IEC Type Test Report

Report Number: TD 01 39 E01

EVP IEC Station Arrester SM Designation Class Station Medium (SM)

This report records the results of this type test made on 10 kA Station Class SM arresters rated 3 thru 228kV in accordance with IEC Standard 60099-4, Ed. 3.0, 2014, “Surge arresters - Part 4: Metal-oxide surge arresters without gaps for a.c. systems.”

Type tests performed on Class Station Medium (SM) arresters demonstrate full compliance with the relevant clauses of the referenced standard and apply to all Hubbell 10 kA Station Class SM 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

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
Principal Engineer

Fayaz Khatri
Design Engineering Supervisor

SEPARATE REPORTS PROVIDE DETAILS OF EACH TEST, ACCORDING TO THE FOLLOWING TABLE:				
Report No.	**Description**	**Clause**	**Issue date**	**Page**
TD 01 39 E01	Insulation Withstand Tests	10.8.2	1/15/2016	3
TD 01 39 E02	Residual Voltage	10.8.3	1/15/2016	7
TD 01 39 E03	MOV Disc Accelerated Aging	10.8.4	1/15/2016	15
TD 01 39 E04	Repetitive Charge transfer Rating Qrs	10.8.5	1/15/2016	17
TD 01 39 E05	Thermal Equivalency	10.8.6	1/15/2016	20
TD 01 39 E06	Switching Surge Thermal Energy Rating Wth	10.8.7	1/15/2016	22
TD 01 39 E07	Power Frequency Voltage-Versus-Time Test	10.8.8	1/15/2016	24
TD 01 39 E08	Short Circuit Tests	10.8.10	1/15/2016	28
TD 01 39 E09	Bending Moment	10.8.11	1/15/2016	30
TD 01 39 E10	RIV Test	10.8.14	1/15/2016	33
TD 01 39 E11	Salt Fog Test	10.8.17.2	1/15/2016	36
TD 01 39 E12	UV Light Test	10.8.17.3	1/15/2016	39

IEC Type Test Report

Report Number: TD 01 39 E01
EVP IEC Station Arrester SM Designation
10 kA Discharge Current

Insulation Withstand Tests
IEC Clause 10.8.2

This report presents the results of type tests made on EVP IEC Station Arrester SM Designation, U_r rated 3 through 228 kV. Tests were performed in accordance with procedures of IEC Standard 60099-4 Edition 3.0, 2014-6 “Surge arresters -- Part 4: Metal-oxide surge arresters without gaps for a.c. systems.”

To the best of our knowledge and within the usual limits of testing practice, tests performed on these arresters demonstrate compliance with the relevant clauses of the referenced standard.

Dennis W. Lenk
Principal Engineer

Fayaz Khatri
Design Engineering Supervisor

Introduction

The voltage withstand tests demonstrate the voltage withstand capability of the external insulation of the arrester housing.

Procedure

Tests were performed in the conditions and with the test voltage shown in Table 1. The outside surface of the insulating parts was carefully cleaned and the internal parts removed per clause 8.2.1 of IEC 60099-4, Edition 3.0, 2014-6 "Surge arresters -- Part 4: Metal-oxide surge arresters without gaps for a.c. systems." Testing was performed on the longest single unit.

During the lightning impulse voltage test, the arrester was subjected to a standard lightning impulse voltage dry test according to IEC 60060-1. Fifteen consecutive impulses at the test voltage value were applied for each polarity. The test voltage shall be at least 1.3 times the maximum residual voltage of the arrester at nominal discharge current.

During the switching impulse voltage test, the station class arresters intended for use on systems greater than 245 kV shall be subjected to a standard switching impulse voltage test according to IEC 60060-1. Fifteen consecutive impulses at the test voltage value were applied for each polarity. The test voltage shall be at least 1.25 times the maximum switching impulse residual voltage of the arrester.

During the power-frequency voltage test, the station class arresters intended for use on systems less than or equal to 245 kV shall withstand a power-frequency voltage with a peak value equal to the switching impulse protection level multiplied by 1.06 for a duration of one minute. The housings of arresters, intended for outdoor use, were tested in wet conditions.

Results

The following table lists the EVP Station Class SM arresters' minimum strike distance, 1.2/50 required and actual impulse withstand levels, and 60 HZ required and actual wet withstand levels as defined in the standard.

TABLE 1. INSULATION WITHSTAND TEST RESULTS

Uc Continuous Voltage	Ur Rated Voltage	Strike Distance	Lightning Impulse Withstand Required	Lightning Impulse Withstand Actual	60 HZ Wet 1 Minute Required [1]	60 HZ Wet 1 Minute Actual [1]	Switching Impulse Withstand Required [1]	Switching Impulse Withstand Actual [1]
(kVrms)	(kVrms)	(mm)	kV peak	kV peak	kV peak	kV peak	kV peak	kV peak
2.55	3	175	10	101	7	71	-	-
5.1	6	175	20	101	13	71	-	-
7.65	9	221	30	127	20	89	-	-
8.4	10	221	32	127	22	89	-	-
10.2	12	221	39	127	27	89	-	-
12.7	15	267	49	153	33	106	-	-
15.3	18	267	59	153	40	106	-	-
17	21	361	66	207	44	143	-	-
19.5	24	361	75	207	51	143	-	-
22	27	361	85	207	57	143	-	-
24.4	30	361	94	207	63	143	-	-
29	36	455	113	261	76	177	-	-
31.5	39	455	122	261	82	177	-	-
36.5	45	546	141	313	95	209	-	-
39	48	546	151	313	101	209	-	-
42	54	546	170	313	114	209	-	-
48	60	640	188	367	126	243	-	-
57	72	734	225	421	152	274	-	-
70	90	1100	282	631	190	389	-	-
74	90	1100	286	631	193	389	-	-
76	96	1100	301	631	203	389	-	-
84	108	1100	340	631	229	389	-	-
88	108	1100	340	631	229	389	-	-
98	120	1135	379	652	255	400	-	-
106	132	1135	413	652	278	400	-	-
115	141	1321	450	758	303	452	-	-
131	158	1613	526	926	354	526	-	-
140	172	1753	541	1006	365	559	-	-
144	180	1753	563	1006	379	559	-	-
152	192	1753	600	1006	404	559	-	-
180	228	2032	713	1166	-	-	566	977

[1] Items not tested are not required per IEC standard

Conclusion

All housings meet or exceed the required levels of voltage clause 8.2 of IEC 60099-4, Ed. 3.0, 2014-06, International Standard.

The lightning impulse voltage test was considered successful per clause 8.2.6 of IEC 60099-4, Ed. 3.0, 2014-06, International Standard. The clause states the arrester shall be considered to have passed the test if no internal disruptive discharges occur and if the number of the external disruptive discharges does not exceed two in each series of 15 impulses. No internal discharges occurred. No external disruptive discharges occurred.

The switching impulse voltage test was considered successful per clause 8.2.7 of IEC 60099-4, Ed. 3.0, 2014-06, International Standard. The clause states the arrester shall be considered to have passed the test if no internal disruptive discharges occur and if the number of the external disruptive discharges does not exceed two in each series of 15 impulses. No internal discharges occurred. No external disruptive discharges occurred.

The power frequency voltage test was considered successful per clause 8.2.8 of IEC 60099-4, Edition 3.0, 2014-6 “Surge arresters -- Part 4: Metal-oxide surge arresters without gaps for a.c. systems.”. No internal discharges occurred. No external disruptive discharges occurred. All required values were met or exceeded.

IEC Type Test Report

Report Number: TD 01 39 E02
EVP IEC Station Arrester SM Designation
10 kA Discharge Current

Residual Voltage Tests
IEC Clause 10.8.3

This report presents the results of type tests made on EVP IEC Station Arrester SM Designation, U_r rated 3 through 72 kV. Tests were performed in accordance with procedures of IEC Standard 60099-4 Edition 3.0, 2014-6 "Surge arresters -- Part 4: Metal-oxide surge arresters without gaps for a.c. systems."

To the best of our knowledge and within the usual limits of testing practice, tests performed on these arresters demonstrate compliance with the relevant clauses of the referenced standard.

Dennis W. Lenk
Principal Engineer

Fayaz Khatri
Design Engineering Supervisor

Introduction

This test is to determine the maximum residual voltage of an arrester.

Procedure

Residual voltage tests were performed on three longest 56mm x 41 mm MOV discs. 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, 3, 5, 10, 20 kA;
3. Switching Impulse Residual Voltage Test: 30-100/60-200 µs and 500 A.

Results

Each of the three test samples was subjected to a 10 kA, 1/2 µs steep current impulse with and without an aluminum disc with the same geometry of the MOV disc. The difference in the residual voltages is the inductive drop across the MOV disc. Figures 1a and 1b show the oscillograms of the measured FOW residual voltage discharges of Sample 3 without and with an aluminum spacer, respectively.

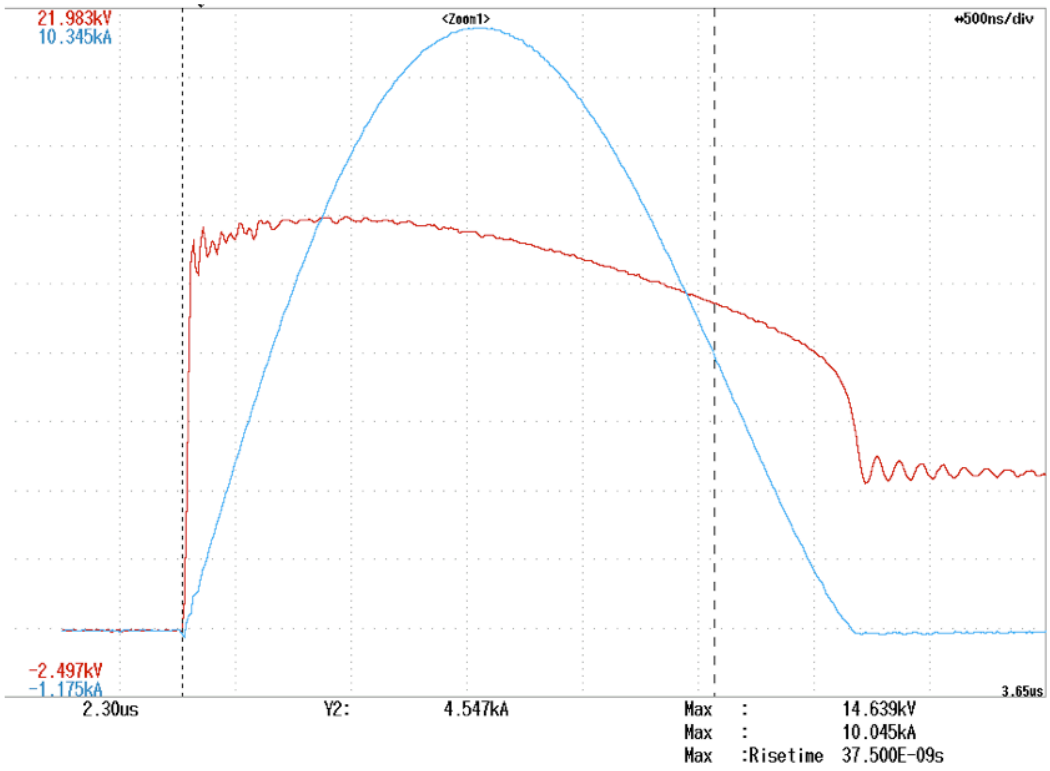


Figure 1a: Sample 3, 10.045 kA, 14.639 kV w/o Aluminum spacer.

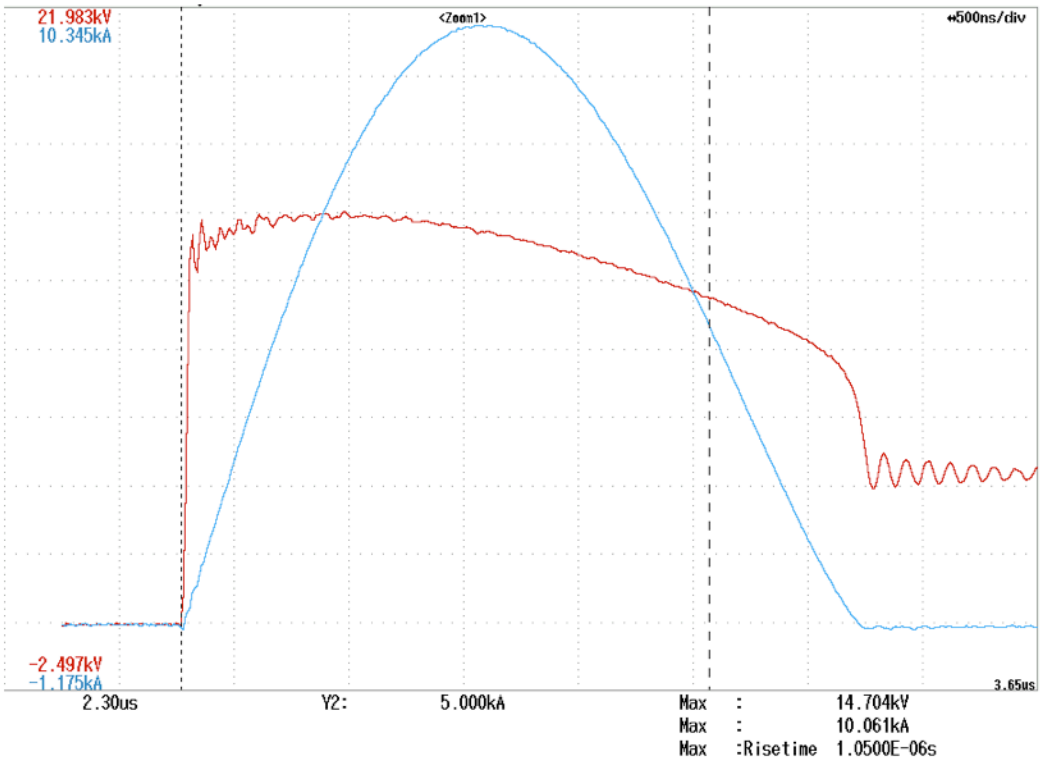


Figure 1b: Sample 3, 10.061 kA, 14.704 kV with Aluminum spacer.

Each sample was then subjected to 1.5, 3.0, 5.0, 10 and 20 kA lightning surge impulses. Figure 2 shows the oscillogram of the 10kA 8/20 discharge of Sample 3.

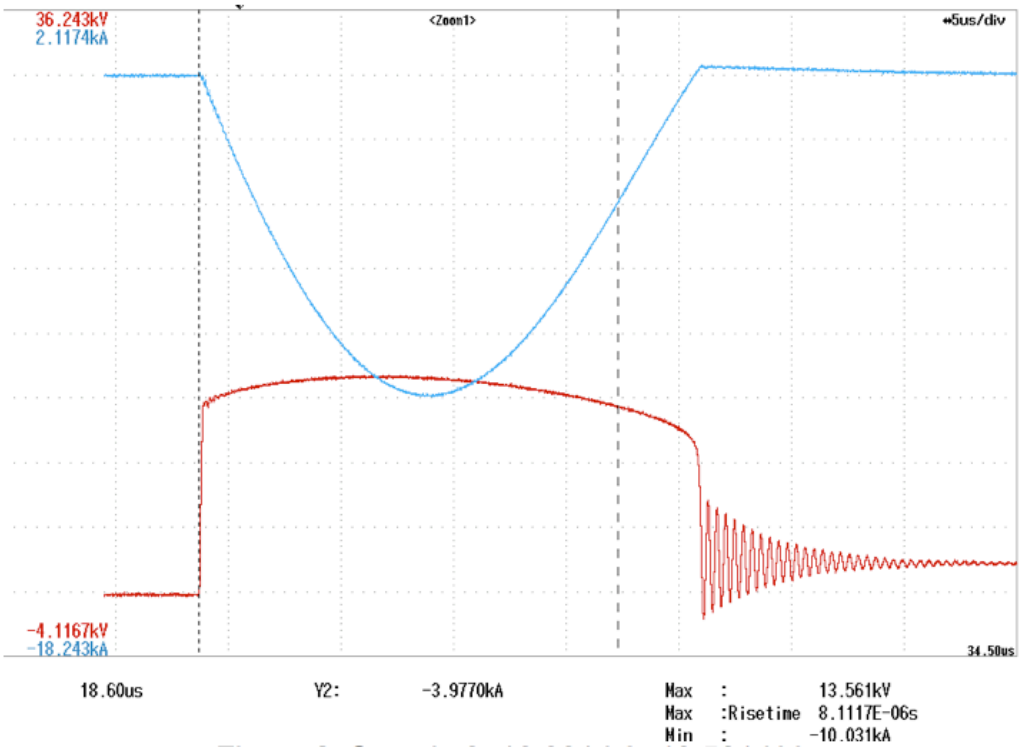


Figure 2: Sample 3, 10.031 kA, 13.561 kV.

Each sample was then subjected to 500 A switching surge impulses. Figure 3 shows the oscillogram of the switching surge discharge of Sample 3

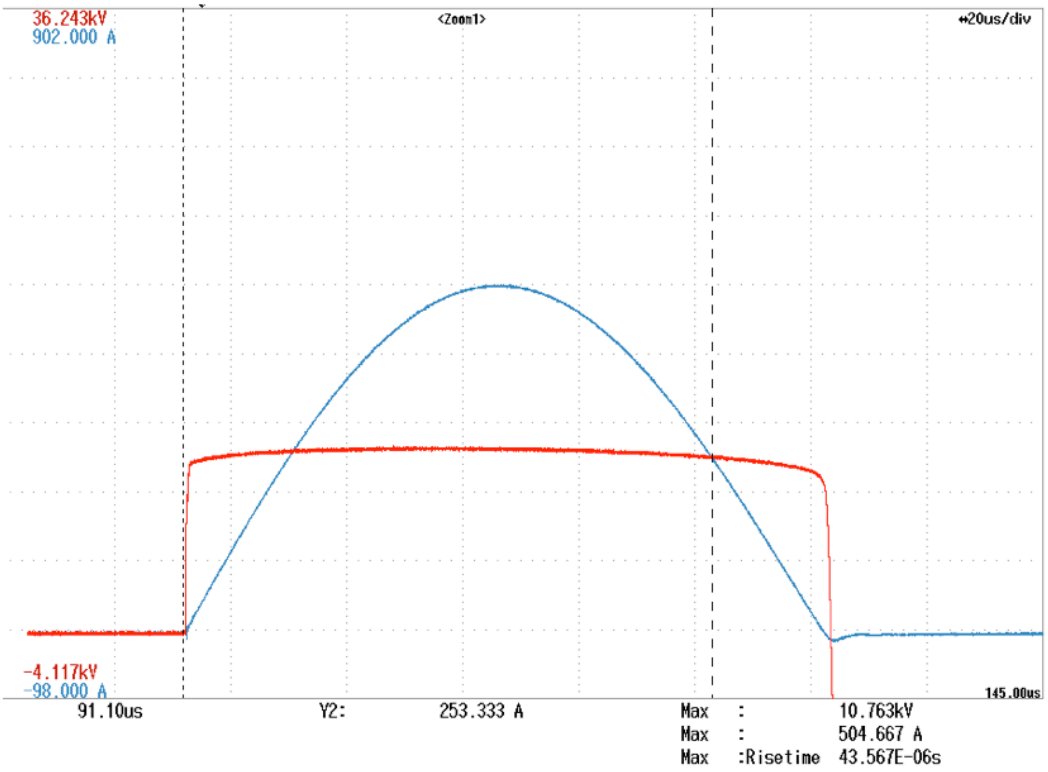


Figure 3: Sample 3, 504.7 A, 10.763 kV.

Table 1 shows the 10 kA IRs of the steep front wave measured with and without the aluminum disc.

TABLE 1: MEASUREMENT OF INDUCTIVE EFFECT ON MOV DISCS

Sample No.	I (kA)	IR (KVpk) with Al disc	IR (KVpk) w/o Al disc	L(di/dt) effect (kV)	Voltage drop across MOV disc w/o inductive effect (kV)
1	10	14.655	14.590	.065	14.525
2		14.688	14.574	.114	14.460
3		14.704	14.639	.065	14.574

Table 2 summarizes the design factors used to extrapolate the 1.5 through 20 kA 8/20 residual voltage, the 500 amp switching surge residual voltage, and MOV disc 0.5 microsecond FOW residual voltage. The highest factor for each wave shape is shown bolded and is multiplied by the 10 kA residual voltage of each rating to develop the family of residual voltage values. Table 3 summarizes the residual voltage values measured and claimed for each arrester rating.

TABLE 2: RESIDUAL VOLTAGE TEST.

Impulse Current (kA)	Wave Shape (µs)	Discharge Voltage (kVpk)			Discharge Voltage Ratio (IR/10kV IR)		
		Sample 1	Sample 2	Sample3	Sample 1	Sample 2	Sample3
0.5	43/91	10.682	10.736	10.763	0.791	0.795	0.794
1.5	8/20	11.503	11.543	11.53	0.852	0.855	0.850
3	8/20	12.161	12.174	12.215	0.900	0.901	0.901
5	8/20	12.592	12.619	12.646	0.932	0.934	0.933
10	8/20	13.507	13.507	13.561	1	1	1
20	8/20	14.664	14.745	14.718	1.086	1.092	1.085
10	1/2 (w/o inductive effect)	14.525	14.46	14.574	1.075	1.071	1.075

TABLE 3: SUMMARY OF ARRESTER DISCHARGE VOLTAGES

MCOV	Rating	IR Multipliers	0.795	0.855	0.901	0.934	1	1.092	1.075	10		
		Wave shape	60/100	8/20	8/20	8/20	8/20	8/20	Disc 0.5 usec	Unit Ht	10 kA Induct Drop	Total Front of Wave
		I (kA)	0.5	1.5	3	5	10	20	10	mm	kV	10
2.55	3	Measured IR	5.99	6.45	6.79	7.04	7.54	8.23	8.11	0.25	2.5	10.62
		Catalog IR	6	6.5	6.8	7.1	7.6	8.3	8.2	0.25	2.5	10.7
5.1	6	Measured IR	11.99	12.89	13.59	14.08	15.08	16.47	16.21	0.25	2.5	18.72
		Catalog IR	12.1	13	13.7	14.2	15.2	16.6	16.3	0.25	2.5	18.9
7.65	9	Measured IR	17.98	19.34	20.38	21.13	22.62	24.7	24.32	0.3	3	27.29
		Catalog IR	18	19.4	20.5	21.2	22.7	24.8	24.4	0.3	3	27.4
8.4	10	Measured IR	19.75	21.24	22.38	23.2	24.84	27.13	26.7	0.3	3	29.67
		Catalog IR	19.9	21.4	22.5	23.4	25	27.3	26.9	0.3	3	29.8
10.2	12	Measured IR	23.98	25.79	27.17	28.17	30.16	32.93	32.42	0.3	3	35.39
		Catalog IR	24.1	25.9	27.3	28.3	30.3	33.1	32.6	0.3	3	35.5
12.7	15	Measured IR	29.85	32.11	33.83	35.07	37.55	41	40.37	0.34	3.4	43.81
		Catalog IR	30	32.2	34	35.2	37.7	41.2	40.5	0.34	3.4	44
15.3	18	Measured IR	35.97	38.68	40.76	42.25	45.24	49.4	48.63	0.34	3.4	52.07
		Catalog IR	36.2	38.9	41	42.5	45.5	49.7	48.9	0.34	3.4	52.4
17	21	Measured IR	39.96	42.97	45.28	46.94	50.26	54.88	54.03	0.44	4.4	58.4
		Catalog IR	40.1	43.2	45.5	47.2	50.5	55.1	54.3	0.44	4.4	58.7
19.5	24	Measured IR	45.84	49.3	51.95	53.85	57.66	62.96	61.98	0.44	4.4	66.35
		Catalog IR	46	49.5	52.2	54.1	57.9	63.2	62.2	0.44	4.4	66.6
22	27	Measured IR	51.71	55.62	58.61	60.76	65.05	71.03	69.93	0.44	4.4	74.3
		Catalog IR	52	55.9	58.9	61.1	65.4	71.4	70.3	0.44	4.4	74.7
24.4	30	Measured IR	57.35	61.68	65	67.38	72.14	78.78	77.55	0.44	4.4	81.92
		Catalog IR	57.6	62	65.3	67.7	72.5	79.2	77.9	0.44	4.4	82.3
29	36	Measured IR	68.47	73.63	77.59	80.44	86.12	94.04	92.58	0.53	5.3	97.88
		Catalog IR	68.8	74	77.9	80.8	86.5	94.5	93	0.53	5.3	98.3
31.5	39	Measured IR	74.17	79.76	84.05	87.13	93.29	101.87	100.29	0.53	5.3	105.6
		Catalog IR	74.57	80.2	84.51	87.61	93.8	102.4	100.8	0.53	5.3	106
36.5	45	Measured IR	85.8	92.3	97.2	100.8	107.9	117.8	116	0.62	6.2	122.2
		Catalog IR	85.9	92.3	97.3	101	108	118	116	0.62	6.2	122
39	48	Measured IR	91.7	98.6	103.9	107.7	115.3	125.9	123.9	0.62	6.2	130.2
		Catalog IR	92.2	99.2	105	108	116	127	125	0.62	6.2	131

MCOV	Rating	IR Multipliers	0.795	0.855	0.901	0.934	1	1.092	1.075	10		
		Wave shape	60/100	8/20	8/20	8/20	8/20	8/20	Disc 0.5 usec	Unit Ht	10 kA Induct Drop	Total Front of Wave
		I (kA)	0.5	1.5	3	5	10	20	10	mm	kV	10
42	54	Measured IR	102	109.7	115.6	119.8	128.3	140.1	137.9	0.62	6.2	144.2
		Catalog IR	104	112	118	122	131	143	141	0.62	6.2	147
48	60	Measured IR	113.1	121.7	128.2	132.9	142.3	155.4	153	0.72	7.2	160.1
		Catalog IR	114	123	130	134	144	157	155	0.72	7.2	162
57	72	Measured IR	137.1	147.4	155.3	161	172.4	188.3	185.3	0.81	8.1	193.4
		Catalog IR	138	148	156	162	173	189	186	0.81	8.1	194
70	90	Measured IR	171.6	184.5	194.4	201.6	215.8	235.7	232	1.18	11.8	243.8
		Catalog IR	173	186	196	203	217	237	233	1.18	11.8	245
74	90	Measured IR	173.9	187.1	197.1	204.4	218.8	238.9	235.2	1.18	11.8	247
		Catalog IR	175	188	198	205	220	240	237	1.18	11.8	248
76	95	Measured IR	183.3	197.2	207.8	215.4	230.6	251.8	247.9	1.18	11.8	259.7
		Catalog IR	184	198	209	217	232	253	249	1.18	11.8	261
84	108	Measured IR	206.9	222.5	234.4	243	260.2	284.1	279.7	1.18	11.8	291.5
		Catalog IR	207	223	235	244	261	285	281	1.18	11.8	292
88	108	Measured IR	206.9	222.5	234.4	243	260.2	284.1	279.7	1.18	11.8	291.5
		Catalog IR	207	223	235	244	261	285	281	1.18	11.8	292
98	120	Measured IR	230.4	247.8	261.1	270.7	289.8	316.5	311.5	1.36	13.6	325.2
		Catalog IR	231	249	262	272	291	318	313	1.36	13.6	326
106	132	Measured IR	251.1	270	284.5	295	315.8	344.9	339.5	1.36	13.6	353.1
		Catalog IR	252	271	286	296	317	346	341	1.36	13.6	354
115	144	Measured IR	274.1	294.8	310.7	322	344.8	376.5	370.7	1.55	15.5	386.2
		Catalog IR	275	296	312	323	346	378	372	1.55	15.5	387
131	168	Measured IR	320.1	344.3	362.8	376.1	402.7	439.7	432.9	1.84	18.4	451.3
		Catalog IR	322	346	365	378	405	442	435	1.84	18.4	454
140	172	Measured IR	329.3	354.1	373.2	386.9	414.2	452.3	445.3	2.12	21.2	466.5
		Catalog IR	331	356	375	389	416	454	447	2.12	21.2	468
144	180	Measured IR	342.3	368.2	388	402.2	430.6	470.2	462.9	2.12	21.2	484.1
		Catalog IR	344	370	390	404	433	473	465	2.12	21.2	487
152	192	Measured IR	365.3	392.9	414	429.2	459.5	501.8	494	2.12	21.2	515.2
		Catalog IR	367	395	416	432	462	505	497	2.12	21.2	518
180	228	Measured IR	433.7	466.4	491.5	509.5	545.5	595.7	586.4	2.4	24	610.4
		Catalog IR	436	469	494	512	548	598	589	2.4	24	613

CONCLUSION

Table 1 summarizes the result of FOW discharge testing performed, per the standard, with and without an aluminum spacer. The MOV disc FOW residual voltage is combined with the inductive drop (associated with the arrester height) to develop each rated arrester's Total FOW residual voltage.

Table 2 summarizes residual voltage measurements for the three test samples across the range of specified wave shapes and current values. 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 2. This ratio was multiplied by the maximum 10-kA residual voltage accumulation specified for each rating. As summarized on Table 3, the residual voltage calculated based on the prorated test samples were less than the maximum declared catalog levels.

IEC Type Test Report

Report Number: TD 01 39 E03
EVP IEC Station Arrester SM Designation
10 kA Discharge Current

Long Term Stability under Continuous Operating Voltage
IEC Clause 10.8.4

This report presents the results of type tests made on EVP IEC Station Arrester SM Designation, U_r rated 3 to 228 kV. Tests were performed in accordance with procedures of IEC Standard 60099-4, Edition 3.0, 2014-06, "Surge arresters -- Part 4: Metal-oxide surge arresters without gaps for a.c. systems."

To the best of our knowledge and within the usual limits of testing practice, tests performed on these arresters demonstrate compliance with the relevant clauses of the referenced standard.

Dennis W. Lenk
Principal Engineer

Fayaz Khatri
Design Engineering Supervisor

Introduction

The test is performed to demonstrate the long term stability of a surge arrester under continuous operating voltage.

Procedure

Long term stability tests were performed on three 56mm diameter and 41mm long MOV discs. Tests were conducted in accordance with the requirements of Clause 10.8.4 of IEC 60099-4, Edition 3.0, 2014-06 (requiring the procedure of Clause 8.4.2 to be administered). The test samples were placed in an air oven and energized at a voltage equal to the corrected maximum continuous operating voltage, U_{ct}, for 1000 hours. U_{ct} is the voltage that corresponds to the maximum voltage to which an MOV disc would be subjected in a complete arrester. Non-uniform voltage distribution along the arrester length is accounted for. EVP arresters are designed such that the maximum voltage stress at any point along the MOV disc column is not more than 1.15 times the average stress along the column.

The temperature of the samples was maintained at 115 °C ± 2 °C for the duration of the test. Power dissipation was measured on each sample throughout the 1000 h test period. Clause 8.4.2 defines three power dissipation values:

- P_{start}, measured 1 to 2 hours after the initial voltage application
- P_{end}, measured after 1000 hours
- P_{min}, the minimum value attained during the 1000 hour test period

Results

Table 1 summarizes the values of P_{start}, P_{end} and P_{min} for each sample.

TABLE 1: POWER DISSIPATION VALUES

Sample No.	Power dissipation at 2 hours	Power dissipation at 1000 hours	Minimum power dissipation	Required ratio < 1.1	Required ratio < 1.3
	Pstart (W)	Pend (W)	Pmin (W)	Pend / Pmin	Pend / Pstart
1	6.39	4.11	4.11	1	0.64
2	6.36	4.11	4.11	1	0.65
3	6.17	4.01	4.01	1	0.65

Conclusion

Each sample demonstrated continually decreasing watts loss at $U_{ct.}$ The P_{end}/P_{min} ratio was less than 1.3 and the P_{end}/P_{start} ratio was less than 1.1. The MOV discs successfully passed the Long Term Stability under Continuous Operating Voltage test.

IEC Type Test Report

Report Number: TD 01 39 E04
EVP IEC Station Arrester SM Designation
10 kA Discharge Current

Repetitive Charge Transfer Rating Qrs
IEC Clause 10.8.5

This report presents the results of type tests made on EVP IEC Station Arrester SM Designation, U_r Rated 3 – 228 kV. Tests were performed in accordance with procedures of IEC 60099-4, Edition 3.0, 2014-06, "Surge arresters– Part 4: Metal oxide surge arresters without gaps for a.c. systems".

To the best of our knowledge and within the usual limits of testing practice, tests performed on these arresters demonstrate compliance with the relevant clauses of the referenced standard.

Dennis W. Lenk
Principal Engineer

Fayaz Khatri
Design Engineering Supervisor

Introduction

The repetitive charge transfer rating test was performed on ten MOV discs per Section 10.8.5 of the IEC 60099-4, Edition 3.0, 2014-06 standard.

Procedure

Test was performed per Figure 2 of IEC 60099-4 , Edition 3.0, 2014-06 standard on ten of the 56mm diameter MOV discs used in the EVP product line which are 41mm long. The U_{res} residual voltage (10kA, 8/20) and the U_{ref} reference voltage (at 9.5 mA) were measured before and after the long duration impulses for evaluation. Each sample was then subjected to ten groups of two long duration impulses of 2.230 ms and a charge content of 3.75 coulomb. Figure 1 shows the long duration impulse waveform applied on each of the MOV discs.

- P_{start}, measured 1 to 2 hours after the initial voltage application
- P_{end}, measured after 1000 hours
- P_{min}, the minimum value attained during the 1000 hour test period

Results

All ten out of ten MOV discs successfully passed the 20 shot durability test performed at 3.75 coulomb charge. Per section 8.5.3, the MOV discs were examined for physical damage and found to have none. Additionally, each MOV disc was tested for 10 kA residual voltage and 9.5 mA reference voltage. Finally, each MOV disc was subjected to a single 13 kA 8/20 current discharge to confirm that each MOV disc was undamaged by the 20 shot discharge duty. The results of the testing are summarized in Table 1.

TABLE 1: RESIDUAL AND REFERENCE VOLTAGES BEFORE AND AFTER QRS TESTING

Sample Number	10 kA residual voltage Before (kVc)	10 kA residual voltage After (kVc)	% Change 10 kA residual voltage	Reference voltage @ 9.5 mA Before (kVc)	Reference voltage @ 9.5 mA After (kVc)	% Change reference voltage	Final 8/20 Current Withstand	
							kA	Pass/ Fail
1	13.41	13.41	0%	8.38	8.46	0.90%	13.25	Pass
2	13.42	13.42	0%	8.37	8.46	1.10%	13.18	Pass
3	13.42	13.42	0%	8.37	8.45	0.90%	13.16	Pass
4	13.43	13.43	0%	8.34	8.42	0.90%	13.13	Pass
5	13.41	13.41	0%	8.39	8.46	0.80%	13.16	Pass
6	13.40	13.40	0%	8.38	8.42	0.50%	13.19	Pass
7	13.40	13.40	0%	8.34	8.38	0.50%	13.11	Pass
8	13.42	13.42	0%	8.36	8.40	0.50%	13.15	Pass
9	13.41	13.41	0%	8.37	8.40	0.40%	13.16	Pass
10	13.41	13.41	0%	8.37	8.40	0.40%	13.99	Pass

CONCLUSION

The repetitive charge transfer rating test was successfully passed with 56mm MOV discs per the IEC requirements. The change in residual voltage and reference voltage were less than 5% of initial value. Each MOV disc successfully passed the final 13 kA 8/20 current discharge. The claimed repetitive charge transfer rating (Qrs) for the Type EVP IEC Station Arrester SM is 3.4 coulomb.

IEC Type Test Report

Report Number: TD 01 39 E05
EVP IEC Station Arrester SM Designation
10 kA Discharge Current

Thermal Equivalency
IEC Clause 10.8.6

This report presents the results of type tests made on EVP IEC Station Arrester SM Designation, U_r Rated 3 – 228 kV. Tests were performed in accordance with procedures of IEC 60099-4, Edition 3.0, 2014-06, "Surge arresters– Part 4: Metal oxide surge arresters without gaps for a.c. systems".

To the best of our knowledge and within the usual limits of testing practice, tests performed on these arresters demonstrate compliance with the relevant clauses of the referenced standard.

Dennis W. Lenk
Principal Engineer

Fayaz Khatri
Design Engineering Supervisor

Introduction

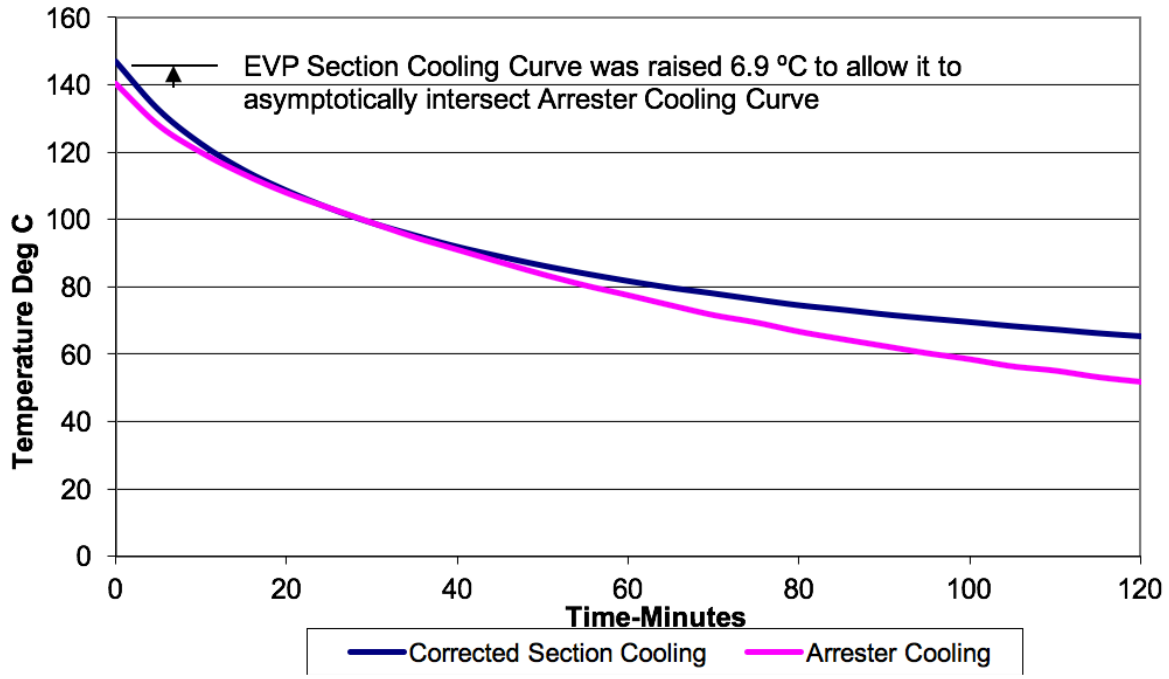
The polymer arrester thermal equivalency tests were performed per Section 8.6 of the IEC 60099-4, Edition 3.0, 2014-06 standard. The purpose of this test is to verify that the thermal cooling curve for the Type EVP arrester prorated section, when internally heated, will cool slower than that of a full size EVP arrester unit.

Procedure

A full size single unit 72 kv rated EVP arrester and a prorated section were heated by applying a temporary overvoltage to the test samples. Per Annex B, both the arrester and the prorated section were energized approximately 10 minutes to a starting temperature of 140 °C, at which time the voltage was removed. Both samples were instrumented with a fiber-optic sensor located in the middle of the MOV disc stack. During the cooling portion of the test, the temperature of the arrester and the test section were monitored at 5 minute intervals to develop the arrester unit cooling curve. Per Annex B, the cooling rate during the first 15 minutes was slower for the EVP section than the arrester. To assure thermal equivalency, as allowed by the standard, the starting temperature of the section cooling curve was raised from the targeted 140 °C point (for the arrester) to 147.7 °C for the prorated section.

Conclusion

The following cooling curve confirms that the cooling rate of the EVP prorated section is slower than that of the full size EVP arrester unit, confirming the thermal equivalency of the prorated section to the full size arrester. Thermal equivalency of the EVP prorated section to the EVP arrester is shown by raising the temperature of EVP prorated sections by 6.9 °C.



Comparison of Corrected EVP Section Cooling Curve Versus 61 kV EVP Arrester (from 140 ºC starting temp)

IEC Type Test Report

Report Number: TD 01 39 E06
EVP IEC Station Arrester SM Designation
10 kA Discharge Current

Operating Duty Test (Rated Thermal Energy (Wth))
IEC Clause 10.8.7

This report presents the results of type tests made on EVP IEC Station Arrester SM Designation, U_r rated 3 through 72 kV. Tests were performed in accordance with procedures of IEC Standard 60099-4 Edition 3.0, 2014-6 "Surge arresters -- Part 4: Metal-oxide surge arresters without gaps for a.c. systems."

To the best of our knowledge and within the usual limits of testing practice, tests performed on these arresters demonstrate compliance with the relevant clauses of the referenced standard.

Dennis W. Lenk
Principal Engineer

Fayaz Khatri
Design Engineering Supervisor

Introduction

The operating duty test is performed to verify that the arrester can thermally recover after energy absorption from a switching event followed by temporary overvoltage and continuous operating voltage conditions.

Procedure

Tests were performed in accordance with clause 10.8.7.

Results

Results of the residual voltages measured before and after the operating duty test are summarized in the table below.

Section	RESIDUAL VOLTAGE (kV)		Change (%)
	Before	After	
1	26.96	27.25	±1.1
2	26.96	27.23	±1.0
3	26.96	27.23	±1.0

The table below summarizes the results of the operating duty thermal energy rating test.

Parameter	Sample 1	Sample 2	Sample 3
COV (kV rms) U_c	9.37	9.38	9.37
Rating (kV rms) U_r	11.72	11.72	11.72
First Shot Energy K_j	47.29	47.37	47.23
Second Shot Energy K_j	48.31	50.42	48.16
Total 2-Shot energy	95.60	97.79	95.39
Validated KJ per kVrms U_r	8.15	8.34	8.14
Claimable KJ per kVrms U_r	8	8	8

Conclusion

The three test sections have successfully demonstrated a claimable Wth = 8 kJ per kVrms of arrester rating (U_r).

In summary the EVP IEC Station Arrester SM design passed the test as required.

IEC Type Test Report

Report Number: TD 01 39 E07
EVP IEC Station Arrester SM Designation
10 kA Discharge Current

Power Frequency Voltage versus Time
IEC Clause 10.8.8

This report presents the results of type tests made on EVP Station Arrester SM Designation, U_r rated 3 to 228 kV. Tests were performed in accordance with procedures of IEC 60099-4, Edition 3.0, 2014-06, “Surge arresters — Part 4: Metal-oxide surge arresters without gaps for a.c. systems.”

To the best of our knowledge and within the usual limits of testing practice, tests performed on these arresters demonstrate compliance with the relevant clauses of the referenced standard.

Dennis W. Lenk
Principal Engineer

Fayaz Khatri
Design Engineering Supervisor

Introduction

The purpose of this test is to prove temporary over voltage (TOV) withstand capability by demonstrating thermal recovery, and a less than 5% change in residual voltage at nominal discharge.

Procedure

Tests were performed per clause 8.8 of IEC 60099-4, Ed. 3.0, 2014-06, International Standard.

Results

No prior duty and prior duty TOV data points versus actual test data points are shown in Figure 1. Figure 2 shows the plotted no prior duty and prior duty TOV curves.

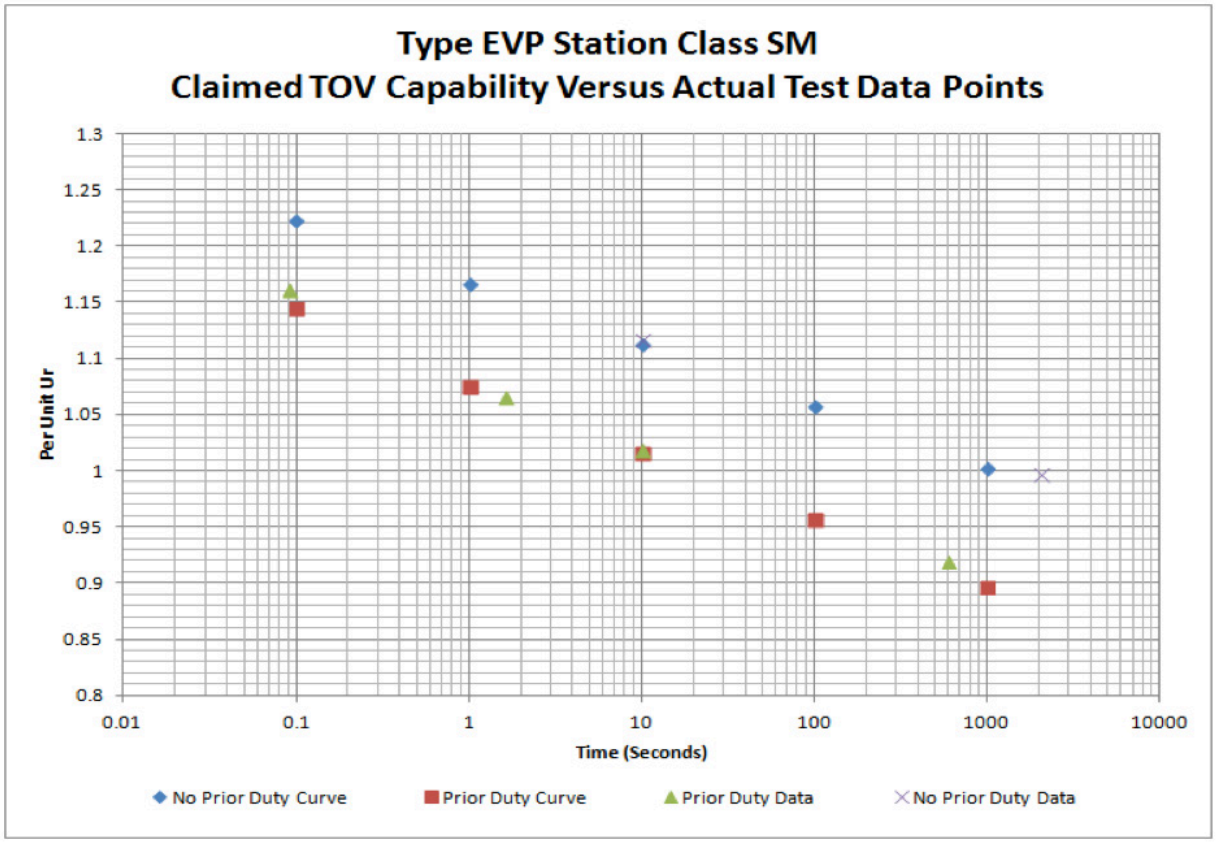


Figure 1. Actual and Theoretical Temporary Over Voltage Data Points

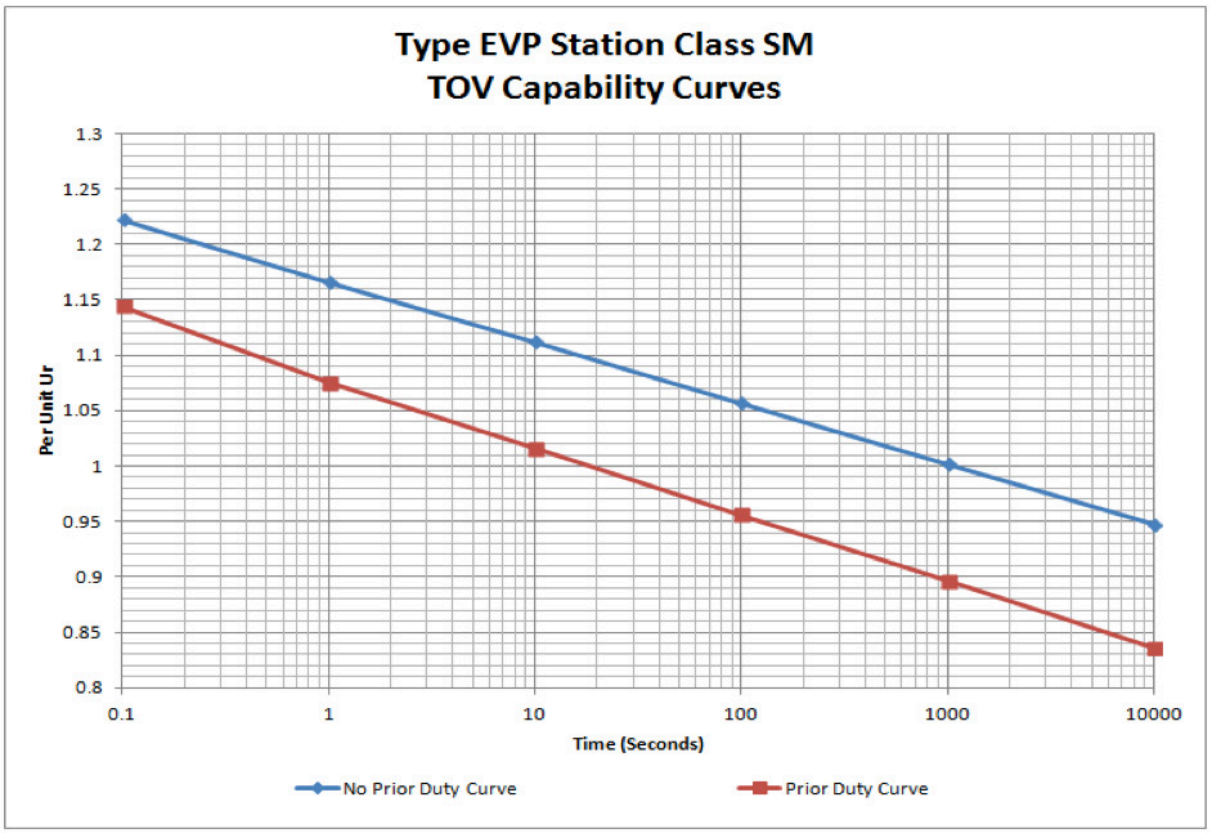


Figure 2. Temporary Over Voltage Data Points.
Prior Duty Curve based on claimed 8 kJ per kV U_r W_{th}

Table 1 summarizes the results of the prior duty and no prior duty TOV capability testing as a function of time duration of applied overvoltage.

TABLE 1: TEMPORARY OVER VOLTAGE

Time (seconds)	No Prior Duty per Unit Times Ur	Prior Duty per Unit Times Ur
0.1	1.222	1.144
1	1.166	1.075
10	1.112	1.016
100	1.057	0.956
1000	1.002	0.896

Test Evaluation was performed in compliance with Clause 10.8.8.5 of the test standard. The standard specifies that the 10 kA residual voltage will be measured prior to and after TOV testing and that the final measured value must not change more than 5% from the initial measured value. Table 2 shows the measured residual voltage values, confirming all samples had a residual voltage change less than the allowed 5%.

TABLE 2: MEASURED RESIDUAL VOLTAGE

Sample Number	Residual Voltage Prior to TOV testing	Residual Voltage After TOV testing	Percent Change
2N	26.960	26.934	-0.1%
6N	26.934	26.907	-0.1%
2P	26.934	27.215	1.0%
6P	26.907	27.081	0.6%
8P	26.960	27.215	0.9%
9P	26.987	27.269	1.0%

Since the test sections could not be disassembled and examined for physical damage, each test section was subjected to an additional two 12.3 kA 8/20 microsecond discharges (per Clause 10.8.8.5 i). The wave shape of the second discharge was compared to that of the first shot to confirm the electrical integrity of each test section. Table 3 summarizes the results of this two-shot testing.

TABLE 3: TWO-SHOT TEST RESULT

Sample Number	First 12.5 kA Residual Voltage Shot	Second12.5 kA Residual Voltage Shot	Percent Change
2N	27.741	27.741	0.0%
6N	27.660	27.714	0.2%
2P	27.831	27.912	0.3%
6P	27.805	27.831	0.1%
8P	27.965	27.965	0.0%
9P	27.965	28.019	0.2%

Conclusion

Test is considered passed if thermal recovery, no physical damage, and change of residual voltage at nominal discharge current is within +/- 5%. As explained in results section, the arrester met the criteria and successfully passed.

IEC Type Test Report

Report Number: TD 01 39 E08
EVP IEC Station Arrester SM Designation
10 kA Discharge Current

Short Circuit Test
IEC Clause 10.8.10

This report presents the results of type tests made on EVP IEC Station Arrester SM Designation, U_r rated 3 through 72 kV. Tests were performed in accordance with procedures of IEC Standard 60099-4 Edition 3.0, 2014-6 "Surge arresters -- Part 4: Metal-oxide surge arresters without gaps for a.c. systems."

To the best of our knowledge and within the usual limits of testing practice, tests performed on these arresters demonstrate compliance with the relevant clauses of the referenced standard.

Dennis W. Lenk
Principal Engineer

Fayaz Khatri
Design Engineering Supervisor

Introduction

This test is conducted to show that an arrester failure is not likely to cause an explosive failure.

Procedure

Tests were performed in accordance with requirements of clause 10.8.10.

Results

The following table summarizes the test results.

Test #	Claimable Test Current - kArms	Measured Short Circuit Duration	Duration of Open Flames (seconds)	Comments
1	63	14.5 cycles	0	Arrester Intact/ Polymer Housing Fractured/no hard parts outside containment wall/flames extinguished within 2 minutes
2	25	13 cycles	0	Arrester Intact/ Polymer Housing Fractured/no hard parts outside containment wall/flames extinguished within 2 minutes
3	12	12 cycles	0	Arrester Intact/ Polymer Housing Fractured/no hard parts outside containment wall/flames extinguished within 2 minutes
4	.600	1.01 seconds	0	Arrester Intact/ Polymer Housing Fractured/no hard parts outside containment wall/flames extinguished within 2 minutes

Conclusion

The EVP IEC Station Arrester SM arrester design passed this test.

IEC Type Test Report

Report Number: TD 01 39 E09
EVP IEC Station Arrester SM Designation
10 kA Discharge Current

Bending Moment
IEC Clause 10.8.11

This report presents the results of type tests made on EVP IEC Station Arrester SM Designation, U_r rated 3 to 228 kV. Tests were performed in accordance with procedures of IEC Standard 60099-4, Edition 3.0, 2014-06, "Surge arresters -- Part 4: Metal-oxide surge arresters without gaps for a.c. systems."

To the best of our knowledge and within the usual limits of testing practice, tests performed on these arresters demonstrate compliance with the relevant clauses of the referenced standard.

Dennis W. Lenk
Principal Engineer

Fayaz Khatri
Design Engineering Supervisor

Introduction

The bending moment test demonstrates the ability of the arrester to withstand the manufacturer's declared values for bending loads.

Procedure

The bending moment test was performed on three 76 kV U_c EVP arresters as described in Clause 10.8.11 of IEC 60099-4, Edition 3.0, 2014-06, for polymer housed arresters without enclosed gas volume. Prior to the mechanical testing, the arresters were subjected to electrical tests to establish initial watts loss, partial discharge and residual voltage values per Clause 10.8.11.2. Tests were performed per Annex G, Figure G.5 of the standard.

Per Section 10.8.11.3.a each of the three test samples were subjected to 1000 cycles of bending moment load. Each cycle consisted of loading the samples from zero to the arrester's specified long-term load (SLL), followed by loading to the SLL in the opposite direction, then returning to zero load. This procedure was repeated 1000 times on each arrester at an approximate frequency of 3 Hz. The maximum deflection for each sample during the test and the residual deflection at completion of the test were recorded.

Sample 1 and 2 were subjected per Section 10.8.11.3.b, Step 1.1 to the specified short-term load (SSL) bending moment test. Each of the units were securely mounted to the horizontal base of the test equipment. Lateral (horizontal) loading was applied to the free end of the unit, in a direction perpendicular to the axis of the unit. The SSL was reached in approximately 50 seconds. The load was then maintained at this level for about 90 seconds. Deflection was measured prior to release of the load. After release of load, the test sample was inspected to verify that no mechanical damage had occurred, and the load-deflection curve was examined to verify that there was no discontinuity which might indicate mechanical damage. The unloaded residual deflection was measured on each sample.

Sample 3 was subjected to mechanical/thermal preconditioning per Section 10.8.11.3.b, Step 1.2. The thermo-mechanical preconditioning portion of the test loads the test sample to its specified long-term load (SLL) while the arrester is being thermally cycled from -40 to +60˚C. All three samples were next subjected to the water immersion test per Section 10.8.11.3.b, Step 2. Each sample was submersed in boiling salt water for 42 hours after which the samples were electrically evaluated.

At the conclusion of the water immersion test, electrical tests were repeated on each sample (per Section 10.8.11.4). The increase in watts loss cannot change more than 20% and the internal partial discharge cannot exceed 10 pC. In addition, residual voltage must maintain within 5% and the difference in U_{ref} measurements does not differ more than 2%. A visual inspection was made to verify that no mechanical damage had occurred.

Results

Preliminary electrical tests were performed on the three EVP 76 kV U_c arresters. Table 1 summarizes the results of those preliminary electrical tests.

TABLE 1: ROUTINE ELECTRICAL TEST RESULTS

Test Parameter	Sample 1	Sample 2	Sample 3
Initial Watts Loss at U_c (W)	5.66	5.48	7.65
Residual Voltage at 10 kA (kVpeak)	230.3	230.6	231.1
Partial Discharge (pC) at 1.05*U_c	3	3	3

Each test sample was subjected to an SLL of 900 Nm (8,000 in-lb) for 1000 cycles. After the 1000 cycle loading there was no recordable residual deflection on the three test samples. Samples 1 and 2 were rigidly base mounted in a cantilever fixture and loaded within 30 to 90 seconds to an SSL of 1800 Nm (16,000 in-lb). This load was maintained for 60 to 90 seconds and subsequently released. The recorded residual deflection on both samples was less than 5 mm (0.19").

Sample 3 was subjected to mechanical/thermal preconditioning. The test sample was next placed inside a thermal cycling oven with the arrester loaded to an SLL of 900 Nm (8,000 in-lb).

At the completion of the specified mechanical loading, all three samples were placed into boiling salt water for 42 hours. After 42 hours exposure the test samples were dried off and electrical tests were repeated. Results are shown in Table 2.

TABLE 2: ELECTRICAL TEST RESULTS

Test Parameter	Sample 1	Sample 2	Sample 3
Final Watts Loss at U_c (W)	5.66	5.42	7.93
Watts Loss Increase (%)	0	-1.1	+3.7
Final Partial Discharge (pC) at 1.05*U_c	5	4	6

Finally, each sample was subjected to two additional 10 kA residual voltage surges spaced 1 minute apart. Results are detailed in Table 3. Close examination of oscillograms showed the traces to be smooth and less than 1% apart, confirming the integrity of each test sample. The percent change for residual voltage and Uref are provided in Table 4.

TABLE 3: U_{ref} AND RESIDUAL VOLTAGE MEASUREMENTS

Test Step	Test Description	Sample 1	Sample 2	Sample 3
1	9.5 mA Uref (kVpeak)	97.79	98.04	98.26
2	8/20 10 kA Residual Voltage (kVpeak)	231.0	231.5	231.3
3	8/20 10 kA Residual Voltage (kVpeak)	231.5	231.3	231.3
4	9.5 mA Uref (kVpeak)	97.72	98.24	98.14

TABLE 4: PERCENT CHANGE FOR RESIDUAL VOLTAGE AND U_{ref} MEASUREMENTS

Test Parameter	Sample 1	Sample 2	Sample 3
Change in Residual Voltage (%)	+0.21	-0.09	0
Change in U_{ref} (%)	-0.07	+0.20	-0.12

Conclusion

Three EVP 76 kV Uc arresters were subjected to bending moment tests as defined in Clause 10.8.11 of IEC 60099-4, Edition 3.0, 2014-06. PD levels were confirmed to be below the allowed 10 pC. The change in watts loss was below the allowed 20% change. 10 kA residual voltage and U_{ref} measurements were within 5% and 2%, respectively. EVP Class SM arresters successfully passed SSL testing at 1800 Nm (16,000 in-lb) and SLL testing was successfully completed at 900 Nm (8,000 in-lb).

IEC Type Test Report

Report Number TD 01 39 E10
EVP IEC Station Arrester SM Designation
10 kA Discharge Current

Radio Influence Voltage (RIV)
IEC Clause 10.8.14

This report presents the results of type tests made on EVP IEC Station Arrester SM Designation, U_r rated 3 through 72 kV. Tests were performed in accordance with procedures of IEC Standard 60099-4 Edition 3.0, 2014-6 "Surge arresters -- Part 4: Metal-oxide surge arresters without gaps for a.c. systems."

To the best of our knowledge and within the usual limits of testing practice, tests performed on these arresters demonstrate compliance with the relevant clauses of the referenced standard.

Dennis W. Lenk
Principal Engineer

Fayaz Khatri
Design Engineering Supervisor

Introduction

This test is performed to verify that the arrester does not emit significant electromagnetic disturbances.

Procedure

Internal ionization and RIV testing was performed per clause 8.14 of the IEC 60099-4-2009 standard. The test was performed on a 180 kV MCOV EVP arrester.

Equipment and test methods conformed to NEMA LA 1-1992 requirements. Prior to the test, the Stoddart Noise Meter NM-25T was calibrated using a General Radio Signal Generator Type 1001-A. Figure 1 shows the test setup for RIV testing this EVP 180 kV MCOV arrester.

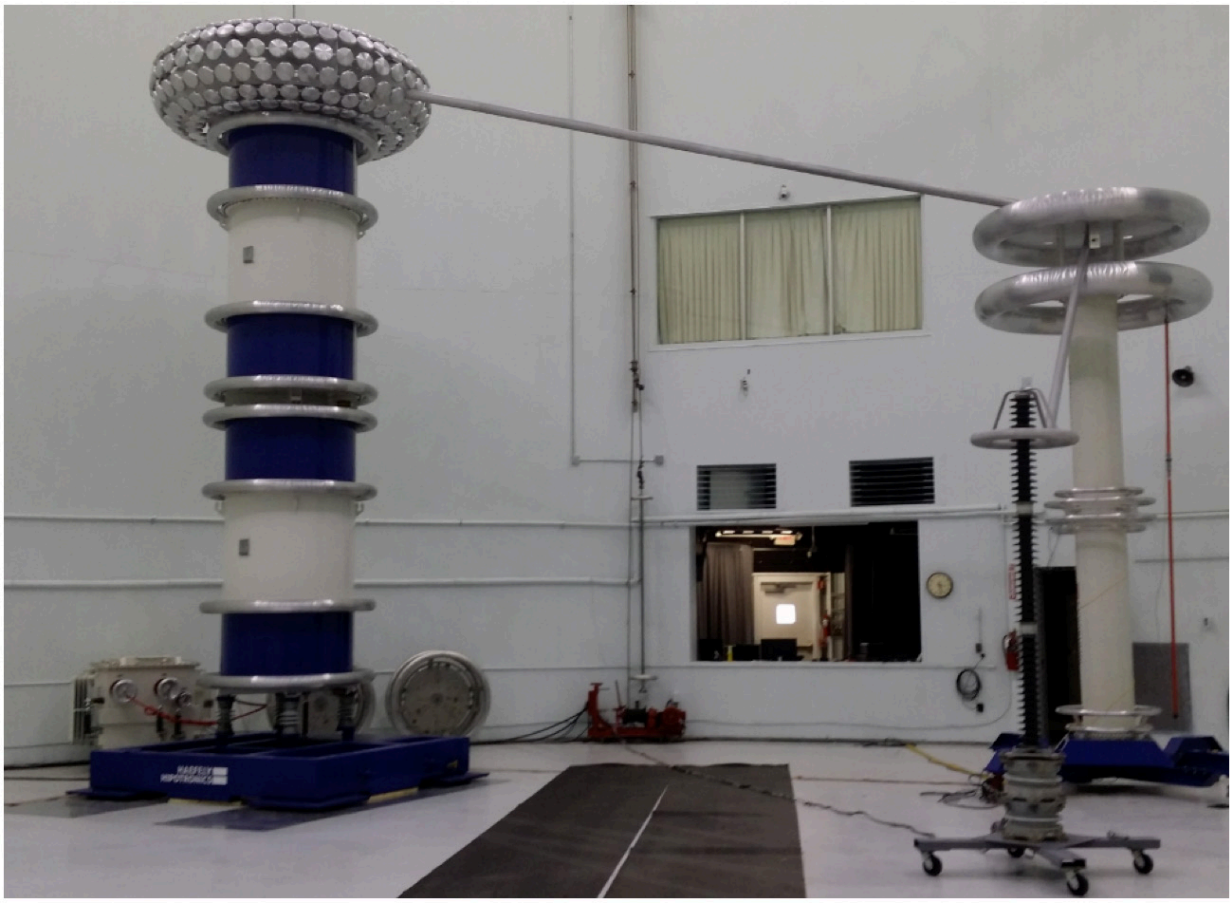


Figure 1. Test set up

Results

Table 1 summarizes the results of RIV tests performed per Section 8.14 of IEC 60099-4 Ed. 3.0 2014-06 Standard.

TABLE 1 RIV TEST RESULTS

Test Voltage	RIV uV	Comments
189	270	Hold at 1.05 of Uc for 5 minutes
162	258	Lower
144	261	Lower
126	242	Lower
108	247	Lower
90	245	50% of Uc
90	245	50% of Uc
108	252	Raise
126	260	Raise
144	275	Raise
162	270	Raise
180	281	Uc
189	286	1.05 of Uc
180	300	Hold at Uc for 5 minutes
180	280	Lower
162	300	Lower
144	262	Lower
126	285	Lower
108	285	Lower
90	283	Stop at 50% of Uc

Atmospheric Conditions of Lab: Temperature 75.5 F, Relative Humidity 49.70%, Barometer 28.9 in Hg

Conclusion

The 180 kV MCOV EVP arrester passed test requirements per Section 8.14 of the IEC 60099-4, Ed 3.0, 2014-06 Standard, as measured noise levels were below the allowed 2500 µV RIV test limit.

IEC Type Test Report

Report Number: TD 01 39 E11
EVP Polymer Housed Arrester
Class Station Medium (SM)

Salt Fog Test
IEC Clause 10.8.17.2

This report presents the type tests performed on the EVP Polymer Housed Class SM Arrester design. Tests were performed in accordance with procedures of IEC 60099-4, Ed. 3.0, 2014-06, "Surge arresters – Part 4: Metal-oxide surge arresters without gaps for a.c. systems."

To the best of our knowledge and within the usual limits of testing practice, tests performed on these arresters demonstrate compliance with the relevant clauses of the referenced standard.

Dennis W. Lenk
Principal Engineer

Introduction

The polymer housing salt fog test was performed per Section 10.8.17.2 of the IEC 60099-4-Ed 3.0, 2014-06 Standard. 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.

Procedure

The 1000 hour test was performed to verify Test series A per Section 10.8.17.2.2 of the IEC 60099-4-Ed 3.0, 2014-06 standard.

This test was performed on an 115kV MCOV EVP arrester (longest electrical unit) that was assembled for this test.

Results

The test arrester successfully withstood the 1000 hour salt fog exposure test with no evidence of surface tracking, puncturing, or erosion through the entire thickness of any part of external coating up to the next layer of material. The 1000 hour test was conducted per Section 10.8.17.2.3, and the resulting reference voltage change was less than the allowed 5%. In addition, the partial discharge measured at the completion of the test was less than the allowed 10pC as shown in Table 2

Figure 1 – Arrester condition after 1000 hour salt fog test

TABLE 1 – REFERENCE VOLTAGE RESULTS		
U_{ref} Before Salt Fog Test (kV)	U_{ref} Before Salt Fog Test (kV)	Percent Change
150.51	152.78	+1.51%

TABLE 2 – PARTIAL DISCHARGE RESULTS	
Partial Discharge Intensity Before Sale Fog Test (pC)	Partial Discharge Intensity After Sale Fog Test (pC)
1.2	6.5

Conclusion

The EVP Station Class SM arrester design successfully passed the 1000 hour salt fog test, as defined in Section 10.8.17.2 of the IEC 60099-4 Ed.3.0, 2014-06 Standard.

IEC Type Test Report

Report Number: TD 01 39 E12
EVP IEC Station Arrester SM Designation
10 kA Discharge Current

UV Light Test
IEC Clause 10.8.17.3

This report presents the results of type tests made on EVP IEC Station Arrester SM Designation, U_r rated 3 through 228 kV. Tests were performed in accordance with procedures of IEC Standard 60099-4 Edition 3.0, 2014-6 "Surge arresters -- Part 4: Metal-oxide surge arresters without gaps for a.c. systems."

To the best of our knowledge and within the usual limits of testing practice, tests performed on these arresters demonstrate compliance with the relevant clauses of the referenced standard.

Dennis W. Lenk
Principal Engineer

Fayaz Khatri
Design Engineering Supervisor

Introduction

Polymer arrester housings are exposed to ultra violet (UV) radiation not only from sunlight, but also from corona and dry band arcing. Resistance to surface degradation resulting from UV exposure is an important factor in confirming the service life of a polymer arrester.

Procedure

The UV life test was performed per clause 10.8.17.3 of IEC 60099-4, Ed. 3.0, 2014-06, International Standard. Tests on polymer housing material used the fluorescent UVB technique specified in clause 10.8.17.3.1. As specified, ASTM G154, ISO 4892-1, and ISO 4892-3 provided details for performing the test. Test duration was 1000 hours on three samples of material.

Results

There was no evidence of surface degradation, cracking or crazing on the arrester housings after completion of the 1000 hour on-voltage test.

Conclusion

The EVP Station Class SM arrester successfully passed the polymer housing UV life test as defined in the IEC 60099-4, Edition 3.0, 2014-6 “Surge arresters -- Part 4: Metal-oxide surge arresters without gaps for a.c. systems.”

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