AC Arc Flash Comparison Case # 3

Comparison of AC Arc flash results against Hand Calculations based on DGUV Information 203-077

Excerpts from Validation Cases and Comparison Results (TCS-SC-521)

Highlights

- Comparison of ETAP Electrical Arc Energy (W_{arc}) results against hand calculations. The test case is based on a published power system from "Thermal hazards due to electric fault arcing," published by Deutsche Gesetzliche Unfallversicherung Spitzenverband (DGUV) 203-077", Example 5.1 [1]
- Comparison of Short circuit power (P_k)
- Comparison of Electric arc power (P_{arc})
- Comparison of Normalized Arc power (k_p)
- Comparison of Current limitation (k_B)
- Comparison of PPEaA protection level at the point of arcing

System Description

This example deals with work performed on a low voltage distribution system at a transformer station with rated capacity of 630 kVA protected by a Fuse with operating class gTr AC 400V. The results from the short-circuit current calculation according to IEC-60909-2016 [3] at the work location yield a prospective value of $I''_{k3,max}$ (maximum) = 24.5 kA and $I''_{k3,min}$ (minimum) = 21.6 kA respectively. The R/X ratio for the network impedance in the fault circuit equates to approximately 0.27. The input parameters such as conductor spacing, working distance and trip time are taken from Figure 3 when working in the vicinity of the work location. The one-diagram in ETAP is shown in Figure1. This document is an excerpt from TCS-SC-521 [2]

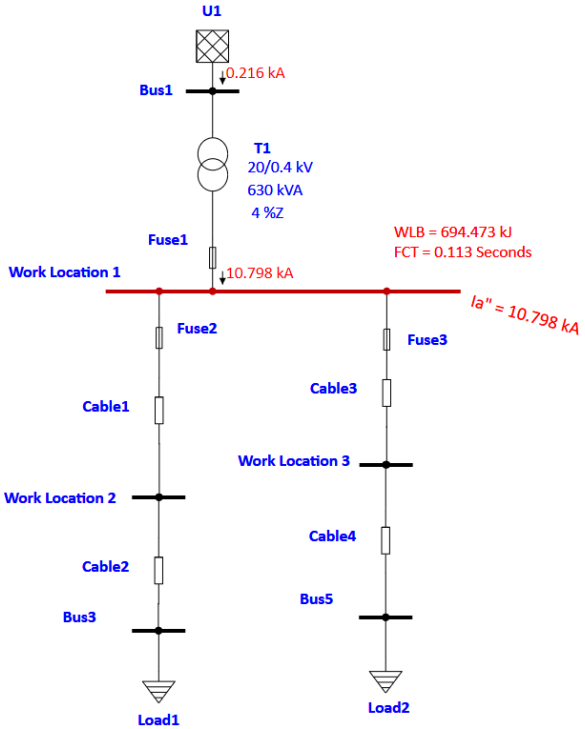

Figure 1: One Line diagram from Low Voltage distribution system for Work Location 1 (Worst-Case)

Comparison of Results

The following tables of comparison show the differences between ETAP Results and those published in the standard (Worst-Case method). Please note that the maximum deviation in the results is about 0.65 % due to the accuracy of significant figures in ETAP.

For a fault at Work location1	Scenario -1 (Worst-Case Method)		
	Hand Calc	ETAP	% Diff.
Electrical arc energy (W_{arc}) kJ	690	694.473	**0.65**
Short circuit power (P_k) MW	16.97	16.97	**0.0**
Electric arc power (P_{arc}) MW	6.1	6.1	**0.0**
Normalized Arc power (k_p)	0.36	0.36	**0.0**
Current limitation (k_B)	0.5	0.5	**0.0**
PPEaA protection level at the point of arcing ($W_{arc, prot\_APC1}$) kJ	252	252	**0.0**
PPEaA protection level at the point of arcing ($W_{arc, prot\_APC2}$) kJ	480	480	**0.0**

Table 1: Comparison of ETAP results against hand calculation results based on the Table A 5-1

A sample arc flash label based on the above results from table 1 is shown in Figure2.

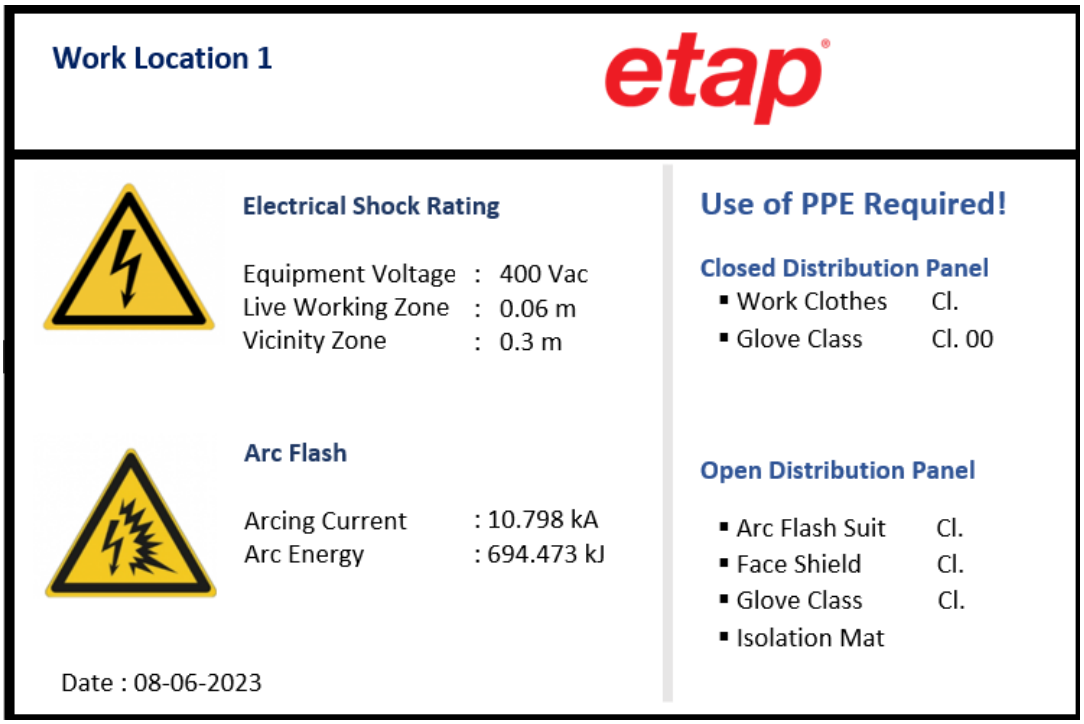

Figure 2: Arc Flash Label based on Worst-Case method.

Table A 5-1 Results of the calculations for W_{arc} and $W_{arc,\ prot}$ for Example 5.1 (630 kVA transformer station)

Work location	630 kVA Low voltage distribution system	Prepared by:	John Doe
Work order	Connection/disconnection of output circuitry, measurement and testing or cleaning tasks	Date:	29 Nov. 2019

Calculation		Parameter	Result (worst-case)	Result with a precise calculation according to [21]
Network parameter	Nominal voltage	U_{Nn}	400V	
Equipment geometry	Conductor spacing	d	60 mm	
Short-circuit current calculation	Max. short-circuit current	$I''_{k\,3,max}$	24.5 kA	
	Min. short-circuit current	$I''_{k\,3,min}$	21.6 kA	
	R/X ratio	R/X	0.27	
Current limitation		k_B	0.5	0.633
Minimum fault current	$I_{k,\ arc} = k_B \cdot I''_{k\,3,min}$	$I_{k,\ arc}$ =	10.8 kA	13.67 kA
Trip time for the overcurrent protection device (circuit breaker set value/ Trip time from the protection fuse characteristics)		t_k	0.113 s	0.045 s
Short-circuit power	$S''_k = \sqrt{3} \cdot U_{Nn} \cdot I''_{k\,3,max}$	S''_k =	16.97 MVA	
Normalized arc power	$k_p = \frac{0.29}{(R/X)^{0.17}}$	k_p =	0.36	0.338
Electric arc power	$P_{arc} = k_p \cdot S''_k$	P_{arc} =	6.1 MW	5.7 MW
Electric arc energy (expected value)	$W_{arc} = k_p \cdot S''_k \cdot t_k$	W_{arc} =	690.3 kJ	258 kJ
Working distance		a	300 mm	
Standardized PPE test level		$W_{arc,\ test\_APC\ 2}$ =	320 kJ	
		$W_{arc,\ test\_APC\ 1}$ =	168 kJ	
Transmission factor		k_T	1.5	
PPEaA protection level at the point of arcing	$W_{arc,\ prot} = k_T \cdot \left(\frac{a}{300\,mm}\right)^2 \cdot W_{arc,\ test}$	$W_{arc,\ prot\_APC\ 2}$ =	480 kJ	
		$W_{arc,\ prot\_APC\ 1}$ =	252 kJ	

Comparison			
	$W_{arc} < W_{arc,\ prot\_APC\ 2}$	NO	YES
	$W_{arc} < W_{arc,\ prot\_APC\ 1}$	NO	NO

Figure 3 Summary of results based on work example from [1]

For electric arc power, the worst-case calculation (Scenario-1) yields P_{arc} = 6.1 MW approximately which corresponds to a normalized arc power of k_p = 0.36 based on the current limiting factor k_B = 0.5. With a short-circuit duration of t_k = 0.113 seconds, the resulting expected value of the converted electric arc energy at the work location (fault location) is W_{arc} = 690 kJ approximately.

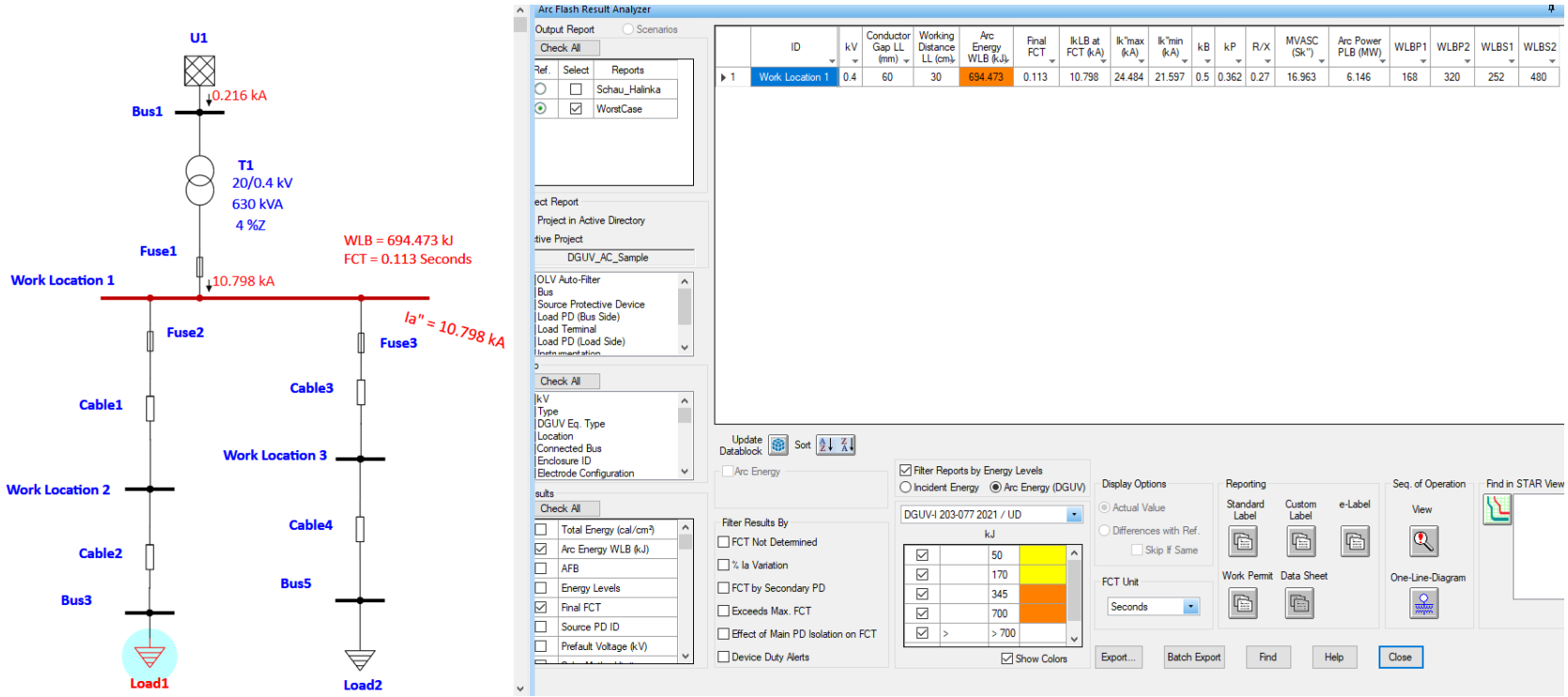

Figure 4: Scenario 1 (Worst-Case Method)

For electric arc power calculated based on Schau, H.; Halinka. A method (Scenario-2) summarized in Table2; the current limiting factor (k_B=0.63) is evaluated more precisely greater than 0.5. This leads to significantly low arc energy levels for clearing times below 1 second. The resulting expected value for arc energy is then $W_{arc,}$ = 258 kJ approximately.

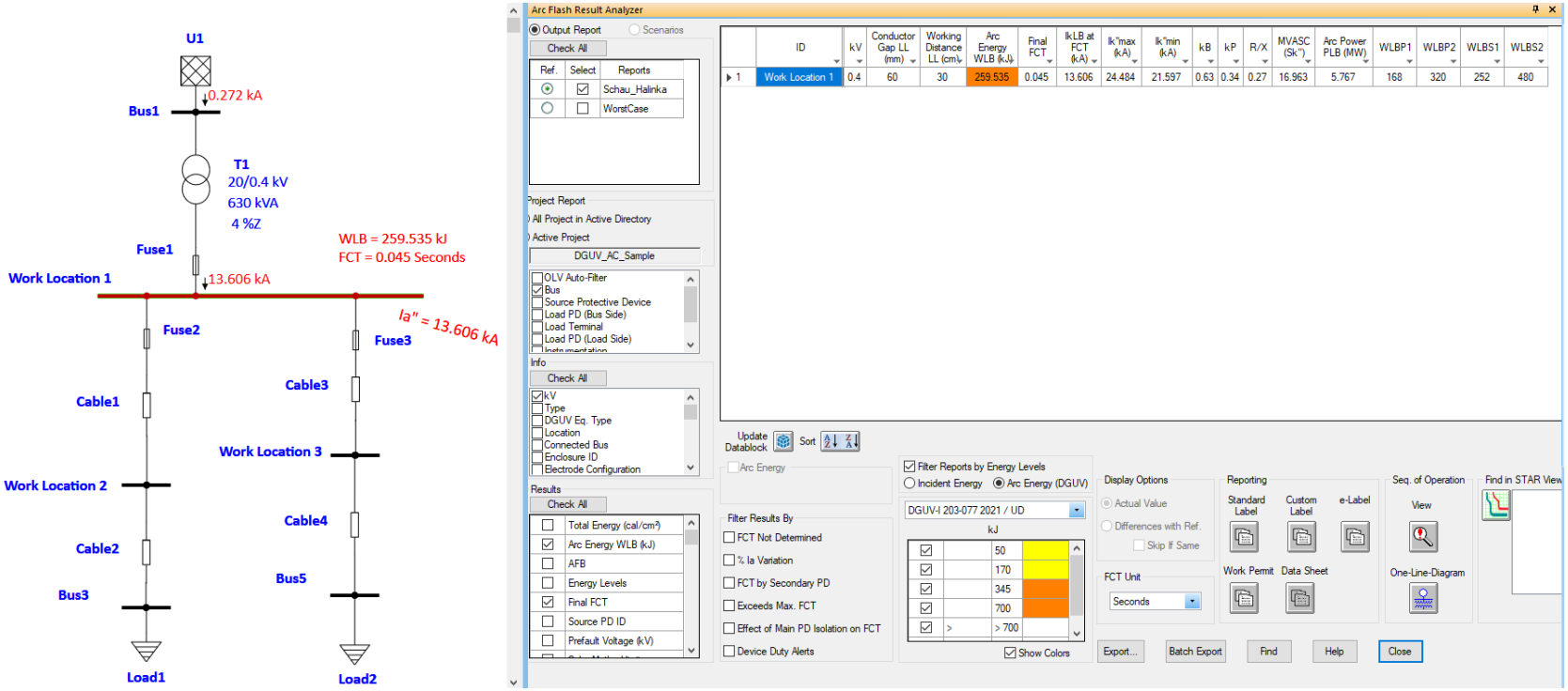

Figure 5 Scenario 2 (Schau.H.; Halinka.A Method)

The following tables of comparison show the differences between ETAP Results and those published in the standard (Schau, H.; Halinka. A). Please note that the maximum deviation in the results is about 0.65 % due to the accuracy of significant figures in ETAP.

For a fault at Work location1	**Scenario-2 (Schau, H.; Halinka. A)**		
	Hand Calc	ETAP	**% Diff.**
Electrical arc energy (W_{arc}) kJ	258	259.535	**0.65**
Short circuit power (P_k) MW	16.97	16.97	**0.0**
Electric arc power (P_{arc}) MW	5.7	5.7	**0.0**
Normalized Arc power (k_p)	0.338	0.34	**0.0**
Current limitation (k_B)	0.633	0.63	**0.0**
PPEaA protection level at the point of arcing ($W_{arc,\ prot\_APC1}$) kJ	252	252	**0.0**
PPEaA protection level at the point of arcing ($W_{arc,\ prot\_APC2}$) kJ	480	480	**0.0**

Table 2: Comparison of ETAP results against hand calculation results based on the Table A 5-1

Reference

1. "DGUV Informtion 203-077, Thermal hazards due to electric fault arcing. Guide for selecting Personal protective equipment" Published by: German Statutory Accident Insurance registered association (DGUV) www.dguv.de/publikationen Web code: p203077.

2. ETAP Short Circuit ANSI SC V&V Documents, Case Number TCS-SC-521.

3. "Short-circuit currents in three-phase a.c. systems – Part 0: Calculation of currents" , IEC-60909-0-2016 edition 2.0. ISBN 978-2-8322-3158-6.