ETAP Arc-Flash Analysis

This document is an example of an ETAP validation test case. This case is just one of many test case scenarios for Arc-Flash Analysis (AF) which are part of the ETAP V&V program. This case is based on comparisons of ETAP ArcFault™ against published IEEE publications.

Arc-Flash Analysis Validation Case # 4

Comparison of ETAP Arc-Flash Results Against IEEE Publication

Excerpt from Validation Case and Comparison Results from TCS-SC-515

Highlights

- Covers ETAP ArcFault™ Method 2 (EPRI) for which is covered in detail in "High Voltage Arc Flash Assessment and Applications" [1].

- ETAP ArcFault™ Method 2 (EPRI) comparisons against BC Hydro's application of the EPRI Arc Flash Empirical equations described in "Arc-flash Assessment for High Voltage Transmission Lines-A BC Hydro Perspective" [2].

- Comparisons for:
    - 69, 138, 230, 289, 360, and 500 kV
    - Open-air equipment experiencing line-to-ground arcing faults.
    - Various combinations of bolted fault currents (Ibf), gap between conductors, working distances and fault clearing times (FCT).

Analysis Description

BC Hydro's [2] publication provides incident energy (IE) level estimates for personnel working on open-air equipment exposed to line-to-ground arcing faults. The IE level estimates are generated using the EPRI empirical calculation model for high voltage arcs. The results published in Figures 4 to 9 of [2] examine a total of 1080 calculations which were all modeled using the ArcFault™ calculator. A sample of ArcFault M2 results can be seen in Figure 1. This document is only an excerpt of the 1080 comparisons included TCS-SC-515.

Show below is a sample of the ArcFault™ M2 results for the "Typical Operation" section shown in Figure 2 for a FCT=0.08 sec and Ibf=40kA.

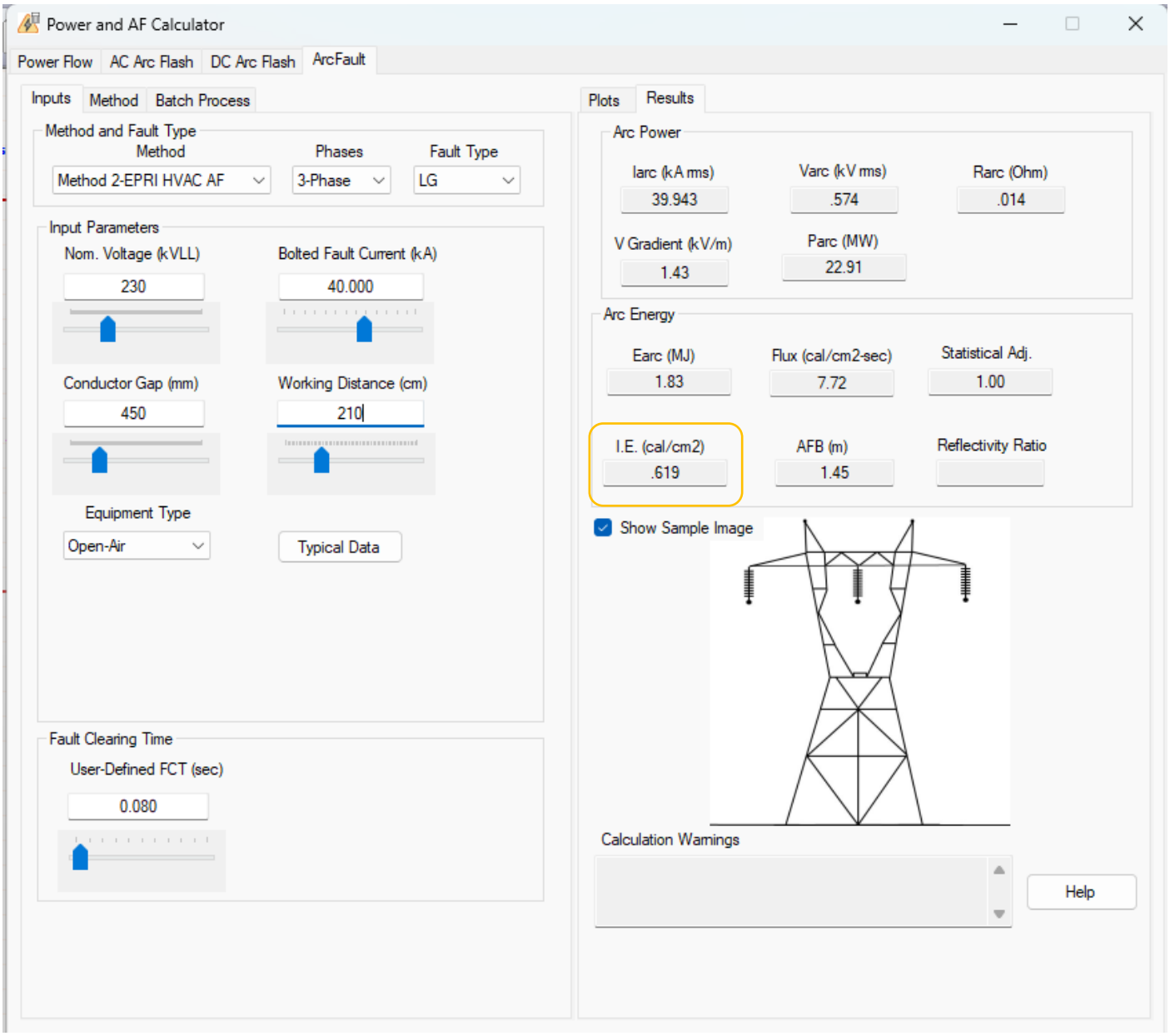

Figure 1: Sample ArcFault™ calculator results

The input data applied for the incident energy results published in [2] for the 230kV transmission line are summarized in Table 1.

FCT (sec)	Ibf (kA)	Gap Between Conductors (mm)	Working Distance (cm)
0.03 to 0.98	1 to 40	450	210

Table 1: Input Data Range for 230kV results shown in Figure 1

The results from [2] are shown in Figure 2 below.

230 kV

Time (s)	Fault Current, kA 1.00	5.00	10.00	15.00	20.00	25.00	30.00	35.00	40.00
0.03	0.00	0.02	0.05	0.08	0.11	0.14	0.17	0.20	0.23
0.08	0.01	0.07	0.14	0.21	0.28	0.36	0.44	0.53	0.62
0.13	0.02	0.11	0.22	0.34	0.46	0.59	0.72	0.86	1.01
0.18	0.03	0.15	0.30	0.47	0.64	0.82	1.00	1.19	1.39
0.23	0.04	0.19	0.39	0.60	0.82	1.04	1.28	1.52	1.78
0.28	0.05	0.23	0.47	0.73	0.99	1.27	1.56	1.86	2.17
0.33	0.05	0.27	0.56	0.86	1.17	1.50	1.84	2.19	2.55
0.38	0.06	0.31	0.64	0.99	1.35	1.72	2.11	2.52	2.94
0.43	0.07	0.36	0.73	1.12	1.53	1.95	2.39	2.85	3.33
0.48	0.08	0.40	0.81	1.25	1.70	2.18	2.67	3.18	3.71
0.53	0.09	0.44	0.90	1.38	1.88	2.40	2.95	3.51	4.10
0.58	0.09	0.48	0.98	1.51	2.06	2.63	3.23	3.84	4.49
0.63	0.10	0.52	1.07	1.64	2.23	2.86	3.50	4.18	4.87
0.68	0.11	0.56	1.15	1.77	2.41	3.08	3.78	4.51	5.26
0.73	0.12	0.60	1.24	1.90	2.59	3.31	4.06	4.84	5.65
0.78	0.13	0.64	1.32	2.03	2.77	3.54	4.34	5.17	6.03
0.83	0.13	0.69	1.41	2.16	2.94	3.76	4.62	5.50	6.42
0.88	0.14	0.73	1.49	2.29	3.12	3.99	4.89	5.83	6.81
0.93	0.15	0.77	1.57	2.42	3.30	4.22	5.17	6.16	7.19
0.98	0.16	0.81	1.66	2.55	3.48	4.44	5.45	6.50	7.58

Typical operation

Incident Energy (cal/cm^2) 0 - 2 2 - 4 4 - 8

Figure 2: IE results from for 230kV for various FCTs and fault currents

Comparative Analysis

In this section, Figures 3 to 11 provide plots for 230kV transmission line IE comparisons between the results published in [2] and ArcFault™ M2. Details for the comparisons are summarized in Table 2 below.

Figure Number	Scenario Description
Fig. 3	IE comparisons for 230kV transmission line for Ibf=1kA and varying FCT.
Fig. 4	IE comparisons for 230kV transmission line for Ibf=5kA and varying FCT.
Fig. 5	IE comparisons for 230kV transmission line for Ibf=10kA and varying FCT.
Fig. 6	IE comparisons for 230kV transmission line for Ibf=15kA and varying FCT.
Fig. 7	IE comparisons for 230kV transmission line for Ibf=20kA and varying FCT.
Fig. 8	IE comparisons for 230kV transmission line for Ibf=25kA and varying FCT.
Fig. 9	IE comparisons for 230kV transmission line for Ibf=30kA and varying FCT.
Fig. 10	IE comparisons for 230kV transmission line for Ibf=35kA and varying FCT.
Fig. 11	IE comparisons for 230kV transmission line for Ibf=40kA and varying FCT.

Table 2: Summary of ArcFault™ M2 Comparisons

Figures 3 to 11 show excellent correlation between the BC Hydro IE estimates from [2] and the ArcFault™ M2 results. The same comparison trend was observed for all 1080 BC Hydro results.

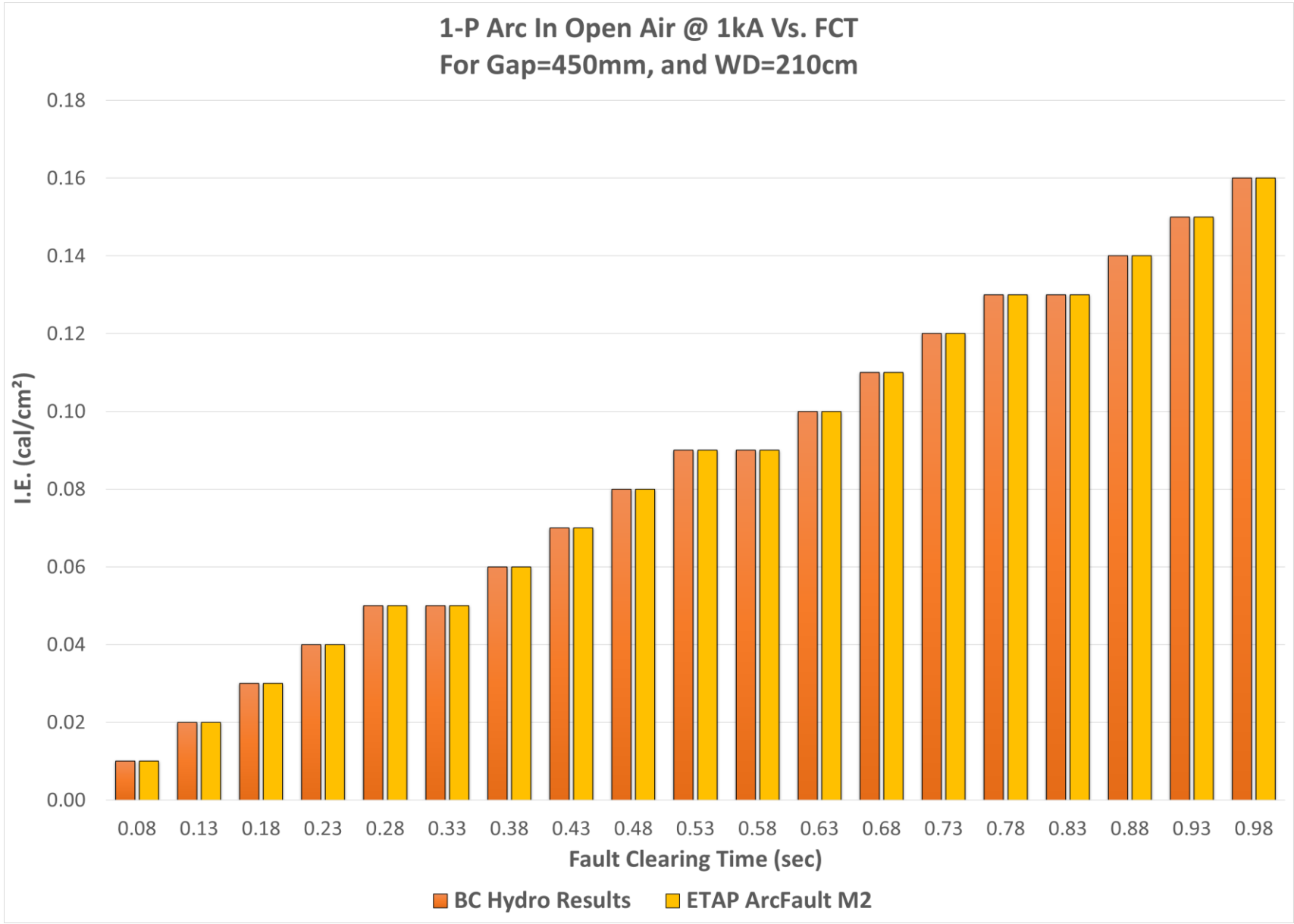

Figure 3:IE comparisons for ETAP ArcFault M2 and results from [2] for Ibf=1kA

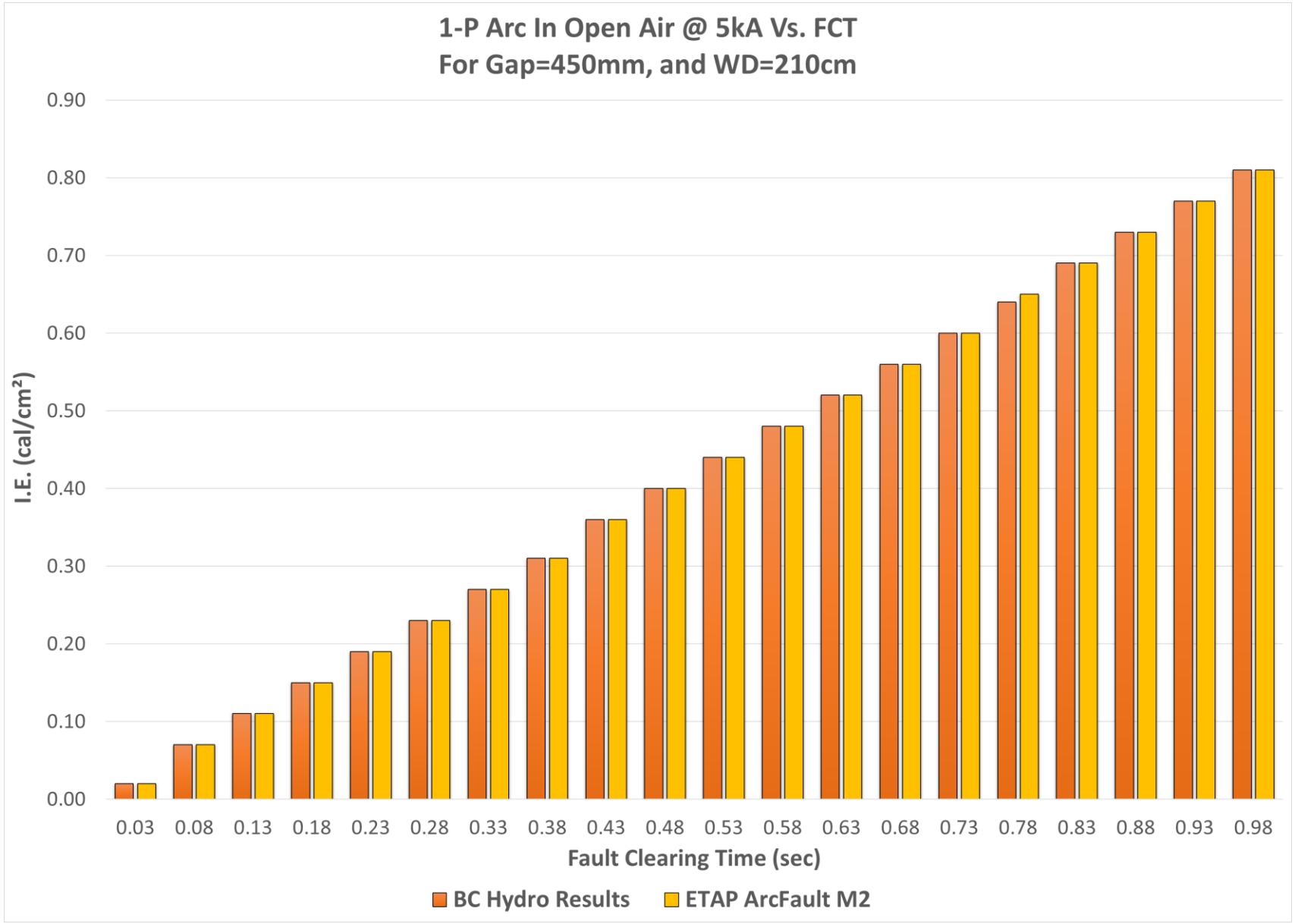

Figure 4: IE comparisons for ETAP ArcFault M2 and results from [2] for Ibf=5kA

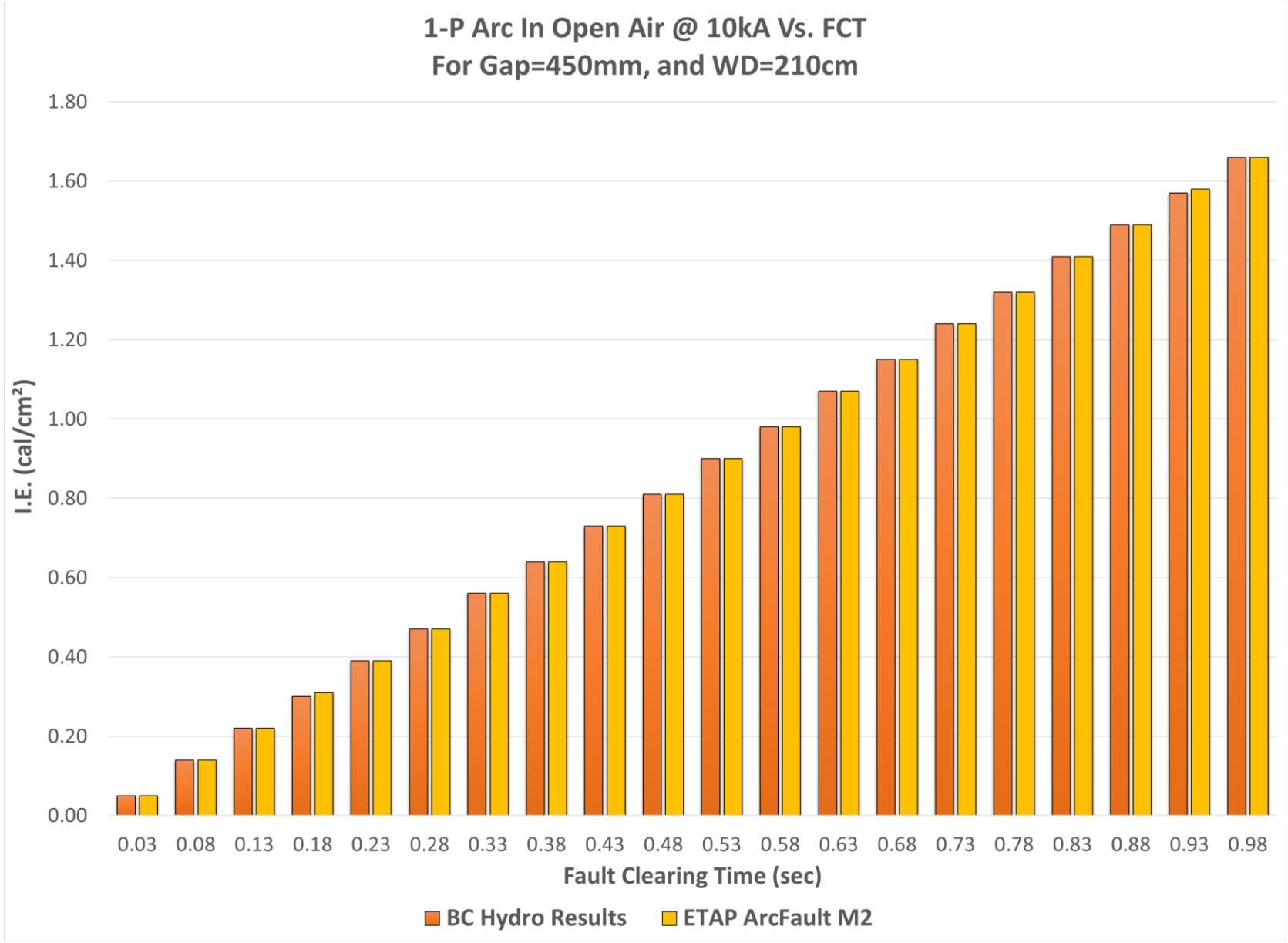

Figure 5: IE comparisons for ETAP ArcFault M2 and results from [2] for Ibf=10kA

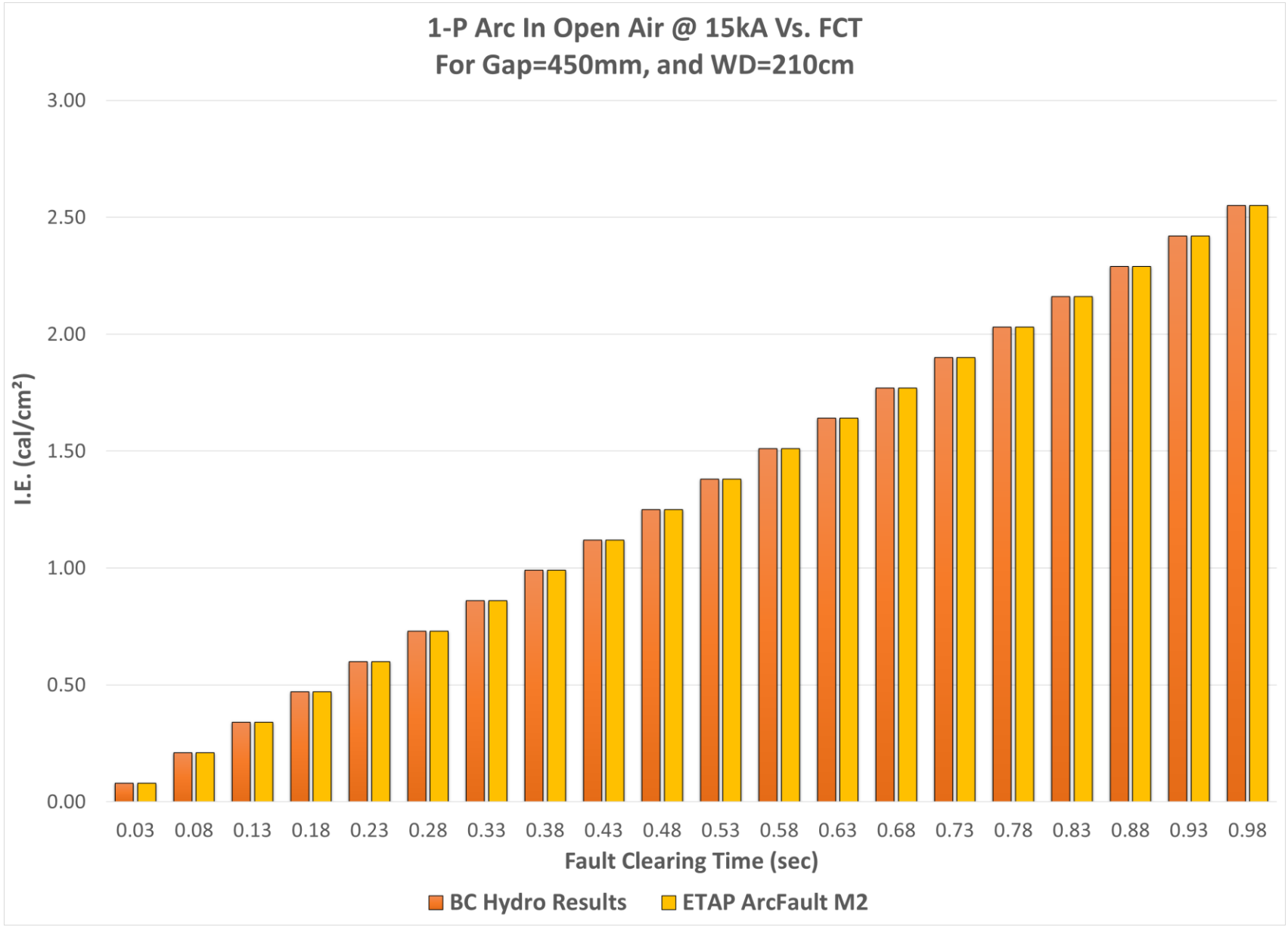

Figure 6: IE comparisons for ETAP ArcFault M2 and results from [2] for Ibf=15kA

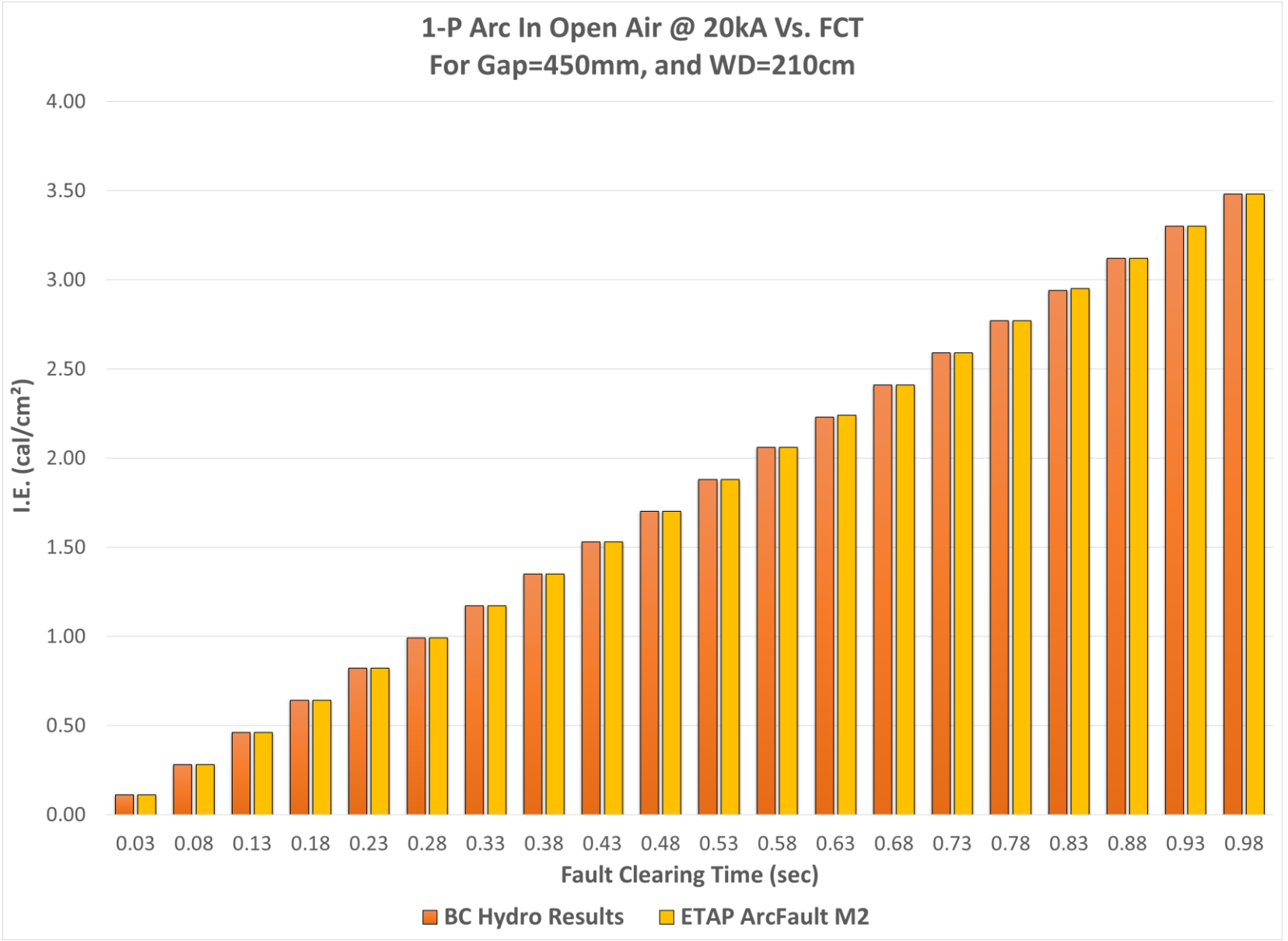

Figure 7: IE comparisons for ETAP ArcFault M2 and results from [2] for Ibf=20kA

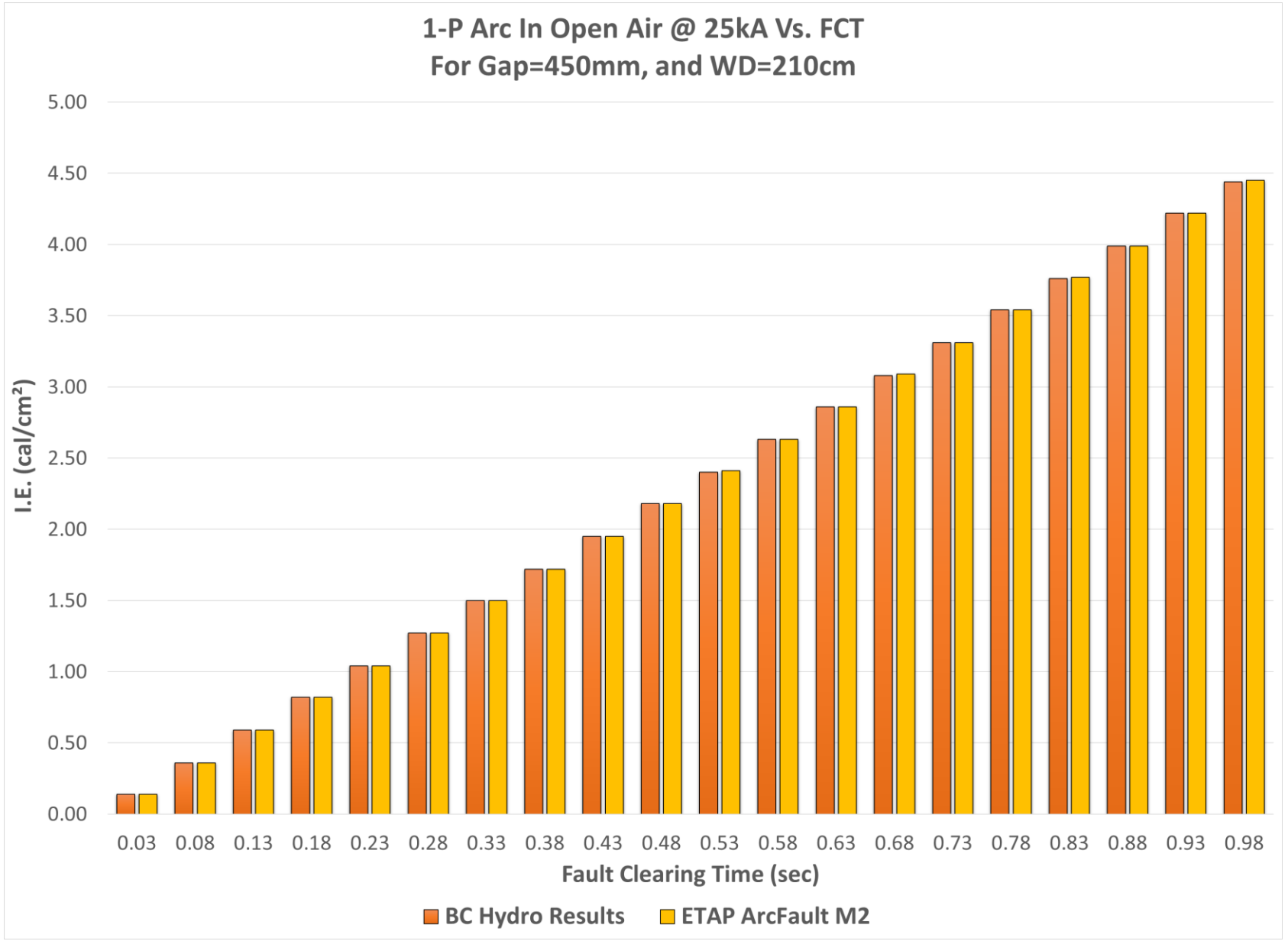

Figure 8: IE comparisons for ETAP ArcFault M2 and results from [2] for Ibf=25kA

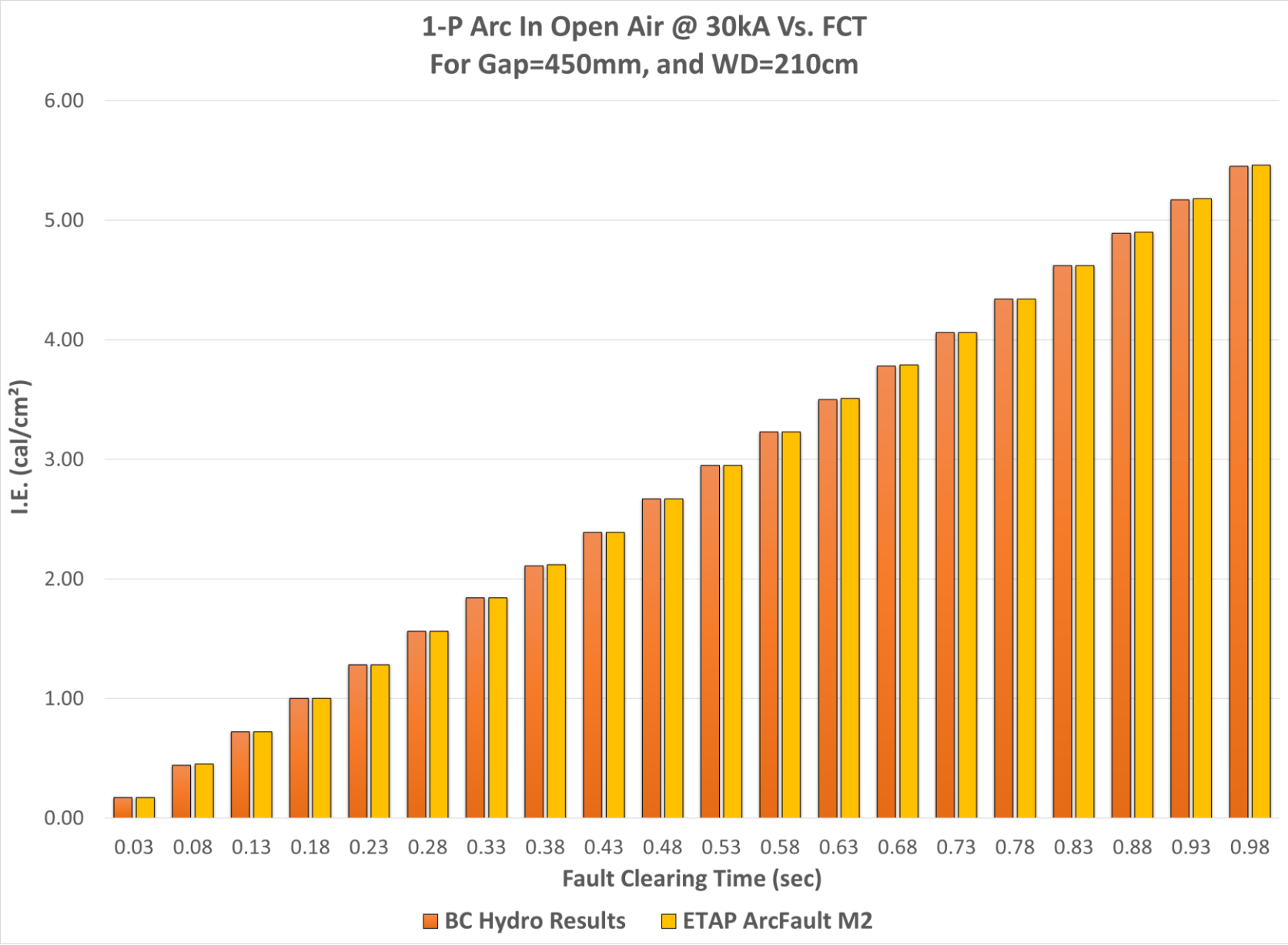

Figure 9: IE comparisons for ETAP ArcFault M2 and results from [2] for Ibf=30kA

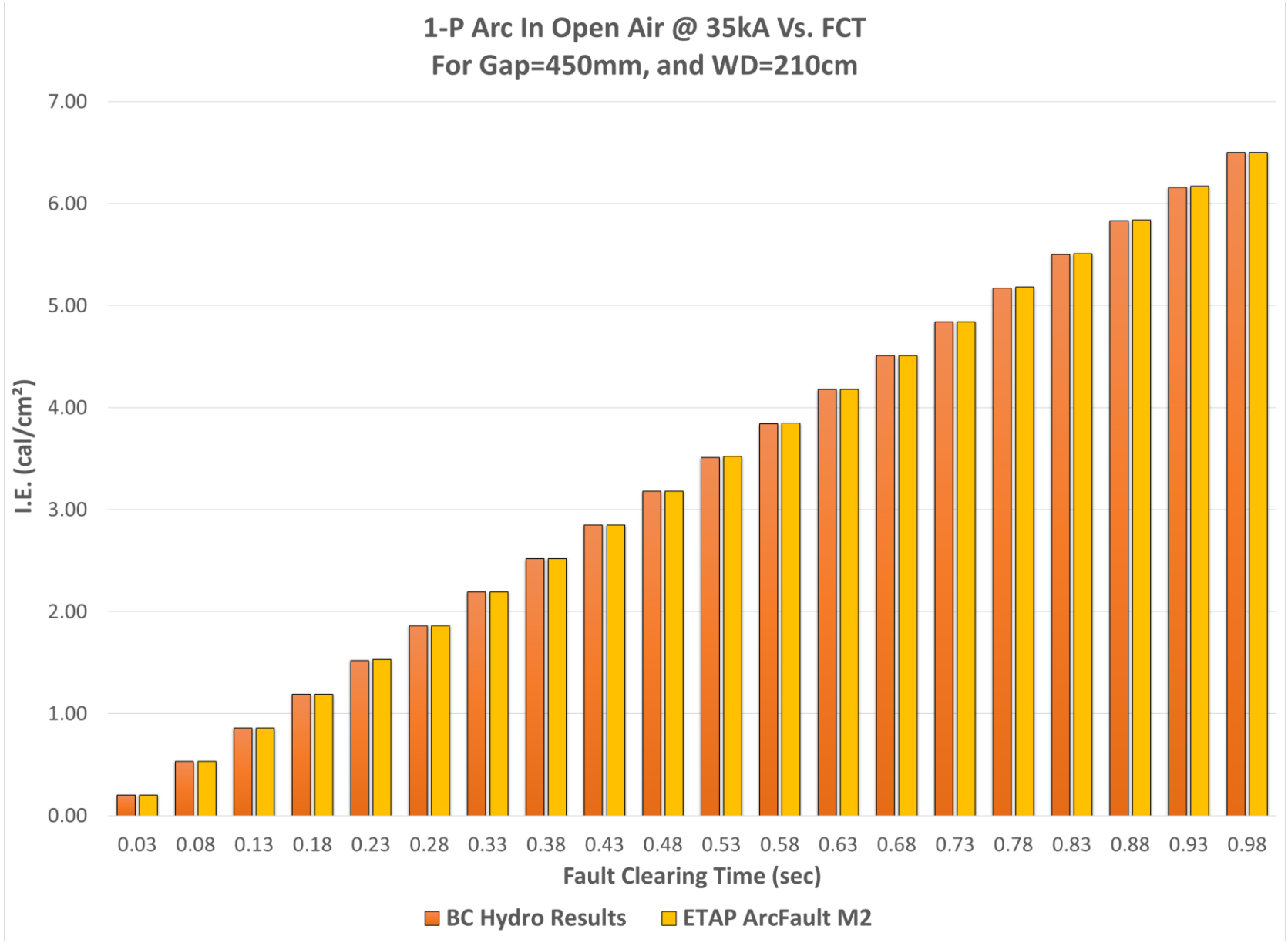

Figure 10: IE comparisons for ETAP ArcFault M2 and results from [2] for Ibf=35kA

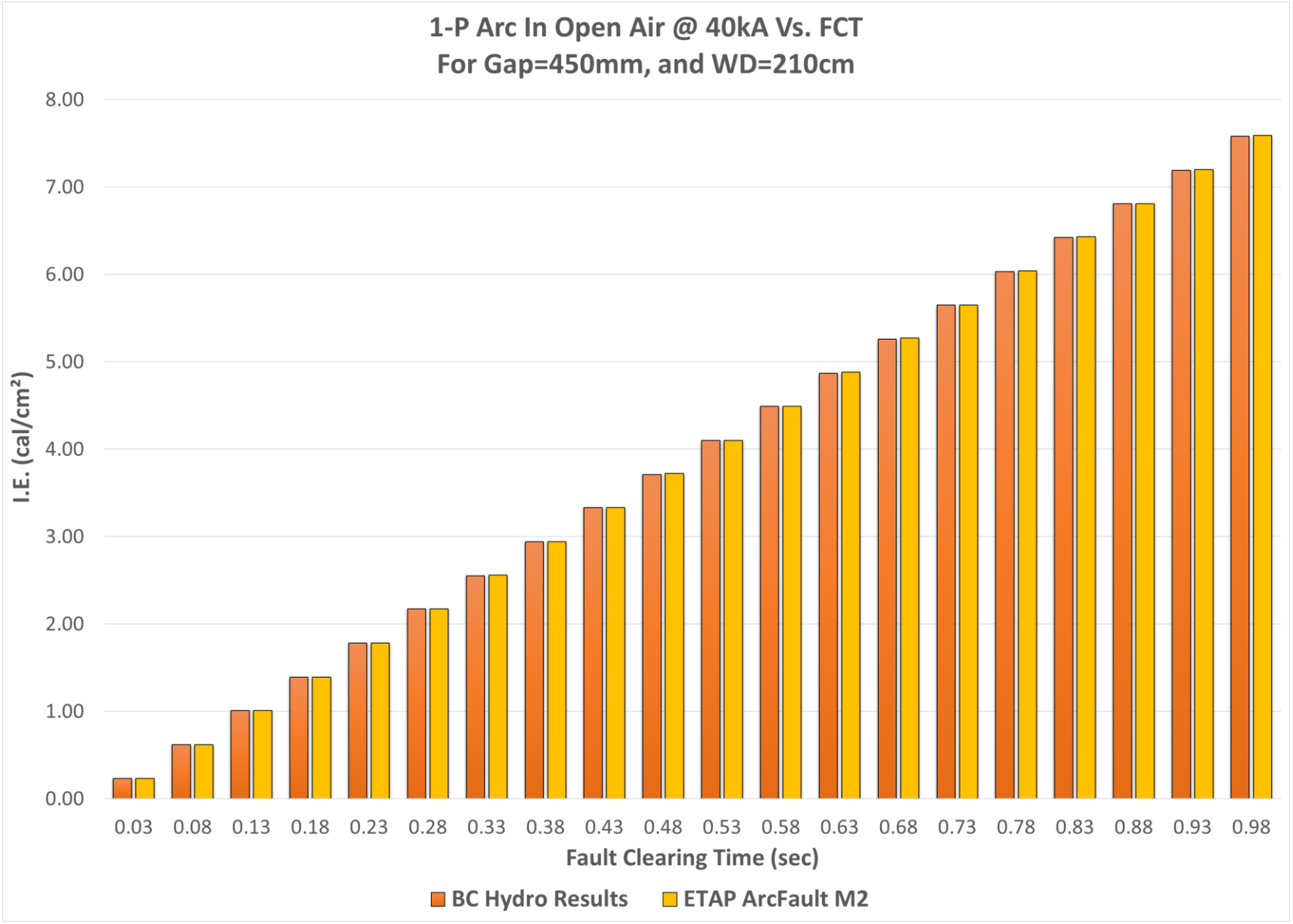

Figure 11: IE comparisons for ETAP ArcFault M2 and results from [2] for Ibf=40kA

References

[1]. Albert Marroquin, et., all, “HIGH VOLTAGE ARC FLASH ASSESSMENT AND APPLICATIONS”, IEEE Transactions on Industry Applications, vol. 56, issue: 3, May-June 2020

[2]. J. Khan, et., all, “Arc-flash Assessment for High Voltage Transmission Lines-A BC Hydro Perspective”, 2020 IEEE Power & Energy Society General Meeting (PESGM), Montreal, QC, Canada, 2020,