

Arc Flash Comparison Case # 2

Verification of ETAP Arc Flash NFPA 70E results against Hand Calculations

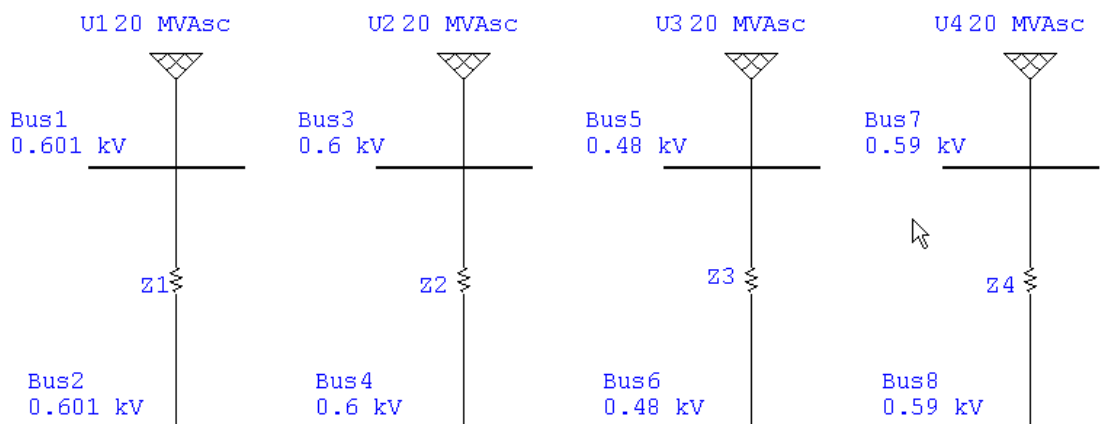
Excerpts from Validation Cases and Comparison Results (TCS-SC-157)

Highlights

- Comparison of ETAP Arc Flash results for Open-air Systems rated higher than 600 Volts against hand calculated values based on equations listed in Standard NFPA 70E 2004.
- The incident energy results and Flash Protection Boundaries have been determined based several working distances and Fault clearing times.
- The hand calculations were created based on the equations shown in the standard with the help of a calculation program called MathCAD Professional version 2000.
- In all cases, the percent difference between hand calculations and ETAP results is less than 1%.

System Description

The systems consist of multiple faulted buses that are configured to test all the situations that are related to a 600 Volt system. Each faulted bus tests a different situation, which includes open-air systems rated at 600 Volts, above or below. In all cases, the buses are energized by Power Grids.



The following is a sample of the MathCAD calculations for a fault at Bus2 based on ANSI short-circuit calculations.

For a fault at Bus2 (ANSI)

$$\begin{array}{l}
 f := 60 \\
 t_a := \begin{pmatrix} 0.25 \\ 0.5 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \\ 8 \\ 10 \\ 30 \\ 40 \\ 50 \\ 60 \\ 70 \\ 80 \\ 90 \\ 100 \\ 110 \\ 120 \end{pmatrix} \\
 V := \begin{pmatrix} 0.601 \\ 0.601 \\ 0.601 \\ 0.601 \\ 0.601 \\ 0.601 \\ 0.601 \\ 0.601 \\ 0.601 \\ 0.601 \\ 0.601 \\ 0.601 \\ 0.601 \\ 0.601 \\ 0.601 \\ 0.601 \\ 0.601 \\ 0.601 \\ 0.601 \end{pmatrix} \\
 F := \begin{pmatrix} 18.095 \\ 18.095 \\ 18.095 \\ 18.095 \\ 18.095 \\ 18.095 \\ 18.095 \\ 18.095 \\ 18.095 \\ 18.095 \\ 18.095 \\ 18.095 \\ 18.095 \\ 18.095 \\ 18.095 \\ 18.095 \\ 18.095 \\ 18.095 \\ 18.095 \end{pmatrix}
 \end{array}$$

$$\begin{array}{l}
 \vec{E}_{18} := \left(\frac{793 \cdot F \cdot V \cdot \frac{t_a}{60}}{18^2} \right) \\
 \vec{E}_{24} := \left(\frac{793 \cdot F \cdot V \cdot \frac{t_a}{60}}{24^2} \right) \\
 \vec{E}_{30} := \left(\frac{793 \cdot F \cdot V \cdot \frac{t_a}{60}}{30^2} \right) \\
 \vec{E}_{36} := \left(\frac{793 \cdot F \cdot V \cdot \frac{t_a}{60}}{36^2} \right) \\
 \vec{E}_{48} := \left(\frac{793 \cdot F \cdot V \cdot \frac{t_a}{f}}{48^2} \right) \\
 \text{FPB} := \left[\left(2.65 \cdot \sqrt{3} \cdot V \cdot F \cdot \frac{t_a}{f} \right)^{0.5} \right]
 \end{array}$$

	0
0	0.456
1	0.645
2	1.29
3	1.58
4	1.824
5	2.04
6	2.234
7	2.58
8	2.884
9	4.996
10	5.769
11	6.45
12	7.065
13	7.631
14	8.158
15	8.653
16	9.121
17	9.566
18	9.992
19	
20	

	0
0	0.111
1	0.222
2	0.887
3	1.331
4	1.774
5	2.218
6	2.662
7	3.549
8	4.436
9	13.309
10	17.745
11	22.181
12	26.617
13	31.053
14	35.49
15	39.926
16	44.362
17	48.798
18	53.234
19	

	0
0	0.062
1	0.125
2	0.499
3	0.749
4	0.998
5	1.248
6	1.497
7	1.996
8	2.495
9	7.486
10	9.981
11	12.477
12	14.972
13	17.467
14	19.963
15	22.458
16	24.954
17	27.449
18	29.944
19	

	0
0	0.04
1	0.08
2	0.319
3	0.479
4	0.639
5	0.799
6	0.958
7	1.278
8	1.597
9	4.791
10	6.388
11	7.985
12	9.582
13	11.179
14	12.776
15	14.373
16	15.97
17	17.567
18	19.164
19	

	0
0	0.028
1	0.055
2	0.222
3	0.333
4	0.444
5	0.555
6	0.665
7	0.887
8	1.109
9	3.327
10	4.436
11	5.545
12	6.654
13	7.763
14	8.872
15	9.981
16	11.09
17	12.2
18	13.309
19	

	0
0	0.016
1	0.031
2	0.125
3	0.187
4	0.25
5	0.312
6	0.374
7	0.499
8	0.624
9	1.872
10	2.495
11	3.119
12	3.743
13	4.367
14	4.991
15	5.615
16	6.238
17	6.862
18	7.486
19	

Comparison of Results:

The following table of comparison shows the differences between ETAP Results and those calculated by Hand using the MathCAD program for the NFPA 70E Arc-Flash method. The difference in all cases is smaller than 1%.

Arc duration	Hand Calculations						ETAP Results					
	FPB (ft)	Incident Energy (Cal/cm ²)					FPB (ft)	Incident Energy (Cal/cm ²)				
Cycles	18 in.	E24 in.	E30 in.	E36 in.	E48 in.	18 in.	E24 in.	E30 in.	E36 in.	E48 in.		
0.250	0.456	0.111	0.062	0.040	0.028	0.016	0.456	0.111	0.062	0.040	0.028	0.016
0.500	0.645	0.222	0.125	0.080	0.055	0.031	0.645	0.222	0.125	0.080	0.055	0.031
2.000	1.290	0.887	0.499	0.319	0.222	0.125	1.290	0.887	0.499	0.319	0.222	0.125
3.000	1.580	1.331	0.749	0.479	0.333	0.187	1.580	1.331	0.749	0.479	0.333	0.187
4.000	1.824	1.774	0.998	0.639	0.444	0.250	1.824	1.775	0.998	0.639	0.444	0.250
5.000	2.040	2.218	1.248	0.799	0.555	0.312	2.040	2.218	1.248	0.799	0.555	0.312
6.000	2.234	2.662	1.497	0.958	0.665	0.374	2.234	2.662	1.497	0.958	0.665	0.374
8.000	2.580	3.549	1.996	1.278	0.887	0.499	2.580	3.549	1.996	1.278	0.887	0.499
10.000	2.884	4.436	2.495	1.597	1.109	0.624	2.884	4.436	2.495	1.597	1.109	0.624
30.000	4.996	13.309	7.486	4.791	3.327	1.872	4.996	13.309	7.486	4.791	3.327	1.872
40.000	5.769	17.745	9.981	6.388	4.436	2.495	5.769	17.745	9.982	6.388	4.436	2.495
50.000	6.450	22.181	12.477	7.985	5.545	3.119	6.450	22.181	12.477	7.985	5.545	3.119
60.000	7.065	26.617	14.972	9.582	6.654	3.743	7.065	26.618	14.972	9.582	6.654	3.743
70.000	7.631	31.053	17.467	11.179	7.763	4.367	7.631	31.054	17.468	11.179	7.763	4.367
80.000	8.158	35.490	19.963	12.776	8.872	4.991	8.158	35.490	19.963	12.776	8.873	4.991
90.000	8.653	39.926	22.458	14.373	9.981	5.615	8.653	39.926	22.459	14.374	9.982	5.615
100.000	9.121	44.362	24.954	15.970	11.090	6.238	9.121	44.363	24.954	15.971	11.091	6.239
110.000	9.566	48.798	27.449	17.567	12.200	6.862	9.566	48.799	27.449	17.568	12.200	6.862

Table 1: ETAP Arc-Flash NFPA 70E Results and Hand Calculated results

Arc duration	% Difference between ETAP and Hand Calcs					
Cycles	FPB (ft)	18 in.	E24 in.	E30 in.	E36 in.	E48 in.
0.250	0.09%	0.18%	0.18%	0.18%	0.18%	0.18%
0.500	0.09%	0.18%	0.18%	0.18%	0.18%	0.18%
2.000	0.09%	0.18%	0.18%	0.18%	0.18%	0.18%
3.000	0.09%	0.18%	0.18%	0.18%	0.18%	0.18%
4.000	0.09%	0.18%	0.18%	0.18%	0.18%	0.18%
5.000	0.09%	0.18%	0.18%	0.18%	0.18%	0.18%
6.000	0.09%	0.18%	0.18%	0.18%	0.18%	0.18%
8.000	0.09%	0.18%	0.18%	0.18%	0.18%	0.18%
10.000	0.09%	0.18%	0.18%	0.18%	0.18%	0.18%
30.000	0.09%	0.18%	0.18%	0.18%	0.18%	0.18%
40.000	0.09%	0.18%	0.18%	0.18%	0.18%	0.18%
50.000	0.09%	0.18%	0.18%	0.18%	0.18%	0.18%
60.000	0.09%	0.18%	0.18%	0.18%	0.18%	0.18%
70.000	0.09%	0.18%	0.18%	0.18%	0.18%	0.18%
80.000	0.09%	0.18%	0.18%	0.18%	0.18%	0.18%
90.000	0.09%	0.18%	0.18%	0.18%	0.18%	0.18%
100.000	0.09%	0.18%	0.18%	0.18%	0.18%	0.18%
110.000	0.09%	0.18%	0.18%	0.18%	0.18%	0.18%
120.000	0.09%	0.18%	0.18%	0.18%	0.18%	0.18%

Table 2: Comparison of ETAP Arc-Flash results against Hand Calculated values based on Section D.7 of NFPA 70E 2004.

Reference

1. Standard NFPA 70E 2004 Section D.7
2. ETAP Short Circuit ANSI V&V Documents, Case Number TCS-SC-157.