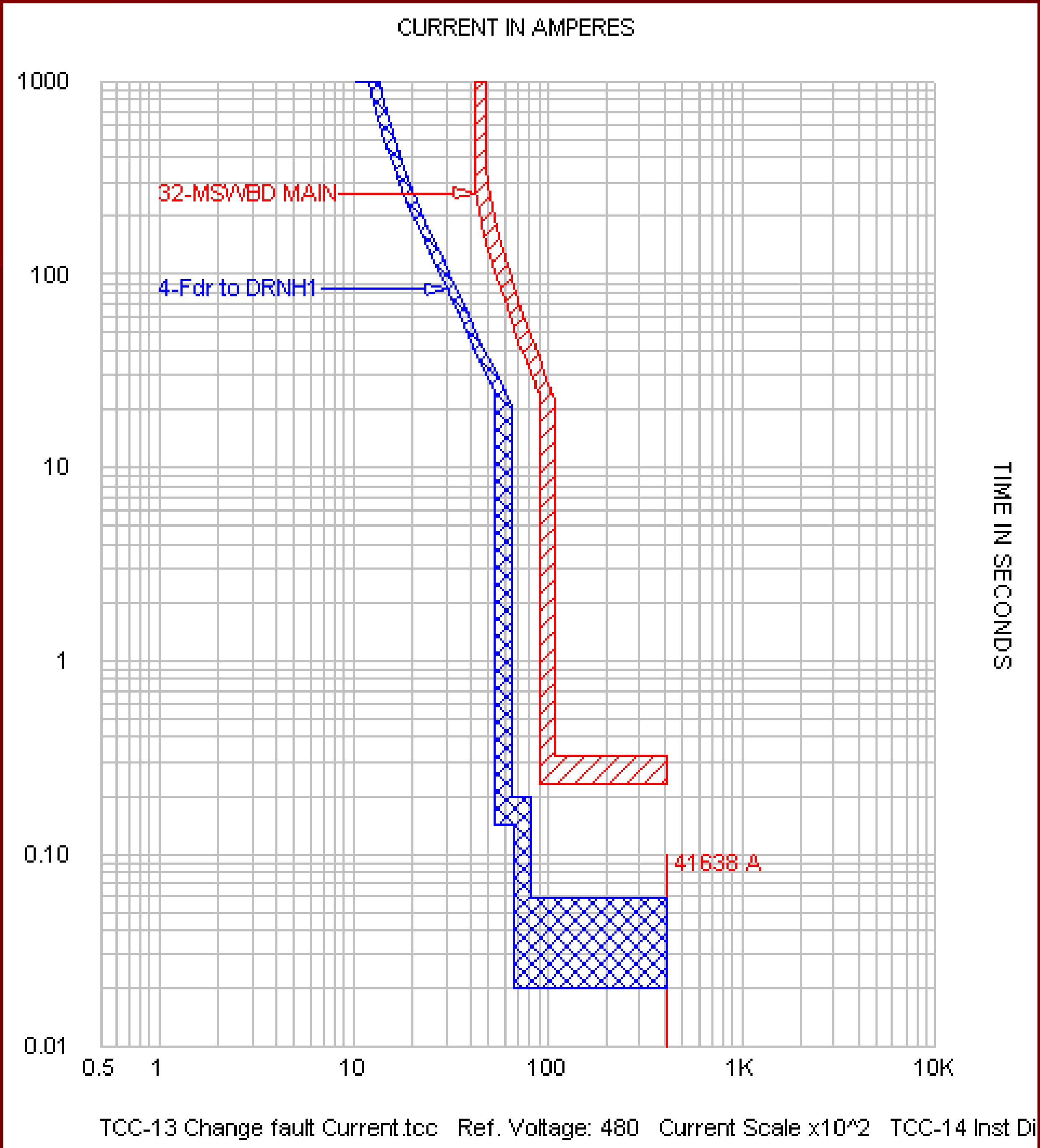
Instantaneous Function – SS Trip

- Adjust Instantaneous curve above the available fault current
- 10X



Instantaneous Function – SS Trip

- Adjust Instantaneous curve above the available fault current
- 12X



Problem – Large Equipment

- Switchboard Feeder and Panelboard Mains many times are ICCB
- Tip #2 – Eliminate Main Breakers in Panelboards.

Switchgear & Switchboard

- Switchgear and switchboard, Panelboard structures are built and tested to different standards:

Switchgear

- ANSI standard C37.20.1
- UL standard 1558
- NEMA standard SG-5
- Switchgear uses power circuit breakers (PCB)
  - ANSI C37.13
  - NEMA SG-3
  - UL-1066
- Unfused switchgear short circuit tested 30 cycles

Switchgear

Instantaneous trip function not required for LVPCBs.

Switchboards

- Group Mounted
- Switchboards Standards
  - NEMA PB-2
  - UL-891.
- Switchboards may use a combination of protective devices

Switchboards – Devices to Use

- Insulated case (ICCB)
- Molded-case circuit breakers (MCCB)
- Fusible switches
- Power circuit breakers

Group-mounted Switchboards, – Short Circuit Testing

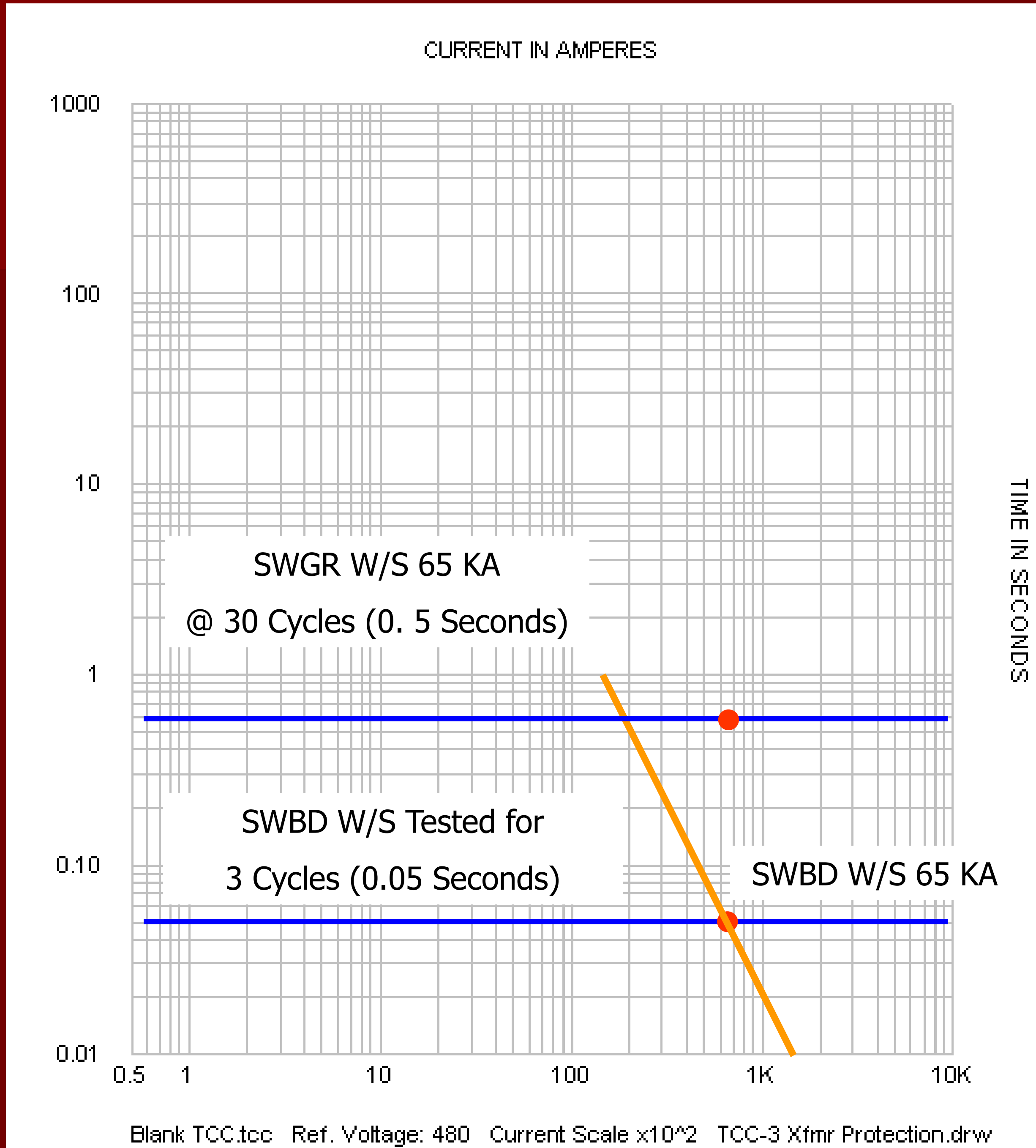
- Short Circuit tested for only 3 cycles
- Protective devices must have instantaneous for UL 891 label
- This Instantaneous trip function reduces selectivity between the main and feeder circuits breakers.

Compartmented Switchboards

- Short Circuit tested for 30 cycles.
- UL 891 Listed

SWBD & SWGR Testing

- ANSI, NEMA, & Manufacturers ….. We need an I2T Withstand Curve!!!!

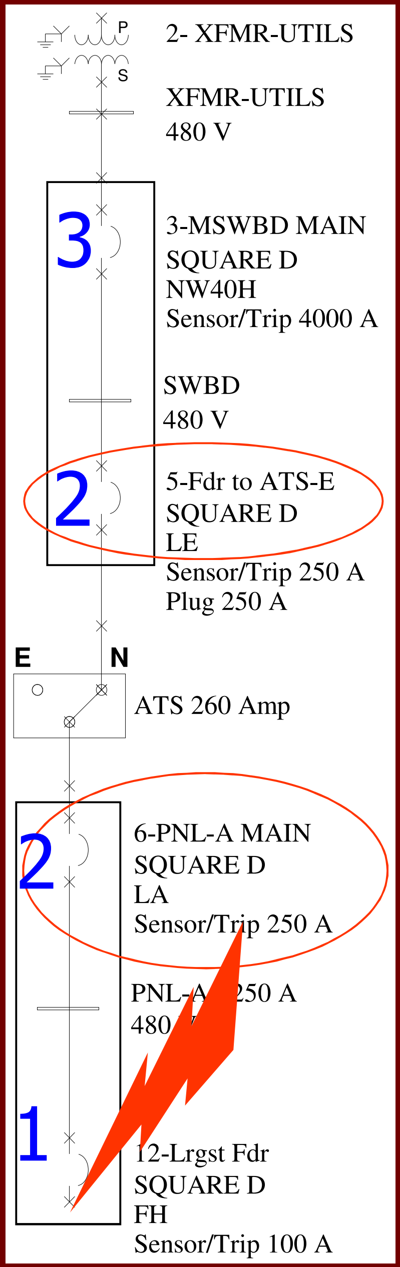


More Tips

- Tip #3
  - T/M breakers must have a 3:1 ratio to selectively coordinate.
- Tip #4
  - Impedance aids in selective coordination
  - Long feeder lengths
  - Air core reactors
  - Transformers

Tip #5 – Feeders to Downstream Mains

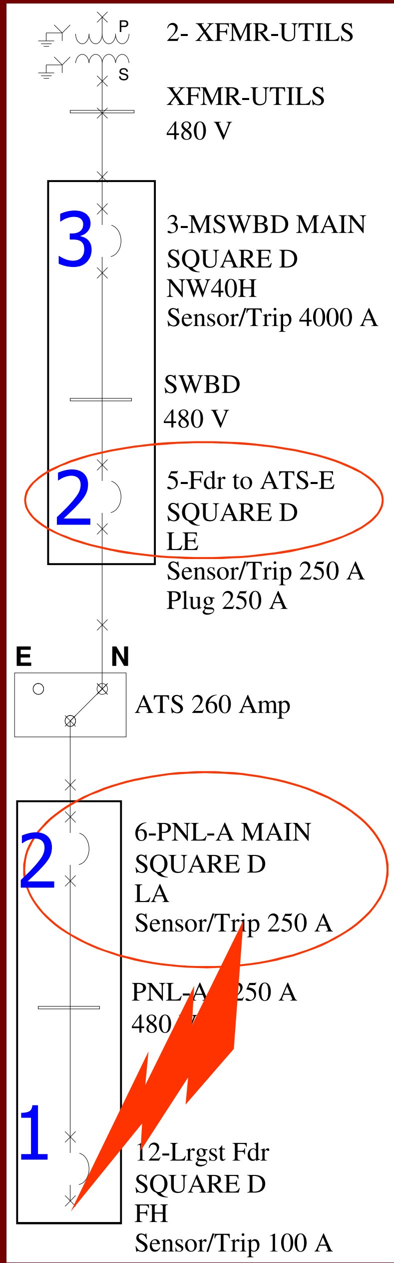
- Feeders to Equipment Main Devices, do not need to coordinate.
- 700.27 & 701.27 (but not 708.54) Coordination. Emergency system(s) overcurrent Exception:



Tip #5 – Feeders to Downstream Mains

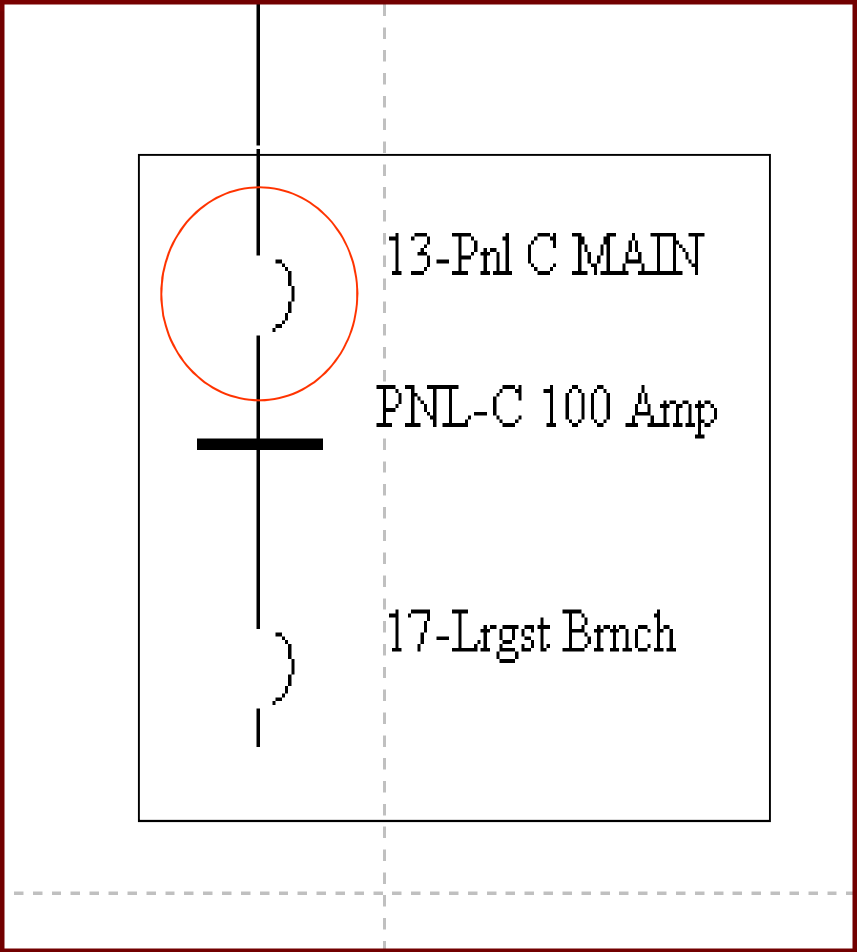
- Selective coordination shall not be required between two overcurrent devices located in series if no loads are connected in parallel with the downstream device.

- They feed the same load!
- Impossible to do with SS Trip Breakers. (LTPU Region)
- Impossible to do with fuses.



Panelboard Mains - MCS

- Use Caution when using Molded Case Switches (MCS)
- May have very low self -protecting instantaneous function

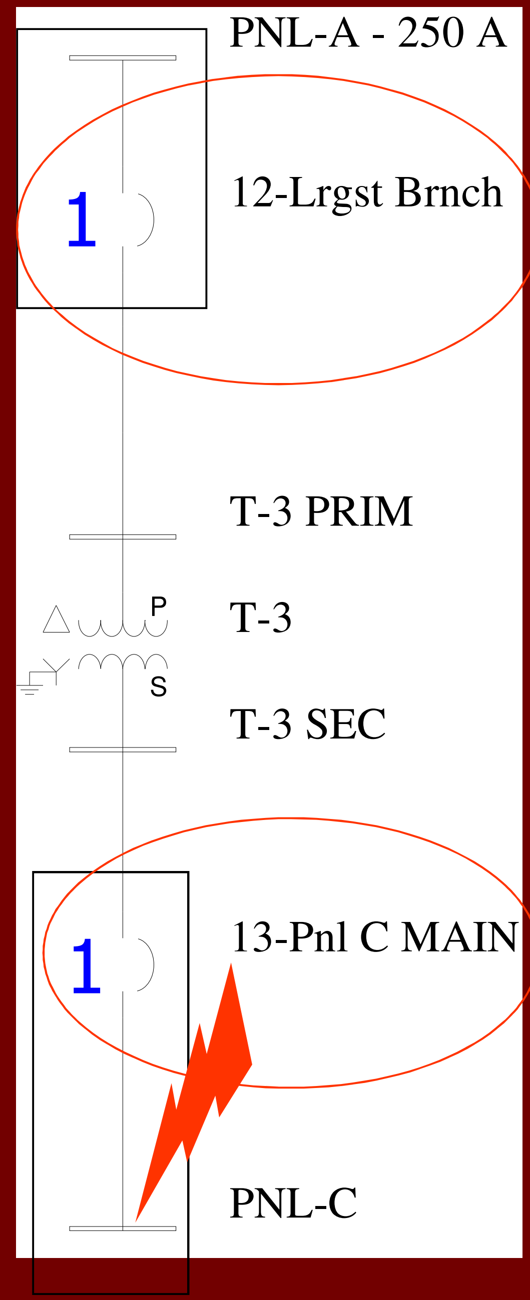


Transformer Protection

- NEC Table 450.3(B) Maximum Rating or Setting of Overcurrent Protection for Transformers
- Delta-Wye LV Transformers require
  - Primary Protection @ ≤ 250% rating
  - Secondary Protection @ ≤ 125%* rating
  - *Use next highest standard rating allowed (see Table 240.6)
- Tip #6 – Keep Table 240.6 within reach

Tip #7 – Primary & Secondary Protection

- Primary & Secondary Devices, do not need to coordinate.
- They feed the same load!
- Difficult to do with fuses. No Fuse selectivity tables.
- Possible with CBs



More Tips

- Tip #8* - Use SS Trips with LSI(0ff) or Fixed Instantaneous Override
- Tip #9* – Specify that SS Trip Units have adjustable:
  - LTPU / LTD
  - STPU / STD / I2T
  - INST(OFF) or Instantaneous Override (above 110% fault current at downstream device)

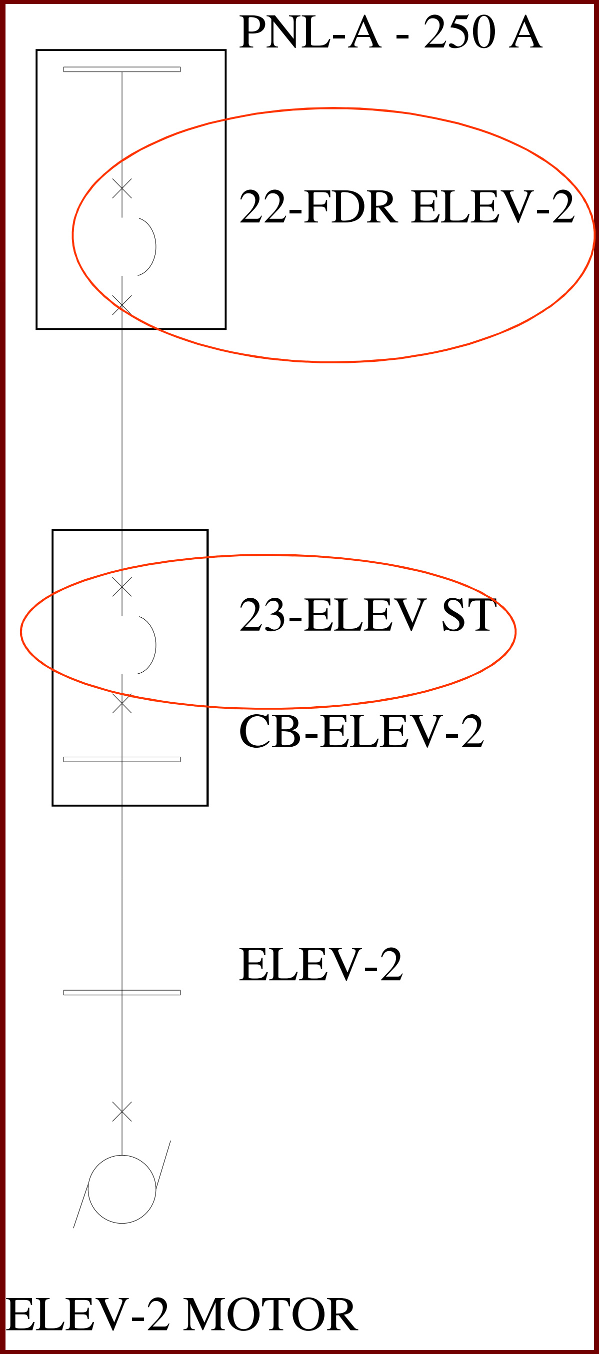
* - Do not forget the generator breaker

Elevator Selective Coordination

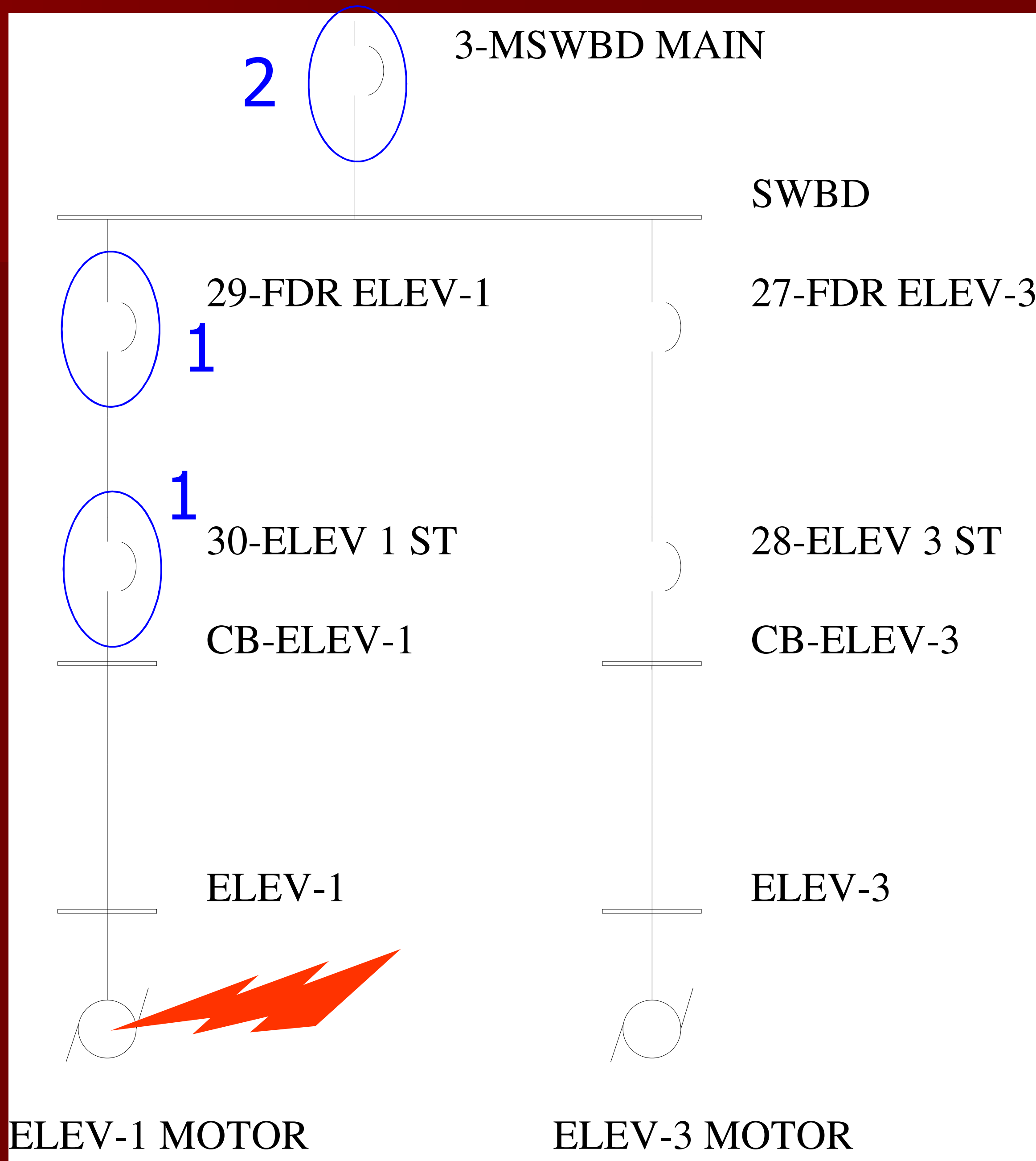
- Elevator Circuits must be selectively coordinated.

Tip #10 – Elevator Circuit Coordination

- Feeder and Shunt Trip Devices, do not need to coordinate.
- They feed the same load!
- Impossible to do with fuses if fuses are same size.
- Impossible with CBs

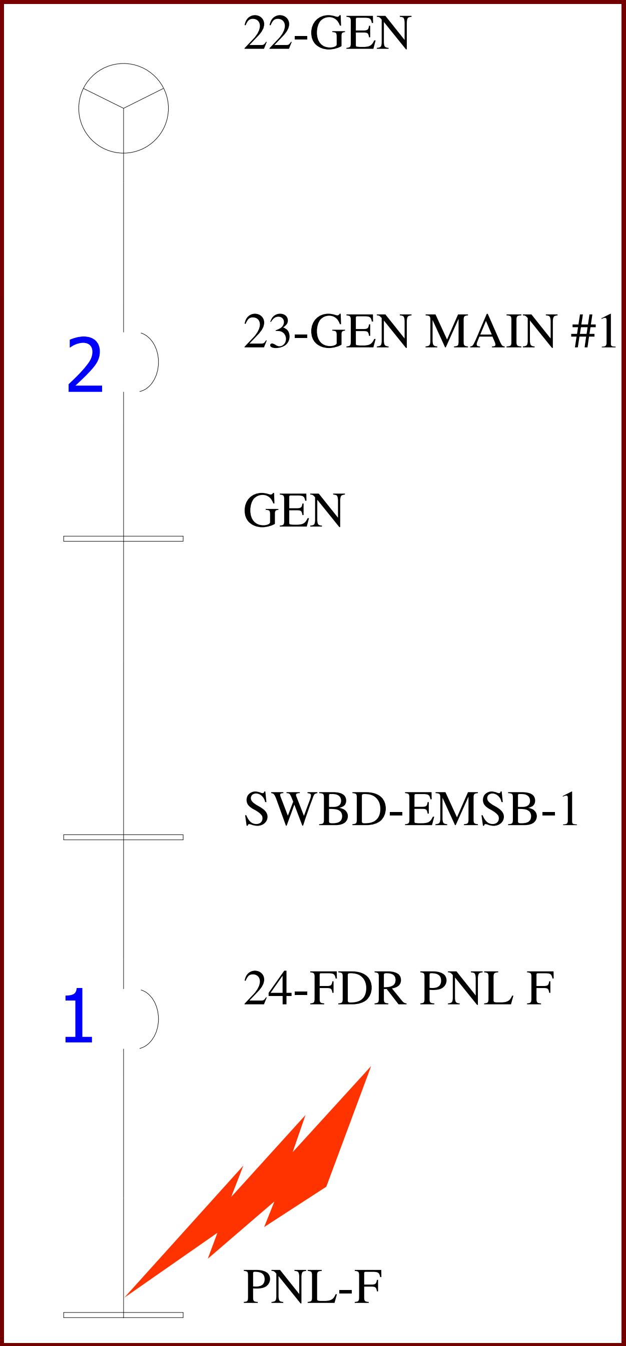


Elevator Circuit Coordination



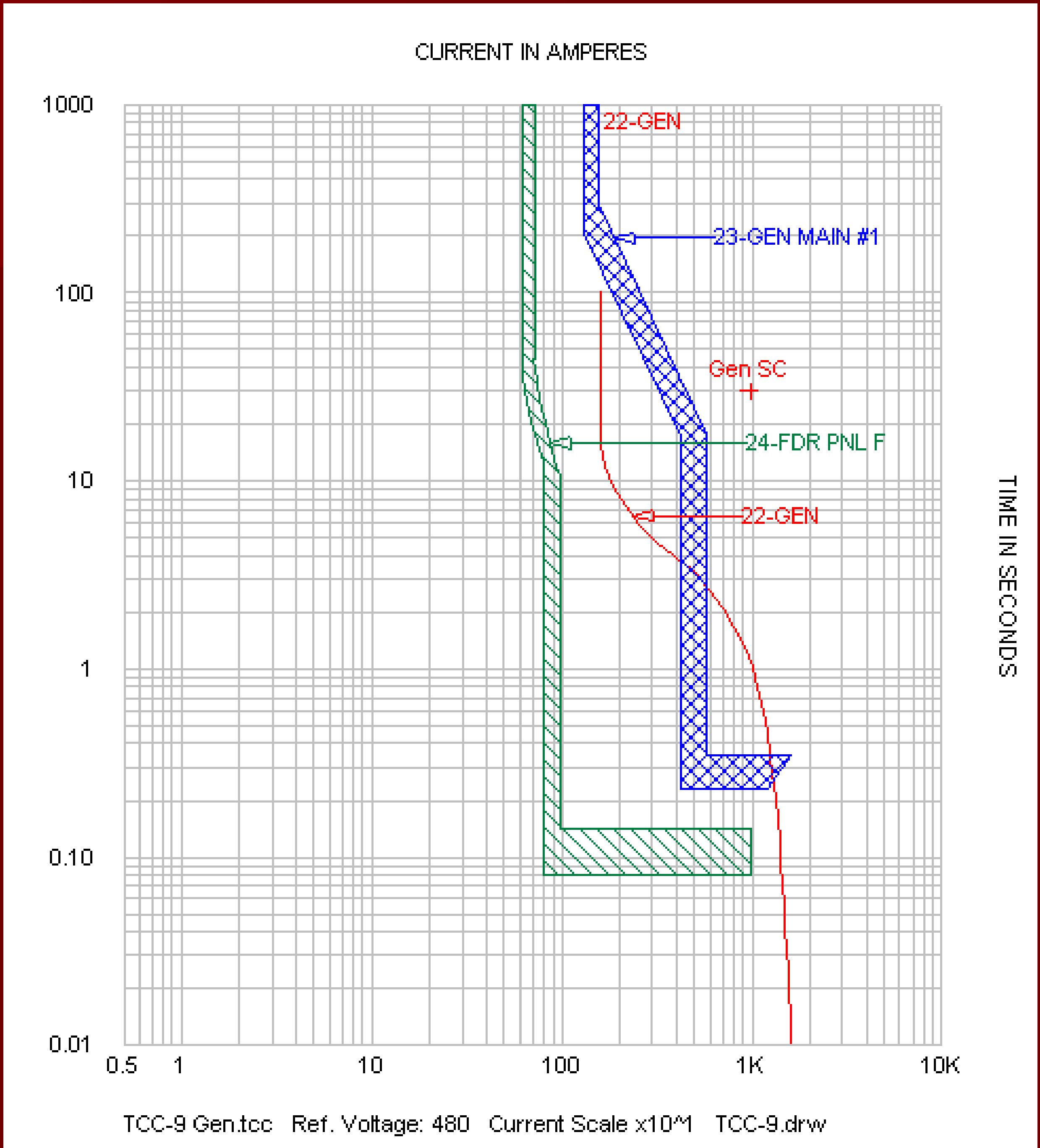
Generator Coordination

- Must Coordinate as well
- Good News! - Lower Fault Currents
- Easier to Coordinate



Gen PDC

- Decrement Curve
- Fault Current < Instantaneous Setting
- Requires 30 Cycle ATSs?

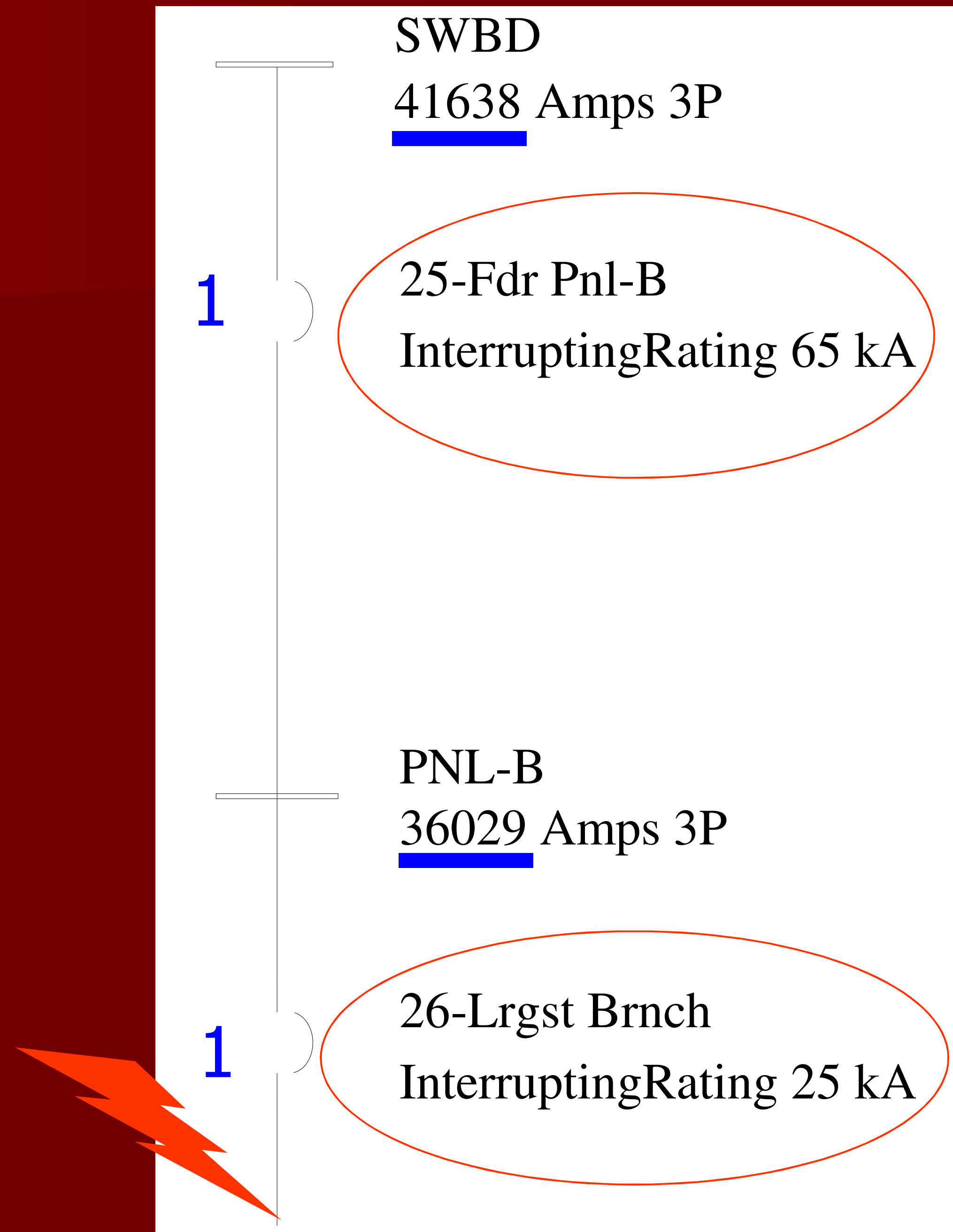


Series Rating of Devices

- Two or More Devices are Short Circuit Tested in Series
- Combinations can be
  - Circuit Breaker
  - Fuses
  - Fuses and Circuit Breakers
- Last device AIC (SC) Rating < Available
- All Devices will operate

Series Rating of Devices

- UL Listed Combination is Series Rated 65 kA
- No Selective Coordination
- Tip #11 – Do Not Use Series Rated Devices



Steps to Meet the Code

- Obtain Utility Data
  - Maximum size of transformer (kVA)
  - Impedance
  - Winding Connections
  - Maximum available primary three phase and line to ground short circuit current
- If selective coordination works for Max Xfmr kVA, then smaller Xfmr will also work.

Steps to Meet the Code

- Model the distribution system in computer
- Perform Short Circuit Study to determine 3P and L-G faults.
- Determine Equipment Full Load Ratings (FLA)

Steps to Meet the Code

- Determine protective device
  - Standard Ampere Rating (NEC 240.6)
  - Short circuit interrupting rating (AIC)
  - Downstream coordination current (DCC)
- Tip #12 – Put the SC numbers on the One Line Drawing

Steps to Meet the Code - Circuit Breakers

- Choose a device manufacturer
- Use NEC, DCC and Circuit Breaker Selection Table
- Pick circuit breakers with instantaneous trips above the DCC.

Steps to Meet the Code - Circuit Breakers

- Plot breaker curves to
  - Verify selective coordination
  - Determine device settings
- For new design projects
  - Repeat above steps for other manufactures
  - Create detailed specifications for competitive bidding
  - Specify the Breaker Trip Unit Types (T/M or SS) and Instantaneous Override Values.

Steps to Meet the Code - Circuit Breakers

- Tip #13 - Add to Project Specifications:

"Where indicated on one line drawing, breakers must have trip units with Instantaneous setting or override ampere rating 110% above the values shown on one line drawing."

Steps to Meet the Code - Fuses

- Use Selectivity Ratio Guide to determine fuse sizes.
- Verify Generator Breaker and Downstream Fuses will coordinate.
- Repeat for multiple fuse manufactures for competitive bidding.

517.17 Ground-Fault Protection.

- (C) Selectivity.
  - Ground-fault protection for operation of the service and feeder disconnecting means shall be fully selective such that the feeder device, but not the service device, shall open on ground faults on the load side of the feeder device.

Ground-Fault Protection

- Code Requires Ground Fault Selective Coordination for Main and Feeders (medical facilities) only.
- Code does not state that Ground Fault Protection Must Coordinate with the Phase Protection.
- Considered a different protection scheme
- Maximum Pickup setting is 1,200 Amperes
- Maximum Time Delay setting is 0.5 sec.

Ground-Fault Protection

- Limited Equipment options for fuses
  - Fuses can not detect low level ground faults
  - Require ground fault relays and pressure bolted switches.
- For Circuit Breakers and Fuses
  - Usually impossible to prevent overlap with ground fault and phase devices.

More Problems with the Code

- Modifications or additions to a facility.
- How far do you go to implement selective coordination?
- Small Transformers (15-45 kVA) and Panelboards

More Problems with the Code

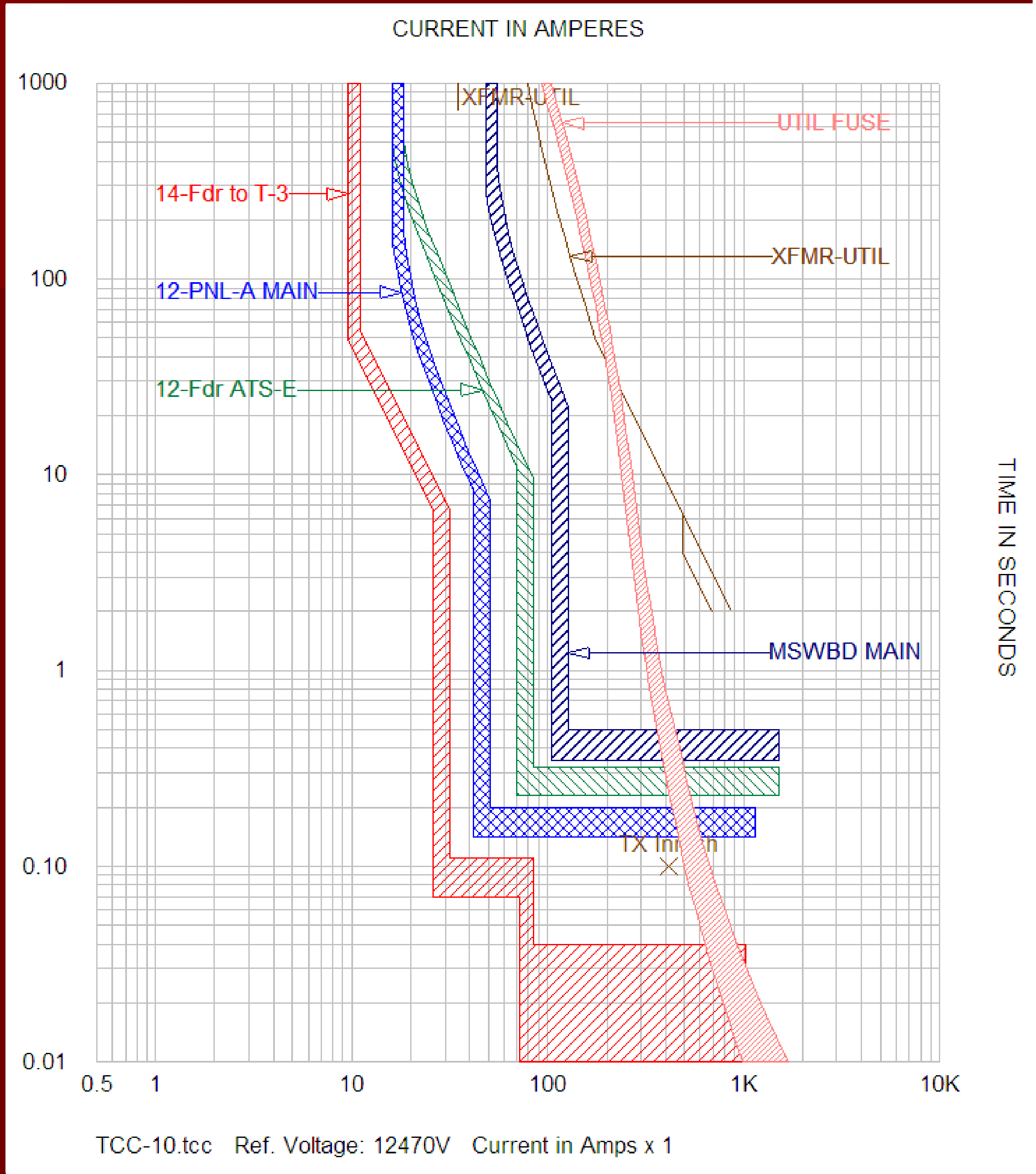
- Hospital Isolation Panelboards

More Problems with the Code

- Utility Transformer Sizing
  - NEC forces designers to over design a building.
  - Actual load 1st year is less than 50% of the design demand.
  - Utilities size transformers 30 – 50% of the designers demand load.
  - Utility fuse overlaps with downstream mains and feeder breakers.

Undersized Utility Transformers

- What the design engineer thinks the size will be. (2000 kVA)
- What the utility installs. (750 kVA)



More Problems with the Code

- Are we sacrificing reliability for safety???
- Decrease in levels of OCPD means...
  - Elimination of mains in Panelboards
  - Feed thru lugs used for riser panelboards
- Longer device delays usually causes higher Arc Flash Energy levels.

Arc Flash

- **Arc Flash:** Violent eruption of energy from an electrical source.

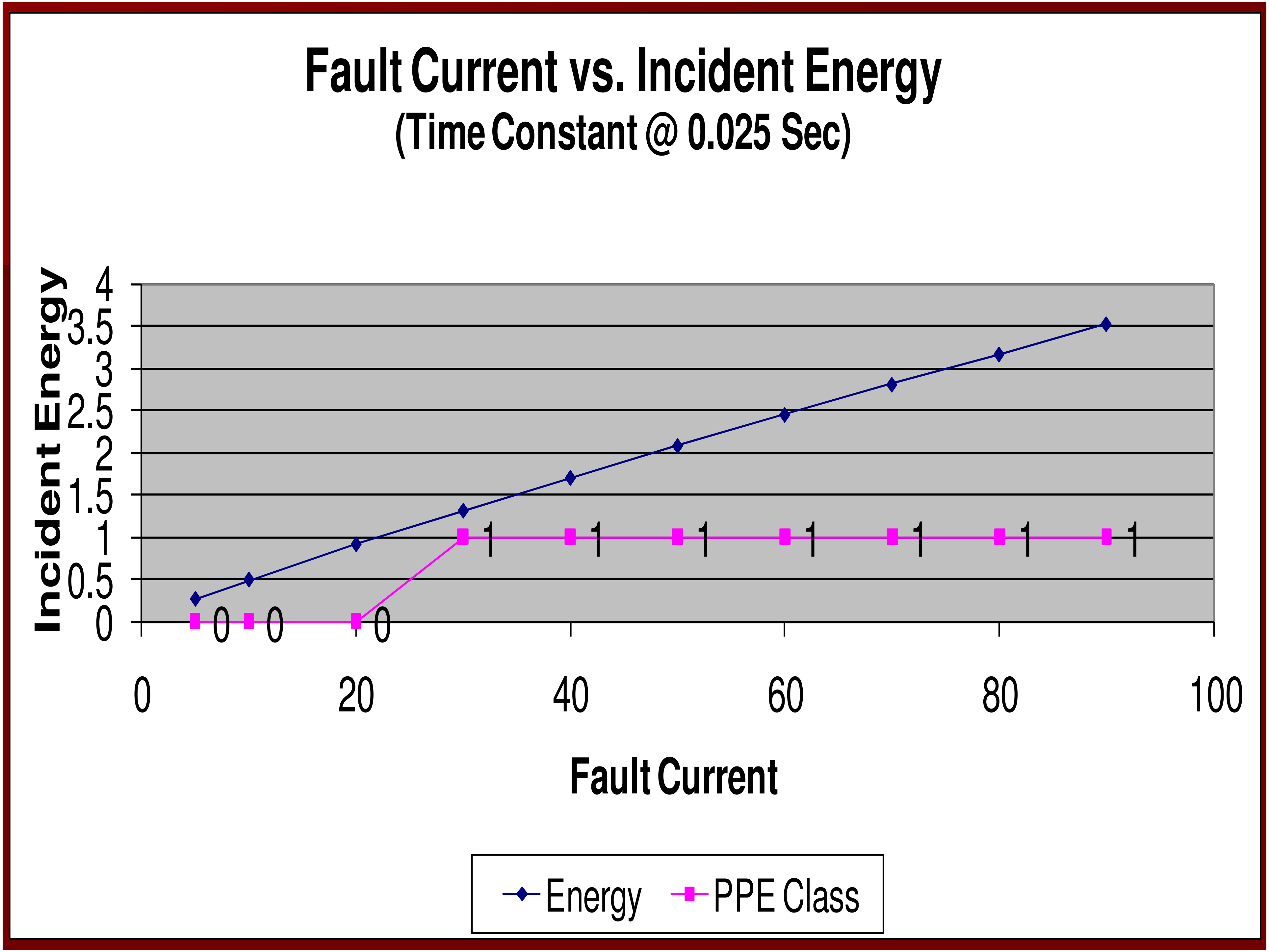
- Arc temperature can reach 35,000°F.
- Fatal burns can occur at distances over 10 feet.
- Over half of all arc flashes occur at 277 volts.

Arc Flash

Arc Flash – Breaker Racking

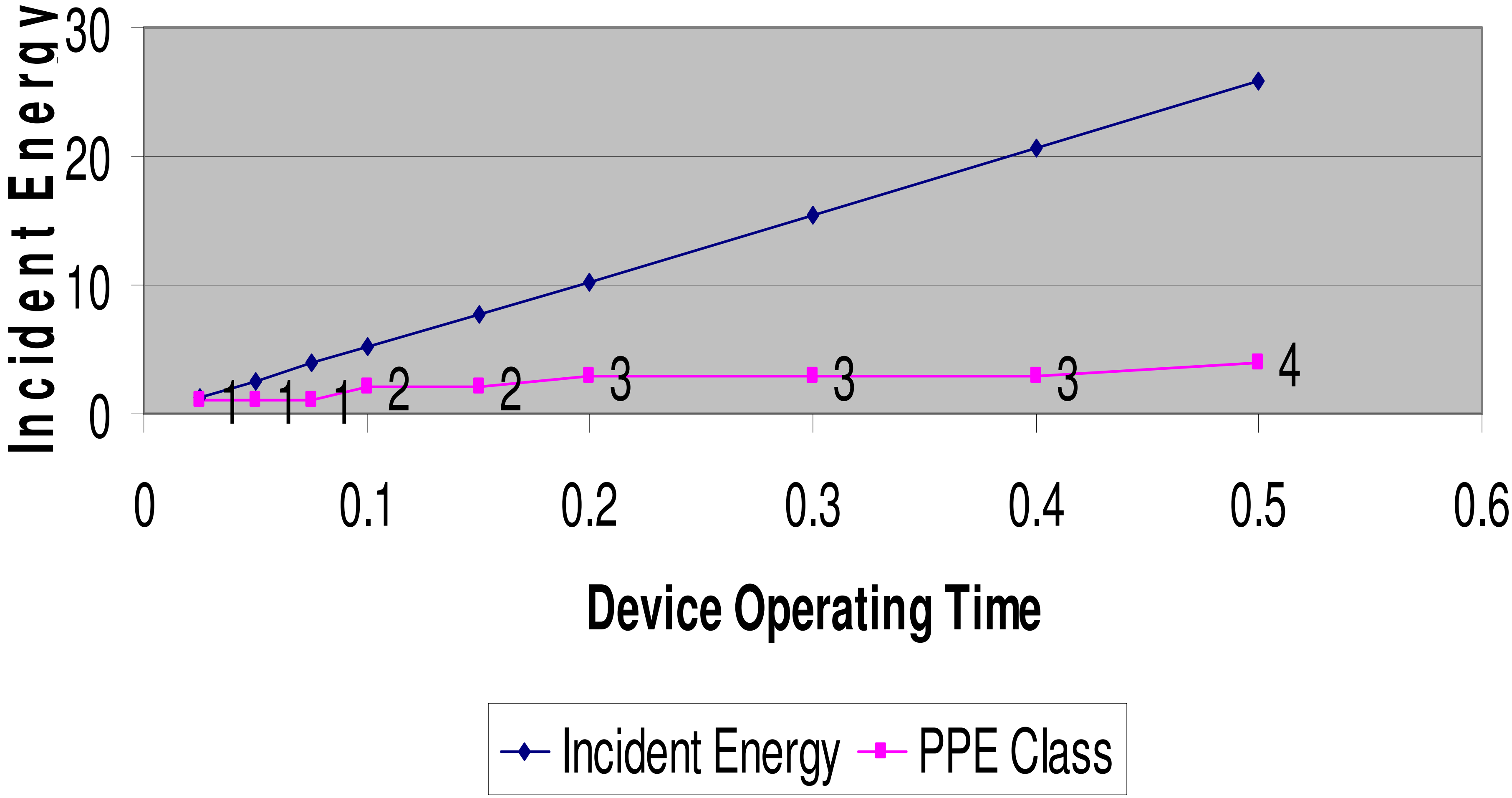
Arc Flash Energy Calculations

- Incident Energy Levels (HRC) are dependent on:
  - Level of arcing fault current
  - Upstream device clearing time.
- Multiple Sources can change the value of fault current.
- Changes in fault current can change device operating times.



Fault Current vs. Incident Energy
(Time Constant @ 0.025 Sec)
Incident Energy
4
3.5
3
2.5
2
1.5
1
0.5
0
0 0 0
1 1 1 1 1 1 1
0
20
40
60
80
100
Fault Current
Energy
PPE Class

Time vs. Incident Energy
(Fault Current Constant @ 30 kA)

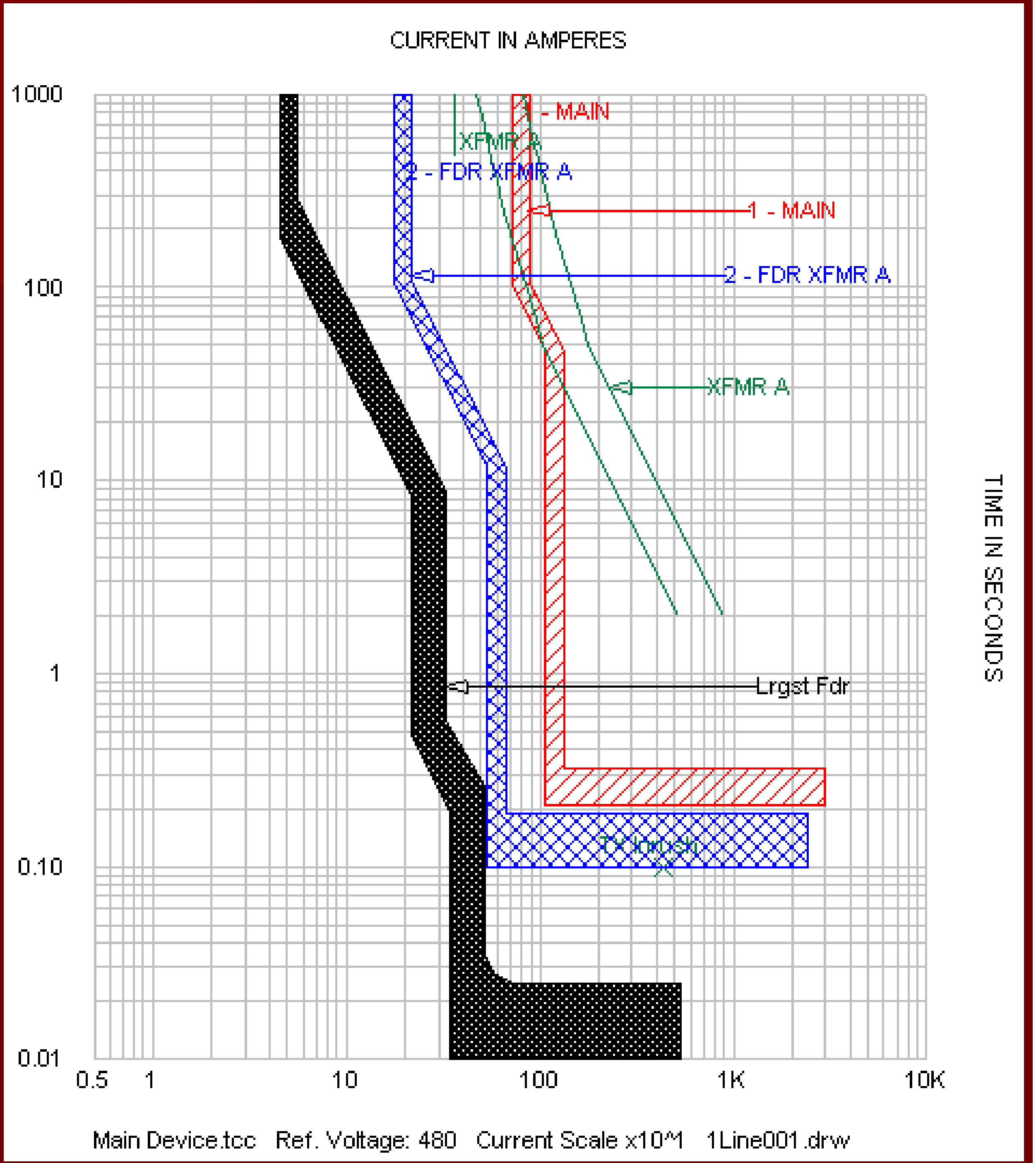


Arc Flash Energy

- Intentionally adding a delay between OCPDs to achieve selective coordination will most likely increase the arc flash energy

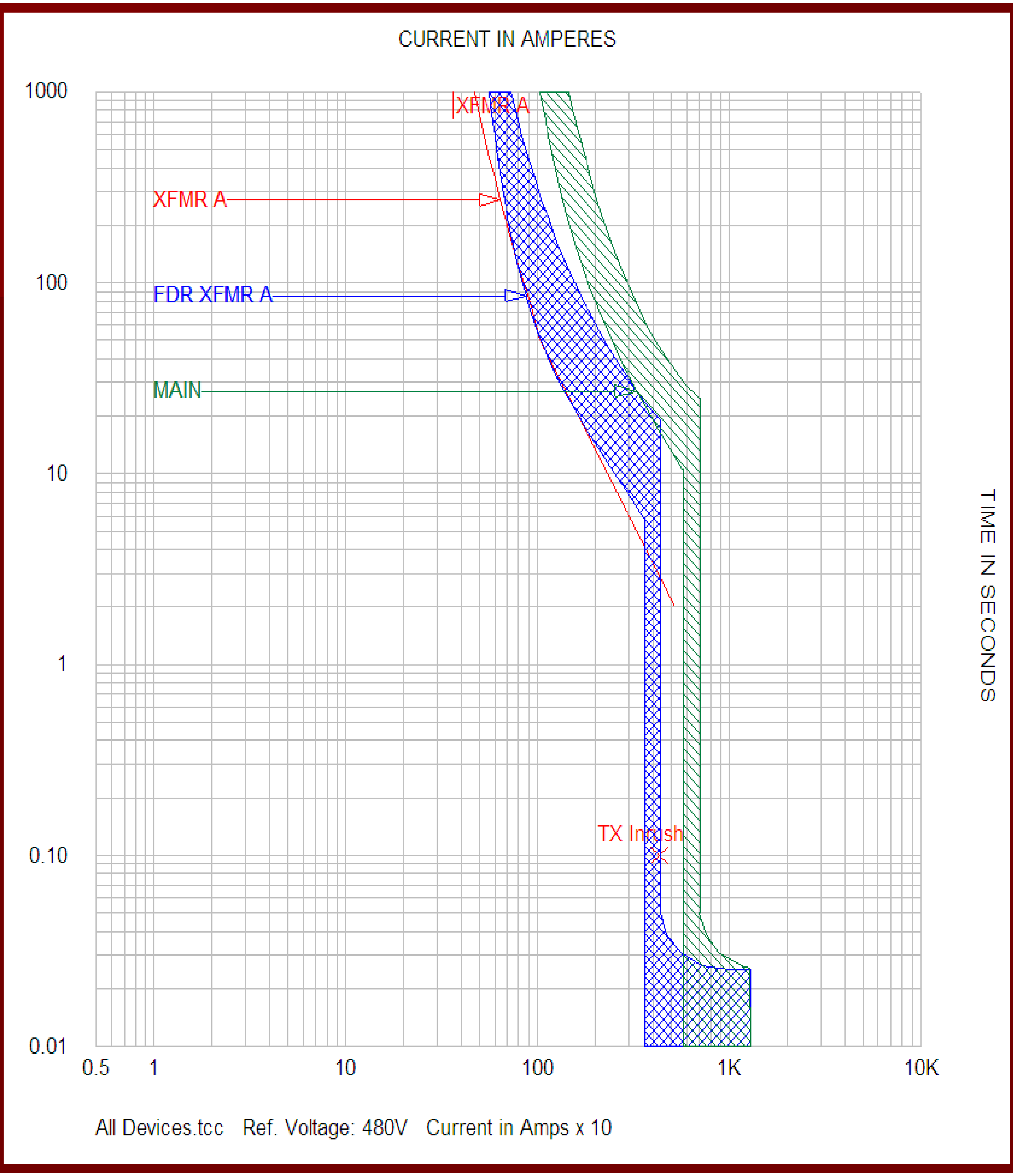
Selective Coordination & Arc Flash Energy

- Arc Flash Energy increases from branch to main



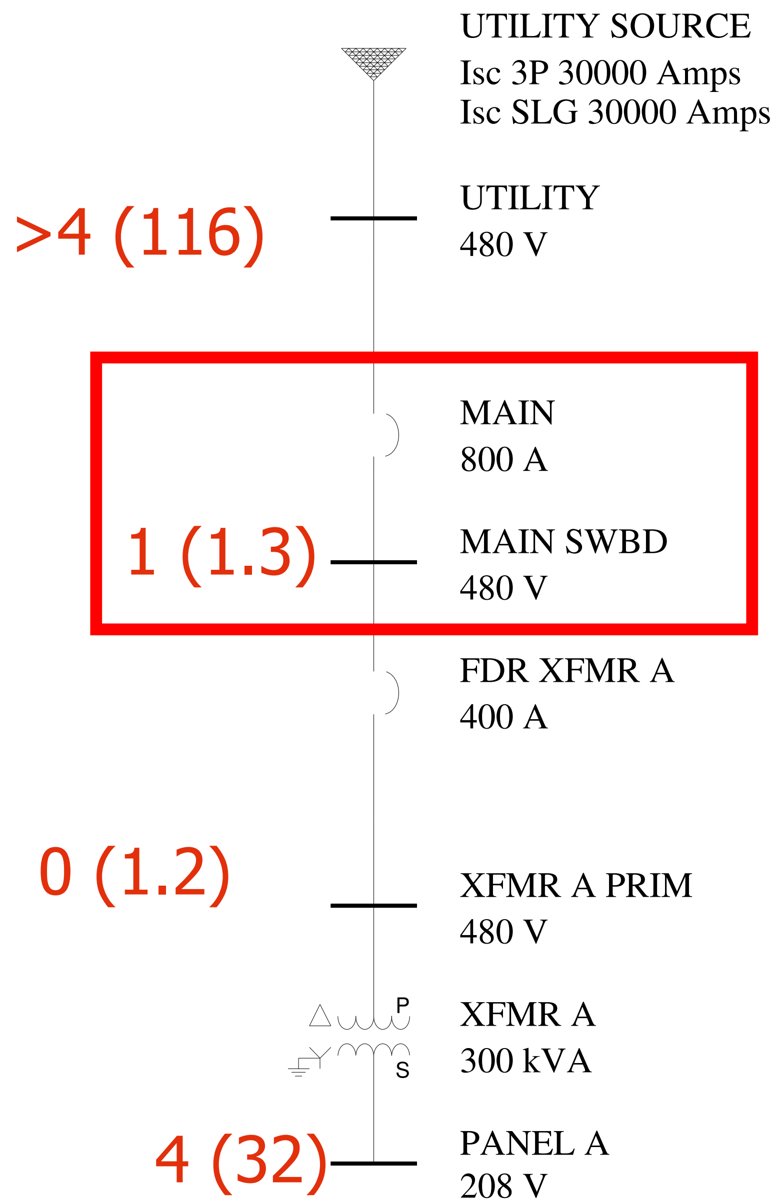
Selective Coordination & Arc Flash Energy

- How we previously used MCCBs.

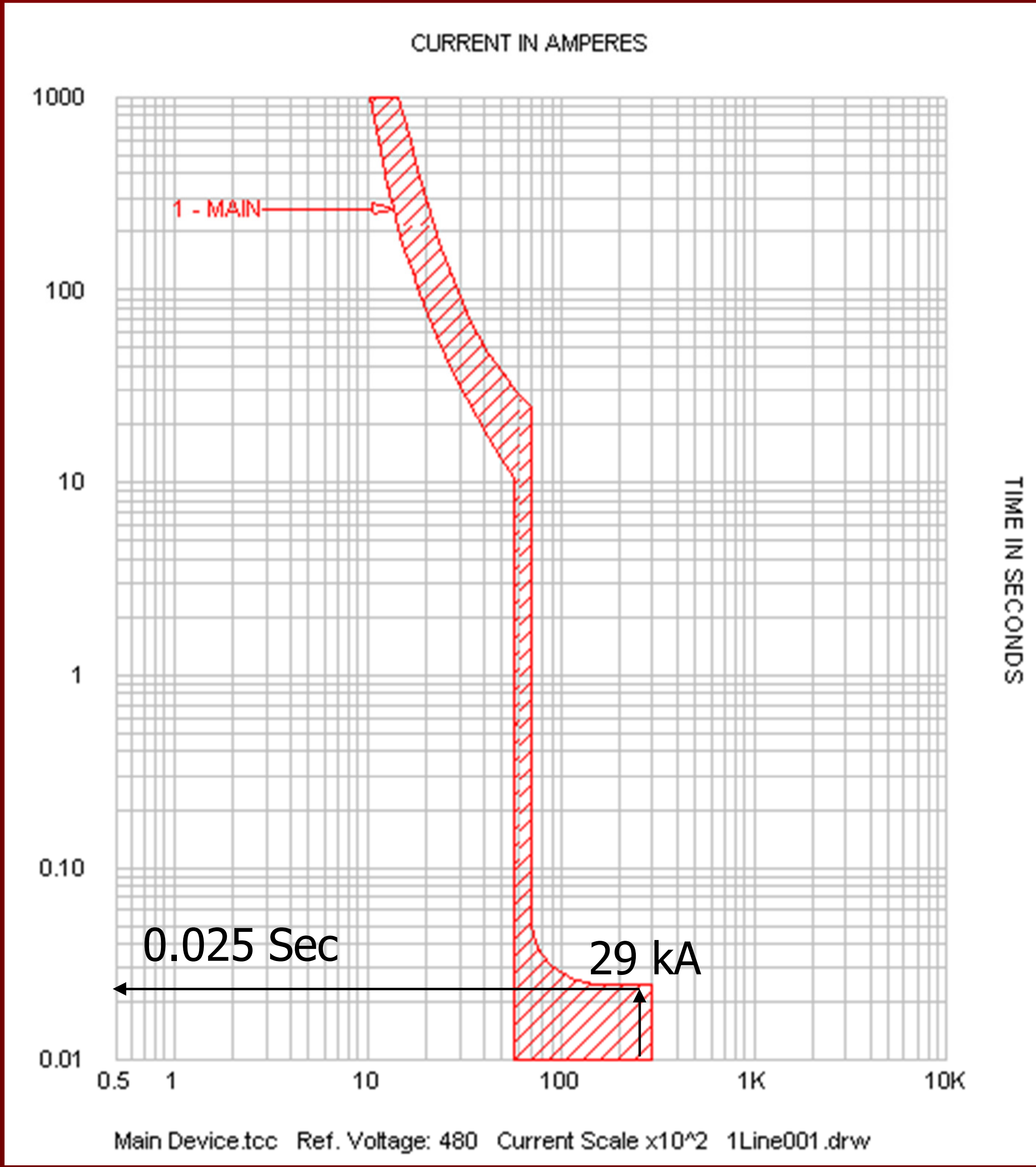


Using T/M Breakers @ 30 kA Available

HRC (Cal/cm^2)

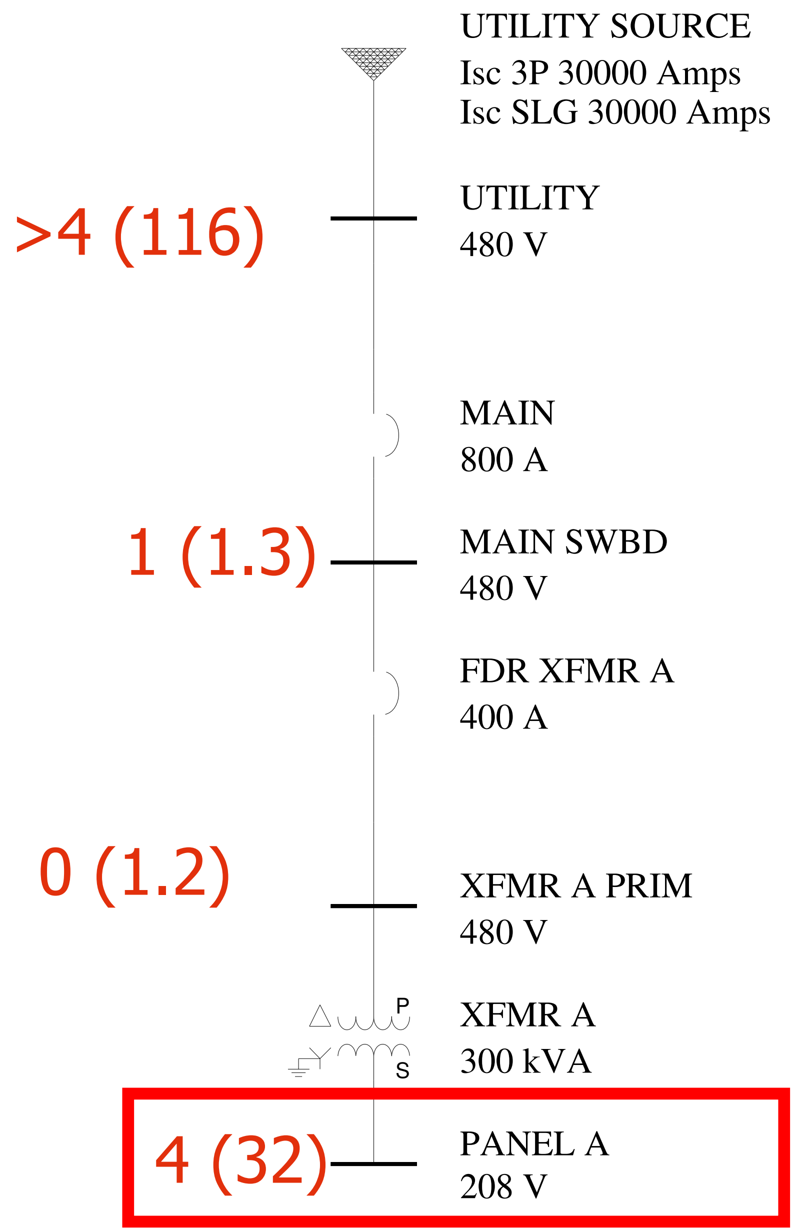


Main Breaker - Thermal Magnetic Breaker



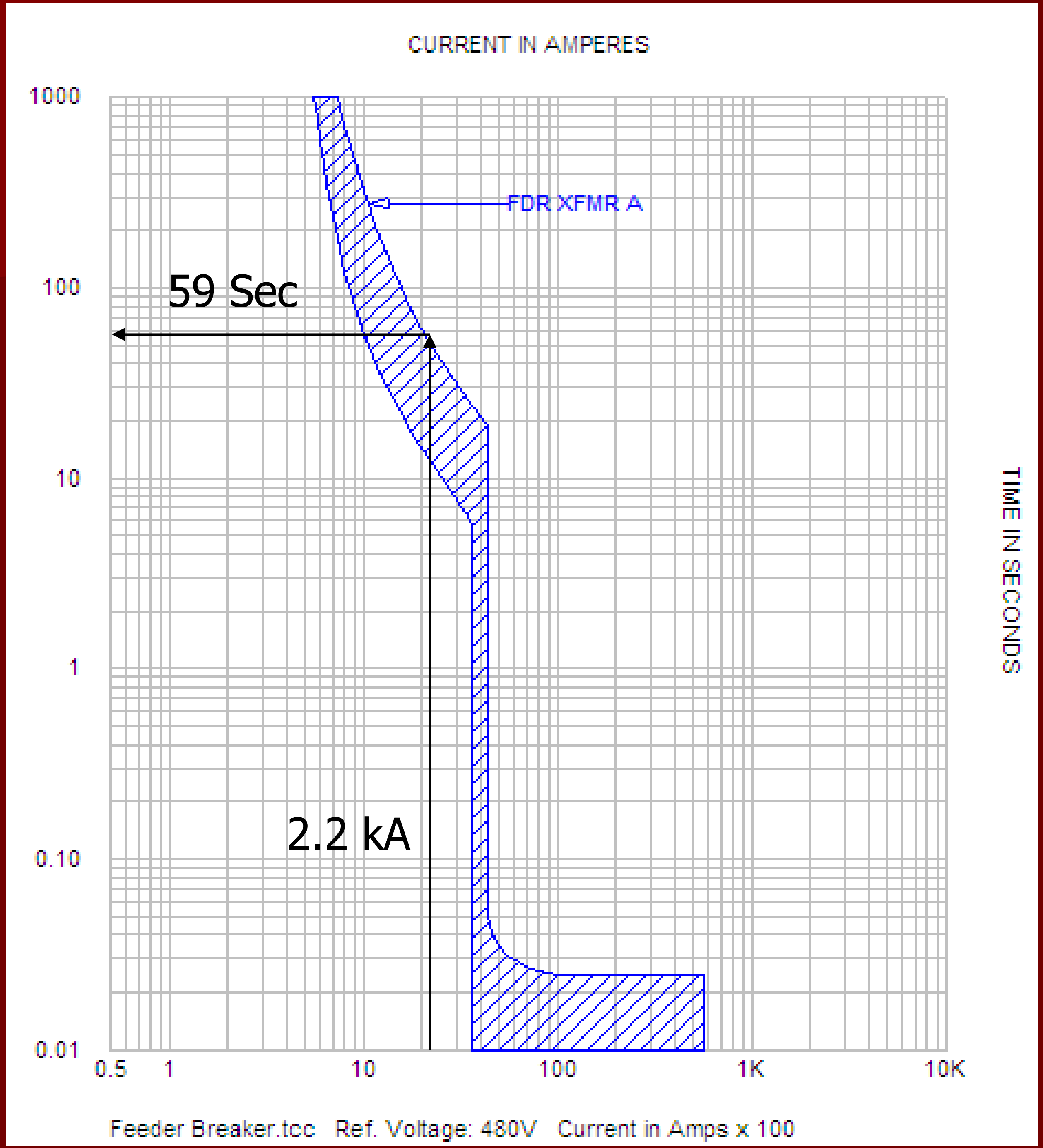
Using T/M Breakers @ 30 kA Available

HRC (Cal/cm^2)



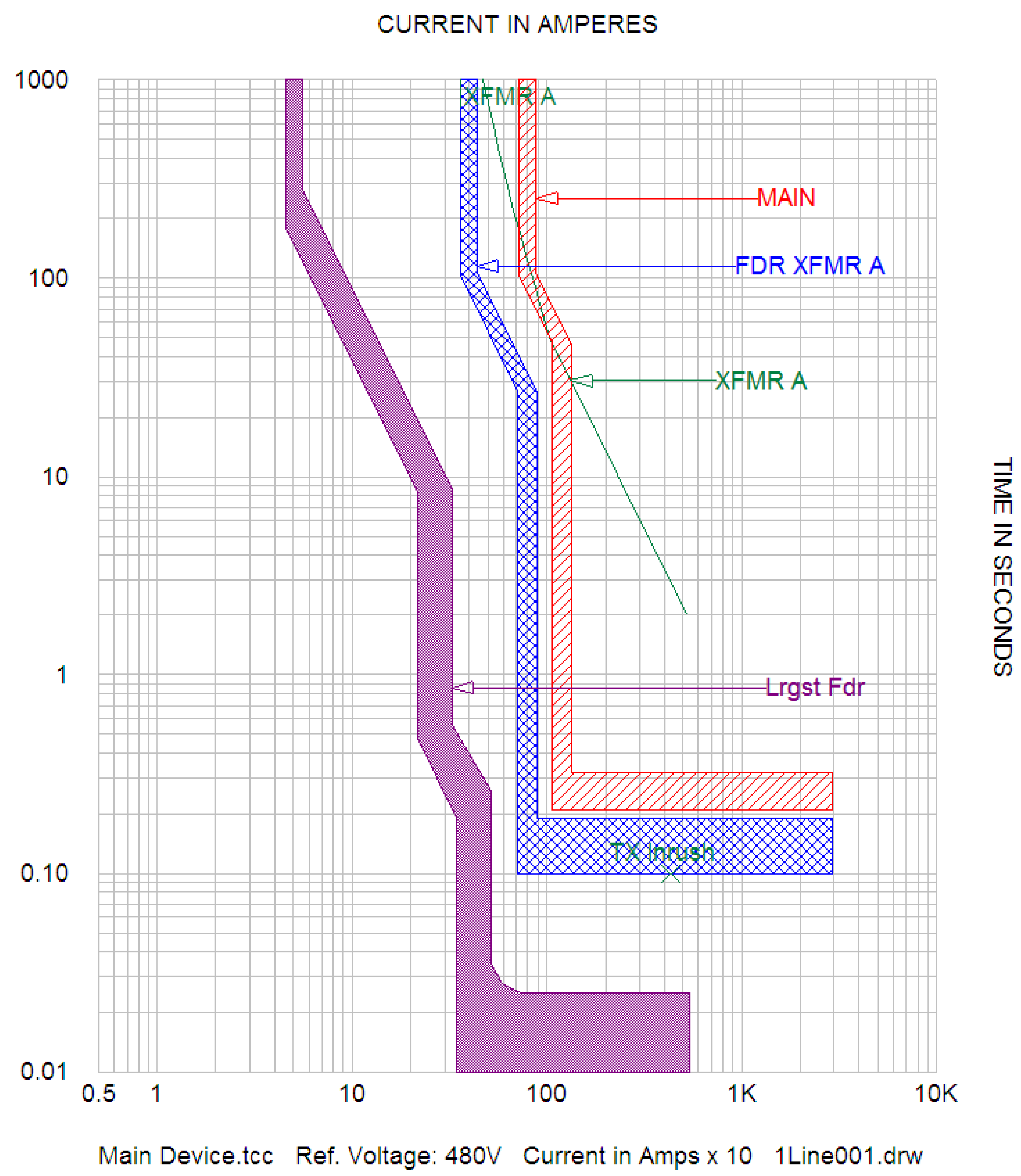
- Arcing Fault Current @ Panel A – 5.0 kA
- Panel A is protected by 400A Feeder Breaker in Main Switchboard
- Current is reduced due to transformer:
  - 5.0 kA @ 208 Volts
  - @ 480 V = 5.0*208/480 = 2.2 kA
- Feeder breaker sees only 2.2 kA for a fault at Panel A!!!

Feeder Breaker - Thermal Magnetic Breaker



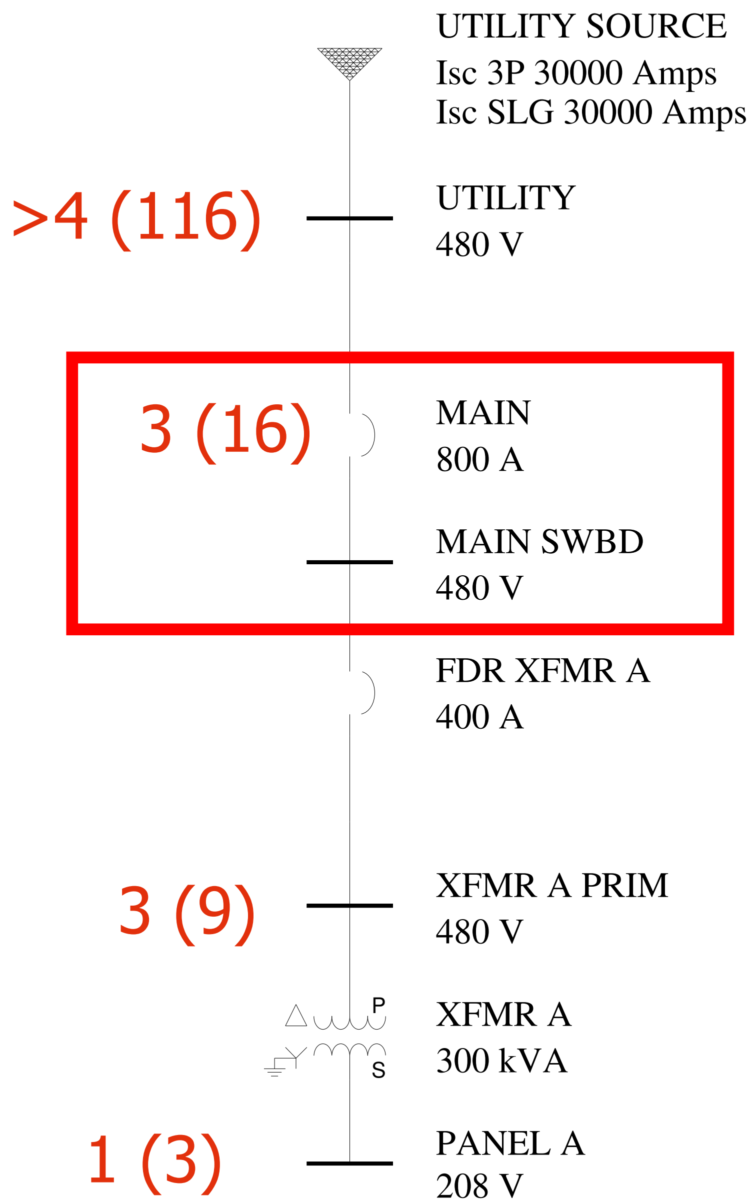
Selective Coordination & Arc Flash Energy

- Main and Feeder Breakers with (LS) Trip Units

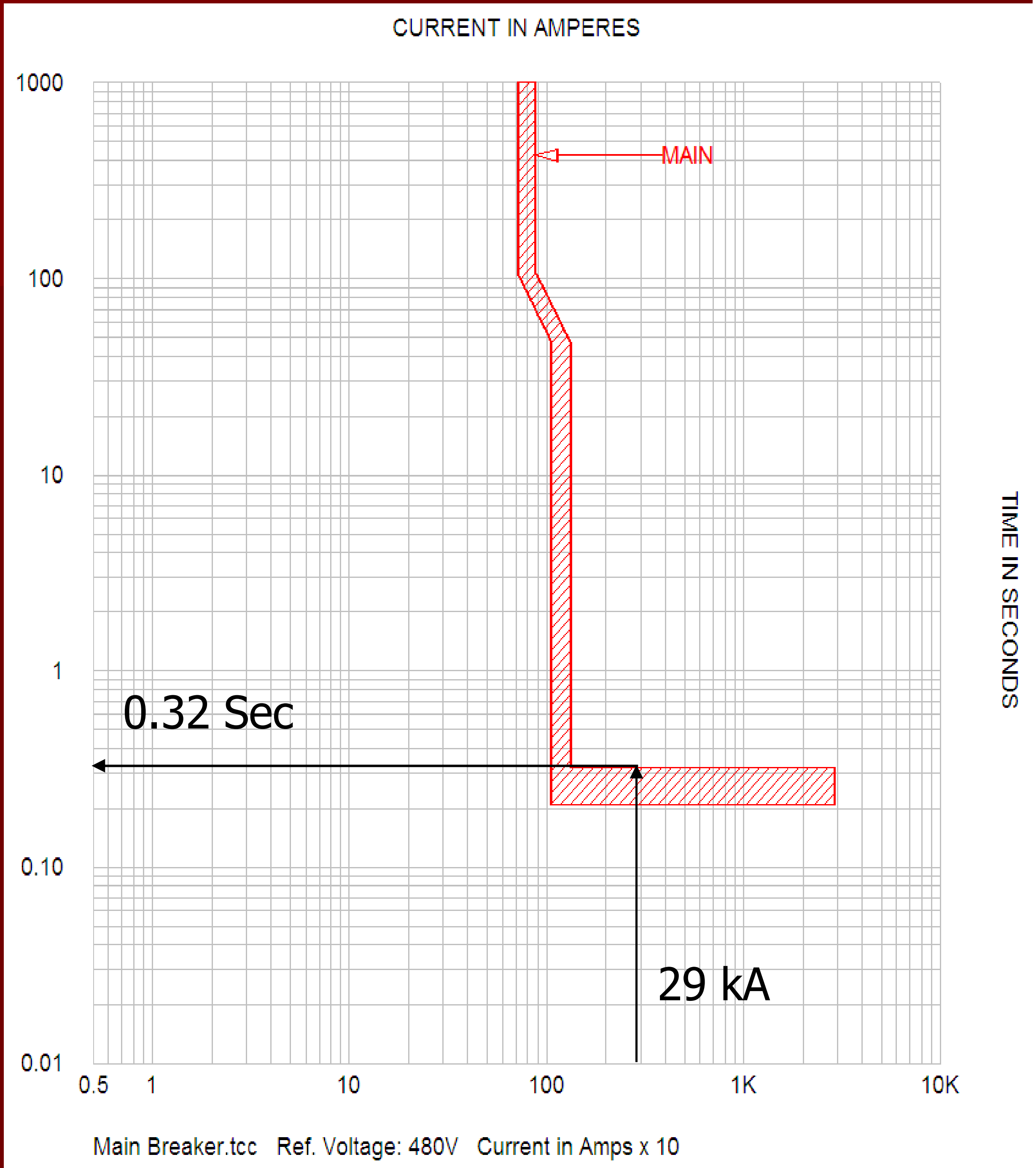


Using Solid State Trip Breakers @ 30 kA Available

HRC (Cal/cm²)

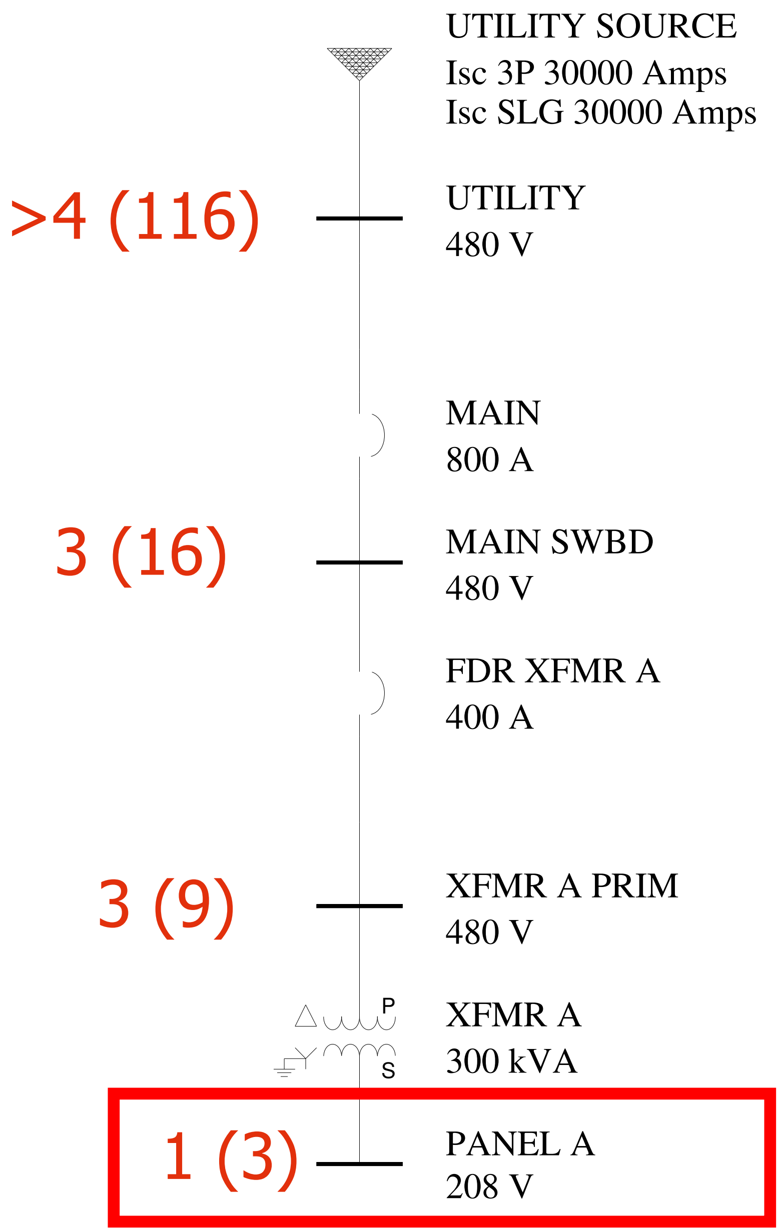


Main Breaker - Solid State Trip Breaker



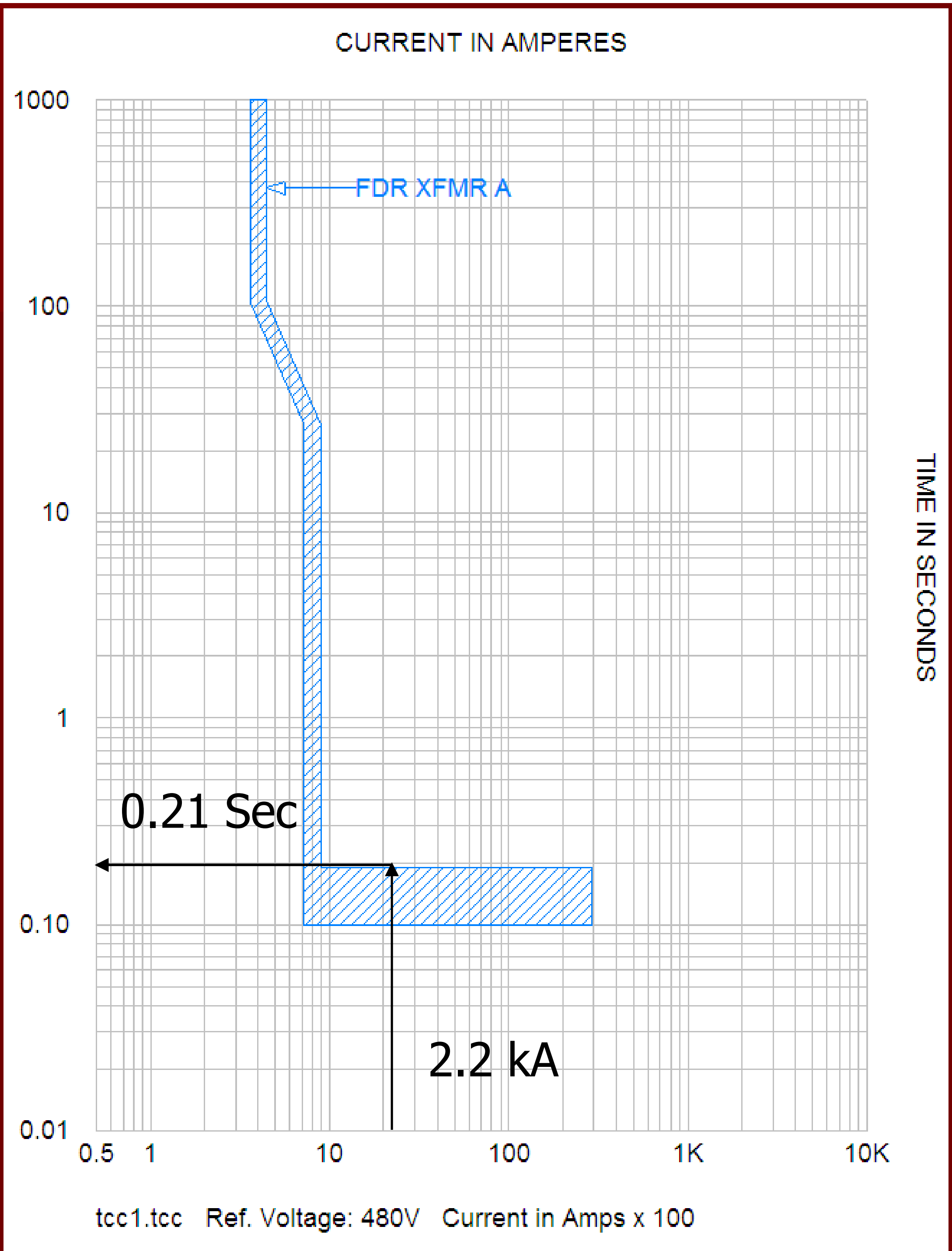
Using Solid State Breakers @ 30 kA Available

HRC (Cal/cm^2)



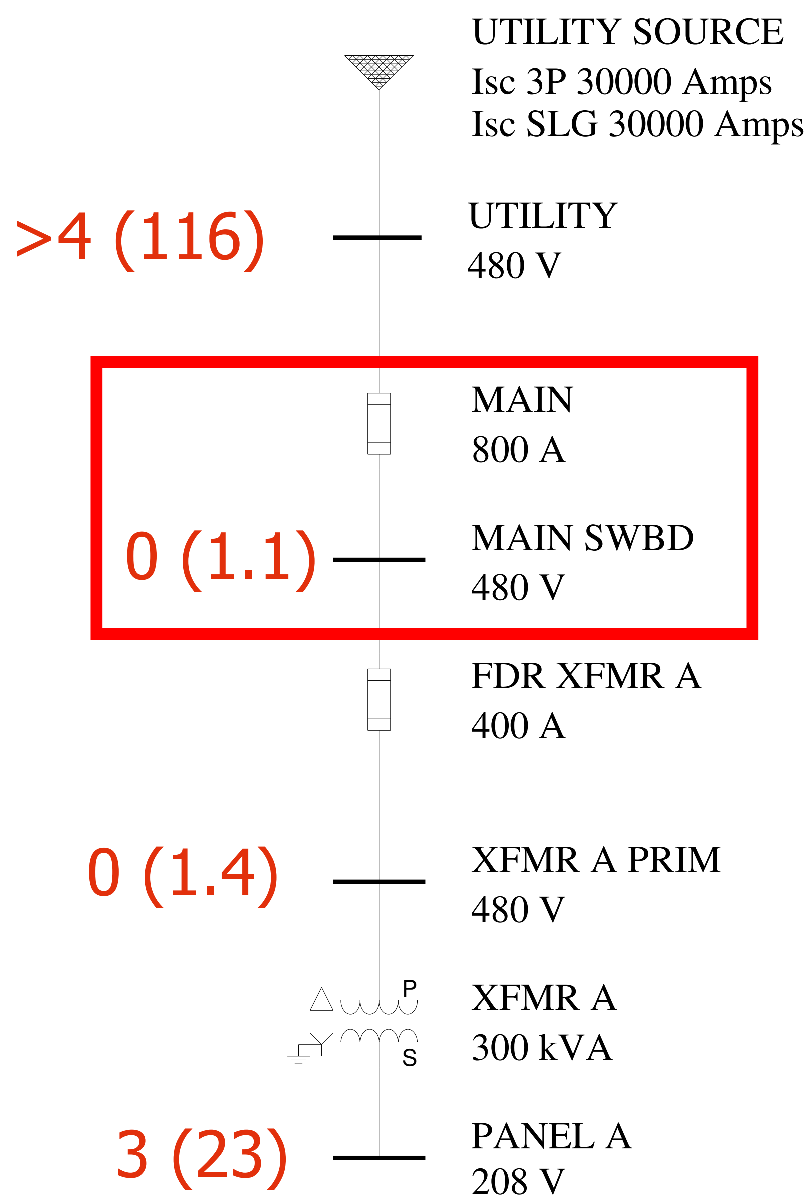
- Arcing Fault Current @ Panel A – 5.0 kA
- Panel A is protected by 400A Feeder Breaker in Main Switchboard
- Current is reduced due to transformer:
  - 5.0 kA @ 208 Volts
  - @ 480 V = 5.0*208/480 = 2.2 kA
- Feeder breaker sees only 2.2 kA for a fault at Panel A!!!

Feeder Breaker - Solid State Trip Breaker

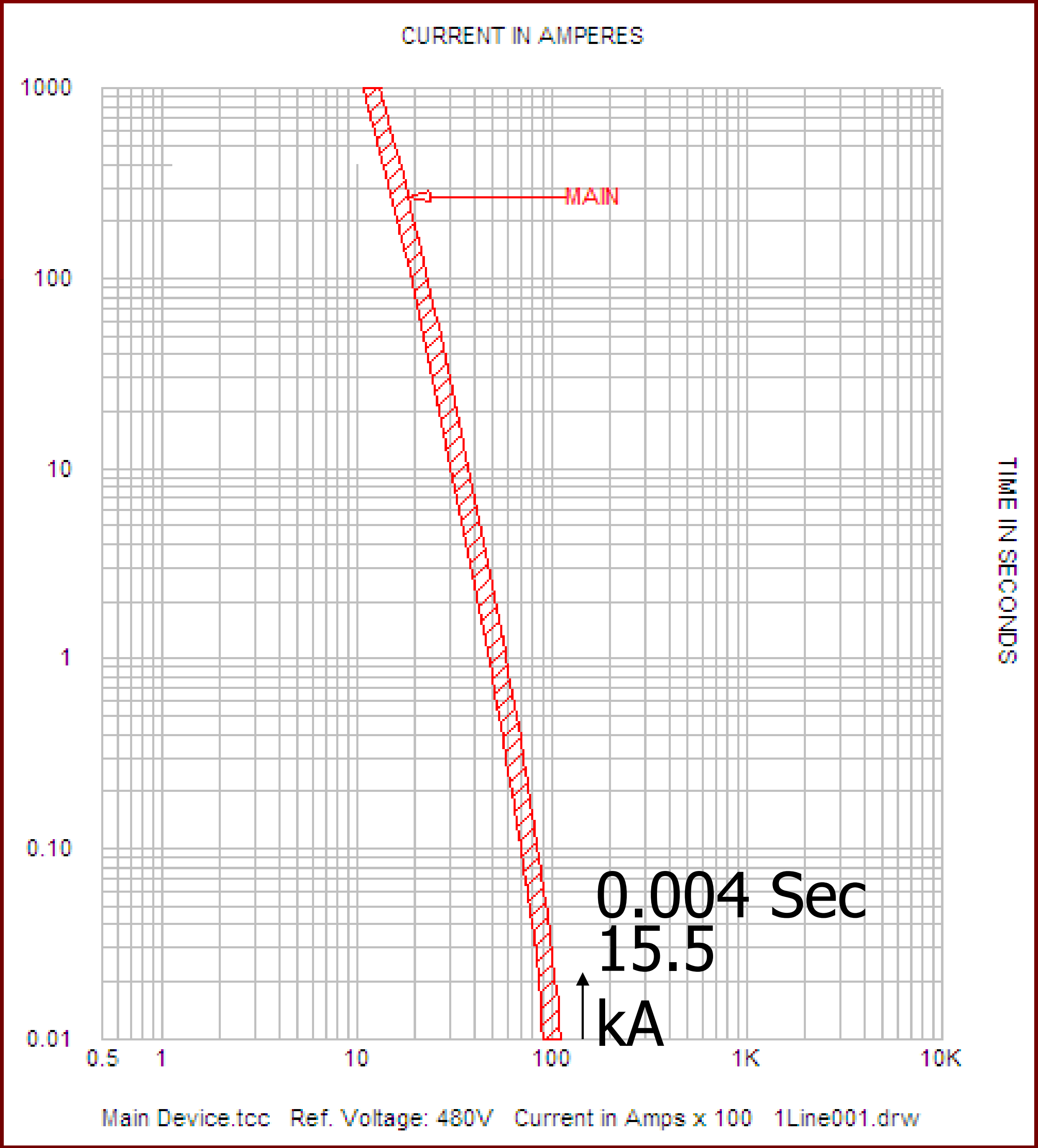


Using CL Fuses @ 30 kA Available

HRC (Cal/cm^2)

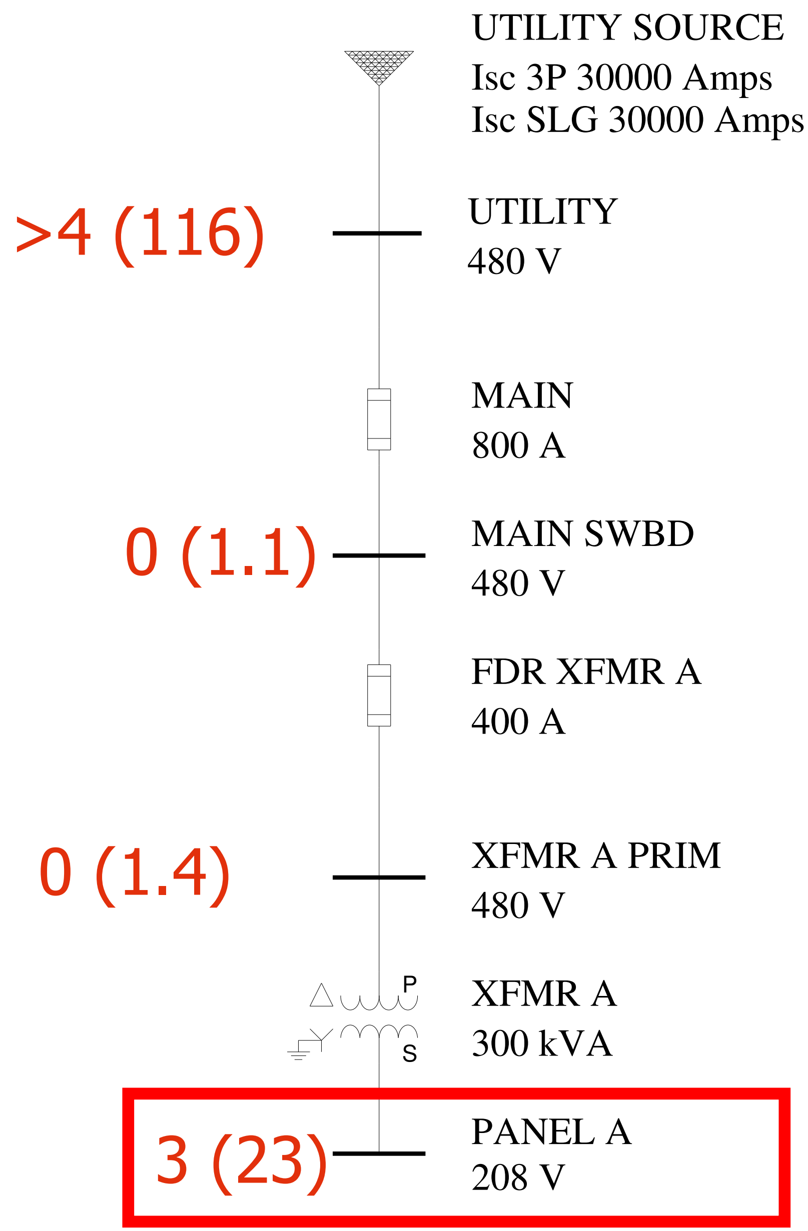


Main- Current Limiting Fuse



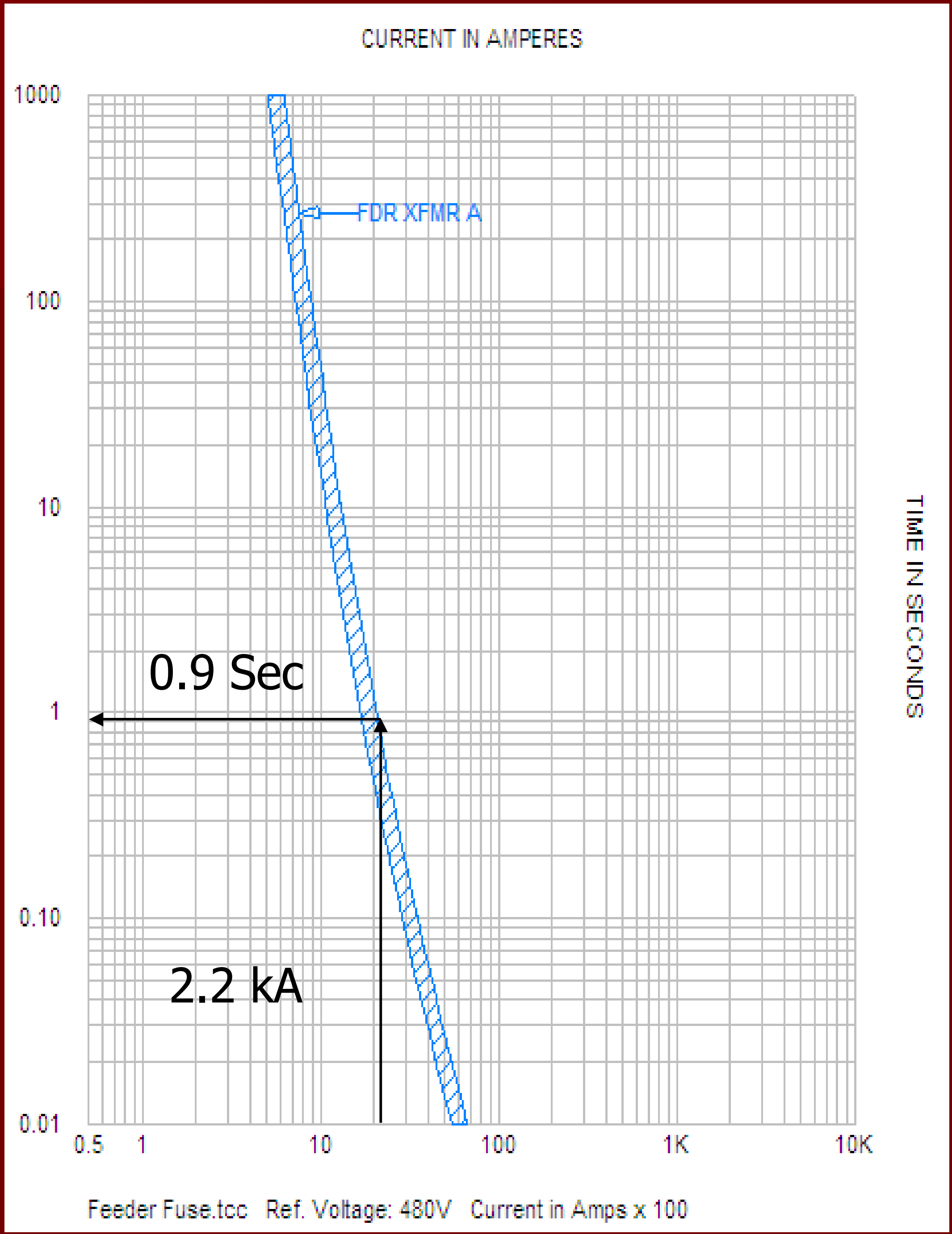
Using CL Fuses @ 30 kA Available

HRC (Cal/cm^2)



- Arcing Fault Current @ Panel A – 5.0 kA
- Panel A is protected by 400A Feeder Fuse in Main Switchboard
- Current is reduced due to transformer:
  - 5.0 kA @ 208 Volts
  - @ 480 V = 5.0*208/480 = 2.2 kA
- Feeder fuse sees only 2.2 kA for a fault at Panel A!!!

Feeder Fuse - Current Limiting Fuse



Tools for Selective Coordination

- All Fuse Manufacturers have Fuse Selectivity Charts
  - Coordination not affected by higher fault currents
- GE, Eaton, Siemens, and Square D –
  - Breaker Selectivity Charts
  - Breaker Coordination Excel Spreadsheet
  - Coordination can be affected by higher fault currents

Tools for Selective Coordination

- Siemens EasyTCC software program
- SKM PowerTools for windows
  - Special Selective Coordination Feature
- Any others I have not mentioned??

New Products to Help!

- Bussmann - Coordination Panel Board 30A – 400A Fusible
- Ferraz Shawmut – Coordination Panel

New Products to Help!

- New Circuit Breakers being Introduced
- Additional Breaker Testing

Resources and Additional Info

- http://www.geindustrial.com/solutions/engineers/selective_coordination.html
- http://www.eaton.com/Electrical/Consultants/SelectiveCoordination/index.htm
- http://www.schneider-electric.us/sites/us/en/customers/consulting-engineer/selective-coordination.page

Resources and Additional Info

- http://www.sea.siemens.com/us/Support/Consulting-Engineers/Pages/SelectiveCoordination.aspx
- http://www1.cooperbussmann.com/2/SelectiveCoordination.html
- http://us.ferrazshawmut.com/resources/articles-white-papers.cfm
- http://us.ferrazshawmut.com/resources/online-training.cfm

Coordination Table.

All Values (Typical) in RMS Current Levels @ 240, 415 / 480 Vac

Downstream (Branch) CB		Upstream (Main) MCCB								
	Rating	EG(125 A)	F (225 A)	JG(250 A)	J (250 A)	K (400 A)	L(600 A)	LG (630A)	N (1200 A)	R (2500 A)
BR, BAB, HQP & QC (10 kA)	15	1.2	2.2	4.0	10.0	10	10	10	10	10
	20	1.2	2.2	3.4	5.0	8.0	10	10	10	10
	30	1.2	2.2	3.4	5.0	8.0	10	10	10	10
	40	0.8	2.2	3.4	4.2	6.0	10	10	10	10
	50	0.8	2.2	2.5	4.2	6.0	10	10	10	10
	60	0.8	2.2	2.5	4.2	6.0	10	10	10	10
	70		2.2	2.5	4.2	5.0	10	10	10	10
	80		2.2	2.5	4.2	5.0	10	10	10	10
	90		2.2	2.5	4.2	5.0	10	10	10	10
	100		2.2	2.5	4.2	5.0	10	10	10	10
	125				4.2	4.2	10	10	10	10
	150					4.2	10	10	10	10

Job Title

Company Name

Available Fault Current Calculation

Enter Available Utility Fault Current		**Amperes**
If not known, enter transformer KVA rating	**300**	**KVA**
Enter transformer impedance (Z)	**5**	**%**

Select Primary System Voltage	Three Phase 480
Select Secondary System Voltage	Three Phase 208Y/120

Transformer Calculations

Primary Voltage	480	**Volts**
Primary Current	361	**Amperes**
Maximum Primary Protection per NEC 450.3(B)	902	**Amperes**
Recommended Primary Breaker Rating	1000	**Amperes**
Secondary Voltage	208	**Volts**
Secondary Current	833	**Amperes**
Maximum Secondary Protection per NEC 450.3(B)	1041	**Amperes**
Recommended Secondary Breaker Rating	1200	**Amperes**
$I_{SCA} = \frac{\text{Transformer FLA} \times 100}{\text{Transformer \%Z}}$	16,655	**Amperes**
Short Circuit Current (RMS symmeterical) @ Transformer Terminals	16,655	**Amperes**
Motor Contributions	1,665	**Amperes**
Total Short Circuit Current (Transformer/Utility+Motor Contribution)	18,320	**Amperes**

Select Conductor Data Between Main MCCB and Branch MCCB

Select Conductor Type & Raceway Charisteristics	Copper in Metalic Raceway	
Select Conductor Size	250 kcmil	
Enter Conductor Length	**100**	**Feet**
Enter Number of Conductors / Phase	**1**	
Fault Current @ Load Terminals of Branch MCCB	**7,815**	**Amperes**
Select Transformer Secondary MCCB	JG(250 A)	
Select Downstream Branch MCCB	F 100A	
Coordination Level	**2,300**	**Amperes**
Results	**Select Larger Frame Size**	

Circuit Breaker Selection Table

- Table Used to Quickly Select Breakers that may coordinate.
- Easily Sorted in Excel.

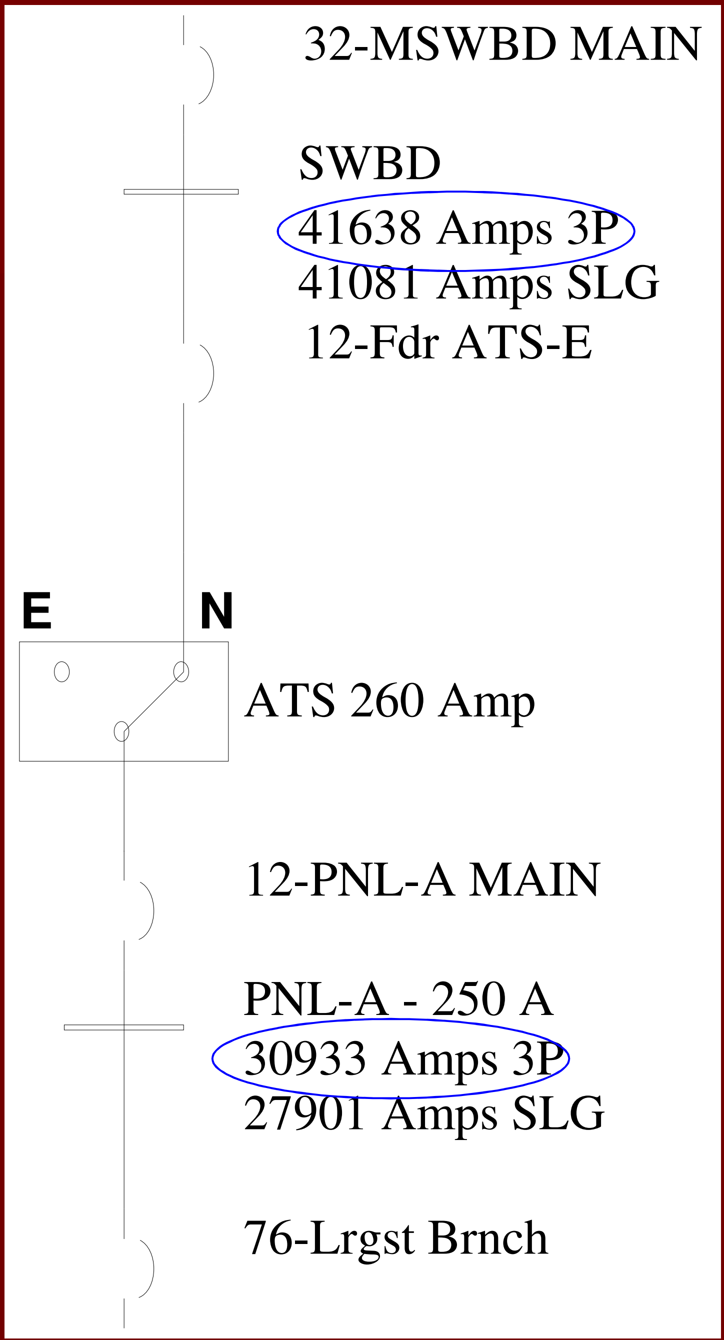
A	B	C	D	E	F	G	H
ID#	Voltage Rating	Frame Size (Amperes)	Interrupting Rating (kA)	Manufacturer	Type	Type of Breaker	Testing Standard
1	480	600	35	SQ D	DG	MCCB	UL© 489

Circuit Breaker Selection Table

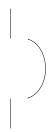
I	J	K	L	M	N	O	P	Q
Trip Unit Type	**Continuous Current Range (Amperes)**	**Number of Long Time Delays**	**Number of Short Time Delays**	**Instantaneous Trip Range**	**Instantaneous Type**	**Instantaneous Overide Trip Range (Amperes)**	**TCC #**	**TCC Date**
STR23SP	60-600	FIXED	4	2-9 x Ir	Adjustable	6,000		

Example 1

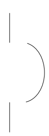
- Determine the Short Circuit Currents
- Determine the breaker type
  - SWBD Main (4000 Amp)
  - Feeder to ATS (200 Amp)
  - Panelboard Main (200 Amp)
  - Largest Feeder is 70A KH AMP



Example 1



32-MSWBD MAIN
SQUARE D
NW40H
Sensor/Trip 4000 A
Settings Phase
  LTPU/LTD (A 0.4-1.0 x S) 1 (4000A); 0.5
  STPU (1.5-10 x LTPU) 5 (20000A)
  STD (INST-0.4) 0.3(I^2 T Out)
  INST (2-15 x S) 15 (60000A)



12-Fdr ATS-E
SQUARE D
NT08H
Sensor/Trip 400 A
Settings Phase
  LTPU/LTD (A 0.4-1.0 x S) 0.5 (200A); 24
  STPU (1.5-10 x LTPU) 6 (1200A)
  STD (INST-0.4) 0.2(I^2 T Out)
  INST Override Fixed (40000A)

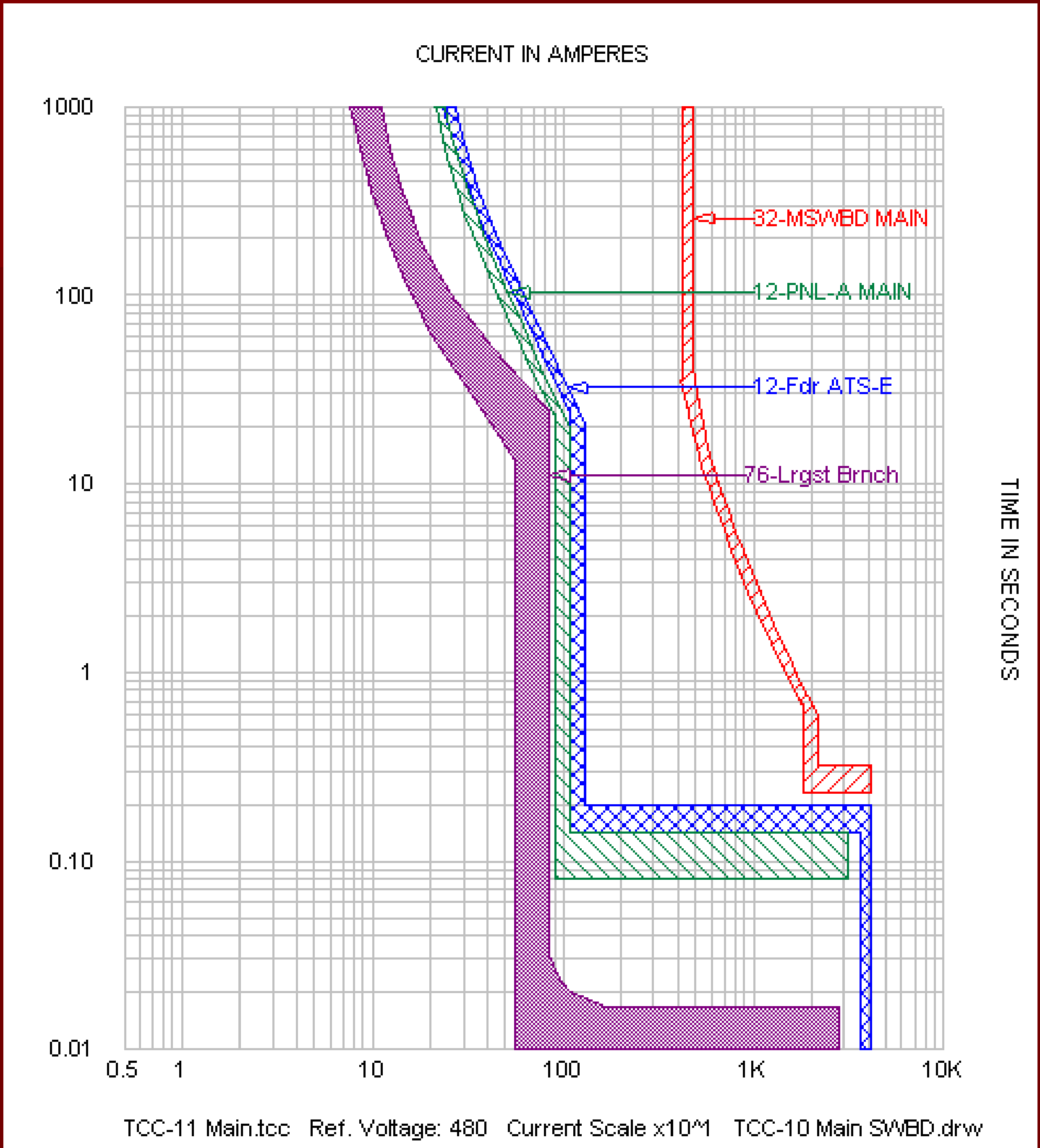
Example 1

12-PNL-A MAIN
SQUARE D
NT08H
Sensor/Trip 400 A
Settings Phase
LTPU/LTD (A 0.4-1.0 x S) 0.5 (200A); 16
STPU (1.5-10 x LTPU) 5 (1000A)
STD (INST-0.4) 0.1(I^2 T Out)
INST Override Fixed (40000A)

76-Lrgst Brnch
SQUARE D
KH
Sensor/Trip 70 A
Settings Phase
Thermal Curve (Fixed)
INST (5-10 x Trip) 10.0 (700A)

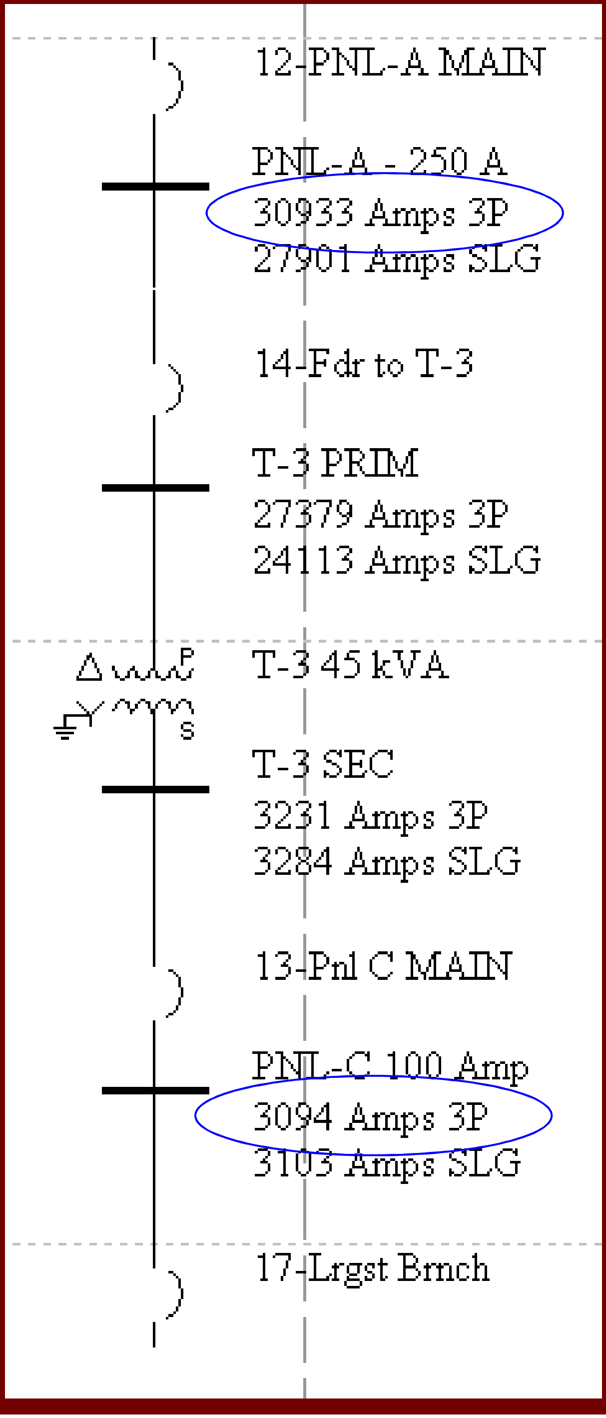
Example 1

- Determine the
  - SWBD Main -
  - Feeder to ATS
  - PNLBD Main
  - Largest Feeder is 70A KH AMP



Example 2

- Determine the
  - Panel A Feeder
  - Panel C Main
  - Panel C Largest Feeder is 20A QO
- Step 1 – Determine 208 V Fault in 480 V amperes.
- 3,094 X 208/480 = 1,341 A



Example 2

- Pick 125 Amp Feeder Breaker T-3
  – Instantaneous OR > 1,341
  – 1,341 / 125 = 10.7 (Can not use T/M)
  – Must Use SS Trip
- Pick Panel C 100 Ampere Main
  – Must Coordinate with Largest Branch Breaker

Example 2

13-Pnl C MAIN
SQUARE D
PG
Sensor/Trip 250 A
Settings Phase
  LTPU/LTD (A 0.4-1.0 x S) 0.4 (100A)
  STPU (1.5-10 x LTPU) 10 (1000A)
  STD (0-0.4) 0.1(I^2 T In)
  INST Override Fixed (24000A)

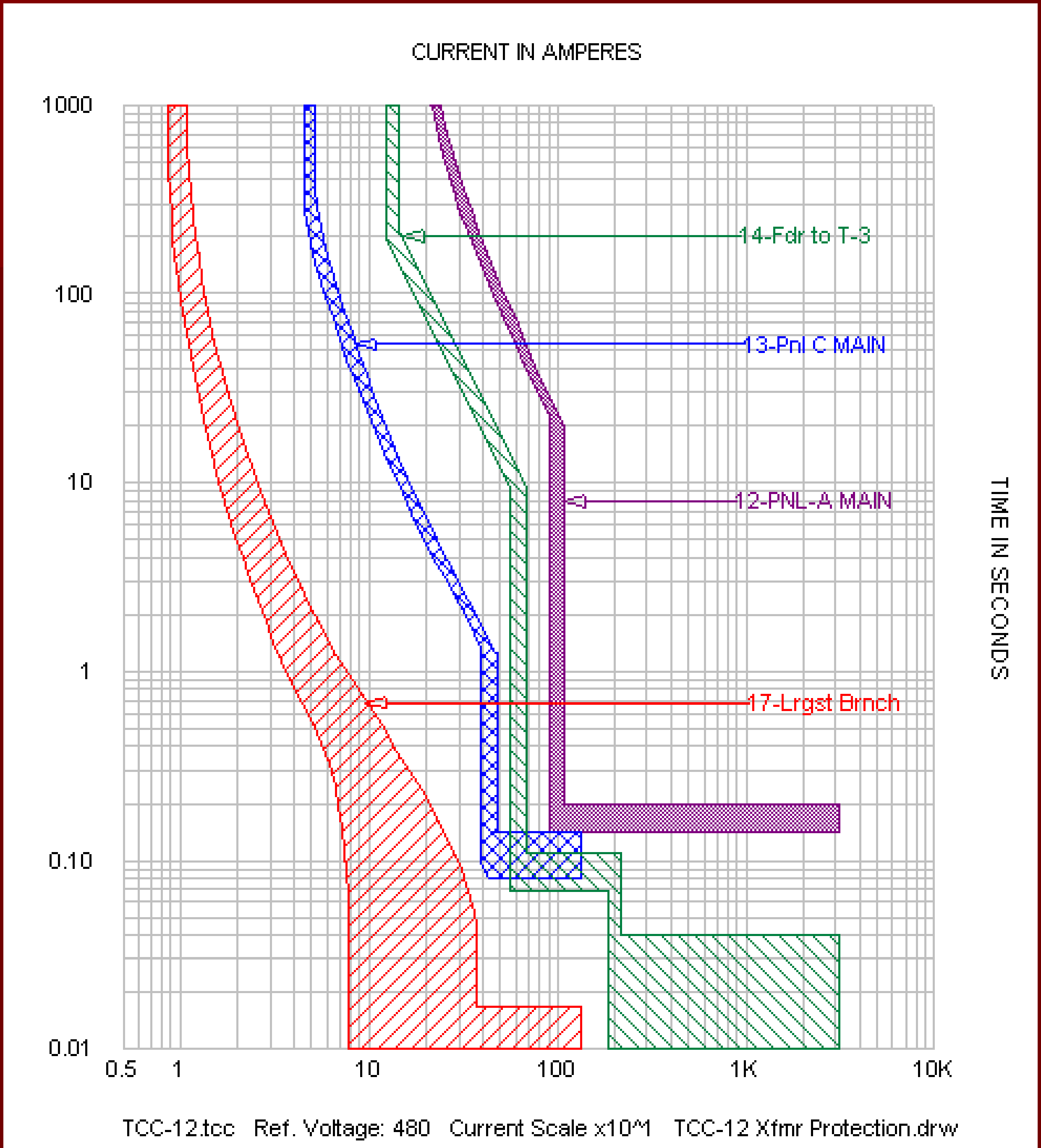
17-Lrgst Brnch
SQUARE D
QO3
Sensor/Trip 20 A
Settings Phase
  Fixed

Example 2

12-PNL-A MAIN
SQUARE D
NT08H
Sensor/Trip 400 A
Settings Phase
LTPU/LTD (A 0.4-1.0 x S) 0.5 (200A); 16
STPU (1.5-10 x LTPU) 5 (1000A)
STD (INST-0.4) 0.2(I^2 T Out)
INST Override Fixed (40000A)

14-Fdr to T-3
SQUARE D
LE
Sensor/Trip 250 A
Plug 250 A
Settings Phase
LTPU (0.5-1.0 x P) 0.5 (125A)
LTD (2-14 Sec.) 2
STPU (2-8 x P) 2.5 (625A)
STD (0.1-0.5 Sec.) 0.1(I^2 T Out)
INST (2.5-8 x P) 8.0 (2000A)

Example 2



CURRENT IN AMPERES
1000
100
10
1
0.10
0.01
0.5
1
10
100
1K
10K
TIME IN SECONDS
14-Fdr to T-3
13-Pnl C MAIN
12-PNL-A MAIN
17-Lrgst Brnch
TCC-12.tcc Ref. Voltage: 480 Current Scale x10^1 TCC-12 Xfmr Protection.drw

Selective Coordination - Ensuring Compliance

Requires

proper engineering,

Specification,

Installation, and Testing

Selective Coordination – Ensuring Compliance

- Engineer
  - Designs must allow selective coordination – Use less levels of OCPDs.
  - For competitive bidding, design should be generic and simple.
  - Require that PDC study be done after manufacture has provided submittals for proposed equipment.

Selective Coordination – Ensuring Compliance

- Contractors
  - Purchase and install OCPDs as specified.
  - Substitutions must be approved by the designer and verified that is can be selectively coordinated.
  - Make sure devices are set per the PDC study.
  - Test the devices to verify proper operation.

Selective Coordination – Ensuring Compliance

- Plan Review and Inspection by AHJ
  - Require PDC Study after Manufacture has provided OCPD submittals.
  - Require that PDC study be done and submitted for review (1 month) after OCPD submittals are provided.
  - Final Inspections and Equipment Energization not allowed until PDC study is reviewed by AHJ.

Selective Coordination Check List

http://www.cooperindustries.com/content/dam/public/bussmann/Electrical/Resources/Solution%20Center/electrical_inspector_tools/BUS_Ele_Selective_Coord_Req_ChkList.pdf

SELECTIVE COORDINATION REQUIREMENTS INSPECTION FORM

ISSUED BY: ______________________________

This form provides documentation to assure compliance with the following NFPA 70, National Electrical Code® requirements for selective coordination found directly in articles **620, 700, 701 & 708**, and indirectly in article **517**.

JOB #: ____________________ NAME: ____________________

LOCATION: ____________________ FIRM: ____________________

COMPLIANCE CHECKLIST

Several sections in the *Code* require all supply side overcurrent protective devices to be selectively coordinated in the circuits supplying life-safety-related loads. These loads are those supplied by elevator circuits (620.62), emergency systems (700.9(B)(5)(b) Exception & 700.27), legally required standby systems (701.18), and critical operations power systems (708.54). These requirements have been taken into account and the installation has been designed to meet the following sections for the normal and alternate circuit paths to the loads. (Check all that apply).

1. Verify Selective Coordination for the System Type -

ARTICLE 620 – ELEVATORS, DUMBWAITERS, ESCALATORS, MOVING WALKWAYS, WHEELCHAIR LIFTS AND STAIRWAY CHAIR LIFTS ☐ YES ☐ NO ☐ N/A

620.62 Selective Coordination. *Where more than one driving machine disconnecting means is supplied by a single feeder, the overcurrent devices in each disconnecting means shall be selectively coordinated with any other supply side overcurrent protective devices.*

ARTICLE 700 – EMERGENCY SYSTEMS ☐ YES ☐ NO ☐ N/A

700.27 Coordination. *Emergency systems overcurrent devices shall be selectively coordinated with all supply side overcurrent protective devices.*
(exception for single devices on the primary and secondary of a transformer and 2 devices of the same ampere rating in series)

ARTICLE 701 – LEGALLY REQUIRED STANDBY SYSTEMS ☐ YES ☐ NO ☐ N/A

701.18 Coordination. *Legally required standby system(s) overcurrent devices shall be selectively coordinated with all supply side overcurrent protective devices.*
(exception for single devices on the primary and secondary of a transformer and 2 devices of the same ampere rating in series)

ARTICLE 708 – CRITICAL OPERATIONS POWER SYSTEMS (COPS) ☐ YES ☐ NO ☐ N/A

708.54 Coordination. *Critical operations power system(s) overcurrent devices shall be selectively coordinated with all supply side overcurrent protective devices.*

ARTICLE 517 – HEALTHCARE FACILITIES ☐ YES ☐ NO ☐ N/A

517.26 Application of Other Articles. *The essential electrical system shall meet the requirements of Article 700, except as amended by Article 517.*
(Article 517 does not amend the selective coordination requirements of Article 700)

2. Verify Selective Coordination for the Overcurrent Protective Device Type -

FUSE SYSTEM –

- Manufacturer's fuse selectivity ratio guide was consulted (Short-circuit current calculations are not necessary if available short-circuit current is less than or equal to 200kA.) ☐ YES ☐ NO ☐ N/A

CIRCUIT BREAKER SYSTEM –

- Completed time current characteristic curves coordination study: Includes integrating the short-circuit current analysis at necessary points in the system, plots of time-current curves, and analysis/interpretation of the curves to ensure selective coordination is achieved. Short-circuit current calculations were performed for all points where circuit breakers are applied. ☐ YES ☐ NO ☐ N/A
- Manufacturer's selective coordination tables were consulted: Selective coordination is achieved by comparing the available short-circuit currents to the specific circuit breaker to circuit breaker selective coordination values in the manufacturer's tables. Short-circuit current calculations were performed for all points where circuit breakers are applied. ☐ YES ☐ NO ☐ N/A

____________________ Signature ____________________ Date P.E. Seal

Summary

- You must change the way you design circuits for:
  - Emergency
  - Standby
  - Elevators
  - Fire Pumps
- Manufacturers must provide:
  - New Equipment to meet the code
  - Tools (tables, spreadsheets, charts)
  - I^2T Withstand curves for Equipment

Need more Information

- www.powerstudies.com
  - Articles
  - Links
  - Specifications for Power System Studies
    - Short Circuit
    - Protective Device Coordination
    - Arc Flash Hazard

Questions??

Thank you for your time!

Who are we?

- Electrical Engineering Consulting Firm
- We Specialize in performing Power System Studies
- We teach Electrical Safety Training Seminars (LV & HV)
- 90% of our business is in performing Power System Studies

Where are we located?

- Our main office is located in Covington (Seattle), WA.
- Branch Office located in San Francisco
- Our territory is Western third and Northeast of US
- We have also done studies for clients in Russia, Central, and South America