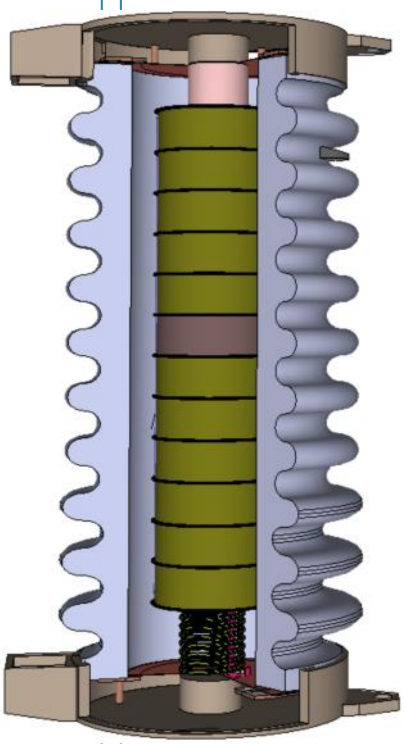
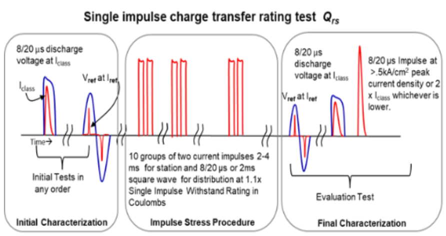
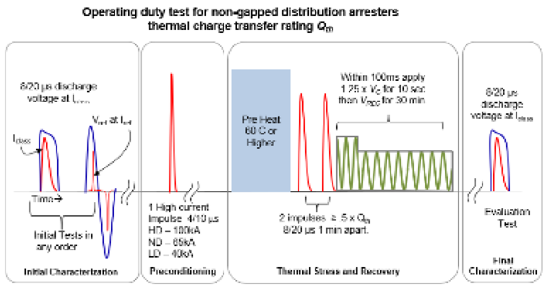
ArresterWorks

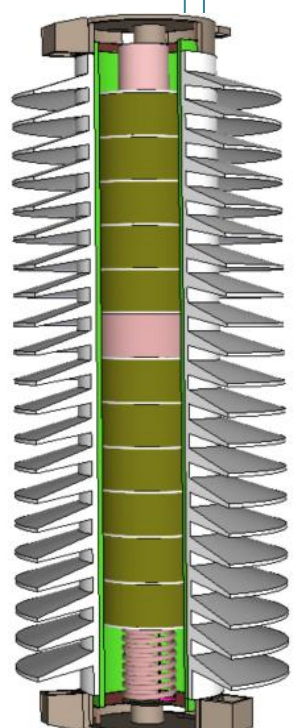
Understanding Changes in IEEE C62.11-2020

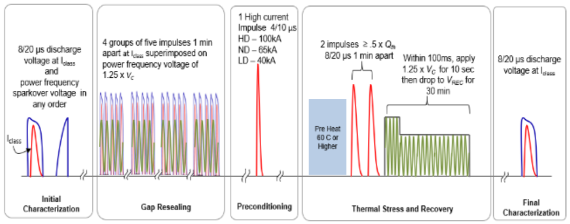
The MOV Arrester Test Standard

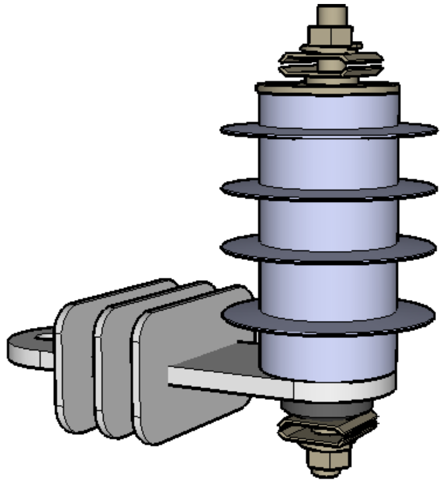












February 2020
Jonathan Woodworth

ArresterFacts 050

ArresterFacts 050 - Understanding Changes in IEEE C62.11-2020

Introduction

The IEEE arrester test standard C62.11-2020 will be published in the next few months. The document is the culmination of 8 years of work by the IEEE Surge Protective Devices Committee WG 3.3.11. The working group consists of 20ish members that have met 2 times per year for the past 8 years and several times per year online in smaller groups. This revised standard continues the trend set by the 2012 edition to rationalize the test to contain more realistic requirements while at the same time harmonize it with the equivalent IEC standard 60099-4. This ArresterFacts is meant to outline the revisions in a manner that makes them more understandable and easier to implement by all stakeholders.

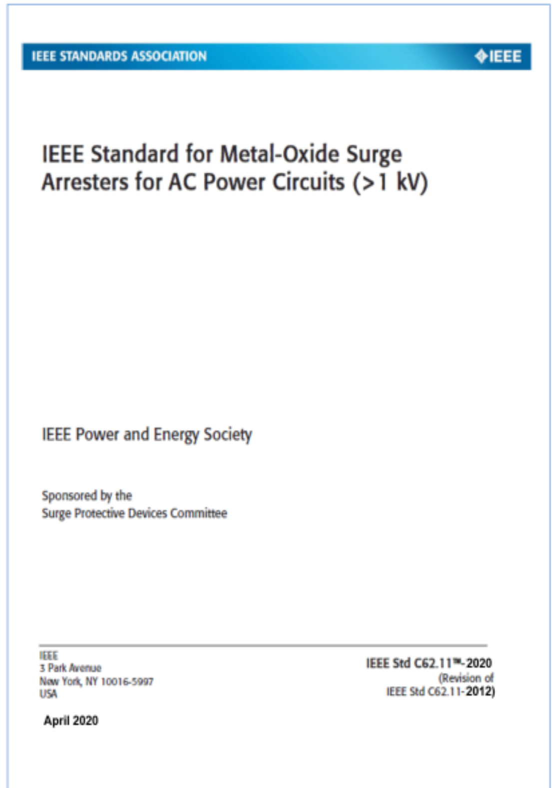
C62.11-2012 Edition

When the 2012 edition of this standard was published, it too was after numerous years of work to update and improve the standard. The changes in the last edition are covered in ArresterFacts 040.

Summary of Fundamental Changes

The following is a summary of the fundamental changes in this standard from the 2012 edition. Each one of these changes are covered in more detail in this ArresterFacts.

1. **Arrester AC Voltage Rating:** The term Arrester Rating has been obsoleted as of the publication of this standard. This is a long overdue change to the standard that has caused confusion in the industry since the term MCOV was introduced in early 1980's..
2. **Distribution Arrester Energy Handling Ratings:** For the first time, the distribution arrester has an energy handling rating.
3. **Standard Altitude** for normal conditions was lowered from 1800m to 1000m. This is now harmonized with 60099-4.
4. **Arrester Housing Withstand Tests:** This test was significantly changed in procedure and is now harmonized with 60099-4-2014. A few minor differences still exist, but the tests can be executed in a lab using the same procedure and be certified to either standard.
5. **Switching Impulse Energy Rating Test (W_{th}):** This test was modified slightly in the IEEE version to harmonize with IEC 60099-4.
6. **Single-impulse Charge Transfer Rating Test (Q_{rs}):** This test previously existed in the IEEE standard for station class arresters only. It was modified only slightly and is now in line with 60099-4. It is also now required for distribution arresters in C62.11 as it is in 60099-4.


IEEE STANDARDS ASSOCIATION
IEEE

IEEE Standard for Metal-Oxide Surge Arresters for AC Power Circuits (>1 kV)

IEEE Power and Energy Society

Sponsored by the
Surge Protective Devices Committee

IEEE
3 Park Avenue
New York, NY 10016-5997
USA

IEEE Std C62.11™-2020
(Revision of
IEEE Std C62.11-2012)

April 2020

Figure 1 Cover of C62.11

7. **Operating Duty Test for Distribution Arresters (Q_{th}):** This test was modified more than any other test in the new C62.11 edition. Since C62.11 also covers gapped MOV arresters, the procedure was split into two versions, one for gapped and one for non-gapped arresters. The non-gapped procedure is now aligned with 60099-4-2014 and the gapped procedure is aligned with 60099-6-2019.
8. **Temporary Overvoltage Test:** This test was slightly modified and if carried out correctly, the results can be used for either IEC or IEEE certifications.
9. **Disconnector Test:** This test was modified significantly to accommodate the new tests C62.11 and is also aligned with 60099-4 and 60099-6

Arrester AC Voltage Rating

The term arrester rating has been in use since the middle of last century. It is the only AC voltage rating of the last generation of Gapped Silicon Carbide Arresters. In the early 1980's when the first edition of the MOV type arrester standard was published, the term MCOV was introduced. The rationale for having two AC ratings at that time is not clear, but the confusion it has caused in the following years is clear. Since the MCOV rating for the un-gapped MOV type arrester is closely related to the line to ground voltage where an arrester is installed, it has become the preferred AC rating term by most stakeholders. The quest to eliminate the term Rated voltage that is only related to a voltage level used in the Operating Duty Test started at least 15 years ago. In the 2012 edition we eliminated the term from the name plate of the arrester, and finally due to lack of relevance, it is officially obsoleted in this edition. The term MCOV (Maximum Continuous Operating Voltage) is exactly what it is, the maximum voltage across the terminals of the arrester that can be applied long term. This is now the official AC rating of MOV type arrester.

Arrester Classifications

Distribution Arresters: The distribution arrester classifications are again defined by the tests they are required to pass however this type of arrester now has two Energy Handling Ratings. Table one shows the new requirements. Both ratings are in coulombs since they are both related to the current carrying capacity of the arrester. The coulomb is now the primary unit of energy handling capability for the Distribution Arrester. It is preferred since it is not affected by the wave shape of the current or the discharge voltage of the arrester, (see Figure 1). These classifications are now identical to the IEC classifications other than the name. Note this is not kJ/kV MCOV as station arresters are sometimes classified.

Distribution Class Arrester	Lightning Impulse Classifying Current I_{class} (kA)	High Current Impulse (kA)	Minimum Single Impulse Charge Transfer Rating Q_{rs} Coulombs	Minimum Thermal Energy Withstand Rating Q_{th} Coulombs
Heavy Duty (HD) (same as IEC DH)	10	100	0.4	1.1
Normal Duty (ND) (same as IEC DM)	5	65	0.2	0.7
Light Duty (LD) (same as IEC DL)	5	40	0.1	0.45

Table 2 Distribution Arrester Classification in IEC and IEEE Standards

	MCOV Range (kV RMS)	Lightning Impulse Classifying Current I_{class} (kA)	Switching Impulse Classifying Current (A)
Station	>448	20	2000
Station	246−448	15	2000
Station	116−245	10	1000
Station	2.55−115	10	500
Intermediate	2.55−115	5	500

Table 2 Station Arrester Classifying Currents

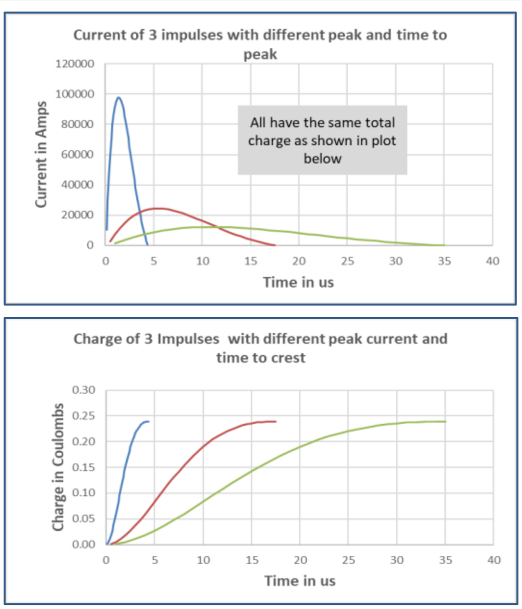


Figure 2 Comparing Charge Vs Waveshape

Energy Class IEEE and (IEC)	Minimum Thermal Energy Withstand Rating (W_{th}) kJ/kV-MCOV	Minimum Single Impulse Withstand Rating (Q_{rs}) Coulombs IEC Only
A	3	
B (SL)	4.5	≥ 1.0
C (SL)	6	≥ 1.0
D (SM)	7.5	≥ 1.6
E (SM)	9	≥ 1.6
F (SH)	11	≥ 2.4
G (SH)	13	≥ 2.4
H (SH)	15	≥ 2.4
J (SH)	18	≥ 2.4
K (SH)	21	≥ 2.4
L (SH)	24	≥ 2.4
M (SH)	27	≥ 2.4
N (SH)	30	≥ 2.4

Table 3 Station Arrester Energy Ratings

Station Class Arresters: The station class arresters require two tables to define their classification. Table 2 shows the impulse characteristics and Table 3 defines the energy withstand ratings of the arrester. The IEC ratings are different and are also shown in Table 3. The tests to verify these ratings are nearly identical. Neither one of these tests are new in the 2020 edition, however the terms W_{th} and Q_{rs} are new and adopted from the IEC standard.

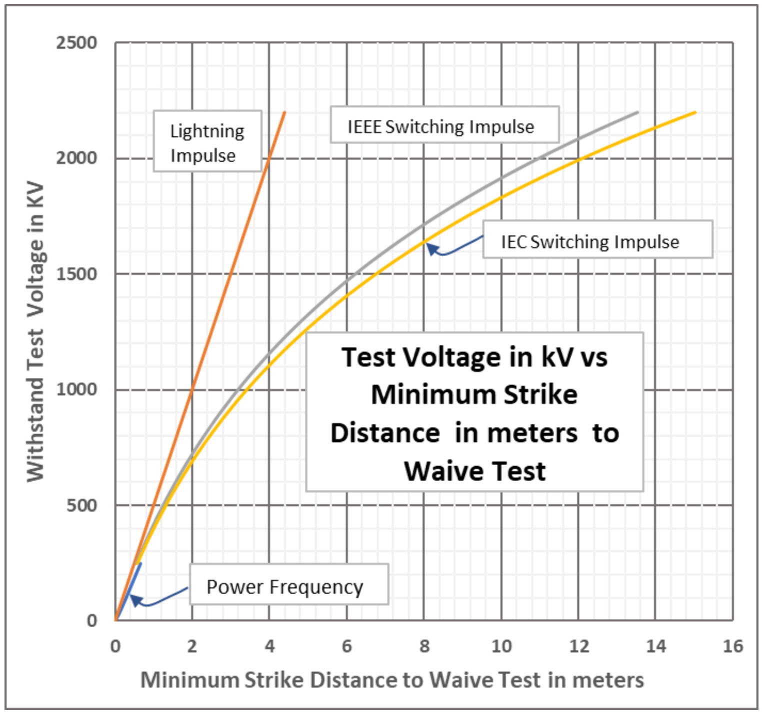


Figure 3 Withstand Test Voltage vs Minimum Strike Distance to Waive Test

Arrester Housing Insulation Withstand Tests

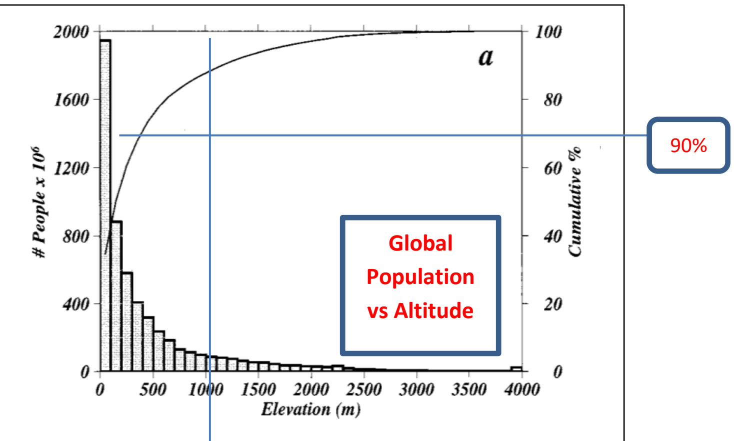
Station Class:

Tests to quantify the housing withstand level for impulse and power frequency voltages can be traced back to the earliest standards of the last century. Both IEC and IEEE standards have sections for station and distribution class arresters.

The objective of both standards is to demonstrate that the housing of the arrester will always withstand more voltage than it will ever experience in service. Because arrester housings are protected by the clamping voltage action of the internal metal-oxide disks, the arrester is said to be self-protected. Because of this unique characteristic of the arrester housing, a special note was included in test rationale of C62.11-2020 edition that states:

New Note in Standard: *It should be noted that the impulse withstand levels of arrester housings are not to be compared to BIL or CFO levels of insulators. Due to the arrester's self-protecting nature, the arrester housing can have a lower withstand voltage than the rest of the system without any negative impact on the system withstand level.*

Also, for this reason arresters are used in standard applications generally do not have standard insulation withstand ratings.



Proc. Natl. Acad. Sci. USA
Vol. 95, pp. 14009–14014, November 1998
Applied Physical Sciences, Social Sciences

Hypsographic demography: The distribution of human population by altitude

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Figure 4: World Population vs Altitude

Station Class Housing Insulation Withstand Test Changes:

1. For all station class voltage ratings, the standard normal design elevation was changed from 1800 meters to 1000 meters. This aligns more with other IEEE standards as well as IEC 60099-4. The rationale for this change is that most of the worlds population and power systems are located at altitudes 1000m and below. See Figure 4
2. Added is the option to waive the testing if sufficient strike distance of the arrester design is used. Formulae are provided for lightning

Comparison of New and Old IEEE-IEC Housing Withstand Test Voltages					
		Lightning Impulse	**Switching Impulse**	**Power Frequency**	**Comments**
Distribution Arresters	Prior IEEE	1.42 x V@20kA 8/20	NA	1.36 x 10 sec TOV Wet	Power Frequency Tested Wet 10 Sec
	New IEEE	1.3 x V@ I_{Class}	NA	RMS test voltage = .62 x V@ I_{Class}	1 minute Withstand test
	IEC	1.3 x V@ In 8/20	NA	Peak AC voltage >.88 x V@In	Power Frequency Tested Wet 1 min
Station Arresters	Previous IEEE All	1.42 x V@20kA 8/20	NA	.82 x Max Switching Discharge Voltage	Power Frequency Tested Wet 10 Sec
	New IEEE MCOV < 140kV Uc	1.3 x V@ I_{Class}	NA	RMS test voltage = .75 x V@ I_{Class}	Power Frequency Tested Wet 1 min
	New IEEE MCOV 140kV - 460 kV	1.3 x V@ I_{Class}	1.25 x @V Switching Impulse Classifying Current	NA	Switching Impulse Tested Wet
	New IEEE MCOV >460kV	By Agreement	By Agreement	NA	
	IEC Uc < 140kV for Us ≤245kV	1.3 x V@LIPL	NA	Peak AC > 1.06 x V@In	Power Frequency Tested Wet 1 min
	IEC Uc ~140kV to ~460 kV, for 245kV<Us≤800kV	1.3 x V@LIPL	>1.25 x Max V@SIPL	NA	Switching Impulse Tested Wet
	IEC >460kV Uc, for Us>800kV	1.3 x V@LIPL	1.25 to 1.36 x Max V@SIPL	NA	Switching Impulse Tested Wet

Table 4 Comparison of Old and New Withstand Test Voltages

impulse, switching impulse and power frequency voltages to make the necessary calculations needed for the waive assessment. This is the first time in C62.11 where a test can be waived if the design is shown to be designed significantly above the standard. Also, C62.11 adopted a slightly less conservative formula than IEC 60099-4 for the switching surge calculation. (See Figure 3)

3. The IEEE adopted the IEC method of testing arrester housings with MCOV ratings above 140 kV. This new test method uses a switching impulse voltage instead of AC voltage to verify the low frequency wet withstand level of the arrester. These higher rated arresters are now tested with a lightning and a switching surge impulse to certify housing withstand and not tested with AC.

4. For arresters with an MCOV rating less than 140 kV, switching surge withstand tests are not used and instead the familiar AC withstand test is applied. For harmonization, the IEEE standard had to accept a 1 min wet withstand test instead of the 10 second wet withstand test of the past. Since arresters are over designed in this area, this was not a difficult change (see Figure 4 for more details). The specified test voltages were similar between the two standards, but there were a few compromises where in some cases a less conservative value was accepted by the IEEE group, however in other cases the values are more conservative. In all cases, the test voltages requirements are lower than the actual design levels presently in use. Also, in all cases the specified test voltages have safety margins built in for a 1000 m altitude (13%) and variations in impulse current of 10-15%.

Insulation Withstand Test Changes for Distribution Class Arrester

Open Air Polymer Housed Arresters:

For the distribution class arresters, the housing withstand tests are tested the same as they were in the past, with lightning impulse discharges and power frequency withstand tests.

Even though the test methods are similar, to harmonize the standards, details in the test were modified.

1. The power frequency withstand test became a 1-minute test instead of a 10 second test. This lowered the test voltage slightly.
2. The lightning impulse withstand test remained the same with a slight reduction in level due to the change in normal design altitude from 1800 meters down to 1000 meters.
3. For the first time in IEEE arrester standards, if the strike distance of the arrester is long enough, the testing can be waived. The same calculations used to predict the station class withstand voltage based on length are used for distribution arresters. If the calculated voltage exceeds the specified minimum withstand voltage, then the test can be waived. In C62.11, the withstand voltage of the insulating hanger is evaluated for its power frequency withstand level. It must withstand a 1.5pu MCOV voltage for 10 seconds wet, between hanger mounting point and the ground end of the arrester. IEC 60099-4 has no equivalent test requirement.

Deadfront Arresters:

One area not harmonized with IEC for distribution arresters is the deadfront arrester design. The test requirements were significantly changed in C62.11 based on changes in IEEE 386. The test requirements in 60099-4 will need to be updated to meet these new requirements since this is basically an IEEE only design.

Tests That Did Not Change

Discharge-voltage Characteristics Test

This test was harmonized with IEC in the 2012 edition of C62.11 and is 100% the same as IEC 60099-4 with one exception. In the IEEE std, the maximum current level to test is 40 kA and is 20 kA in the IEC.

Power-frequency Sparkover Test

This test applies only to gapped MOV arresters and is harmonized with IEC 60099-6.

Impulse Protective Level Voltage-time Characteristic Test

This test applies only to Gapped MOV arresters and is harmonized with IEC 60099-6.

Accelerated Aging Test of Metal-oxide Disks

The test procedures for this test are nearly identical between C62.11 and 60099-4 however the pass-fail criteria are not exactly the same. In both cases, this test must be satisfied for disks of the same design to be used in the rest of the certification process. If disks do not pass this test, there is no recourse other than to use disks of a different design.

This test was not changed in C62.11-2020.

Accelerated Aging Test of Polymer-housed Distribution Arresters with Exposure to Light and Electrical Stress

This section is unique to C62.11 and has no equivalent in 60099-4. This test partially overlaps with the salt fog test, but the salt fog test does not evaluate the insulating hanger. For this reason, it needs to be evaluated again in the next C62.11 edition. Work in both standards is needed here to harmonize.

Accelerated Aging Test of Polymer-housed Arresters with Exposure to Salt Fog

This test is harmonized with IEC 60099-4 Section 10.8.17.2. There is some discussion in both working groups and this section may change in the next edition of each standard.

Contamination Test

This test is similar to Annex C.7.1 in IEC 60099-4. However, these two sections are not harmonized. Much work will be needed to harmonize this test.

Distribution Arrester Seal Integrity Design Test

There is no equivalent test in IEC 60099-4 or 60099-6. IEC needs to adopt this test in its entirety.

Radio-influence Voltage (RIV) Test

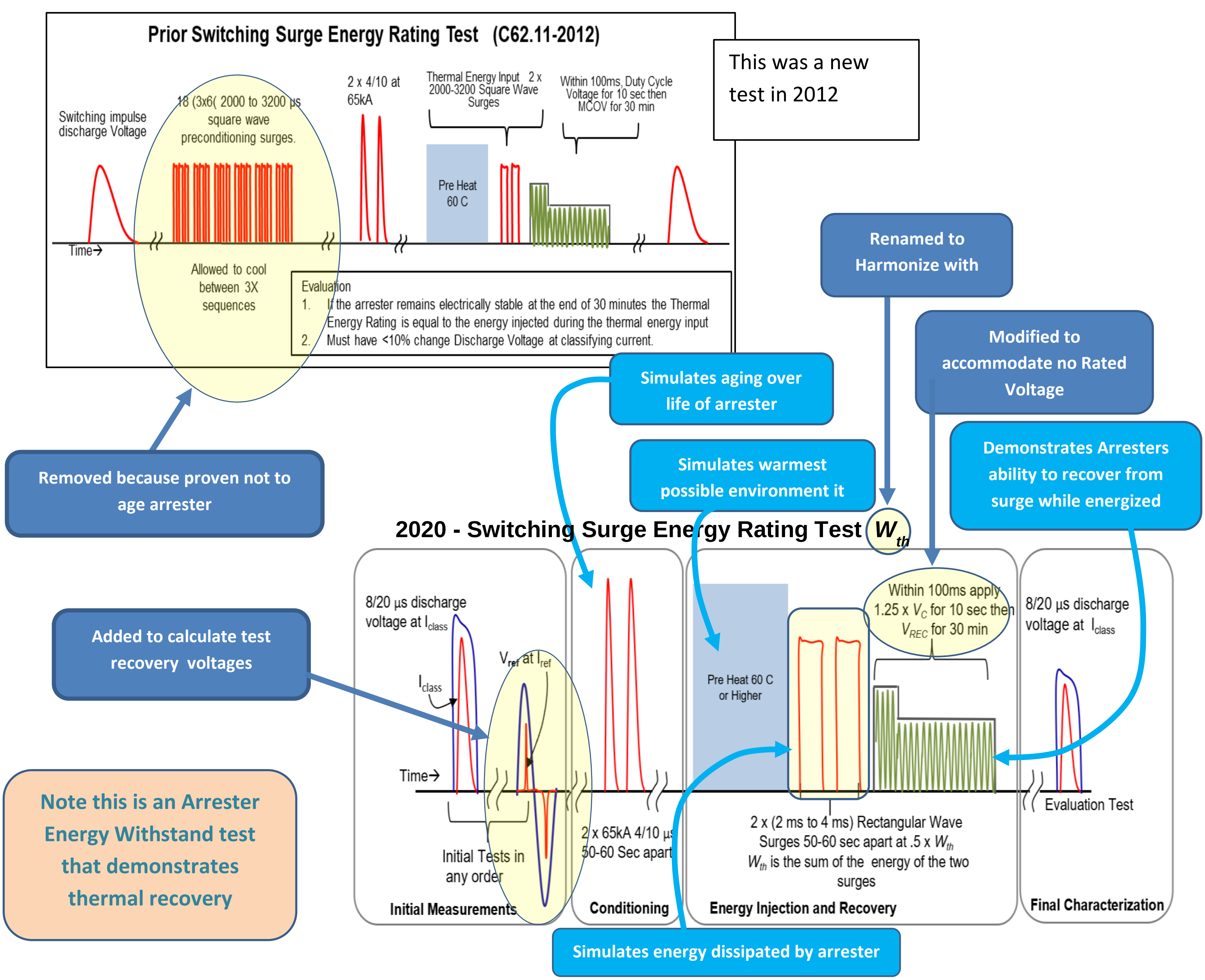
This test applies to arresters with an MCOV >70 kV. The procedure and results are harmonized with IEC.

Switching Impulse Energy Rating Test (W_{th})

This test was first introduced into the IEEE with C62.11-2012. It is similar to the previously titled Operating Duty Cycle Test for Station Class arresters.

This test is fully harmonized with 60099-4. The primary difference between C62.11-2012 and the 2020 edition is the elimination of the 18 preconditioning impulses. It has been agreed based on research that the only effective preconditioning of metal-oxide disks comes from high current impulses and not from lower current surges. The test is now referred to as the W_{th} rating test however the resulting energy ratings are still the same in the 2020 edition as they were in the 2012 edition but now defined as W_{th} as it is in 60099-4. See Figure below to compare the procedures of past and present tests.

Switching Surge Energy Rating Test (W_{th})



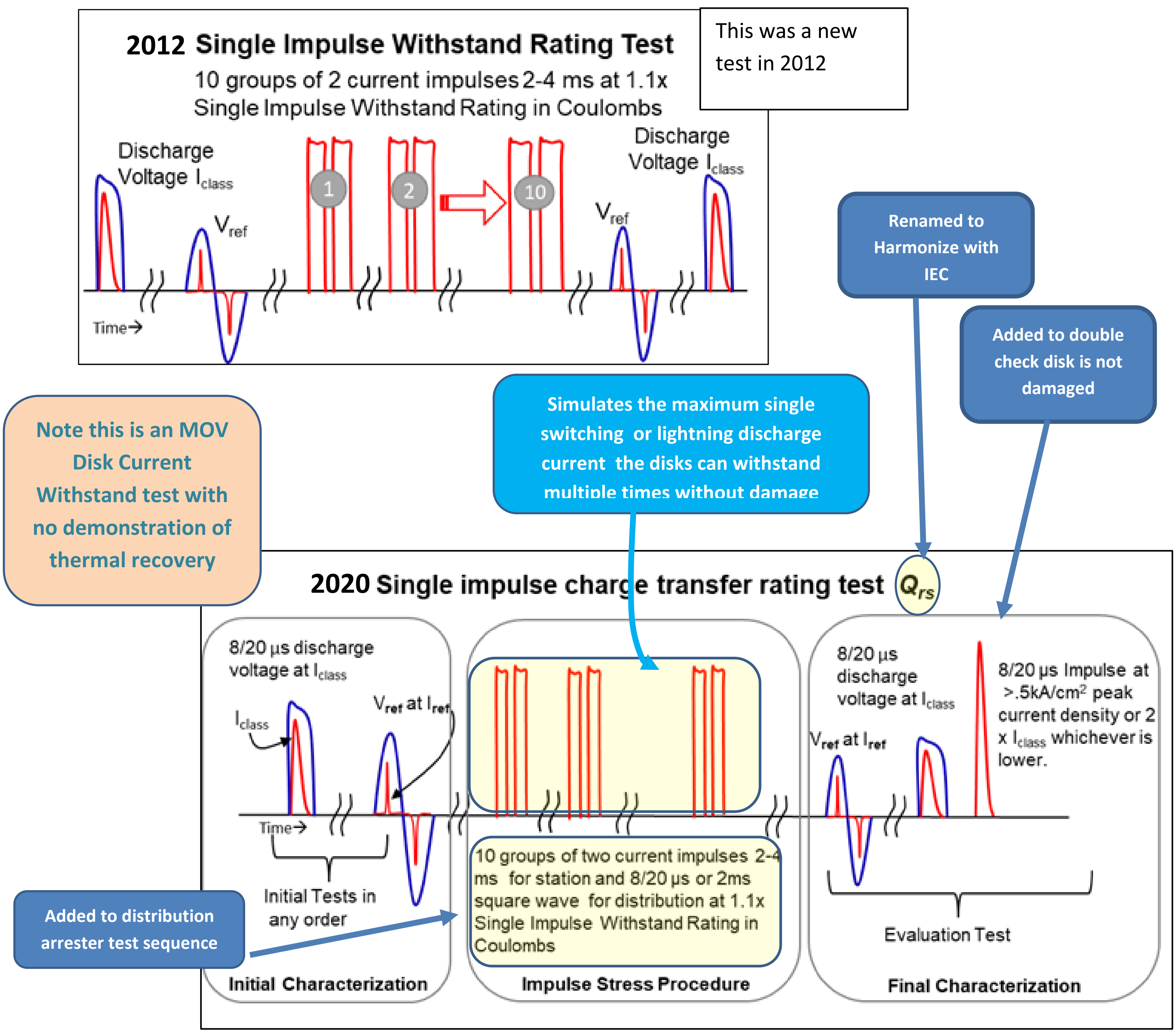
Single-impulse Charge Transfer Rating Test (Q_{rs})

This test was previously called the Single Impulse Withstand Rating Test, for the sake of harmonization it is now referred to as a Charge Transfer Rating Test with the actual parameter of importance being Q_{rs}.

The most significant difference in this test is not the test itself, but the fact that it is now applied to all arresters, not just station class arresters as it had in the past. This change along with a final higher current impulse at the end of the test harmonized this test with IEC 60099-4 and IEC 60099-6. See figure below to compare the details of past and future test procedures.

The one difference between IEC and IEEE with the Q_{rs} rating, is that in the IEEE, there is no minimum for station arresters. In the IEC minimum ratings are given. This may change in either of the standards in the next cycle as more Q_{rs} data evolves.

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

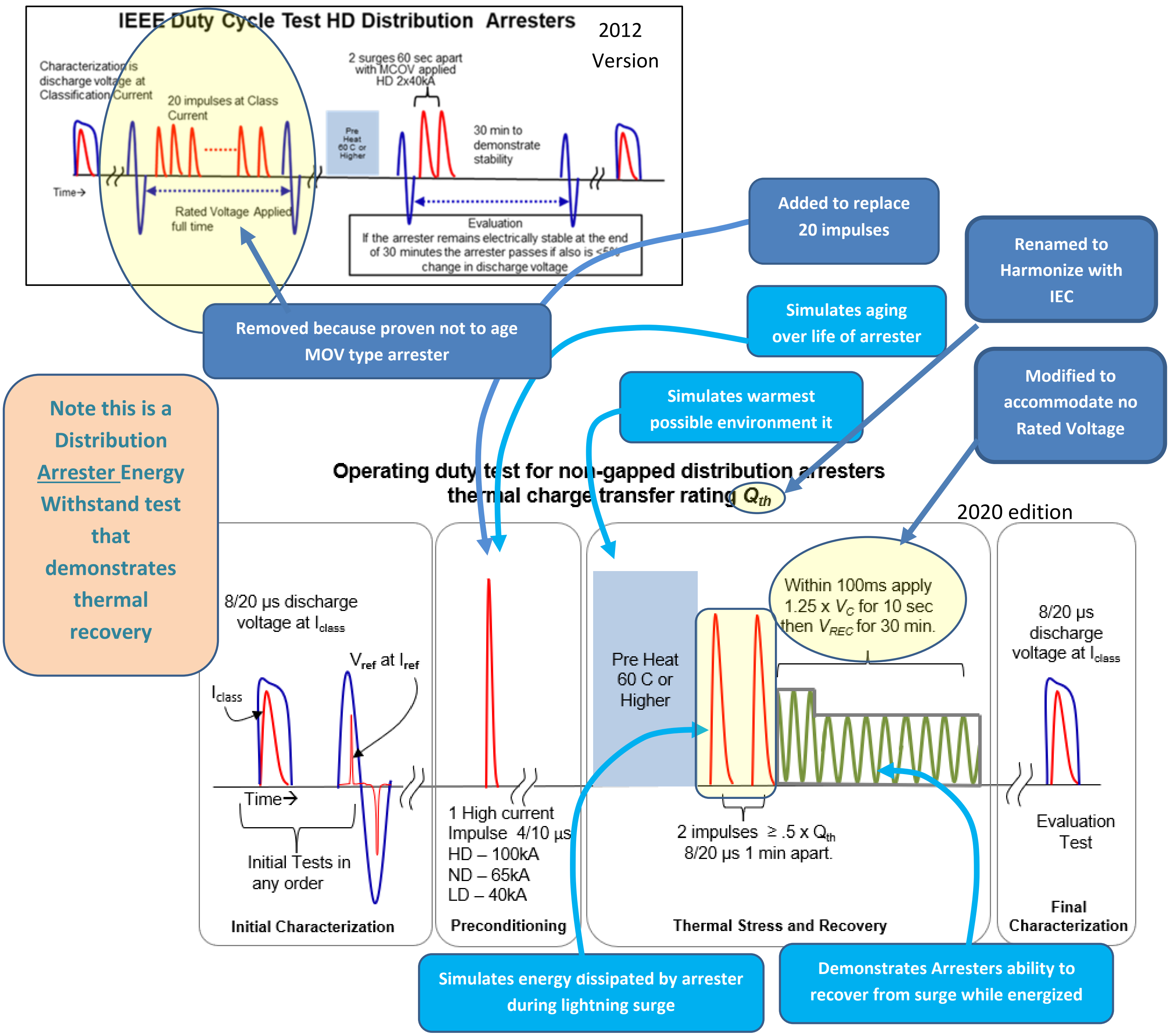


Operating Duty Test for Un-Gapped Distribution Arresters (Q_{th})

The Operating Duty Test was a big change for the IEEE team if it was to harmonize with 60099-4. However, after months of discussion and the separation of the test into gapped and non-gapped procedures it happened. As of the next edition of C62.11, we will have an improved duty cycle test that verifies the thermal charge transfer rating (Q_{th}) of distribution arresters. See below to compare the details of the past and future test procedures.

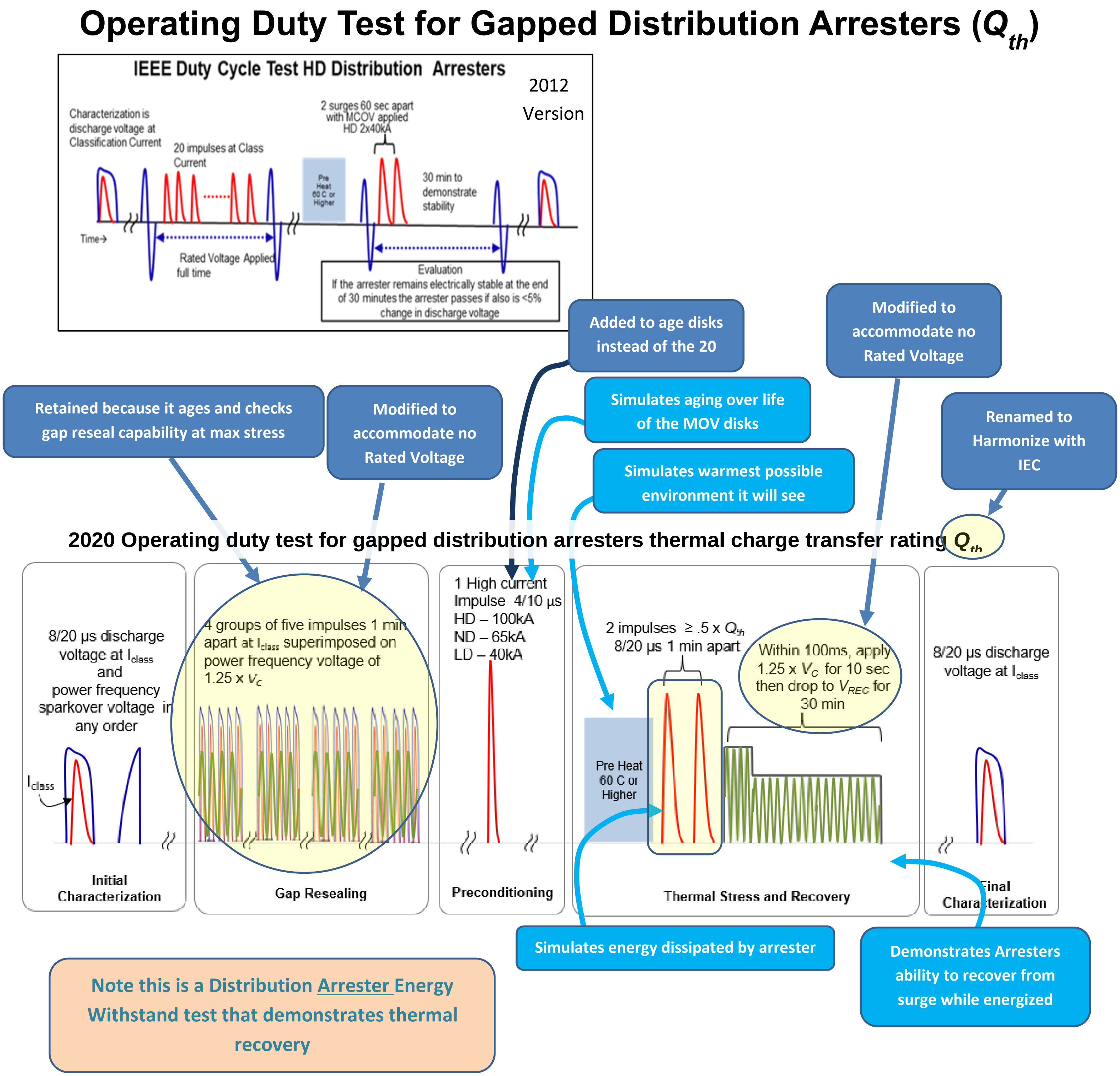
The fundamental difference is that 20 low current (10 kA) preconditioning impulses are replaced with a single high current impulse. This change was accepted because it was clarified in the activity of CIGRE WG A3.17 that the important condition for the verification of thermal stability was the total charge and amplitude of the preconditioning impulses rather than the number of impulses. This work was published in CIGRE TB 544-2013. Because the gapped metal-oxide arrester is not included in this test, the IEEE accepted the removal of the preconditioning impulses at 10 kA with rated voltage applied.

Operating Duty Test for Non-Gapped Distribution Arresters Q_{th})

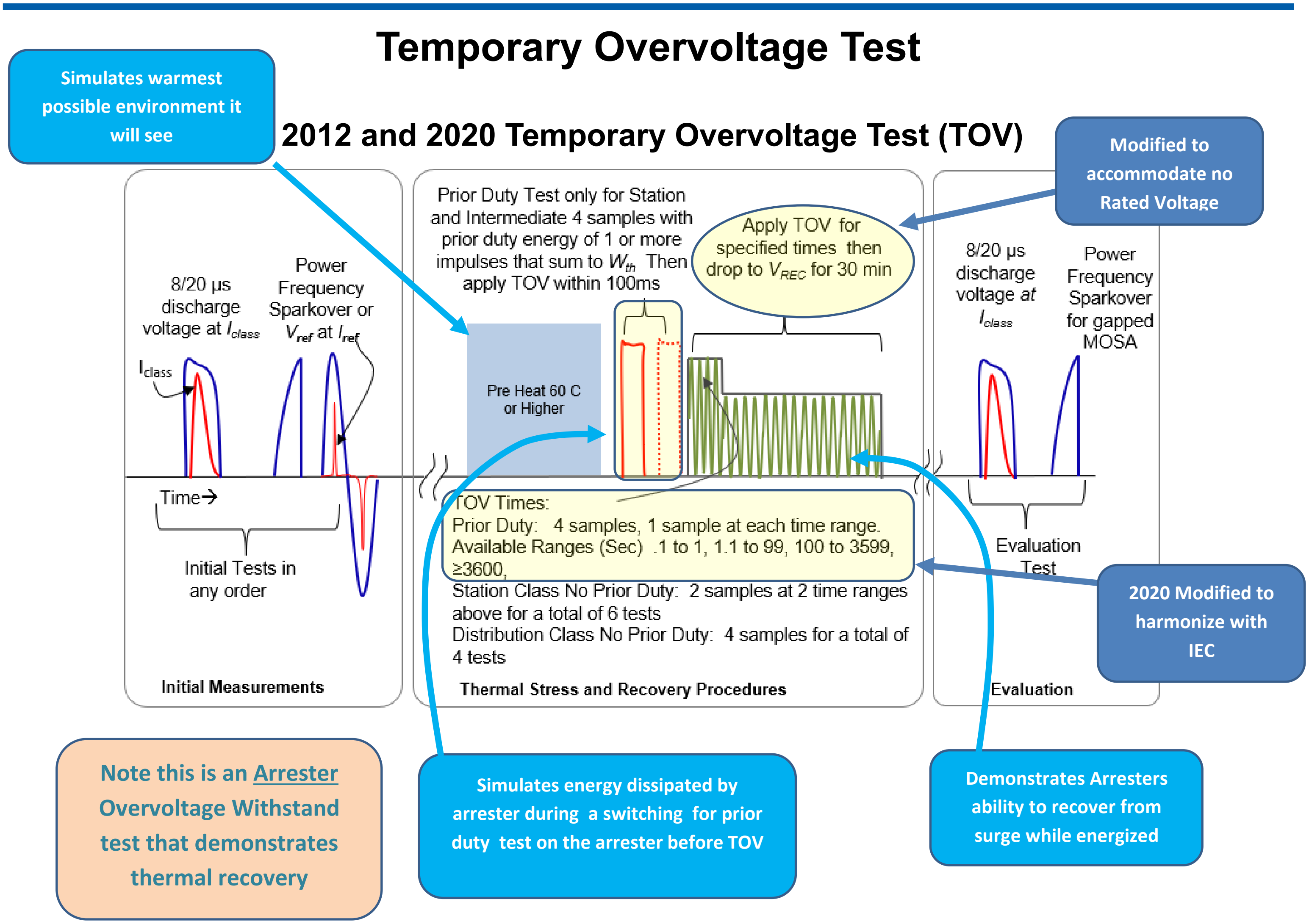


Operating Duty Test for Gapped Distribution Arresters (Q_{th})

The Operating Duty Test for gapped metal-oxide arresters is as follows and is harmonized with IEC 60099-6. It is essentially the same as the Non-gapped metal-oxide arrester test except it still has the 20 preconditioning impulses with AC voltage applied. These preconditioning impulses verify the durability and long term dependability of the gaps of the arrester.



Temporary Overvoltage (TOV) Test
The TOV test was the last of the major tests to be harmonized to IEC 60099-4. Since the test procedures were already very similar, only modification to the overvoltage durations was needed. In the end, even though they are not identical, the two tests can be executed so that they will meet both standards if that is desired. The figure below shows the details of the TOV test procedure.



Tests Removed from the 2020 Edition

High-current Short-duration Test
This test has been in the arrester standard for decades. It was eliminated as a separate test in this edition and rolled into the Operating Duty Test as an means of aging the MOV material. This means of aging the MOV material was proven in the CIGRE work that was published in TB 544-2013.

Low-current Long-duration Test
This test was eliminated as a stand-alone test in the 2020 edition. It had been in the standard since the 1950's but was never really justified since long duration surges are not typically present on distribution systems. A similar type surge has been introduced in the Single Impulse Charge Transfer Test for distribution arresters.

Arrester Disconnector Test Changes

The test objective did not change, however since the High-current Short-duration test and the Low-current Long-duration test were eliminated from the standard, the disconnector test could not include them. Instead the disconnector will now be part of the Single Impulse Charge Transfer Test and the Operating Duty Test. In both of these tests, they must endure the test without operation.

The disconnectors will continue to be tested for proper operation during fault current tests of 20-800 amps.

Closing Thoughts

C62.11-2020 will publish this year, and the next revision of the standard will also start this year. Working Group 3.3.11 is titled continuous revision of C62.11 and that is how we operate. There are several minor tests that still need updating and harmonizing, they are on our hit list.

ArresterFacts are a compilation of facts about arresters to assist all stakeholders in the application and understanding of arresters. All ArresterFacts assume a base knowledge of surge protection of power systems; however, we always welcome the opportunity to assist a student in obtaining their goal, so please call if you have any questions. Visit our library of ArresterFacts for more reading on topics of interest to those involved in the protection of power system at www.arresterworks.com.

About the author:

Jonathan started his career after receiving his Bachelor's degree in Electronic Engineering from The Ohio Institute of Technology, at Fermi National Accelerator Laboratory in Batavia, IL. As an Engineering Physicist at Fermi Lab, he was an integral member of the high energy particle physics team in search of the elusive quark. Wishing to return to his home state, he joined the design engineering team at McGraw Edison (later Cooper Power Systems) in Olean, New York. During his tenure at Cooper, he was involved in the design, development, and manufacturing of arresters. He served as Engineering Manager as well as Arrester Marketing Manager during that time. Jonathan has been active for the last 30 years in the IEEE and IEC standard associations. Jonathan is inventor/co-inventor on five US patents. Jonathan received his MBA from St. Bonaventure University.

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