

Understanding the New Energy Handling Tests of IEEE C62.11-2019

Introduction

There are many parameters of arresters, but its energy rating is near the top in importance. Since arresters are installed on power systems to clamp both lightning surges and switching surges, they can dissipate fairly high levels of energy in the course of this activity. However, high voltage arresters are designed to handle this energy. Since there are numerous arrester types and functions, there are several different energy ratings to consider. The purpose of this paper is to explain the rationale of the new energy test to be adopted in the next edition of IEEE C62.11.

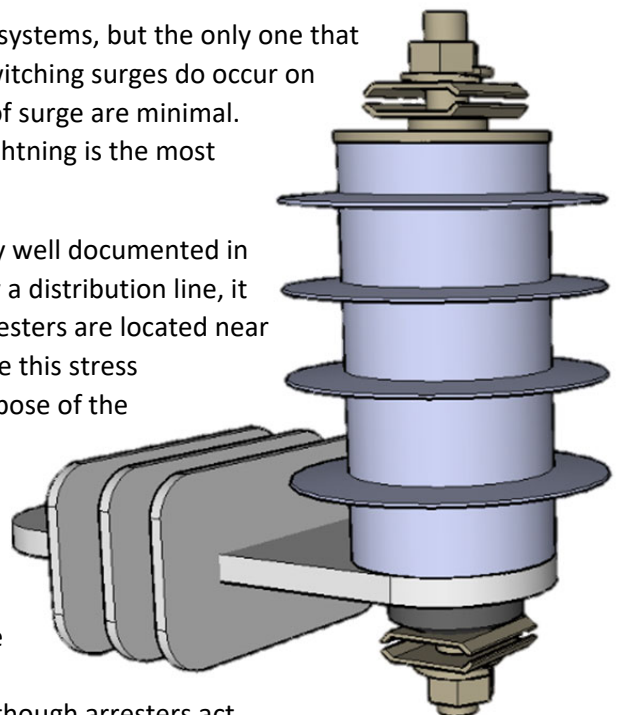
The energy handling tests in IEEE arrester standard C62.11 were changed in the 2012 edition for the station class arrester and in the upcoming 2019 edition it will be modified again for both the station and distribution class arresters. This paper provides a simplified overview of these changes. The IEEE application guide C62.22a was updated in 2013 to help in this change, and it will be modified again soon after 2019 to accommodate the next changes.

Arrester Classifications - IEEE				
Distribution Arresters	Classifying Current	LCLD Current	Lightning Impulse Limit	Pressure Relief
Heavy Duty	10 kA	250 A	100 kA	10-20kA
Normal Duty	5 kA	75 A	65 kA	10-20kA
Light Duty	5 kA	75 A	40 kA	10-20kA
Station and Intermediate Arresters	Classifying Current	Switching Surge Energy kJ/kV MCOV	Switching Impulse Limit Coulombs	Pressure Relief
Class A	10 kA	3	~.8	40-80 kA
Class B	10 kA	4.5	~ 1	
Class C	10 kA	6	~1.3	
Class D	10 kA	7.5	~1.6	
Class E	10 kA	9	~ 2.4	

Distribution Class Arresters

There are numerous overvoltage anomalies on distribution systems, but the only one that can result in stressing a distribution arrester is lightning. Switching surges do occur on distribution systems, but the energy related with this type of surge are minimal. Even with large capacitor banks on a distribution system, lightning is the most significant surge.

The lightning surge has been studied for decades and is very well documented in all aspects. When lightning directly strikes or strikes nearby a distribution line, it stresses every component on that line. The distribution arresters are located near equipment (transformers, reclosers, etc.) that cannot handle this stress without failure if not protected. In this application, the purpose of the arrester is to limit the voltage across the insulation of the equipment to avoid its failure. It accomplishes this act by channeling the charge from the stroke around the protected equipment to earth with as little energy dissipation as possible in the arrester. When lightning current discharges through the arrester, some of the charge is converted instantaneously to heat energy due to a small resistance the arrester has during its "turned on" mode. Although arresters act

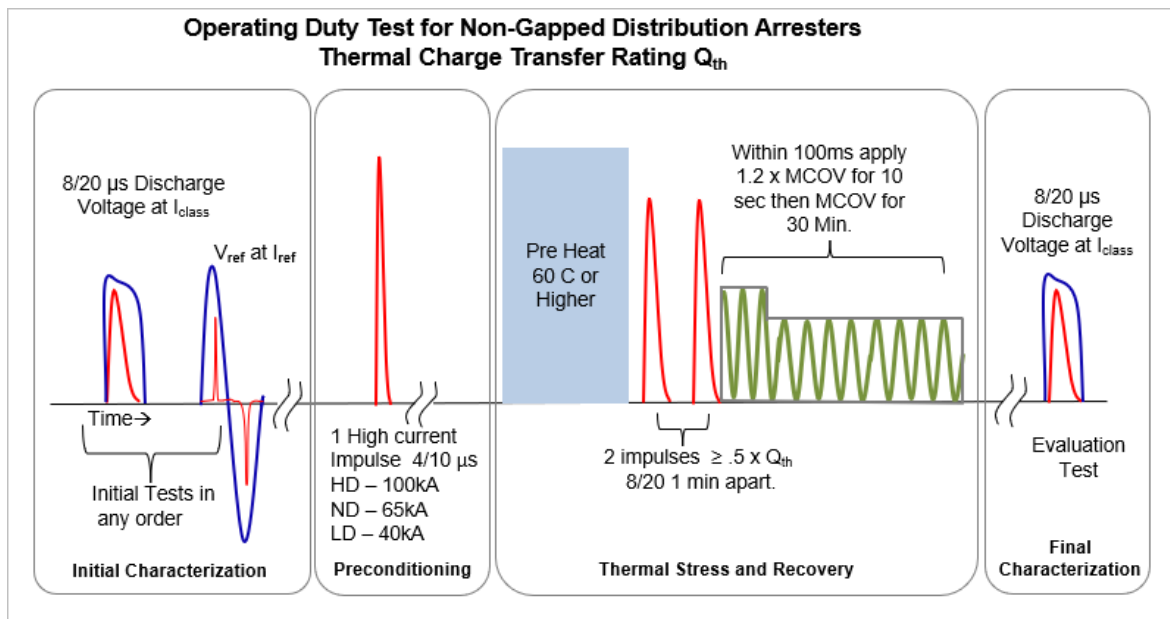


like a switch to divert the lightning charge around its protected equipment, since it is an electronic semiconductor, it cannot switch on to a zero-ohm state without producing heat.

During this charge transfer event, the arrester must handle the rapid increase in temperature without thermal/mechanical damage or without heating beyond its thermal stability limit. A good quality arrester will handle this energy event without any real effect on the semi conductive metal oxide material. The energy tests specified in IEEE C62.11 are design to verify this.

New Operating Duty Test for Non-gapped Distribution Class Arresters

In 2019 a revised Operating Duty Test will be introduced for non-gapped distribution arresters. The purpose of this test is to confirm that the specified arrester will remain stable and operational after significant charge transfer in the worst possible conditions on the system. Since this is a test of thermal stability, it is carried out on a sample that has the exact thermal cooling characteristics as the longest arrester in the design family. It is assumed that the longest rating has the worst case thermal cooldown parameters since there are so many hot disks in series.



The test achieves its purpose by requiring 4 separate tests in series for each arrester design. The rationale for each section of the test are:

1. In initial characterization two test are run that verify the protection level (discharge voltage) and arrester rating (V_{ref}). The protection level is again tested at the end of the test to verify that the arrester has not changed its fundamental parameter. The V_{ref} test ensures that the MCOV level used during Part 3 is at the correct level.
2. In preconditioning a high current impulse is applied to represent a severe field experience that may change the arrester parameters over its lifetime. Arrester research has indicated that high current surges are the only type of surge that can age or change characteristics. In the past,

lower current surges were used as a carryover from methods used for the previous arrester type (SiC).

3. The thermal stress and recovery part of this test verifies that the arrester will remain stable after it is subjected to its maximum design charge transfer. The arrester is heated prior to the test to represent the hottest environment it could ever experience. It is then subjected to two 8/20 lightning current impulses within one minute, having enough magnitude that the accumulated charge is at least equal to the claimed thermal charge transfer rating. Within 100ms after the second impulse, the arrester is energized with an AC voltage at $1.2 \times \text{MCOV}$ for 10sec. At 10 seconds the voltage is reduced to MCOV and if after 30 minutes the arrester has cooled down, it means the arrester is thermally stable and has passed this part of the test.
4. Final characterization is a retest of the discharge voltage (protective level) and its value is compared to the value at the start of the test. If the discharge voltage has not changed more than 5%, then the arrester is said to have passed the test and is capable of remaining stable when subjected to its maximum design level.

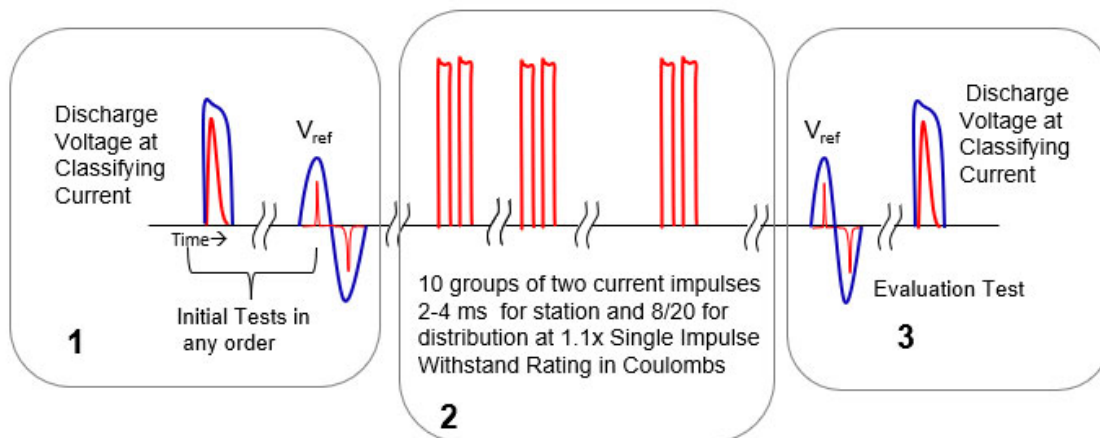
This revised Duty test has been adopted to better represent field conditions and is believed to test the arrester performance better than the previous Duty Cycle Test.

History has shown the industry that if an arrester can handle the 100kA tests, then it can handle anything that comes at it in the field. The heavy-duty distribution arrester has a higher energy handling capability than a normal duty arrester and should be used for applications that may require more duty.

New Distribution Arrester Single Impulse Energy Capability Test

In 2012 the station class arrester was required to pass a single impulse test, starting in 2019 the distribution class arresters will also be required to pass this test. This test replaces the low current long duration test on distribution class arresters that was never quite relevant to distribution class arresters. The purpose of this test is to demonstrate the arrester's ability to repeatedly withstand a charge transfers through the arrester at the level to which it is certified. Note this is not a thermal evaluation of the arrester, strictly a single impulse surge withstand capability repeated 20 times. This test can be completed on an assembled arrester or disks since it is not a thermal test.

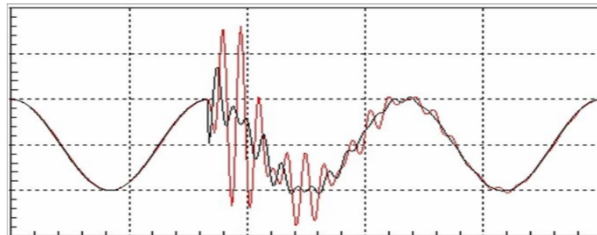
Single Impulse Charge Transfer Rating Test Q_{rs}



1. The first part of this test is simply initial tests to verify the protective characteristics and the turn on voltage of the arrester (V_{ref}). The sample for this test is a disk in open air or single disk arrester if desired as opposed to a thermal section of an arrester.
2. Part 2 is a severe series of 20 impulses (2 at a time) at 1.1 x the desired charge transfer rating of the disk Q_{rs} . It is understood that failure of disks is somewhat a statistical event and it is accepted that this is not a truly statistical test, but 20 impulses is more severe than 1 or 2 impulses. If no more than one disk fails, the disk can be rated at 91% of the tested charge level. If two disks fail in the test, 10 more disks must be tested. If no more than 2 out of 20 disks fail, the disks have passed, and the evaluation section can be carried out.
3. Part 3 is the verification section of this test. If the parameters have not changed more than specified in the test, then any arrester manufactured with this disk can be rated at 10% below the tested charge level, and the actual Q_{rs} rating is selected according to the step size fixed in the standard.

Station Class Arresters

Station class arresters also need to contend with significant surges, but in this case circuit breakers are the source and not lightning. Every time a circuit breaker operates, it creates a switching surge at some level. If the breaker contacts close to energize a system when the voltage is at peak value, a switching surge of up to 3+ times the normal voltage can appear on the line. Since most station class arresters begin to protect the system at levels as low as 20-30% above the operating voltage, when a switching surge appears on the line the arrester turns on immediately. When turned on, they clamp the voltage and generate heat internally due to the resistance of the arrester.



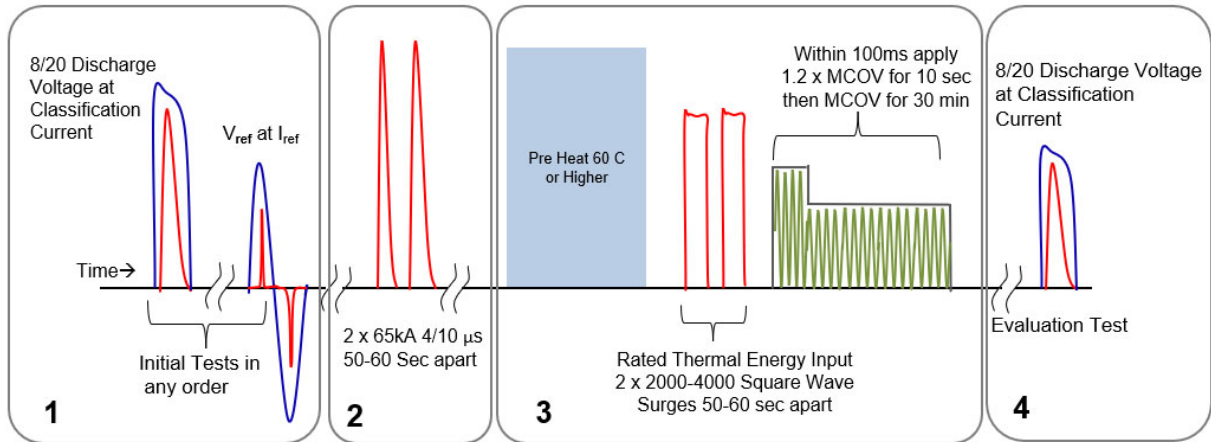
These switching surges increase in energy content as the system voltage increases. The energy content of a switching surge also increases as the length of the line increases. A third variable with respect to the energy content of a switching surge is the presence of capacitor banks. Between the three of these and a few other minor variables, a switching surge can inject megajoules of energy into an arrester.



Switching Surge Thermal Energy Rating

To verify the switching surge capability of a station arrester IEEE C62.11 specifies that each design must be subjected to a Switching Surge Energy Rating Test and remain thermally stable for a time period after the injection of energy. From this test, thermal energy ratings are given in kJ/kV-MCOV and are in the ranges of 3.0 to 15.

Switching Surge Energy Rating Test (Thermal Energy Rating W_{th})



- Part 1 of this test is to establish the pretest protective level and the AC rating of the test. The 8/20 impulse establishes the protective level and the V_{ref} is used to establish the MCOV of the sample.
- The two 65kA surges represent the worst case possible electrical aging this arrester could experience. This level is lower than distribution arresters since station arresters seldom see high lightning currents in a substation.
- The third part of the test is to inject significant switching surge energy into the sample and then check for stability after the event. The arrester is heated to 60C to replicate the worst possible environmental situation in the field. The sum of the energy dissipated by the arrester will be the maximum switching surge energy rating of the unit. After the energy input, the arrester is subjected to a 10 second overvoltage that represents a typical 10 second TOV, followed by the application of MCOV for 30 minutes. If the arrester cools down and becomes electrically stable in this time period, it is considered to have passed this part of the test.
- The final impulse is to verify that the arrester was not damaged during the surge and to verify that the protective characteristics had not changed by more than the specified amount.

Note that this test is ran on a thermally and voltage prorated arrester to ensure that it adequately represents the longest (worst case thermally) arrester in the family.

The available thermal energy ratings for station class arresters are as follows:

Energy Class	Energy Rating (Two Shot) kJ/kV MCOV	Thermal recovery impulses kJ/kV MCOV
A	3.0	1.5
B	4.5	2.25
C	6.0	3.0

D	7.5	3.75
E	9	4.5
F	11	5.5
G	13	6.5
H	15	7.5
J	18	9.0
K	21	10.5
L	24	12.0
M	27	13.5
N	30	15.0

Single Impulse Charge Transfer Rating Test (Q_{rs})

The purpose of this test is to ensure that the MOV disks used in the design are capable of repeatedly withstanding surges at its maximum single impulse rating. The parameter for this test has been adopted from the IEC standard as Q_{rs} . The test procedure is identical to that of the distribution arrester (Figure 3) with only amplitude and waveshapes changing. Since station arresters are stressed by switching surges at higher levels than lightning, the repeated impulse is a rectangular wave.

Summary

The improvements to the energy handling test in the next edition of IEEE C62.11 will bring a more realistic and practical set of tests to evaluate modern MOV arresters. The energy tests of the past were originally specified for Gapped Silicon Carbide arresters and the change herein will result in better arresters for the market.