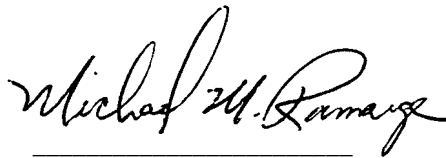


20 kA Class 4
Certified Test Report
IEC 60099-4 2009

CERTIFICATION

*Statements made and data shown are, to the best of our knowledge and belief,
correct and within the usual limits of commercial testing practice.*



Michael M. Ramarge
Arrester Engineering Manager

INTRODUCTION

This test report certifies that the UltraSIL VariSTAR arresters 20 kA- Class 4 were successfully tested to IEC 60099-4:2009 “Metal-Oxide surge arresters without gaps for a.c. systems”.

TEST PROGRAM

OBJECT

To demonstrate that the UltraSIL VariSTAR Arresters 20 kA– Class 4 meet all performance requirements.

PROCEDURE

The following design tests were performed on a sufficient number of samples to demonstrate all performance requirements are met.

TYPE TESTS

- A. Insulation Withstand Test
 - a) Lightning Impulse Voltage Test Per IEC 60099-4 Section 10.8.2.6
 - b) Switching Impulse Voltage Test Per IEC 60099-4 Section 10.8.2.7
 - c) Power Frequency Voltage Test..... Per IEC 60099-4 Section 10.8.2.8
- B. Residual Voltage Test
 - a) Steep Current Impulse Residual Voltage Test ... Per IEC 60099-4 Section 10.8.3.1
 - b) Lightning Impulse Residual Voltage Test Per IEC 60099-4 Section 10.8.3.2
 - c) Switching Impulse Residual Voltage Test Per IEC 60099-4 Section 10.8.3.3
- C. Long Duration Current Impulse
 Withstand Test Per IEC 60099-4 Section 10.8.4.2
- D. Switching Surge Operating Duty Test..... Per IEC 60099-4 Section 10.8.5.5
- E. Power Frequency Voltage vs. Time Per IEC 60099-4 Section 6.10, Annex D
- F. Short Circuit Tests Per IEC 60099-4 Section 10.8.7
- G. Internal Partial Discharge Tests Per IEC 60099-4 Section 10.8.8
- H. Test of the Bending Moment
 - a) Mechanical/Thermal Pre-conditioning..... Per IEC 60099-4 Section 10.8.9.3.1
 - b) Terminal Torque Pre-conditioning..... Per IEC 60099-4 Section 10.8.9.3.1.1
 - c) Thermo Mechanical Pre-conditioning..... Per IEC 60099-4 Section 10.8.9.3.1.2
 - d) Thermal Pre-conditioning Per IEC 60099-4 Section 10.8.9.3.1.3
 - e) Water Immersion Test..... Per IEC 60099-4 Section 10.8.9.3.2
 - f) Test Evaluation Per IEC 60099-4 Section 10.8.9.4
- I. Weather Aging Tests
 - a) Test Series A: 1000 hr Per IEC 60099-4 Section 10.8.14.2.1
- J. Accelerated Ageing Test of the Resistor Blocks.....Per IEC 60099-4 Section 10.8.5.2
- K. Radio Intereference Voltage (RIV) Test.....Per IEC60099-4 Section 10.8.12

RESULTS

The UltraSIL VariSTAR arresters met all performance requirements of IEC 60099-4:2009.

**TEST A:
INSULATION WITHSTAND**

Test Report Number: K-015943-RC-001-R00
Certifying Laboratory: Kinectrics

Object: To demonstrate the voltage withstand capability of the external insulation of the arrester housing.

Lightning Impulse Voltage Test

Procedure: The sample was clean and dry. The sample was subject to fifteen positive and negative 1.2 X 50 μ s impulses.

Results: The sample passed with less than two discharges at the positive and negative voltage values. No internal discharges occurred.

Switching Impulse Voltage Test

Procedure: The sample was subject to fifteen consecutive positive and negative impulses.

Results: The sample passed with less than two discharges at the positive and negative voltage values. No internal discharges occurred.

Power Frequency Voltage Test

Procedure: The sample was clean and tested under wet conditions. The sample was subject to a power frequency voltage of 1.06 times the switching impulse protection level for a period of sixty seconds.

Results: The sample passed with no discharges during the sixty-second period.

**TEST B:
RESIDUAL VOLTAGE TESTS**

Test Report Number: B2002839
Certifying Laboratory: CESI

Object: To determine the maximum discharge voltage for each discharge current.

Steep Current Impulse Residual Voltage Test

Procedure: One steep current impulse was applied to each sample with a peak value equal to the nominal discharge current of the arrester. The current impulse had a front time between 0.9 μ s to 1.1 μ s and the virtual time to half-value on the tail was not longer than 20 μ s.

Lightning Impulse Residual Voltage Test

Procedure: A lightning current impulse was applied to each sample for approximately 0.5, 1, and 2 times the nominal discharge current. The current impulse had a front time between 7 μ s to 9 μ s and the virtual time to half-value on the tail was between 18 μ s to 22 μ s.

Switching Impulse Residual Voltage Test

Procedure: One switching current impulse was applied to each sample at 125 A and 500 A. The current impulse had a front time greater than 30 μ s and less than 100 μ s and a virtual time to half-value of approximately twice the virtual front time.

Results:

Arrester Rating U_r (kV, rms)	Arrester COV U_c (kV, rms)	Steep Current Residual Voltage (kV Crest)	Lightning Impulse Residual Voltage (kV Crest) 8/20 μ s Current Wave						"Switching Impulse Residual Voltage (kV Crest) 30/60 Current Wave"			
			1.5 kA	3 kA	5 kA	10 kA	20 kA	40 kA	125 A	250 A	500 A	1000 A
3	2.55	7.8	6.3	6.6	6.9	7.4	7.9	8.7	5.6	5.7	5.9	6.1
6	5.1	15.5	12.6	13.2	13.7	14.8	15.8	17.4	11.2	11.4	11.8	12.2
9	7.65	23.2	18.9	19.8	20.6	22.2	23.7	26.1	16.7	17.1	17.6	18.3
10	8.4	25.5	20.8	21.7	22.6	24.3	26	28.6	18.4	18.8	19.4	20.1
12	10.2	30.9	25.2	26.4	27.4	29.5	31.6	34.8	22.3	22.8	23.5	24.3
15	12.7	38.5	31.4	32.8	34.1	36.8	39.3	43.3	27.8	28.4	29.3	30.3
18	15.3	46.3	37.8	39.5	41.1	44.3	47.3	52.1	33.4	34.2	35.2	36.5
21	17	51.5	42	43.9	45.6	49.2	52.6	57.9	37.1	38	39.2	40.5
24	19.5	59.1	48.1	50.4	52.3	56.4	60.3	66.4	42.6	43.6	44.9	46.5
27	22	66.6	54.3	56.8	59.1	63.6	68	74.9	48.1	49.2	50.7	52.4
30	24.4	73.9	60.2	63	65.5	70.6	75.4	83.1	53.3	54.6	56.2	58.2
33	27.5	83.3	67.8	71	73.8	79.5	85	93.7	60.1	61.5	63.3	65.5
36	29	87.8	71.5	74.9	77.8	83.9	89.6	98.8	63.3	64.8	66.8	69.1
39	31.5	95.4	77.7	81.3	84.5	91.1	97.4	108	68.8	70.4	72.5	75.1
42	34	103	83.9	87.8	91.2	98.3	106	116	74.2	76	78.3	81
45	36.5	111	90	94.2	97.9	106	113	125	79.7	81.6	84	87
48	39	119	96.2	101	105	113	121	133	85.1	87.2	89.8	92.9
54	42	128	104	109	113	122	130	143	91.7	93.9	96.7	101
60	48	146	119	124	129	139	149	164	105	108	111	115
66	53	161	131	137	143	154	164	181	116	119	122	127
72	57	173	141	148	153	165	177	195	125	128	132	136
78	62	188	153	161	167	180	192	212	136	139	143	148
84	68	206	168	176	183	197	211	232	149	152	157	162
90	72	218	178	186	194	209	223	246	158	161	166	172
96	76	230	188	197	204	220	235	259	166	170	175	181
	77	233	190	199	207	223	238	263	169	173	178	184
108	84	255	208	217	226	243	260	286	184	188	194	201
120	98	297	242	253	263	284	303	334	214	219	226	234
132	106	321	262	274	285	307	328	361	232	237	244	253
138	111	336	274	287	298	321	343	378	243	248	256	265
144	115	348	284	297	309	333	356	392	251	257	265	274
150	120	364	296	310	322	347	371	409	262	269	277	286
162	130	394	321	336	349	376	402	443	284	291	300	310
168	131	397	323	339	352	379	405	446	286	293	302	312
172	140	424	346	362	376	405	433	477	306	313	323	334
180	144	436	355	372	387	417	445	491	315	322	332	343
192	152	460	375	393	408	440	470	518	332	340	350	362
198	160	485	395	413	430	463	495	545	350	358	369	382
204	165	500	407	426	443	477	510	562	361	369	380	393
216	174	527	429	450	467	503	538	593	380	389	401	415
228	180	545	444	465	483	521	557	613	393	403	415	429
240	190	575	469	491	510	550	587	647	415	425	438	453

**TEST C:
LONG DURATION CURRENT IMPULSE WITHSTAND TEST**

Test Report Number: B2011154
Certifying Laboratory: CESI

Object: To demonstrate the ability of the arrester to meet the long duration current impulse withstand test requirements.

Procedure: The sample was subject to eighteen impulses, divided into six groups of three operations, with 50-60 seconds between impulses. The samples cooled to ambient temperature between impulses.

Results: The samples met test requirements with less than 5% change in residual voltage the physical integrity was verified by the oscillogram of the 19th impulse.

**TEST D:
SWITCHING SURGE OPERATING DUTY TEST**

Test Report Number: B2002845
Certifying Laboratory: CESI

Object: To demonstrate the ability of the arrester to meet the switching surge operating duty test requirements.

Procedure: The sample was subject to twenty 8/20 lightning current impulses with a peak value equal to the nominal discharge current of the arrester with the sample at $1.2 * U_C'$. The impulses were divided into four groups of five impulses, with 50-60 s between impulses and 25-30 minutes between groups. The sample was then subject to two $100kA \pm 10kA$ high current impulses. The sample was then subject to two long duration current impulses at an elevated temperature of $60 \pm 3 ^\circ C$ with 50-60 s between impulses. Within 100ms of the second impulse, the sample shall be energized at U_R' for 10s and U_C' for 30 minutes.

Results: The samples met test requirements with less than 5% change in residual voltage, achieving thermal stability. After the test, the two additional long duration current impulse were applied which demonstrated physical integrity and no damage occurred.

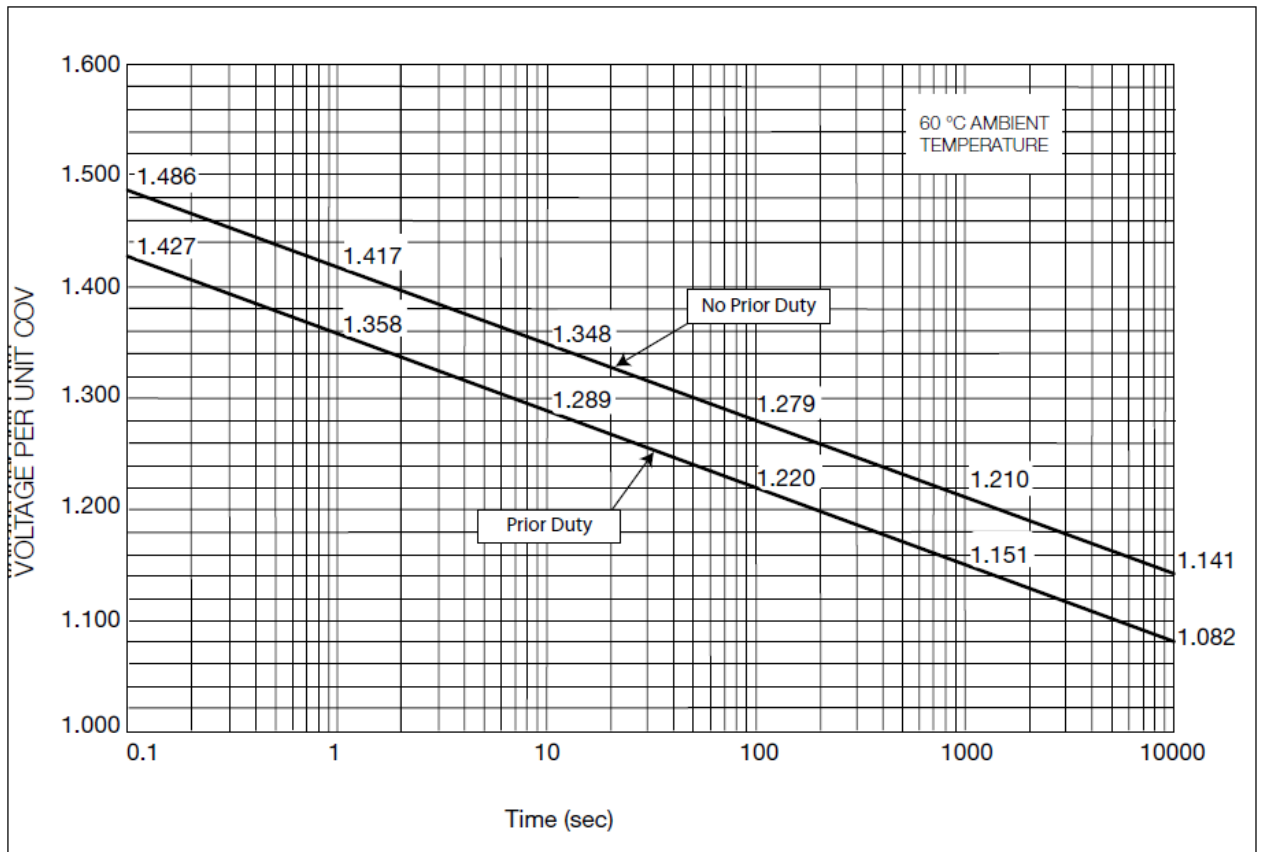
**TEST E:
POWER FREQUENCY VOLTAGE VS. TIME**

Test Report Number: B2002848
Certifying Laboratory: CESI

Object: To determine the over voltage values and time durations for the arrester design.

Procedure: The sample was subjected to two long duration current impulses at an elevated temperature of $60 \pm 3^\circ\text{C}$ with 50-60 s between impulses. The sample was then subject to an over voltage at for the specified time range. The recovery voltage of U_c' was applied to the sample for thirty minutes.

Results:



**TEST F:
SHORT CIRCUIT TEST**

Test Report Number: C11201-K4
Certifying Laboratory: KEMA

Object: To verify arrester internal fault is not likely to create an explosive event.

Procedure: The sample was thermally pre-killed using an over voltage applied for 5 ± 3 minutes. One 72kV arrester was tested at high current of 63kA, low current of 800 Amps and two reduced currents of 25kA and 12kA respectively.

Results: The 72kV arresters tested met the evaluation criteria of no violent shattering, no parts found outside of the test enclosure except for soft polymeric parts, and self-extinguished within 2 minutes.

**TEST G:
INTERNAL PARTIAL DISCHARGE TESTS**

Test Report Number: B2006464
Certifying Laboratory: CESI

Object: To verify the arrester design does not generate excessive partial discharge.

Procedure: The sample was energized to the rated voltage for 2 seconds. The voltage was then lowered to $1.05 * U_C$ and the partial discharge level was recorded.

Results: The samples met test requirements with partial discharge $\leq 10\text{pC}$.

**TEST H:
TEST OF THE BENDING MOMENT**

Test Report Number: B2034556
Certifying Laboratory: CESI

Object: To verify the arrester design's ability to withstand the manufacturer's declared value for bending loads. The test also evaluates the design will not decrease in performance under thermo-mechanical and moisture conditions.

Procedure: The samples were subjected to a series of preconditioning tests including power loss, internal partial discharge, residual voltage, terminal torque, and thermo-mechanical preconditioning. The specified long term load (SLL) of 1600 Nm was applied for 1000 cycles and validated on all three samples. Two samples were then subjected to the specified short term load (SSL) of 2000 Nm, while the other sample was subjected to thermal mechanical pre-conditioning which included thermal variations of two 48 hour cycles of heating and cooling with the direction of the SLL changing every 24 hours. The samples were then immersed in 80°C de-ionized water with 1kg/m³ of NaCl for a period of 52 hours. The samples remained in the water until the temperature cooled to 50 °C. After the samples reached ambient temperature they were tested for changes in power loss, internal partial discharge and residual voltage.

Results: All samples showed no signs of physical damage, the slope of the force-deflection curve remains positive up to the SSL value except for dips not exceeding 5% of the SSL magnitude, demonstrated less than a 20% change in power loss, the internal partial discharge did not exceed 10pC, and there was a less than 5% deviation in residual voltage with no signs of breakdown seen in the voltage and current oscillograms.

**TEST I:
WEATHER AGING TESTS**

TEST SERIES A: 1000 HR

Test Report Number: H 12036
Certifying Laboratory: CESI

Object: To verify the ability of the arrester to withstand continuous salt fog conditions and endure surface arcing and heating.

Procedure: The samples were placed in an enclosure filled with a salt fog mist. The samples were energized at U_C for a period of 1000 hours. The samples underwent pre and post testing consisting of partial discharge and reference voltage.

Results: All samples met the test requirements of: no housing punctures or housing erosion, no internal breakdowns, no surface tracking was evidenced by physical examination, the arrester reference voltage did not decrease by more than 5%, and the partial discharge level did not exceed 10 pC.

**TEST J:
ACCELERATED AGING TEST OF THE RESISTOR BLOCKS**

Test Report Number: B2019437
Certifying Laboratory: CESI

Object: To determine the voltage values U_C' and U_R' for operating duty testing.

Procedure: Samples of the resistor blocks in composite wrap material were at $115^{\circ}\text{C} \pm 4 \text{ K}$ for 1000 hours. Power losses were monitored for the duration of the test.

Results: The power loss ratio between the start of the test and the end power loss was less than 1.0 for all samples. No correction factor during operating duty testing must be applied.

**TEST K:
RADIO INTERFERENCE VOLTAGE (RIV) TEST**

Test Report Number: B2004678
Certifying Laboratory: CESI

Object: To verify that under normal operating conditions the surge arrester does not generate external partial discharges resulting in radio influence voltage exceeding a stated level.

Procedure: The 240kV rated surge arrester was increased to 1.15 x COV, then lowered to 1.05*COV and maintained there for 5 minutes. The voltage was then decreased in approximately 19 kV steps to 0.5*COV and then raised again to 1.05 x COV and maintained for 5 minutes. At each step the RIV was measured, recorded and plotted versus the applied voltage.

Results: All measured values did not exceed the 2500 μ V and therefore the test results were positive.