HUBBELL® POWER SYSTEMS, INC.

IEC Type Test Report
Report No. EU1120-HR2-00.6
Type PDV 100 Polymer Arrester
10,000 A Line Discharge Class 1

This report records the results of this type test made on 10 kA Class 1 arresters rated 3 thru 36 kV in accordance with IEC Standard 60099-4, 2005, "Surge arresters - Part 4: Metal-oxide surge arresters without gaps for a.c. systems."

Type tests performed on 10 kA Class 1 arresters demonstrate full compliance with the relevant clauses of the referenced standard and apply to all Hubbell 10 kA Class 1 arresters of this design manufactured and assembled at the following ISO 9001:2008 certified Hubbell locations:

Hubbell Power Systems
1850 Richland Avenue, East
Aiken, South Carolina
29801

Hubbell Electric (Wuhu) Company, Ltd.
Exports Processing Zone, No 68
North Jiuhua Road, Wuhu City
Anhui Province, PR China

The above locations manufacture, assemble, and test utilizing manufacturing, quality, and calibration procedures developed from Hubbell Engineering Department Specifications. Engineering Department Specifications are controlled by Arrester Business Unit design engineering in the USA.

Dennis W. Lenk

D. W. Lenk
Principal Engineer
Date: 8/27/2012

Separate reports provide details of each test, according to the following table:

Report No.	Description	Clause	Issue date
EU1120-HR2-01.5	Insulation Withstand Test on Arrester Hsg	8.2	8/27/2012
EU1120-HR2-02.3	Residual Voltage	8.3	8/27/2012
EU1120-HR2-03.3	Long Duration Current Withstand	8.4	8/27/2012
EU1120-HR2-04.2	Accelerated Aging Procedure	8.5.2	8/27/2012
EU1120-HR2-05.2	Heat Dissipation Behavior of Test Section	8.5.3	8/27/2012
EU1120-HR2-06.2	High Current Operating Duty	8.5.4	8/27/2012
EU1120-HR2-07.2	Disconnector	8.6	8/27/2012
EU1120-HR2-08.2	Power Frequency Voltage Versus Time	Annex D	8/27/2012
EU1120-HR2-09.1	Short Circuit	Annex N	8/27/2012
EU1120-HR2-10.1	Moisture Ingress	10.8.13	8/27/2012
EU1120-HR2-11.1	Weathering-Series B-5000 Hours	10.8.14.2.2	8/27/2012
EU1120-HR2-12.1	Salt Fog-Series A- 1000 Hours	10.8.14.2.1	8/27/2012

HUBBELL® POWER SYSTEMS, INC.

IEC Type Test Report
Report No. EU1120-HR2-01.5
Polymer Distribution Arresters
10,000 A Line Discharge Class 1

INSULATION WITHSTAND TESTS ON THE ARRESTER HOUSING
IEC CLAUSE 8.2

This report records the results of this type test made on PDV-100™ arresters in accordance with IEC Standard 60099-4, 2005 "Surge arresters - Part 4: Metal-oxide surge arresters without gaps for a.c. systems."

Dennis W. Lenk

D. W. Lenk
Principal Engineer

Date: 8/27/2012

IEC Type Test Report

INSULATION WITHSTAND TESTS ON THE ARRESTER HOUSING
IEC CLAUSE 8.2

Table 1 summarizes polymer housing minimum leakage and strike distances for each arrester rating, and 60 Hz and impulse withstand requirements for each housing size. In all cases, the actual withstand values of each arrester housing exceed the minimum values specified in the Standard.

Table 1. Insulation Withstand Voltage Requirements of PDV-100 Arresters.

						Recommended Clearances						
Ur kV rms	Uc kV rms	IEC Class1 Cat #	Arr Ht mm	Min Leak mm	Min Strike (mm)	Ph-Ph (mm)	Ph-Gnd (mm)	Weight (kg)	IEC Reqd Imp (kVc)	Actual Imp WS Arr Only kVc	IEC reqd wet WS kVc	Actual 1 min wet WS Arr Only kVc
3	2.55	214203	140	390	155	127	76	1.9	13.2	125	8	34
		214403	140	390	155	127	76	1.9	13.2	125	8	34
6	5.1	214205	140	390	155	137	86	1.9	24.9	125	15	34
		214405	140	390	155	137	86	1.9	24.9	125	15	34
9	7.65	214208	140	390	155	152	102	1.9	35.7	125	21	34
		214408	140	390	155	152	102	1.9	35.7	125	21	34
10	8.4	214209	140	390	155	157	107	1.9	39	125	23	34
		214409	140	390	155	157	107	1.9	29	125	23	34
12	10.2	214210	140	390	155	191	140	2	46.3	125	27	34
		214410	275	780	155	191	140	2.8	26.3	125	27	34
15	12.7	214213	216	660	245	216	165	2.6	57.6	180	34	50
		214413	275	780	270	216	165	2.8	57.6	185	34	60
18	15.3	214215	216	660	245	241	191	2.6	68.6	180	40	50
		214415	275	780	270	241	191	2.8	68.6	185	40	60
21	17	214217	216	660	245	254	203	2.8	80	180	47	50
		214417	275	780	270	254	203	2.8	80	185	47	60
24	19.5	214220	274	780	285	270	220	3.4	93.7	210	55	65
		214420	414	1170	400	270	220	4.2	93.7	250	55	90
27	22	214222	437	1320	455	280	230	4.4	104	280	61	100
		214422	414	1170	400	280	230	4.2	104	250	61	90
30	24.4	214224	437	1320	455	290	240	4.4	116	280	68	100
		214424	414	1170	400	290	240	4.2	125	250	74.8	90
36	29	214230	437	1320	455	330	290	4.9	138	280	82	100
		214430	550	1560	530	330	290	5.6	138	325	82	110

42	33	214233	437	1320	455	380	340	4.9	160	280	95	100
		214433	700	1950	660	380	340	7	160	390	95	125
45	36	214236	643	1980	665	400	370	5.9	173	400	102	130
		214436	700	1950	660	400	370	7	208	390	125	125
48	39	214240	643	1980	665	430	390	5.9	186	400	109	130
		214440	720	2340	790	430	390	8.2	186	450	109	145

HUBBELL® POWER SYSTEMS, INC.

IEC Type Test Report
Report No. EU1120-HR2-02.3
Polymer Distribution Arresters
10,000 A Line Discharge Class 1

RESIDUAL VOLTAGE TESTS
IEC CLAUSE 8.3

This report records the results of this type test made on PDV-100™ arresters in accordance with IEC Standard 60099-4, 2004-05 "Surge arresters - Part 4: Metal-oxide surge arresters without gaps for a.c. systems."

Dennis W. Lenk

D. W. Lenk
Principal Engineer

Date: 8/27/2012

IEC Type Test Report

RESIDUAL VOLTAGE TESTS
IEC CLAUSE 7.3

Sample Preparation

Residual voltage tests were performed on three prorated test samples. Each test sample consisted of two (2) 40-mm diameter MOV discs.

Test Procedure

The following tests were performed on each sample. Each sample was allowed to cool to ambient temperature between discharges.

1. Steep Current Impulse Residual Voltage Test: 1/2 µs, 10 kA;
2. Lightning Impulse Residual Voltage Test: 8/20 µs, 1.5, 2.5, 3, 5, 10, 20, and 40 kA;
3. Switching Impulse Residual Voltage Test: 30-100/60-200 µs, 125 and 500 A.

Test Results

Each of the three test samples was subjected to a 10 kA, 1/2 µs steep current impulse. Figure 1 shows the oscillogram of the discharge of Sample 1.

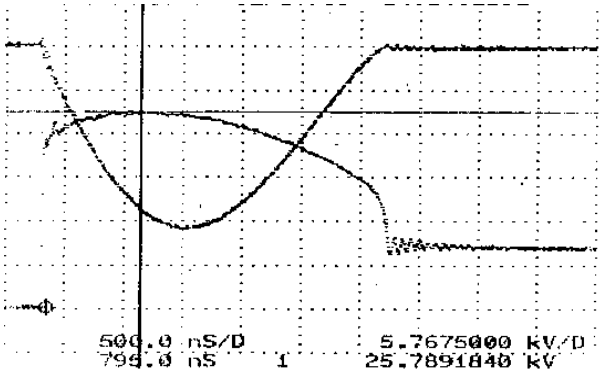


Figure 1. Sample 1, 10.16 kA, 25.79 kV, 1.0/2.2 µs.

Each sample was then subjected to 1.5, 2.5, 3, 5, 10, 20, and 40-kA lightning surge impulses. Figures 2 - 8 show oscillograms of the discharges of Sample 1.

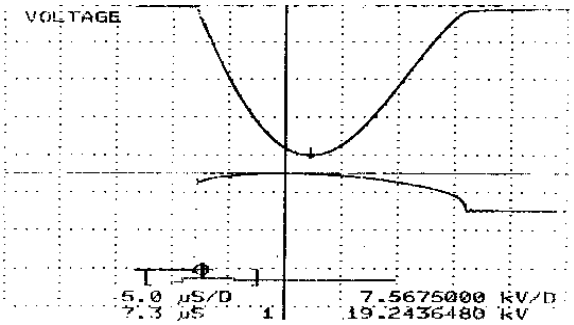


Figure 2. Sample 1, 1.51 kA, 19.24 kV, 8.0/18.8 µs.

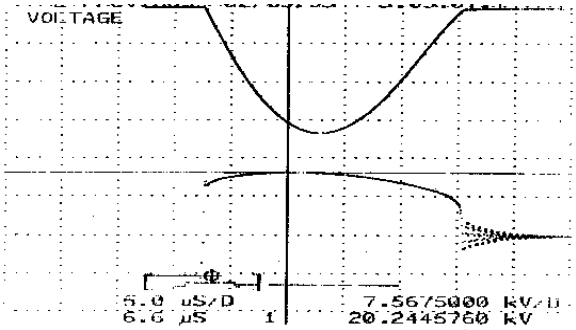


Figure 3. Sample 1, 2.52 kA, 20.25 kV, 8.0/18.4 µs.

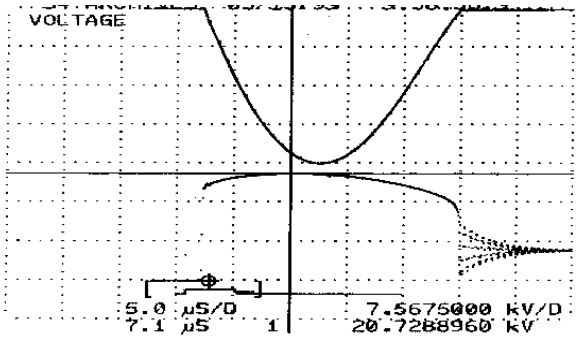


Figure 4. Sample 1, 3.04 kA, 20.73 kV, 8.2/18.3 µs.

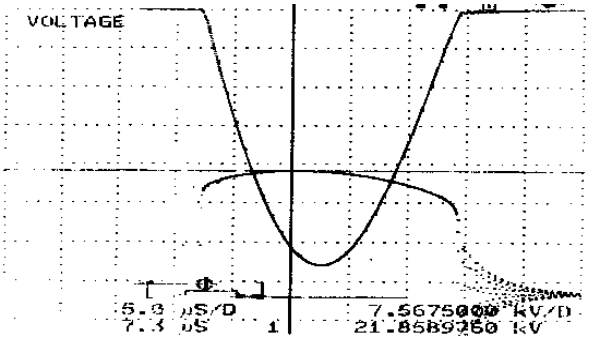


Figure 5. Sample 1, 5.03 kA, 21.86 kV, 8.1/18.1 µs.

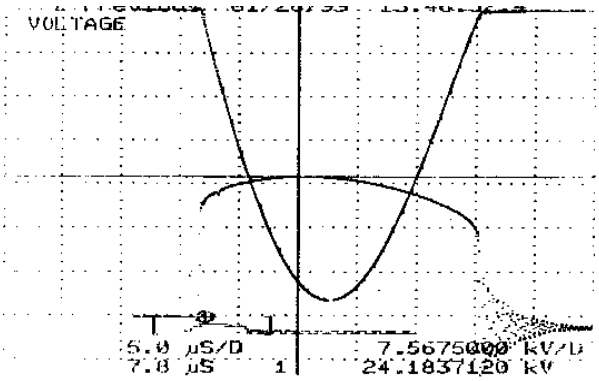


Figure 6. Sample 1, 10.15 kA, 24.18 kV, 8.6/18.5 µs.

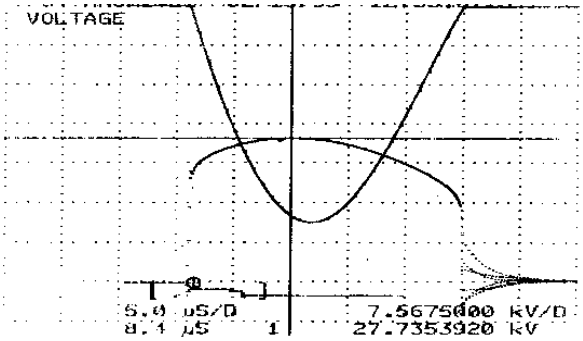


Figure 7. Sample 1, 20.95 kA, 27.74 kV, 8.5/19.2 µs.

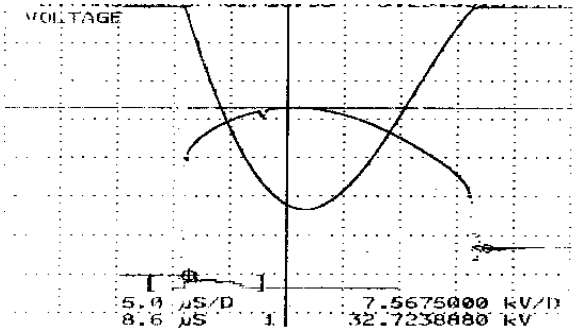


Figure 8. Sample 1, 40.50 kA, 32.72 kV, 8.5/19.7 µs.

Each sample was finally subjected to 125 and 500 A switching surge impulses. Figures 9 and 10 show oscillograms of the discharges of Sample 1.

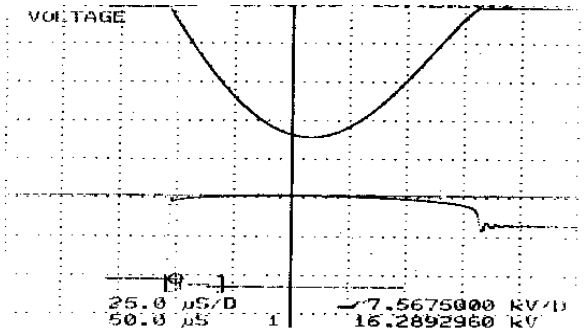


Figure 9. Sample 1, 126.7 A, 16.29 kV, 51/102 µs.

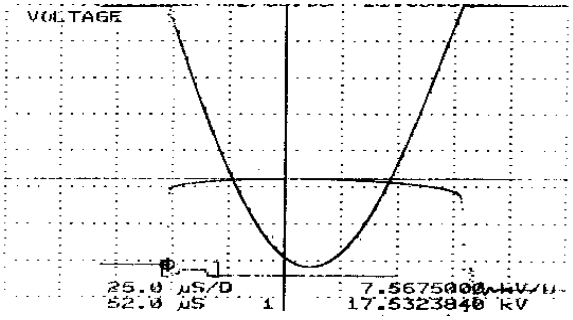


Figure 10. Sample 1, 534.7 A, 17.53 kV, 62.5/108 µs.

Test Summary

Table 1 summarizes residual voltage measurements for the three test samples. The residual voltage of each MOV disc is measured as a routine test with a discharge current of 10 kA, 8/20 µs. The MOV discs of each arrester are accumulated within 10 kA residual voltage ranges as specified for each arrester rating. To verify the catalog maximum residual voltage levels, a discharge voltage ratio was established at each current level based on the 10 kA residual voltage of each test sample, as shown in Table 1. This ratio was multiplied by the maximum 10-kA residual voltage accumulation specified for each rating. As summarized on Table 2, the residual voltage calculated based on the prorated test samples were under the maximum declared catalog levels.

Table 1. Residual Voltage Test.

Impulse Current (A)	Wave Shape (μs/μs)	Discharge Voltage (kV)			Discharge Voltage Ratio (IR/10 kV IR)		
		Sample 1	Sample 2	Sample 3	Sample 1	Sample 2	Sample 3
125	60/100	16.289	16.225	16.144	0.674	0.671	0.670
500	60/100	17.532	17.468	17.371	0.725	0.722	0.721
1500	8/20	19.244	19.260	19.163	0.796	0.796	0.796
2500	8/20	20.245	20.244	20.132	0.837	0.837	0.836
3000	8/20	20.729	20.664	20.567	0.857	0.854	0.854
5000	8/20	21.859	21.875	21.778	0.904	0.905	0.904
10000	8/20	24.184	24.184	24.087	1.000	1.000	1.000
20000	8/20	27.735	27.655	27.622	1.147	1.144	1.147
40000	8/20	32.724	32.740	32.611	1.353	1.354	1.354
10000	1/2	25.789	25.986	25.592	1.066	1.075	1.062

Table 2. Summary of Arrester Discharge Voltages

Uc kV	Ur kV	IR Multipliers, Max.	0.674	0.725	0.796	0.857	0.905	1	1.147	1.354	1.075
		Impulse Wave (μs/μs)	60/100	60/100	8/20						1/2
		Current Magnitude (kA)	0.125	0.5	1.5	3	5	10	20	40	10
2.55	3	Guaranteed IR (kV)	6.8	7.3	8.0	8.7	9.1	10.1	11.6	13.7	10.9
		Max Prorated Sample IR	6.7	7.2	8.0	8.6	9.0	10.0	11.5	13.5	10.7
5.1	6	Guaranteed IR (kV)	12.9	13.8	15.2	16.4	17.3	19.1	21.9	25.9	20.5
		Max Prorated Sample IR	12.7	13.7	15.0	16.2	17.1	18.9	21.7	25.6	20.3
7.65	9	Guaranteed IR (kV)	18.2	19.6	21.5	23.2	24.5	27	30.1	36.6	29.1
		Max Prorated Sample IR	18.0	19.4	21.3	22.9	24.2	26.7	29.9	36.2	28.7
8.4	10	Guaranteed IR (kV)	20.2	21.8	23.9	25.7	27.2	30	34.4	40.6	32.3
		Max Prorated Sample IR	19.9	21.4	23.5	25.3	26.7	29.5	33.8	39.9	31.7
10	12	Guaranteed IR (kV)	23.1	25.0	27.3	29.4	31.0	34.3	39.3	46.4	36.8
		Max Prorated Sample IR	23.1	24.8	27.3	29.3	30.9	34.2	39.2	46.3	36.7
12.7	15	Guaranteed IR (kV)	28.8	31.0	34.0	36.7	38.7	42.8	49.0	57.9	46.0
		Max Prorated Sample IR	28.7	30.8	33.9	36.4	38.5	42.5	48.8	57.6	45.7
15.3	18	Guaranteed IR (kV)	35.5	38.2	41.9	45.2	47.7	52.7	60.4	71.4	56.7
		Max Prorated Sample IR	35.2	37.8	41.5	44.7	47.2	52.18	59.9	70.7	56.1
17	21	Guaranteed IR (kV)	40.4	43.8	48.0	51.3	53.4	60	68.2	80.2	64.5
		Max Prorated Sample IR	40.0	43.1	47.3	50.9	53.8	59.4	68.1	80.1	63.9
19.5	24	Guaranteed IR (kV)	46.2	50.0	54.6	58.7	62.0	68.5	78.6	92.8	73.6
		Max Prorated Sample IR	46.2	49.6	54.5	58.7	62.0	68.4	78.5	92.7	73.6

22	27	Guaranteed IR (kV)	52.0	55.9	61.4	66.1	69.8	77.1	88.4	104.4	82.9
		Max Prorated Sample IR	51.8	55.7	61.1	65.8	69.5	76.8	88.1	104.0	82.6
24.4	30	Guaranteed IR (kV)	57.6	62.0	68.1	73.3	77.4	85.5	98.1	115.8	91.9
		Max Prorated Sample IR	57.3	61.6	67.7	72.8	76.9	85	97.5	115.1	91.4
29	36	Guaranteed IR (kV)	71.4	76.9	84.4	90.8	95.9	106	121.6	143.5	114.0
		Max Prorated Sample IR	70.3	75.6	83.0	89.4	94.4	104.3	119.6	141.2	112.1
33	39	Guaranteed IR (kV)	80.9	87.6	96.0	102.4	106.8	120	136.4	162.4	129.0
		Max Prorated Sample IR	80.1	86.1	94.6	101.8	107.5	118.8	136.3	160.9	127.7
36.5	45	Guaranteed IR (kV)	86.5	93.0	102.0	109.8	116.1	128.4	147.0	173.7	138.0
		Max Prorated Sample IR	86.0	92.5	101.6	109.4	115.5	127.6	146.4	172.8	137.2
39	48	Guaranteed IR (kV)	93.2	100.2	109.9	118.4	125.1	138.3	158.4	187.2	148.7
		Max Prorated Sample IR	92.5	99.5	109.2	117.6	124.2	137.2	157.4	185.8	147.5

HUBBELL® POWER SYSTEMS, INC.

IEC Type Test Report
Report No. EU1120-HR2-03.3
Polymer Distribution Arresters

10,000 A Line Discharge Class 1

LONG DURATION CURRENT IMPULSE WITHSTAND TESTS
IEC CLAUSE 8.4

This report records the results of this type test made on PDV-100™ arresters in accordance with IEC Standard 60099-4, 2004-05 "Surge arresters - Part 4: Metal-oxide surge arresters without gaps for a.c. systems."

Dennis W. Lenk

D. W. Lenk
Principal Engineer

Date: 8/27/2012

IEC Type Test Report

LONG DURATION CURRENT IMPULSE WITHSTAND TESTS
IEC CLAUSE 8.4

Sample Preparation

Long duration current impulse withstand tests were performed on three test samples. Each test sample consisted of two (2) 40-mm diameter MOV discs. The length of the two discs was 35 and 28 mm, respectively. MOV discs for each test sample were selected to represent the lowest acceptable reference voltage level.

Test Parameters and Procedure

Three samples were subjected to line discharge tests in accordance with line discharge Class 1 in Table 4 of Clause 8.4. All generator parameters conformed to Class 1 line discharge requirements as defined. Prior to the transmission line discharge tests, 10 kA, 8/20 µs discharge voltage and reference voltage of the test samples were measured. Initial measurements and associated parameters for the three samples are given in Table 1.

Table 1. Parameters for Line Discharge Tests
on 10 kA Line Discharge Class 1 Arrester Samples.

Test Parameters	Sample 1	Sample 2	Sample 3
Initial Residual Voltage (kV) @ 10 kA, 8/20 µs	25.23	25.30	25.48
Reference Current (mA) I_{ref}	5	5	5
Reference Voltage (kV_c) V_{ref}	14.36	14.49	14.50
COV (kV rms) U_c	8.01	8.08	8.09
Rating (kV rms) U_r	9.94	10.03	10.04
Arrester Classification (kA)	10	10	10
Line Discharge Class	1	1	1
Virtual Duration of Peak (µs, 90-90%)	2206	2206	2206
Max. Generator Impedance (Ω) Z_g	48.71	49.16	49.21
Min. Generator Charging Voltage (kV) U_L	31.81	32.10	32.14

The transmission line discharge tests defined by IEC Standard 60099-4, 2004-05, consisted of subjecting each test sample with eighteen rectangular waveshape discharges. The eighteen discharges were of six groups with three consecutive operations at a time interval of 50 to 60 seconds between the consecutive operations. The samples were allowed to cool to ambient temperature between groups of discharges.

Test Results

Figure 1 shows the surge impedance of the transmission line generator and confirms the virtual duration of the generator. The samples were exposed to still air at ambient temperature of 21 °C during the test. A summary of the test results is shown in Table 2.

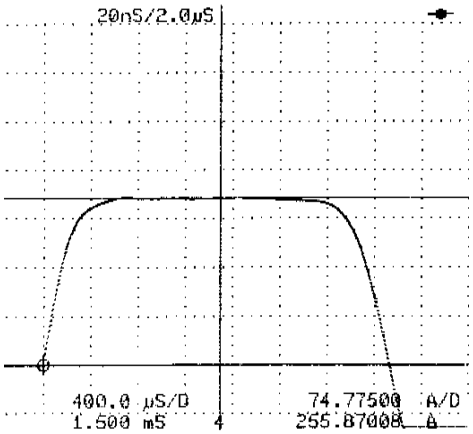
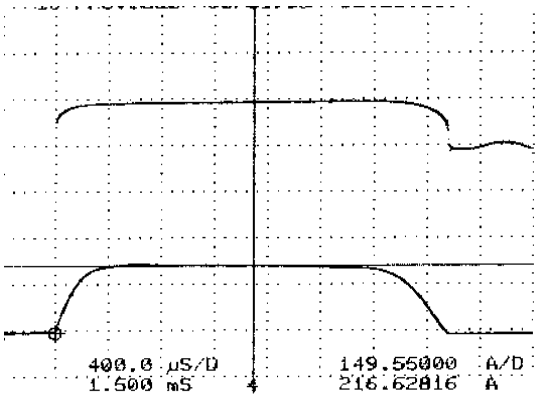


Figure 1. Z_g = 5066 V / 255.9 A = 19.80 Ω, Virtual Peak Duration = 2206 µs.

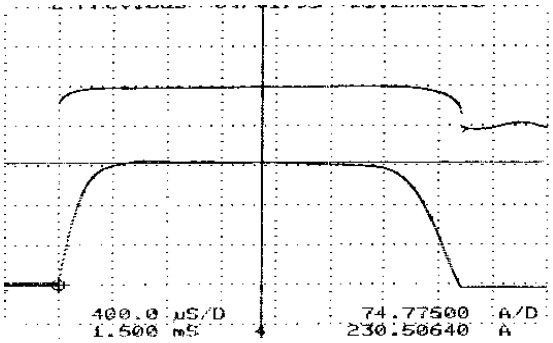
Table 2. Transmission Line Discharge Tests.

Impulse	Sample 1			Sample 2			Sample 3		
	I (A)	V (kV)	E (kJ)	I (A)	V (kV)	E (kJ)	I (A)	V (kV)	E (kJ)
1	235	18.41	11.15	233	18.39	11.09	221	18.59	10.66
2	221	18.53	10.63	223	18.52	10.72	212	18.70	10.33
3	217	18.64	10.46	219	18.63	10.58	215	18.80	10.46
4	233	18.44	11.14	237	18.45	11.34	229	18.62	11.03
5	224	18.56	10.80	229	18.55	11.01	219	18.74	10.62
6	221	18.66	10.69	223	18.65	10.79	214	18.81	10.46
7	233	18.50	11.17	235	18.48	11.27	225	18.64	10.90
8	224	18.61	10.82	225	18.58	10.85	218	18.77	10.59
9	219	18.70	10.62	220	18.66	10.66	213	18.83	10.37
10	231	18.51	11.07	235	18.50	11.27	224	18.69	10.82
11	224	18.63	10.81	224	18.62	10.84	216	18.76	10.48
12	219	18.72	10.59	221	18.70	10.71	213	18.85	10.38
13	231	18.53	11.09	231	18.50	11.07	234	18.71	11.36
14	221	18.63	10.66	235	18.66	11.34	227	18.82	11.06
15	217	18.74	10.55	229	18.76	11.14	221	18.89	10.83
16	242	18.59	11.65	243	18.57	11.69	237	18.70	11.48
17	233	18.70	11.30	235	18.67	11.36	227	18.85	11.06
18	228	18.77	11.10	230	18.76	11.19	224	18.93	10.95

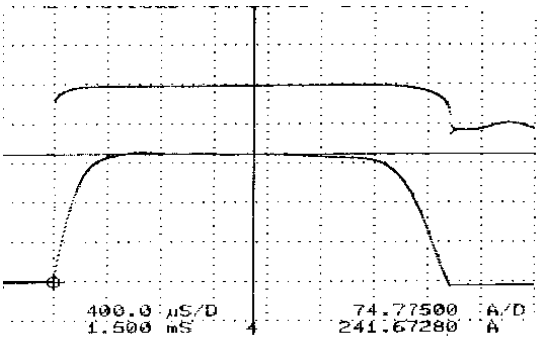
Figure 2 shows oscillograms of the third, tenth and sixteenth transmission line discharge of sample 1.



Sample 1, Shot 3, Discharge Current = 217 A
Discharge Voltage = 18.64 kV, Energy under V-I Curve = 10.46 kJ



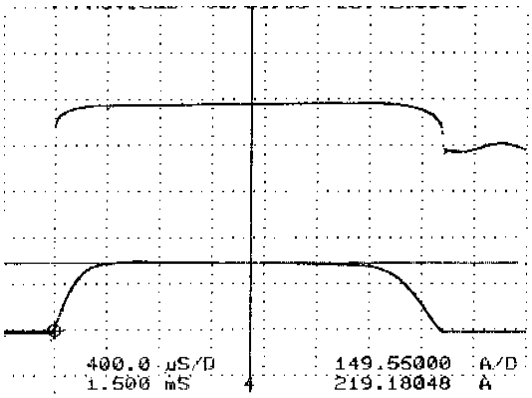
Sample 1, Shot 10, Discharge Current = 231 A
Discharge Voltage = 18.51 kV, Energy Under V-I Curve = 11.07 kJ



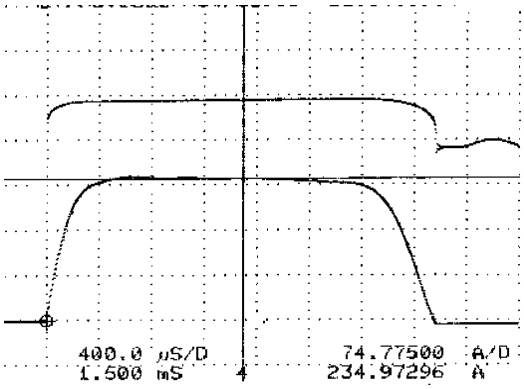
Sample 1, Shot 16, Discharge Current = 242 A
Discharge Voltage = 18.59 kV, Energy Under V-I Curve = 11.65 kJ

Figure 2. Transmission line discharges of sample 1.

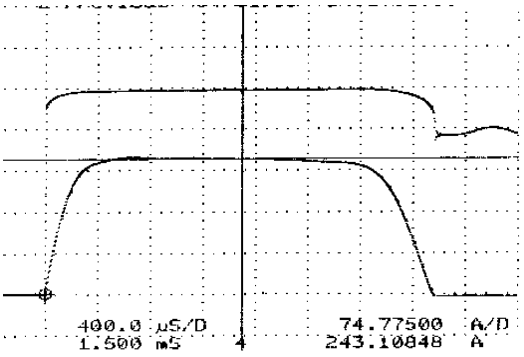
Figure 3 shows oscillograms of the third, tenth and sixteenth transmission line discharge of sample 2.



Sample 2, Shot 3, Discharge Current = 219 A
Discharge Voltage = 18.63 kV, Energy Under V-I Curve = 10.58 kJ



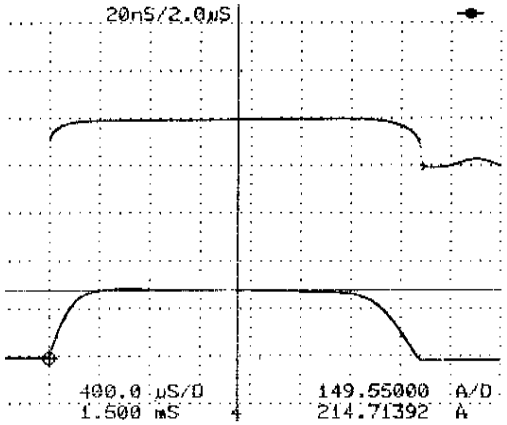
Sample 2, Shot 10, Discharge Current = 235 A
Discharge Voltage = 18.50 kV, Energy Under V-I Curve = 11.27 kJ



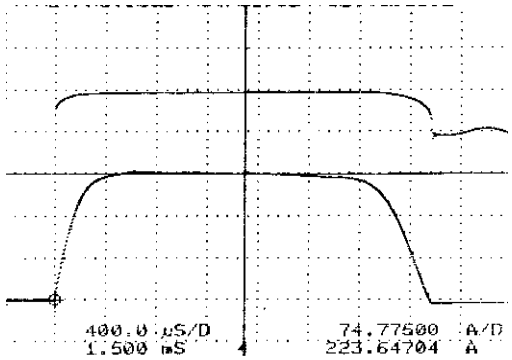
Sample 2, Shot 16, Discharge Current = 243 A
Discharge Voltage = 18.57 kV, Energy Under V-I Curve = 11.69 kJ

Figure 3. Transmission line discharges of sample 2.

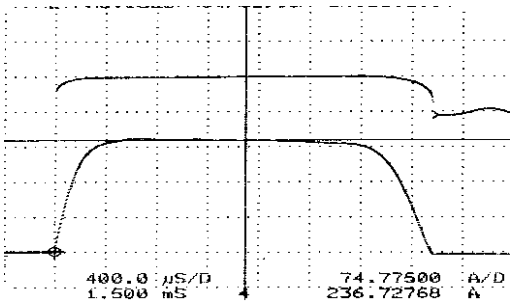
Figure 4 shows oscillograms of the third, tenth and sixteenth transmission line discharge of sample 3.



Sample 3, Shot 3, Discharge Current = 215 A
Discharge Voltage = 18.80 kV, Energy Under V-I Curve = 10.46 kJ



Sample 3, Shot 10, Discharge Current = 224 A
Discharge Voltage = 18.69 kV, Energy Under V-I Curve = 10.82 kJ



Sample 3, Shot 16, Discharge Current = 237 A
Discharge Voltage = 18.70 kV, Energy Under V-I Curve = 11.48 kJ

Figure 4. Transmission line discharges of sample 3.

Subsequent to the completion of the transmission line discharges, 10 kA, 8/20 µs discharge voltage of the three test samples was measured. Results of the residual voltage measurements are summarized in Table 3. The maximum change of residual voltage of the three samples is less than the permissible change of 5 % defined by IEC Standard 60099-4, 2004-05.

Table 3. Residual Voltage (10 kA, 8/20 µs) Measurements
before and after Transmission Line Discharges.

SAMPLE	RESIDUAL VOLTAGE (kV)		CHANGE (%)
	Before	After	
1	25.23	25.54	1.23
2	25.30	25.49	0.75
3	25.48	25.85	1.45

Test Summary

The three test samples successfully passed the transmission line discharge tests per Section 8.4 of IEC Standard 60099-4, 2004-05. For all three samples, the change of 10 kA, 8/20 µs residual voltage measured before and after the transmission line discharges is less than 5%. Disassembly revealed no evidence of physical damage to the three test samples. Each of the three test samples has fulfilled the transmission line discharge requirements of IEC Class 1 arresters.

HUBBELL® POWER SYSTEMS, INC.

IEC Type Test Report
Report No. EU1120-HR2-04.2
Polymer Distribution Arresters

10,000 A Line Discharge Class 1

ACCELERATED AGEING PROCEDURE
IEC CLAUSE 8.5.2

This report records the results of this type test made on PDV-100™ arresters in accordance with IEC Standard 60099-4, 2004-05 "Surge arresters - Part 4: Metal-oxide surge arresters without gaps for a.c. systems."

Dennis W. Lenk

D. W. Lenk
Principal Engineer

Date: 8/27/2012

IEC Type Test Report

ACCELERATED AGEING PROCEDURE
IEC CLAUSE 8.5.2

Tests were performed to measure the MOV disc aging characteristics. Measured watts loss values are used to develop an elevated voltage ratio K_{ct} that is used in the operating duty test to simulate the performance of an arrester with service life equivalent to 1000 hours at 115 °C.

Sample Preparation

Three test samples were prepared. Each sample consisted of a 40-mm diameter MOV disc with standard module construction.

Test Procedure

Accelerated aging tests were performed per Section 8.5.2 of IEC Standard 60099-4, 2004-05. Test samples were energized by a voltage equal to the corrected maximum continuous operating voltage U_{ct} of the three test samples for 1000 hours at 115 °C ± 2 °C.

Individual watts loss and temperature were measured at U_{ct} at the start (2 hours) and at the end (1000 hours) of the aging tests after energization. The initial watts loss is designated as P_{1ct} while the final watts loss is P_{2ct}. Table 1 summarizes the results of the 1000 hour accelerated aging tests. The watts loss values were measured at 115 °C ± 2 °C.

Table 1. Accelerated Aging Tests.

Sample	Length of Sample (mm)	Reference Voltage U_{ref} (kV_c)	Maximum COV U_c (kV_c)	Actual Test Voltage U_{ct} (kV_c)	Watts Loss at 2 Hr P_{1ct} (W)	Watts Loss at 1000 Hr P_{2ct} (W)	Elevation Factor K_{ct}
1	35	8.08	6.37	6.51	1.451	0.879	1.0
2	35	7.89	6.23	6.51	1.697	1.016	1.0
3	35	8.08	6.37	6.51	1.397	0.838	1.0

Test Summary

For each sample, the final watts loss value at U_{ct} is less than the initial watts loss value measured. Therefore, no elevation factors were required to apply to COV (U_c) or Rating (U_r) during the operating duty tests.

HUBBELL® POWER SYSTEMS, INC.

IEC Type Test Report
Report No. EU1120-HR2-05.2
Polymer Distribution Arresters

10,000 A Line Discharge Class 1

HEAT DISSIPATION BEHAVIOUR OF TEST SAMPLES
IEC CLAUSE 8.5.3

This report records the results of this type test made on PDV-100™ arresters in accordance with IEC Standard 60099-4, 2004-05 "Surge arresters - Part 4: Metal-oxide surge arresters without gaps for a.c. systems."

Dennis W. Lenk

D. W. Lenk
Principal Engineer

Date: 8/27/2012

IEC Type Test Report

HEAT DISSIPATION BEHAVIOUR OF TEST SAMPLES
IEC CLAUSE 8.5.3

Tests were performed in accordance with Annex B of IEC Standard 60099-4, 2004-05. The purpose of this test was to verify that the thermal cooling curve of the arrester prorated sections, when internally heated, cools slower than that of full size arrester units.

Sample Preparation

Full size single module 21 kV rated arresters and thermally prorated arrester sections of approximatly10 kV rating were built. The 21 kV rated arrester was chosen as it is of the highest percent MOV mass per unit arrester length, the lowest mass per unit COV, and the highest V_{ref} per unit length at minimum design tolerance. Figure 1 provides a sketch of the thermally prorated test section.

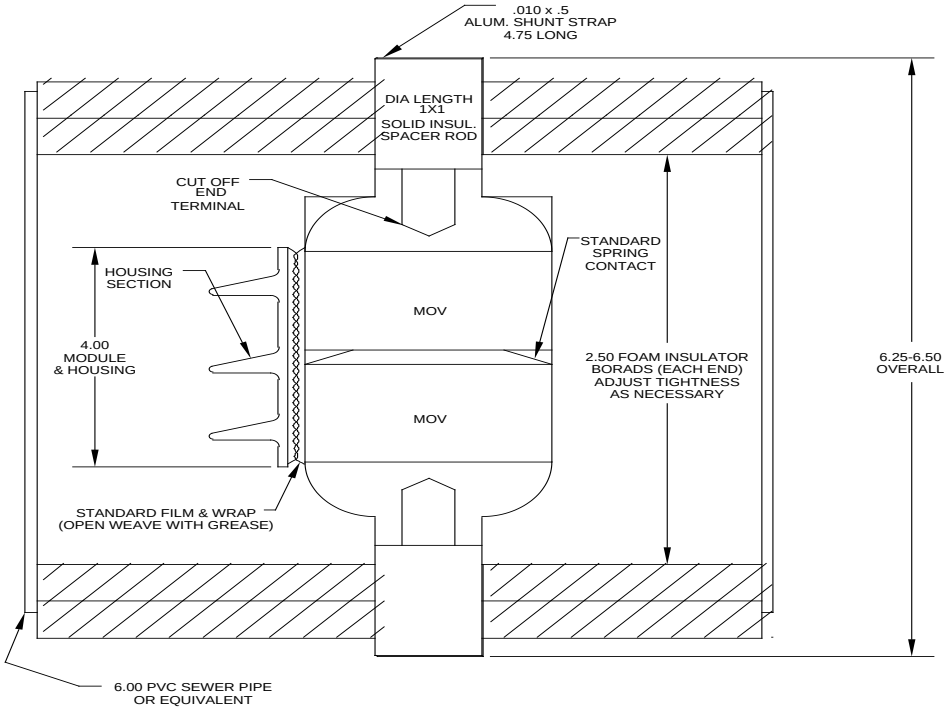


Figure 1. Thermal Section, all dimensions in inches.

Thermocouples were located 1/3 of the distance from the top of the 21 kV arrester and at the midpoint of the thermal test section. In both cases, the thermocouples were located between MOV discs.

Test Procedure

The test units were placed in still air at ambient temperature. Full arresters and prorated arrester sections were simultaneously heated using a 60 Hz source. The target temperature was 120 - 130 °C with the test lab ambient temperature at 22 °C. The duration of the applied voltage was approximately 10 minutes which is essentially the same for the arrester and the section, while the total test heating time was under 15 minutes. Voltage was turned off 4 times during the test to allow monitoring of temperatures with thermocouples. The "off" periods were between 30 - 60 seconds long.

Upon achieving the desired disc temperature, thermocouples were attached to a data logger and temperature was monitored continuously for 2 hours.

Test Summary

Figure 2 contains the cooling curves that verified that the 21 kV arrester cooling rate was always greater than that of the prorated thermal test section, which proved the thermal equivalency of the prorated section to the full size arresters.

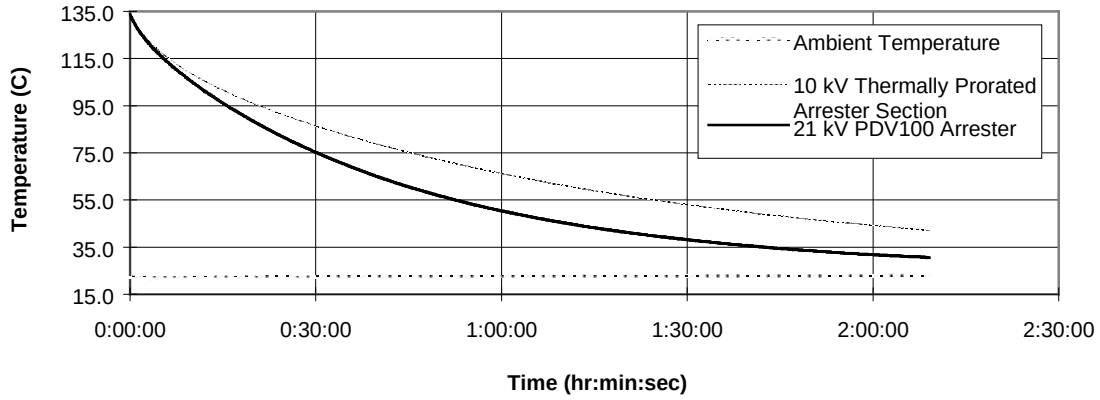


Figure 2. Verification of PDV-100 Prorated Thermal Test Section.

HUBBELL® POWER SYSTEMS, INC.

IEC Type Test Report
Report No. EU1120-HR2-06.2
Polymer Distribution Arresters

10,000 A Line Discharge Class 1

HIGH CURRENT IMPULSE OPERATING DUTY TESTS
IEC CLAUSE 8.5.4

This report records the results of this type test made on PDV-100™ arresters in accordance with IEC Standard 60099-4, 2004-05 "Surge arresters - Part 4: Metal-oxide surge arresters without gaps for a.c. systems."

Dennis W. Lenk

D. W. Lenk
Principal Engineer

Date: 8/27/2012

IEC Type Test Report

HIGH CURRENT IMPULSE OPERATING DUTY TESTS
IEC CLAUSE 7.5.4

Sample Preparation

High current impulse operating duty tests were performed on three prorated test sections prepared based on the thermal equivalency test results. Each section consisted of two (2) 40 mm diameter MOV discs with one 35 mm long and one 28 mm long. The MOV discs for each sample were selected to represent the lowest acceptable reference voltage level.

Test Procedure

Prior to the conditioning series, reference voltage of each section was measured at 5 mA reference current and room temperature. Initial 10 kA, 8/20 µs residual voltage of each section was also measured.

Conditioning tests consisted of subjecting each prorated section to (20) 10 kA, 8/20 µs lightning current impulses, divided into four groups of five impulses. The interval between impulses was between 50 and 60 seconds and the interval between groups was between 25 and 30 minutes. Test sections were energized at 60 Hz voltage of $1.2 \times U_c$ during each group testing. The impulses were timed to occur 60° before the crest of the 60 Hz voltage with the same polarity of the impulse. Tests were performed in still air at ambient temperature of 20 °C.

During the operating duty test, each section was subjected to two (2) 100 kA, 4/10 µs current impulses. Between the two shots, each section was placed in an oven and heated overnight to 60 ± 3 °C. Within 100 milliseconds of the last high current impulse, rated voltage (U_r) was applied to each section for 10 seconds immediately followed by U_c for a recovery test of 30 min. During the recovery period, power dissipation of each section was monitored.

After this test sequence, each section was allowed to cool to ambient temperature and then its 10 kA, 8/20 µs discharge voltage was measured.

Test Results

Initial measurements and parameters of the prorated sections are shown in Table 1.

Table 1. Initial Measurements and Parameters of Prorated Sections.

Test Parameters	Section 1	Section 2	Section 3
Initial Residual Voltage (kV) @ 10 kA, 8/20 µs	25.50	25.29	25.32
Reference Current (mA) I_{ref}	5	5	5
Reference Voltage (kV peak) U_{ref}	14.61	14.63	14.61
Maximum COV (kV rms): U_c	8.15	8.16	8.15
Maximum Rating (kV rms): U_r	10.12	10.13	10.12

A summary of results of the three sections for the 20-shot conditioning test is shown in Table 2. The sections were exposed to still air at ambient temperature of 20 °C during the test.

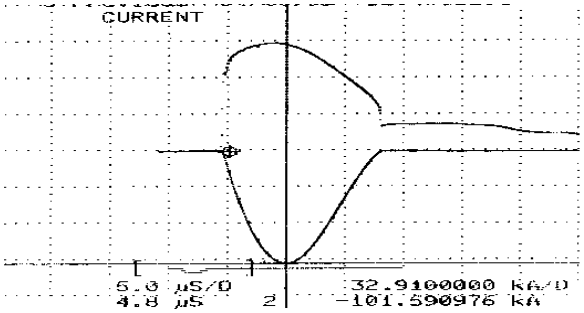
Table 2. 20-Shot Conditioning Test.

IMPULSE NUMBER	SECTION 1 I (kA)	SECTION 2 I (kA)	SECTION 3 I (kA)
1	10.40	10.21	10.45
2	10.37	10.29	10.40
3	10.32	10.25	10.30
4	10.33	10.24	10.27
5	10.27	10.20	10.20
Cool			
6	10.23	10.34	10.32
7	10.22	10.31	10.27
8	10.12	10.26	10.25
9	10.19	10.25	10.13
10	10.17	10.24	10.14
Cool			
11	10.21	10.31	10.22
12	10.20	10.20	10.21
13	10.21	10.23	10.15
14	10.14	10.22	10.13
15	10.13	10.14	10.10
Cool			
16	10.29	10.23	10.18
17	10.23	10.24	10.14
18	10.15	10.19	10.13
19	10.14	10.13	10.12
20	10.21	10.09	10.14

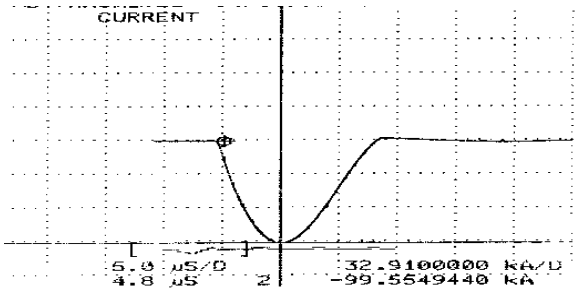
Subsequent to the completion of the 20 shot test, each section was subjected to two (2) 100 kA nominal 4/10 µs impulses as specified in IEC Standard 60099-4, 1998. Table 3 shows test results of the first and second 100 kA impulses for the three sections. Figure 1 shows oscillograms of the test for the three sections.

Table 3. 100 kA, 4/10 µs Conditioning Test.

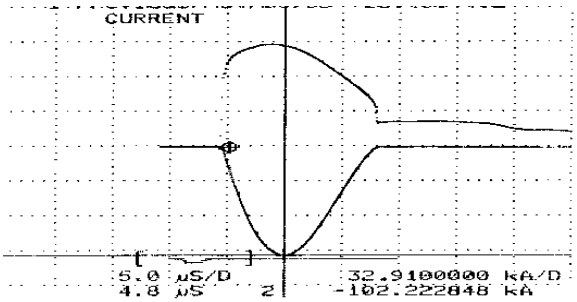
IMPULSE	SECTION 1 I (kA)	SECTION 2 I (kA)	SECTION 3 I (kA)
1	101.59	102.22	101.52
2	99.56	101.31	101.17



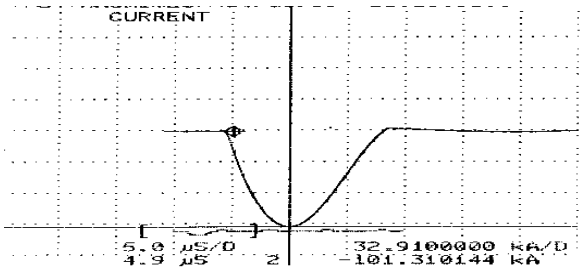
Section 1, Shot 1, Discharge Current = 101.59 kA



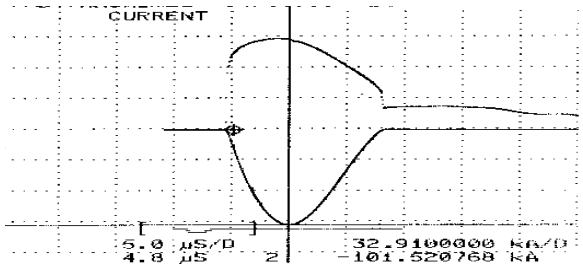
Section 1, Shot 2, Discharge Current = 99.56 kA



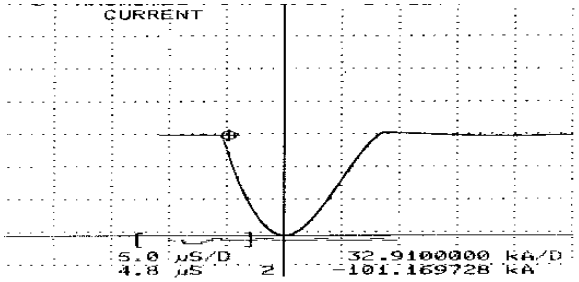
Section 2, Shot 1, Discharge Current = 102.22 kA



Section 2, Shot 2, Discharge Current = 101.31 kA



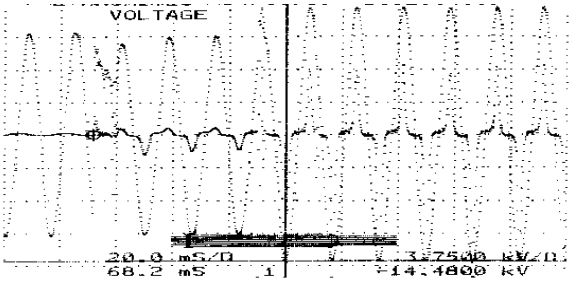
Section 3, Shot 1, Discharge Current = 101.52 kA



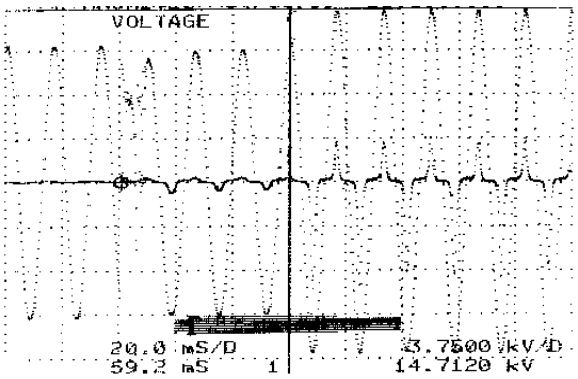
Section 3, Shot 2, Discharge Current = 101.17 kA

Figure 1. 100 kA nominal 4/10 µs impulses.

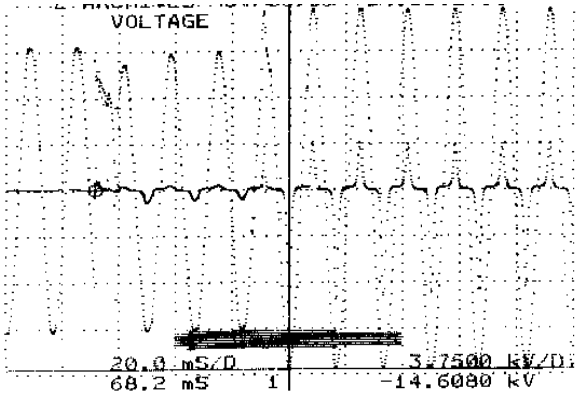
Figure 2 shows oscillograms of the time delay from the high current shot until the application of U_r to each of the three sections. Table 4 summarizes the 10-second rated voltage test results on the three sections.



Section 1, 68.2 millisecond delay



Section 2, 59.2 millisecond delay



Section 3, 68.2 millisecond delay

Figure 2. Time delay from the high current impulse until the application of U_r.

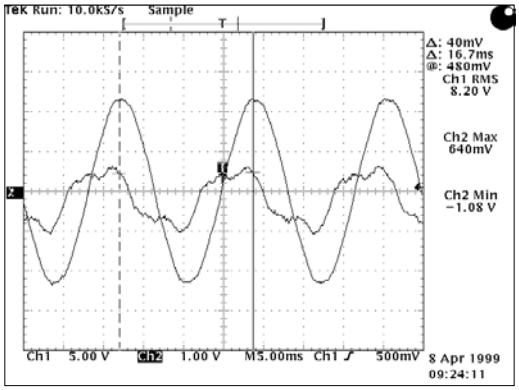
Table 4. 10-Second Rated Voltage Test.

Section 1			Section 2			Section 3		
Time (Second)	Rated Ur (kVc)	Current I (mA)	Time (Second)	Rated Ur (kVc)	Current I (mA)	Time (Second)	Rated Ur (kVc)	Current I (mA)
0.068	14.46	95.9	0.059	14.62	132.7	0.068	14.60	139.3
1	14.59	75.9	1	14.58	85.1	1	14.63	90.2
2	14.57	63.1	2	14.60	78.5	2	14.65	79.9
4	14.56	55.3	4	14.64	72.0	4	14.64	68.6
6	14.58	53.7	6	14.62	65.3	6	14.64	63.3
8	14.58	49.8	8	14.61	60.8	8	14.64	59.0
10.33	14.61	47.9	10.29	14.63	60.1	10.29	14.64	58.1

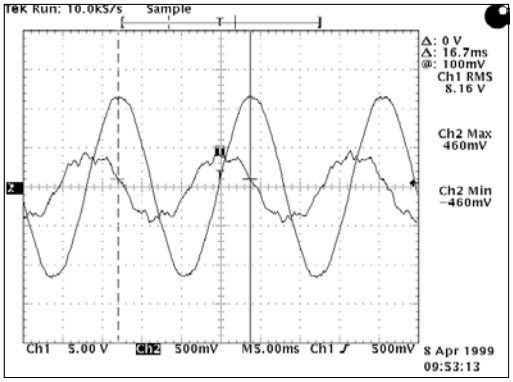
Thermal stability defined by Section 7.5.6 of IEC Standard 60099-4, 1998, was verified during the recovery period by continuous monitoring of power dissipation of the test sections. Typical values of the measurements are shown in Table 5. Typical recovery voltage and current oscillograms for each section are shown in Figure 3. The results indicated that all three sections demonstrated thermal stability.

Table 5. Power Dissipation in Thermal Models during Recovery.

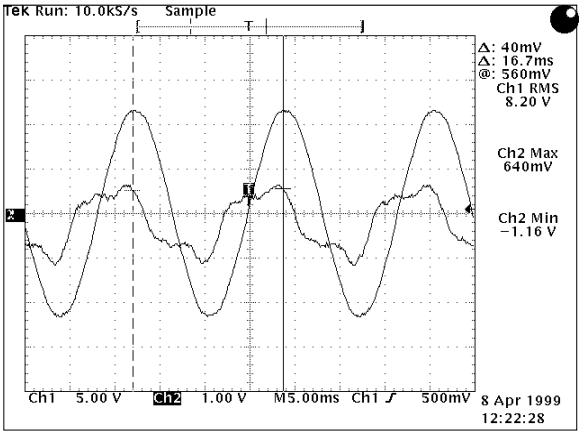
RECOVERY TIME (Min)	SECTION 1 WATTS LOSS (W)	SECTION 2 WATTS LOSS (W)	SECTION 3 WATTS LOSS (W)
0	18.4	12.4	13.3
0.5	7.4	7.7	7.1
1	5.9	6.2	6.1
2	4.5	4.7	4.7
5	3.0	3.2	3.2
10	2.1	2.1	2.2
20	1.4	1.5	1.3
30	1.0	1.1	1.0



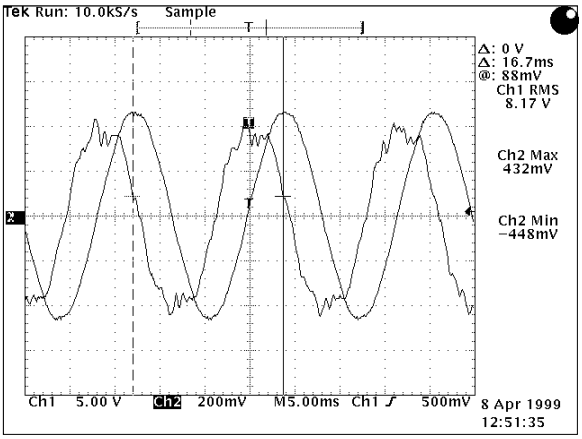
Section 1, Recovery at 1 min.



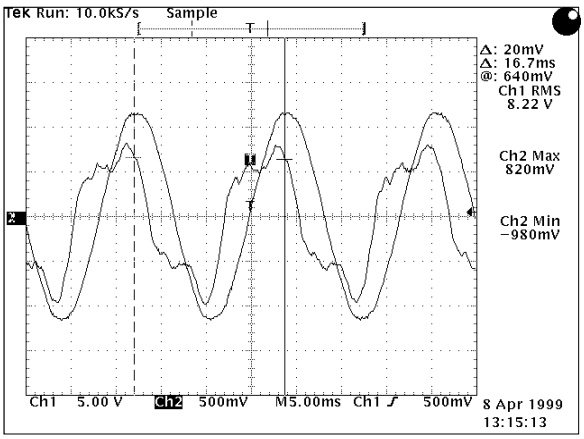
Section 1, Recovery at 30 min.



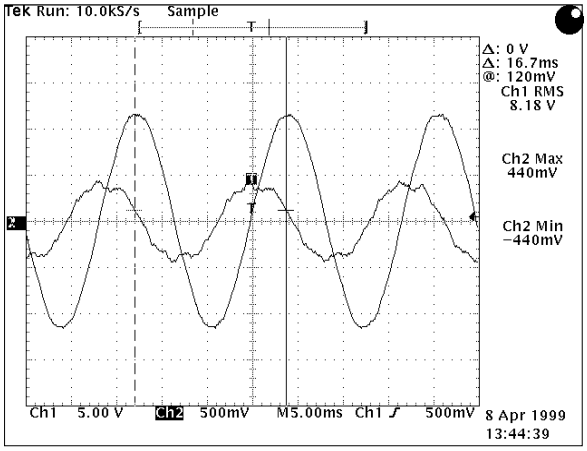
Section 2, Recovery at 1 min.



Section 2, Recovery at 30 min.



Section 3, Recovery at 1 min.



Section 3, Recovery at 30 min.

Figure 3. Typical recovery voltage and current.

Results of the residual voltages measured are given in Table 6. The maximum change of the residual voltages of the three sections is less than the permissible value of 5 %.

Table 6. Summary of Residual Voltage Measurements.

SECTION	RESIDUAL VOLTAGE (kV)		Change
	Before	After	(%)
1	25.50	26.11	2.39
2	25.29	25.94	2.57
3	25.32	25.99	2.65

Test Summary

The three prorated sections successfully passed the operating duty test per Section 8.5 of IEC Standard 60099-4, 2004-05. Disassembly revealed no evidence of puncture, flashover or cracking of the non-linear metal oxide resistors in any of the three sections. All three sections demonstrated thermal stability. The change of residual voltage measured before and after the test is less than 5 %. The three test sections have fulfilled the operating duty test requirements.

HUBBELL® POWER SYSTEMS, INC.

IEC Type Test Report
Report No. EU1120-HR2-07.2
Polymer Distribution Arresters

10,000 A Line Discharge Class 1

TESTS ON ARRESTER DISCONNECTORS
IEC CLAUSE 8.6

This report records the results of this type test made on PDV-100™ arresters in accordance with IEC Standard 60099-4, 2004-05 "Surge arresters - Part 4: Metal-oxide surge arresters without gaps for a.c. systems."

Dennis W. Lenk

D. W. Lenk
Principal Engineer

Date: 8/27/2012

IEC Type Test Report

TESTS ON ARRESTER DISCONNECTORS
IEC CLAUSE 8.6

The ground lead disconnector is an integral part of the insulating base bracket. High current short duration and low current long duration duty tests and duty cycle tests were performed on thermally prorated test sections having the disconnector assembly connected in series. Disconnectors did not operate when subjected to these tests.

Disconnector detonation tests were performed on five (5) bracket/disconnector assemblies each at 20, 200, and 800 A rms. Figure 1 shows the rms value of the current and time duration to the first movement of the disconnector. This test was performed without the arrester. The ground lead arrester disconnectors tested met the requirements of this IEC Clause.

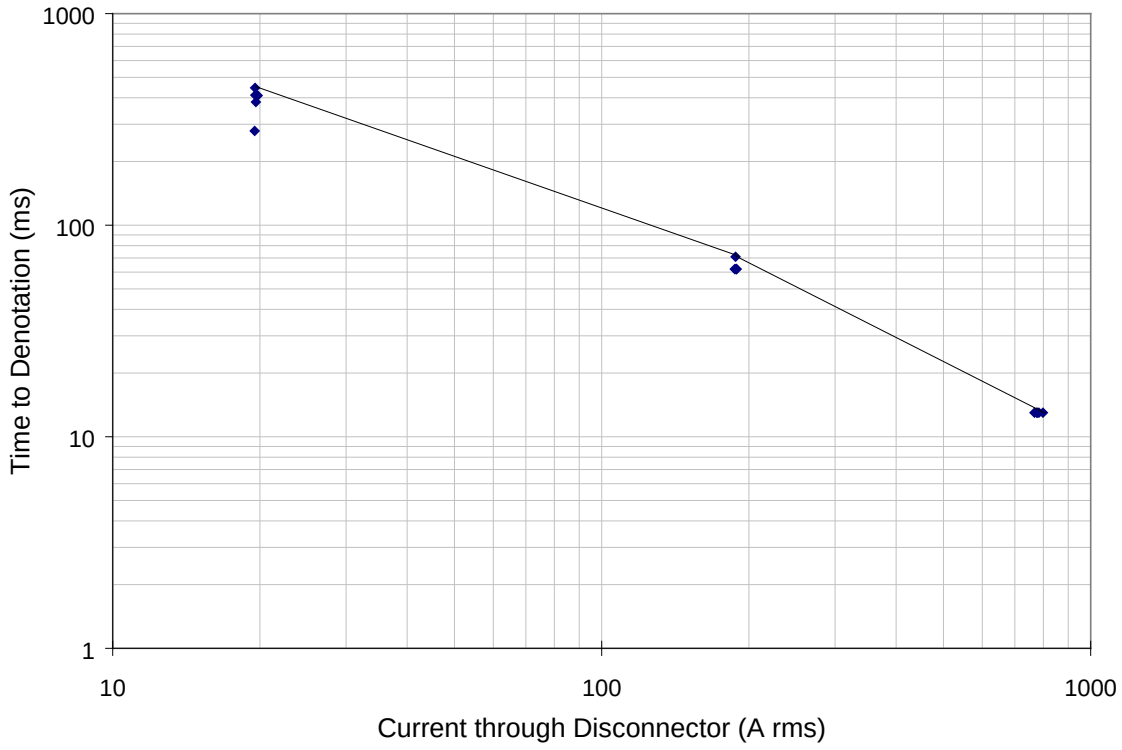


Figure 1. Time vs. current characteristics of disconnectors.

HUBBELL® POWER SYSTEMS, INC.

IEC Type Test Report
Report No. EU1120-HR2-08.2
Polymer Distribution Arresters

10,000 A Line Discharge Class 1

POWER FREQUENCY VOLTAGE VERSUS TIME CHARACTERISTICS
IEC ANNEX D

This report records the results of this type test made on PDV-100™ arresters in accordance with IEC Standard 60099-4, 2004-05 "Surge arresters - Part 4: Metal-oxide surge arresters without gaps for a.c. systems."

Dennis W. Lenk

D. W. Lenk
Principal Engineer

Date: 8/27/2012

IEC Type Test Report

POWER FREQUENCY VOLTAGE VERSUS TIME CHARACTERISTICS
IEC ANNEX D

The claimed power frequency voltage capability for the PDV-100 design is summarized in Figure 1. The test procedure is listed below:

1. Preheat to 60 ± 3°C;
2. Apply single 100 kA 4/10 lightning surge;
3. Within 100 ms of the second discharge, apply the selected p. u. of voltage for a time greater than the abscissa value on Figure 1;
4. Apply the continuous operating voltage (U_c) for 30 minutes and monitor the power loss to confirm stability.

The PDV-100 arresters met the requirements of this clause.

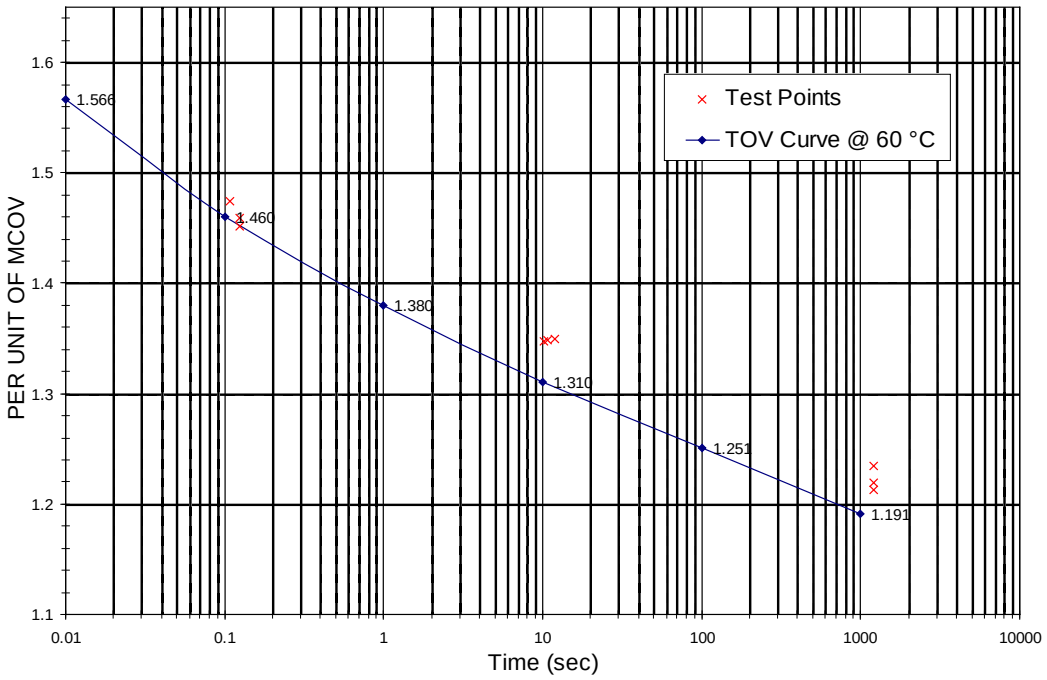


Figure 1. Power frequency voltage versus time characteristics.

IEC TYPE TEST REPORT
Report No. EU 1120-HR2-09.1
Polymer Distribution Arrester

10,000 A Line Discharge Class 1

SHORT CIRCUIT TEST

This report records the results of type tests made on 10 kA Class 1 arresters rated 3 thru 36 kV in accordance with IEC Standard 60099-4, 2005, “Surge arresters-Part 4: Metal Oxide surge arresters without gaps for a.c. systems”.

Dennis W. Lenk

Dennis W. Lenk

Date: 8/27/2012

IEC Type Test Report

SHORT CIRCUIT TEST

Introduction

Short circuit tests were performed on the Type PDV100 10 kA Class 1 polymer-housed Distribution Class arrester per Annex N of IEC 60099-4 Standard.

Procedure and Results

The following table summarizes the results these tests which validated the claimed maximum 20 kA_{rms} symmetrical, 12 cycle fault current withstand capability of this design, with an applied ratio of 1.55 between total asymmetrical to symmetrical rms currents. This corresponds to a 2.6 ratio, in the first half loop of fault current, between the crest asymmetrical to rms symmetrical current, i.e., full offset. In addition to testing at the claimed maximum capability, two tests were also performed, using the 2-source procedure, at both half the claimed capability and at 600 amps.

Fault current test were performed on the longest mechanical section, as required in Section 8.15.1 of the standard. As required in Section 8.15.1.1, two test samples for the high current test were assembled with a fuse wire oriented axially between the mov disc stack and the fiberglass-epoxy wrap. These samples were subjected to the full offset current test. In addition, six samples represented standard production arresters. These samples were failed using the specified 2-source failure mode procedure. All tests were performed at full voltage. Therefore, the prospective fault current, as measured during the bolted fault test on the generator, is the claimable fault current capability of the design.

Calibration Test 21.85 kA Symmetrical RMS 34.74 kA Asymmetrical RMS

Sample #	Failure Mode	Minimum Test Duration-seconds	Condition of Module/Polymer Housing After Test
1	Fuse Wire	.2	Module Intact/Housing Separated
2	Fuse Wire	.2	Module Intact/Hsg Torn but in Place
3	2-Source	.2	Module Intact/Hsg Torn but in Place
4	2-Source	.2	Module Intact/Hsg Torn but in Place

Calibration Test 10.1 kA Symmetrical RMS No Asymmetrical Requirement

Sample #	Failure Mode	Minimum Test Duration-seconds	Condition of Module/Polymer Housing After Test
5	2-Source	.2	Module Intact/Hsg Torn but in Place
6	2_Source	.2	Module Intact/Hsg Separated

Calibration Test 600 Amp Symmetrical RMS No Asymmetrical Requirement

Sample #	Failure Mode	Minimum Test Duration-seconds	Condition of Module/Polymer Housing After Test
7	2-Source	1.0	Module Intact/Hsg Torn but in Place
8	2-Source	1.0	Module Intact/Hsg Torn but in Place

Conclusion

The eight test arresters assembled with the longest mechanical unit met the test evaluation criteria as specified in Annex N IEC 60099-4 Standard. In all tests, the arrester module remained intact on the insulating support bracket after the completion of each test. The flexible polymer housing wall section split, as intended, on all samples to allow venting of internal arcing gases to the outside of the arrester. In all cases, flames associated with the fault current test extinguished immediately after completion of the test, well within the allowed 2 minute duration. These tests have demonstrated the capability of the PDV100 10 kA Class 1 arrester design to discharge a maximum claimable 20 kA_{rms} symmetrical fault current.

IEC Type Test Report
Report No. EU1120-HR2-10.1
Base Mounted Polymer Arrester
10 kA Class 1

Moisture Ingress Test

This report records the results of type tests made on 10 kA Class 1 Type PDV 100 arresters in accordance with IEC Standard 60099-4, 2004-05 “Surge arresters - Part 4: Metal-oxide surge arresters without gaps for a.c. systems.”

Dennis W. Lenk

D. W. Lenk
Principal Engineer

Date: 08/27/2012

IEC TYPE TEST REPORT

Moisture Ingress Test

IEC Clause 10.8.13

TEST SAMPLES: The moisture ingress test was performed on a 21 kV rated arrester. Tests were performed to validate the seal integrity of the PDV 100 design after being subjected to its claimed continuous cantilever rating.

TEST PROCEDURE: Testing was performed per the procedures specified in Section 10.8.13 of IEC Std 60099-4. Prior to cantilever loading, per clause 10.8.13.2.1, the recommended arrester top end tightening torque was applied for 30 seconds to the top end of the arrester. The test arrester was rigidly mounted at its base and top end loading applied to develop 240 inch-pound base end cantilever load. Successive loading was performed at 0^o, 90^o, 180^o, and 270^o. The arrester was subjected to a combination of 1400 inch-pound load rotations and temperature excursions for 96 hours as specified in Figure 6 of 60099-4 Standard. After completion of the thermo-mechanical preconditioning test, the arrester was placed into boiling salt water for 42 hours, as specified in Clause 10.8.13.3. Finally, electrical and physical tests were performed per Clause 10.8.13.4 to confirm the seal integrity of the test arrester.

TEST RESULTS: The following table summarizes the results of the electrical tests performed before and after the moisture ingress test.

Sample	Watts Loss @ .8 MCOV	Watts Loss @ .8 MCOV	Watts Loss	10 kA Residual Voltage kVc	10 kA Residual Voltage kVc	10 kA IR kVc	Partial discharge Pc	Partial discharge Pc
#	Initial	Final	Change	Initial	Final	Change	Initial	Final
1	0.249	0.287	15.30%	56.4	57.6	2.12%	1	1
2	0.284	0.26	-8.50%	56.8	57.6	1.41	1	1
3	0.232	0.27	16.40%	56.4	57.2	1.41%	1	1

CONCLUSION: Per the test results summarized above, the electrical characteristics of the PDV 100 IEC 10 kA Class 1 arrester met the allowable limits specified in Clause 10.8.13.4. Visual examination revealed no evidence of mechanical damage. The above tests validated the seal integrity of the PDV 100 arrester when loaded to the 1400 inch-pound continuous cantilever rating.

HUBBELL® POWER SYSTEMS, INC.

IEC Type Test Report
Report No. EU1120-HR2-11.1
Type PDV 100
Polymer Arrester
10,000 A Line Discharge Class 1

5000 HOUR WEATHER AGING TEST
SERIES B

This report records the results of this type test made on IEC 10 kA Class 1 arresters rated 3 thru 36 kV in accordance with IEC Standard 60099-4, 2004-05 "Surge arresters - Part 4: Metal-oxide surge arresters without gaps for a.c. systems."

Dennis W. Lenk

Dennis. W. Lenk
Principal Engineer

Date: 8/27/2012

IEC Type Test Report

5000 HOUR WEATHER AGING TEST

IEC CLAUSE 10.8.14.2.2

Introduction

Tests were performed in accordance with clause 10.8.14.2.2 of IEC Standard 60099-4, 2004-05. The purpose of this test was to verify the electrical integrity of the arrester polymer housing after being subjected to 5000 hours in a weathering chamber.

Sample Preparation

Three 29 kV MCOV Type PDV 100 10 kA Class 1 arresters were assembled for this test.

Test Procedure

The 5000 hour weathering test was performed per IEC 61109 test procedure with the arrester energized at 30.6 kV_{rms} over the entire 24 hour test cycle. Salt fog salinity was 7 kg per cubic meter.

Test Results

The test arresters successfully withstood the 5000 hour aging test with no evidence of surface tracking, erosion, or puncturing. Figure 1 shows close-up views of the test arrester after completion of the 5000 hour test. In addition, electrical reference voltage and partial discharge were measured before and after testing. Table 1 summarizes the results of these tests.

Sample #	Uref before @ 5 ma	Uref After @ 5 ma	Uref Change (%)	PD before @ mcov (pC)	PD before @ mcov (pC	PD before @ mcov (pC
1	62.77	63.11	+0.5	0	0	0
2	62.21	62.53	+0.5	0	0	0
3	62.59	63.17	+0.9	0	0	0

Test Conclusions

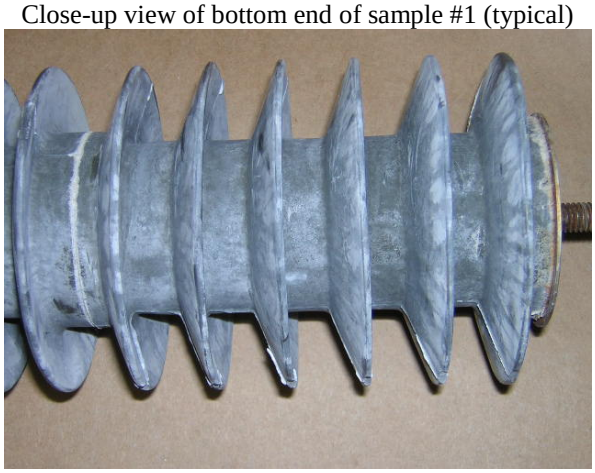
The Type PDV 100 IEC 10 kA Class 1 arrester design successfully passed the 5000 hour weathering test, as defined in IEC 60099-4 standard.

Figure 1
Photographs of PDV 100 36 kV Rated Arrester After 5000 Hour Weathering Test

Photograph of three test arresters after 5000 hour test

Close-up view of top end of sample #1 (typical)

Close-up view of bottom end of sample #1 (typical)



HUBBELL® POWER SYSTEMS, INC.

IEC Type Test Report
Report No. EU1120-HR2-12.1
Base Mounted Polymer Arrester
10,000 A Line Discharge Class 1

1000 HOUR SALT FOG TEST
SERIES A

This report records the results of this type test made on IEC 10 kA Class 1 arresters rated 3 thru 72 kV in accordance with IEC Standard 60099-4, 2005 "Surge arresters - Part 4: Metal-oxide surge arresters without gaps for a.c. systems."

Dennis. W. Lenk
Principal Engineer

Date: 8/27/2012

IEC Type Test Report

1000 HOUR SALT FOG TEST

IEC CLAUSE 10.8.14.2.1

Introduction

Tests were performed in accordance with clause 10.8.14.2.1 of IEC Standard 60099-4, 2005. The purpose of this test was to verify the electrical integrity of the arrester polymer housing after being subjected to 1000 hours in a salt fog environment.

Sample Preparation

Two 39 kV MCOV IEC Class 1 arresters were assembled for this test.

Test Procedure

The 1000 hour weathering test was performed per clause 10.8.14.2.2 of IEC 60099-4. Salt fog salinity was 10 kg per cubic meter.

Test Results

The test arrester successfully withstood the 1000 hour salt fog exposure test with no evidence of surface tracking, erosion, or puncturing. The following table summarizes the results of electrical tests performed on the arrester before and after the salt fog exposure.

Sample No.	Initial PD @ 1.05 times Uc (pC)	Final PD @ 1.05 times Uc (pC	Initial 5 ma reference voltage kVc	Final 5 ma reference voltage kVc
1	<1	<1	56.7	57.3
2	<1	<1	54.8	55.7

Test Conclusions

Reference voltage changed less than 2% as a result of salt fog exposure. No tracking, shed puncture or significant erosions were evidenced by visual inspection carried out at the end of the test. The IEC Class 1 arrester design successfully passed the 1000 hour salt fog test, as defined in IEC 60099-4 standard.

For details of test report, reference CESI AT-A2/019896 test report.