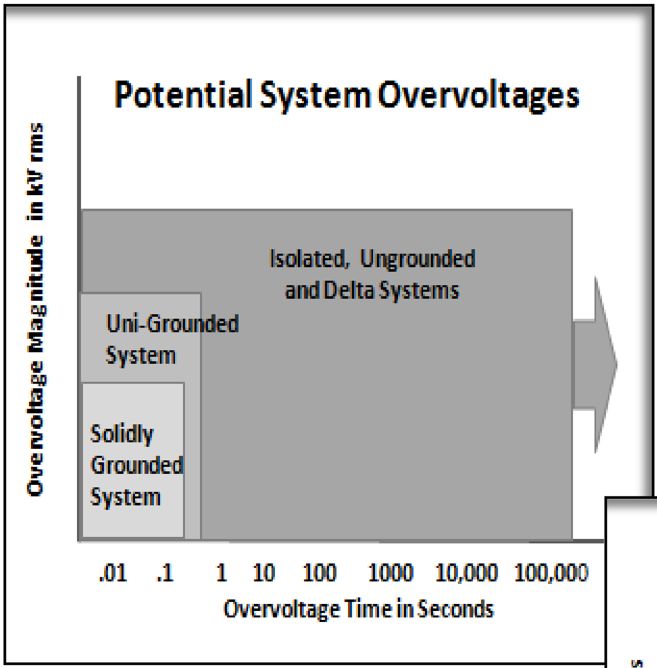
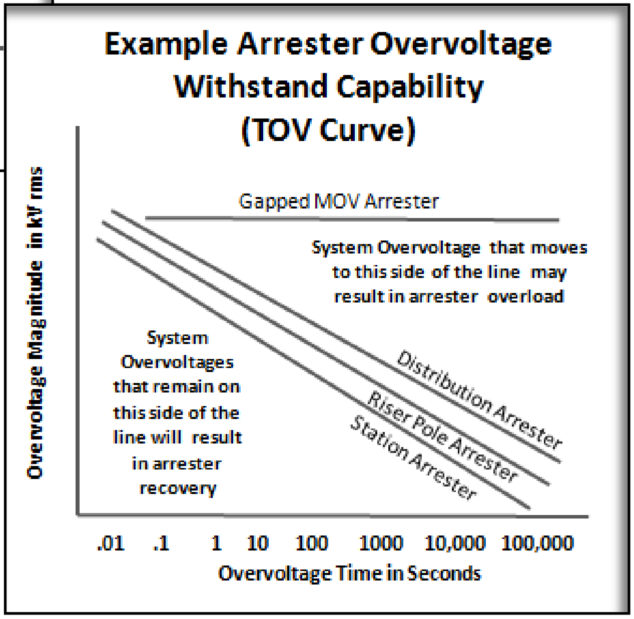
ArresterFacts 016

Selecting Arrester MCOV and U_c

Part 1 of Arrester Selection Guide





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Introduction

There are several necessary steps that need to be taken when selecting an arrester for an application. An early step in this selection is the determination of the voltage rating of the arrester. The only voltage rating of an arrester that is important is the MCOV (Maximum Continuous Operating Voltage **IEEE**) and Uc (Continuous Operating Voltage **IEC**). This MCOV - Uc rating however is not always obvious without a fairly good understanding of the system to which it is to be applied. The objective of this ArresterFacts is to make this decision clearer and understandable.

Definitions

MCOV rating (IEEE) - The maximum designated root-mean square (rms) value of power frequency voltage that may be applied continuously between the terminals of an arrester.

Duty-cycle voltage rating (IEEE) - The designated maximum permissible voltage between its terminals at which an arrester is designed to perform its duty cycle test.

TOV Curve – A graph that shows the power frequency withstand voltage vs. time for arrester from .01 sec to 100,000 sec (**IEEE**, **IEC**)

Ground Fault – An event where current flows from the power system to ground when a system phase conductor is connected to earth either through a direct contact or through an arc. (**IEEE**, **IEC**)

Uc - Continuous operating voltage (IEC)
The designated permissible r.m.s. value of power-frequency voltage that may be applied continuously between the arrester terminals indefinitely.

Ur - Rated voltage of an arrester (IEC)
Maximum permissible r.m.s. value of power-frequency voltage between its terminals at which it is designed to operate correctly under temporary overvoltage conditions as established in the operating duty tests.

NOTE 1
The rated voltage is used as a reference parameter for the specification of operating characteristics.

NOTE 2
The rated voltage as defined in this standard is the 10 s power-frequency voltage used in the operating duty test after high-current or long-duration impulses. Tests used to establish the voltage rating in IEC 60099-1, as well as some national standards, involve the application of repetitive impulses at nominal current with power frequency voltage applied. Attention is drawn to the fact that these two methods used to established rating do not necessarily produce equivalent values.

Determining Line-Gnd Voltage and Minimum MCOV or Uc

When arresters are applied to protect systems from lightning or switching surges, they are installed between the phase and earth. For this application, the MCOV of the installed arrester must be equal or higher to the continuous voltage between the phase and earth. On three phase systems, the line to ground voltage is equal to the phase to phase voltage divided by 1.73. For example, on a 760kV transmission system, the nominal system phase to phase voltage is 760kV therefore the line to earth voltage would be 440kV. Since all systems have some regulation error, this too must be taken into consideration. If the regulation is 10%, then for example, on the above system, the line to ground voltage could be 440x 1.10 = 485kV. The MCOV or Uc or an arrester for this system at a minimum should be 485kV.

Typical IEEE System Voltages			
Nom Line to Line Voltage	Max Line to Line Voltage	Max Line to Grnd Voltage	Min MCOV
kV rms	kV rms	kV rms	kV rms
2.40	2.52	1.46	1.46
4.16	4.37	2.52	2.52
4.80	5.04	2.91	2.91
6.90	7.25	4.19	4.19
8.32	8.74	5.05	5.05
12.0	12.6	7.28	7.28
12.5	13.1	7.57	7.57
13.2	13.9	8.01	8.01
13.8	14.5	8.38	8.38
20.8	21.8	12.6	12.6
22.9	24.0	13.9	13.9
23.0	24.2	14.0	14.0
24.9	26.2	15.1	15.1
27.6	29.0	16.8	16.8
34.5	36.2	20.9	20.9
46.0	48.3	27.9	27.9
69.0	72.5	41.9	41.9
115.0	121	69.8	69.8
138.0	145	83.8	83.8
161.0	169	98	97.7
230.0	242	140	140
345.0	362	209	209
500.0	525	303	303
765.0	800	462	462

Typical IEC System Voltages			
Nominal Line to Line Voltage	Typical Max Line to Line Voltage	Max Line to Grnd Voltage	Minimum Uc
kV rms	kV rms	kV rms	kV rms
3.3	3.7	2.1	2.1
6.6	7.3	4.2	4.2
10.0	11.5	6.6	6.6
11.0	12.0	6.9	6.9
16.4	18.0	10.4	10.4
22.0	24.0	13.9	13.9
33.0	36.3	21.0	21.0
47.0	52	30.1	30.1
66.0	72	41.6	41.6
91.0	100	57.8	57.8
110.0	123	71.1	71.1
132.0	145	83.8	83.8
155.0	170	98.3	98.3
220.0	245	142	142
275.0	300	173	173
330.0	362	209	209
400.0	420	243	243

System Configurations

Once the system voltages are understood, the next step in the selection process is to determine the system configuration to which the arrester will be applied. In other words, one must determine if it is a wye or delta system (star or delta in the IEC world). Also needed for selection is to know how the system neutral conductor is used in the circuit if there is one. The power source transformer and the neutral bonding scheme determine how high the line to ground voltage of the unfaulted phases will rise during a ground fault. Fortunately the number of system configurations are limited.

The most common IEEE configuration is the 4 wire solid multi-grounded neutral as shown in figure 2a. This is also known as an effectively grounded system.

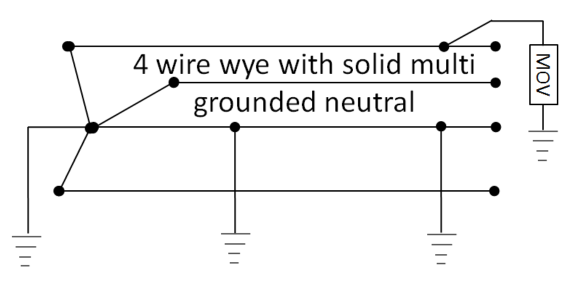

Figure 2a Solidly Multi-grounded 4 wire system

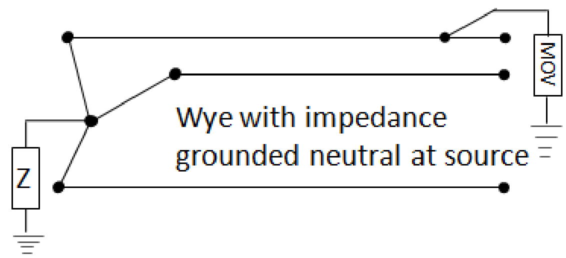

Figure 2b Impedance or Resonant Grounded System

A common industrial and very common IEC configuration is the 3 wire impedance grounded wye (or star). The reason for popularity of this system is that the fault current to earth is limited by the impedance. When low impedance is used, it can limit the fault current to levels that allow for lower fault current rated equipment to be used on the system. This is often a cost savings configuration. When the impedance is high, a Petersen coil is used which can offer fault extinguishing capabilities without using breakers to break the fault. This is sometimes referred to as a resonant grounded system.

A third common system configuration is an isolated or ungrounded system. This can be either delta or wye configured. Figure 2c and 2d show these two systems.

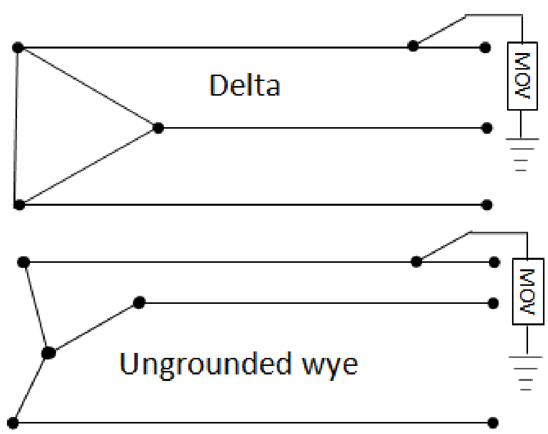

Figure 2c Ungrounded systems (isolated neutral)

A common transmission line configuration is the single grounded Wye as seen in Figure 2d .

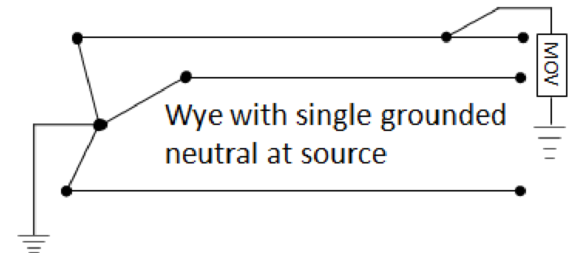

Figure 2d Single grounded neutral system (Uni-grounded system)

Determining Phase Voltage Rise due to Earth or Ground Faults

When a three phase power system experiences a fault to earth on any one of its phases, the two unfaulted phases experience an increase in the voltage between the phase and ground. Since arresters are most often applied between the phase conductor and earth, then they also see this increase in voltage across their terminals. This increase in voltage will remain across the arrester until a system breaker operates and breaks or interrupts the fault. This is a very significant event in the life of an arrester and must be accounted for during the voltage rating selection of an arrester.

The determination of a voltage rise during a ground fault is not an easy task if a precise value is desired. There are some rules of thumb and graphs that can be used, but these are quit crude and difficult at best to use. Annex C of IEEE standard C62.22 and Annex A of IEC 60099-5 cover this subject.

For distribution systems where the system and transformer impedances are relatively unknown, a worst case scenario is used for each type of system. The voltage rise during a fault in these cases is determined by multiplying the line to ground voltage by a ground fault factor or earth fault factor. Figure 3 lists the ground fault factors used to determine the unfaulted phase voltage rise during a ground fault.

Type of System	Ground Fault Factor
Solidly Grounded 4 wire systems	1.25
Uni-grounded 3 wire systems	1.4
Impedance grounded systems	1.73
Isolated Ground Systems and Delta Systems	1.73

Figure 3 Ground Fault Factors

For example in a 13.8kV multi-grounded system, the maximum continuous line to ground voltage is 8.38kV. The voltage during a ground fault on the unfaulted phases can reach 8.38 x 1.25 or 10.47kV rms. This is the voltage an arrester will see across its terminals for as long as the fault exists.

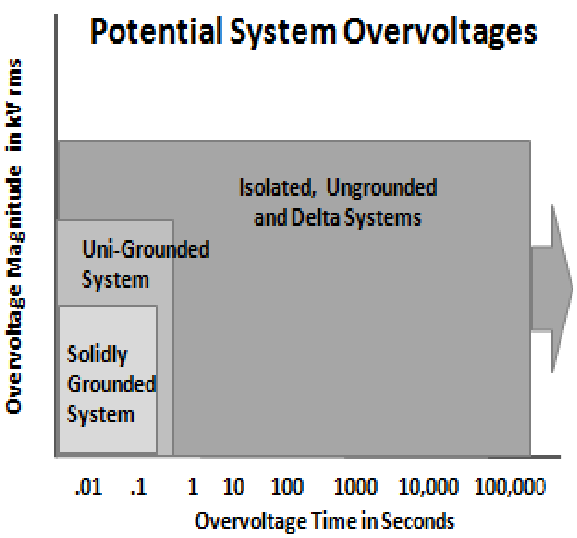

Figure 4 Potential System Overvoltages

Mixed Configurations

It is also important to note that the grounding of the neutral at the source transformer is the configuration referred to in determining the voltage rise of the system.

For example as seen in Figure 5, a delta/delta transformer is tied to a solidly grounded wye system. In this case MOV1 should be sized for a solidly grounded system, and MOV 2 should be sized for an isolated ground system.

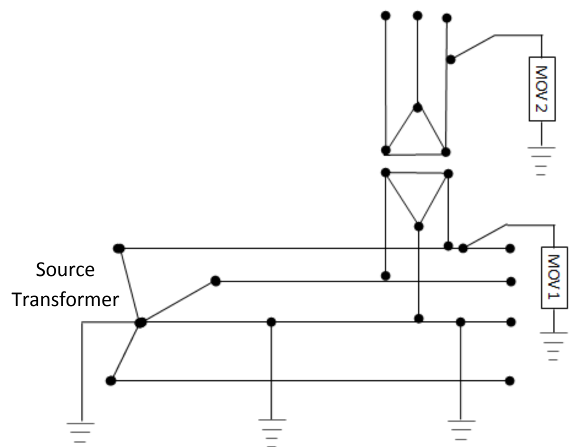

Figure 5 Mixed Configuration Use the source transformer grounding scheme to determine the MOV rating

Using the TOV Curve to Select an Arrester's MCOV

After the system configuration and potential overvoltage is determined, it must be compared to the arrester TOV curve. Figure 6 shows TOV curves of several types of arresters. Figure 6 shows a comparison of system overvoltage and arrester TOV capability.

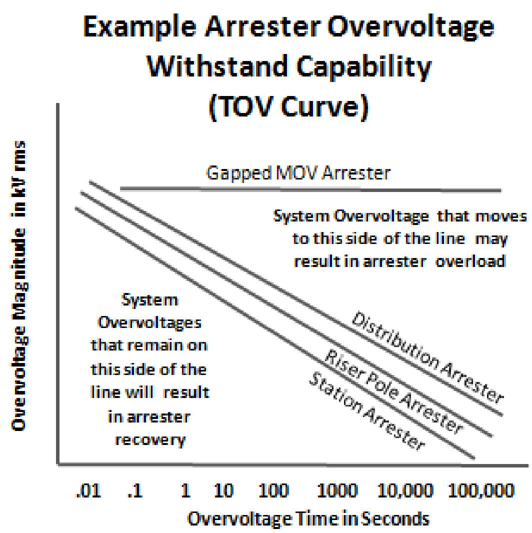

Figure 6 Example Arrester TOV Curve

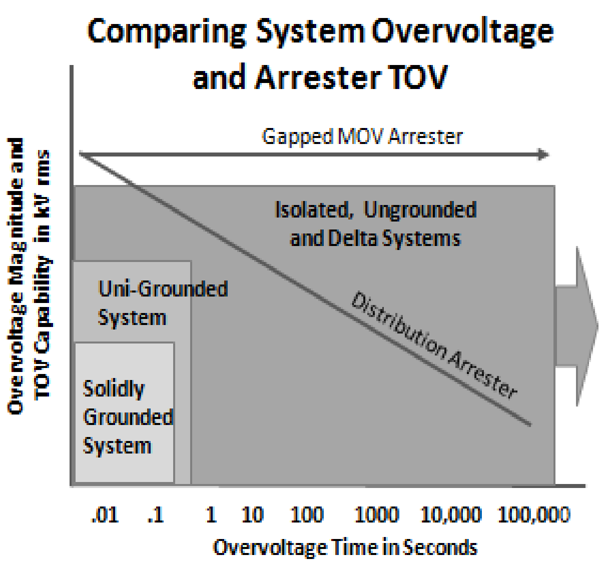

Figure 7 Comparing TOV Curve and Potential System Overvoltage

In the example in Figure 7, the selected distribution arrester would not withstand an overvoltage of an ungrounded or delta system, but would withstand an overvoltage from a uni-grounded and multi-grounded system. However if a gapped MOV arrester was selected, it could withstand even an ungrounded system overvoltage.

For distribution systems, the process of comparing the potential system overvoltage and the arrester withstand capability is seldom completed because the time of the overvoltage is unknown. Because of this issue, for all systems other than the multi grounded system, the MCOV or Uc of the arrester is selected to equal or exceed the line to line voltage. Most manufacturers also offer a quick lookup table to select the arrester rating based on the system to which it is attached. See Figure 8 for this recommendation.

For substation applications, the comparison of the potential system overvoltage and the arrester overvoltage withstand capability is essential in selecting the arrester MCOV or Uc. In the case of transmission systems and substations, the expected system overvoltage magnitude and duration are known quantities so this comparison is quite accurate.

The best means of obtaining the expected overvoltage during a fault on a transmission system is to ask the persons responsible for relay settings. They have usually modeled the system extensively with proven software, they can supply both magnitude and durations of faults at most location on the system. Use this information to compare against the target arresters' TOV curve.

Transmission Line Arresters

The selection of transmission line arresters (TLA) MCOV rating or Uc rating is different than a distribution or substation arrester. In the case of TLA's the objective is to only protect insulators from the undesirable backflash during a switching or lightning surge. Since overhead insulators are generally a self-restoring type of insulation it is not imperative to have the lowest possible clamping voltage for the arrester to mitigate flashover. Sometimes it is also desirable to size the arrester so that it does not absorb any significant energy during a switching surge. In this case increasing the MCOV or Uc rating is an effective means to do just this. However if the TLA is being applied to mitigate switching surges, then the arrester MCOV should be similar to that of the substation arresters.

Summary

Selection of an arrester MCOV rating or Uc rating can be daunting at times, but once the system configuration and overvoltage potentials are known it is a simple comparison.
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Figure 8a IEEE MCOV Suggested Ratings (based on historical preference and TOV analysis)

Typical IEEE System Voltages				Suggested IEEE Arrester MCOV Rating			
Nom Line to Line Voltage	Max Line to Line Voltage	Max Line to Grnd Voltage		Solid Multi-grounded Systems (4 wire)	Uni-grounded Systems (3 wire)	Impedance grounded, Ungrounded and Delta Systems	Transmission Line Arresters for Lightning Protection Only
kV rms	kV rms	kV rms		MCOV	MCOV [*]	MCOV [*]	
2.40	2.52	1.46				2.55	
4.16	4.37	2.52		2.55	5.1	5.1	
4.80	5.04	2.91				5.1	
6.90	7.25	4.19				7.65	
8.32	8.74	5.05		5.1	7.65		
12.0	12.6	7.28		7.65	10.2		
12.5	13.1	7.57		7.65	12.7 [7.65]		
13.2	13.9	8.01		8.4	12.7 [8.4]		
13.8	14.5	8.38		8.4	12.7 [8.4]	15.3 [8.4]	15.3
20.8	21.8	12.6		12.7	15.3 [12.7]		21
22.9	24.0	13.9		15.3	19.5 [15.3]		22-24
23.0	24.2	14.0		15.3-17		24.4 [15.3]	22-24
24.9	26.2	15.1		15.3	22 [15.3]		24-29
27.6	29.0	16.8		17	24.4 [17]		24-29
34.5	36.2	20.9		22	29 [22]	36-39 [22]	29-36
46.0	48.3	27.9			29	39	29-39
69.0	72.5	41.9			42-48	53-67	48-67
115.0	121	69.8			70-76	84-98	76-98
138.0	145	83.8			84-98	106-115	98-115
161.0	169	98			98-115	115-131	115-131
230.0	242	140			140-152	182-190	152-190
345.0	362	209			209-245	230-289	245-289
500.0	525	303			318-452		>452
765.0	800	462			462-490		>490

[*] MCOV rating of a Gapped MOV arrester

Figure 8b Suggested Uc for IEC systems

Typical IEC System Voltages				Suggested Uc for IEC Systems		
Nominal Line to Line Voltage	Typical Max Line to Line Voltage	Max Line to Grnd Voltage		Solidly Earthed Neutral at the Source Transformer	Impedance Earthed, Isolated and Delta Systems	Transmission Line Arresters for Lightning Protection Only
kV rms	kV rms	kV rms		Uc	Uc	
3.3	3.7	2.1		2.4	4.0	
6.6	7.3	4.2		4.8	7.2	
10.0	11.5	6.6		7.2	12	
11.0	12.0	6.9		9.6	12	12
16.4	18.0	10.4		12	18	18
22.0	24.0	13.9		16.8-24	24	24
33.0	36.3	21.0		24-36	36	36
47.0	52	30.1		33-43	53	43-53
66.0	72	41.6		43-58	72	58-72
91.0	100	57.8		66-77	102	77-102
110	123	71.1		77-86	125	86-125
132	145	83.8		96-115	145	115-145
155	170	98.3		110-125	170	125-170
220	245	142		154-188	245	188-245
275	300	173		182-192	300	192-300
330	362	209		221-230	360	230-360
400	420	243		269-288	420	288-420
500	550	318		420-440	550	440-550

Other ArresterFacts Available

- Arrester Lead Length
- Field Testing Arresters
- Infrared Thermometer
- Guide for Selecting an Arrester Field Test Method
- VI Characteristics
- The Externally Gapped Arrester (EGLA)
- The Disconnector
- Understanding Mechanical Tests of Arresters
- What is a Lightning Arrester?
- The Switching Surge and Arresters
- The Lightning Surge and Arresters
- Understanding the Arrester Energy Handling Issue
- Understanding Discharge Voltage
- What is a Riser Pole Arrester?

Thank you for using www.ArresterWorks.com as your source of information on high voltage surge arresters.

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