ANSI DESIGN TEST REPORT
Report No. EU 1480-HR-00.2
Type PVR Riser Pole Distribution Class Surge Arrester

This report records the results of the design tests made on Type PVR Optima Riser Pole Distribution Class surge arresters in accordance with IEEE Standard C62.11-2012 "IEEE Standard for Metal Oxide Surge Arresters for AC Power Circuits (> 1kV)".

Type tests performed on PVR Riser Pole arresters demonstrate compliance with the relevant clauses of the referenced standard and apply to all Hubbell PVR Riser Pole 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.

Saroni Brahma
Design Engineer

Dennis W. Lenk P.E.
Principal Engineer

Date: 10/31/2013

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

Report No.	Description	Clause	Issue Date
EU 1480-HR-01.2	Insulation Withstand	8.1	10/31/2013
EU 1480-HR-02.2	**Discharge Voltage**	**8.2**	**10/31/2013**
EU 1480-HR-03.2	**Disc Accelerated Aging**	**8.5**	**01/22/2014**
EU 1480-HR-04.2	Polymer Accelerated Aging	8.6	10/31/2013
EU 1480-HR-05.2	**Salt Fog Accelerated Aging**	**8.7**	**12/16/2013**
EU 1480-HR-06.2	**Verification of Thermal Equivalency**	**7.2.2**	**10/31/2013**
EU 1480-HR-07.2	Seal Integrity	8.9	10/31/2013
EU 1480-HR-08.2	Partial Discharge	8.11	10/31/2013
EU 1480-HR-09.2	**High Current, Short Duration**	**8.12**	**10/31/2013**
EU 1480-HR-10.2	**Low Current, Long Duration**	**8.13**	**10/31/2013**
EU 1480-HR-11.2	**Duty Cycle**	**8.16**	**10/31/2013**
EU 1480-HR-12.3	**Temporary Overvoltage**	**8.17**	**10/31/2013**
EU 1480-HR-13.2	**Short Circuit**	**8.18**	**10/31/2013**
EU 1480-HR-14.2	Disconnector	8.21	10/31/2013
EU 1480-HR-15.2	MDCL and Moisture Ingress	8.22	10/31/2013

TYPE TEST REPORT No. EU 1480-HR-01.2

Insulation Withstand Tests on PVR
Riser Pole Distribution Arrester Housing

CERTIFICATION

This is to certify that insulation withstand design tests have been successfully performed on Ohio Brass Type PVR Riser Pole Heavy Duty Distribution Class surge arresters.

Saroni Brahma
Design Engineer

Dennis W. Lenk P.E.
Principal Engineer

10/31/2013
Attachments

DESIGN TEST REPORT

Type PVR Riser Pole Distribution Class Surge Arrester

TITLE: Arrester Insulation Withstand Tests:

OBJECTIVE: To demonstrate that the voltage withstand capability of the arrester housing external insulation meets the requirements as specified in the Insulation Withstand section 8.1.2.1 of IEEE Standard C62.11-2012.

CONCLUSION: Table 1 lists PVR arrester minimum strike distance and minimum leakage distance as well as minimum required arrester 1.2/50 impulse withstand, arrester 60 Hz 10 second wet, and bracket 60 Hz 10 second wet withstand capabilities.

All PVR arrester ratings meet or exceed these levels of withstand voltage.

Table 1
Summary Data - Insulation Withstand Test

Catalog Number	MCOV (kV)	Rated Voltage (kV)	Total Arrester Strike Distance (in.)	Strike Distance w/ NEMA Bracket (in.)	Arrester Leakage Distance (in.)	Required Arrester 1.2 x 50 Impulse Withstand kVc	Required Arrester 10 sec wet 60 Hz Withstand kVrms	Required Bracket 10 sec wet 60 Hz Withstand kVrms
221603	2.55	3	2.9	2.9	8	14.8	4.8	3.8
221605	5.1	6	6.1	5.2	15.4	29.8	9.6	7.7
221608	7.65	9	6.1	5.2	15.4	39.9	14.4	11.5
221609	8.4	10	6.1	5.2	15.4	44.0	15.8	12.6
221610	10.2	12	6.1	5.2	15.4	53.0	19.1	15.3
221613	12.7	15	9.7	7.1	26	66.0	23.8	19.1
221615	15.3	18	9.7	7.1	26	79.7	28.7	23
221617	17	21	9.7	7.1	26	90.6	31.9	25.5
221620	19.5	24	11.3	7.7	30.8	105.6	36.6	29.3
221622	22	27	18.0	12.2	52	117.3	41.3	33
221624	24.4	30	18.0	12.2	52	131.9	45.8	36.6
221629	29	36	18.0	12.2	52	156.2	54.4	43.5

HUBBELL POWER SYSTEMS

OHIO BRASS

TYPE TEST REPORT No. EU 1480-HR-02.2

Discharge Voltage Characteristic
PVR Riser Pole Distribution Arrester

CERTIFICATION

This is to certify that the discharge voltage characteristic design tests have been successfully performed on Ohio Brass Type PVR Riser Pole Heavy Duty Distribution Class surge arresters.

Saroni Brahma
Design Engineer

Dennis W. Lenk P.E.
Principal Engineer

10/31/2013
Attachments

DESIGN TEST REPORT
Type PVR Riser Pole Distribution Class Surge Arrester

Introduction: Discharge voltage tests were performed on three 40mm diameter x 40mm long MOV discs. Tests were conducted in accordance with clause 8.3 of ANSI/IEEE Standard C62.11-2012" IEEE Standard for Metal-Oxide Surge Arresters for AC Power Circuits (>1kV)". Individual MOV discs were subjected to 8/20 current waves with magnitudes ranging from 1.5 kA through 20 kA. In addition, Front-of-wave and switching surge discharge voltage tests were performed.

Test Results: The results of the discharge voltage tests for each MOV are summarized on Table 1, which shows the actual voltage measurements on each MOV disc at each wave shape and current level. On the right side of table 1, for each disc, the measured residual voltage levels are normalized against that disc's 8/20 10 kA IR. For each current level/wave shape, the highest ratio has been bolded. It is this bolded factor (for each current magnitude/wave shape) that is used to verify that all protective levels derived from the 8/20 10 kA IR for each arrester rating do not exceed the guaranteed maximum discharge voltage for that rating.

Table 1
Sample Discharge Voltage Data Summary

Impulse Current (A)	Wave Shape	Discharge Voltage (kV)			Discharge Voltage Ratio		
		Sample 1	Sample 2	Sample 3	Sample 1	Sample 2	Sample 3
500	60/100	12.986	13.028	13.007	0.787	**0.789**	0.788
1,500	8/20	13.878	13.964	13.861	0.841	**0.846**	0.840
3,000	8/20	14.67	14.704	14.662	0.889	**0.891**	0.889
5,000	8/20	15.236	15.376	15.334	0.923	**0.932**	0.929
10,000	**8/20**	**16.505**	**16.505**	**16.501**	**1**	**1**	**1**
20,000	8/20	18.242	18.267	18.217	1.105	**1.107**	1.104
10,000	1/2	17.627	17.652	17.627	1.068	**1.069**	1.068

Conclusions: Arresters are assembled from discs accumulated within the 10 kA IR ranges that are specified for each arrester rating. To verify that catalog maximum IR levels were not exceeded, a discharge voltage ratio was established in Table 1 for each current level based on the MOV disc's 8/20 10 kA IR. Table 2 utilizes the discharge voltage ratio factors and extrapolates the expected discharge voltage values for each arrester build and compares that with the catalog discharge voltage values for that arrester rating. As Table 2 verifies, in all cases the extrapolated IR values are less than the catalog guaranteed values. Note that the FOW values for each arrester has been corrected, per Section 8.2.2.3 of C62.11-2012 Standard, to include the affects of arrester inductive voltage drop.

Table 2
PVR Arrester Discharge Voltage Summary

		IR Multipliers	0.789	0.846	0.891	0.932	1	1.107	FOW Including L di/dt
		Impulse Wave	60/100	8/20	8/20	8/20	8/20	8/20	0.5μsecV
MCOV	Rating	I Magnitude (A)	500	1500	3000	5000	10000	20000	10000
2.55	3	Prorated Sect Max IR	7.07	7.58	7.98	8.35	8.96	9.92	10.4
		Catalog Maximum IR	**7.2**	**7.7**	**8.1**	**8.4**	9.1	**10.2**	**10.5**
5.1	6	Prorated Sect Max IR	14.31	15.35	16.16	16.91	18.14	20.08	20.8
		Catalog Maximum IR	**14.4**	**15.4**	**16.2**	**17**	18.3	**20.5**	**20.9**
7.65	9	Prorated Sect Max IR	19.31	20.71	21.81	22.82	24.48	27.10	27.6
		Catalog Maximum IR	**19.4**	**20.8**	**21.9**	**22.9**	24.5	**27.5**	**27.8**
8.4	10	Prorated Sect Max IR	21.24	22.77	23.99	25.09	26.92	29.80	30.2
		Catalog Maximum IR	**21.3**	**22.8**	**24.1**	**25.2**	27	**30.4**	**30.4**
10.2	12	Prorated Sect Max IR	25.60	27.44	28.90	30.23	32.44	35.91	36.1
		Catalog Maximum IR	**25.7**	**27.5**	**29**	**30.3**	32.5	**36.5**	**36.3**
12.7	15	Prorated Sect Max IR	31.94	34.25	36.07	37.73	40.48	44.81	45.5
		Catalog Maximum IR	**32.1**	**34.4**	**36.2**	**37.9**	40.5	**45.4**	**45.7**
15.3	18	Prorated Sect Max IR	38.57	41.35	43.55	45.56	48.88	54.11	54.5
		Catalog Maximum IR	**38.7**	**41.5**	**43.7**	**45.7**	48.9	**54.6**	**54.8**
17	21	Prorated Sect Max IR	43.63	46.78	49.27	51.54	55.3	61.22	61.3
		Catalog Maximum IR	**43.8**	**46.9**	**49.4**	**51.7**	55.6	**61.6**	**61.7**
19.5	24	Prorated Sect Max IR	51.19	54.89	57.81	60.47	64.88	71.82	72.2
		Catalog Maximum IR	**51.3**	**55**	**57.9**	**60.6**	64.9	**72.4**	**72.6**
22	27	Prorated Sect Max IR	56.49	60.57	63.80	66.73	71.6	79.26	80.9
		Catalog Maximum IR	**56.6**	**60.7**	**63.9**	**66.9**	72	**80.5**	**81.4**
24.4	30	Prorated Sect Max IR	63.88	68.49	72.14	75.45	80.96	89.62	90.9
		Catalog Maximum IR	**64**	**68.6**	**72.3**	**75.6**	81	**90.3**	**91.4**
29	36	Prorated Sect Max IR	75.57	81.03	85.34	89.27	95.78	106.03	106.8
		Catalog Maximum IR	**75.7**	**51.2**	**85.5**	**89.4**	96.1	**108**	**107.4**

TYPE TEST REPORT No. EU 1480-HR-03.2

Disc Accelerated Aging
PVR Riser Pole Arrester

CERTIFICATION

This is to certify that the disc accelerated aging design tests have been successfully performed on Ohio Brass Type PVR Riser Pole Heavy Duty Distribution Class Surge arresters.

Saroni Brahma
Design Engineer

Dennis W. Lenk P.E.
Principal Engineer

10/31/2013
Attachments

DESIGN TEST REPORT
PVR Riser Pole Distribution Class Surge Arrester
Accelerated Aging Procedure

TITLE: Accelerated aging procedure

TEST PROCEDURE: Tests were performed to measure MOV disc aging characteristics. Measured watts values are used to develop elevated voltage ratios k_c and k_r for use in proration of duty cycle and discharge current withstand test samples.

TEST SAMPLES: Six arrester modules were prepared. The first (3) (sections 1 through 3) modules consisted of the shortest 40 mm diameter MOV disc, spring, end terminals, barrier film and fiberglass/epoxy wrap using standard module construction. The second (3) (sections 4 through 6) modules were constructed similarly with the longest 40mm diameter discs.

TEST PROCEDURE: Tests were performed per section 8.5 of IEEE Standard C62.11-2012. Samples were placed inside a 115 °C ±2 °C. oven and energized at the assigned MCOV for 1,000 hours.

TEST RESULTS: Watts loss for each sample was measured at MCOV voltage two hours after energization and at the completion of the 1000 hour test duration. The table below summarizes test data.

Accelerated aging test data

Sample Number	2 Hour Watts Loss @ MCOV P_{1c} (W)	1000 Hour Watts Loss @ MCOV P_{2c} (W)	Elevation Factor k_c
1	0.928	0.608	1
2	0.997	0.594	1
3	1.129	0.713	1
4	1.481	0.973	1
5	1.397	0.995	1
6	1.286	1.271	1

CONCLUSION: Each test sample demonstrated continually declining watts loss at MCOV. Therefore, K_c factor equals 1.0.

TYPE TEST REPORT No. EU 1480-HR-04.2
Polymer Accelerated Aging
PVR Riser Pole Arrester

CERTIFICATION

This is to certify that the polymer accelerated aging design tests have been successfully performed on Ohio Brass Type PVR Riser Pole Heavy Duty Distribution Class surge arresters.

Saroni Brahma
Design Engineer

Dennis W. Lenk P.E.
Principal Engineer

10/31/2013
Attachment

DESIGN TEST REPORT
PVR Riser Pole Distribution Class Surge Arrester
Accelerated Aging Tests of External Polymeric Insulating Systems for Distribution Arresters.

Introduction: These tests were performed per clause 8.6 of IEEE Standard C62.11-2012. Accelerated aging tests by exposure to light were performed per clause 8.6.1 test method 8.6.1.2.c. Tests on polymer housing and insulating bracket material using the fluorescent UV technique described in ASTM G53-1996. Test duration was 1000 hours on three samples of each material. Accelerated aging tests by exposure to electrical stress were performed per clause 8.6.2.

Samples: Accelerated aging tests by exposure to electrical stress were performed per clause 8.6.2. Three PVR 10.2 kV MCOV and three PVR 17 kV MCOV arresters were tested. These represent the highest MCOV stress based on leakage distance and arcing distance. Tests were performed by attaching arresters to a vertical Ferris wheel. As the wheel rotates, each arrester is sequentially dipped into a 400 ohm-centimeter water bath. Each arrester is allowed to drip off excessive contaminant and is then energized at MCOV to force the arrester housing into a dry band arcing condition. The test is performed until each arrester has reached 1000 hours of energized test time. Prior to and after the 1000 hour test, each arrester is subjected to a 10 kA 8/20 discharge to confirm its electrical integrity.

The final portion of the test procedure consists of subjecting each arrester insulating bracket to 20 hours on voltage with the insulating bracket energized at MCOV. At the completion of the above tests, the arresters are examined to ensure there is no evidence of surface tracking.

Conclusion: Both polymer housing and insulating bracket materials passed the test requirements of clause 8.6.1.3, as there were no cracks greater than the allowed depth of 0.1 mm. The arresters also passed the requirements of clause 8.6.2.4, as the arrester discharge voltage changed by less than 1 % as a result of the 1000 hour Ferris wheel test. There was no evidence of external flashovers, punctures, or internal breakdowns during the described tests. There was no evidence of surface tracking on the PVR arrester housings after the 1000 hour on-voltage test or on the insulating bracket after the 20 hour on-voltage test.

HUBBELL® POWER SYSTEMS, INC.

TYPE TEST REPORT No. EU 1480-HR-05.2
1000 Hour Salt Fog
PVR Riser Pole Arrester

CERTIFICATION

This is to certify that the polymer accelerated aging design tests have been successfully performed on Ohio Brass Type PVR Riser Pole Heavy Duty Distribution Class surge arresters.

Saroni Brahma
Design Engineer

Dennis W. Lenk P.E.
Principal Engineer

12/16/2013
Attachment

Design Test Report
PVR Riser Pole Distribution Class Surge Arrester
1000 Hour Salt Fog Test

TITLE: 1000 Hour Salt Fog Exposure Test

TEST OBJECTIVE: Perform 1000 hour salt fog exposure test per section 8.7 of C62.11 – 2012 Standard.

TEST SAMPLE: Two 29 kV MCOV arresters were tested. Arrester #1 was tested with its insulating support bracket attached to the base end of the arrester. Arrester #2 was tested without the insulating support bracket.

TEST PROCEDURE: The arresters were mounted vertically inside the salt fog chamber. Prior to and after the 1000 hour test, the reference voltage and partial discharge of the sample were measured. The 1000 hour test was performed with a spray having an NaCl salt content of 10 kg/m^3 per the procedure specified in section 8.7.3 of the standard

TEST RESULTS: The test arrester passed the 1000 hour salt exposure. The physical condition of the polymer housings showed no signs of surface tracking or surface erosion. There was no evidence of housing or shed punctures. The following table summarizes the results of the electrical testing.

Sample #	Reference Voltage kVc Before Salt Fog	Reference Voltage kVc After Salt Fog	Reference Voltage % Change	Partial Discharge After Salt Fog PC
1	38.8	39.0	+0.5	<1
2	39.2	40.0	+2.0	<1

Photograph #1 shows the salt-contaminated surfaces of the two arresters after completion of the 1000 hour duration salt fog test. Photograph # 2 shows a close-up view of the undamaged condition of the polymer housings. There was no evidence of surface tracking, erosion, or shed punctures.

Photograph #1

Photograph #2

CONCLUSION: The physical condition of the test arrester and the electrical testing confirmed that the PVR Optima arrester successfully passed the 1000 hour salt fog exposure test.

TYPE TEST REPORT No. EU 1480-HR-6.2

VERIFICATION OF THERMALLY PRORATED SECTION

CERTIFICATION

This is to certify that verification tests demonstrating thermal equivalency were successfully performed on Ohio Brass Type PVR Heavy Duty Distribution Class surge arrester.

Saroni Brahma
Design Engineer

Dennis W. Lenk P.E.
Principal Engineer

10/31/2013
Attachments

DESIGN TEST REPORT
PVR Heavy Duty Riser Pole Distribution Class Surge Arrester

TITLE: Verification of thermally prorated arrester section:

INTRODUCTION: Tests were performed as required by clause 7.2.2.3 of IEEE C62.11-2012 Standard, to compare the cooling characteristics of the prorated test sections used for type tests with those of a full-size arrester unit.

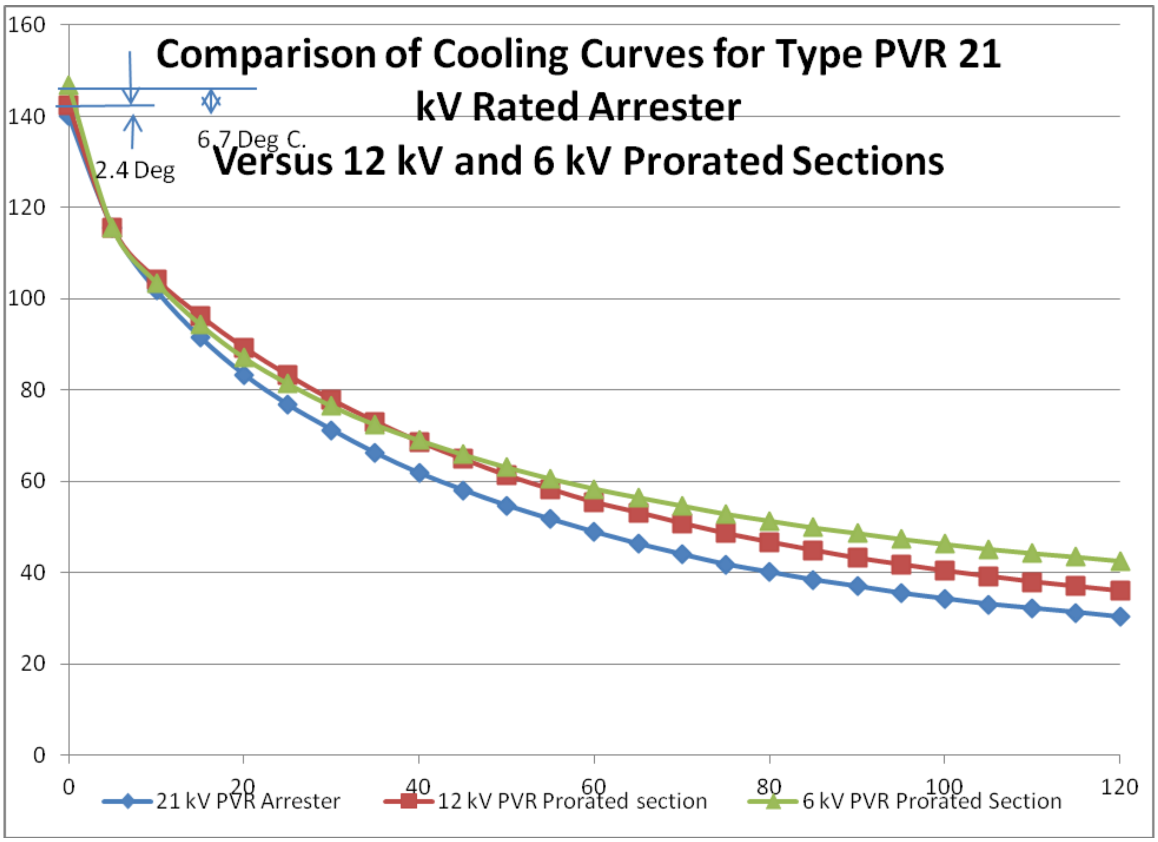
PURPOSE: The purpose of this test is to verify that the thermal cooling curve for the Type PVR prorated sections, when internally heated, will cool slower than that of a full size 21 kV rated arrester unit.

PROCEDURE: A full size single unit 21 kV rated Type PVR arrester and a 12 kV and a 6 kV prorated section were heated up by applying a temporary overvoltage to the test samples. Per clause 7.2.2.3, all samples (the arrester and the prorated sections) were energized in approximately 10 minutes to a starting temperature of 140 ºC, at which time the voltage was removed. The full size arrester and the two prorated sections were instrumented with (1) fiber-optic sensors located in the middle of the MOV disc stack. During the cooling portion of the test, the temperatures of the arrester and the test sections were monitored at 5 minute intervals to develop the cooling curve for each sample.

SUMMARY: As allowed in clause 7.2.2.3.5, the cooling curves for both the 12 kV and 6 kV prorated sections were adjusted higher to assure that, at no time during the 120 minute cooling period, do the section cooling curves drop below that of the full size arrester. The adjusted temperature shown for each rated section was added to the durability tests requiring a 60 degree C. preheat.

The cooling curve (Figure 1 below) confirms that the cooling rate of the 12 kV and 6 kV prorated sections is slower than that of the full size 21 kV Rated Type PVR arrester unit, confirming the thermal equivalency of the prorated sections to the full size arrester.

Figure 1


Comparison of Cooling Curves for Type PVR 21 kV Rated Arrester Versus 12 kV and 6 kV Prorated Sections
6.7 Deg C.
2.4 Deg
160
140
120
100
80
60
40
20
0
0
20
40
60
80
100
120
21 kV PVR Arrester
12 kV PVR Prorated section
6 kV PVR Prorated Section

TYPE TEST REPORT No. EU 1480-HR-07.2

Seal Integrity Test
PVR Riser Pole Arrester

CERTIFICATION

This is to certify that the seal integrity design tests have been successfully performed on Ohio Brass Type PVR Riser Pole Heavy Duty Distribution Class Surge arresters.

Saroni Brahma
Design Engineer

Dennis W. Lenk P.E.
Principal Engineer

10/31/2013
Attachments

DESIGN TEST REPORT
PVR Riser Pole Distribution Class Surge Arrester
Seal Integrity Design test

TEST SAMPLES: Tests were performed per section 8.9 of IEEE Standard C62.11-2012 on four 12 kV and four 18 kV rated arresters.

TEST PROCEDURE: The seal integrity test consisted of the following steps:

a) Initial Electric Test: Watts loss and IIV were measured while each arrester was energized at rated voltage.
b) Terminal Torquing: A ¼” diameter hard lead was inserted between the wire clamp and arrester end stud on one side only. The clamping nut was torqued to 22 ft-lb.
c) Thermal Conditioning: Each arrester was placed in a $70^{o}C \pm 3^{o}$ C environment for 14 days, after which the arresters were stabilized at ambient room temperature and watts was measured.
d) Seal Pumping: The arresters were heated to $60^{o}C \pm 3^{o}C$ for one hour, then placed into a $4^{o}C \pm 3^{o}C$ water bath for two hours, after which the samples were returned to the $60^{o}C$ oven. Each arrester was subjected to ten repetitions of this cycle. The transfer time between media was 1-2 minutes.
e) Final Electrical Test: Step (a) was repeated.
f) Final Inspection: The arresters were disassembled to verify no moisture penetration was evident.

TEST RESULTS: As indicated in the following table, all arresters demonstrated adequate sealing with no evidence of internal moisture or change in watts loss or IIV.

Sample Number	Applied Voltage (kV rms)	Initial Watts Loss	Final Watts Loss	Initial Internal Noise (microvolts)	Final Internal Noise (microvolts)
1	18	1	1	0.5	0.5
2	18	1	1.1	0.5	0.5
3	18	1	0.9	0.5	0.5
4	18	1.1	1.2	0.5	0.5
5	12	0.8	0.7	0.6	0.6
6	12	0.8	0.8	0.6	0.6
7	12	0.8	0.8	0.6	0.5
8	12	0.7	0.7	0.6	0.5

CONCLUSION: The arrester watts loss increase was less than 10%, below the allowed 50% level. Internal partial discharge was unchanged after completion of the seal integrity test. In addition, disassembly revealed no evidence of internal moisture inside the test arresters. Therefore, the PVR Riser Pole arrester successfully passed the seal integrity design test.

TYPE TEST REPORT No. EU 1480-HR-08.2

Partial Discharge Test
PVR Riser Pole Arrester

CERTIFICATION

This is to certify that the partial discharge design test has been successfully performed on Ohio Brass Type PVR Riser Pole Heavy Duty Distribution Class surge arrester.

Saroni Brahma
Design Engineer

Dennis W. Lenk P.E.
Principal Engineer

10/31/2013
Attachments

DESIGN TEST REPORT
PVR Riser Pole Distribution Class Surge Arrester
Partial Discharge test

TEST PROCEDURE AND SAMPLE: Partial discharge testing was performed per section 8.11 of IEEE Standard C62.11-2012. The test was performed on a 36 kV rated, 29.0 kV MCOV PVR Riser Pole arrester.

TEST RESULTS: The measured partial discharge at 1.05 times MCOV was 0 pc.

CONCLUSION: The 36 kV rated PVR Riser Pole arrester passed test requirements as measured partial discharge was well below the allowed 10 pc test limit. As there was no extra shielding on the top end of the arrester, the RIV test was not performed.

TYPE TEST REPORT No. EU 1480-HR-09.2

HIGH CURRENT, SHORT DURATION TEST
PVR Riser Pole Arrester

CERTIFICATION

This is to certify that the high current, short duration design test has been successfully performed on Ohio Brass Type PVR Riser Pole Heavy Duty Distribution Class surge arrester.

Saroni Brahma
Design Engineer

Dennis W. Lenk P.E.
Principal Engineer

10/31/2013
Attachments

DESIGN TEST REPORT
PVR Riser Pole Distribution Class Surge Arrester
High Current, Short Duration Discharge Withstand Tests:

Introduction: High current, short duration discharge withstand tests were performed per clause 8.12 IEEE Standard C62.11-2012. Tests were performed per Heavy Duty Distribution arrester requirements using a prorated test section, as required in clause 8.12.1.

Test Procedure: Per Clauses 8.12.2 and 8.12.3, test sections were subjected to two 100 kA 4-6/10-15 surges, with cooling to ambient between surges. Within 100 msec after the 2nd surge, recovery voltage is applied for 30 minutes during which the arresters watts is monitored to demonstrate thermal stability after the 2^{nd} lightning surge.

Test Results: Each test sample was subjected to two 100 kA, 4/10 discharges. Sufficient time was allowed between discharges for the sample to cool to ambient temperature 23 $^{\circ}$C. Within 100 msec after the second high current discharge, the sample was energized at the prorated section recovery voltage. Watts loss was monitored over a 30 minute period demonstrating thermal stability. Figures #1 and 2 show oscillograms of the two 100 kA shots, including the start of the 30 minute recovery portion of the tests performed on Sample #1. These are typical oscillograms for the three tested samples.

Figure #1
First Shot
101.01 kA Magnitude

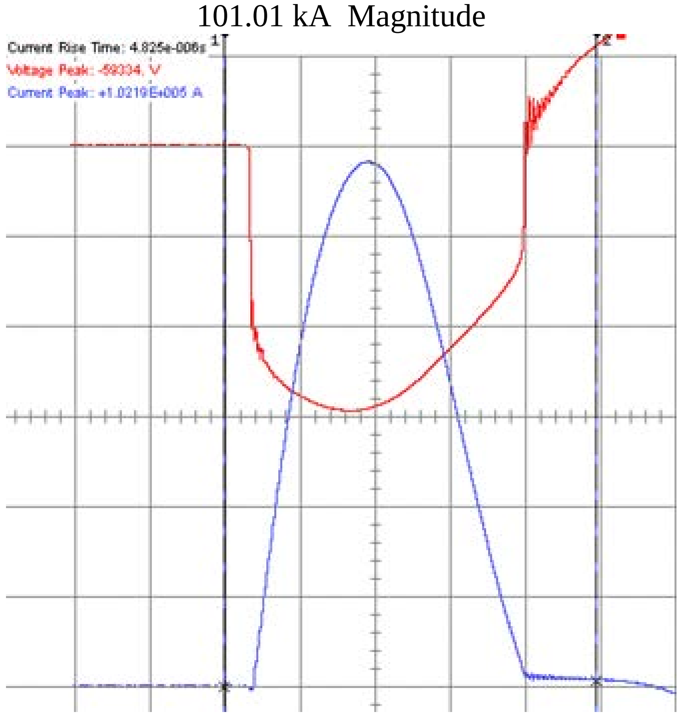


Figure #2
Second Shot, Including 80 msec application of recovery voltage
110.1 kA Magnitude

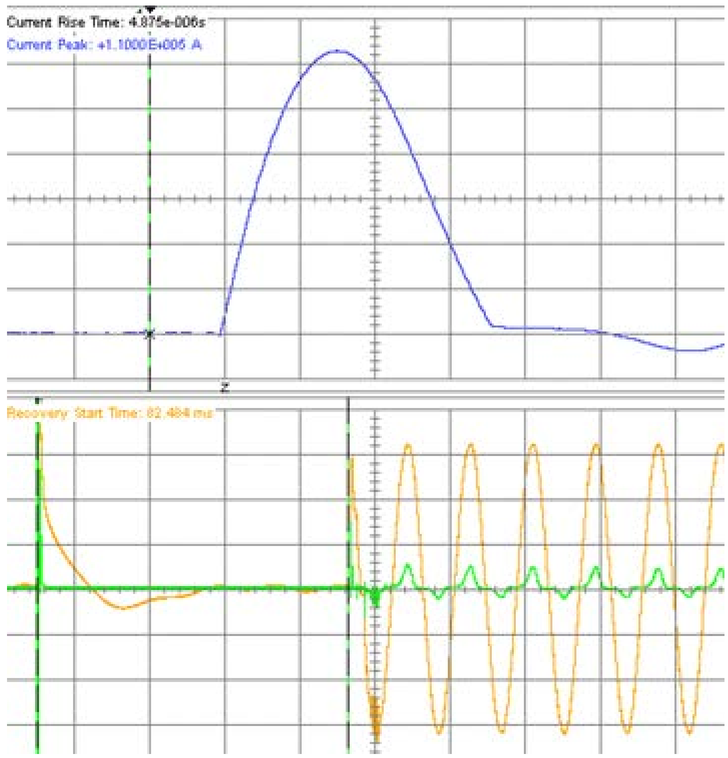


Table #1 summarizes the results of the two 100 kA shots and the watts measured during the 30 minute recovery test performed on the three test samples.

Table #1

Shot No.	Section 1 kA	Section 2 kA	Section 3 kA
1	101.015	101.491	102.186
2	110.004	104.080	101.520
N.O. Vacuum switch closed @ 80 msec			
Elapsed Time	**Section 1 Watts**	**Section 2 Watts**	**Section 3 Watts**
0:00:00	46.81	36.78	40.72
0:00:30	15.43	14.42	16.72
0:01:00	10.20	9.77	11.59
0:02:00	6.33	5.87	7.92
0:05:00	3.99	3.59	5.51
0:10:00	3.18	2.81	4.49
0:20:00	2.36	2.35	3.73
0:30:00	1.99	2.08	3.34

Residual voltage was measured on each test sample prior to and after the 100 kA surge duty test. Table #2 summarizes the results this testing.

Table #2

Sample #	10 kA IR Before - kVc	10 kA IR After - kVc	% Change
1	17.057	17.501	+2.6
2	17.177	17.312	+0.8
3	16.868	16.934	+0.4

Conclusion: The three prorated test samples successfully completed the high current test and demonstrated thermal stability during the recovery test. The 10 kA residual voltage increase ranged from 0.4 to 2.6%, less than the allowed 10%. Disassembly revealed no evidence of physical damage to the test sample. There was no detonation of the disconnector during the 2-shot 100 kA duty test. The PVR design successfully met the High Current, Short Duration requirements of a Heavy Duty Distribution Class Arrester.

TYPE TEST REPORT No. EU 1480-HR-10.2

LOW CURRENT, LONG DURATION TEST
PVR Riser Pole Arrester

CERTIFICATION

This is to certify that the low current, long duration design test has been successfully performed on Ohio Brass Type PVR Riser Pole Heavy Duty Distribution Class surge arrester.

Saroni Brahma
Design Engineer

Dennis W. Lenk P.E.
Principal Engineer

10/31/2013
Attachments

DESIGN TEST REPORT
PVR Heavy Duty Distribution Class Surge Arrester
Low Current, Long Duration Discharge Withstand Tests

Introduction: The low current, long duration discharge withstand test was performed per clause 8.13 IEEE Standard C62.11-2012. Tests were performed per Heavy Duty distribution arrester requirements using 6 kV rated test samples.

Test Samples: Per section 8.21.2.1, a ground lead disconnector (GLD) was connected in series with each of the three LCLD 6 kV rated test samples.

Procedure: Per section 8.13.3, each test sample was subjected to six sets of three 250 A, 2000 μs discharges. Sufficient time was allowed between sets of discharges for the section to cool to room ambient temperature. Per section 8.13.4, the 10 kA residual voltage of each MOV disc section was measured prior to and after the (18) shot LCLD test.

Results: Table 1 summarizes the results of the 18 shot test performed on the three test samples.

Table 1

	Sample #1		Sample #2		Sample #3	
Shot No.	**Amps**	**KJ/Shot**	**Amps**	**KJ/Shot**	**Amps**	**KJ/Shot**
1	256.3	7.89	255.1	7.89	255.6	7.89
2	252.3	7.81	249.9	7.78	253.1	7.86
3	254.2	7.91	252.8	7.91	251.3	7.81
4	254.0	7.85	250.9	7.79	266.4	8.04
5	255.3	7.93	254.9	7.94	260.9	7.95
6	254.9	7.96	251.5	7.88	260.9	7.95
7	255.3	7.89	252.2	7.81	259.7	7.86
8	254.0	7.91	252.4	7.89	259.9	7.91
9	253.8	7.92	250.9	7.87	257.6	7.85
10	254.7	7.85	249.9	7.77	259.5	7.88
11	250.7	7.81	253.8	7.92	259.9	7.93
12	253.6	7.93	252.0	7.92	257.0	7.86
13	252.6	7.82	250.9	7.82	262.2	7.97
14	254.0	7.91	252.8	7.91	259.1	7.91
15	253.2	7.91	250.1	7.85	259.3	7.94
16	246.1	7.77	253.4	7.89	261.1	7.91
17	252.4	7.85	251.3	7.87	259.3	7.87
18	248.8	7.91	252.8	7.93	257.2	7.87

Figures 1 and 2, respectively show oscillograms of the 1st and 18 shots performed on sample #2. These oscillograms are typical for all three test samples.

Figure #1

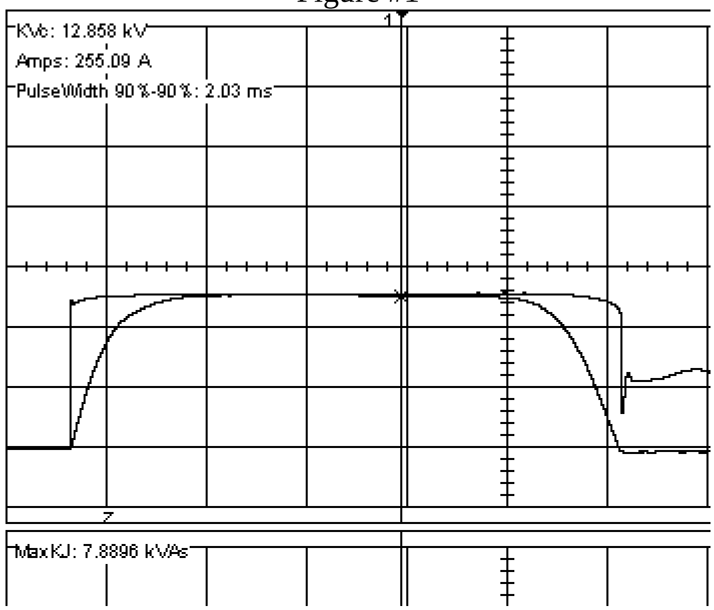
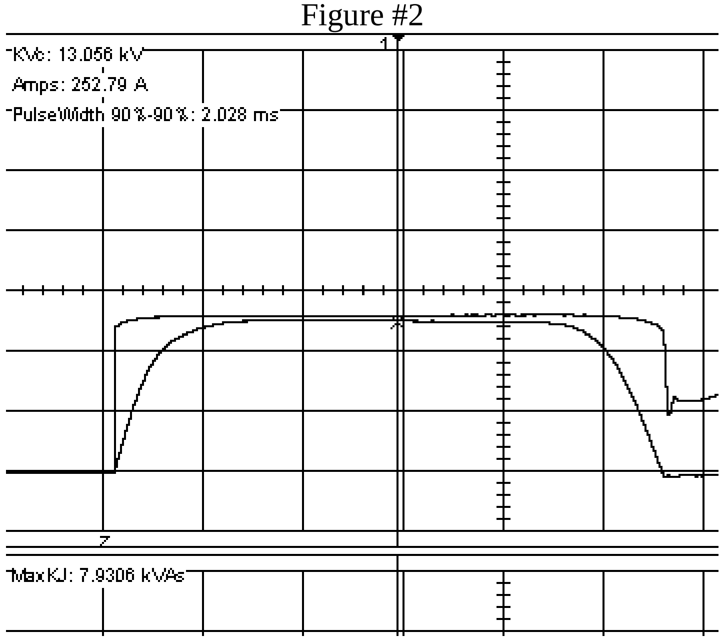


Figure #2



Residual voltage at 10 kA was measured prior to and following the 18-shot 250 A discharge tests. Table 2 summarizes the results of the 10 kA discharge voltage testing.

Table 2

Sample #	10 kA IR-kVc (Before)	10 kA IR-kVc (After)	10 kA IR % Change
1	17.057	17.501	+2.6
2	17.177	17.312	+0.8
3	16.868	16.934	+0.4

Conclusion: The prorated test samples successfully completed the 18-shot low current, long duration test. The sample discharge voltage increase ranged from 0.4 to 2.6%, well below the 10% change allowed in Section 8.13.4 of IEEE C62.11-2012 Standard. Disassembly revealed no evidence of physical damage to the test samples. The ground lead disconnectors did not detonate during the 18 shot test series. The PVR arrester successfully met the LCLD requirements of the Heavy Duty Distribution Class arrester.

TYPE TEST REPORT No. EU1480-HR-11.2

DUTY CYCLE TEST
Type PVR Heavy Duty Distribution Riser Pole Arrester

CERTIFICATION

This is to certify that the duty cycle design test has been successfully performed on the Ohio Brass Type PVR Riser Pole Heavy Duty Distribution Class surge arrester per Clause 8.16 of IEEE C62.11-2012 Standard.

Saroni Brahma
Design Engineer

Dennis W. Lenk P.E.
Principal Engineer

10/31/2013
Attachments

DESIGN TEST REPORT
PVR Riser Pole Heavy Duty Distribution Class Surge Arrester
Duty Cycle Test

Introduction: Duty cycle tests were performed per clause 8.16 of IEEE Standard C62.11-2013. Tests were performed on the PVR prorated secctions per Heavy Duty Distribution arrester requirements. As required by clause 8.21, tests were performed on three prorated sections with a ground lead disconnector (GLD) to demonstrate that the GLD does not detonate during the test procedure.

Test Procedure: The prorated test section was energized at its rated voltage and subjected to twenty 10 kA, 8/20 μs discharges spaced at 1 minute intervals. Following the twentieth impulse, the test section was placed in an oven at 63°C. After reaching 63°C, the sample was subjected to two additional 40 kA, 8/20 μs discharges. Within 5 minutes after the second high current discharge, the sample was energized at the prorated recovery voltage. Watts loss was monitored over a 30 minute period demonstrating thermal stability.

Test Results: Tests were successfully completed on three prorated sections, each assembled with a GLD. The following data summarizes the results of tests performed on prorated section #1.

The following data summarizes the results of the duty cycle test performed on prorated section #1. Figures 1 and 2 show the 1st and 20th shot performed during the rated voltage portion of the duty cycle test.

Figure 1

1st Shot @ Rated Voltage

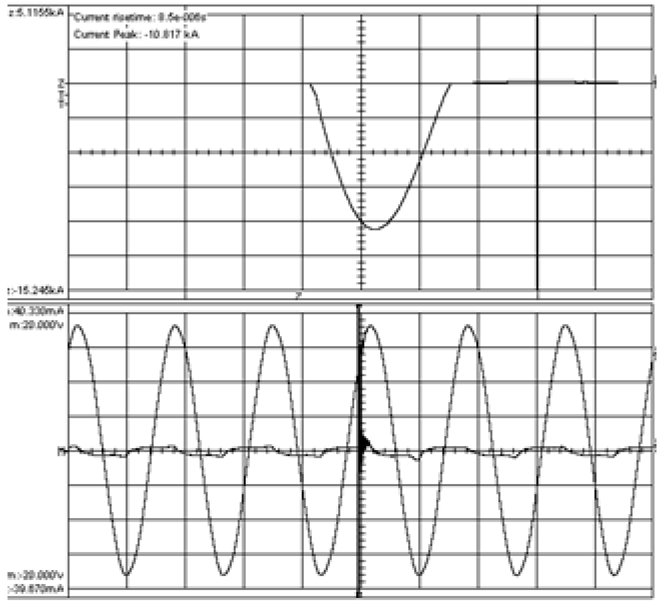


Figure 2

20th Shot @ Rated Voltage

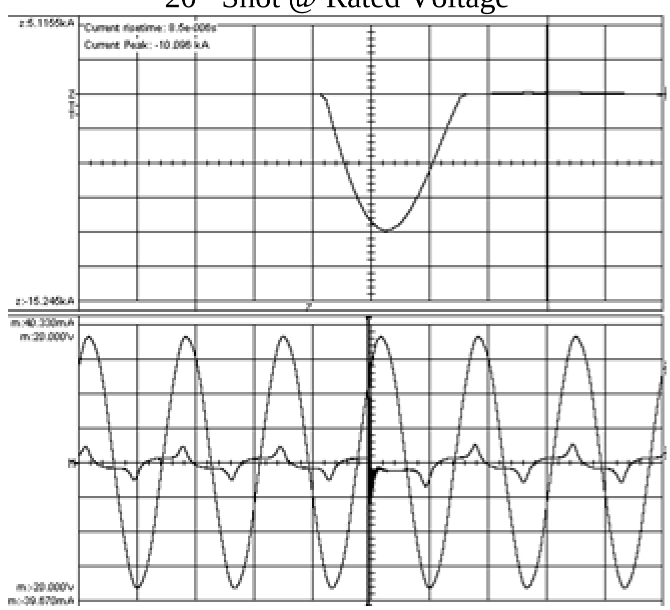
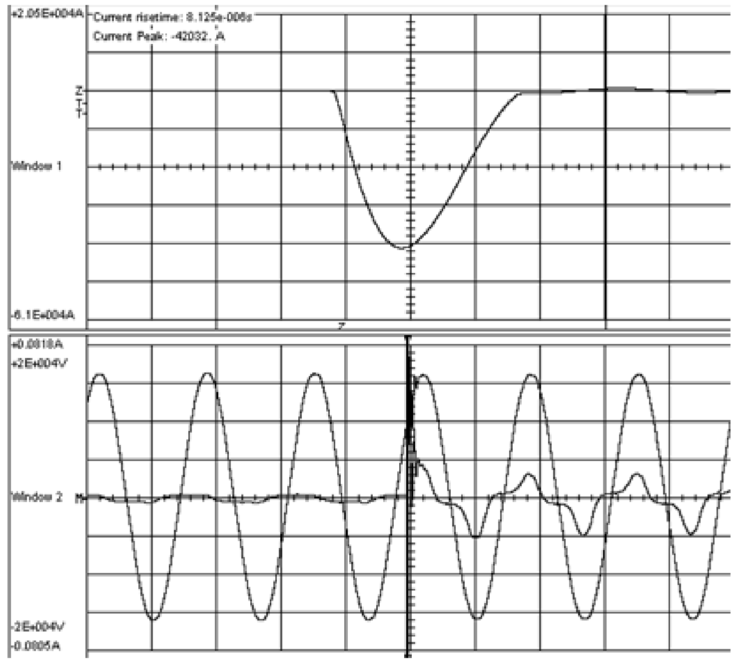


Figure 3 shows the oscillogram for the 2nd 40 kA impulse applied to the prorated section #1 during the recovery portion of the duty cycle test.

Figure 3

2nd 40 kA Discharge Prior to Recovery



Figures 4 and 5 show oscillograms of the prorated section #1 grading current through the test section at time zero and 30 minutes after application of recovery voltage, demonstrating thermal recovery has occurred.

Figure 4

Recovery @ Time = 0 Minutes

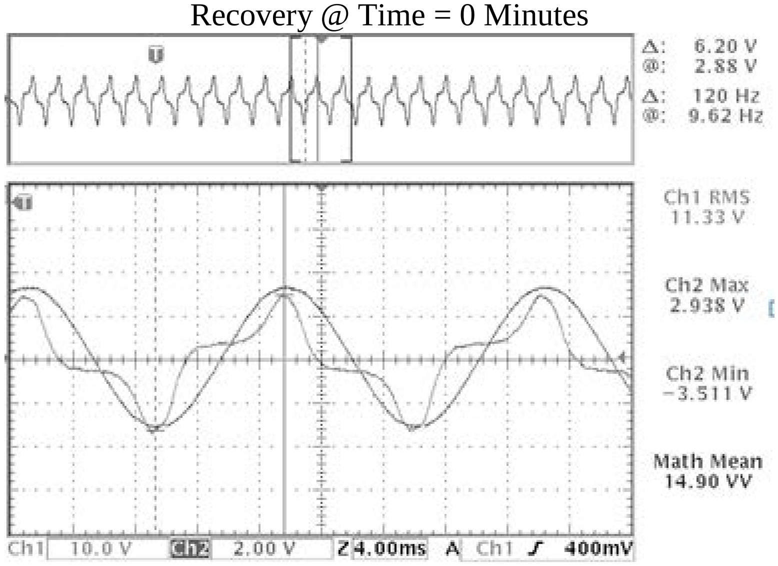
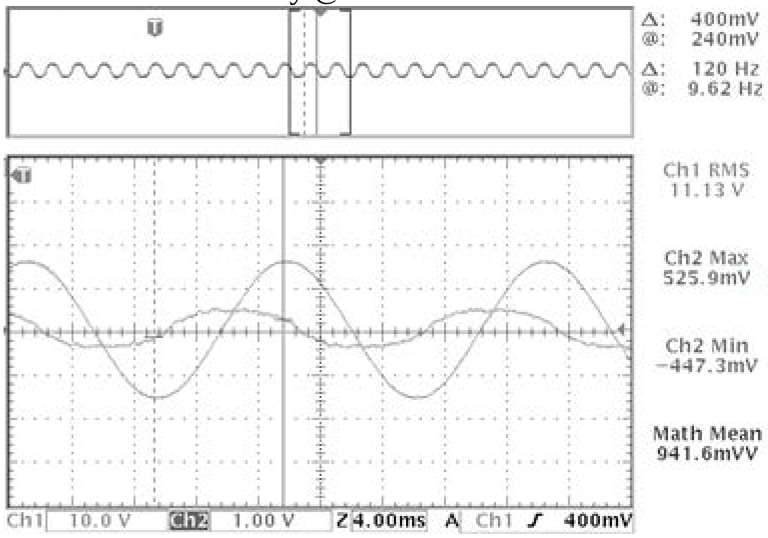


Figure 5

Recovery @ Time = 30 Minutes



Prior to and after the duty cycle test, the 10 kA, 8/20 µs discharge voltage was measured on the three prorated sections. Table 1 summarizes this test data.

Table 1

Section #	10 kAQ IR kVc (Before)	10 kAQ IR kVc (After)	10 kA IR % Change
1	31.93	32.235	1.0%
2	31.93	32.352	1.3%
3	31.91	32.166	0.8%

CONCLUSION: The Type PVR prorated test samples successfully completed Duty Cycle testing and demonstrated thermal stability during the recovery test. The 10 kA discharge voltage increased 1.3%, less than the allowed 10% limit specified in Section 8.16.4 of the IEEE C62.11-2012 standard. Disassembly revealed no evidence of physical damage to the test samples. The ground lead disconnector (GLD) on each prorated section successfully withstood the duty cycle testing without detonating. The Type PVR arrester successfully met the Heavy Duty Distribution arrester Duty Cycle requirements.

TYPE TEST REPORT No. EU 1480-HR-12.3

TEMPORARY OVERVOLTAGE TEST
PVR Riser Pole Arrester

CERTIFICATION

This is to certify that the temporary overvoltage design test has been successfully performed on Ohio Brass Type PVR Riser Pole Distribution Class surge arrester per Clause 8.17 of the IEEE C62.11-2012 Standard..

Saroni Brahma
Design Engineer

Dennis W. Lenk P.E.
Principal Engineer

10/31/2013
Attachments

DESIGN TEST REPORT
PVR Riser Pole Distribution Class Surge Arrester
Temporary Over-Voltage Tests (TOV) Performed on Arrester Section
Without Insulating Bracket:

Introduction; Temporary over-voltage tests were performed per clause 8.17 of IEEE Standard C62.11-2012. Tests were performed per Heavy Duty distribution arrester requirements using four prorated test sections.

Test Sections: Nominally 6 and 12 kV rated prorated sections were used to facilitate testing. The short time data points were generated using 6 kV rated sections while the longer time data points used 12 kV rated sections. As both sizes of arresters were thermally equivalent to the highest rated PVR arrester, the results of these tests cover ratings 3 - 36 kV with corresponding MCOV levels of 2.55 - 29.0 kV.

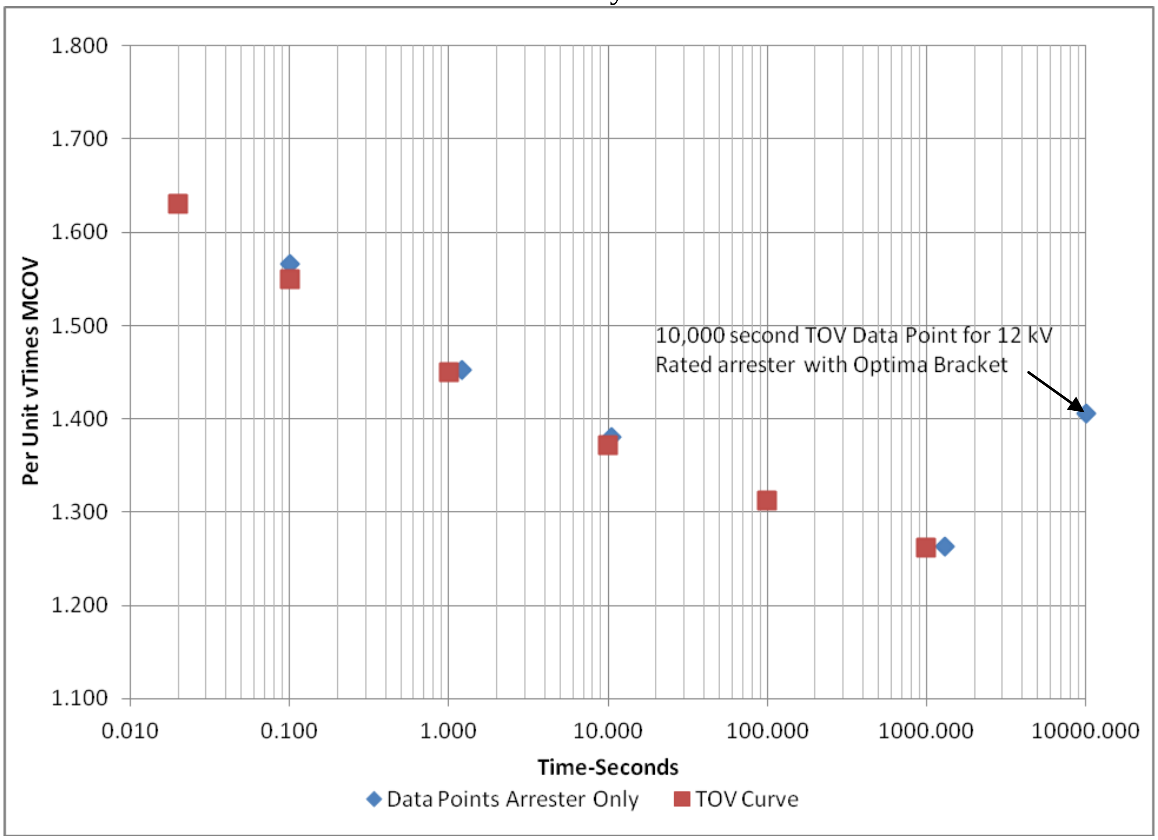
Results: Per clause 8.17.3, each prorated sample was tested within four of the six designated time ranges a - f, spanning over-voltage durations of .01 - 10,000 seconds. The tests were performed demonstrating TOV capability of the design under "no prior duty" conditions. For each TOV voltage setting, the test circuit applied voltage to the sample (preheated to 67^{o}C) for a time duration sufficient to exceed that claimed on the "no prior duty" curve. TOV voltage was superimposed over recovery voltage such that when TOV was removed, there was no delay prior to application of recovery voltage. Recovery voltage was applied for 30 minutes to demonstrate thermal stability. As required by Section 8.17.3, Table 1 summarizes the Type PVR No Prior Duty TOV data points for the arrester assembled without the ground lead disconnecting (GLD) bracket.

Table 1

Time-Seconds	TOV Per Unit Times MCOV
0.02	1.63
0.1	1.55
1	1.45
10	1.372
100	1.313
1000	1.262

Figure 1 summarizes the results of the TOV testing performed on the prorated sections without the ground lead disconnecting (GLD) bracket. The single 1.406 per unit MCOV/10,000 second data point was generated using a 12 kV rated section connected in series with the GLD bracket, validating the claimed 1.40 per unit MCOV/10,000 second claim for the 12 kV arrester mounted on the GLD insulating support bracket.

Figure 1
PVR No Prior Duty TOV Curve



Per Section 8.17.4, the 10 kA discharge voltage for each test section was measured prior to and after TOV testing. Table 2 summarizes the results of that testing.

Table 2

Data Range	Time Seconds	Section Size	10 kA Discharge Voltage -kVc		
			Before TOV	After TOV	% Change
a	0.1	6 kV	16.712	16.927	1.3%
c	1.2	6 kV	16.730	16.910	1.2%
d	10.5	12 kV	31.931	31.863	-0.2%
f	1300	12 kV	31.952	31.907	-0.2%

Conclusion: Tests were successfully completed on four prorated samples in four specified time ranges. Each sample demonstrated thermal stability after TOV exposure. Residual voltage at 10 kA measured prior to and after the TOV test series changed much less than the allowed 10%. There was no evidence of physical damage to the test sections, validating the PVR arrester TOV capability claim.

DESIGN TEST REPORT
PVR Optima Distribution Class Surge Arrester

TITLE: Temporary over-voltage tests (TOV) performed on arrester with insulating bracket):

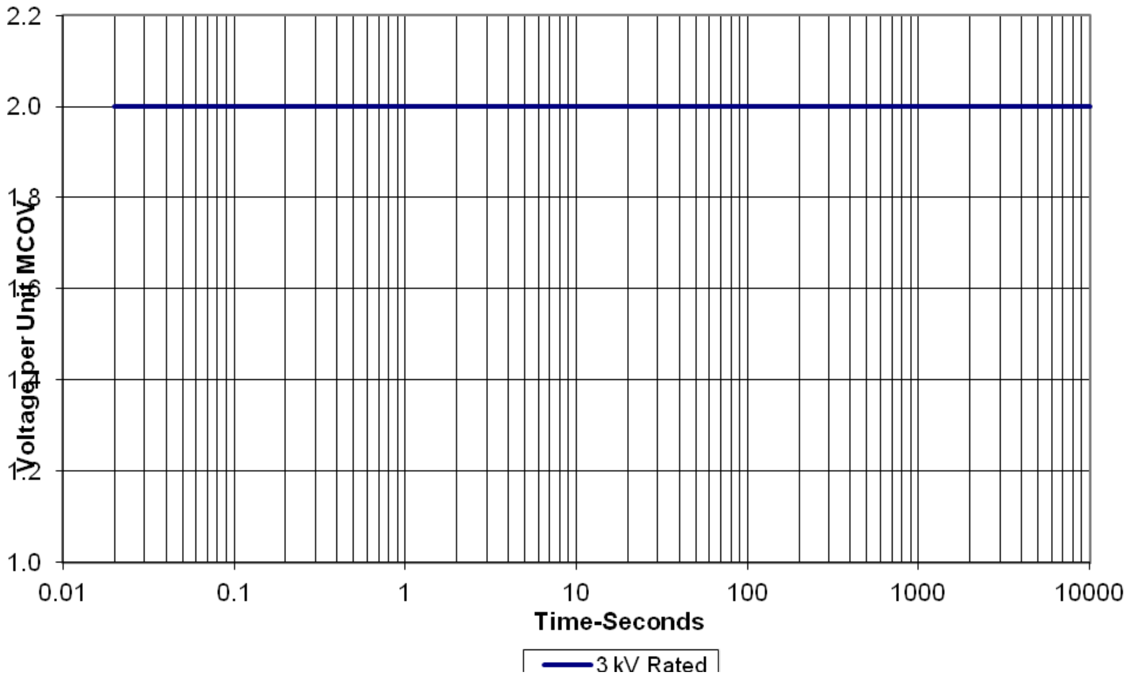
OBJECTIVE: Laboratory testing reveals that attachment of the PVR Optima arrester to the insulating bracket significantly improves the long time TOV capability of the arrester assembly. The degree of improvement is a function of the individual arrester ratings. The following curves show the improved TOV characteristic of the various arrester ratings mounted to the insulating bracket.

SAMPLES: Arresters ranging in rating from 3 thru 36 kV were assembled with the insulating bracket and subjected to TOV testing.

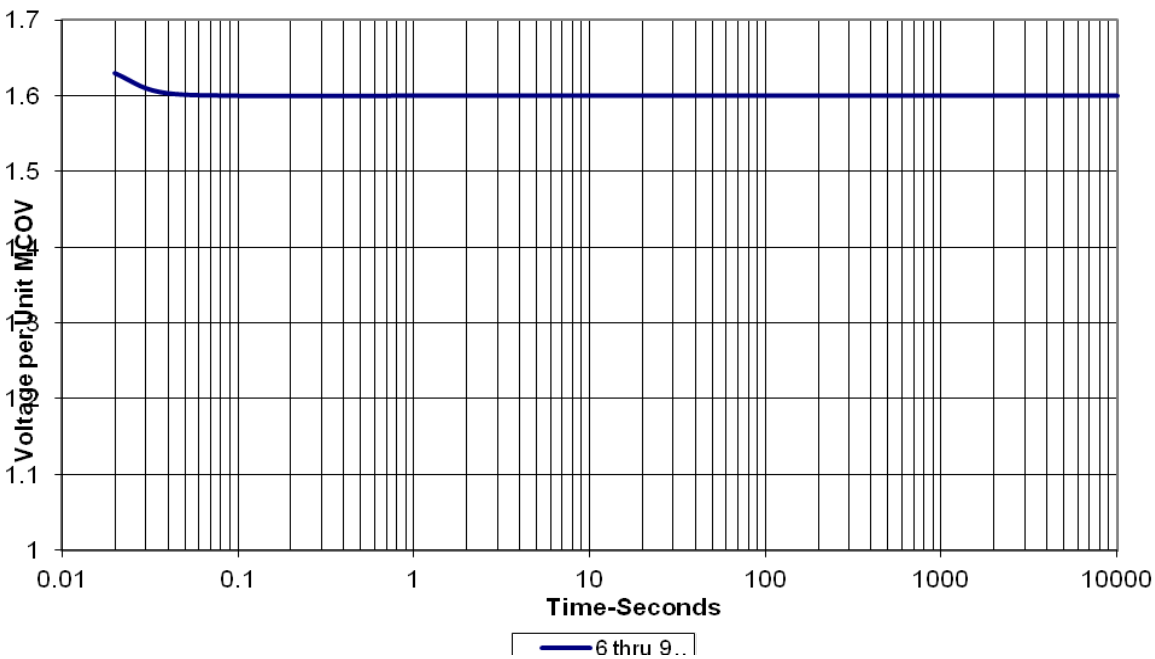
TEST RESULTS: The following tables summarize the claimable temporary overvoltage capability of the various PVR Optima arrester ratings mounted on an insulating base bracket.

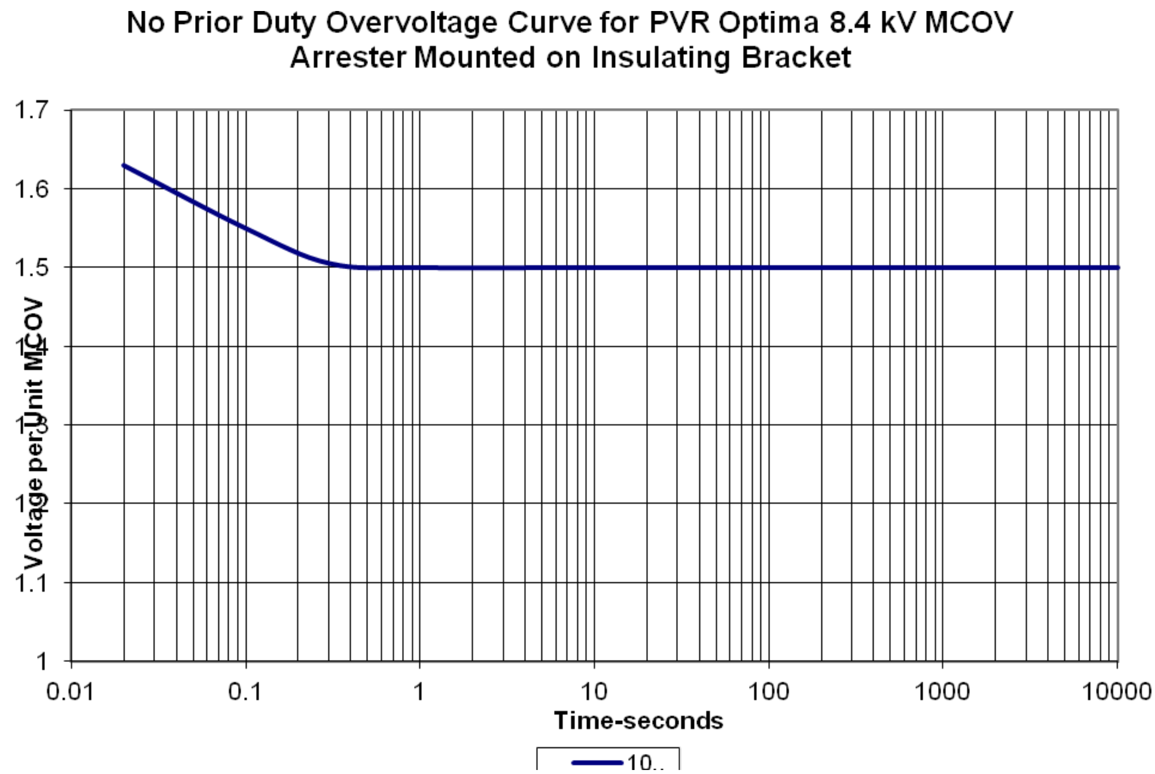
CONCLUSION (Arrester Mounted On Insulating Bracket): The following family of curves defines the overvoltage withstand capability of the various rated PVR Optima bracket-mounted arresters when subjected to overvoltages with time durations ranging from .02 to 10,000 seconds duration.

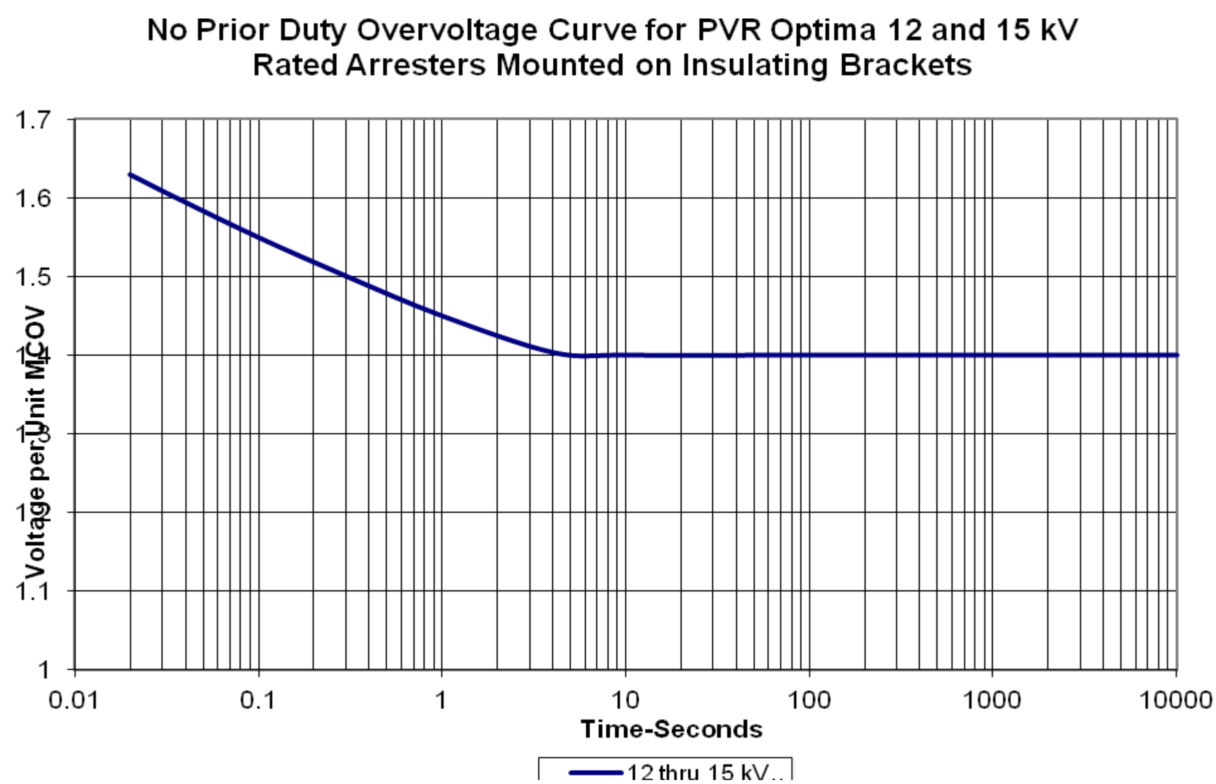
No Prior Duty Overvoltage Capability Curve for PVR Optima 3 kV Rated arrester Mounted on Insulating Bracket



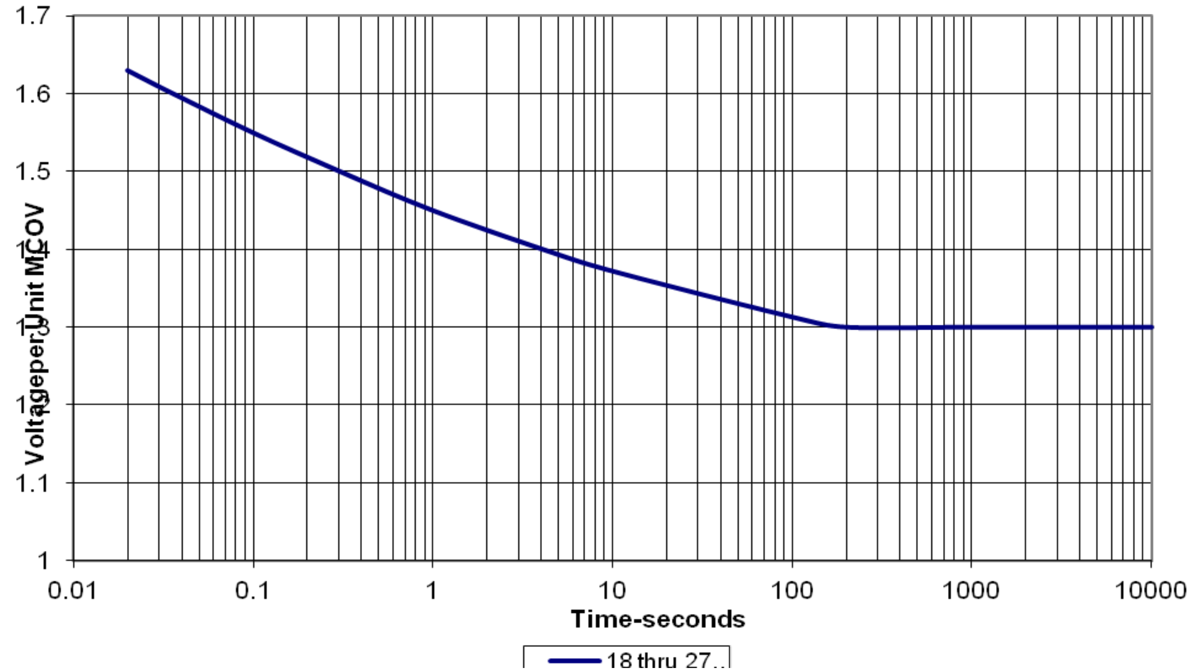
No Prior Duty Overvoltage Curve for PVR Optima 6 and 9 kV Rated Arresters Mounted on Insulating Bracket



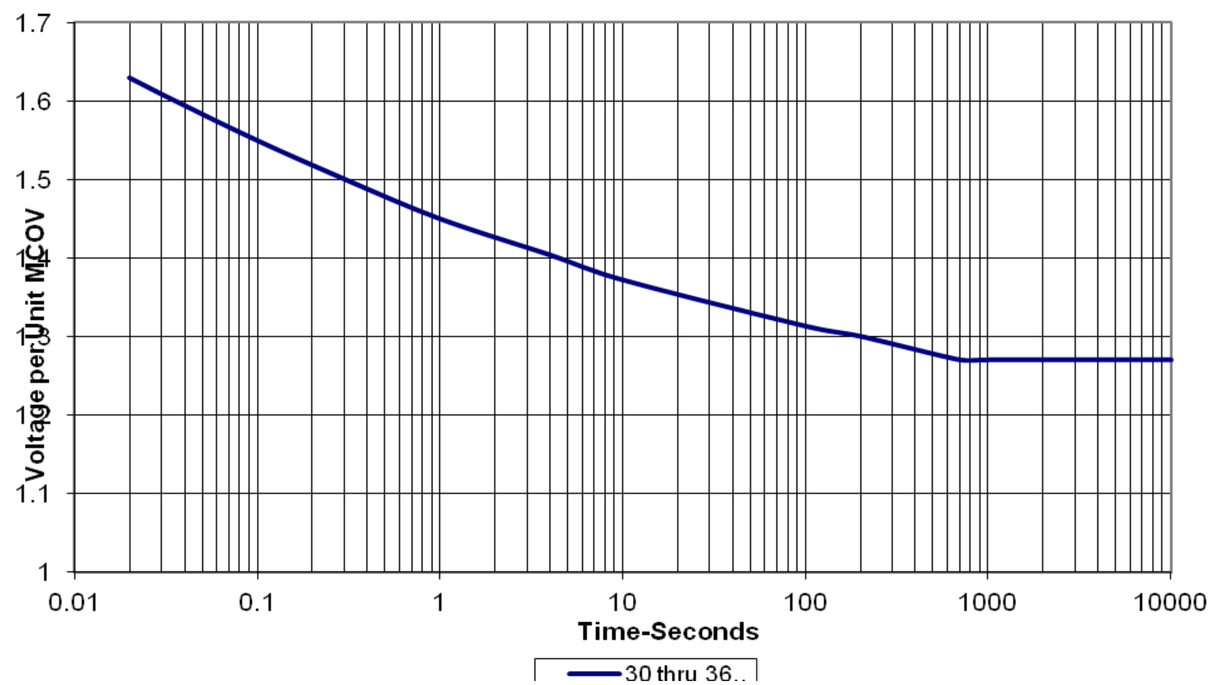

No Prior Duty Overvoltage Curve for PVR Optima 8.4 kV MCOV
Arrester Mounted on Insulating Bracket
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1
Voltage per Unit MCOV
0.01
0.1
1
10
100
1000
10000
Time-seconds
10..


No Prior Duty Overvoltage Curve for PVR Optima 12 and 15 kV
Rated Arresters Mounted on Insulating Brackets
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1
Voltage per Unit MCOV
0.01
0.1
1
10
100
1000
10000
Time-Seconds
12 thru 15 kV..

No Prior Duty Overvoltage Curve for PVR Optima 18 thru 27 kV rated Arresters Mounted on Insulating Bracket



No Prior Duty Overvoltage Curve for PVR Optima 30 thru 36 kV Rated arresters Mounted on Insulating Bracket



TYPE TEST REPORT No. EU 1480-HR-13.2

SHORT CIRCUIT TEST
PVR Riser Pole Arrester

CERTIFICATION

This is to certify that the short circuit design test has been successfully performed on Ohio Brass Type PVR Riser Pole Distribution Class surge arrester.

Saroni Brahma
Design Engineer

Dennis W. Lenk P.E.
Principal Engineer

10/31/2013
Attachments

DESIGN TEST REPORT
PVR Riser Pole Distribution Class Surge Arrester
Short-Circuit Test

OBJECTIVE: Short circuit tests were performed on the Type PVR Riser Pole Distribution Class arrester per section 8.18 of IEEE Standard C62.11-2012. Tests were performed in compliance with Table 14 of the referenced standard. Additional short circuit tests were performed as shown.

TEST SAMPLE: Fault current tests were performed on the longest mechanical section, as required in Section 8.18.1 of the standard. As required in Section 8.18.1, two test samples were tested (one at 20 kArms/12 cycle high current and one at 600 amp/ 1 second) using the specified 2-source failure method. One additional 2-source and two additional 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. The fuse wire samples were subjected to the full offset current test. In addition, two samples were tested per the 2-source method at 10 kArms. These samples were failed using the specified 2-source failure mode procedure.

TEST 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, tests were also performed, using the 2-source procedure, at half the claimed capability and at 600 amps as specified in Table 14 of the standard.

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 Section 8.18.3 of IEEE C62.11-2012 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 PVR arrester design to discharge a maximum claimable 20 kA_{rms} symmetrical fault current using the test procedure defined in Section 8.18 of IEEE C62.11-2012 Standard.

TYPE TEST REPORT No. EU 1480-HR-14.2

DISCONNECTOR TESTS
PVR Optima Riser Pole Arrester Insulating Bracket

CERTIFICATION

This is to certify that the disconnector tests have been successfully performed on Ohio Brass Type PVR Riser Pole Distribution Class surge arrester insulating bracket.

Saroni Brahma
Design Engineer

Dennis W. Lenk P.E.
Principal Engineer

10/31/2013
Attachments

DESIGN TEST REPORT
PVR Optima Riser Pole Distribution Class Surge Arrester
Insulating Bracket Disconnector Tests

OBJECTIVE: Tests were performed per clause 8.21 of IEEE Standard C62.11-2012.

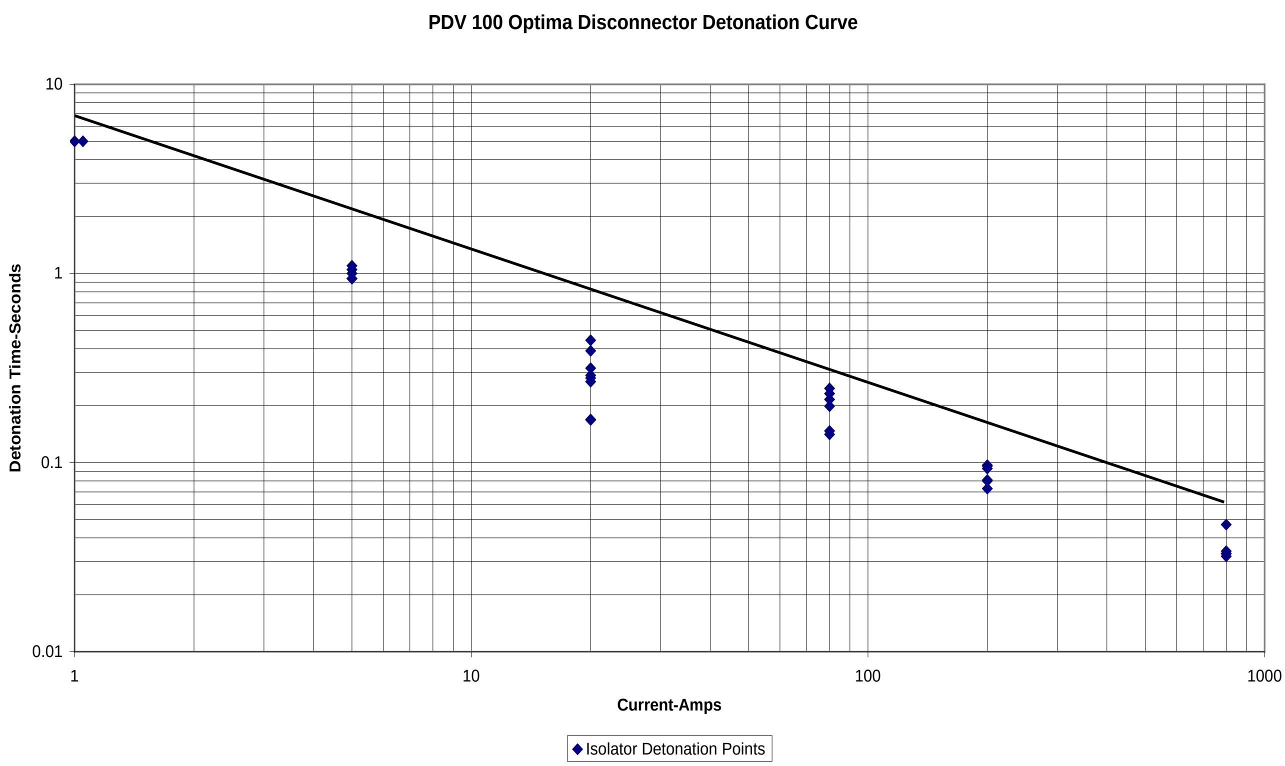
TEST PROCEDURES: High current short duration, low current long duration discharge, and duty cycle tests were performed on thermally prorated test sections having the disconnector assembly connected in series.

Disconnector detonation testing was performed on five bracket/isolator assemblies each at 20, 80, 200, and 800 A_{rms}. In addition, detonation testing was also performed at 1 and 5 A_{rms}.

TEST RESULTS: Disconnectors did not operate when subjected to high current short duration, low current long duration discharge duty tests, and duty cycle tests.

In all cases, disconnectors separated during detonation tests at each of the required current levels.

CONCLUSION: The disconnector passed all requirements of clause 8.21. The following figure shows the detonation curve for the PVR Riser Pole Optima disconnector, which is the same as that used on the PDV100 Optima arrester.



TYPE TEST REPORT No. EU 1480-HR-15.2

MAXIMUM DESIGN CANTILEVER AND MOISTURE INGRESS TEST
PVR Riser Pole Distribution Arrester

CERTIFICATION

This is to certify that the maximum design cantilever (MDCL) and moisture ingress test has been successfully performed on the Ohio Brass Type PVR Riser Pole Distribution Class surge arrester.

Saroni Brahma
Design Engineer

Dennis W. Lenk P.E.
Principal Engineer

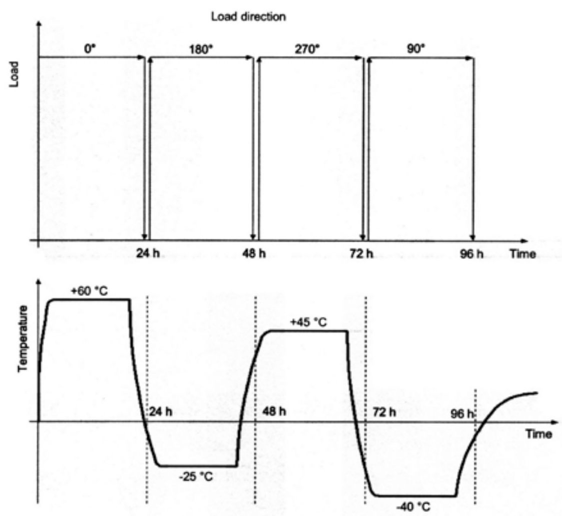
10/31/2013
Attachments

DESIGN TEST REPORT
PDV 100 Optima Distribution Class Surge Arrester

TITLE: Maximum design cantilever (MDCL) and moisture ingress test:

TEST SAMPLES: The maximum design cantilever and moisture ingress test was performed on a PVR Riser Pole 17 kV MCOV arrester, representing the longest mechanical unit. Tests were performed on this 8.6" long arrester to validate the claimed 1200 inch-pound continuous cantilever rating.

TEST PROCEDURE: The test was performed per section 8.22 of C62.11-2012 standard. The test arrester was subjected to PD, watts loss, and discharge voltage tests prior to the bending moment and boiling water immersion test. The mechanical portion of the test consisted of first applying a 20 ft-lb torque to the arrester end terminals for 30 second duration. The test arrester was then placed inside a thermal cycling oven and mechanically loaded to its 1200 in-lb continuous cantilever rating. The load application and test temperature is shown on the attached figure.



After completion of the mechanically loading portion of the test procedure, the water immersion portion of the bending moment test was performed per para. 8.22.3.3.a) and consists of placing the mechanically stressed arrester into a boiling salt water bath for 42 hours, after which the same is cooled to room temperature and electrical tests are repeated.

TEST RESULTS:

Sample No.	Initial Watts @ .8*Uc	Final Watts @ .8*Uc	Initial PD @ 1.05 times Uc (pC)	Final PD @ 1.05 times Uc (pC	Initial 10 kA Residual Voltage kVc	Final 10 kA Residual Voltage kVc
1	.284	.260	0	0	56.8	57.6

CONCLUSION: Per Section 8.22.4, the partial discharge levels were unchanged and the watts loss changed 8.5%, less than the allowed 20% increase. Top end deflection measurements unchanged, less than the allowed 10% as a result of the thermal cycling test. The 10 kA IR changed 1.4%, less than the allowed 10%. Visual examination revealed no evidence of mechanical damage or moisture ingress inside the arrester as a result of the test procedure. The above tests have validated the 1200 inch-pound continuous cantilever rating of the base mounted PVR Riser Pole arrester.