Understanding the Arrester Datasheet

Introduction

Part of selecting a good quality arrester is understanding the published data. A good quality supplier will fully disclose the relevant data in a format that is comprehensible and user-friendly. This article is a guide to understanding the arrester datasheet and what is behind it.

Discharge Voltage Table

In every arrester datasheet, you will find a most important table about the discharge voltage of the arrester in question. This table documents how well the arrester clamps lightning and switching surges, which is the fundamental purpose of arresters. This example is for a station class arrester but can be used to understand all discharge voltage tables of all arresters.

Arrester Ratings: MCOV and Rated Voltage

Metal-oxide varistor (MOV) type arresters have two voltage ratings: maximum continuous operating voltage (MCOV) and rated voltage. The arrester MCOV is shown in group 2 of **table 1** and given in kV (1 kV=1000 volts). This voltage is determined during the course of testing the arrester to IEEE standard C62.11 and is the most important voltage rating of the arrester. It is an AC rating and should in all circumstances be higher than the maximum line-to-ground voltage of the system to which it will be applied. In some circumstances, due to higher temporary overvoltage (TOV) conditions, the MCOV may need to be increased on the arrester, but it should never be decreased below the steady-state line-to-ground voltage of the system.

Group 1	Group 2	Group 3	Group 4						Group 5			
Arrester rating	Arrester MCOV	.5µs 10kA maximum IR (kV)	Maximum discharge voltage (kV crest) 8/20 µs current wave						Switching surge maximum IR (kV crest)			
(kV rms)	(kV rms)	(kV Crest)	1.5 kA	3 kA	5 kA	10 kA	20 kA	40 kA	125 A	250 A	500 A	1000 A
9	7.65	25.5	19.9	21	21.8	23.4	25.8	29.1	17.6	18.1	18.6	19.3
10	8.4	28	21.9	23	23.9	25.7	28.3	31.9	19.4	19.8	20.4	21.2
18	15.3	50.4	39.9	41.9	43.5	46.6	51.4	57.6	35.3	36.1	37.2	38.5
27	22	72.4	57.3	60.3	62.6	67	73.7	82.5	50.7	52	53.4	55.4
36	29	95.3	75.6	79.5	82.5	88.3	97.1	109	66.8	68.5	70.4	73
54	42	138	109	115	119	128	141	157	96.8	99.2	102	106
60	48	157	125	132	137	146	161	179	111	113	117	121
84	68	223	177	186	193	207	228	254	157	161	165	171
120	98	310	249	260	269	286	314	350	222	227	233	242
144	115	365	292	305	316	336	368	412	261	267	274	284
180	144	457	366	382	395	421	461	515	326	334	343	355
192	152	482	386	403	417	444	487	544	344	352	362	375
240	190	603	483	504	522	555	608	680	431	441	452	468

Table 1 Typical discharge voltage

The rated voltage (group 1) is a rating from the days of the gapped silicon-carbide arrester and has become a number we are familiar with. For that reason, it carried over to the MOV arrester at its initial introduction to the market. Although the rated voltage of the arrester is not relevant to the actual operating voltage of the modern day MOV arrester, it continues to be a common designation used to specify an arrester.

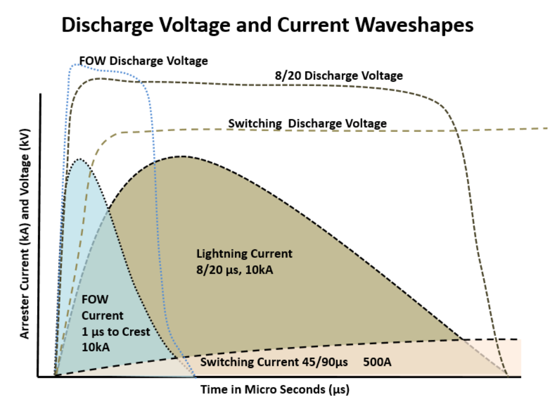

Figure 1 Typical wave shapes for discharge current and discharge voltage

8/20µs Maximum Discharge Voltage

Group 4 data in **table 1** shows the discharge voltage across an arrester. This data shows the discharge voltages for seven different impulse currents amplitudes all of the same 8/20µs wave shape. The wave shapes are shown in **figure 1**. Since lightning comes in various amplitudes, from a few kA (1 kA=1000 amps) to occasionally >100kA, this table shows what the clamping voltage would be for 95% of the impulse current levels that occur in nature. The data found in the 10kA column is most often used to compare one arrester to another. It is often referred to as the “lightning protective level” (it is also referred to as the voltage at the arrester classifying current). If two arresters are being compared, the 10kA, 8/20 discharge voltage in this column can be used to compare similar ratings, and the lower level is considered better protection.

.5µs 10kA Maximum IR

The data found in group 3 is another form of discharge voltage, also known as the front-of-wave (FOW) protective level. In this case, the wave shape has a faster rise time than the 8/20µs used for maximum discharge voltage and represents the second subsequent surges in a multi-stroke lightning flash. Per IEEE C62.11-2012, the current wave shape for this protective level is 1 µs to crest, with no specification on the tail. Note that, in **table 1**, the term IR is used twice: this is a term that means voltage, as in E = I x R, where E stands for *voltage*, I for *amps*, and R for *ohms*. This term is used by some suppliers but not all.

Switching Surge Maximum IR

The data found in group 5 of **table 1** (switching surge protective level, 45/90µs discharge voltage) is the third type of discharge voltage that is measured and published for arresters. The peak current levels can vary from 125 amps to 2000 amps, depending on the class of the arrester. This discharge voltage represents the response of an arrester to a slow-rising surge generated within the power systems during breaker or switch operations.

Arrester Rating Selection

Probably the most widely used table in arrester datasheets is the arrester rating selection table. The example in **table 2** is for both distribution and transmission systems. The two most important factors used to select an arrester rating are the system voltage and the neutral grounding configuration of the source transformer. These tables assume that the maximum duration and amplitude of the worst-case overvoltage during a line-to-ground fault are unknown. When two ratings are offered, the lower rating would be the minimum possible, and the higher rating is for the worst-case scenario when nothing is known about potential overvoltage events.

System line-to-line voltages (kV rms)		Recommended arrester ratings (MCOV) kV rms		
Nominal	Assumed maximum	Four-wire wye multi-grounded neutral	Three-wire or four-wire wye solidly grounded neutral @ source	Delta and ungrounded wye
12.0	12.6	9 (7.65)	9 (7.65) or 10 (8.40)	12 (10.2) or 15 (12.7)
12.47	13.1	9 (7.65)	9 (7.65) or 10 (8.40)	15 (12.7) or 18 (15.3)
13.2	13.9	10 (8.40)	10 (8.40) or 12 (10.2)	15 (12.7)
13.8	14.5	10 (8.40)	10 (8.40) or 12 (10.2)	15 (12.7) or 18 (15.3)
20.78	21.8	15 (12.7)	15 (12.7) or 21 (17.0)	24 (19.5) or 27 (22.0)
22.86	24.0	18 (15.3)	18 (15.3) or 21 (17.0)	24 (19.5) or 27 (22.0)
24.9	26.2	18 (15.3)	18 (15.3) or 21 (17.0)	24 (19.5) or 27 (22.0)
34.5	36.2	27 (22.0)	27 (22.0) or 30 (24.4)	36 (29.0) or 39 (31.5)
46.0	48.3	N/A	36 (29.0) or 39 (31.5)	48 (39.0)
69.0	72.5	N/A	54 (42.0) or 60 (48.0)	72 (57.0)
115	121	N/A	90 (70.0) or 96 (76.0)	108 (84.0)
138	145	N/A	108 (84.0) or 120 (98.0)	132 (106) or 144 (115)
161	169	N/A	120 (98.0) or 144 (115)	144 (115) or 168 (131)
230	242	N/A	172 (140) or 192 (152)	228 (180) or 240 (190)

Table 2 Arrester rating selection

System Line-to-Line Voltages
Since most three-phase systems are referred to by the phase-to-phase voltage, that is how the table is set up. In many cases, the arrester rating is less than the line-to-line voltage because arresters are applied line to ground. The line-to-ground voltage is line-line voltage divided by 1.73, for those wishing to calculate it.

The nominal and maximum system voltages are both shown in the table; the arrester rating is calculated based on the maximum expected system voltage.

Recommended Arrester Ratings
This rating is divided into several columns to cover the various system configurations. The neutral configuration of the transformer providing the power to the circuit is the only neutral configuration that needs to be considered. Downstream transformers do not affect the potential overvoltages unless it is part of the fault source.

Four-Wire Wye Multi-Grounded Neutral
This column is primarily a distribution-type circuit where the neutral conductor is grounded in many places along the circuit as well as at the feed transformer. In this case, the maximum overvoltage on this type of system is 1.25 per unit of line-ground voltage (pu) and the duration of an overvoltage is be very short (a few cycles).

Three- or Four-Wire Wye Solidly Grounded Neutral at Source
This circuit can be a distribution- or transmission-type circuit. The selected arrester is the same for both types of circuits. In this

case, the maximum overvoltage magnitude is about 1.4pu and could last for a very long duration.

Delta and Ungrounded Wye

This can be either a distribution or transmission circuit. In this case, the worst-case overvoltage from a faulted circuit is 1.73pu line-to-ground voltage. This means the line-to-ground voltage can increase to equal the line-to-line voltage in some instances.

Short Circuit, Fault Current Tables or Pressure Relief Ratings

Per IEEE C62.11, all arresters shall have a fault current rating. This rating indicates how much 60Hz short-circuit current from the power system can flow through the arrester without violent rupture and large fragment expulsion. Note that this is not a lightning or switching current but instead a power frequency, system-sourced current.

Arrester type	Short-circuit test current (amps)	Short-circuit test duration (seconds)
Model A	15000	0.2
	7500	0.2
	500	1
Model B	2000	0.2
	1000	0.2
	500	1

Table 3 Fault current

The short-circuit test is conducted by putting a failed arrester in series with a fault current source for the given duration in seconds, or cycles, as shown in column three of **table 3**. The listed current level must flow through or around the arrester for the given duration without expulsion of internal parts in order to pass the tests. Distribution arresters are tested at current levels up to 20,000 amps for 12 cycles, and station class arresters are tested as high as 63,000 amps and up. A lower current of 500 amps is also tested and is shown in **table 3**.

To ensure minimum collateral damage to other equipment in the event that an arrester is overloaded, the available system short-circuit current should not exceed the level as shown in column two of **table 3**.

Energy Handling Specification Tables

Every good arrester datasheet will tabulate the energy handling capability of an arrester. The information in **table 4** is according to IEEE C62.11-2005. In the 2012 edition, different tests are mandated and the values are different. Until 2012, this rating was not standardized, and manufacturers published slightly different levels. See **table 5** for more information on how to use the new data.

Impulse Classifying Current

The impulse classification current, shown in **table 3**, is a value that some manufacturers choose to add to their datasheets to provide extra information. This is the impulse current level used during the IEEE duty cycle tests in IEEE C62.11. For distribution arresters, it can be 5 or 10kA, and for station arresters it can be 5, 10, 15, or 20kA. Generally, the higher the current, the higher the arrester durability.

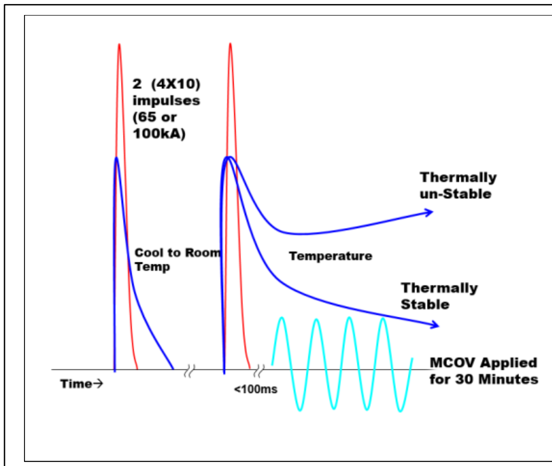

Figure 2 High-current, short-duration energy withstand test

High-Current Withstand

The high-current withstand capability is almost always found in an arrester datasheet, as shown in **figure 2**. This current refers to the impulse current level used during the IEEE high current short duration test. For normal duty arresters it is 65kA, for heavy duty and riser pole arresters it is 100kA, and for station class arresters the minimum level is 65kA. It may seem odd that a station class arrester can be certified lower than a distribution arrester, but this is because station arresters are designed for use in substations that are almost always shielded by overhead wires and direct strokes do not reach the station class arresters. This rating is actually the only means of evaluating the energy handling capability of a distribution arrester since they are not tested using other energy rating tests.

Arrester energy handling capability per IEEE C62.11-2005		
Arrester voltage rating	Single impulse rating	Double impulse rating
	kJ/kV-MCOV	kJ/kV-MCOV
Station arrester model A	3.4	5.5
Station arrester model B	5.6	8.8
Station arrester model C	8.9	14.5
Distribution intermediate and station arresters		
High current withstand	100kA	
Impulse classifying current	10kA	

Table 4 Energy handling capability

Rated Discharge Energy in kJ/kV MCOV

This rating comes from IEEE C62.11-2005 and has been superseded by the switching surge tests in the 2012 edition. This rating, as shown in **table 4**, indicates the maximum-level switching surge this arrester can handle without out failing. Historically, this test was a one- or two-impulse test, depending on the supplier. The 2012 standard rectified this discrepancy. This rating applies only to station class arresters and not distribution arresters. The values are derived from running the transmission-line discharge tests.

Energy Ratings Tables

IEEE C62.11-2012 introduced two new energy rating tests for arresters. The switching surge energy rating is similar to the previous rated discharge energy. The benefit of this change for arrester users is that the standard now specifies how to calculate the actual rating, making this value consistent from one manufacturer to the next. **Table 5** provides an example of how future ratings will be displayed in the datasheets.

Station arrester energy handling capability per IEEE C62.11-2012			
Arrester voltage rating	Switching surge energy class	Switching surge energy level	Single-impulse energy rating
	Energy class	kJ/kV-MCOV	C (coulombs)
Model A	A	3.0	1.0
Model B	B	4.5	2.0
Model C	C	6.0	3.0
Distribution intermediate and station arresters			
High-current withstand	100kA		
Impulse classifying current	10kA		

Table 5 Arrester energy handling, based on IEEE C62.11-2012

Suggested Switching Surge Energy Class and Level

The switching surge energy class and energy ratings are determined during tests according to IEEE C62.11. This value indicates the level of energy an arrester can dissipate during a switching surge. Equations to calculate this value are available in the same standard. The IEEE application guide C62.22 suggests energy ratings that an arrester should have for various system voltages. This table is summarized in **table 6** of this document.

Typical switching surge energy classifications and suggested system application		
Maximum system rms L-L voltage kV	Minimum rms MCOV rating kV	Minimum switching surge energy handling class and kJ rating
Station arresters		
72	42	A (3.0)
121	70	A (3.0)
242	140	B (4.5)
362	209	D (7.5)*
550	318	B (4.5)*
800	462	D (7.5)*
Intermediate arresters		
4.37–145	2.55–84	A (3.0)
*Note: The levels are based on a switching surge protective level of 1.71pu		

Table 6 Suggested arrester energy ratings per IEEE application guide C62.22-2013

Temporary Overvoltage

All good arrester datasheets will have a TOV curve similar to the one shown in **figure 3**. This curve is used to determine the minimum MCOV rating that can be used for systems that can experience a TOV. Note that arresters are designed to withstand AC overvoltages, not mitigate them. TOVs can be caused by single line-to-ground faults, loss of neutral, or other system phenomena. See IEEE C62.22 for more details on how to use this curve. In simplest terms, if a line representing the amplitude and duration of a TOV, as shown in **table 6**, crosses the arrester TOV curve, then a higher rated arrester should be used.

For example, a TOV of 1.4 times MCOV for a duration of 100 seconds would exceed the capability of this arrester, and a higher MCOV would need to be selected. If a TOV of 1.3 times MCOV for a duration of 10 seconds (green line in **figure 3**) would not exceed the arrester capability, and the MCOV selected can be used.

The "no prior duty" curve in **figure 3** should be used if it is certain that the arrester would not absorb energy prior to the TOV. This is usually

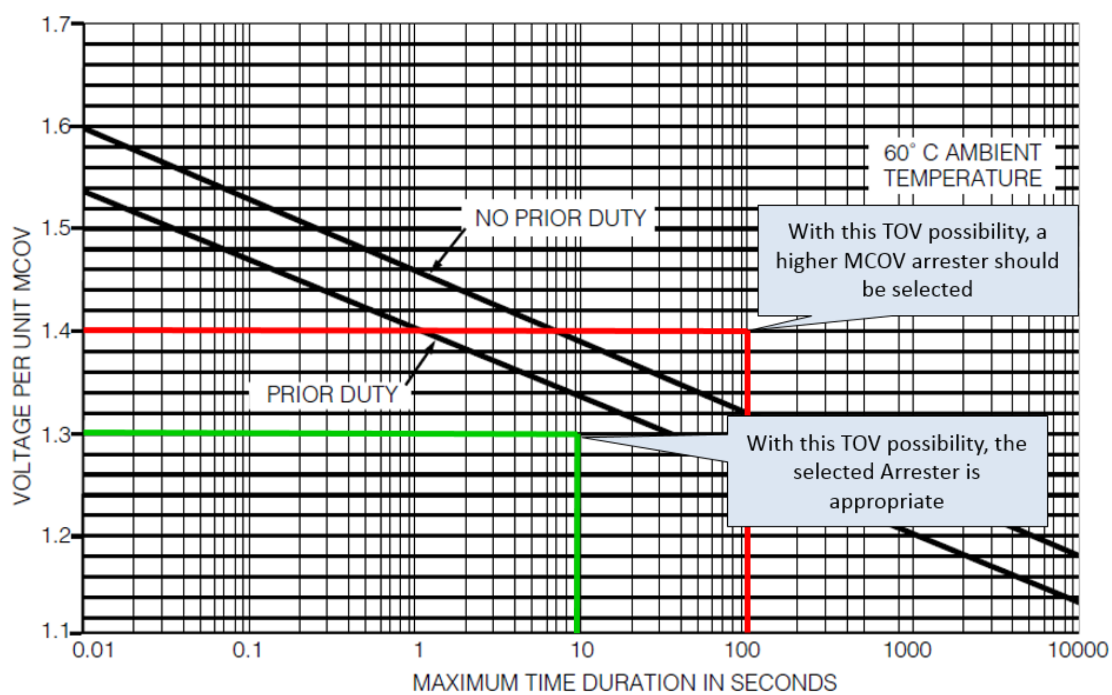

Figure 3 Typical TOV curve

the case for single line-to-ground faults. If it is uncertain whether the arrester in question could absorb energy prior to the TOV, then the prior duty curve must be used, which is the more conservative method. Per-unit MCOV on the vertical axis is a convenient way to show the TOV for all arrester ratings. To get the actual overvoltage level that can be withstood by the model you have selected, multiply the PU level on the curve for the given duration by the MCOV of the selected arrester. As shown in **figure 3**, if the MCOV of your selected arrester is 98kV, then the TOV withstand capability for 10 seconds of the arrester 98kV arrester is 98 x 1.4 = 137kV.

TOV is sometimes specified in a table with specific voltages that can be withstood for 1 or 10 seconds. This is the same data that is supplied with the TOV curve, but instead of being per unit MCOV, the TOV withstand voltage is in actual kV rms.

Insulation Withstand Tables

The insulation withstand table presented in arrester datasheets, as shown in **table 7**, is easily misunderstood. The misunderstanding occurs when these values are compared to system basic impulse insulation levels (BIL). Arrester housing withstand values are not BIL; they are voltage withstand of the housing when the internal components of the arrester are removed (more below). The creepage distance is often but not always reported in the same table.

Creepage Distance

The creepage distance for arresters, shown in table 7, should be similar to that of all insulators on the system to which it will be applied. Often for coastal or high-pollution areas, extra creep units are used. The definition of creepage distance is shown in **figure 4.**

Insulation withstand voltages						
Arrester ratings	Arrester MCOV	1.2/50 impulse	Switching surge impulse	60 Hz dry 60 seconds	60 Hz wet 10 seconds	Creepage distances
kV RMS	kV RMS	kV peak	kV peak	kV RMS	kV RMS	Inches
9	7.65	149	153	102	68	20.3
10	8.4	149	153	102	68	20.3
18	15.3	193	189	126	93	28.4
27	22	236	216	144	117	36.5
54	42	344	273	182	178	56.7
60	48	366	288	192	190	60.8
84	68	602	495	330	308	97.2
90	70	623	507	338	320	101.3
96	76	644	519	346	332	105.3
108	84	710	561	374	368	117.5
120	98	732	576	384	380	128.1
144	115	890	776	517	467	166.5
180	144	1029	960	586	533	192.2
192	152	1212	1166	690	633	222
198	160	1256	1208	708	657	230.6

Table 7 Creepage distance and housing insulation withstand voltages

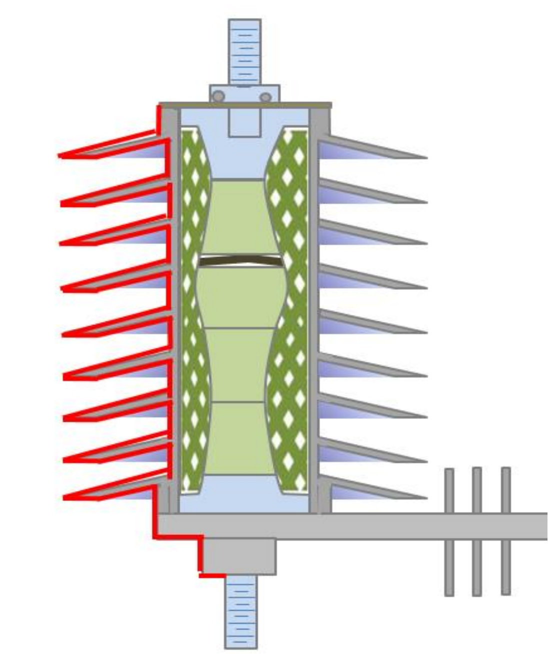

Figure 4 Demonstration of creepage

1.2/50µs Impulse

This is the lightning impulse withstand voltage of the arrester housing if the internal varistors are removed from the arrester, as shown in column three of **table 7**. Since the arrester will always be self-protected with the internal components, this characteristic is essentially irrelevant. This 1.2/50µs level does not and should not match the BIL of the insulators on the system. The level on the arrester datasheet will always be lower than the BIL of the system. The minimum value is mandated in IEEE C62.11-2012.

Switching Surge Impulse

This characteristic of the arrester housing is also measured without the internal components of the arrester installed, shown in column four of **table 7**. With the internal components of the arrester installed, this level will never be reached because of the self-protecting nature of an arrester. This level will very likely not be as high as the switching impulse withstand characteristics of the system. The minimum value is mandated in IEEE C62.11-2012.

60Hz Wet and Dry

These two withstand characteristics have mandated minimum values per IEEE C62.11, as shown in columns four and five of **table 7**. The minimum value is based on the system voltage, maximum application altitude, and maximum TOV of the arrester. These values do not need to be the same as the insulators on the system.

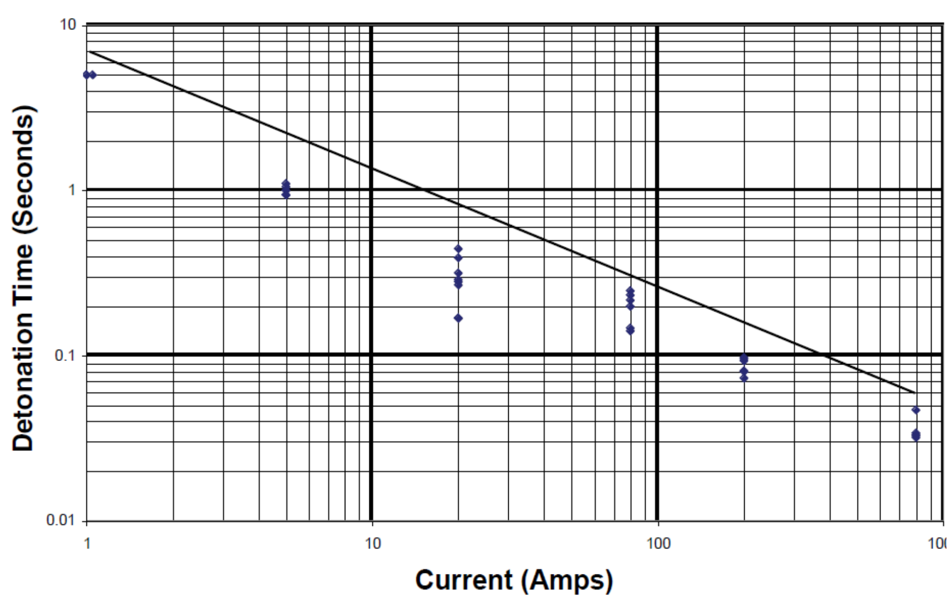

Figure 5 Typical disconnector ignition curve

Disconnector Ignition Curve

If a distribution arrester is equipped with a ground lead disconnector, the datasheet will likely contain an ignition curve, as shown in **figure 5**. Arrester users that are interested in how fast a disconnector operates can use this curve to show the point in time when the disconnector begins to operate. It is important to note that this is not a clearing curve but an ignition curve. This is because disconnectors are not clearing devices

Mechanical withstand capability per IEEE C62.11-2005		
Cantilever strength (in lbs)	Ultimate	MDCL static
Model A	15,000	6,000
Model B	20,000	8,000
Model C	35,000	14,000
Model D	100,000	40,000

Table 8 Typical cantilever strength

Polymer-Housed Arresters

The maximum design cantilever strength (MDCL static), as tabulated in **table 8**, is tested and verified during the IEEE certification test process. This is the steady-state working strength of an arrester should it be used to support buss or cable. It is generally understood that for mechanical systems, such as the polymer housed arrester, the breaking force or ultimate strength (column two of **table 8**) is 60% above the working strength. **Figure 6** shows the basic setup of the test.

Porcelain-Housed Arresters

The cantilever strength is tested by applying a force until the unit breaks. This is the ultimate mechanical strength (UMS) of a porcelain housed arrester. It is accepted that the working strength is 40% of this level.

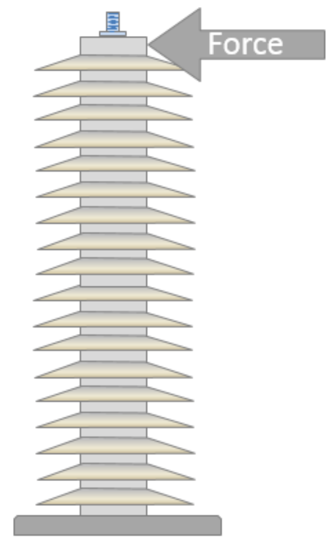

Figure 6 Typical cantilever force diagram

Conclusions

Arrester datasheets will vary from manufacturer to manufacturer, but the basic data is all the same. The definitions above cover all complex characteristics found on these datasheets. If the datasheet does not cover all the topics discussed in this document, a quality supplier will be able to provide this information.