

Arc Flash Analysis

Lessons Learned
Standards

Objectives

- Background
- Standards and Calculation Methods
- Impact of Protection Philosophies
- Implementation Plan

How it Started

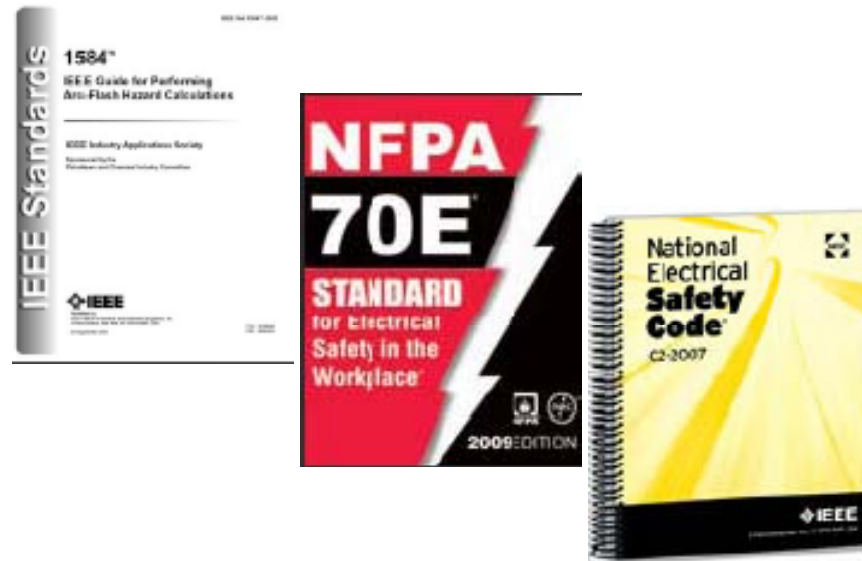
- NESC 2007, 410.3
 - “Effective as of January 1, 2009, the employer shall ensure that an assessment is performed to determine the potential exposure to an electric arc for employees who work on or near energized parts or equipment. If the assessment determines a potential employee exposure greater than 2 cal/cm² exists..., the employer shall require employees to wear clothing or a clothing system that has an effective arc rating not less than the anticipated level of arc energy.”

Issues and Concerns - 2007

- Many established methods at the time limited to lower voltage systems
- Numerous industry standards and guidelines – cause of confusion
- Higher voltage systems (above 15 kV)
 - “Lee Method” versus NESC Tables

Standards

- IEEE 1584
- NFPA 70E
- NESC 2007



All address arc flash analysis in different ways and yield different results in some instances

More Standards

- IEEE 516
 - *IEEE Power and Energy Society*
 - Addresses minimum approach distances (MAD), not arc flash specifically
 - OSHA recognizes this as the standard for energized line work
 - This 2009 version was not ready for the pre-print proposals for 2012 NESC



IEEE Guide for Maintenance Methods on Energized Power Lines

IEEE Power & Energy Society

Sponsored by the
Transmission and Distribution Committee

516™

IEEE
3 Park Avenue
New York, NY 10016-5007, USA
24 June 2009

IEEE Std 516™-2009
(Revision of
IEEE Std 516-2003)

NESC Tables

- Table 410-1: Clothing and clothing systems for voltages 1 to 46 kV
 - Calculations based on open air phase-to-ground arc
 - Working distance of 15 inches arc to employee
 - Arc gaps defined based on voltage
- Table 410-2: Clothing and clothing systems for voltages 46.1 to 800 kV
 - Open air phase-to-ground arc as above
 - Working distance calculated from minimum approach distances in Table 441-2
 - Arc gaps calculated based on voltage
 - Clearing times updated in Tentative Interim Amendment

More on NESC Tables



Tentative Interim Amendment 2007-5
to the
National Electrical Safety Code
ANSI C2-2007

5 September 2008

- Table 410-2; ...for voltages 46.1 to 800 kV
- Respective clearing times slightly longer

Table 410-2: Since the publishing of the 2007 Edition of the Code, it has come to attention of Subcommittee 8 that, as published, Table 410-2 contains errors. The values in Table 410-2 have been recalculated (using the same commercial software and methodologies) and validated by circulating the revised table to several individuals that verified the revised values.

Table 410-2

Table 410-2—Live-line tool work clothing and clothing systems—voltage, fault current, and maximum clearing time for voltages 46.1 to 800 kV[Ⓞ]
 (See Rule 410A3.)

Phase-to-phase voltage (kV)	Fault current (kA)	4-cal system	8-cal system	12-cal system
		Maximum clearing time (cycles)	Maximum clearing time (cycles)	Maximum clearing time (cycles)
46.1 to 72.5	20	<u>18.2</u>	<u>36.4</u>	<u>54.5</u>
	30	<u>10.2</u>	<u>20.4</u>	<u>30.6</u>
	40	<u>6.6</u>	<u>13.2</u>	<u>19.7</u>
	50	<u>4.6</u>	<u>9.2</u>	<u>13.9</u>
72.6 to 121	20	<u>9.9</u>	<u>19.8</u>	<u>29.8</u>
	30	<u>5.7</u>	<u>11.4</u>	<u>17.1</u>
	40	<u>3.8</u>	<u>7.5</u>	<u>11.3</u>
	50	<u>2.7</u>	<u>5.4</u>	<u>8.1</u>
138 to 145	20	<u>12.1</u>	<u>24.1</u>	<u>36.2</u>
	30	<u>7.4</u>	<u>14.9</u>	<u>22.3</u>
	40	<u>5.2</u>	<u>10.4</u>	<u>15.6</u>
	50	<u>3.9</u>	<u>7.8</u>	<u>11.7</u>

NESC 2007 Tentative Interim Amendment, 5 September 2008

Arc Flash Formulas

- IEEE 1584
 - Three phase faults within a range of parameters
 - “Open air” or “in-a-box” based on equipment type
 - Uses the Lee Method for voltages above 15 kV or for values outside the range of parameters
 - Acknowledgement that this will yield “conservative” results...an understatement!
- NESC 2007 Tables
 - Tables based on single-phase open air arc
 - Calculated using ARCPRO
 - Assumed working distances
 - Know and understand the limitations

ARCPRO Multipliers

Energy for	Multiplier
Single Phase Arc in a Box	1.5
Three Phase Open Air Arc	1.2 to 2.2
Three Phase Arc in a Box	3.7 to 6.5

IEEE 1584 vs ARCPRO

13.8 kV, 10 kA, 15 cycle clearing

	IEEE 1584 Results	ArcPRO Results -- 1ph	ArcPRO Results -- 3ph (1 ph results x 2.2)
D (inches)	E (cal/cm ²) _{IEEE1584}	E (cal/cm ²) _{ArcPro1ph}	E (cal/cm ²) _{ArcPro3ph}
15	6.85	3.12	6.86
24	2.68	1.22	2.68
36	1.19	0.54	1.19
48	0.67	0.31	0.67
72	0.30	0.14	0.30
Boundary (in.):	35.9	25.0	35.9

Note:

With multiplier of 2.2 applied, ARCPRO yields similar results

Lee Method versus ARCPRO

22.86 kV, 10 kA Fault, 15 cycle clearing -- at various working distances

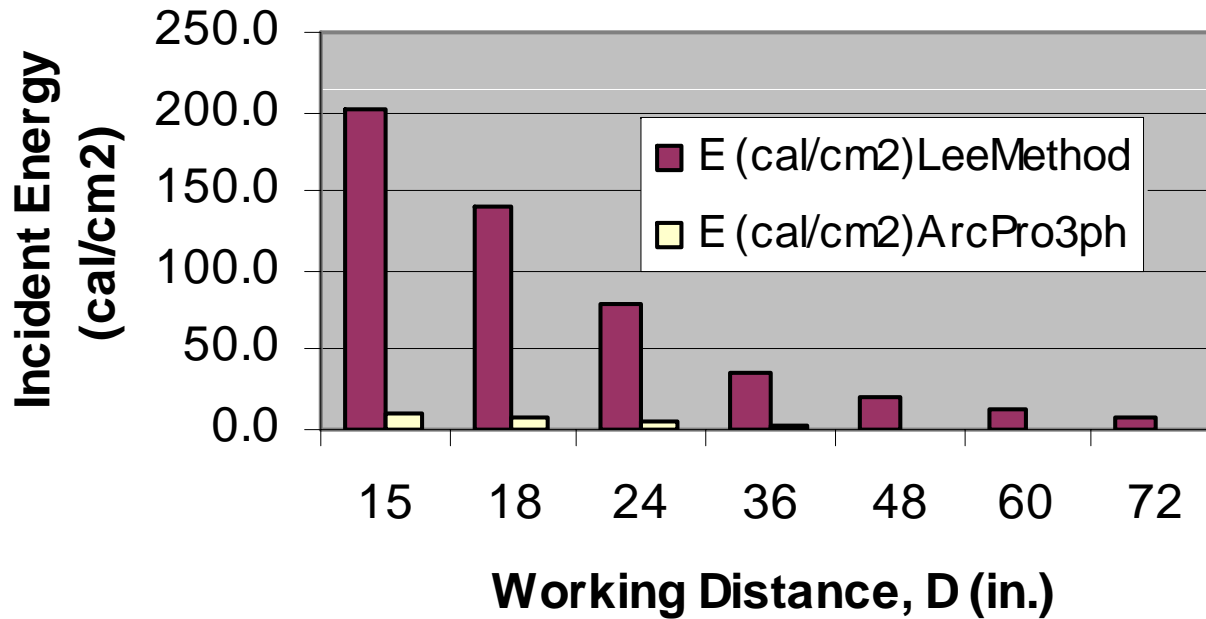
	Lee Method Results	ArcPRO Results -- 1ph	ArcPRO Results -- 3ph ⁽¹⁾
D (in.)	E (cal/cm ²) _{LeeMethod}	E (cal/cm ²) _{ArcPro1ph}	E (cal/cm ²) _{ArcPro3ph}
15	201.6	5.21	11.46
18	140.0	3.63	7.99
24	78.7	2.04	4.49
36	35.0	0.91	2.00
48	19.7	0.51	1.13
60	12.6	0.33	0.72
72	8.7	0.23	0.50
	Boundary (inches)		
	194.8	31.3 ⁽²⁾	44.7 ⁽²⁾

Notes:

- (1) ARCPRO 3-ph results obtained by multiplying 1-ph results by 2.2 per ARCPRO documentation
- (2) ARCPRO boundaries obtained by interpolation

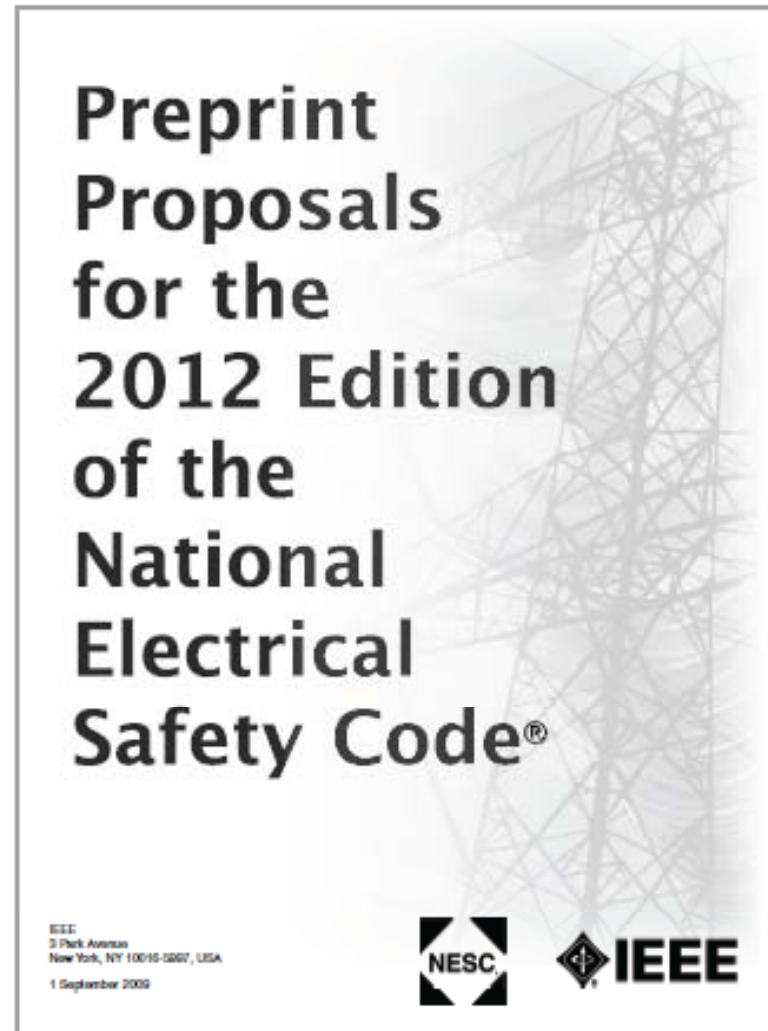
22.86 kV, 10 kA, 15 Cycle Clearing Time

Lee Method vs ARCPRO



2012 NESC Proposals

- Public comment period open through 5/1/2010
- Numerous proposed changes to Part 4
 - SC 8 responsible for changes to Part 4
 - Secondary voltages
 - Minimum Approach Distances (MAD)
 - Work practices



NESCS 2012 Part 4 Proposed Changes

- Require employer to determine arc exposures for 50 to 1000 volts
 - Delete the exception allowing 4 cal clothing for secondary systems under 1000 volts
 - New table (410-1) offers tabulated values for clothing similar to existing tables
 - Proposes using 18 in. working distance rather than 15 in.
- Clause 9, FR Clothing and PPE
 - Methodology for risk factors to consider such as equipment condition, work methods, analysis methods
 - Includes calculation methods for typical transformer installations

Implementing an Arc Hazard Plan

Surprises

- Utilities that still have not completed assessments
- Resistance...particularly from the people this is intended to protect
- Lack of awareness...among people that should be stakeholders in this

Resistance & Awareness

Things I've heard over the past 2 years...

- *“You’re just trying to get us to wear more FR clothing and that’s not going to work in this heat”* ...a lineman from Florida.
- *“Why can’t we just go by the NESC tables?”* ...a technician in Mississippi.
- *“What’s an arc flash study?”* ...a protection engineer in the Midwest.

Cultural Issues

- PPE Issue
 - It's not just about protective clothing!!
 - Heat is a valid concern, particularly in southern climates
 - Culture, & the belief that this is unnecessary
 - It is (or should be) about a comprehensive and ongoing effort to educate & inform personnel of the hazards involved in energized line work
- Establish appropriate “engineering controls” to mitigate arc flash hazards
- Training and education in work practices must be continuous
 - Enforcement and documentation

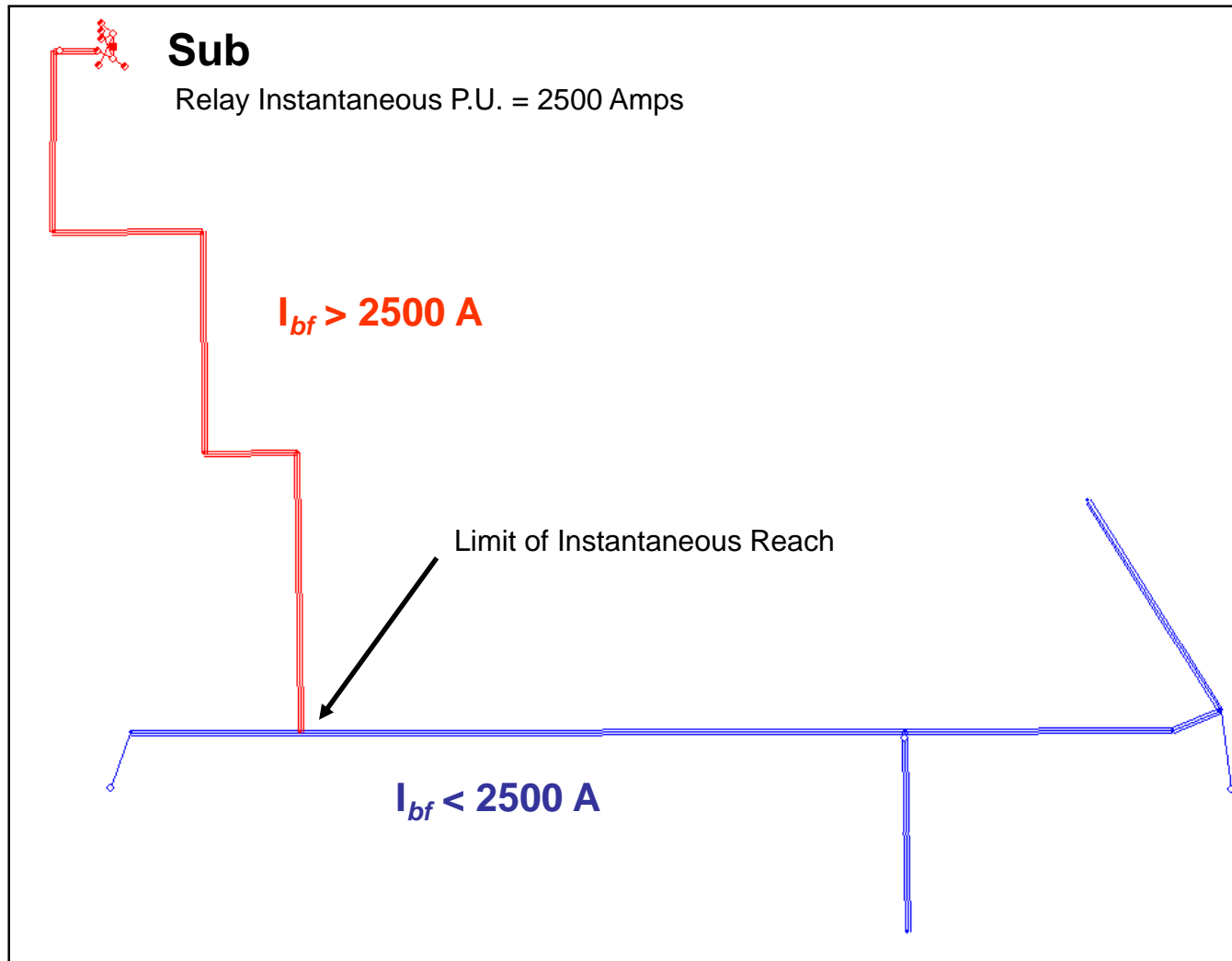
Engineering Controls

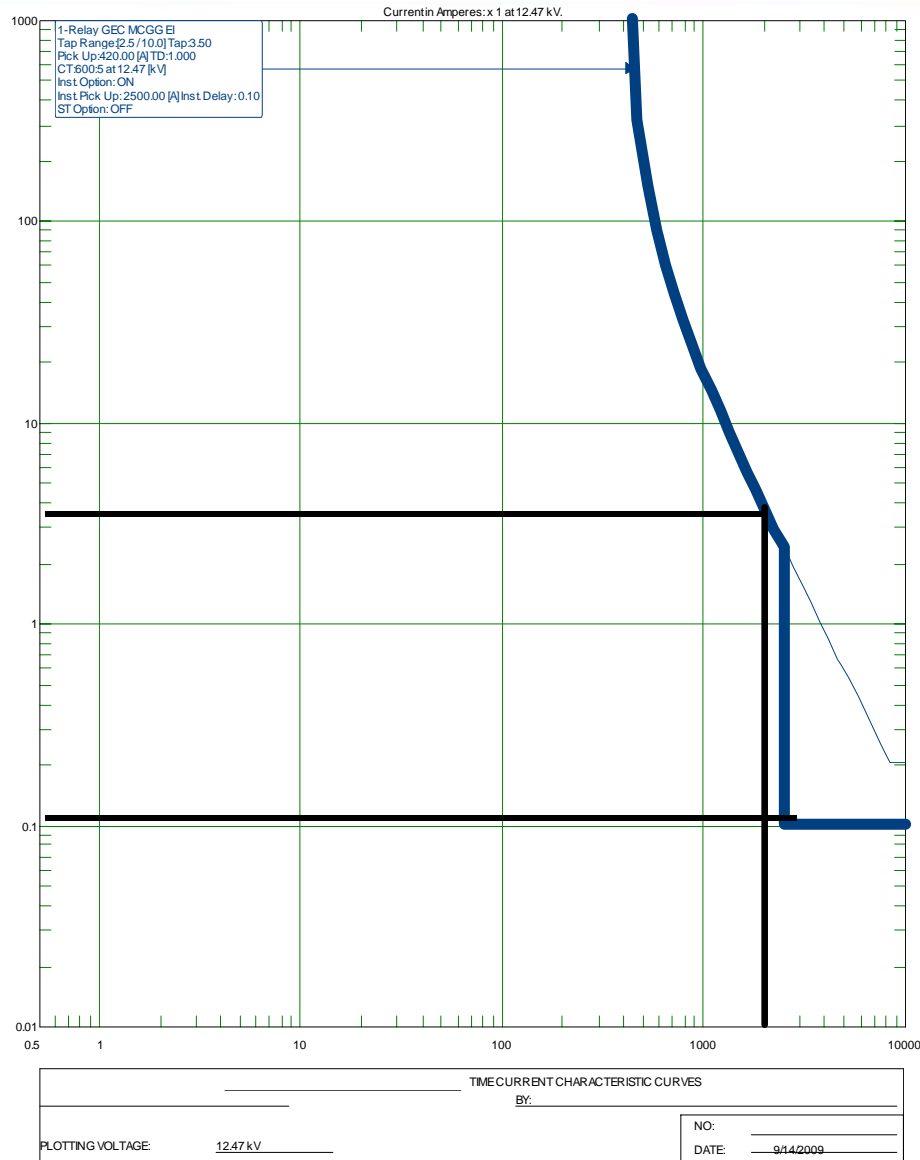
- Application of system protection scheme
- Use of devices to limit arc energy or detect arc flash conditions

Protective Scheme

- Instantaneous/Fast Trip – Fuse Blow Schemes
 - Hi set instantaneous
 - Disabled or no instantaneous/fast trip
 - Adaptive relaying “storm mode”
- Alternate Settings
 - Easy to do with electronic relays and recloser controls
 - Instantaneous should be enabled and reach ensured during energized line work
 - Similar to one-shot (non-reclosing) for live line work
 - Reliability impacts

Instantaneous Reach





Energy, E (cal/cm²)

13.8 kV System, IEEE 1584

At $I_{bf} = 2000$ Amps, 15" W.D.

$E = 19.8 \text{ cal/cm}^2$ at $t = 4 \text{ sec}$

Boundary = 61 in.

(w/o instantaneous)

$E = 0.5 \text{ cal/cm}^2$ @ 0.1 sec

Boundary = 9.6 in.

(with instantaneous, if it reached)

Protection Philosophy

- Review protection guidelines
 - Some actions performed to reduce momentary interruptions often increase incident energy levels...consider all trade-offs
 - Arc flash issue presents us with yet another excellent reason to evaluate guidelines and update the protective coordination study

Recommendations

- Evaluate energy levels at multiple working distances
 - Gloving operations
 - Tying insulators
 - Moving conductors
 - Hot stick operations
 - Pulling elbows (box configuration)
 - Fusing cutouts
 - Switching
- Evaluate task elements and work practices
 - Modify work practices if necessary
- Evaluate potential engineering controls to limit energy
- Familiarize yourself with proposed NESC changes and comment – we are all stakeholders

Team Approach

- Everyone has a stake in this
 - Engineers & technicians
 - Protection
 - Relaying
 - Reliability
 - Safety professionals
 - Operations personnel
 - Dispatchers
 - Line workers

Implementation

- Develop a comprehensive arc hazard mitigation plan...it's not just a PPE plan
- Training program
- Work practices and methods
- Engineering controls
- Document, document, document
 - And keep up with the evolving standards

Thank You!

Questions???

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