Arc Flash Calculations Not Covered by IEEE 1584-2018

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The presentation will start at the top of the hour.

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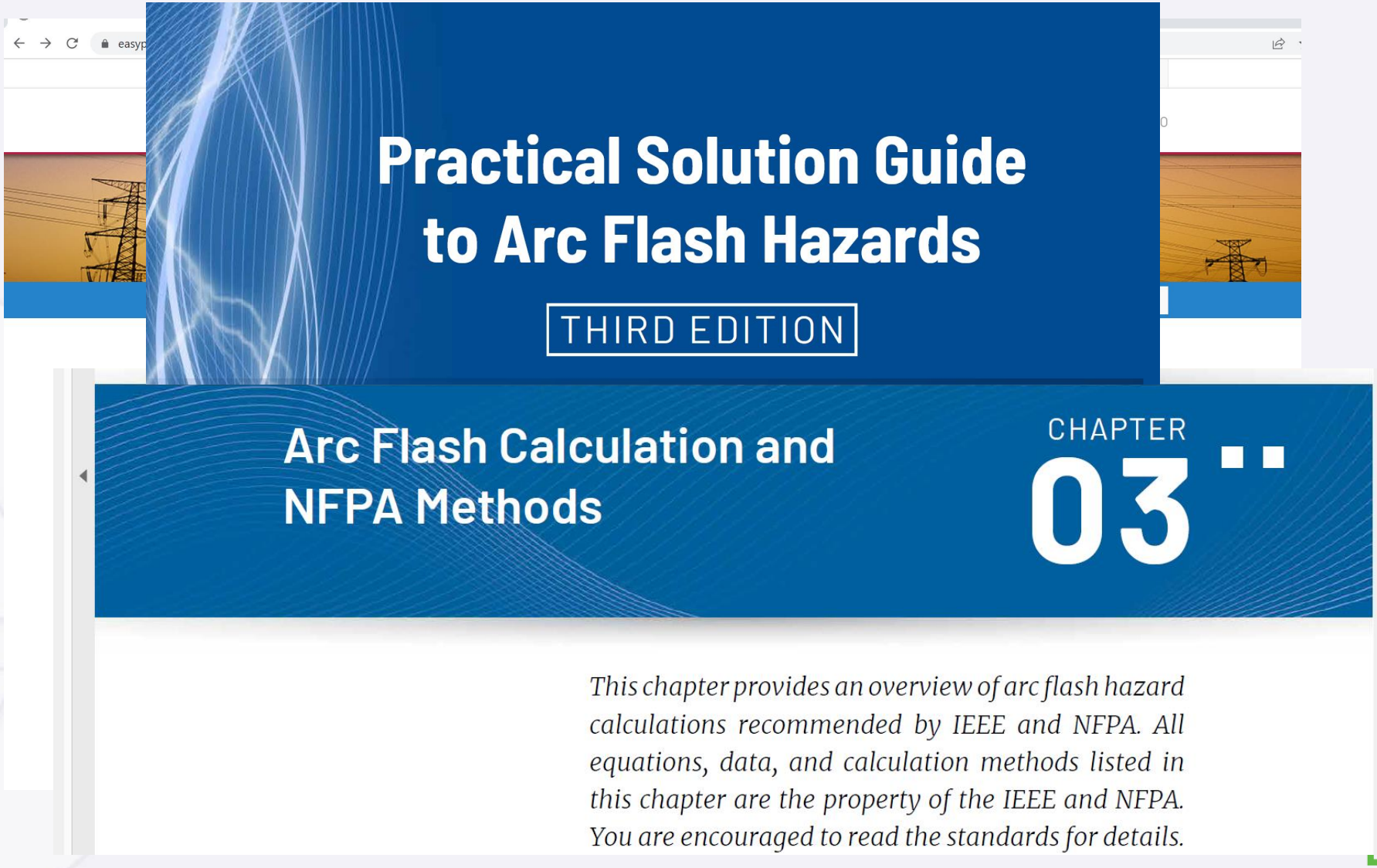
Poll Questions

- How often do your projects involve elements greater than 15 kV?
- What has been your primary tool for calculating arc flash for Direct Current applications?
- The main concern you have regarding MV arc flash involve the potential for:
  - Single line to ground arcs
  - Line to Line arcs
  - Three phase arcs

Spoiler Alert



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Two ‘70E’ Approaches to Arc Flash

- Arc flash PPE category method and AF Boundary
  - Table 130.7(C)(15)(a) AC
  - Table 130.7(C)(15)(b) DC
  - Table 130.7(C)(15)(c) PPE description
  - Informational notes with each
  - Conservative
- Incident Energy Calculation

Conventional Wisdom says:

- “If the only tool you have is a hammer, everything looks like a nail.”
- Keeping with the analogy:
  - EasyPower is the more like a ‘Swiss army knife’ for arc flash analysis.
  - The more you understand the functions, the better your tool utilization will be.
  - EasyPower features included in Arc Flash module

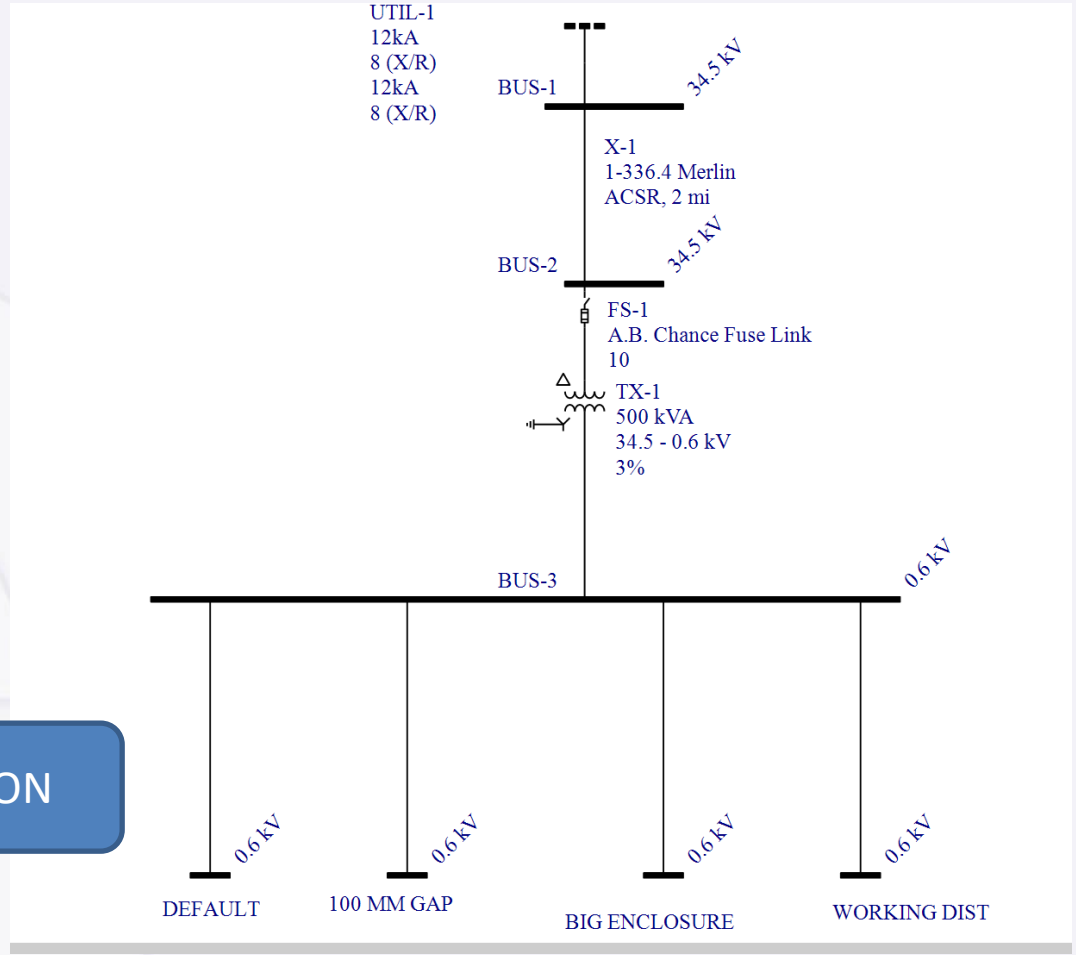
Range of model (IEEE 1584-2018 4.2)

- Voltages in the range of 208 V to 15,000 V, three-phase (line-to-line)
- Frequency of 50 Hz or 60 Hz
- — Bolted fault current (rms symmetrical)
  - — 208 V to 600 V: 500 A to 106 000 A
  - — 601 V to 15,000 V: 200 A to 65 000 A
- — Gaps between conductors
  - — 208 V to 600 V: 6.35 mm to 76.2 mm (0.25 in to 3 in)
  - — 601 V to 15,000 V: 19.05 mm to 254 mm (0.75 in to 10 in)
- Working distances greater than or equal to 305 mm (12 in)
- Enclosure dimension limits (established using the enclosures from the 2002 version of this guide)
- — Maximum height or width: 1244.6 mm (49 in)
- — Maximum opening area: 1.549 m^2 (2401 in^2)
- — Minimum width: The width of the enclosure should be larger than four times the gap between
- conductors (electrodes).

IEEE 1584-2018

- Empirical- developed to fit the data
  - Not necessarily linear over any range/parameter
  - Employs conditional ‘Correction Factors’
  - Valid for a specific range
  - EasyPower will indicate ‘out of range’ but you can decide if results are valid

Correction factors



Correction Factors
Typical values included in
IEEE 1584 Standard

01 CORRECTION

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Working Distance

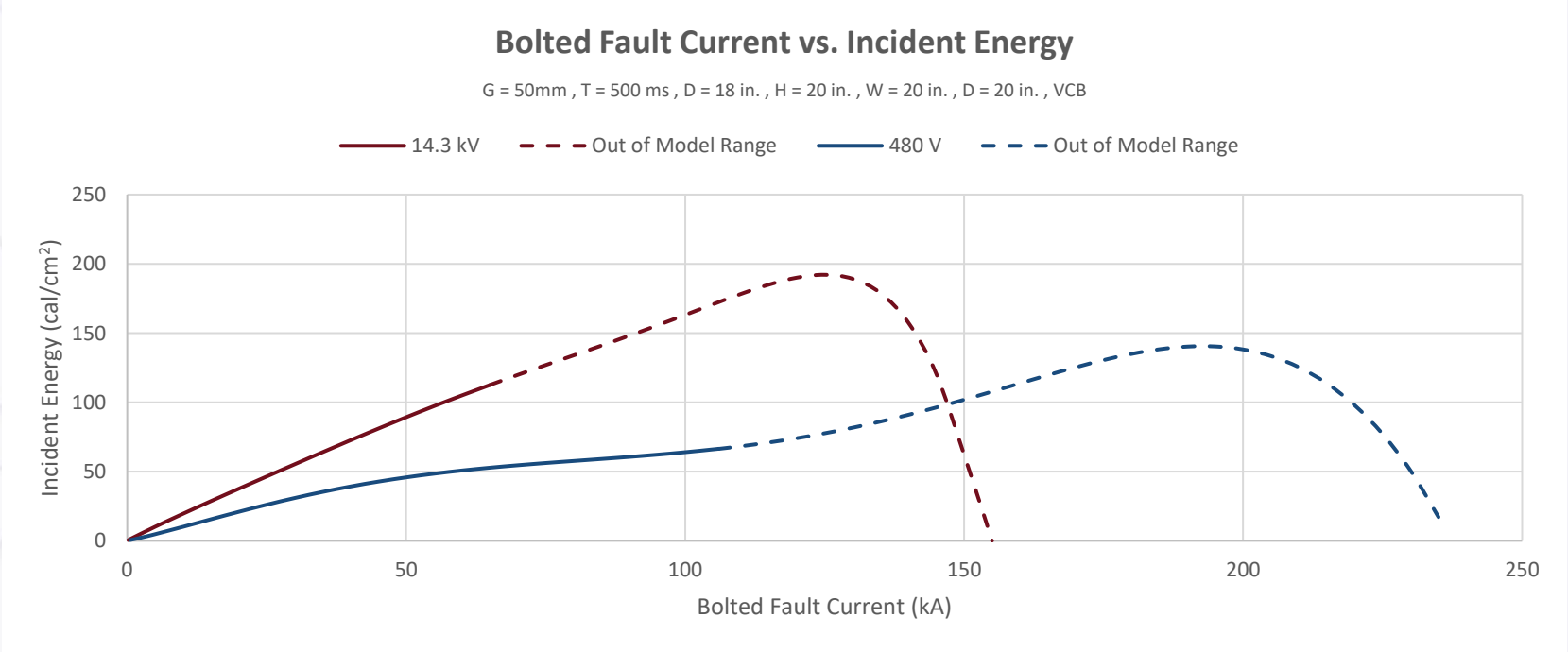
- Working distance for label

- Working distance for ‘Hot Work’
  - Hot work instructions may require different PPE based on nature of task
  - Example Maintenance mode could suggest lower rater IE than label indicates

Bolted Fault Current - Model Range

Low Voltage (≤ 600 V): 500 A through 106 kA

Medium Voltage (> 600 V): 200 A through 65 kA



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DC Systems

- IEEE 1584 – 2018
  - Does not include DC arc flash model
- Choices
  - EasyPower includes Max Power Method applied to DC systems
  - Option to apply to greater than 1 kV DC
  - Also reference other methods based on IEEE papers

021 DC ARC

Single Phase 15 kV or less

- IEEE 1584 -2018
  - States the model is **not** for single phase faults
  - Suggests that conservative result
    - Determine single phase fault current
    - Use current in 3 phase model to get incident energy
    - No additional EasyPower settings

022 SINGLE

Higher Voltage or Current

- IEEE 1584 – 2018
  - Makes no recommendation for calculations greater than 15 kV
- EasyPower has the option of using
  - 'Lee Equations' – 3 phase arcs
  - NFPA 70E 2009 - SLG

NFPA 70 E

SECTION	SOURCE	
D.2	Lee, "The Other Electrical	
D.3	Doughty, et al., "Predicting Manage the Electrical Arc Distribution Systems"	
		50 kA
	IEEE 1584, Guide for Performing Arc Flash Calculations	Calculates incident energy and arc flash boundary for: 208 V to 15 kV; three-phase; 50 Hz to 60 Hz; 700 A to 106,000 A short-circuit current; and 13 mm to 152 mm conductor gaps

Calculates incident energy and arc flash boundary for arc in open air; conservative over 600 V and becomes more conservative as voltage increases

040 RALPH LEE

Single Line to Ground

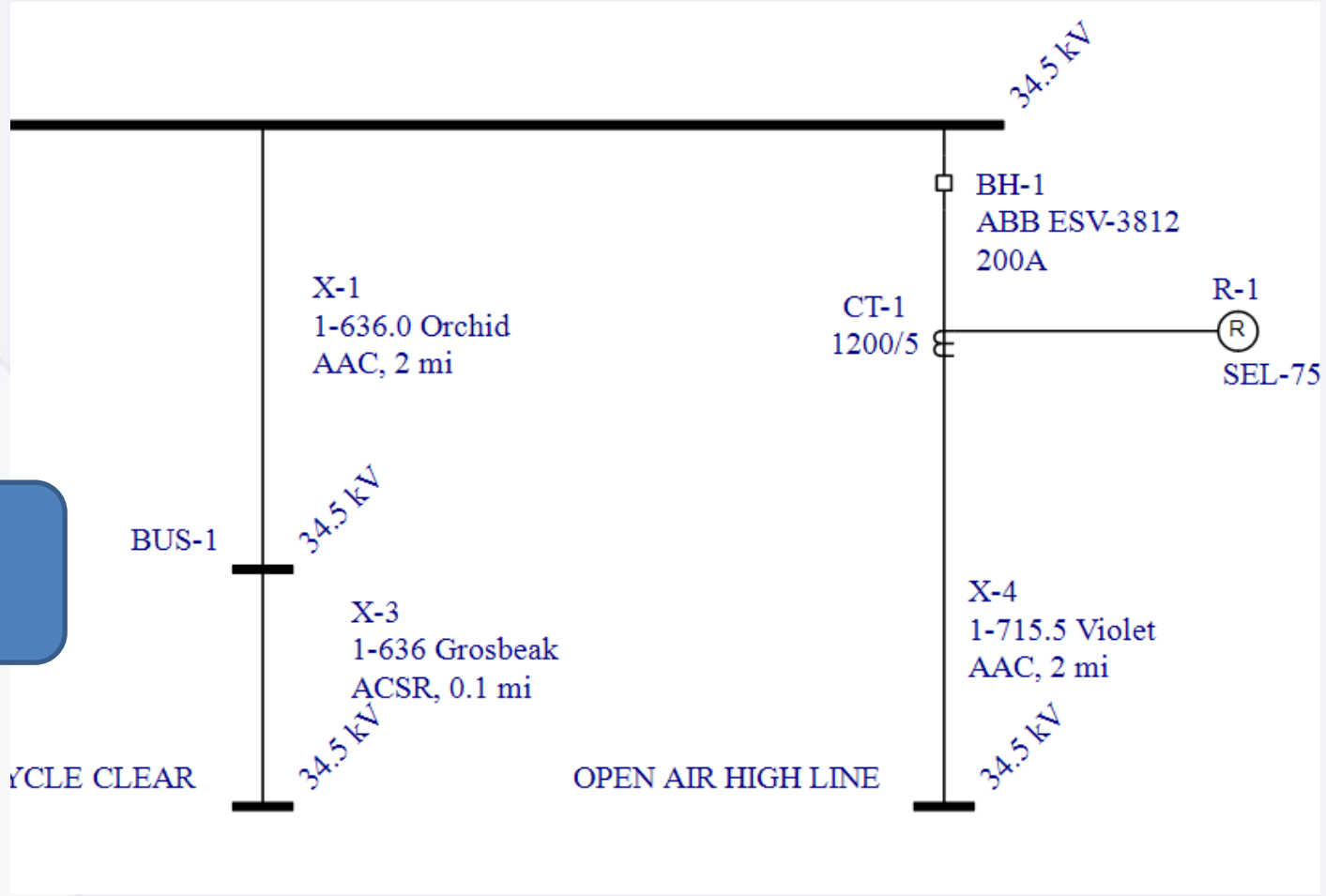
- Examples of HV Single Line to ground arc flash calcs for use when phase spacing is large enough that SLG is more likely fault

Steps

- 1 Set up bus dialog
  - Open air bus
- 2 In Short Circuit Options
  - Arc Flash Hazard tab
    - Advanced select Open Air
    - Option > 1 KV; >15 kv
    - WD NFPA 70E/Options
- 3 Fault Single Line to Ground

SLG HV in Open Air

050 SLG



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NFPA 70E – 2009 (ANSI C2 Table 410)

- D.8
  - "Estimated Incident Energy Exposure for Live Line Work on Overhead Open Air Systems 1 kV to 800kV,
  - Table D.8(1) and D.8(2) list the heat flux rate in cal/cm^2/sec derived from ANSI/IEEE C2,
  - Tables 410-1 and 410-2. To estimate the incident energy, multiply the heat flux rate in tables by the maximum clearing time (in seconds.)"

Table D.8(1) & Notes

Max Fault Current (kA)	Phase-to-Phase Voltage (kV)			
	1 to 15	15.1 to 25	25.1 to 36	36.1 to 46
	Heat Flux Rate (~~cal/cm²~~/sec)			
5	4.9	8.7	11.6	14.8
10	12.5	20.8	27.1	34.5
15	22.2	35.6	45.4	56.2
20	34	52.8	66.4	78.7

- These calculations are based on **open air phase to ground arcs.**
- These calcs are based on 15 in. 'separation distance'; gap 1-15 kV = 2"; 15.1 -25kV=4";25.1-36kV=6"; 36.1-46kV= 9"
- These calculation were derived using a commercially available computer program. Other methods are available to estimate arc exposure values & may yield slightly different but equally acceptable results.
- (Equivalent to Arc Pro)

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Table D.8(2) & Notes

Table D.8(2)

Max Fault Current (kA)	Phase-to-Phase Voltage (kV)							
	46.1 to 72.5	72.6 to 121	138 to 145	161 to 169	230 to 242	345 to 362	500 to 550	765 to 800
	Heat Flux Rate (cal/cm^2/sec)							
20	12.4	24.2	19.4	21.1	17.7	8.3	9.8	8.2
30	22.3	42.1	33.5	34.2	28.7	13.5	15.8	13.3
40	34.7	63.6	50.4	49	41.1	19.3	22.7	19
50	49.5	88.7	70	65.2	54.7	25.6	30.2	25.3

- These calculations are based on open-air phase-to-ground arcs.
- Arc gap is calculated by taking phase-to-ground voltage and divide by 10. Dielectric of air = 10 kV/inch.
- Distance from arc to employee is calculated by using MAD (ANSI C2) and subtracting two times gap length.
- These calculations were derived using commercially available software. Other methods may yield slightly different but are equally acceptable.

Single Line to Ground

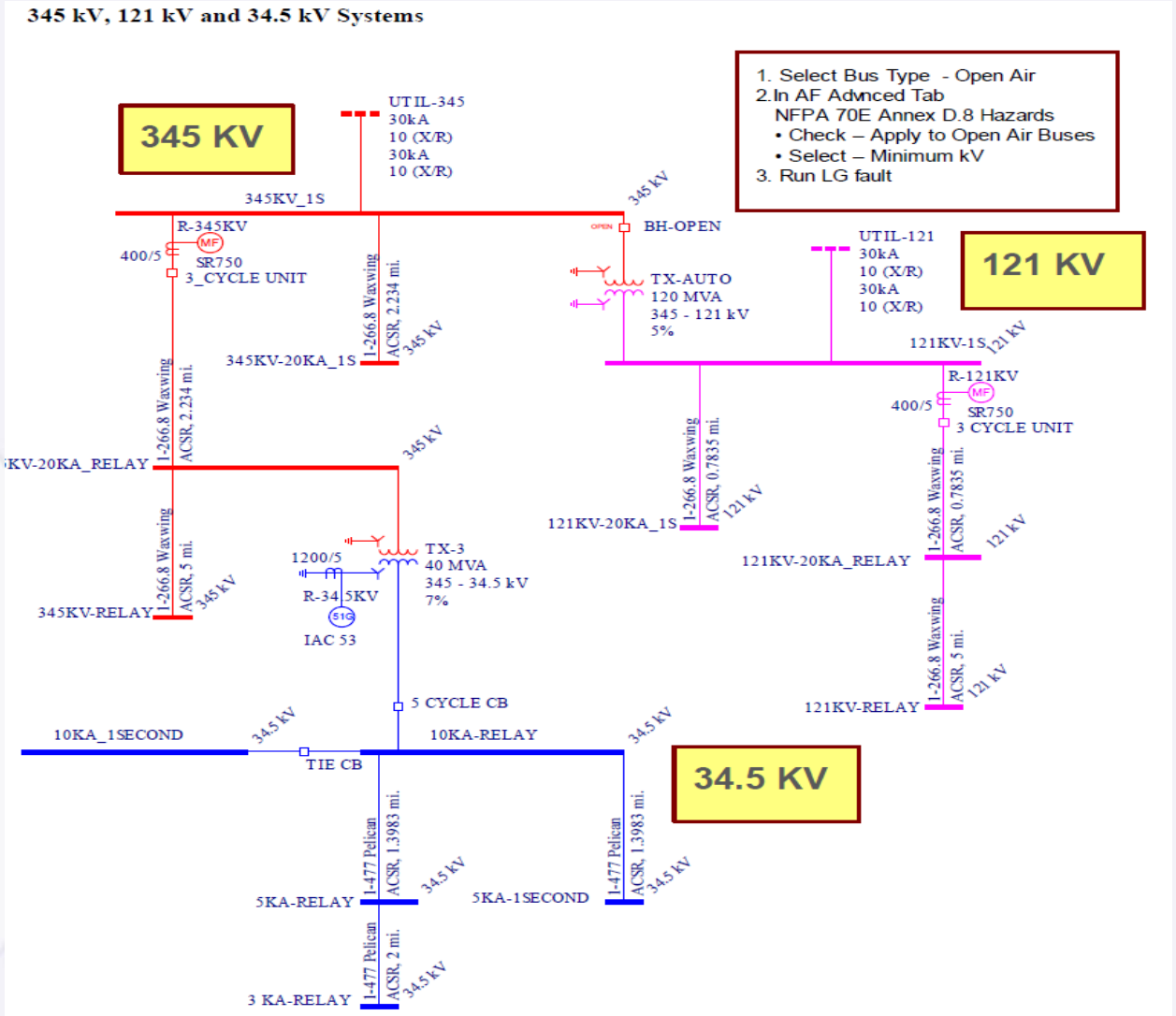
Air Gap Based on Voltage

- SLG voltage = Phase-Phase Voltage /1.73

- Air dielectric strength = 10kV/in. (IEEE Std 4 – "High Voltage Test Techniques)
  - Air gap(inches) = SLG Voltage /10 kV
  - Air gap (mm) = Air gap(inches) * 25.4 mm/inch
- Combined
  - Air gap (inches) (Phase-Phase Voltage)*(1.73)*(1/10)
  - Air gap (mm) = (Phase-Phase Voltage)*(1/1.73) *(1/10)*(25.4)
  - Air gap (mm) = (Ph-PH Voltage) * 1.468

- PH- PH = 765 kV
  - Air gap (inches) = 44.21 inches
  - Air gap (mm) = 1123 mm

In EasyPower



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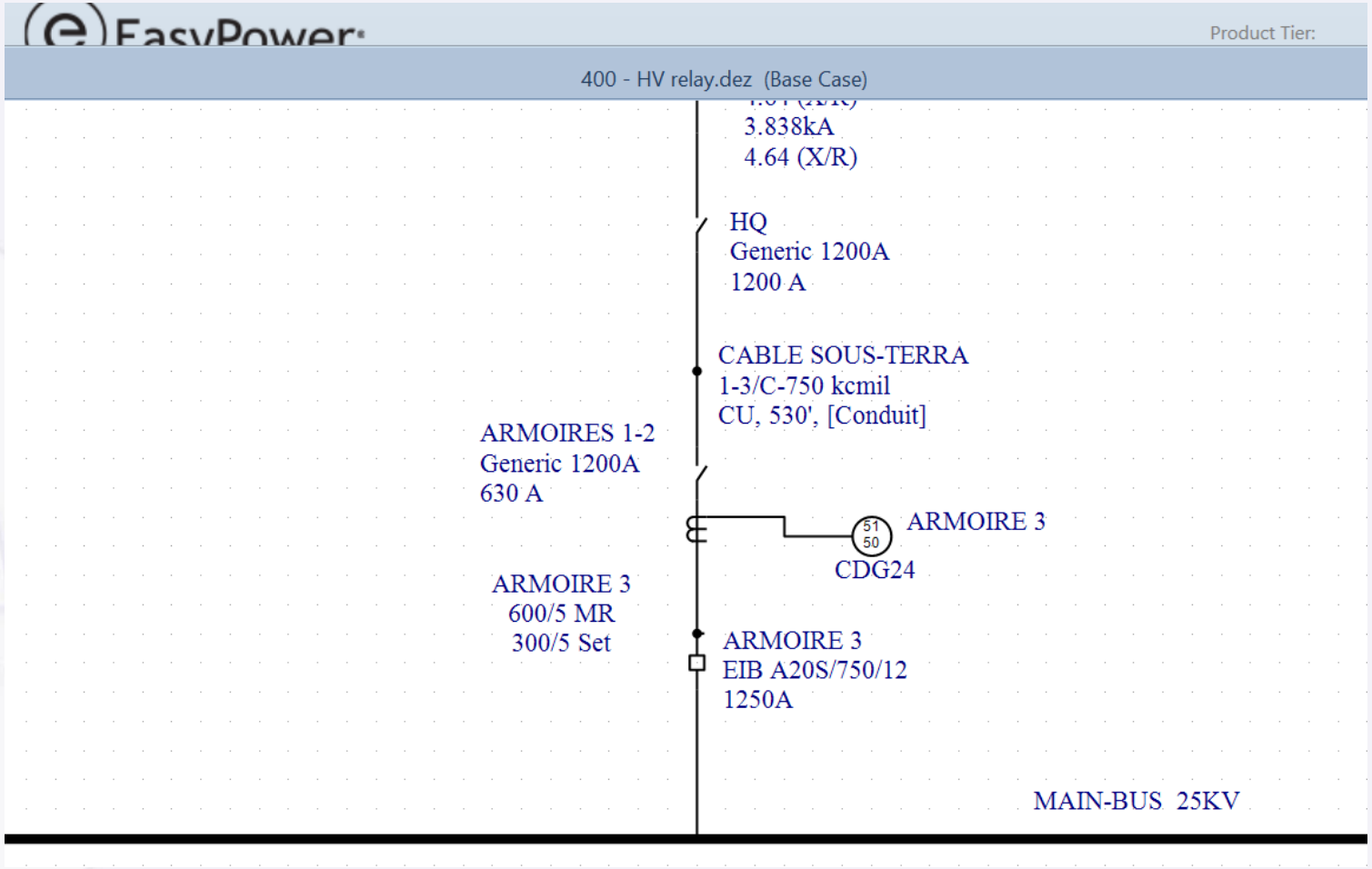
“Relay has no effect on bus Arc Flash”



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What we covered

- Examples
  - 1 Outside of “range” of IEEE 1584-2018 (correction factor parameters) - EasyPower –warning flag; extrapolated from IEEE data
  - 2 “Lee equations” high side of volts and current – no IEEE guidance
- 3 Examples of HV Single Line to ground arc flash calcs
- 4 Examples using ‘Suggested single phase Arc Flash’ method
- 5 Examples of DC arc flash using Max Power method.

EasyPower Resources

- 1 User Guide includes details for each
- 2 www.easypower.com
  - Regional training live on-line
- 3 Free monthly Arc Flash Workshop
- Support@easypower.com