DC Arc Flash Comparison Case # 1

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

Excerpts from Validation Cases and Comparison Results (TCS-DCSC-081)

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 5.8
- 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 UPS system (uninterruptible power supply) which yields prospective short-circuit current of I_{kDC} = 4.086 kA. The intermediate circuit voltage equals 400V as shown in Figure1. When working in the vicinity of the work location, a conductor spacing of d= 30 mm is assumed when introducing an electric arc short-circuit which yields a current limiting factor of k_B = 0.677 and an actual fault current (electric arc short-circuit current) of $I_{k,\,arc}$ = 2.76 kA. The work location may not be within the protection zone of the NH gR Bat fuse, the most unfavorable case for an exposure time t_k = 1 second must be assumed (maximum exposure time or duration of time, in which a person is able to withdraw from the immediate danger area). This document is an excerpt from TCS-DCSC-081 [2]

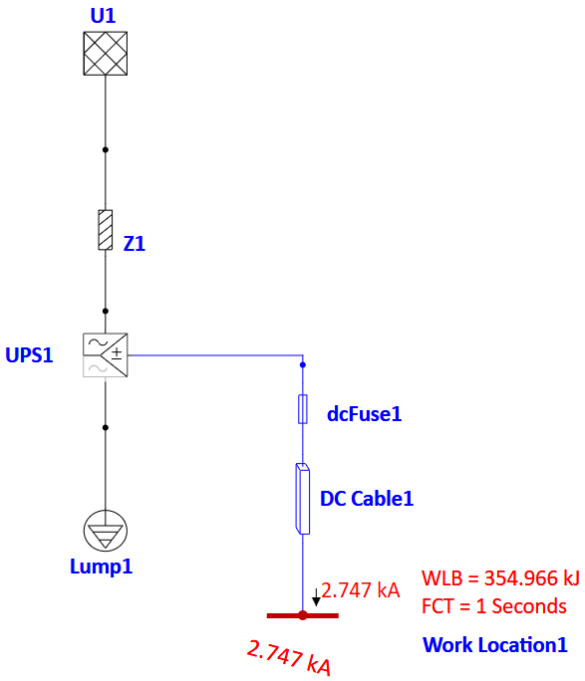


Figure 1: One Line diagram from the UPS system for Work Location 1 (Iterative method)

Comparison of Results

The following tables of comparison show the differences between ETAP Results and those published in the standard (Iterative 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 (Iterative Method)		
	Hand Calc	ETAP	% Diff.
Electrical arc energy (W_{arc}) kJ	357	354.966	**0.65**
Short circuit power (P_k) MW	1.6	1.6	**0.0**
Electric arc power (P_{arc}) MW	0.408	0.408	**0.0**
Normalized Arc power (k_p)	0.219	0.219	**0.0**
Current limitation (k_B)	0.677	0.677	**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 5-12

A sample arc flash label based on the above results from table1 is shown in Figure2.

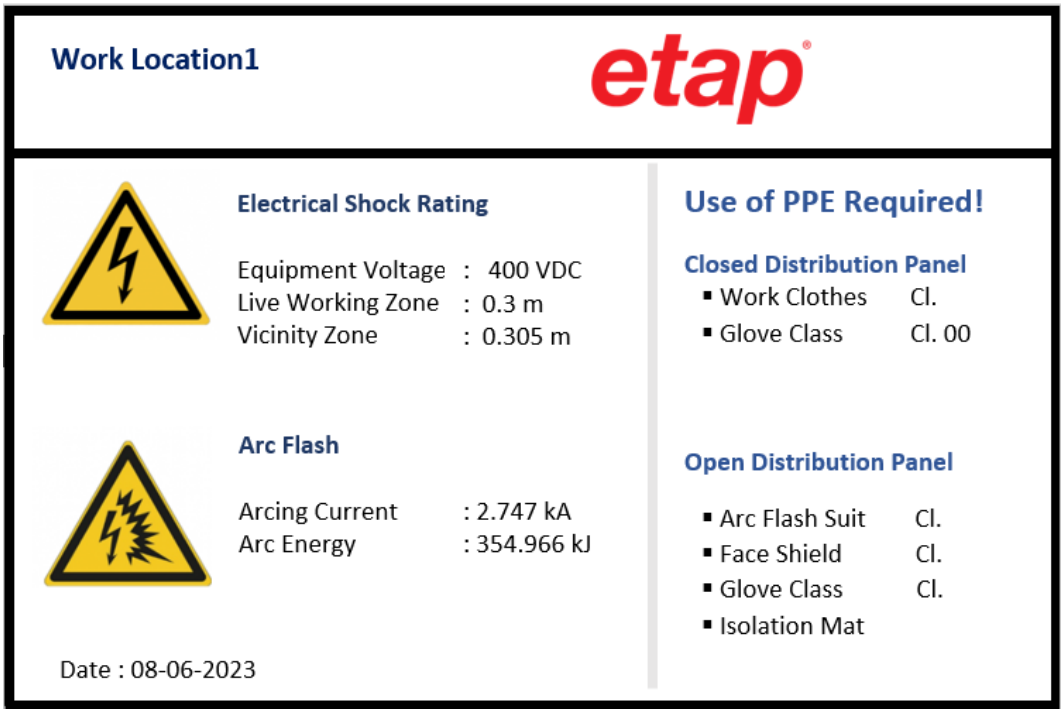


Figure 2: Arc Flash Label based on Iterative method.

Table A 5-12 Summary of the example for work on UPS systems at Work location 1

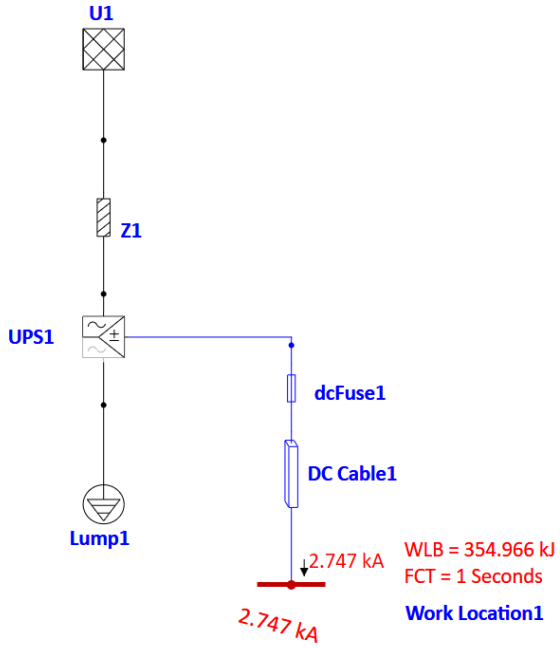
Work location	Working on an inverter	Prepared by:	John Doe
Work order	200 kVA UPS system	Date:	29 Nov. 2019

Calculation		Parameter	Result
Network parameter	Nominal voltage	U_{Nn}	400V
Equipment geometry	Conductor spacing	d	30 mm
Short-circuit current calculation	Sustained short-circuit current	I_{kDC}	4.0 kA
	Time constant τ	τ	0.002 s
Current limitation		k_B	0.677
Electric arc current (fault current)	$I_{k,\,arc\,(i+1)} = \frac{U_{Nn}}{\frac{(34 + 0.532 \cdot d)}{I_{k,\,arc\,(i)}^{0.88}} + \frac{U_{Nn}}{I_{kDC}}}$	$I_{k,\,arc}$ =	2.76 kA
Trip time for the overcurrent protection device (circuit breaker set value/ Trip time from the protection fuse characteristic curve)		t_k	1.000 s
Short-circuit power	$P_k = U_{Nn} \cdot I_{kDC}$	P_k =	1.6 MW
Electric arc power	$P_{arc} = U_{arc} \cdot I_{k,\,arc}$	P_{arc} =	0.36 MW
Normalized arc power	$k_p = P_{arc} / P_k$	k_p =	0.219
Electric arc energy (expected value)	$W_{arc} = P_{arc} \cdot t_k$	W_{arc} =	357.46 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		
	$W_{arc} < W_{arc,\,prot\_APC\,2}$	YES
	$W_{arc} < W_{arc,\,prot\_APC\,1}$	NO

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

For electric arc power, the iteration calculation (Scenario-1) yields P_{arc} = 358 kW approximately which corresponds to a normalized arc power of k_p = 0.219. With a short-circuit duration of t_k = 1 second, the resulting expected value of the converted electric arc energy at the work location (fault location) is W_{arc} = 358 kJ.



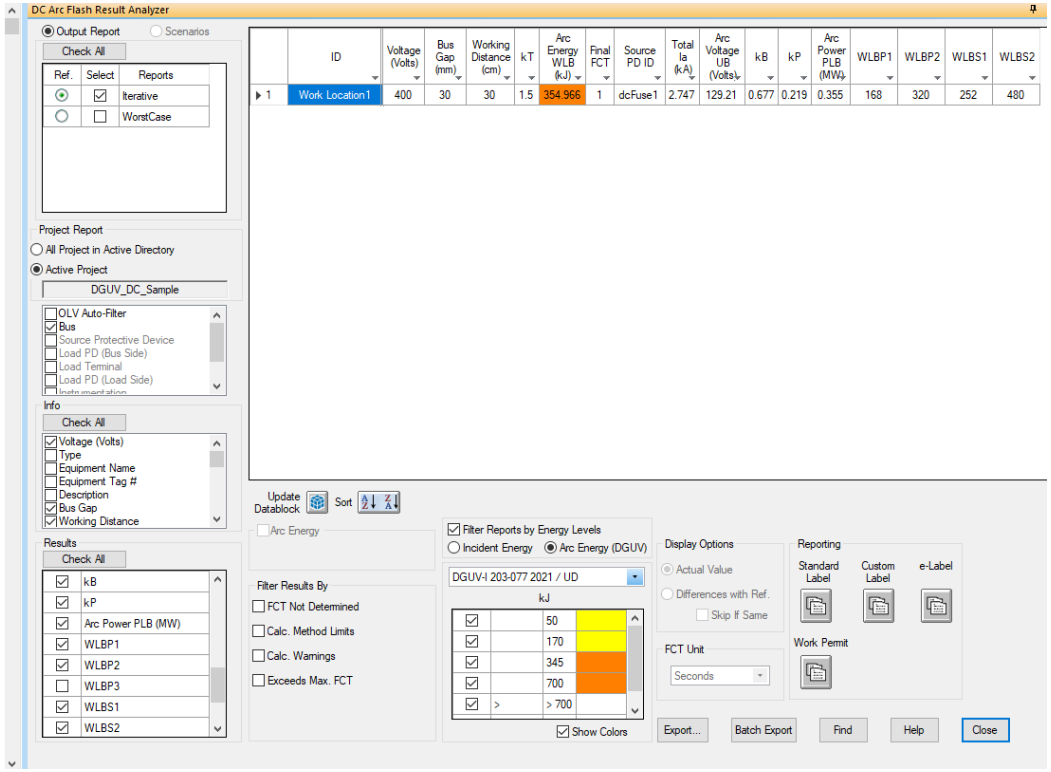


Figure 4: Scenario 1 (Iterative Method 1)

For electric arc power is calculated with a worst-case estimation (Scenario-2) summarized in Table2, without considering the electrode gap for the relationship of $P_{arc} = 0.25 * P_k$ with network parameters for network voltage level, prospective short-circuit current and the short-circuit power at $P_k = U_n \cdot I_{kDC}$, then it follows that $P_{arc,\,max} = 0.25 \cdot 1.634$ MVA = 0.408 MW. The resulting expected value for arc energy is then $W_{arc,\,max} = 408.5$ kJ.

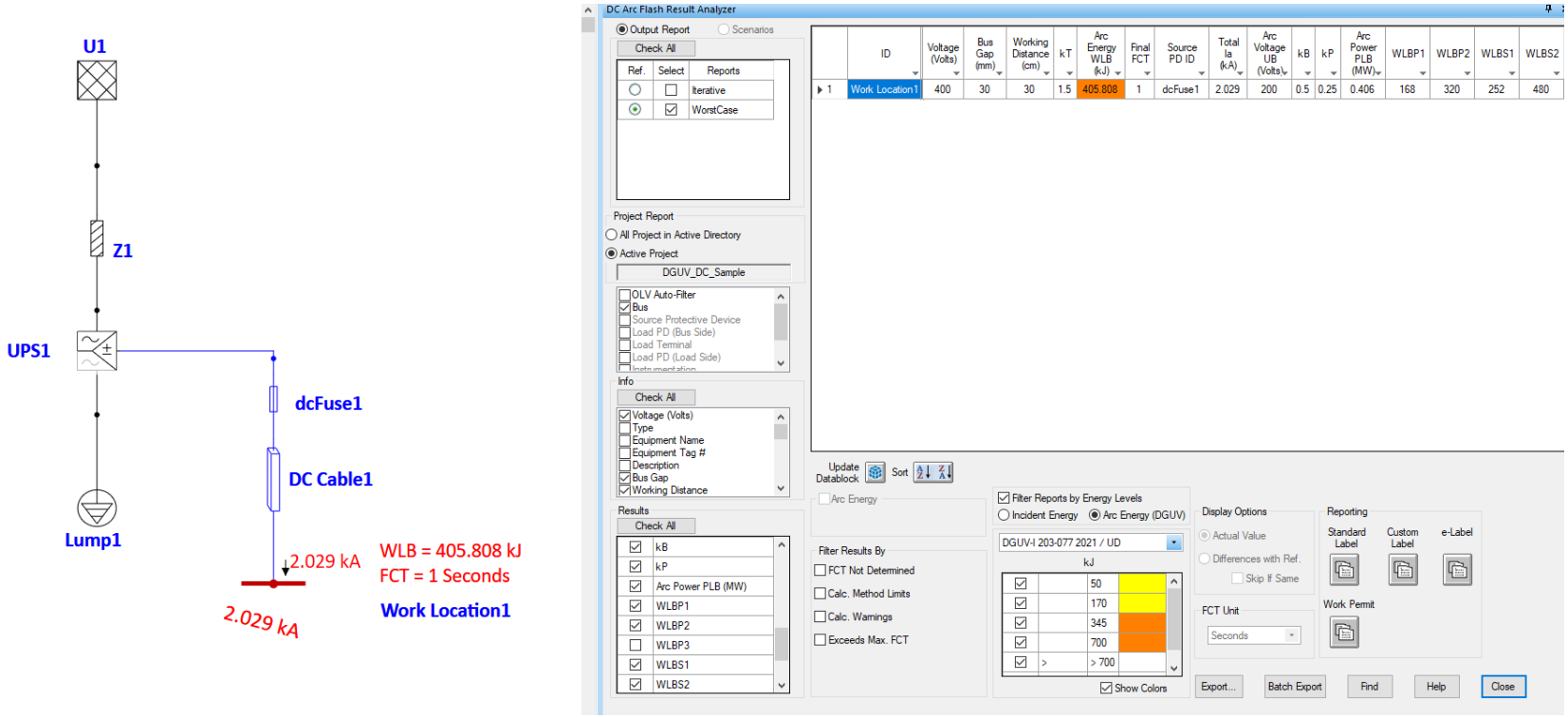


Figure 5 Scenario 2 (Worst-Case Method 2)

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 -2 (Worst-Case Method)**		
	Hand Calc	ETAP	**% Diff.**
Electrical arc energy (W_{arc}) kJ	408	405.808	**0.65**
Short circuit power (P_k) MW	1.6	1.6	**0.0**
Electric arc power (P_{arc}) MW	0.406	0.406	**0.0**
Normalized Arc power (k_p)	0.25	0.25	**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 2: Comparison of ETAP results against hand calculation results based on the Table A 5-12

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 DCSC V&V Documents, Case Number TCS-DCSC-081.