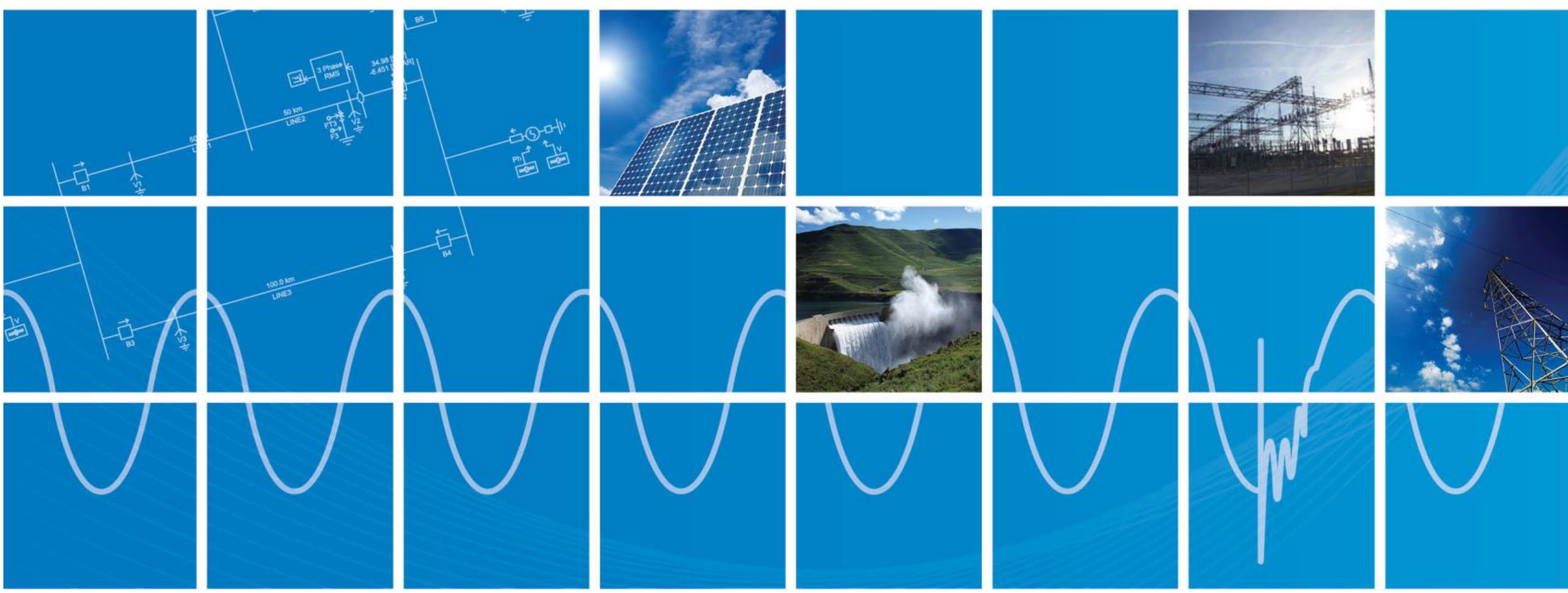
Metal Oxide Surge Arrester

For PSCAD Version 5.0

January 30, 2020

Initial



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CONTENTS

1. OVERVIEW

1.1. Surge Arrester General Information

The maximum continuous operating voltage (Uc, MCOV) and rated voltage (Ur) are two significant characteristic points that define the performance of a surge arrester during the steady state operation.

MCOV is the maximum power frequency voltage under which the surge arrester can operate. As recommended by IEC 60099-5, the MCOV of a surge arrester should be at least 5% higher than the highest continuous voltage of the power system.

The rated voltage specifies the temporary overvoltage handling capability of a surge arrester for a period of 10 to 100 seconds. Figure 1 depicts the typical IEEE surge arrester TOV withstand capability.

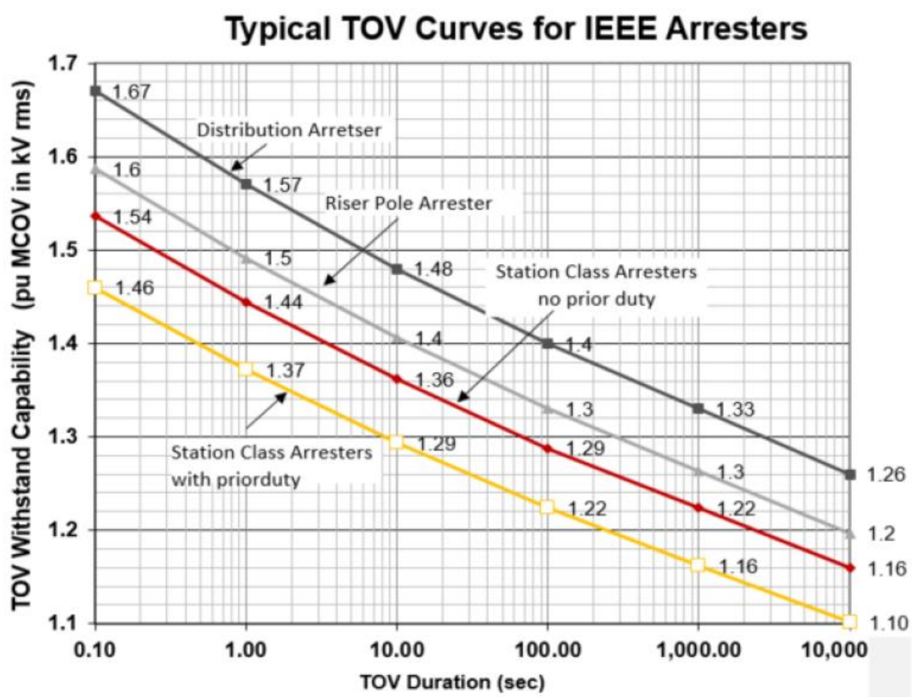
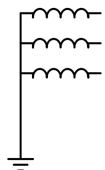
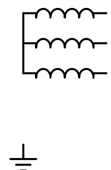
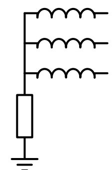
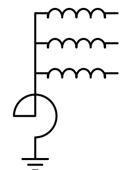


Figure 1: Typical TOV curves for IEEE arresters

Rated voltage is generally 1.25 of MCOV. Table 1 below shows the typical surge arrester rated voltage under different system voltages and applications [4] [5].

Table 1: Typical rated voltages U_r for highest system voltage [4] [5]

Highest voltage of system	Solidly earthed neutral system	Isolated neutral system	Impedance earthed neutral system	Resonant earthed neutral system	Neutral Protection
U_s (kV)	U_r (kV)	U_r (kV)	U_r (kV)	U_r (kV)	U_r (kV)
					
3.6	3	6	3	6	3
7.2	6	9	9	9	3
12	9	15	12	15	6
17.5	15	24	15	24	9
24	18	30	21	30	12
36	27	45	33	45	15
52	39	66	45	66	21
72.5	54	96	66	96	30
123	90	154	108	154	51
145	108	183	126	183	60
170	123	216	147	216	69
245	180				102
300	222				120
362	261				147
420	336				168
550	396				222
800	580				321

The characteristic above 0.1kA is generally considered as the switching and lightning impulse protective characteristic of a surge arrester. In a surge arrester data sheet, the I-V characteristic is generally provided up to 40kA under specified wave shapes as listed below. Figure 2 depicts the typical data provided in a manufacture surge arrester data sheet [5] with the wave shape highlighted. The typical I-V characteristics of various manufactures are given in Appendix A.

- Typical switching impulse testing wave shape: 30/60us
- Typical lightning impulse testing wave shape: 8/20us

Highest voltage of the system	Rated voltage	Continu-ous operating voltage	Line discharge class	Long duration current 2ms	Maximum values of the residual voltages at discharge currents of the following impulses						
U_s kV	U_r kV	U_c kV	LD Class	A	30/60 µs 0.5 kA kV	30/60 µs 1 kA kV	30/60 µs 2 kA kV	8/20 µs 5 kA kV	8/20 µs 10 kA kV	8/20 µs 20 kA kV	8/20 µs 40 kA kV
245	192	154	5	3200	347	355	367	392	413	446	487

Figure 2: Typical manufacture surge arrester data sheet [5]

1.2. Arrestor I-V Characteristic Data

The arrestor I-V characteristic data can be supplied to the model by the following means:

- Use the default characteristics (ASEA XAP-A)
- Enter the data directly using the arrestor input parameters
- Enter the data through an external data file

Generally, the data provided by the manufacturer are in [kA] versus [kVpk] or [kVrms] format. However, the PSCAD/EMTDC requires the voltages to be entered in per-unit. The PSCAD/EMTDC then will use the following equation to convert the voltage in kV (phase-to-ground peak voltage) for the simulation.

Voltage points (Peak Ph-G) = Voltage points in pu * Arrester Voltage Rating

Therefore, one approach is to model the surge arrester in PSCAD/EMTDC as per the manufacture I-V characteristics, and set the Arrester Voltage Rating to 1 kV. This will allow user to directly enter the V characteristics points in without additional per-unitization. Section 2.1 provides an example to clarify this approach.

Default Characteristics (ASEA XAP-A)

To use the arrestor default characteristics, ensure that **I-V Characteristic** | **Default** is selected. The default characteristics approximate the ASEA XAP-A metal oxide surge arrester. The ASEA XAP-A characteristics are given below for reference:

I [kA]	V [pu]
0.001	1.100
0.01	1.600
0.1	1.700
0.2	1.739
0.38	1.777
0.65	1.815
1.11	1.853
1.50	1.881
2.00	1.910
2.80	1.948
200.0	3.200

Note that the voltage is in per-unit, and so the **Arrester Voltage Rating** input parameter should be the rated voltage in kV.

Entering Data from an External File

If entering the I-V coordinates from an external data file, a certain structured format must be followed. Descriptive comments cannot be used. The last data point must be followed by a '/'. A maximum of 100 data points is allowed. Also, an 'ENDFILE:' statement must be placed at the end of the file. An example data file is given below:

```
0.001 1.1
0.01   1.6
0.1     1.7 /
ENDFILE:
```

1.3. Frequency Dependent Surge Arrester Model

This section provides an accurate and practical frequency dependent surge arrester modeling technique based on [1] and [2].

Under the fast front transients such as the lightning, the metal-oxide arrester depicts its dynamic and the frequency-dependent characteristics. The voltage across the arrester increases as the time to crest of the arrester current decreases and the arrester voltage reaches its peak before the arrester current reaches its peak.

The time to crest for lightning surges can range from 0.5 µs to several microseconds. This frequency dependent model surge arrester will give good results for current surges with time to crest from 0.5 µs to 45 µs.

For the fast front model, there are two sections of the non-linear resistance designated A0 and A1 as shown in Figure 3; each comprised of the surge arrester model used for switching surge transients above. An R-L filter separates the two sections. For slow front surges, this R-L filter has very little impedance, but is significant for fast front surges.

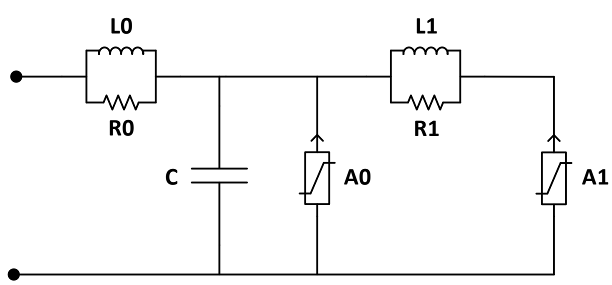


Figure 3: Surge Arrester fast front model

The V-I characteristics of A0 and A1 are shown in Table 2 [1] [2]. Characteristic A0 has a higher voltage for a given current than A1, but when the two are considered in parallel and the R-L filter is not acting significantly, their combined characteristic is that for slow front (i.e. switching surges).

Table 2: I-V Characteristic for A0 and A1 [1] [2]

Current (kA)	V-I characteristics*	
	A0 V (pu)	A1 V (pu)
0.01	1.40	-
0.1	1.54	1.23
1	1.68	1.36
2	1.74	1.43
4	1.80	1.48
6	1.82	1.50
8	1.87	1.53
10	1.90	1.55
12	1.93	1.56
14	1.97	1.58
16	2.00	1.59
18	2.05	1.60
20	2.10	1.61

*Note: pu in the table above is based on a model element that had a 1.6kV IR at 10kA.

The RLC elements are initially determined by the following equations [1] [2]:

$$L1 = 15\ d/n\ \mu H \quad (1)$$

$$R1 = 65\ d/n\ \Omega \quad (2)$$

$$Lo = 0.2\ d/n\ \mu H \quad (3)$$

$$Ro = 100\ d/n\ \Omega \quad (4)$$

$$C = 100\ n/d\ pF \quad (5)$$

Where:

d = is the estimated height of the arrester in metres (use the overall dimension from the catalog data).

n = number of parallel columns of metal oxide in the arrester.

The inductance “Lo” represents the inductance from the magnetic fields in the immediate vicinity of the arrester. The resistor “Ro” helps to stabilize the numerical integration during simulation on a digital computer program. The capacitance “C” represents the terminal-to-terminal capacitance of the arrester.

Equations (1) to (5) only provide an adequate estimate of parameters for the frequency-dependent model. Further tuning is normally required base on the initial calculation. Parameter “L1” has the most impact, whereas the other parameters have little impact. The following procedures are recommended for choosing the parameters of the frequency-dependent model.

- Use the provided equations to derive the initial values for L0, R0, L1, R1, C, and the nonlinear characteristics A0 and A1.

- Adjust the per-unit value on the curves for characteristics A0 and A1 to get a close match for the published discharge voltages associated with switching surge discharge currents (time to crest of approximately 45 µs).

- Adjust the value of L1 to get a close match of published arrester discharge voltages for 8/20 µs discharge currents.

The resulting parameters will provide close results for the surges with times to crest in the range of 0.5 µs to 45 µs. Section 2.2 provides a simple example to demonstrate the operation of the surge arrester frequency-dependent model.

2. PSCAD/EMTDC EXAMPLE DESCRIPTION

2.1. Example 1

This example demonstrates the modeling of a surge arrester based on a given I-V characteristic with rated voltage (voltage base) of 360 kV. The example surge arrester I-V characteristic curve is shown in Table 3.

Table 3: Example Surge Arrester I-V Characteristics

I (kA)	V (pu)	V (kV)
0.000001	1.10	396.0
0.001	1.60	576.0
0.01	1.70	612.0
0.02	1.74	626.4
0.5	1.95	702.0
1	2.02	727.2
2	2.10	756.0
3	2.14	770.4

The same surge arrester is modeled in three different ways.

- User defined (table), Arrester Voltage Rating at 360 kV
- User defined (table), Arrester Voltage Rating at 1 kV
- User defined (external data file), Arrester Voltage Rating at 360 kV

2.2. Example 2

The purpose of this example is to demonstrate the modeling of a frequency dependent surge arrester model in PSCAD/EMTDC. The data provided in [2] was used.

A one-column 1.45m metal-oxide surge arrester is modeled in this example. The discharge voltage provided by the manufacturer and the simulated results of the PSCAD/EMTDC model are shown in Table 4.

Table 4: Discharge voltage comparison

Current Wave shape	Current Magnitude	Discharge Voltage	
		Manufacture	PSCAD/EMTDC Model
8/20 µs	10kA	248kV	246kV
300/1000 µs	3kA	225kV	225kV

The test circuit and modeled surge arrester are depicts in Figure 4. The RLC elements of the frequency dependent surge arrester are initially calculated based on the equations (1) - (5). The value of L1 is further adjusted to improve the accuracy of the model.

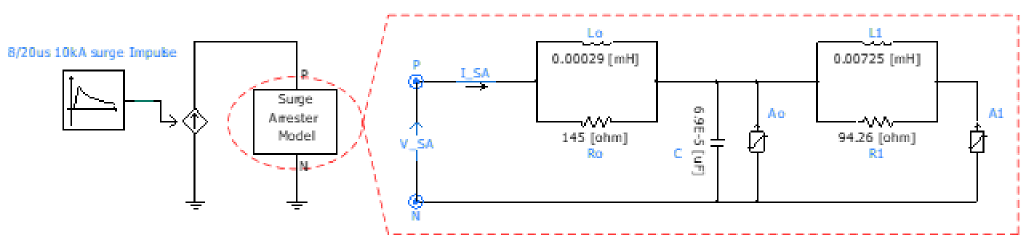


Figure 4: Frequency Dependent Surge Arrester

Figure 5 depicts the simulation results of the frequency dependent PSCAD/EMTDC surge arrester model. The modeled surge arrester residual voltage under different wave shapes of impulse current shows close agreement with the manufacturer provided data.

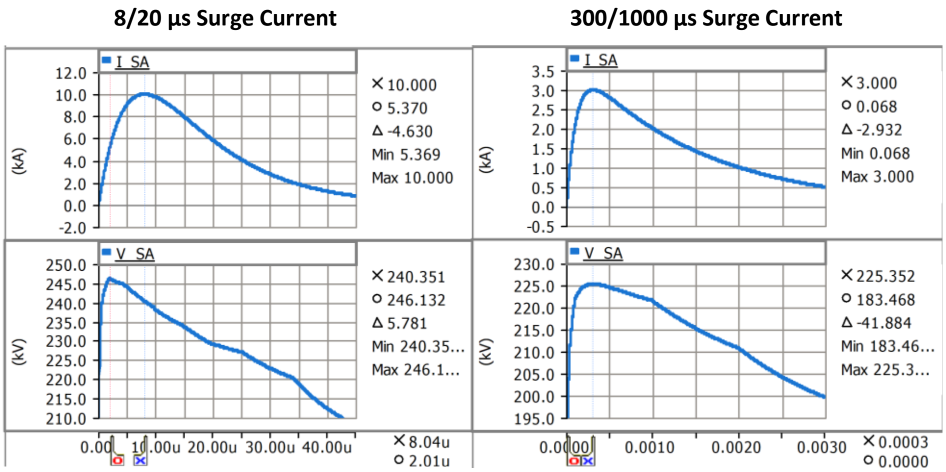


Figure 5: PSCAD Surge Arrester Model Simulation Results

2.3. Example 3

Surge arresters protect the equipment in close proximity from surges such as the lighting or switching. However, the voltage at the protected equipment can sometimes be significantly higher than the voltage across the surge arrester due to the traveling wave process [3]. This example provides a simple demonstration on such phenomenon.

Figure 6 depicts a simplified substation layout. The surge arrester at the station entry was design to protect all the equipment within the substation.

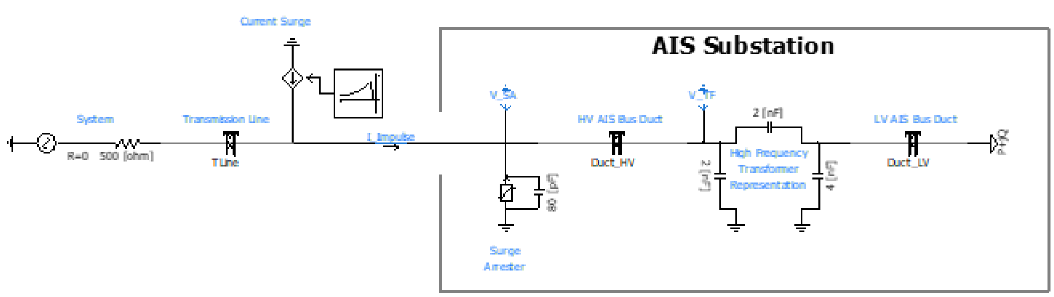


Figure 6: Traveling Wave Process Demonstration Circuit

The surge arrester can prevent overvoltage at the station entry point from the incoming surges. As the voltage wave front propagate from the station entry point to the transformer and then reflected back, the incoming and reflected voltage waveform superimposed at the terminal of the transformer. Depending on the Bus duct distance from the transformer to the surge arrester, the superimposed voltage at the terminal of the transformer can be significantly higher than the voltage at the surge arrester terminal. From Figure 7, for a 10kA surge current is injected at station entry, the voltage at the station entry was limited under 260kV by the surge arrester, but the maximum transient voltage at the transformer terminal increases as the distance between the surge arrester and the transformer increases.

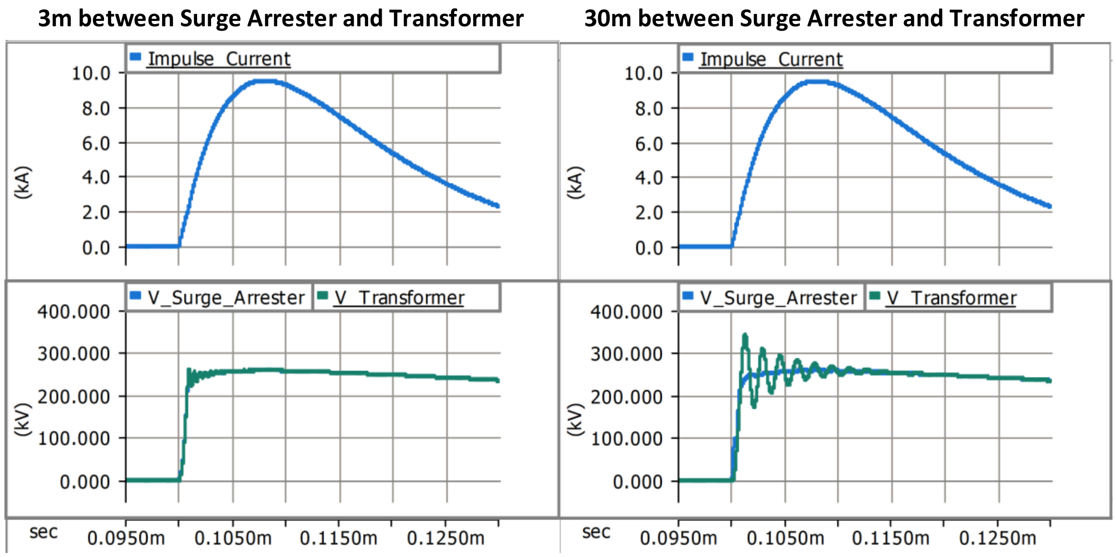


Figure 7: Traveling Wave Process Simulation Results

3. REFERENCES

[1] "IEEE Guide for the Application of Metal-Oxide Surge Arresters for Alternating-Current Systems," in IEEE Std C62.22-2009 (Revision of IEEE Std C62.22-1997) , vol., no., pp.1-142, 3 July 2009 doi: 10.1109/IEEESTD.2009.6093926

[2] "Modeling of metal oxide surge arresters," in IEEE Transactions on Power Delivery, vol. 7, no. 1, pp. 302-309, Jan. 1992. doi: 10.1109/61.108922

[3] Hinrichsen, V. Metal-oxide surge arresters in high-voltage power systems Fundamentals. Erlangen, Germany: Siemens AG, 2012

[4] IEC 60099-4, Edition 3.0, 2014-06: Surge arresters - Part 4: Metal-oxide surge arresters without gaps for a.c. systems

[5] High-voltage surge arresters product guide. Erlangen, Germany: Siemens AG, 2014

[6] ABB High Voltage Surge Arresters buyer's Guide. LUDVIKA, Sweden: ABB AB, 2008

[7] SURGE ARRESTERS - IEC 5kA, 10kA Class 1 & 2, Distribution Medium & High Surge Arresters IEEE Normal Duty, Heavy Duty & Riser Pole Surge Arresters. USA: Hubbell Inc, 2017

[8] Surge Arresters Catalog. Franklin Park, Illinois: MacLean Power Systems, 2010

[9] Surge Arresters - IEC Line Discharge Classes 2, 3, 4 & 5. AIKEN, South Carolina: Hubbell/Ohio Brass, 2015

Additionally useful resources:

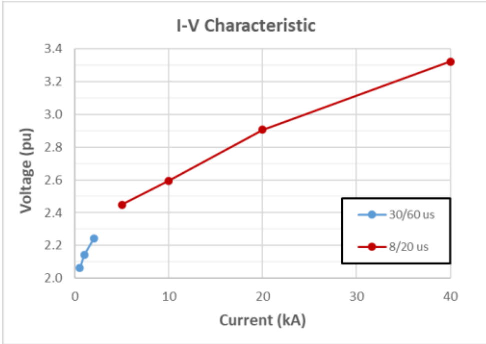
- PSCAD Application Guide and theory workbook: https://hvdc.ca/knowledge-base/read,article/283/pscad-application-guide-and-theory-workbook/v:
- Arrester Works: http://www.arresterworks.com/

APPENDIX A SAMPLE SURGE ARRESTER DATA

A.1 ABB [6] - Per unit voltage based on rated voltage Ur

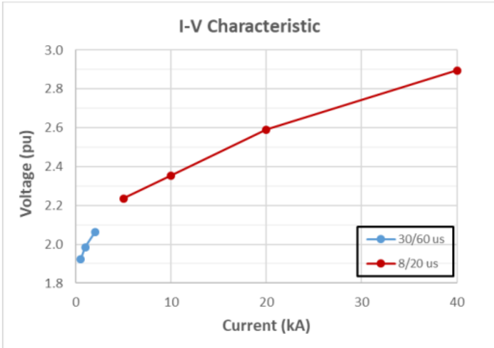
PEXLIM R

	kA	pu
30/60 us	0.5	2.062
	1	2.142
	2	2.242
8/20 us	5	2.448
	10	2.595
	20	2.907
	40	3.323



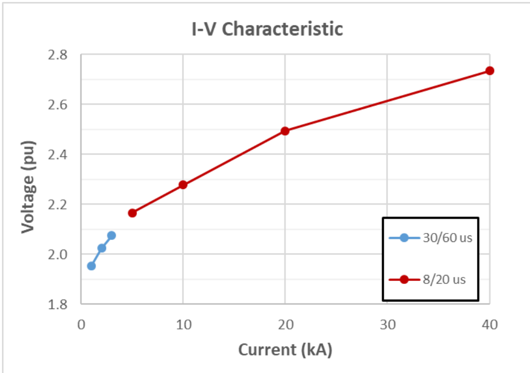
PEXLIM Q

	kA	pu
30/60 us	0.5	1.923
	1	1.985
	2	2.063
/20 us	5	2.236
	10	2.354
	20	2.590
	40	2.896



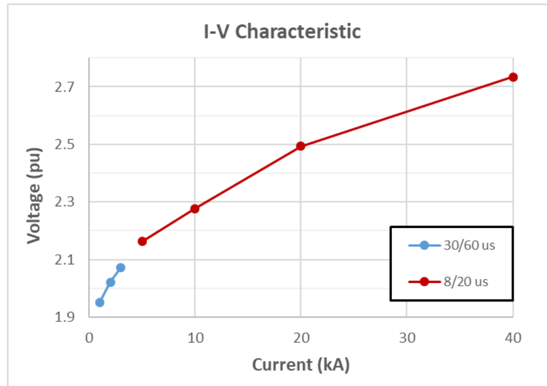
PEXLIM P

	kA	pu
30/60 us	1	1.953
	2	2.024
	3	2.074
8/20 us	5	2.165
	10	2.279
	20	2.495
	40	2.734



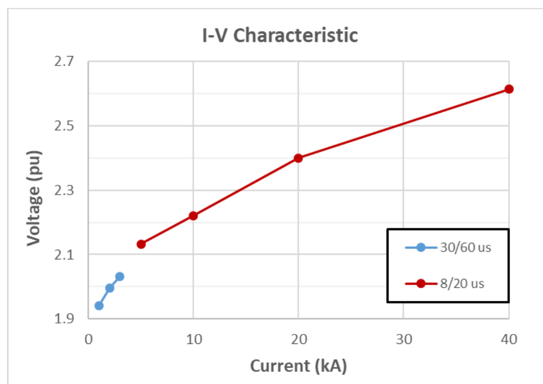
PEXLIM P-T

	kA	pu
30/60 us	1	1.951
	2	2.022
	3	2.072
8/20 us	5	2.163
	10	2.277
	20	2.494
	40	2.734



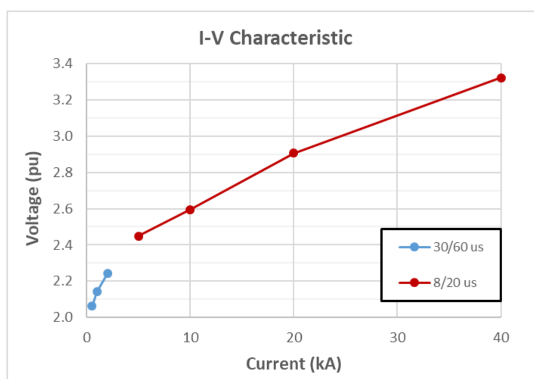
PEXLIM T-T

	kA	pu
30/60 us	1	1.940
	2	1.996
	3	2.033
8/20 us	5	2.133
	10	2.221
	20	2.400
	40	2.613



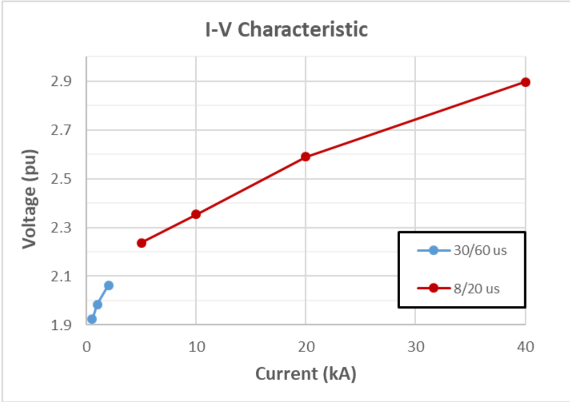
EXLIM R

	kA	pu
30/60 us	0.5	2.062
	1	2.142
	2	2.242
8/20 us	5	2.448
	10	2.595
	20	2.907
	40	3.323



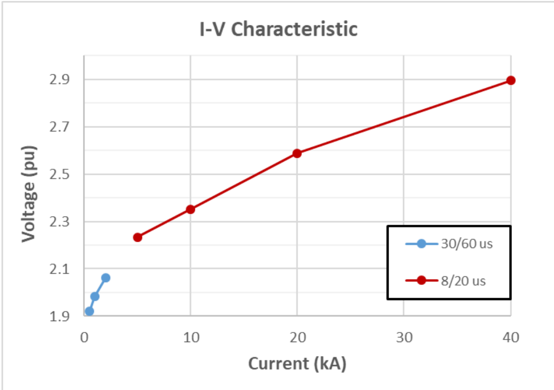
EXLIM Q-E

	kA	pu
30/60 us	0.5	1.924
	1	1.985
	2	2.063
8/20 us	5	2.237
	10	2.354
	20	2.591
	40	2.897



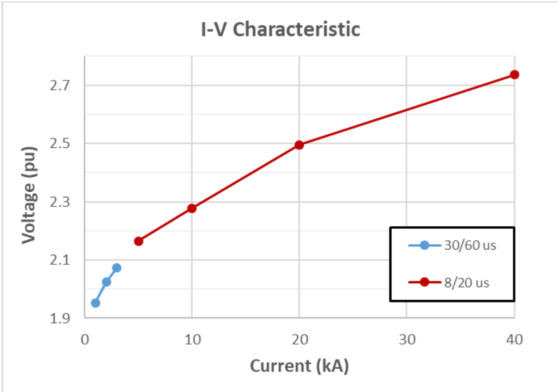
EXLIM Q-D

	kA	pu
30/60 us	0.5	1.922
	1	1.983
	2	2.061
8/20 us	5	2.235
	10	2.352
	20	2.588
	40	2.896



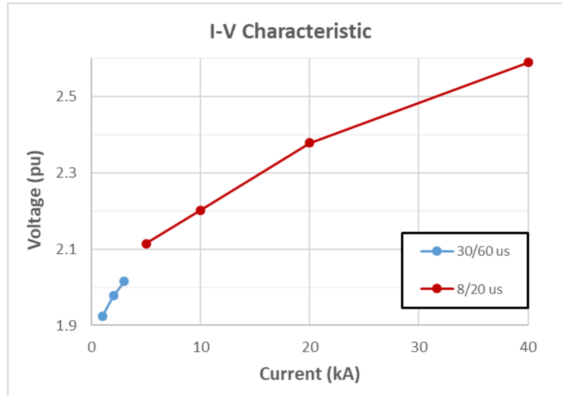
EXLIM P

	kA	pu
30/60 us	1	1.953
	2	2.023
	3	2.074
8/20 us	5	2.165
	10	2.278
	20	2.495
	40	2.736



EXLIM T

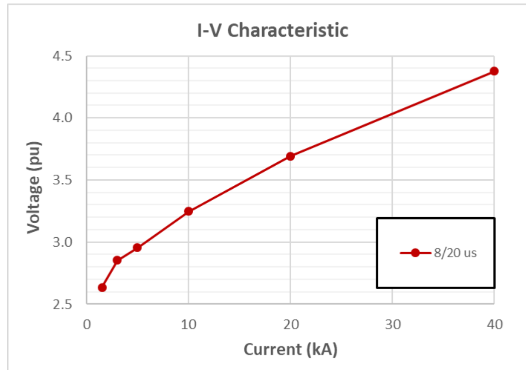
	kA	pu
30/60 us	1	1.923
	2	1.978
	3	2.015
8/20 us	5	2.114
	10	2.202
	20	2.379
	40	2.590



A.2 HUBBELL [7] - Per unit voltage based on rated voltage U_r

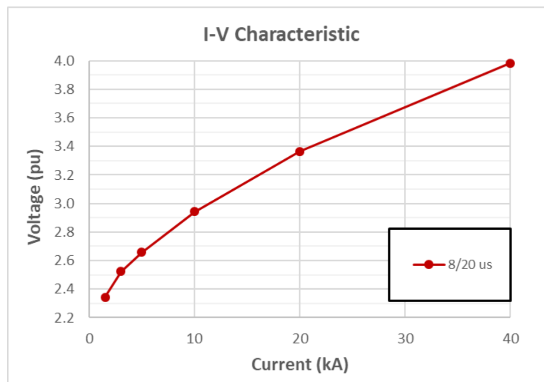
IEC 5kA Arrester PDV-65

	kA	pu
8/20 us	1.5	2.634
	3	2.852
	5	2.954
	10	3.249
	20	3.693
	40	4.377



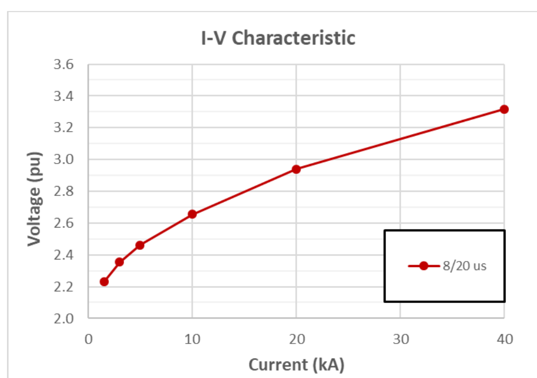
IEC 10kA CLASS1 ARRESTER PDV100

	kA	pu
8/20 us	1.5	2.343
	3	2.522
	5	2.657
	10	2.943
	20	3.364
	40	3.982



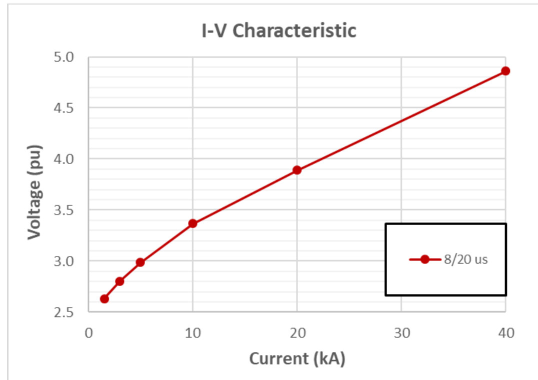
IEC 10kA CLASS2 ARRESTER PVI-LP

	kA	pu
8/20 us	1.5	2.229
	3	2.354
	5	2.461
	10	2.656
	20	2.941
	40	3.316



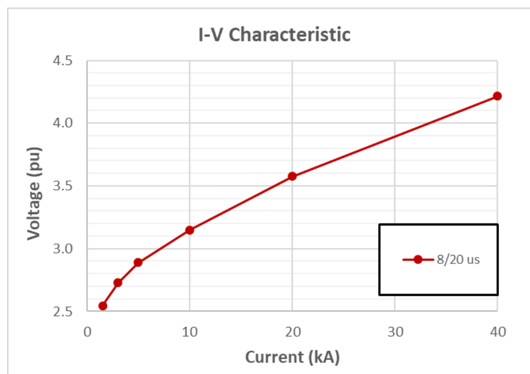
IEC 5kA DM PDV 65 Optima

	kA	pu
8/20 us	1.5	2.633
	3	2.805
	5	2.988
	10	3.366
	20	3.888
	40	4.860



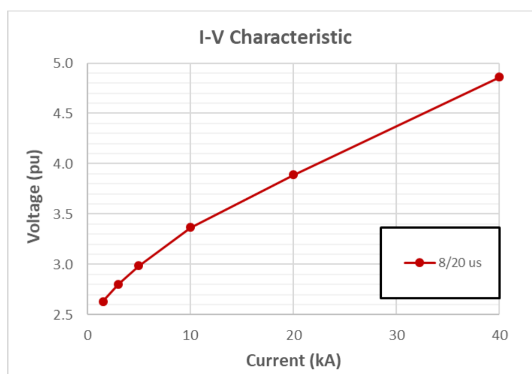
IEC 10kA DH PDV 100 Optima

	kA	pu
8/20 us	1.5	2.547
	3	2.727
	5	2.888
	10	3.148
	20	3.575
	40	4.216



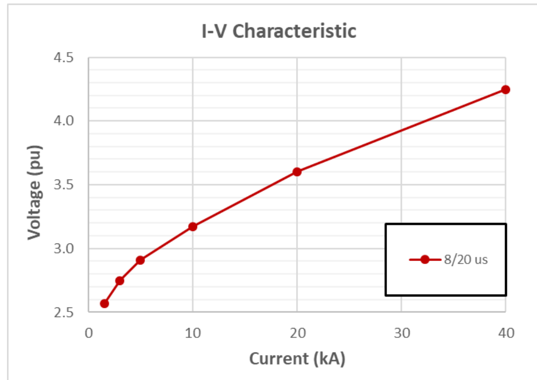
IEEE NORMAL-PDV65-OPTIMA

	kA	pu
8/20 us	1.5	2.633
	3	2.805
	5	2.988
	10	3.366
	20	3.888
	40	4.860



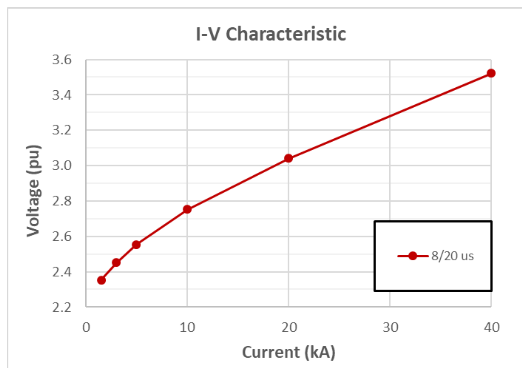
IEEE HD PDV100-OPTIMA

	kA	pu
8/20 us	1.5	2.566
	3	2.748
	5	2.910
	10	3.173
	20	3.603
	40	4.248



IEEE RISER Pole PVR-OPTIMA

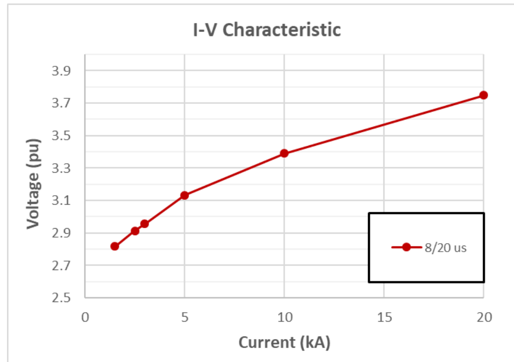
	kA	pu
8/20 us	1.5	2.352
	3	2.452
	5	2.553
	10	2.752
	20	3.041
	40	3.521



A.3 MacLean Power System [8] - Per unit voltage based on rated voltage U_r

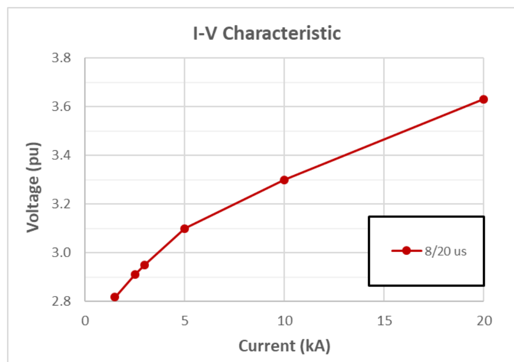
Zforce ZNP 5kA Normal Duty Poly

	kA	pu
8/20 us	1.5	2.816
	2.5	2.912
	3	2.955
	5	3.132
	10	3.389
	20	3.749



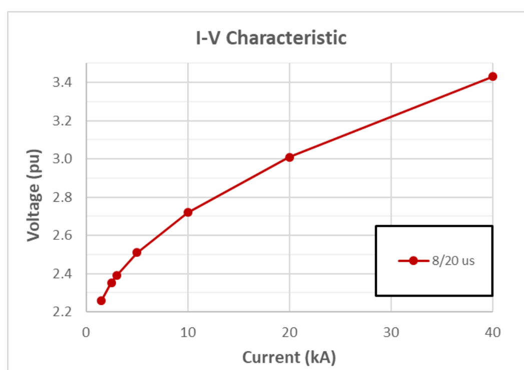
Zforce ZHP 10kA Heavy Duty Poly

	kA	pu
8/20 us	1.5	2.818
	2.5	2.909
	3	2.950
	5	3.100
	10	3.300
	20	3.631



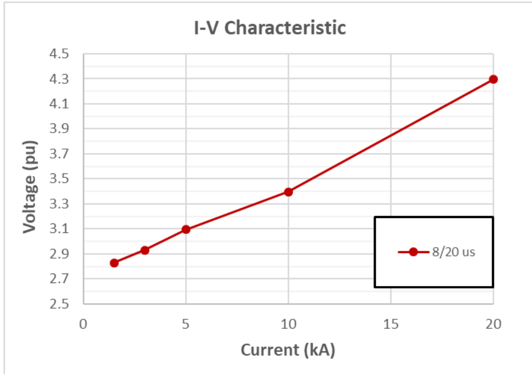
Zforce ZRP 10kA Riser Pole Poly

	kA	pu
8/20 us	1.5	2.261
	2.5	2.352
	3	2.391
	5	2.510
	10	2.721
	20	3.010
	40	3.431



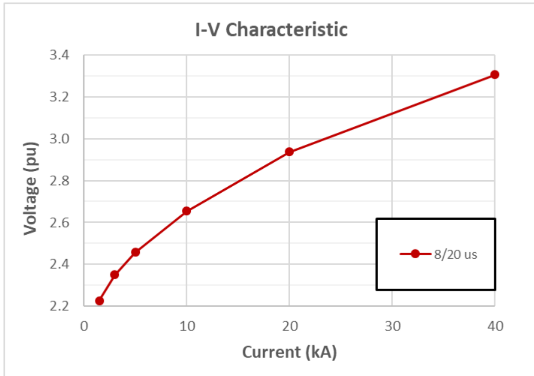
ZE Elbow Distribution Arrester

	kA	pu
8/20 us	1.5	2.829
	3	2.929
	5	3.096
	10	3.396
	20	4.294



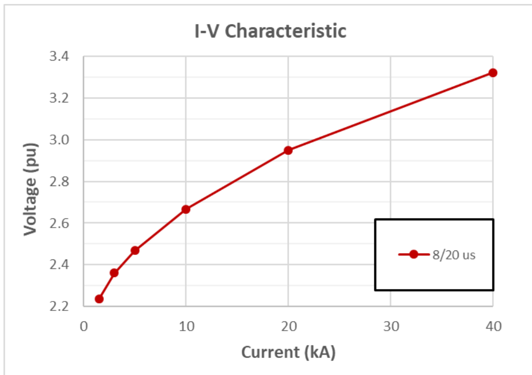
ZIP Intermediate Class Arrester

	kA	pu
8/20 us	1.5	2.225
	3	2.350
	5	2.458
	10	2.654
	20	2.936
	40	3.307



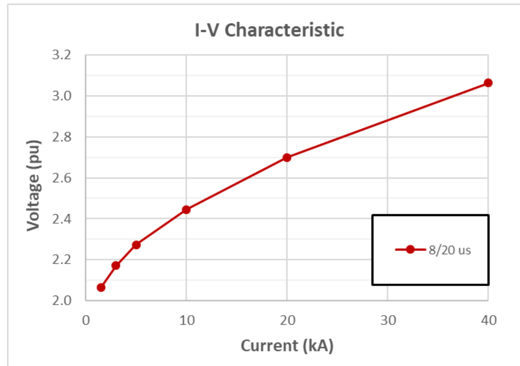
ZJP Intermediate Class Arrester

	kA	pu
8/20 us	1.5	2.235
	3	2.360
	5	2.469
	10	2.667
	20	2.949
	40	3.323



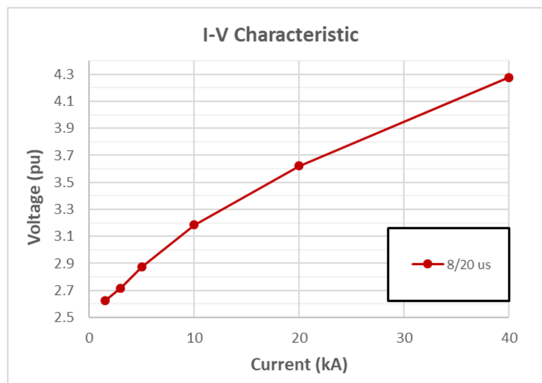
ZSP Station Class Arrester

	kA	pu
8/20 us	1.5	2.063
	3	2.172
	5	2.272
	10	2.446
	20	2.700
	40	3.064



ZQPT Transmission Line Arrester

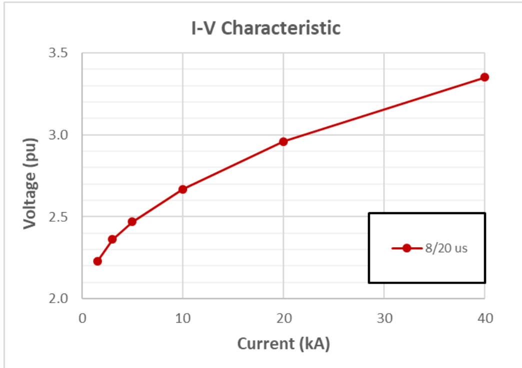
	kA	pu
8/20 us	1.5	2.623
	3	2.717
	5	2.874
	10	3.186
	20	3.623
	40	4.278



A.4 Ohio Brass [9] - Per unit voltage based on rated voltage U_r

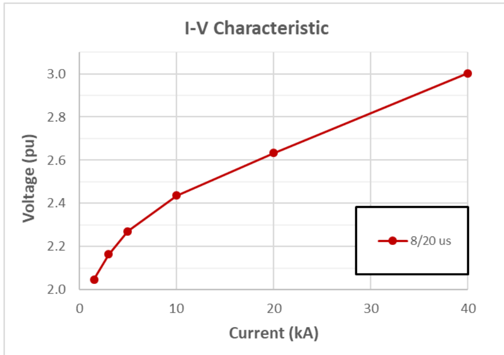
Type PVI-LP

	kA	pu
8/20 us	1.5	2.228
	3	2.362
	5	2.469
	10	2.669
	20	2.961
	40	3.352



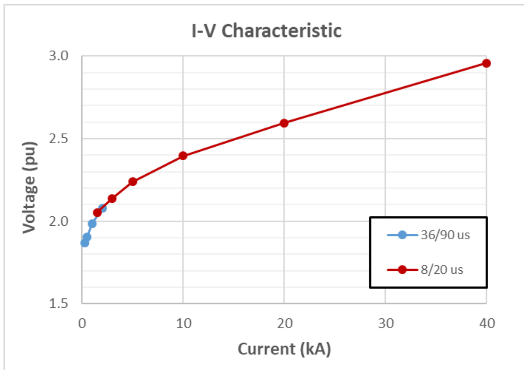
Type EVP

	kA	pu
8/20 us	1.5	2.047
	3	2.164
	5	2.270
	10	2.436
	20	2.633
	40	3.003



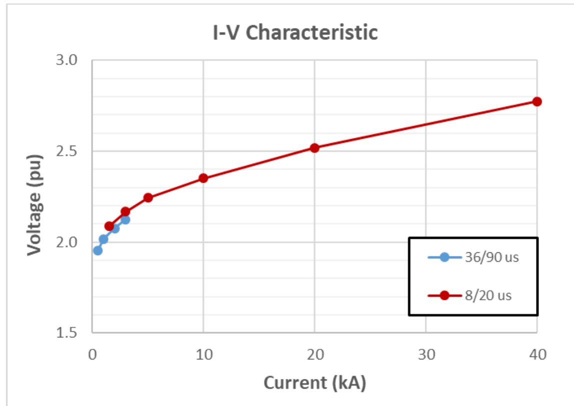
PH3

	kA	pu
36/90 us	0.25	1.866
	0.5	1.906
	1	1.984
	2	2.077
8/20 us	1.5	2.054
	3	2.138
	5	2.239
	10	2.396
	20	2.596
	40	2.959



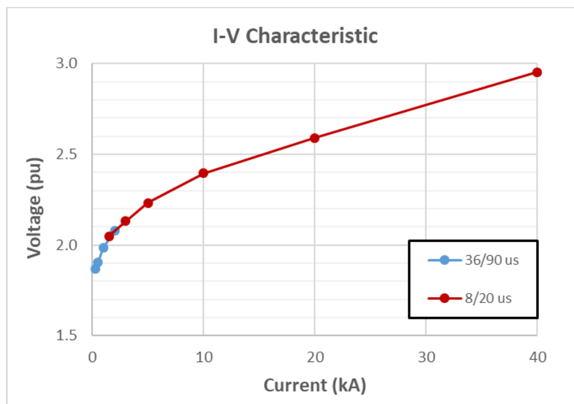
PH4

	kA	pu
36/90 us	0.5	1.955
	1	2.014
	2	2.075
	3	2.125
8/20 us	1.5	2.086
	3	2.167
	5	2.242
	10	2.352
	20	2.518
	40	2.774



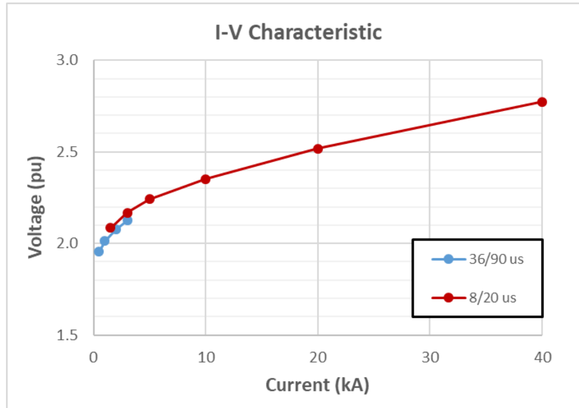
MH3

	kA	pu
36/90 us	0.25	1.868
	0.5	1.906
	1	1.984
	2	2.078
8/20 us	1.5	2.049
	3	2.132
	5	2.233
	10	2.395
	20	2.589
	40	2.954



MH4

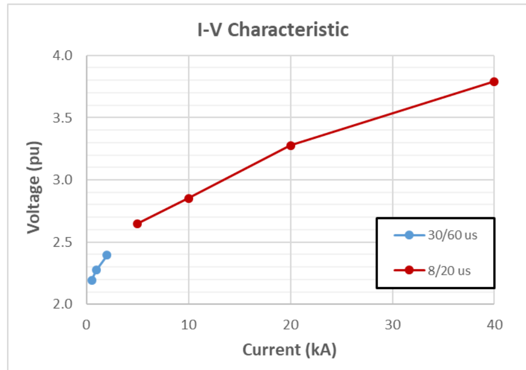
	kA	pu
36/90 us	0.5	1.955
	1	2.013
	2	2.075
	3	2.125
8/20 us	1.5	2.085
	3	2.167
	5	2.242
	10	2.351
	20	2.517
	40	2.774



A.5 Siemens [5] - Per unit voltage based on rated voltage U_r

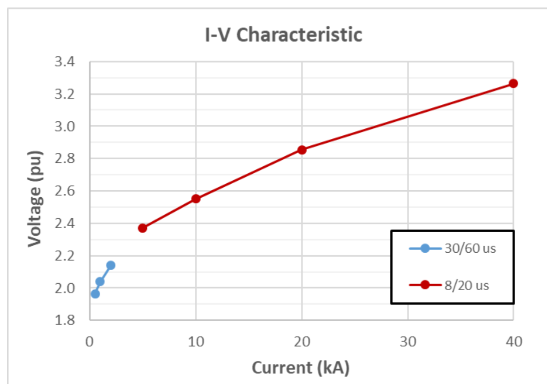
3EL5 Phase

	kA	pu
30/60 us	0.5	2.196
	1	2.280
	2	2.395
8/20 us	5	2.650
	10	2.851
	20	3.277
	40	3.790



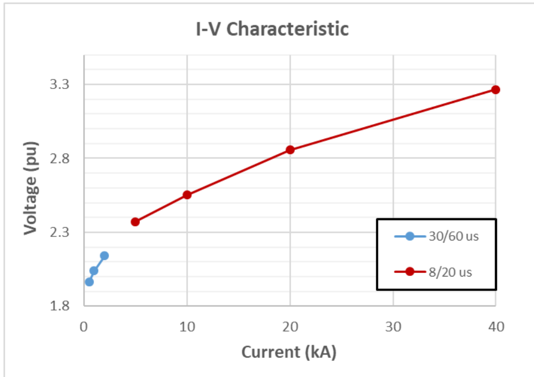
3EL1 Phase

	kA	pu
30/60 us	0.5	1.964
	1	2.040
	2	2.142
8/20 us	5	2.371
	10	2.552
	20	2.856
	40	3.265



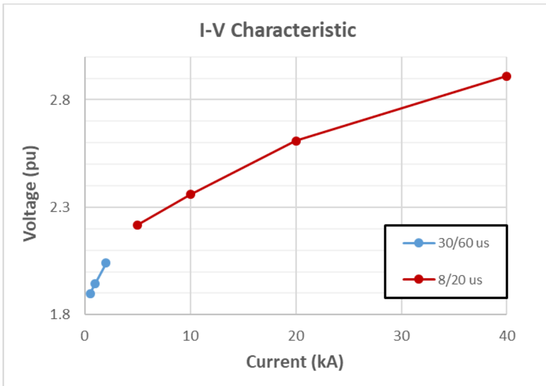
3EL1 N-G

	kA	pu
30/60 us	0.5	1.964
	1	2.040
	2	2.141
8/20 us	5	2.373
	10	2.552
	20	2.858
	40	3.265



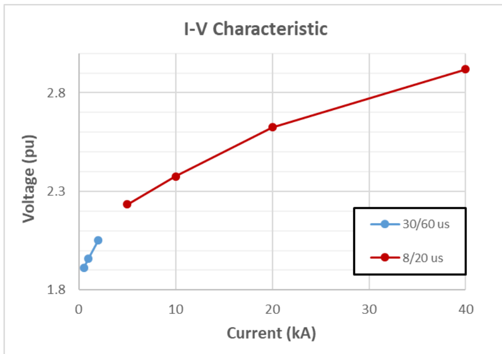
3EL2 Phase

	kA	pu
30/60 us	0.5	1.899
	1	1.945
	2	2.040
8/20 us	5	2.219
	10	2.360
	20	2.609
	40	2.911



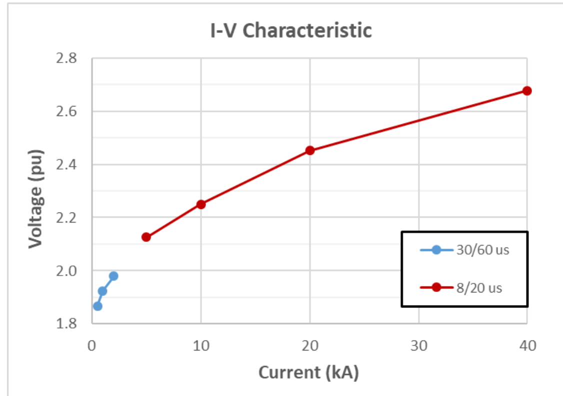
3EL2 N-G

	kA	pu
30/60 us	0.5	1.912
	1	1.959
	2	2.054
8/20 us	5	2.233
	10	2.375
	20	2.625
	40	2.920



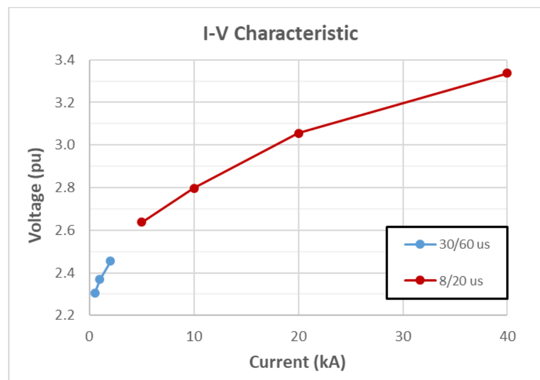
3EL3 Phase

	kA	pu
30/60 us	0.5	1.868
	1	1.924
	2	1.980
8/20 us	5	2.126
	10	2.251
	20	2.452
	40	2.677



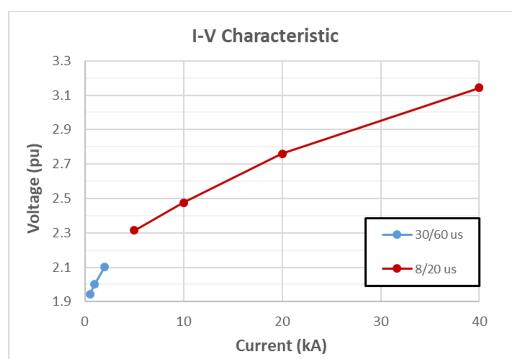
3EL3 N-G

	kA	pu
30/60 us	0.5	2.304
	1	2.369
	2	2.454
8/20 us	5	2.637
	10	2.797
	20	3.056
	40	3.337



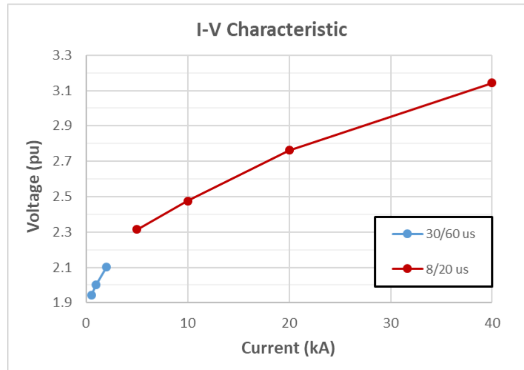
3EP5 Phase

	kA	pu
30/60 us	0.5	1.942
	1	2.004
	2	2.103
8/20 us	5	2.314
	10	2.476
	20	2.761
	40	3.144



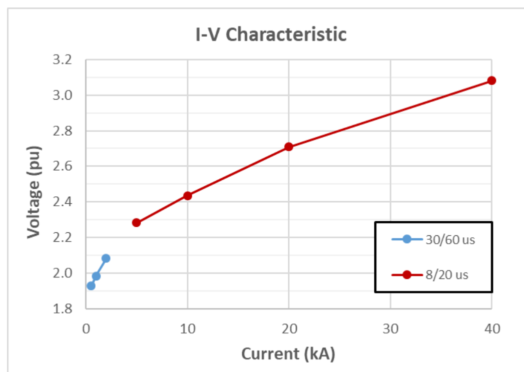
3EP5 N-G

	kA	pu
30/60 us	0.5	1.942
	1	2.003
	2	2.104
8/20 us	5	2.314
	10	2.476
	20	2.762
	40	3.144



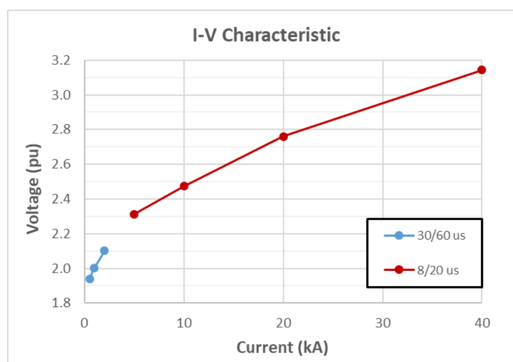
3EP4 Phase

	kA	pu
30/60 us	0.5	1.927
	1	1.983
	2	2.081
8/20 us	5	2.282
	10	2.435
	20	2.710
	40	3.081



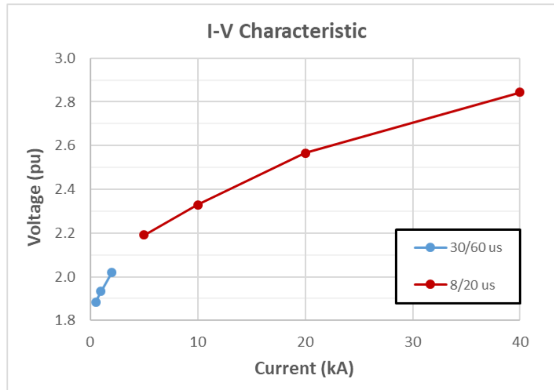
3EP4 N-G

	kA	pu
30/60 us	0.5	1.941
	1	2.002
	2	2.102
8/20 us	5	2.313
	10	2.475
	20	2.761
	40	3.143



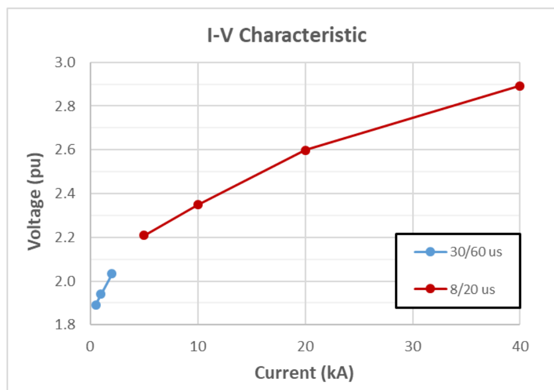
3EP6 Phase

	kA	pu
30/60 us	0.5	1.885
	1	1.934
	2	2.021
8/20 us	5	2.191
	10	2.328
	20	2.567
	40	2.844



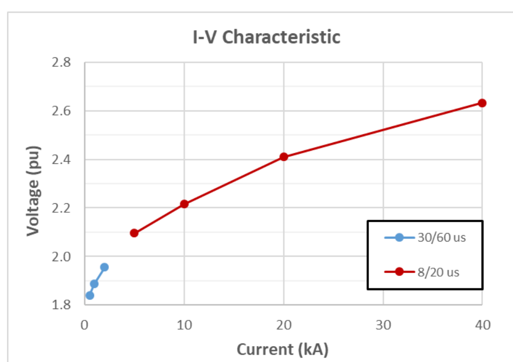
3EP6 N-G

	kA	pu
30/60 us	0.5	1.891
	1	1.940
	2	2.033
8/20 us	5	2.209
	10	2.349
	20	2.598
	40	2.893



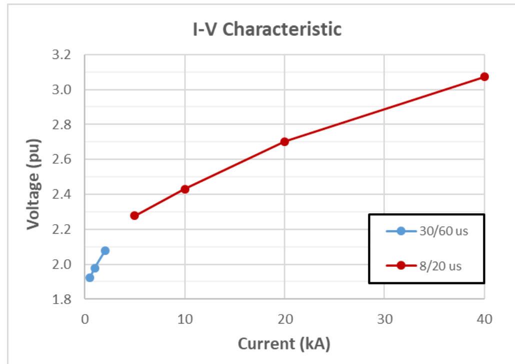
3EP3 Phase

	kA	pu
30/60 us	0.5	1.840
	1	1.889
	2	1.955
8/20 us	5	2.097
	10	2.216
	20	2.410
	40	2.632



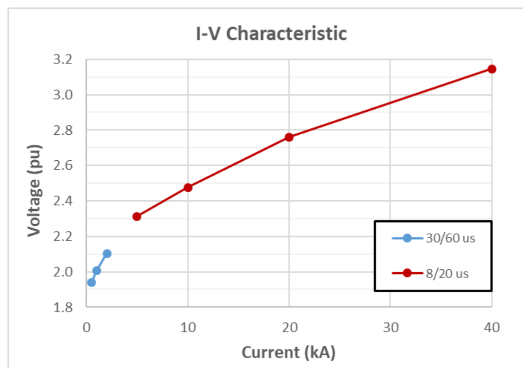
3EQ1 Phase

	kA	pu
30/60 us	0.5	1.923
	1	1.979
	2	2.076
8/20 us	5	2.277
	10	2.429
	20	2.703
	40	3.073



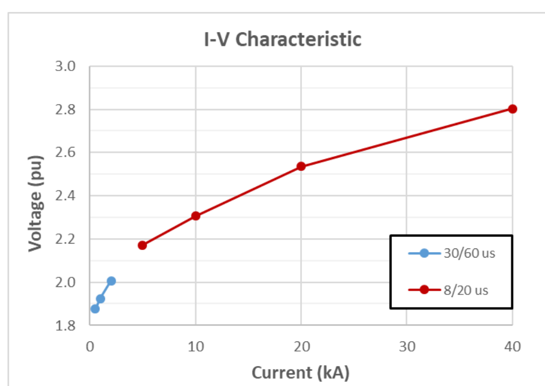
3EQ1 N-G

	kA	pu
30/60 us	0.5	1.941
	1	2.006
	2	2.104
8/20 us	5	2.313
	10	2.476
	20	2.761
	40	3.145



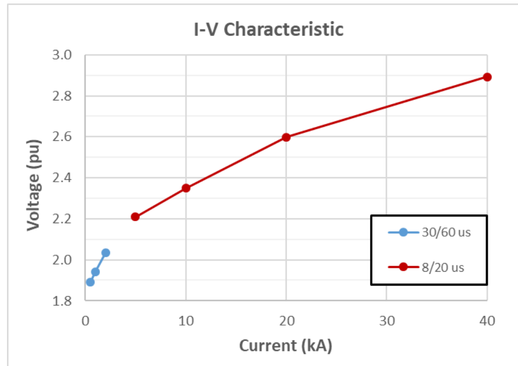
3EQ4 Phase

	kA	pu
30/60 us	0.5	1.876
	1	1.925
	2	2.007
8/20 us	5	2.172
	10	2.306
	20	2.535
	40	2.802



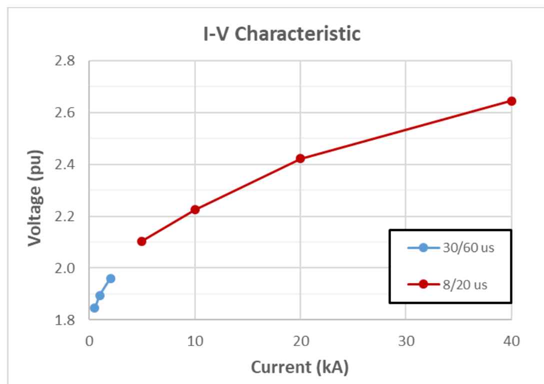
3EQ4 N-G

	kA	pu
30/60 us	0.5	1.891
	1	1.940
	2	2.033
8/20 us	5	2.209
	10	2.349
	20	2.598
	40	2.893



3EQ3 Phase

	kA	pu
30/60 us	0.5	1.845
	1	1.895
	2	1.961
8/20 us	5	2.104
	10	2.225
	20	2.422
	40	2.645



DOCUMENT TRACKING

Rev.	Description	Date
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