

EXAMPLE COMPARISON OF 1584-2002 AND 1584-2018 INCIDENT ENERGY CALCULATIONS

1.0 INTRODUCTION

The IEEE Guide for Performing Arc-Flash Hazard Calculations was first published in 2002. It was a ground-breaking document that provided guidance to the industry for making arc flash calculations. The publication of that document also set in motion a significant testing project to expand the knowledge base in this area. Based on this work, the standard was updated in 2018. One of the significant variables, which was investigated since 2002, included the placement of the three electrodes (or phases). In Figures 1 and 2, the variation of the phases is illustrated.

In Figure 1, a vertical arrangement of the three phases is illustrated with an arc flash at the bottom of the electrodes. There can be a significant difference in the heat that is expelled out the open front of the enclosure, depending upon how open the area is where the arc occurs. The configuration on the left is labeled as VCB, with the electrodes in a vertical position and an open space at the bottom of the electrodes. The configuration at the right is labeled as VCBB, with the electrodes also in a vertical position but with very little open space at the bottom. The VCBB configuration generally results in more heat being expelled out the front opening toward the person. It should be noted that the testing which produced the 2002 document was predominantly done with configurations that were similar to VCB.

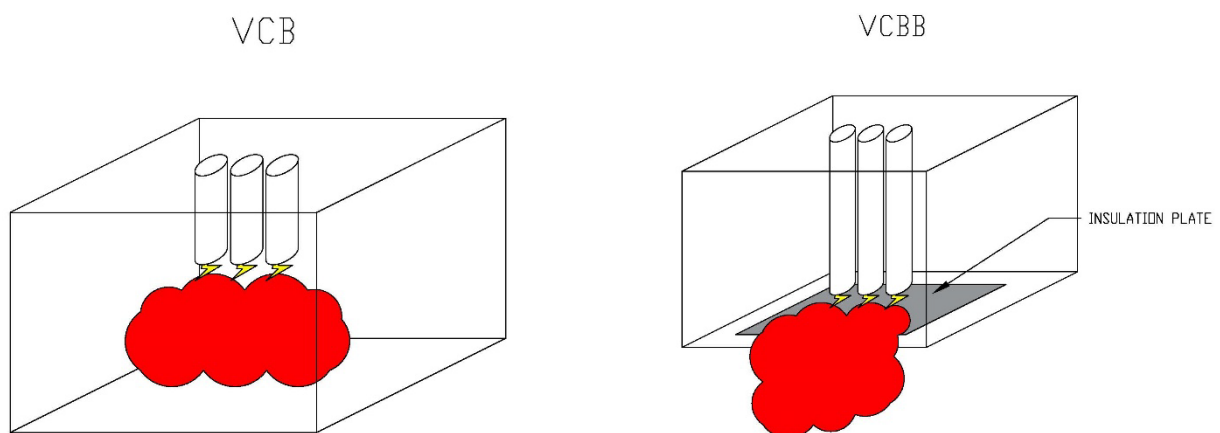


Figure 1 – Vertical Electrodes

In Figure 2, a horizontal arrangement of the three phases is illustrated with an arc flash at the end of the electrodes. This configuration is labeled as HCB. With the electrodes in a horizontal position, even more heat, i.e., incident energy, can be expelled out the front opening toward the person.

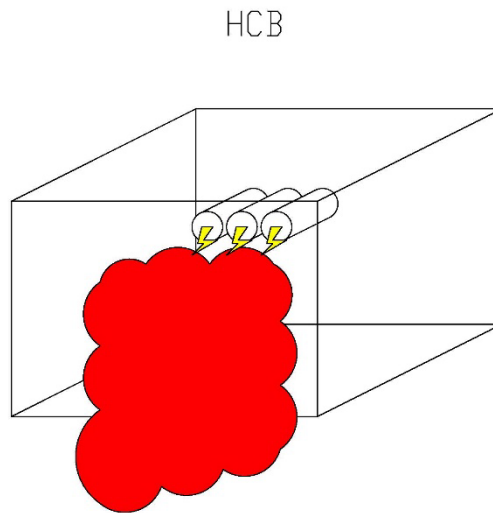


Figure 2 – Horizontal Electrodes

IEEE Standard 1584-2018 provides the equations for making the incident energy calculations for these three configurations. The dimensions of the enclosure are also variables in the calculations. The result is that the new equations are more complex and require more information about the physical configuration of the equipment.

2.0 EXAMPLE – COMPARING 1584-2002 WITH 1584-2018

An example system is used to compare the equations in 1584-2002 with those in 1584-2018. It is set up with very specific parameters, but it does give a big-picture view of how the incident energy calculations can change. The calculations for the example system are given in Figures 3 thru 6 as follows:

- Figure 3 IEEE 1584-2002
- Figure 4 IEEE 1584-2018 VCB Configuration
- Figure 5 IEEE 1584-2018 VCBB Configuration
- Figure 6 IEEE 1584-2018 HCB Configuration

The results of the calculations are given in Tables 1 through 3. The following observations are noted:

- In Table 1, the calculations are compared in calories/cm² at 13.8 kV and 480V.
- In Table 2, the calculations are given in % of the 1584-2002 methodology.
 - The VCB configuration gives results that are closest to the 1584-2002 methodology.
 - The VCBB configuration tends to give incident energies that are approximately 1.5 times the VCB calculations, except for the 480V panelboard and MCC equipment, where the values are closer.
 - The HCB configuration tends to give incident energies that are approximately 2.0 times the VCB calculations.
- In Table 3, the calculations are summarized by PPE level where PPE = 2 is for incident energy values ≤ 8 cal/cm² and PPE = 4 is for values ≤ 40 cal/cm². The areas where a PPE level would change are noted in the table.

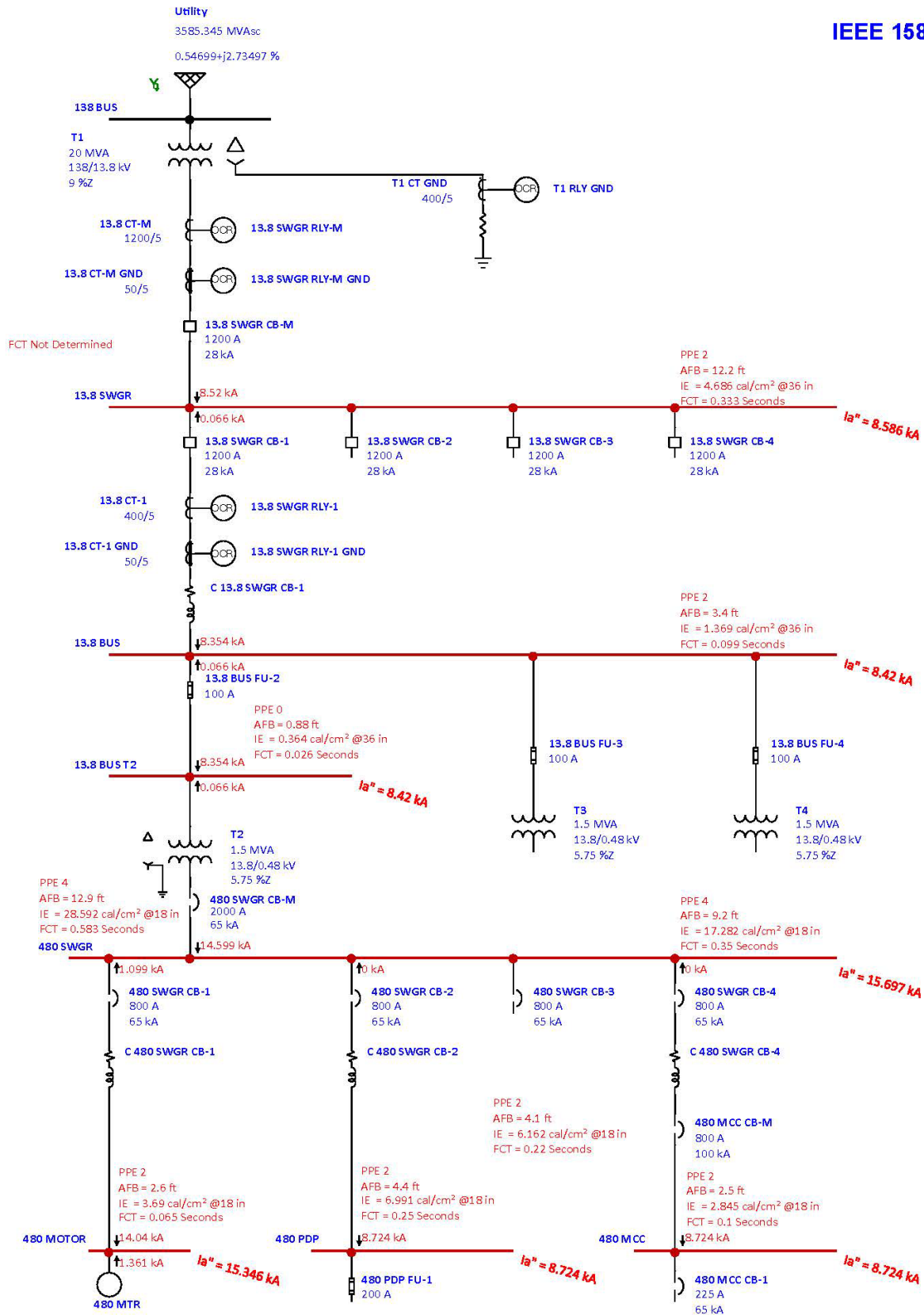


Figure 3

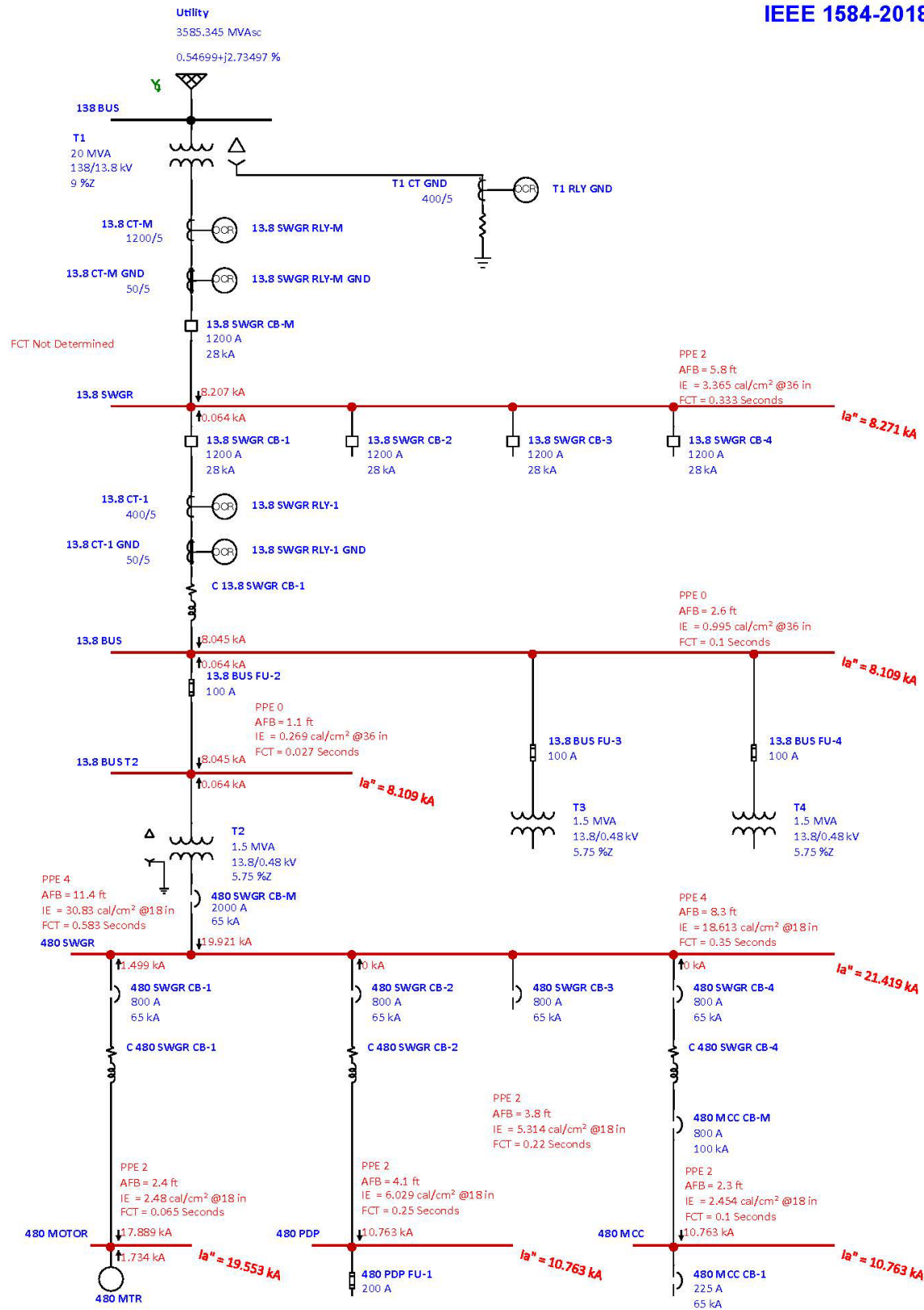


Figure 4

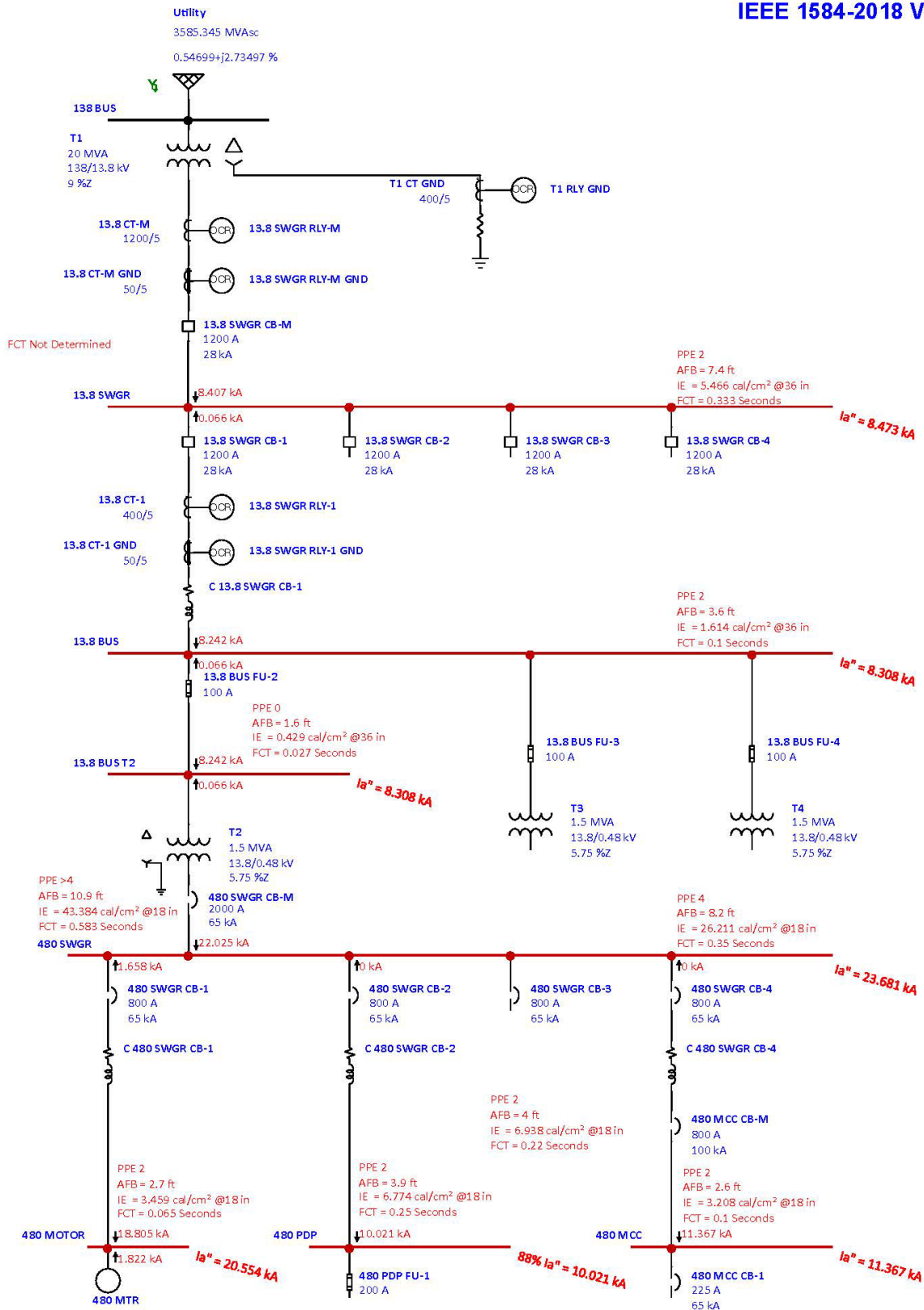


Figure 5

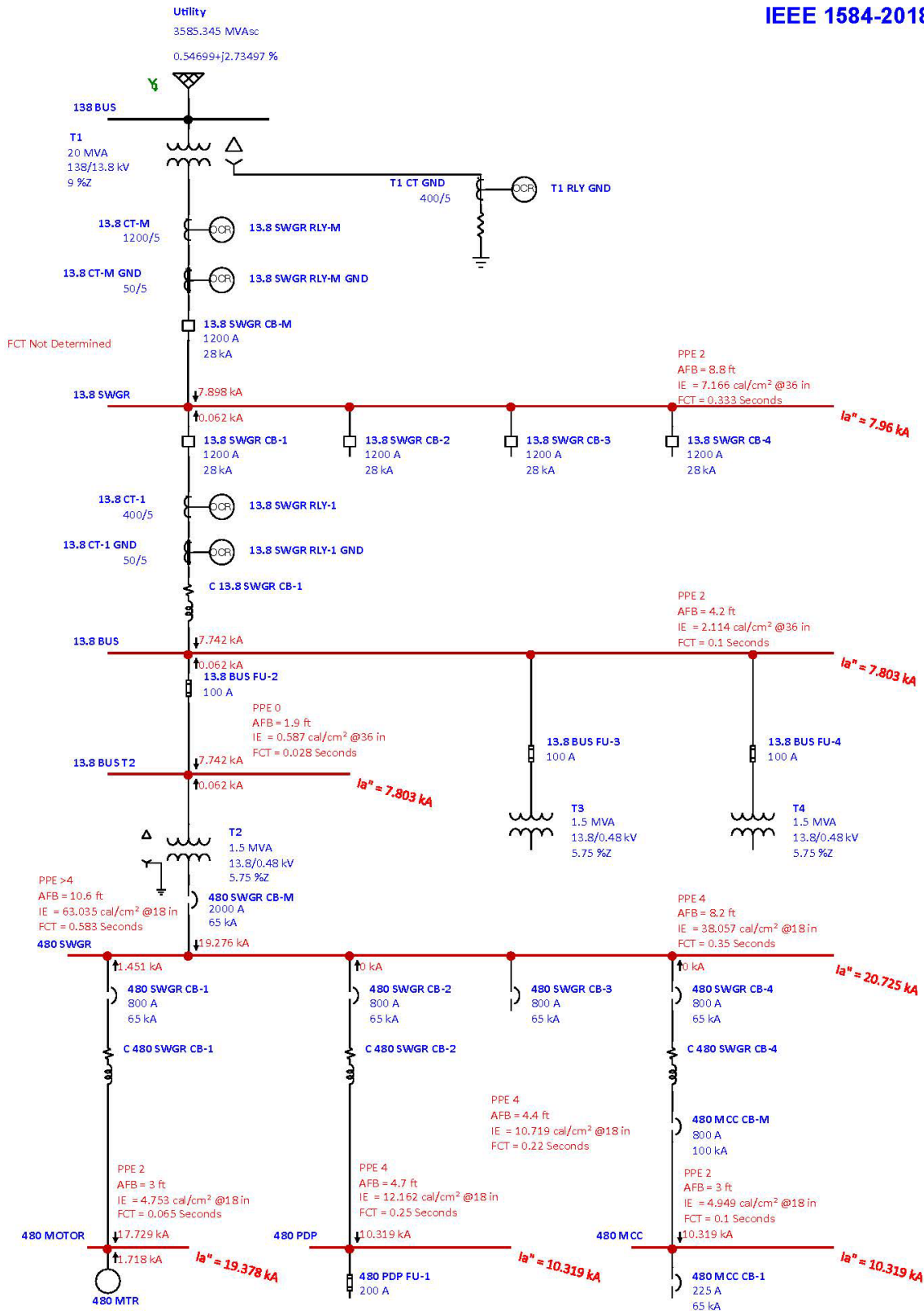


Figure 6

Table 1 - Comparison of Incident Energy Calculations

Bus	Voltage (kV)	Equipment Type	Working Distance (Inches)	Enclosure Dimensions (Inches)					Clearing Time (seconds)	Incident Energy (cal/cm ²)			
				H	x	W	x	D		2002	2018		
									VCB		VCBB	HCB	
13.8 SWGR	13.8	Switchgear	36	45	30	30	0.33	4.7	3.4	5.5	7.2		
13.8 BUS	13.8	Switchgear	36	45	30	30	0.10	1.4	1.0	1.6	2.1		
13.8 BUS T2	13.8	Switchgear	36	45	30	30	0.03	0.4	0.3	0.4	0.6		
480 SWGR CB-M	0.48	LVCB	18	20	20	20	0.58	28.6	30.8	43.4	63.0		
480 SWGR	0.48	Switchgear	18	20	20	20	0.35	17.3	18.6	26.2	38.1		
480 MOTOR	0.48	Other	18	14	12	8	0.07	3.7	2.5	3.5	4.8		
480 PDP	0.48	Panelboard	18	14	12	8	0.25	7.0	6.0	6.8	12.2		
480 MCC	0.48	MCC	18	14	12	8	0.10	2.9	2.5	3.2	4.9		

Table 2 - Comparison of % of 2002 Calculation Method

Bus	Voltage (kV)	Equipment Type	Working Distance (Inches)	Enclosure Dimensions (Inches)				Clearing Time (seconds)	Incident Energy as % of 2002				
				H	x	W	x		D	2002	2018		
								VCB			VCBB	HCBB	
13.8 SWGR	13.8	Switchgear	36	45	x	30	x	30	0.33	100%	72%	117%	153%
13.8 BUS	13.8	Switchgear	36	45	x	30	x	30	0.10	100%	73%	118%	154%
13.8 BUS T2	13.8	Switchgear	36	45	x	30	x	30	0.03	100%	74%	118%	161%
480 SWGR CB-M	0.48	LVCB	18	20	x	20	x	20	0.58	100%	108%	152%	220%
480 SWGR	0.48	Switchgear	18	20	x	20	x	20	0.35	100%	108%	152%	220%
480 MOTOR	0.48	Other	18	14	x	12	x	8	0.07	100%	67%	94%	129%
480 PDP	0.48	Panelboard	18	14	x	12	x	8	0.25	100%	86%	97%	174%
480 MCC	0.48	MCC	18	14	x	12	x	8	0.10	100%	86%	113%	174%

Table 3 - Comparison of PPE Levels

Bus	Voltage (kV)	Equipment Type	Working Distance (Inches)	Enclosure Dimensions (Inches)					Clearing Time (seconds)	PPE Level (2 or 4)			
				H	x	W	x	D		2002	2018		
									VCB		VCBB	HCB	
13.8 SWGR	13.8	Switchgear	36	45	x	30	x	30	0.33	2	2	2	2
13.8 BUS	13.8	Switchgear	36	45	x	30	x	30	0.10	2	2	2	2
13.8 BUS T2	13.8	Switchgear	36	45	x	30	x	30	0.03	2	2	2	2
480 SWGR CB-M	0.48	LVCB	18	20	x	20	x	20	0.58	4	4	>4	>4
480 SWGR	0.48	Switchgear	18	20	x	20	x	20	0.35	4	4	4	4
480 MOTOR	0.48	Other	18	14	x	12	x	8	0.07	2	2	2	2
480 PDP	0.48	Panelboard	18	14	x	12	x	8	0.25	2	2	2	4
480 MCC	0.48	MCC	18	14	x	12	x	8	0.10	2	2	2	2

This is a change in PPE from the 2002 calculation method.

3.0 EXAMPLE – REEVALUATION BASED ON 1584-2018

Based on the information determined in Section 2.0, the example system is reevaluated with the following considerations:

1. Step 1 – Choose an appropriate electrode configuration for the equipment in this example:
 - a. For the 13.8 kV switchgear, HCB is chosen. Based on the ability to draw out the medium voltage switchgear, this is often an appropriate choice.
 - b. For the 480V main switchgear, HCB is also chosen. Based on the use of low-voltage switchgear that can be drawn out, this is often an appropriate choice.
 - c. For the downline 480V equipment, VCB is chosen. This is often composed of molded case circuit breakers and other equipment where the cables are brought in from above to make bolted connections.

These electrode configurations and resultant incident energies are listed in Table 4. (The incident energies are taken from Table 1.)

2. Step 2 – Consider working distance changes:
 - a. In reviewing Table 4, the area where there is a significant difference in incident energy is at the 480V main switchgear.
 - b. This was evaluated using 18" previously to maintain a consistent working distance for all 480V equipment. Standard 1584 suggests that 24" is often used for low-voltage, draw-out switchgear.

Consequently, for the low-voltage switchgear, 24" is chosen for this reevaluation. Based on the revised information, the detailed calculations are given in Figure 7 and summarized in Table 5; the incident energy at the main switchgear is significantly reduced by a factor of approximately 1.8 to less than 40 cal/cm² when working at 24".

3. Step 3 – Determine PPE levels:
 - a. Based on steps 1 and 2 with an increase in working distance at the main 480V switchgear, the PPE levels at the locations evaluated are summarized in Table 6. They are the same as previously determined.
 - b. In other applications, it may be necessary to change the settings of overcurrent devices or add faster methods of determining the fault condition to achieve an acceptable incident energy level, which could result in some miscoordination of overcurrent devices.
 - c. In this particular case, the key area became the 480V switchgear. Without changing the working distance, the incident energy in this area could have been reduced by reducing the clearing times for faults above and below the main 480V circuit breaker.

REEVALUATION BASED ON 1584-2018

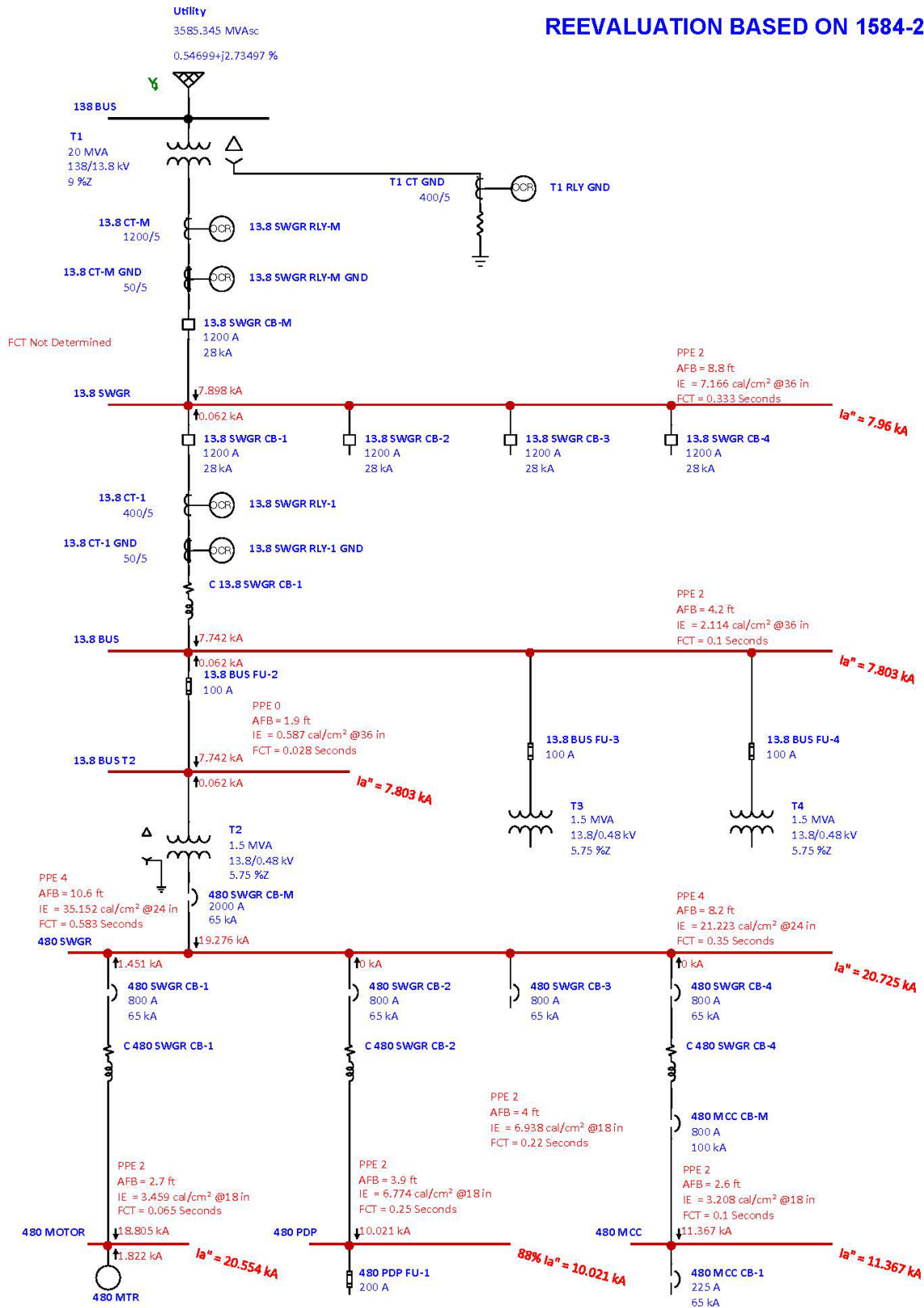


Figure 7

Table 4 - Step 1 --> Choose Appropriate Electrode Configurations

Bus	Voltage (kV)	Equipment Type	2002						Clearing Time (seconds)	Incident Energy (cal/cm ²)		
			Working Distance (Inches)	Enclosure				2018				
				Dimensions (Inches)						Electrode		
				H	x	W	x	D		2002	Configuraton	2018
13.8 SWGR	13.8	Switchgear	36	45	30	30	0.33	4.7	HCB	7.2		
13.8 BUS	13.8	Switchgear	36	45	30	30	0.10	1.4	HCB	2.1		
13.8 BUS T2	13.8	Switchgear	36	45	30	30	0.03	0.4	HCB	0.6		
480 SWGR CB-M	0.48	LVCB	18	20	20	20	0.58	28.6	HCB	63.0		
480 SWGR	0.48	Switchgear	18	20	20	20	0.35	17.3	HCB	38.1		
480 MOTOR	0.48	Other	18	14	12	8	0.07	3.7	VCBB	3.5		
480 PDP	0.48	Panelboard	18	14	12	8	0.25	7.0	VCBB	6.8		
480 MCC	0.48	MCC	18	14	12	8	0.10	2.9	VCBB	3.2		

Table 5 - Step 2 --> Consider Working Distance Changes

Bus	Voltage (kV)	Equipment Type	2018					Incident Energy (cal/cm ²)		
			Working Distance (Inches)	Enclosure				Clearing Time (seconds)	2018	
				Dimensions (Inches)					Electrode	2018
				H	x	W	x			
								2002	Configuraton	
13.8 SWGR	13.8	Switchgear	36	45	30	30	0.33	4.7	HCB	7.2
13.8 BUS	13.8	Switchgear	36	45	30	30	0.10	1.4	HCB	2.1
13.8 BUS T2	13.8	Switchgear	36	45	30	30	0.03	0.4	HCB	0.6
480 SWGR CB-M	0.48	LVCB	24	20	20	20	0.58	28.6	HCB	35.2
480 SWGR	0.48	Switchgear	24	20	20	20	0.35	17.3	HCB	21.2
480 MOTOR	0.48	Other	18	14	12	8	0.07	3.7	VCBB	3.5
480 PDP	0.48	Panelboard	18	14	12	8	0.25	7.0	VCBB	6.8
480 MCC	0.48	MCC	18	14	12	8	0.10	2.9	VCBB	3.2

Table 6 - Step 3 --> Determine PPE Levels

Bus	Voltage (kV)	Equipment Type	2018	Enclosure				Clearing	PPE Level (2 or 4)			
			Working	Dimensions (Inches)				Time	2018			
			Distance						Electrode			
			(Inches)	H	x	W	x	D	(seconds)	2002	Configuraton	2018
13.8 SWGR	13.8	Switchgear	36	45		30		30	0.33	2	HCB	2
13.8 BUS	13.8	Switchgear	36	45		30		30	0.10	2	HCB	2
13.8 BUS T2	13.8	Switchgear	36	45		30		30	0.03	2	HCB	2
480 SWGR CB-M	0.48	LVCB	24	20		20		20	0.58	4	HCB	4
480 SWGR	0.48	Switchgear	24	20		20		20	0.35	4	HCB	4
480 MOTOR	0.48	Other	18	14		12		8	0.07	2	VCBB	2
480 PDP	0.48	Panelboard	18	14		12		8	0.25	2	VCBB	2
480 MCC	0.48	MCC	18	14		12		8	0.10	2	VCBB	2

Electrode Configurations Chosen

Working Distance Change