



IEEE 1584-2018: Application of the New Arc-Flash Calculation Model

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Agenda

Review of Arc-Flash Requirements

Intro to IEEE 1584-2018

Comparison with IEEE 1584-2002

Real-World Impacts

Learning Objectives

Upon Completion of this Presentation, you should be able to:

- Identify key changes in the updated IEEE 1584 standard
- Determine how these changes affect arc-flash calculations
- Identify parameters that need to be considered when performing studies or writing specifications

What is Arc Flash?

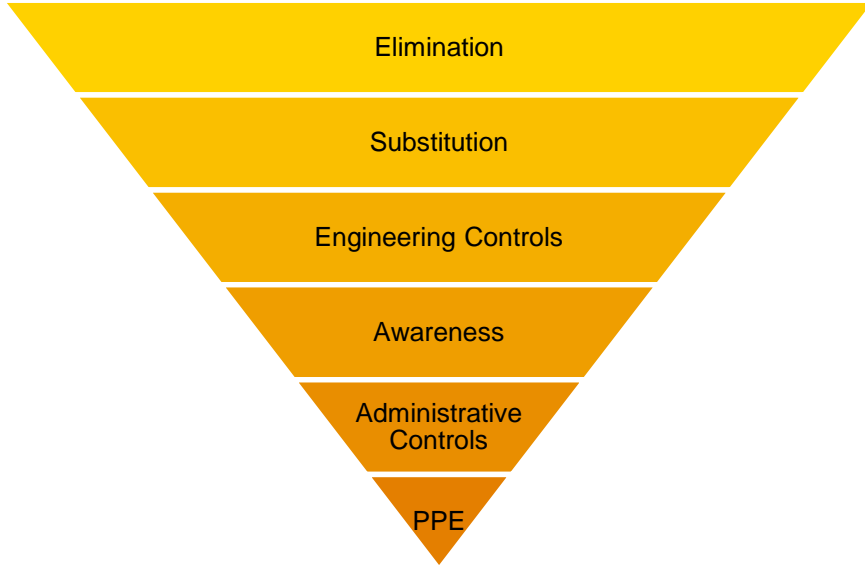
- NFPA 70E, “Arc Flash Hazard” – a source of possible injury or damage to health associated with the release of energy caused by an electric arc.
- Short-circuit flowing through air rather than through cables or busbar ★
- Can be a very violent event
 - Significant light, heat, pressure, sound is released
 - Damage to equipment, injury to workers



Arc Flash Requirements in NFPA 70E

- NFPA 70E: *Standard for Electrical Safety in the Workplace*
- (Very) High-Level Overview of Safety Requirements
 - De-energize electrical equipment before you work on it
 - If you can't, protect yourself!
- Arc-flash Risk Assessment
 - Are you exposed? Based on task, equipment, equipment condition, etc.
 - How bad is it? Arc-flash analysis
 - How are you going to protect against it? Equipment solutions, work practices, arc-rated PPE

NFPA 70E: Mitigation Methods



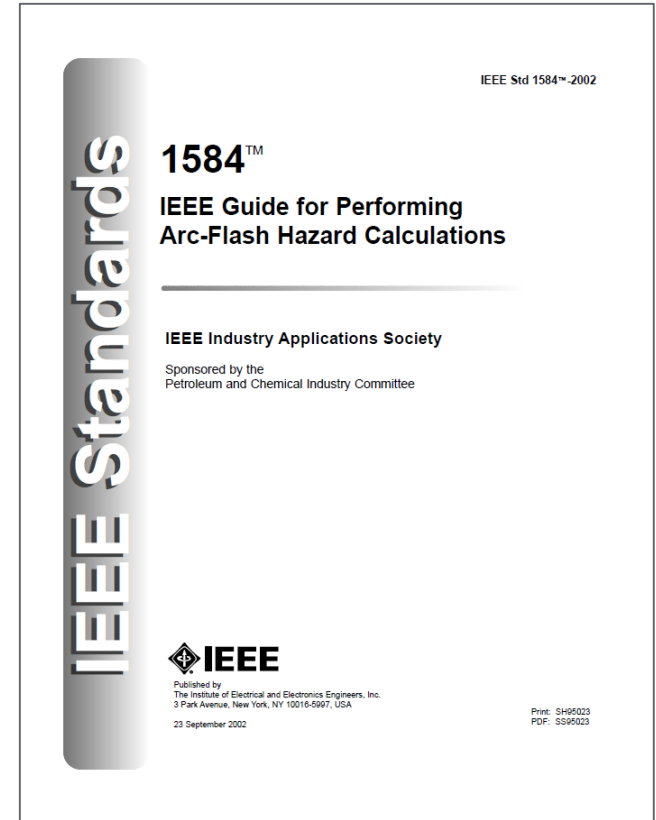
Hierarchy of Controls



Personal Protective Equipment

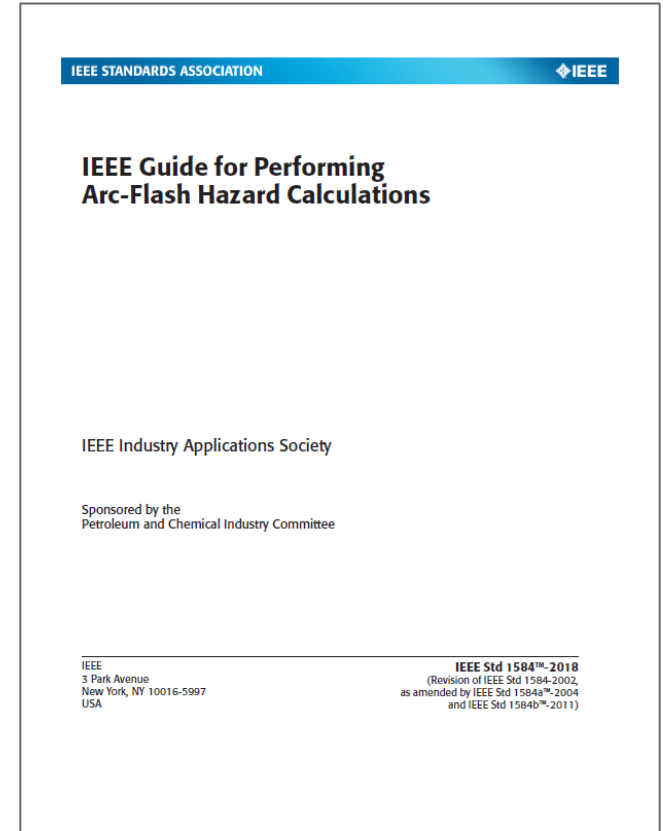
IEEE 1584-2002

- Empirical calculation model – 208V to 15kV
 - Arcing Fault Current – somewhat less than Bolted Fault Current
 - Incident Energy – heat energy “incident” on worker
 - Arc-flash Boundary – distance where energy equals 1.2 cal/cm^2
- Based on lab testing – “in box” and Open-air arcs
- Used extensively over last ~15 years – but some questioned!
 - What about other configurations?
 - What about the Range of the Model?
 - How accurate is this, anyway? Especially at the “fringes”



IEEE 1584-2018

- IEEE 1584 standard was revised late last year
- Much more data behind it – 6-7x as many tests run
- Range is similar – but accuracy is believed to be better
 - 208V to 15kV, three-phase systems
 - 500A to 106kA bolted FC @ LV
 - 200A to 65kA bolted FC @ MV
 - DC and single-phase still not directly addressed
- Considers additional equipment configurations
- Can consider Enclosure Size and its effect on IE
- All good...but the price is Increased Complexity!



Equations – a Sampling

$$I_{arc} = \frac{1}{\sqrt{\left[\frac{0.6}{V_{oc}}\right]^2 \times \left[\frac{1}{I_{arc_600}^2} - \left(\frac{0.6^2 - V_{oc}^2}{0.6^2 \times I_{bf}^2}\right)\right]}}$$

$$I_{arc_600} = 10^{(k_1 + k_2 \lg I_{bf} + k_3 \lg G)} (k_4 I_{bf}^6 + k_5 I_{bf}^5 + k_6 I_{bf}^4 + k_7 I_{bf}^3 + k_8 I_{bf}^2 + k_9 I_{bf} + k_{10})$$

LV Arcing Fault
Current

$$E_{\leq 600} = \frac{12.552}{50} T \times 10^x$$

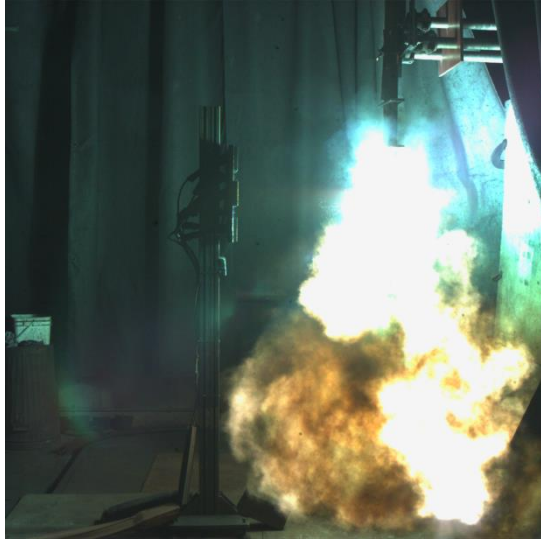
$$k_1 + k_2 \lg G + \frac{k_3 I_{arc_600}}{k_4 I_{bf}^7 + k_5 I_{bf}^6 + k_6 I_{bf}^5 + k_7 I_{bf}^4 + k_8 I_{bf}^3 + k_9 I_{bf}^2 + k_{10} I_{bf}} + k_{11} \lg I_{bf} + k_{12} \lg D + k_{13} \lg I_{arc} + \lg \frac{1}{CF}$$

LV Incident Energy

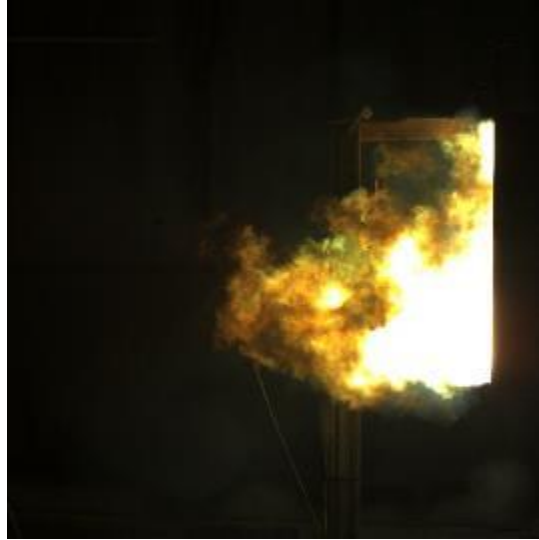
The Calculations are Complex!

- Many coefficients – that vary per Electrode Configuration and Voltage Level
 - Arcing Current Variation – sensitivity analysis to account for randomness of Arcing Current
 - MV Calculations – do three calculations at “anchor” voltages and interpolate to actual voltage
 - Enclosure Correction Factor – further modifies the results
 - Much more potential Resolution
 - Much more potential Complexity
-
- Not practical to do a study without a Commercial Analysis Software Package

Electrode Configurations are a Big Deal



Parallel Electrodes, Open-Air

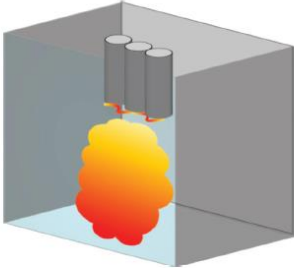

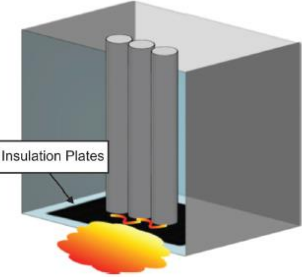
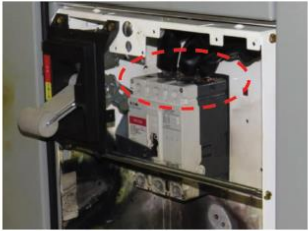


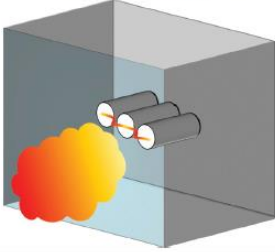
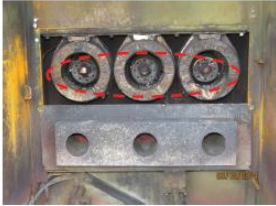
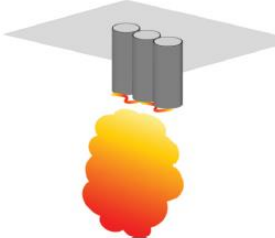

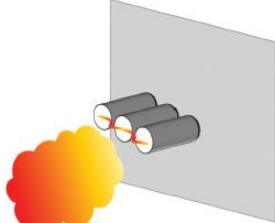

Parallel Electrodes, Inside Enclosure



Horizontal (Perpendicular) Electrodes

Electrode Orientation

	Electrode configuration in test	Electrode configuration in equipment
VCB		
VCBB		

	Electrode configuration in test	Electrode configuration in equipment
HCB		
VOA		
HOA		

Electrode Configuration – What We Know

- Orientation Matters! One of the key parameters in the new calculation model
- What about relative results?
 - 2018 vs. 2002 – results are variable, and depend on specific configuration of system
 - 2018 vs. 2018:
 - HCB is generally going to produce more energy than VCB or VCBB.
 - If HCB is not possible, then higher IE is usually VCBB...but not always!
- Recommended Practice:
 - If HCB possible – no further Electrode cases are needed
 - If VCB + VCBB – have to evaluate both to find worst-case

Configuration Example: QED-2 Switchboard



- Front/back: VCB + VCBB
- Yes, busbars are Horizontally oriented – but they're parallel to a worker standing outside
- Remove end covers: HCB
- Two IE values in one section?
- Guidance from Product Safety: apply one label based on worst-case exposure – i.e., HCB

Enclosure Correction Factor

- We've known for a long time that the Enclosure affects the Arc Flash levels
 - Open-air configuration – arc energy is free to dissipate in any direction
 - Arc in an enclosure – the enclosure focuses the energy towards the opening...and the worker
- IEEE 1584-2002 – the multiplying factor is “built in” but not adjustable
- IEEE 1584-2018 – the multiplying factor can be adjusted base on enclosure size

Lots of
Energy over
here...



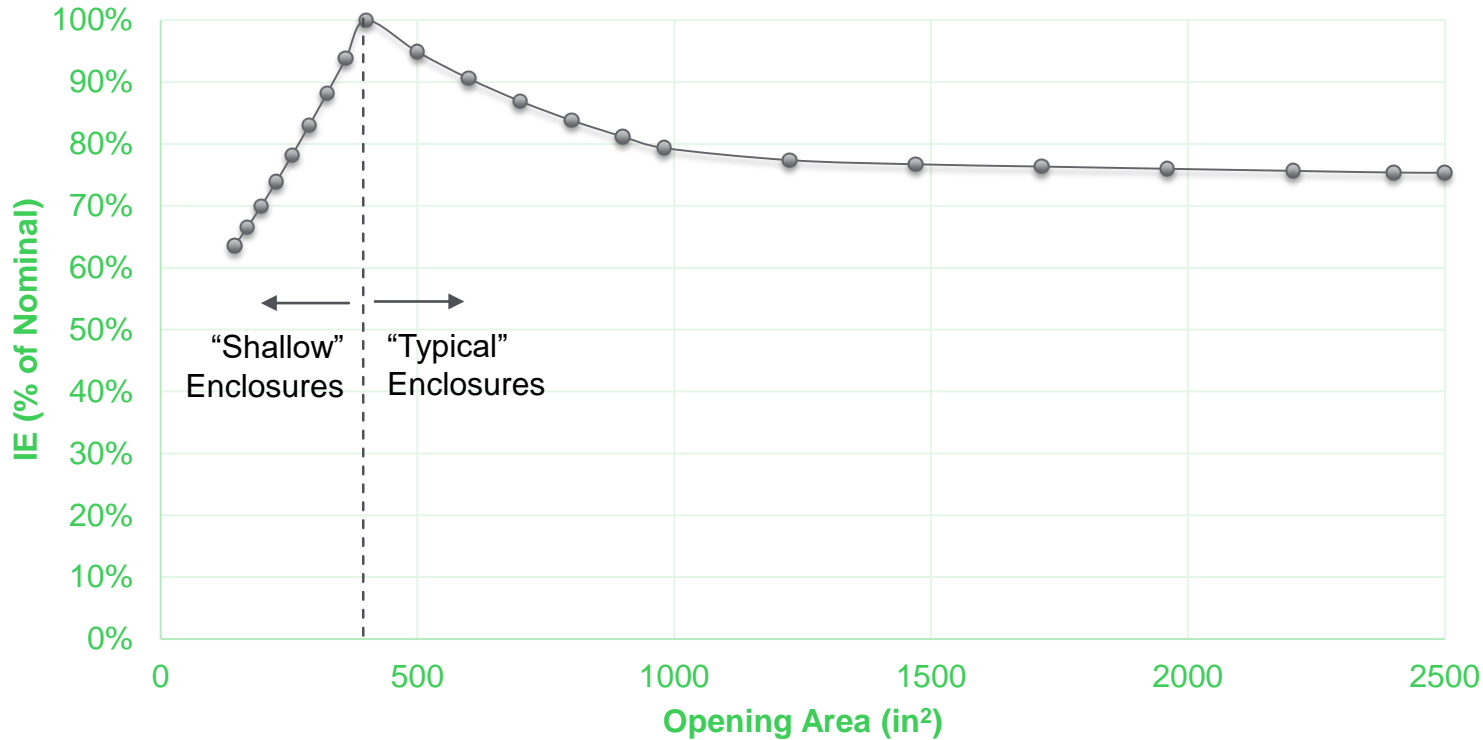
Clearly
Constrained by
the Enclosure

Enclosure Correction Factor – the Details

- Two types of enclosure: “Shallow” and “Typical”
 - Shallow - < 8” deep, but also small – H + W both < 20”. Most commonly applies to small Load Centers or Safety Switches
 - Typical – everything else. “Standard size” is 20”x20”; de-rate up to 49”x49”
- Many actual equipment enclosures much larger than 20”x20”
- IE De-rating in action:
 - LV Lighting Panel - ~5-10%
 - LV Power Panel (I-Line) - ~15%
 - LV Switchboard – up to ~20%
- It can get Confusing – do you really want a different arc-flash label on every MCC bucket?



IE vs. Enclosure Opening Size (VCB)



Peak at
“nominal”
20x20
opening

Note: this
simplifies
things a bit,
but it gives
you an
idea...

Low-Voltage Systems (i.e., $\leq 240\text{V}$)

- IEEE 1584-2002 –

While the accuracy of the model at 208 V is not in the same class with the accuracy at 250 V and higher, it will work and will yield conservative results. The arc-flash hazard need only be considered for large 208 V systems: systems fed by transformers smaller than 125 kVA should not be a concern.

- IEEE 1584-2018 –

Sustainable arcs are possible but less likely in three-phase systems operating at 240 V nominal or less with an available short-circuit current less than 2000 A.

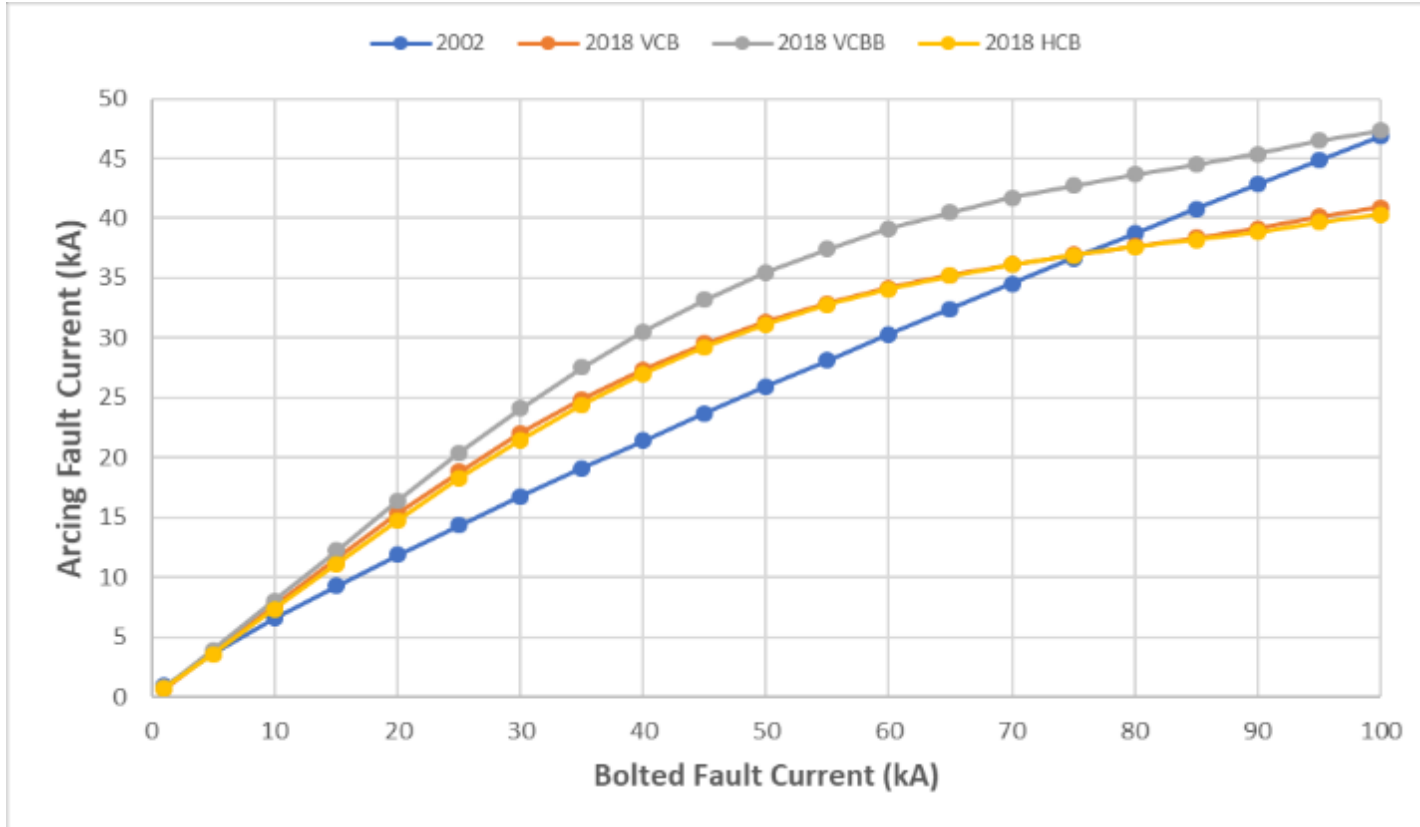
What to Make of This?

- 2002 model – typical interpretation was to assume 1.2 cal/cm² downstream of < 125kVA transformers
- 2018 model – probably reasonable to assume 1.2 cal/cm² when bolted FC < 2kA
- It doesn't take much transformer to get your fault current levels > 2kA
 - 208V buses fed from some 15kVA transformers will exceed this limit!
 - Available fault current on the primary side of the transformer doesn't matter much unless it's very low
- How to deal with it? Two options:
 - Model and analyze everywhere
 - Apply a Simplified PPE system

Simplified PPE System & LV Arc Flash Analysis

- NFPA 70E-2018, Table 130.5(G) – defines two-level PPE system with breakpoints at 12 cal/cm² and 40 cal/cm²
 - Some locations – 8/40 cal/cm²
 - The point being – do you really need five different levels of PPE?
- If your minimum PPE level is 12 cal/cm², you don't get there until ~5500A bolted fault current
 - Will cover nearly everything 45kVA or smaller
 - Will even cover some 75kVA transformers
 - Not many locations from these transformers where IE is less than 1.2 cal/cm²

Arcing FC vs. Bolted FC: LV Systems

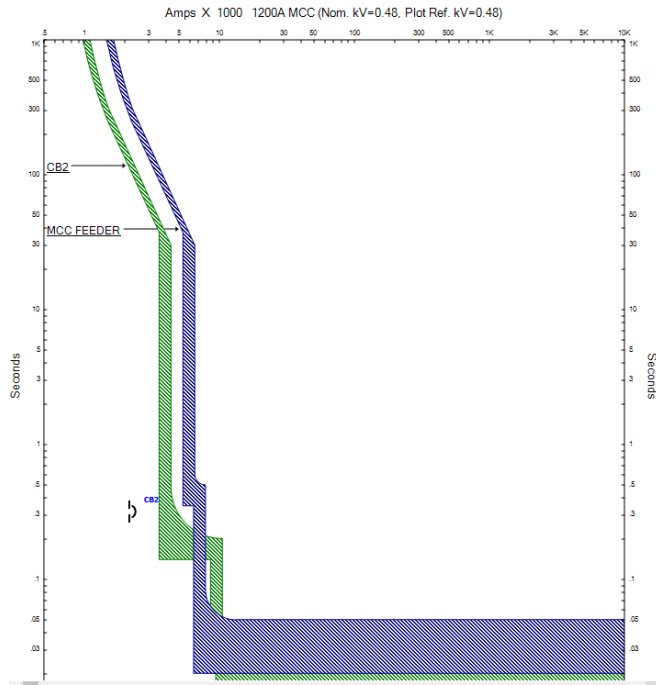


New Model –
at the peak,
larc ~25-40%
higher than
2002 model.

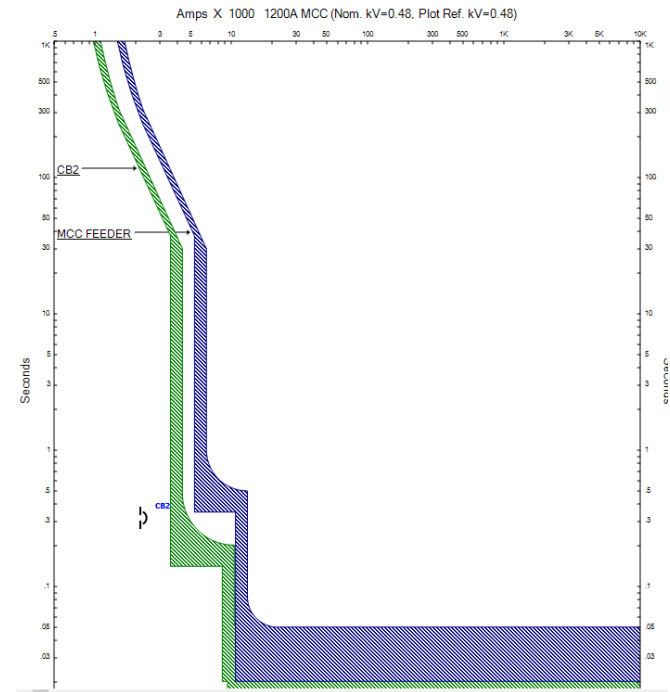
Easier to
Mitigate +
Coordinate?

Mitigation + Coordination: Example

Breaker Settings required to Minimize Arc Flash Energy at MCC

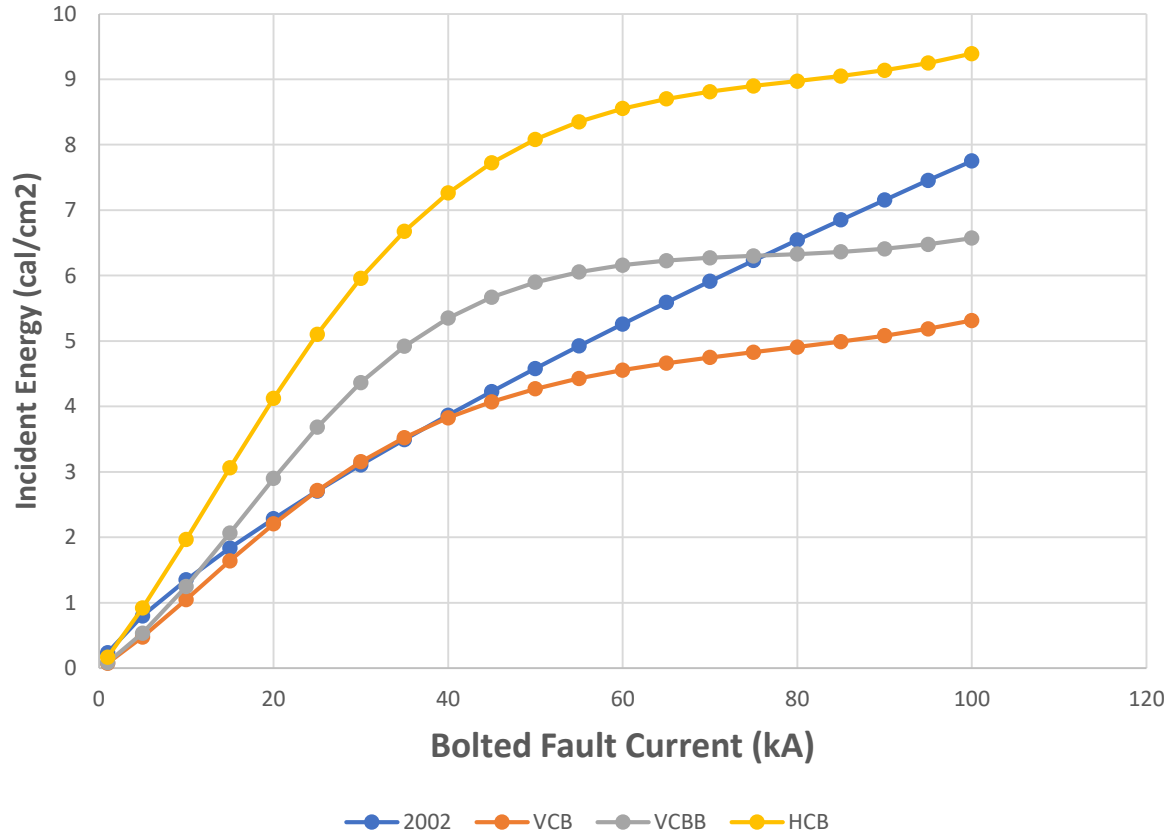


2002 Calculation – Coordination Not Maintained



2018 VCB Configuration – Coordination Maintained

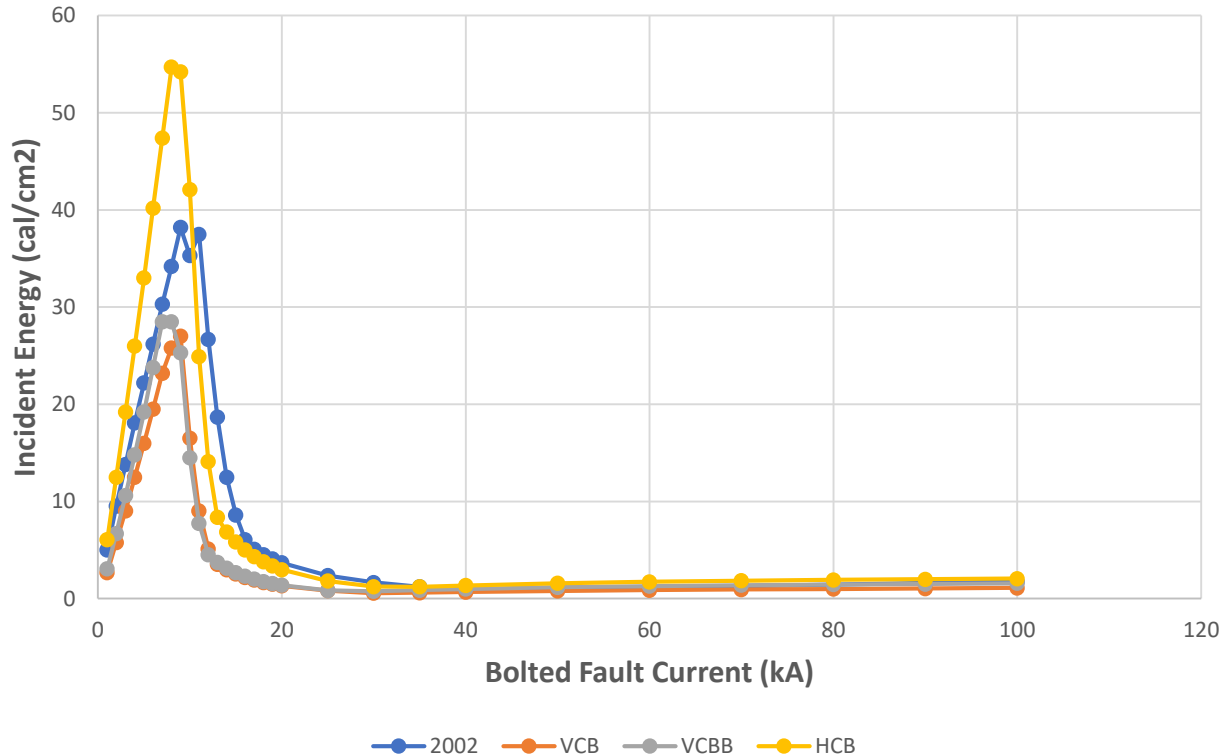
IE vs. Bolted FC: LV Systems



208V System, LV
“panelboard”
configuration, constant
100ms clearing time

IE with OCPD in circuit: 480V, 600A RK-5 Fuse

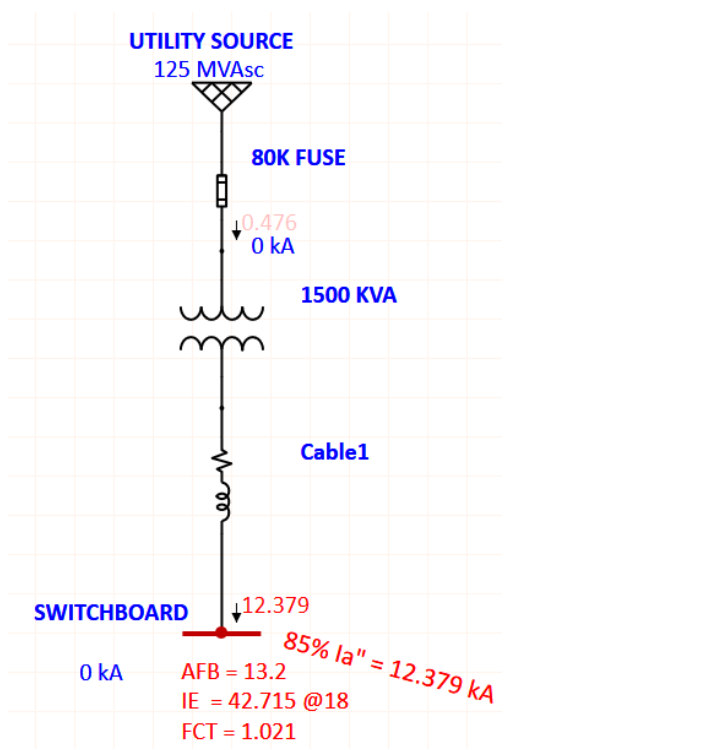
IE vs BFC - 480V, Panel, 600A RK-5 Fuse



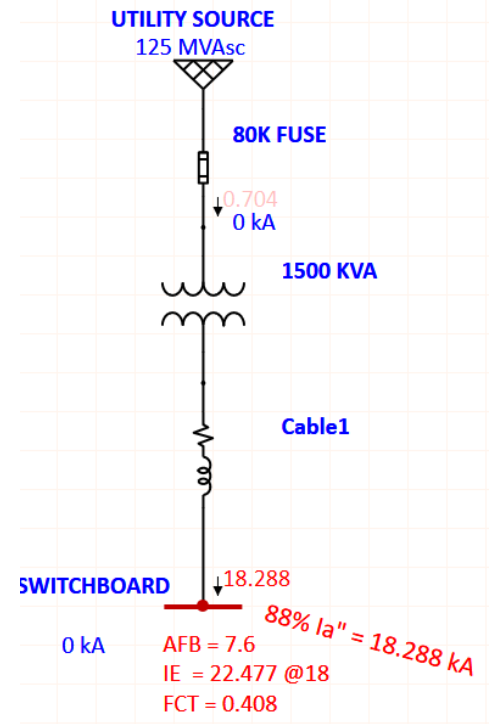
Updated with correct results. Shows HCB hits maximum peak but 2002 still higher over a good bit of the range. Once fuse enters C-L operation all models are close (and IE is low).

480V Switchboard: 2002 vs. VCBB

12.47kV primary, 1500kVA XFMR, ~6kA available, 80K primary fuse



2002 Model



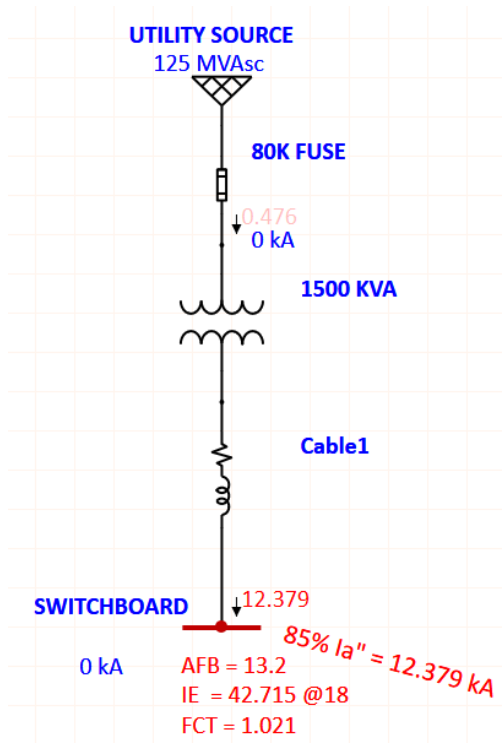
2018 Model (VCBB)

Life Is On

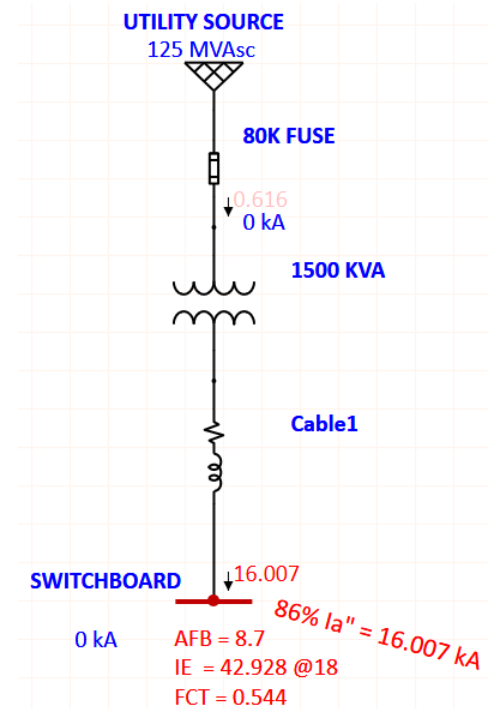


480V Switchboard: 2002 vs. HCB

12.47kV primary, 1500kVA XFMR, ~6kA available, 80K primary fuse



2002 Model



2018 Model (HCB)

Life Is On



Things to Consider – Electrode Configuration

- You know it's going to matter
- It's not “one size fits all” – different equipment may have different types
- So...what do you do?
 - Worst-case HCB all around? Simple, but could be highly conservative
 - Try and determine actual? But how do you know for some equipment? Unknown -> HCB
 - Consideration of multiple Configurations may be required at some equipment
- What you should expect: study should not just consider default software options. Study should document Electrode Configurations that are used so that you can evaluate.

Things to Consider – Enclosure Size

- Enclosure Size can make a difference
- How much does it really matter? Sample studies – changed PPE level ~10-15% of the time
 - Do you have a performance requirement? If so, every cal/cm² may count. If not, who cares?*
- What kind of Resolution do you really want? Do you want a unique calculation for each and every MCC bucket?
- Detailed consideration of Enclosure Size ultimately means more expensive studies
- Fallback position: default dimensions from IEEE 1584-2018 are conservative – will not result in workers being inadequately protected
- Study Reports should document Dimensional Data that was used in the analysis

* - obviously we care. The point being, if you're not trying to meet some specific target, why does it matter that you calculate Incident Energy to the 2nd or 3rd decimal place?

Things to Consider – PPE Methodology

- Ideal world: study outputs (including Arc Flash Labels) are consistent with a customer's Electrical Safe Work Practices policy
- Real world: study engineers send out whatever their software spits out, and end-users are left to figure out how to apply it all
- Does anybody actually use 5 PPE “Levels” in the real world?
- Suggestion: think a little more about real-world application of Safety Practices. Suggest to end-users that they adopt a simplified PPE approach. Use that to simplify labeling and analysis.

Things to Consider – Equipment Labeling



How many labels are appropriate: One worst-case label, or several individual calculations?

Impacts in Real Power Systems

- Study practices – as we’ve already discussed
- Safety practices – on some level, unchanged. But the analysis and “awareness” parts are different.
- Arc-flash mitigation:
 - Remote Racking – helps you avoid HCB exposure
 - Could there be less of a need for Maintenance Switches? For Mitigation at all?
- Equipment Designs:
 - Non-removable (or less-removable) end covers →
 - “Prevention” solutions like **ArcBlok**, Avoidance techniques like IR windows or embedded sensors



Life Is On



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