Arc Flash Hazard Calculations – What does it all mean?

Robert E. Fuhr, P.E.

PowerStudies, Inc.

Why are Arc Flash Hazard Studies Needed?

- To Increase Electrical Safety at your facility!
- Required by National Electric Code (NEC) and OSHA
- To Protect You!

2000 HELMET
Highest Ballistic Integrity in the World. Tested and Defeated Fragments Over 2000 FPS

VISOR
705 M/S 2315 FPS

FRONT
V0 (No Penetration)
1667 M/S 5471 FPS
(Includes Chest/Groin Plates)

ARMS
563 M/S 1850 FPS

LEGS
563 M/S 1850 FPS


05/27/03 M01 C47% 10:51:24

OSHA Requirements

- Standard 29 CFR 1910 Subpart S, 1910 to 1910.335
- Must identify all hazards above 50 Volts
- Must put safeguards in place for these hazards
- Must train employees on safe work practices
- OSHA will fine you if you do not use NFPA 70E and there is an injury investigation.

- Employers must provide workers with appropriate PPE as per the OSHA 29 1910.132 (h)(1) PPE payment requirement, i.e., (PPE) used to comply with this part, shall be provided by the employer at no cost to employees. Paragraph (h) became effective February 13, 2008, and employers must implement the PPE payment requirements no later than May 15, 2008

Key References in NEC ® -2017

- 110.16(A) General - Electrical equipment, such as switchboards, switchgear, panelboards, industrial control panels, meter socket enclosures, and motor control centers, that is in other than dwelling units, and is likely to require examination, adjustment, servicing, or maintenance while energized,

NEC 110.16 (continued)

- ….shall be field or factory marked to warn qualified persons of potential electric arc flash hazards.

NEC 110.16 (continued)

- The marking shall meet the requirements in 110.21(B) and shall be located so as to be clearly visible to qualified persons before examination, adjustment, servicing, or maintenance of the equipment.

NEC 110.16 (continued)

- (B) - In other than dwelling units, in addition to the requirements in (A), a permanent label shall be field or factory applied to service equipment rated 1200 amps or more. The label shall meet the requirements of 110.21(B) and contain the following information:

NEC 110.16 (continued)

(1) Nominal system voltage

(2) Available fault current at the service overcurrent protective devices

(3) The clearing time of service overcurrent protective devices based on the available fault current at the service

(4) The date the label was applied

Exception: Service equipment labeling shall not be required if an arc flash label is applied in accordance with acceptable industry practice.

NEC 110.16 (continued)

Informational Notes No. 1 & 3 Point to NFPA-70E for guidance as to how to determine the values & information to put on the labels.

NFPA 70E -Flash Hazard Analysis

- **130.5(A) General.** An arc flash risk assessment shall be performed:
  - (1) To identify arc flash hazards
  - (2) To estimate the likelihood of occurrence of injury or damage to health and the potential severity of injury or damage to health
  - (3) To determine if additional protective measures are required, including the use of PPE

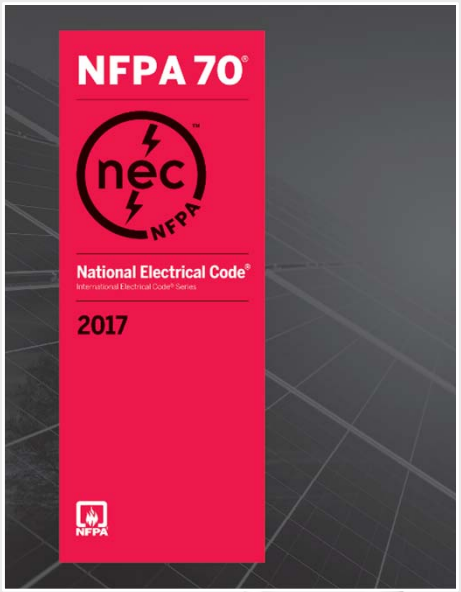
NFPA 70E -Flash Hazard Analysis

- **130.5(F) Arc Flash PPE**. One of the following methods shall be used for the selection of arc flash PPE:
  - (1) The incident energy analysis method in accordance with 130.5(G)
  - (2) The arc flash PPE category method in accordance with 130.7(C)(15)*

    * - Use with extreme caution!!!

NFPA Approach to Electrical Safety

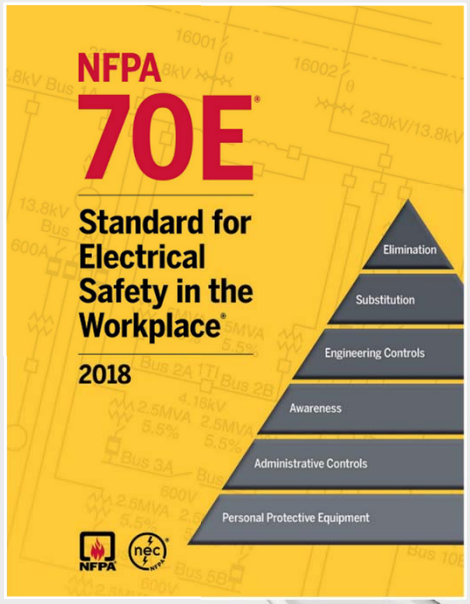
How to…



BUILD it safely

Upgrade/replace
latest NEC applies

Maintain/repair
latest 70E applies



WORK on it safely

MAINTAIN it properly

Arc Flash Hazard Analysis Key Steps

- Use NFPA 70E* Tables, IEEE 1584, Arc Pro, or Lee Equations to Determine
  - Incident energy levels
  - Arc Flash hazard boundary

* Use with extreme caution!

Arc Flash Hazard Analysis Key Steps

- Use
  - Calculated Incident Energy
  - NFPA 70E Table 130.5(G)
  - to determine
- Required PPE

NFPA 70E –Arc Flash Labeling

- **130.5(H) Equipment Labeling.** Electrical equipment such as switchboards, panelboards, industrial control panels, meter socket enclosures, and motor control centers that are in other than dwelling units and that are likely to require examination, adjustment, servicing, or maintenance while energized shall be marked with a label containing all the following information:
  REF3

Slide 18

REF3 Start here.
Robert E Fuhr, 3/22/2018

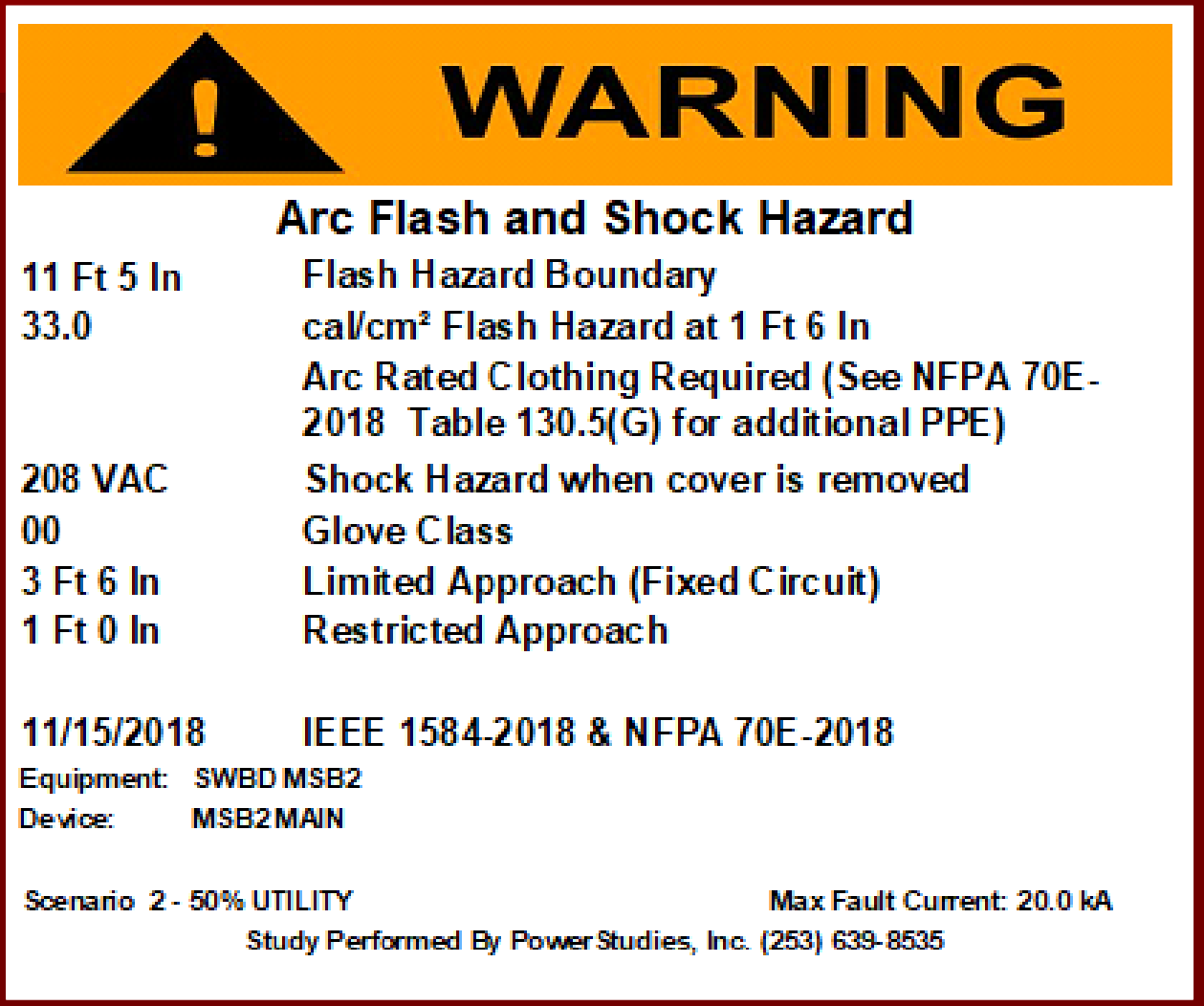
NFPA 70E –Arc Flash Labeling

(1) Nominal system voltage
(2) Arc flash boundary
(3) At least one of the following:
    a. Available incident energy and the corresponding working distance, or the arc flash PPE category in Table 130.7(C)(15)(a) or Table 130.7(C)(15)(b) for the equipment, but not both.
    b. Minimum arc rating of clothing
    c. Site-specific level of PPE

NFPA 70E –Arc Flash Labeling

- The data shall be reviewed for accuracy at intervals not to exceed 5 years.
  - (Arc Flash Refresher Study)
- The owner of the electrical equipment shall be responsible for the documentation, installation, and maintenance of the marked label.

Informative Label



WARNING

Arc Flash and Shock Hazard

11 Ft 5 In	Flash Hazard Boundary
33.0	cal/cm² Flash Hazard at 1 Ft 6 In
	Arc Rated Clothing Required (See NFPA 70E-2018 Table 130.5(G) for additional PPE)
208 VAC	Shock Hazard when cover is removed
00	Glove Class
3 Ft 6 In	Limited Approach (Fixed Circuit)
1 Ft 0 In	Restricted Approach
11/15/2018	IEEE 1584-2018 & NFPA 70E-2018

Equipment: SWBD MSB2
Device: MSB2 MAIN

Scenario 2 - 50% UTILITY — Max Fault Current: 20.0 kA

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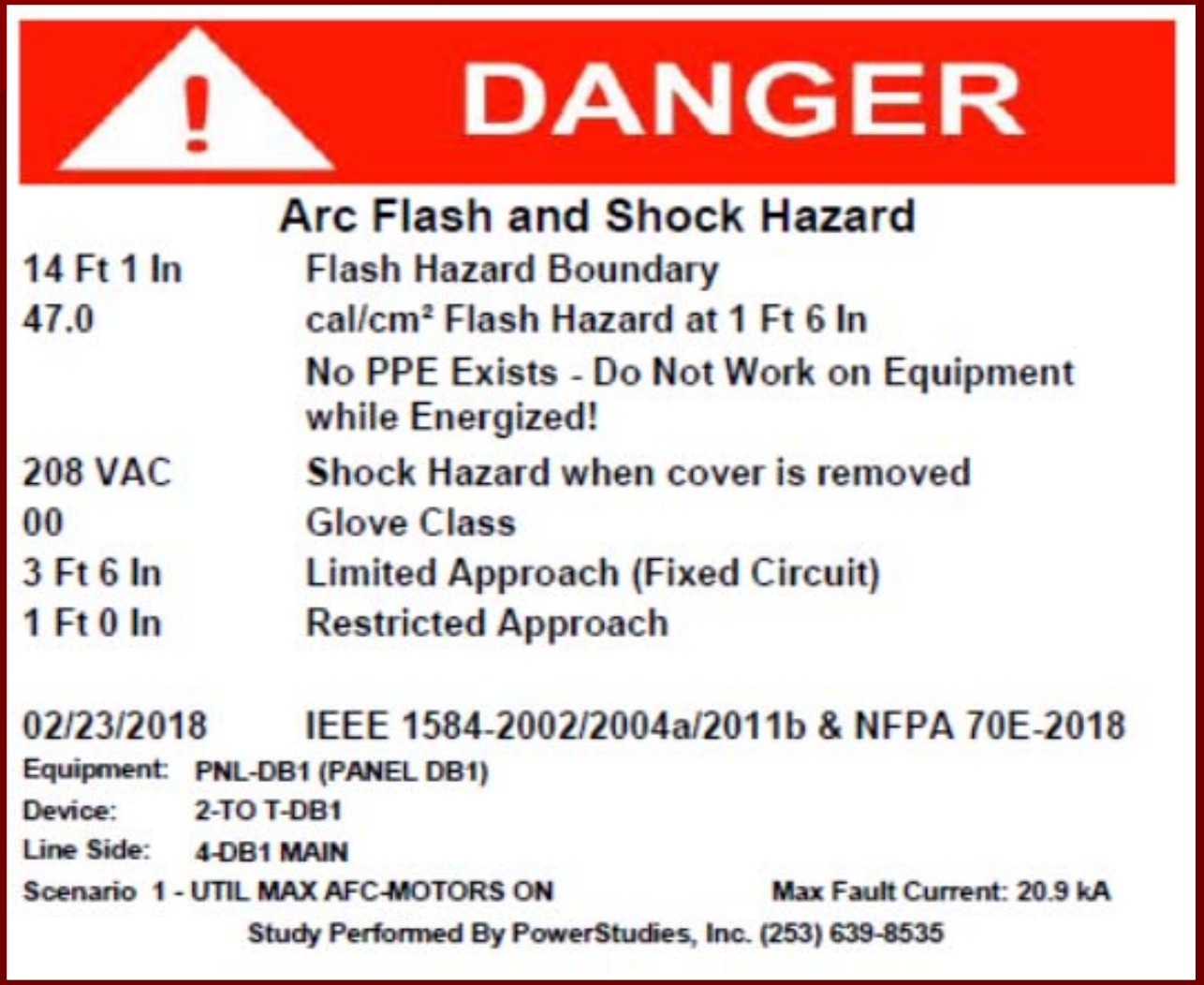
Informative Label



DANGER

Arc Flash and Shock Hazard

14 Ft 1 In	Flash Hazard Boundary
47.0	cal/cm² Flash Hazard at 1 Ft 6 In
	No PPE Exists - Do Not Work on Equipment while Energized!
208 VAC	Shock Hazard when cover is removed
00	Glove Class
3 Ft 6 In	Limited Approach (Fixed Circuit)
1 Ft 0 In	Restricted Approach

02/23/2018 IEEE 1584-2002/2004a/2011b & NFPA 70E-2018

Equipment: PNL-DB1 (PANEL DB1)

Device: 2-TO T-DB1

Line Side: 4-DB1 MAIN

Scenario 1 - UTIL MAX AFC-MOTORS ON Max Fault Current: 20.9 kA

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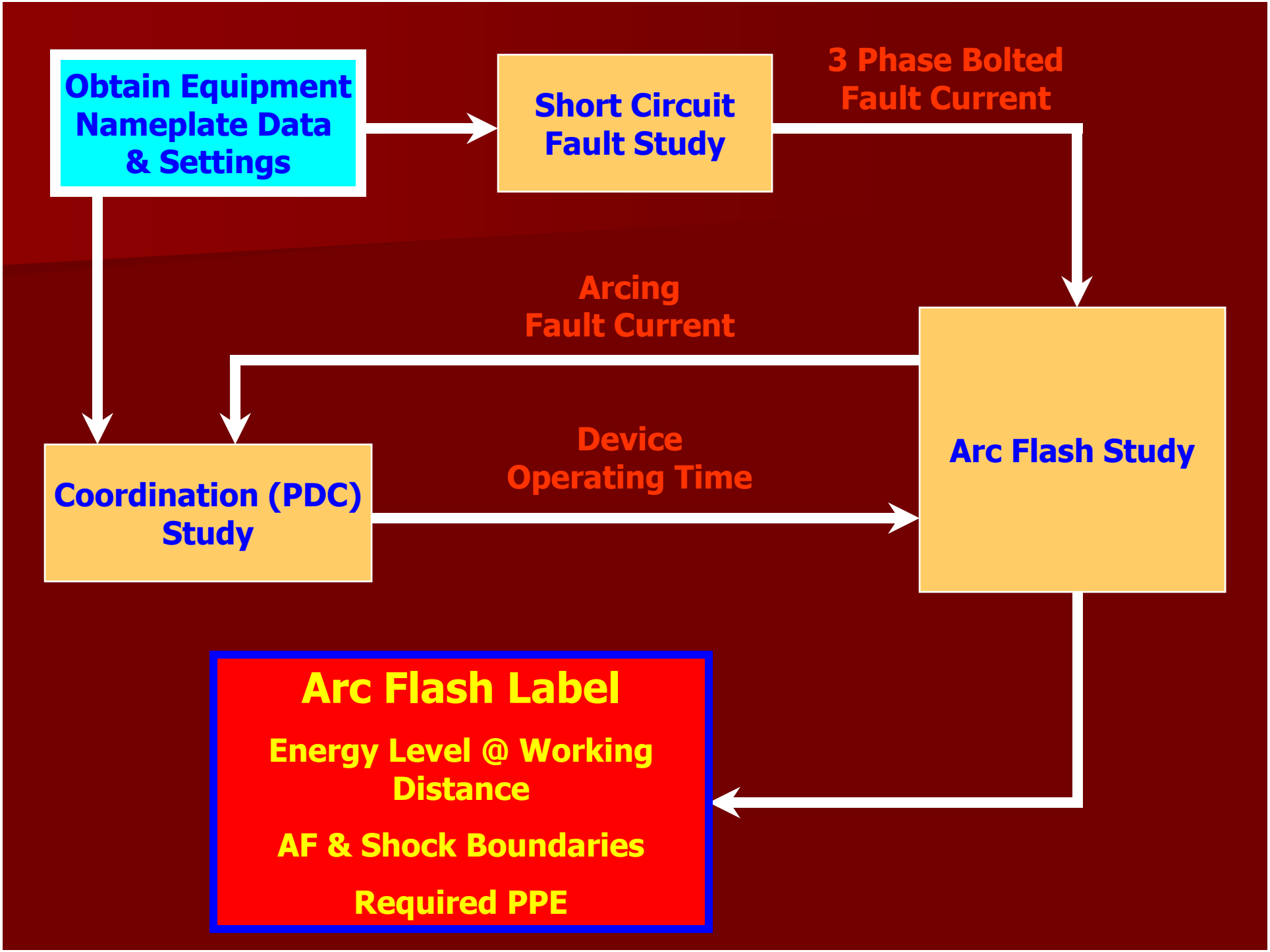
Obtain Equipment Nameplate Data & Settings
Short Circuit Fault Study
3 Phase Bolted Fault Current
Arcing Fault Current
Arc Flash Study
Coordination (PDC) Study
Device Operating Time
Arc Flash Label
Energy Level @ Working Distance
AF & Shock Boundaries
Required PPE

Arc Flash Hazard Analysis Key Steps

REF5

- Determine:
  - Bolted Fault Currents (Short Circuit Study)
  - Arcing Fault (AF) Current
  - Upstream Protective Device Clearing Times (PDC Study) using AF

Slide 24

REF5 Start

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Arc Flash Hazard Analysis Key Steps

- Calculate Arc Flash Energy
- Use NFPA 70E Tables to determine:
  - Glove Rating Class
  - Limited Approach Boundary
  - Restricted Approach Boundary
  - Required PPE

Arc Flash Hazard Analysis Key Steps

- Arc Flash Warning Labels showing the details.

Informative Label

WARNING

Arc Flash and Shock Hazard

11 Ft 5 In	Flash Hazard Boundary
33.0	cal/cm² Flash Hazard at 1 Ft 6 In
	Arc Rated Clothing Required (See NFPA 70E-2018 Table 130.5(G) for additional PPE)
208 VAC	Shock Hazard when cover is removed
00	Glove Class
3 Ft 6 In	Limited Approach (Fixed Circuit)
1 Ft 0 In	Restricted Approach
11/15/2018	IEEE 1584-2018 & NFPA 70E-2018

Equipment: SWBD MSB2
Device: MSB2 MAIN

Scenario 2 - 50% UTILITY — Max Fault Current: 20.0 kA

Study Performed By Power Studies, Inc. (253) 639-8535

How a Short Circuit Study is Performed

- Obtain distribution system nameplate data for:
  - Transformers
  - Motors
  - Circuit breakers, fuses, relays
  - Switchgear
  - Motor Control Centers
  - Conductor sizes and lengths

How a Short Circuit Study is Performed

- Enter data into the computer program.
- Simulate short circuit at each location and calculate the fault current.
- Compare calculated fault current to equipment short circuit rating.

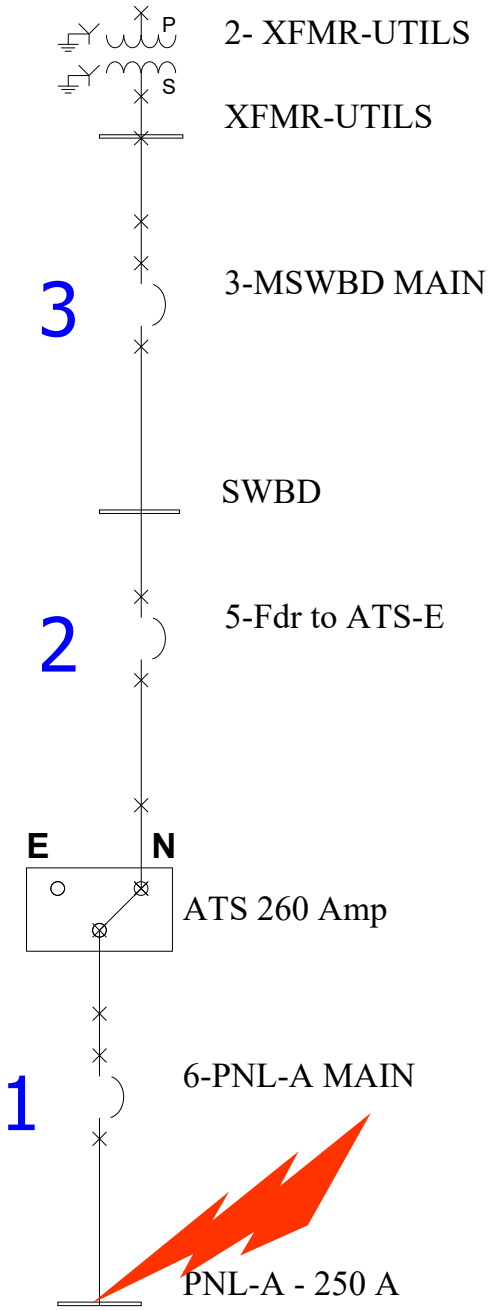
What is Protective Device Coordination (PDC) Study?

- Determines:
  - fuse sizes
  - Settings for relays and circuit breakers
  - Device operating time
- The study has 2 conflicting goals

Goal #1 - Maximum Selective Coordination Between Equipment

- Correct fuse sizes and settings will allow the device closest to a fault to trip.
- If the first device fails to operate, then the next upstream device will trip.
- Longer device trip delays = increased device coordination= greater incident energy

Selective Coordination

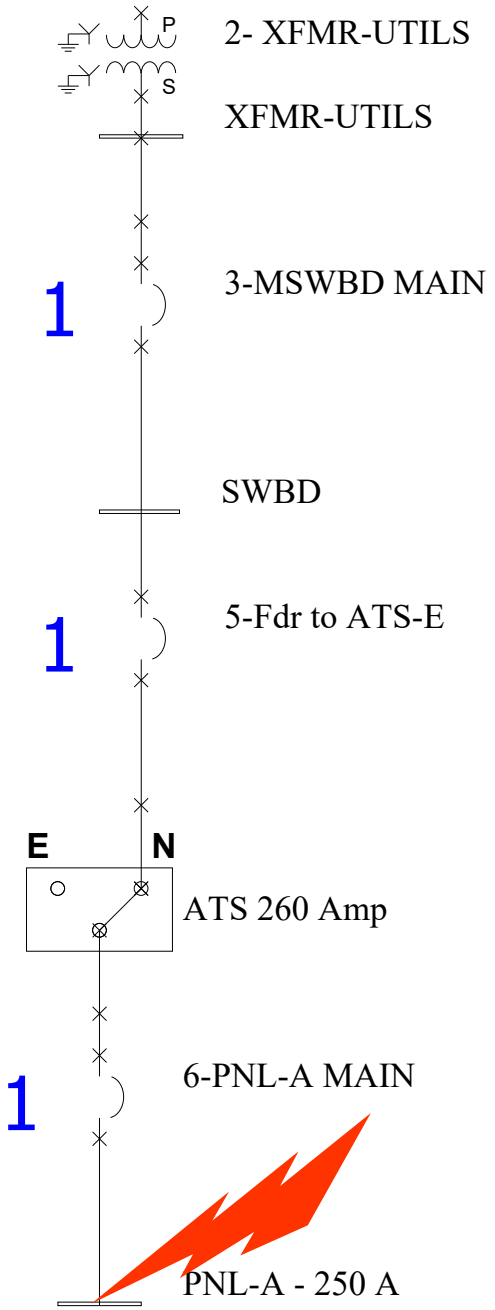


Goal #2 - Maximum Equipment Protection and Reduction in Arc Flash Energy

- Correct fuse sizes and device settings will quickly interrupt the fault current for a short circuit downstream.
- Shorter device delays = decreased equipment damage = less Incident Energy

Maximum Equipment Protection

- (No Selective Coordination)



- Must balance these two conflicting goals based upon the type of facility.

PDC Vocabulary

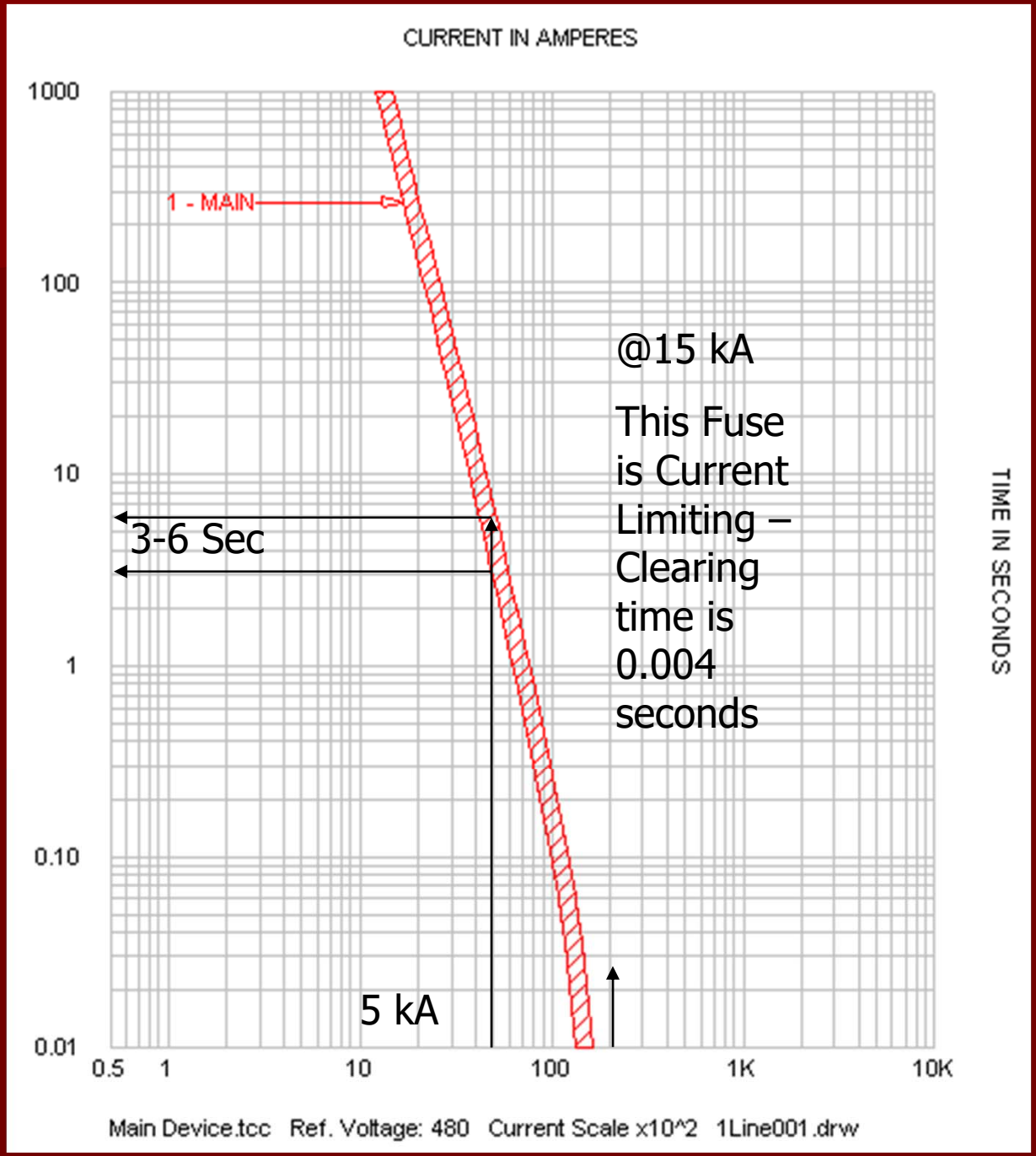
- Time Current Curve (TCC)
- Log-log graph of time versus current
- Every breaker, fuse, and relay has a time current characteristic curve.

PDC Vocabulary

- Selective Device Coordination
  - The devices plotted on the time current curves are coordinated for all levels of fault current and time.


AMP-TRAP
2000
DUAL ELEMENT
TIME DELAY
Any Red = Open
AJT400
400A
600V AC
500V DC
Ferraz
Shawmut

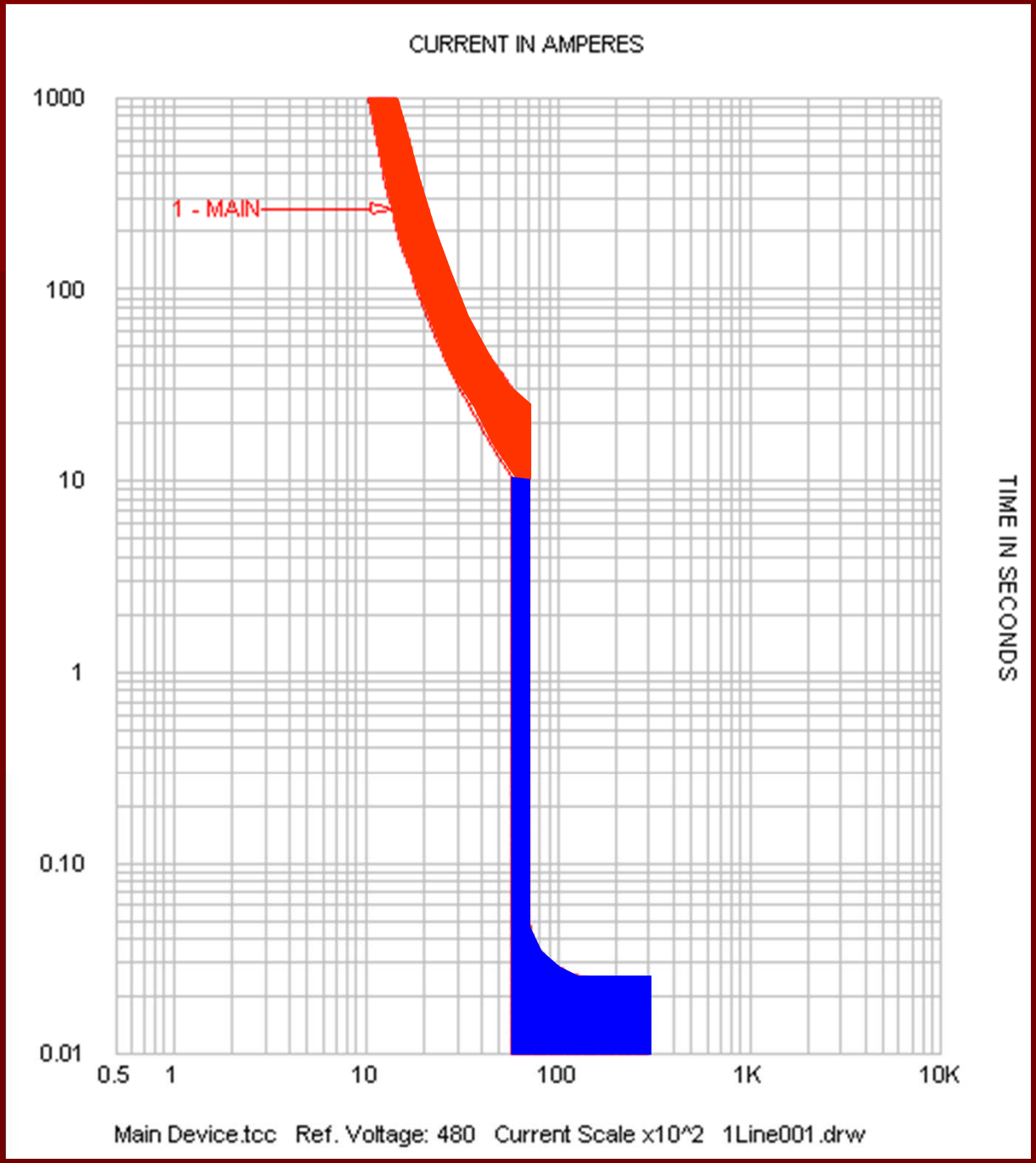
Fuse TCC


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

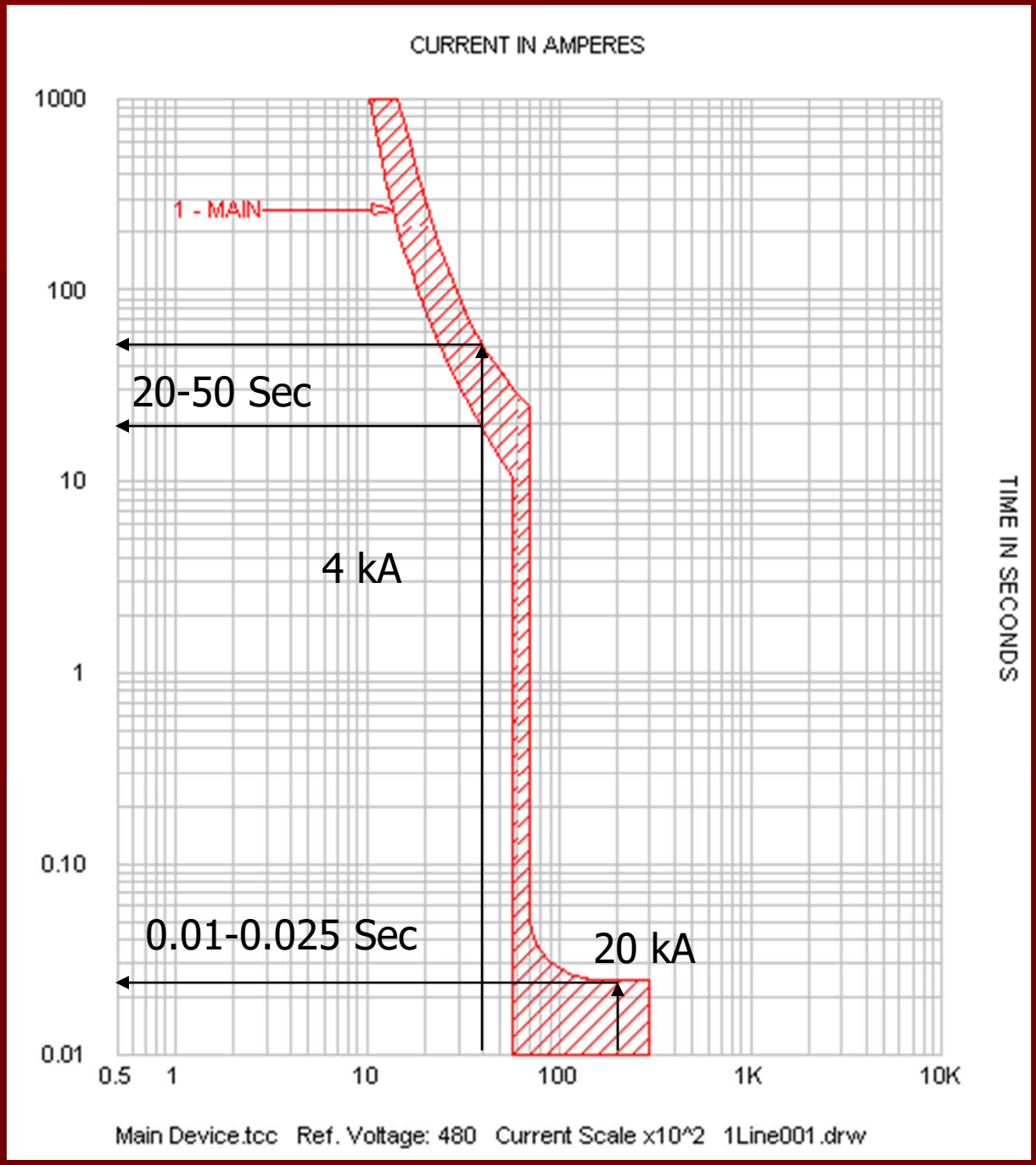

DANGER
I-T-E
Sentron™ Series
SIEMENS
225
ON
Accessories
Left Pole:
Right Pole:
PUSH TO TRIP
225A.
LO
HI

Thermal Magnetic Trip Unit

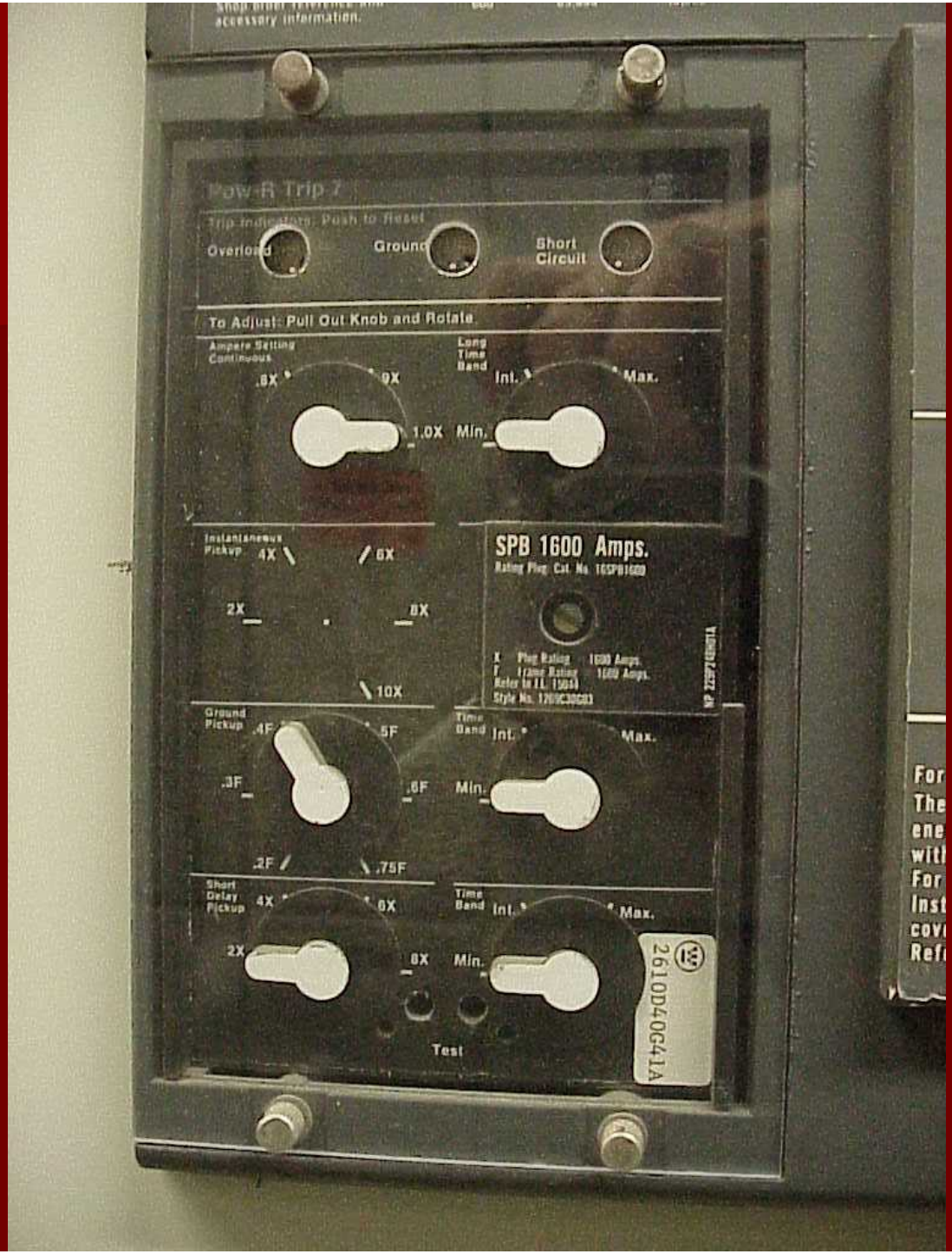
- Thermal Unit is Fixed
- Instant-aneous
  - Fixed
  - Adjustable



Thermal Magnetic Breaker

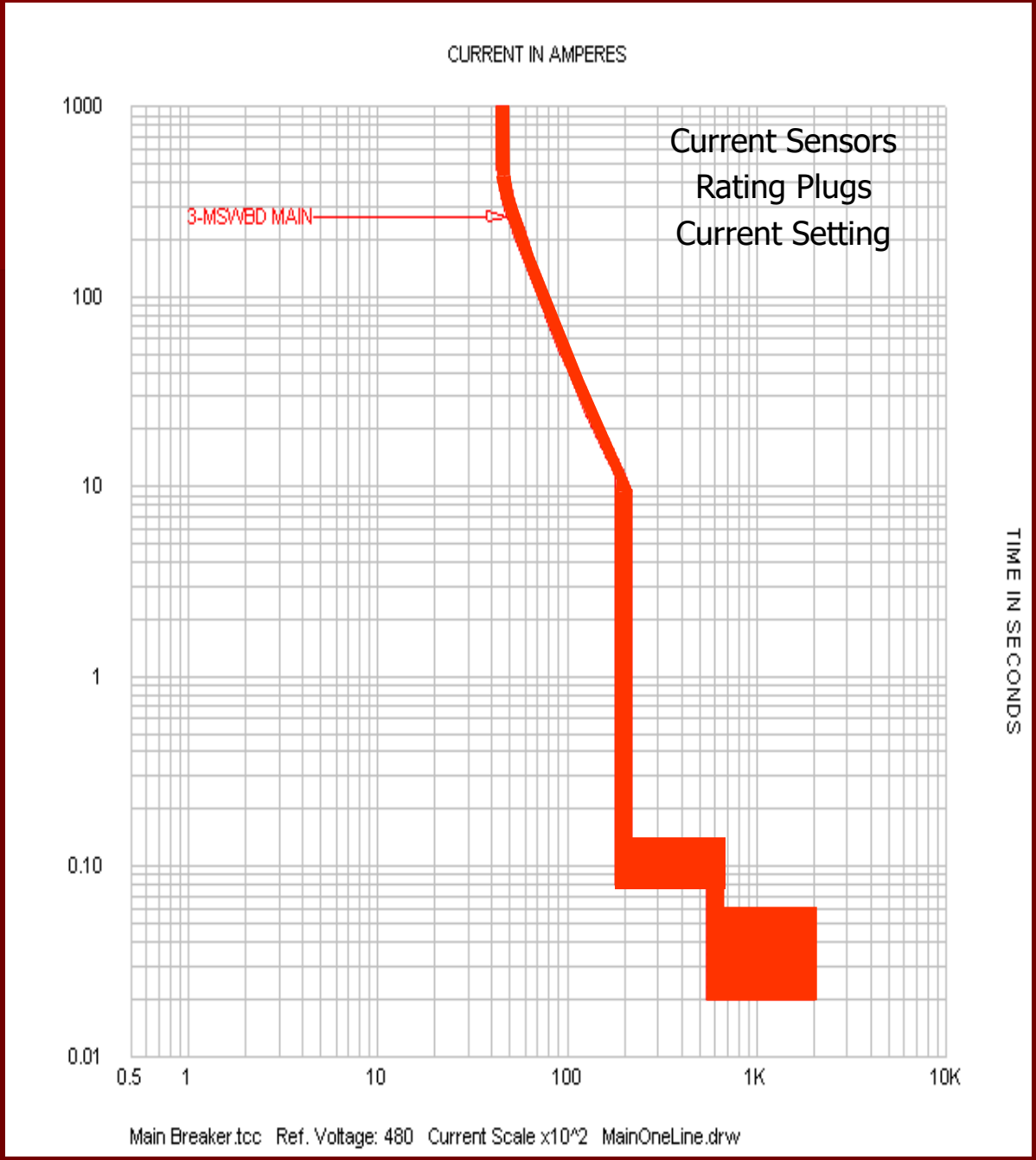



Westinghouse
SPB 100
Systems Pow-R Breaker
3 Pole— 1,600 Amp Frame
Stored Energy
Discharged
Contact Position
Closed
Push to Close
Push to Open
SPB 1600 Amps.


accessory information.
Pow-R Trip 7
Trip Indicators: Push to Reset
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.
Rating Plug Cat. No. 1605PB1600
X Plug Rating 1600 Amps.
Refer to I.L. 15044
Style No. 1201C30G03
Ground Pickup
.4F
.5F
.3F
.6F
.2F
.75F
Time Band
Int.
Max.
Min.
Short Delay Pickup
4X
6X
2X
8X
Time Band
Int.
Max.
Min.
Test
2610D40G41A

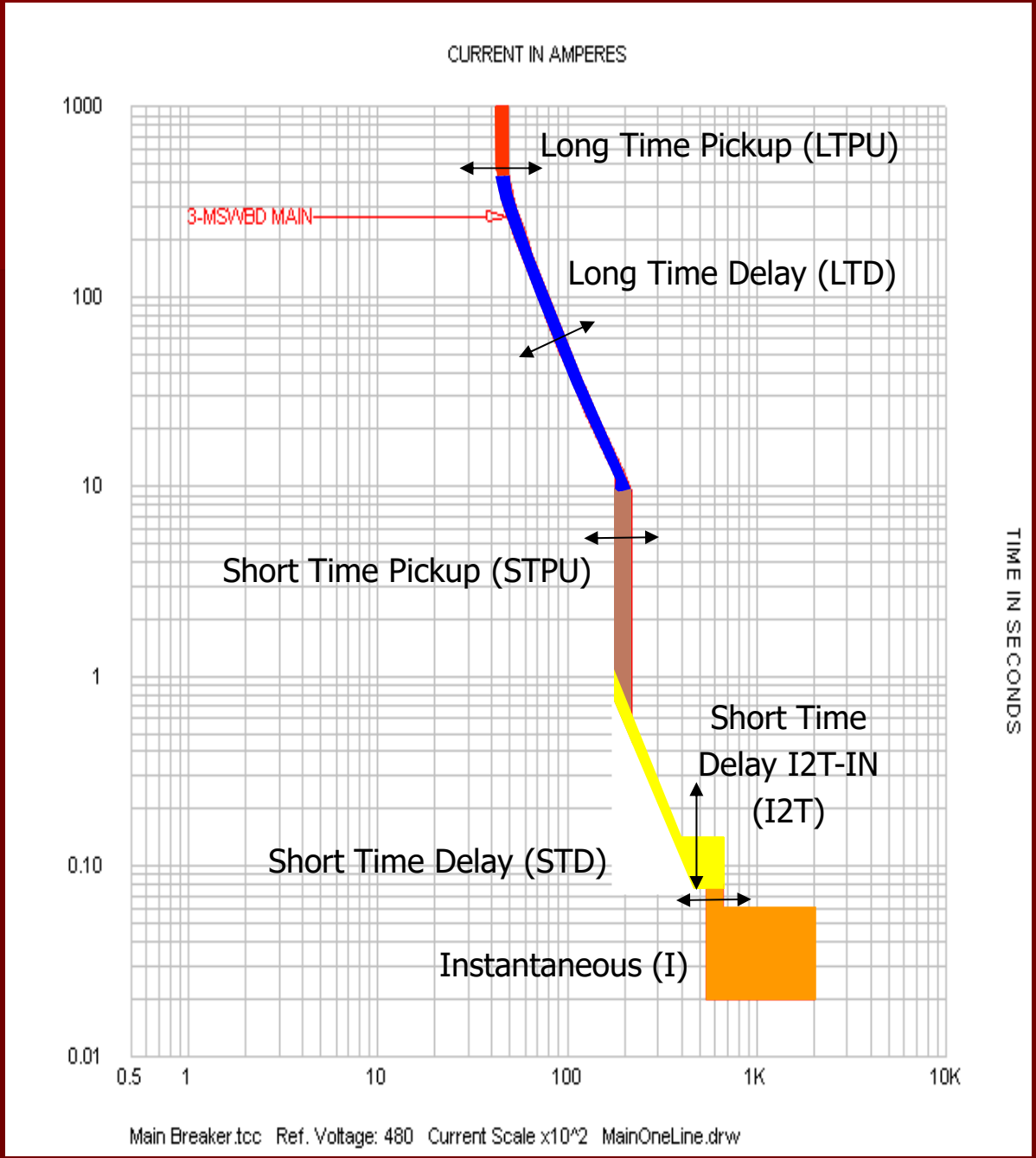
Solid State Trip Unit

- SQ D NW 40H
- 4000 Amp
- Micrologic



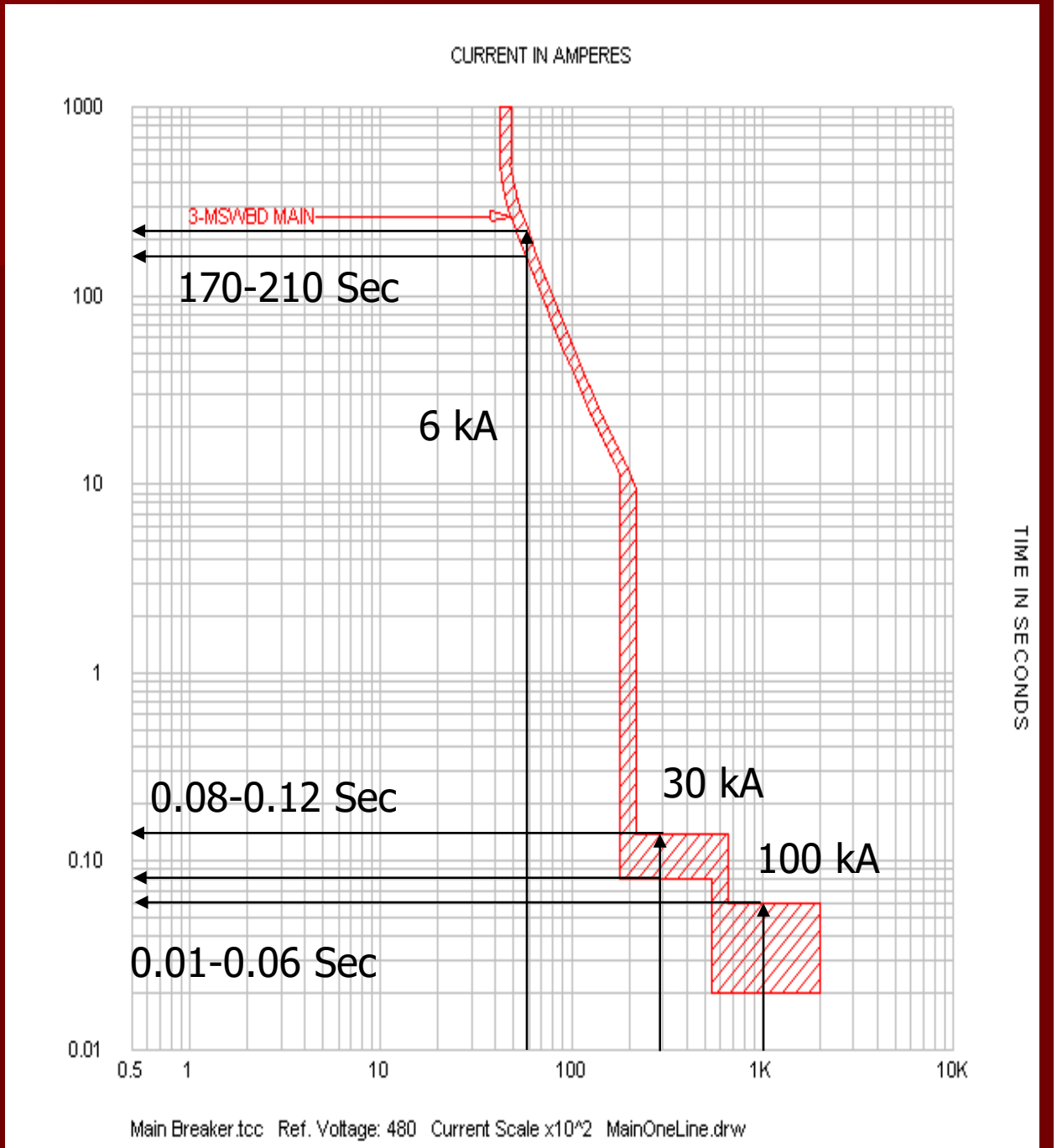
Solid State Trip Unit

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



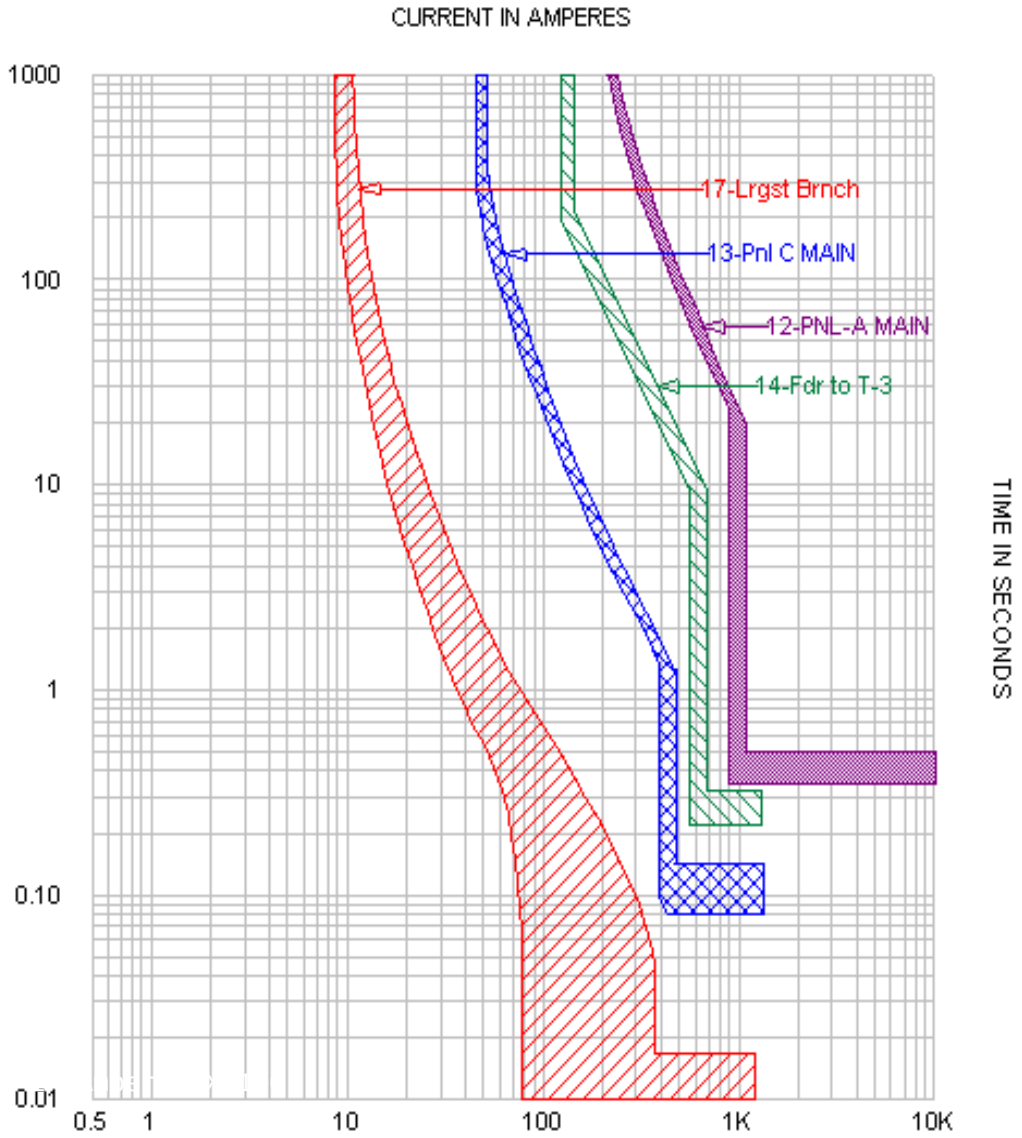
Solid State Trip

- SQ D NW 40H
- 4000 Amp
- Micrologic



Time Current Curves

- An example of a TCC with Coordinated Devices

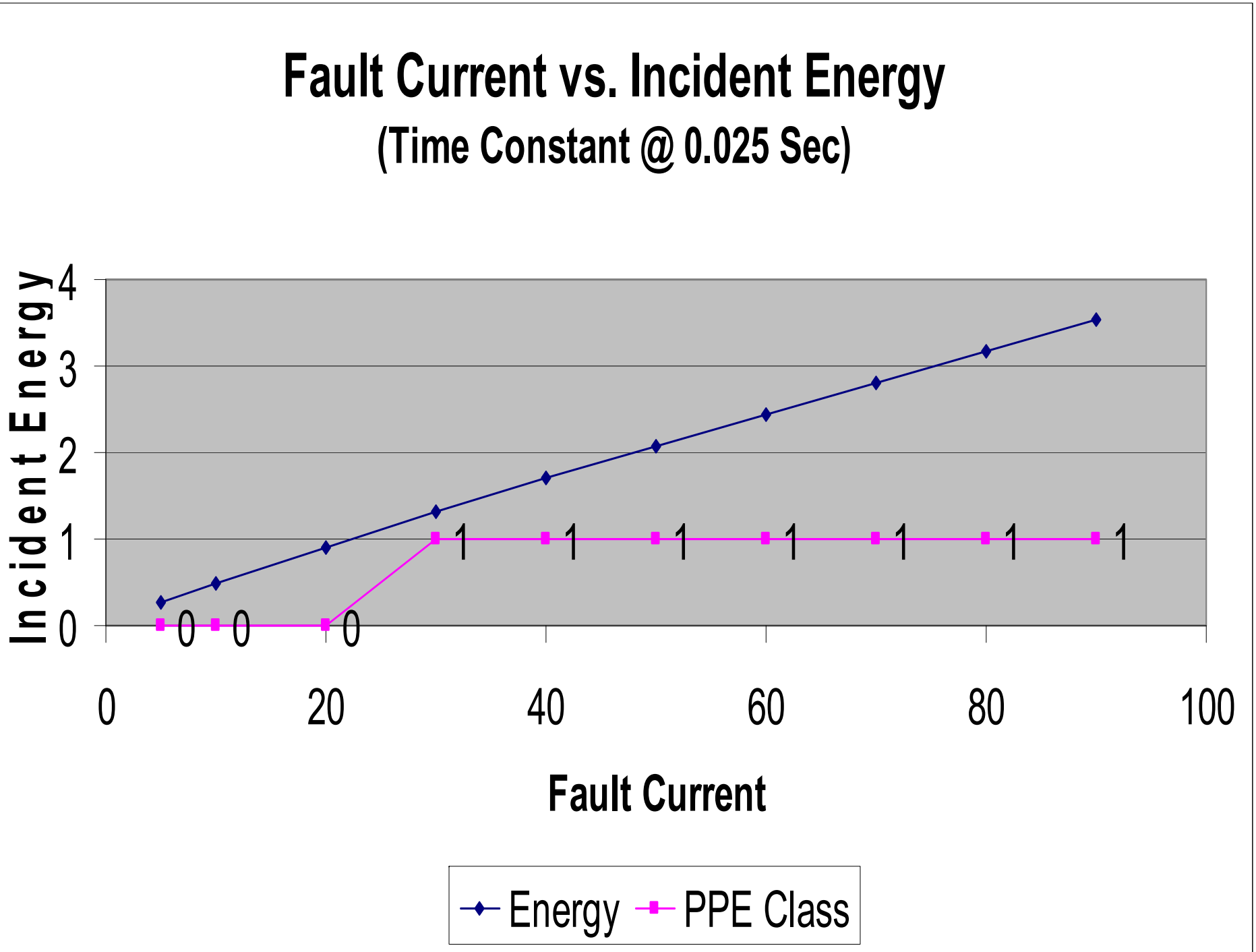


Arc Flash Energy Calculations

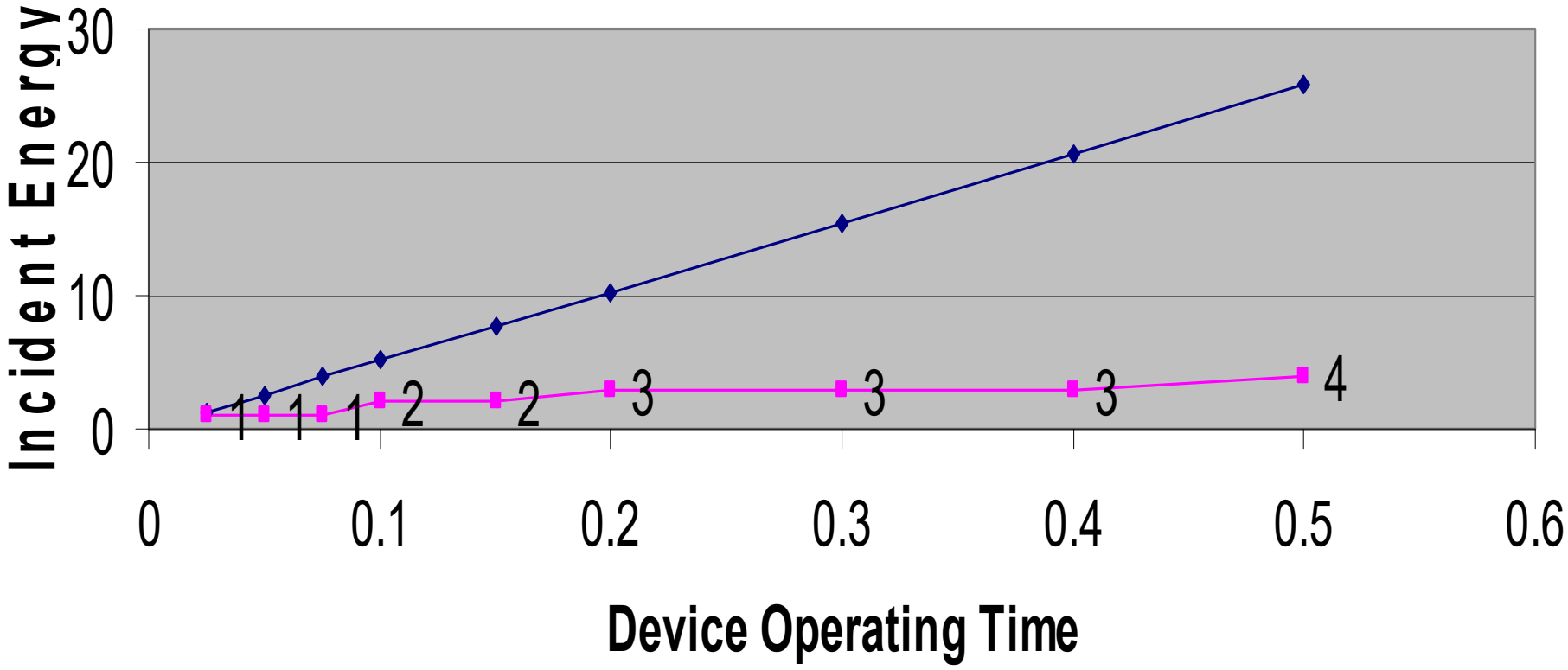
- Incident Energy Levels are dependent on:
  - Level of arcing fault current
  - Upstream device clearing time.
- Multiple Sources

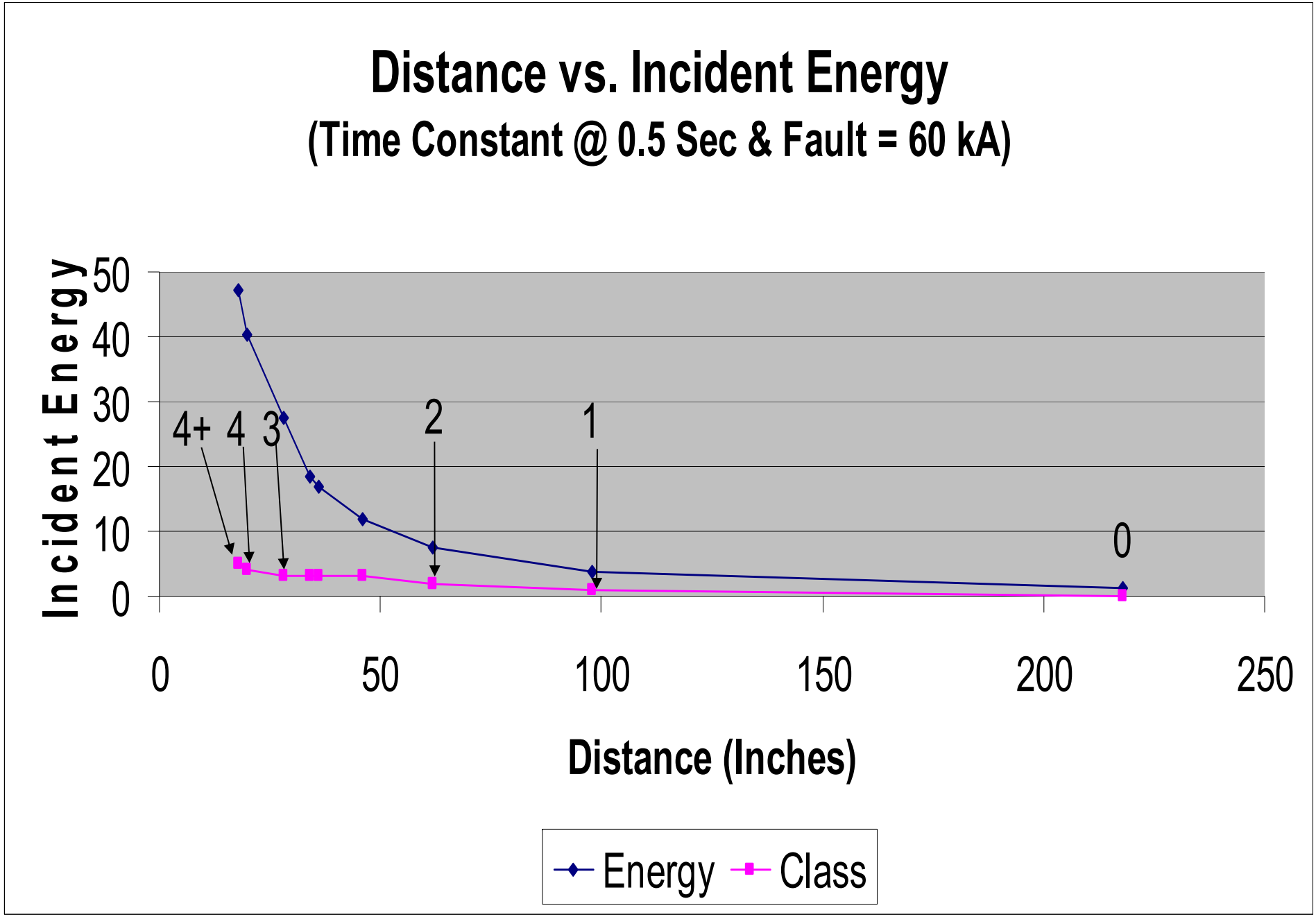
Typical Assumptions for an Analysis

- Trip time is determined by the upstream protective device settings.
- Worker is stationary.
- The maximum time that a worker will be exposed to the arc flash is 2.0 seconds. (Depends upon location!!!)


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

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




Distance vs. Incident Energy
(Time Constant @ 0.5 Sec & Fault = 60 kA)
Incident Energy
50
40
30
20
10
0
4+
4
3
2
1
0
0
50
100
150
200
250
Distance (Inches)
Energy
Class

Arc Flash Warning Labels

- What does it mean?

Informative Label

Arc Flash and Shock Hazard

11 Ft 5 In	Flash Hazard Boundary
33.0	cal/cm² Flash Hazard at 1 Ft 6 In
	Arc Rated Clothing Required (See NFPA 70E-2018 Table 130.5(G) for additional PPE)
208 VAC	Shock Hazard when cover is removed
00	Glove Class
3 Ft 6 In	Limited Approach (Fixed Circuit)
1 Ft 0 In	Restricted Approach
11/15/2018	IEEE 1584-2018 & NFPA 70E-2018

Equipment: SWBD MSB2
Device: MSB2 MAIN

Scenario 2 - 50% UTILITY — Max Fault Current: 20.0 kA

Study Performed By Power Studies, Inc. (253) 639-8535

Limited Approach Boundary:

- An approach limit at a distance from an exposed energized electrical conductor or circuit part within which a shock hazard exists.
- This value is determined by NFPA 70E Table 130.4(D)(a).
- Qualified Persons
- Unqualified if accompanied by a Qualified Persons

Restricted Approach Boundary

- An approach limit at a distance from an exposed energized electrical conductor or circuit part within which there is an increased likelihood of electric shock, due to electrical arc-over combined with inadvertent movement.
- Determined by NFPA 70E Table 130.4(D)(a)

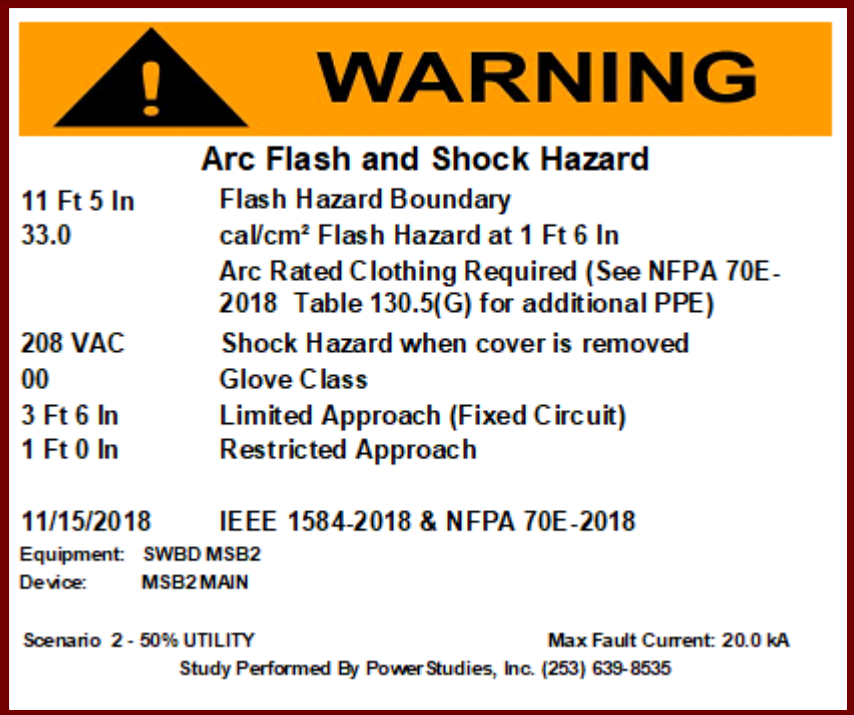
Arc Flash Label Installation

- Always clean the surface with detergent to remove all grease and dirt. Wipe surface dry before applying the label.
- Some locations will have a Line Side Label. They should be installed at locations where maintenance staff could be exposed to energized parts on the line side of a fuse or circuit breaker. Examples of this are Main Breakers in Switchboards and Switchgear.

Arc Flash Label Installation

- Transformer Labels are for small distribution transformers (480/208 V) where both the 480 and 208 Volts terminals are exposed.
- Locations where the label will be exposed to direct sun light should be brought to the attention of PowerStudies, Inc. We will provide labels with a special UV protective covering to protect the label from fading.

Line Side vs Bus AF Labels



WARNING

Arc Flash and Shock Hazard

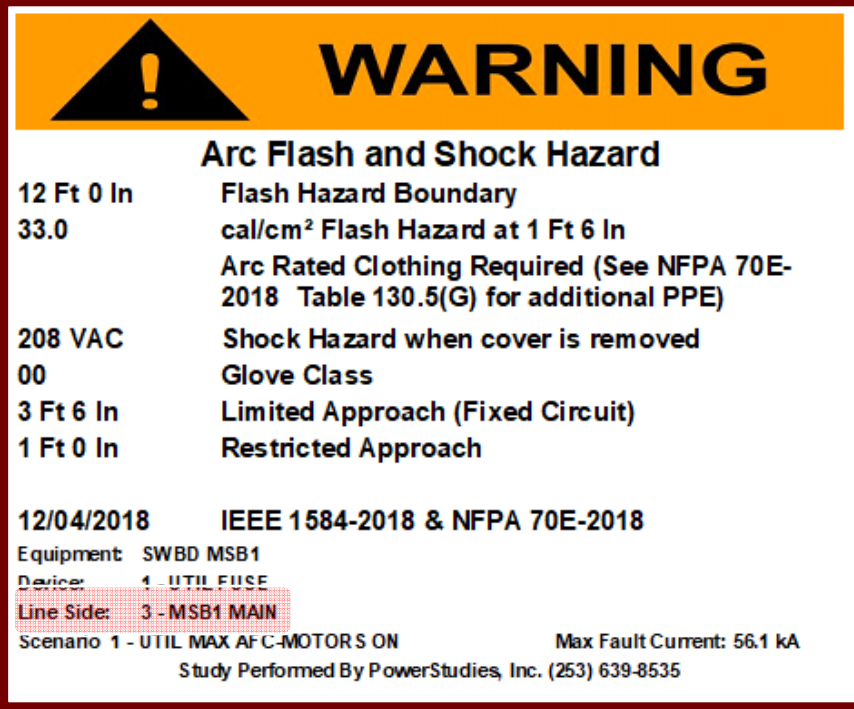
11 Ft 5 In	Flash Hazard Boundary
33.0	cal/cm² Flash Hazard at 1 Ft 6 In
	Arc Rated Clothing Required (See NFPA 70E-2018 Table 130.5(G) for additional PPE)
208 VAC	Shock Hazard when cover is removed
00	Glove Class
3 Ft 6 In	Limited Approach (Fixed Circuit)
1 Ft 0 In	Restricted Approach

11/15/2018 IEEE 1584-2018 & NFPA 70E-2018

Equipment: SWBD MSB2
Device: MSB2 MAIN

Scenario 2 - 50% UTILITY Max Fault Current: 20.0 kA

Study Performed By PowerStudies, Inc. (253) 639-8535



WARNING

Arc Flash and Shock Hazard

12 Ft 0 In	Flash Hazard Boundary
33.0	cal/cm² Flash Hazard at 1 Ft 6 In
	Arc Rated Clothing Required (See NFPA 70E-2018 Table 130.5(G) for additional PPE)
208 VAC	Shock Hazard when cover is removed
00	Glove Class
3 Ft 6 In	Limited Approach (Fixed Circuit)
1 Ft 0 In	Restricted Approach

12/04/2018 IEEE 1584-2018 & NFPA 70E-2018

Equipment: SWBD MSB1
Device: 1 - UTIL FUSE
Line Side: 3 - MSB1 MAIN

Scenario 1 - UTIL MAX AFC-MOTORS ON Max Fault Current: 56.1 kA

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Need more Information

- www.powerstudies.com
  - Articles
  - Links
  - Specifications for Power System Studies
    - Short Circuit
    - Protective Device Coordination
    - Arc Flash Hazard
- Phone: 253-639-8535
- Email: fuhr@powerstudies.com or Quotes@powerstudies.com

Thank you for your time!

- Questions?????