COMPARATIVE PERFORMANCE OF CONVENTIONAL 220 KV INSULATOR STRINGS AND MULTI-CHAMBER INSULATOR-ARRESTERS STRINGS UNDER SPECIFIC ICE CONDITIONS OF RUSSIA

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Abstract: Multi-Chamber Insulators-Arresters (MCIA) combine characteristics of insulators and arresters. A prototype of 220 kV voltage class MCIA String is intended for use in different environments including iced environments. The results of ice tests showed that multi-chamber system (MCS) installed at the insulators do not reduce the electrical strength of insulator strings under ice conditions defined as thickness 30 mm on the rotating rod and 100 µS/cm of applied water conductivity.

1. INTRODUCTION

Streamer Electric Company in Russia has developed Multi-Chamber System (MCS) which enables produce Multi-Chamber Arresters (MCA) and Multi-Chamber Insulators-Arresters (MCIA) that combine characteristics of insulators and arresters. Among them is a prototype of 220 kV voltage class MCIA String (MCIAS) [1,2]. These arresters are intended for use in different environments including polluted and iced environments, which may theoretically influence the electrical strength of the string equipped by MCIA. The aim of the performed test was thus to compare the flashover performance of 220 kV glass cap-and-pin insulator strings with and without MCS under ice conditions. STRI-developed Ice Progressive Stress (IPS) method and included in the recently published IEEE Standard [3] was already used practically for the recommendations for the improvement of line insulation profile in ice areas of Norway [4] and for comparison of different options of breakers for ice areas in Sweden and Norway. This time the same method is applied to simulated specific ice environment in Russia.

2. RESULTS AND DISCUSSION

Individual flashover voltages and their averages are presented in Table 1. Examples of flashovers of insulators taken from video recordings are presented in Figure 1.

Table 1: Recorded individual flashover voltage values.

Test object	String	Flashover voltage, kV	Average, kV
Insulator string without MCS	No 1	220	236
	No 2	211	
	No 3	276	
Insulator string with MCS	No 1	265	230
	No 2	231	
	No 3	193	

The average flashover voltages for the strings with/without MCIA are approximately the same (236/230 kV) and are much higher than maximum operating voltage for 220 kV voltage class (146 kV phase-to-ground).

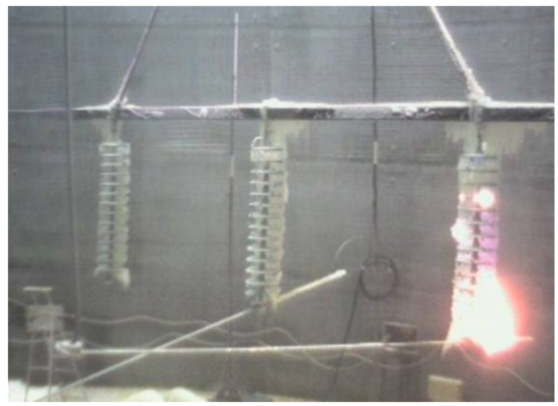

Figure 1: Example of flashover at the insulator string equipped by MCS.

3. CONCLUSION

Ice Progressive Stress test method was successfully used for the comparison of strings of cap-and-pin insulators with and without multi-chamber system (MCS). The test was performed for specific Russian environment defined as glazed ice 30 mm with 100 µS/cm of applied water conductivity.

The results showed that MCS does not reduce the electrical strength of insulator strings under such ice conditions.

4. REFERENCES

[1] G.V. Podporkin, E.Y. Enkin, E.S. Kalakutsky, V.E. Pilshikov, A.D. Sivaev: “Overhead Lines Lightning Protection by Multi-Chamber Arresters and Insulator-Arresters”, IEEE Transactions on Power Delivery, vol. 26, No. 1, January 2011, pp. 214-221

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Insulator-arrester; multi-chamber; ice tests; ice thickness; ice conductivity

I. Introduction

Streamer Electric Company in Russia has developed Multi-Chamber System (MCS) which enables produce Multi-Chamber Arresters (MCA) and Multi-Chamber Insulators-Arresters (MCIA) that combine characteristics of insulators and arresters. Among them is a prototype of 220 kV voltage class MCIA String (MCIAS) [1, 2], see Figure 1. These arresters are intended for use in different environments including polluted and iced environments, which may theoretically influence the electrical strength of the string equipped by multi-chamber system (MCS). Streamer has tested MCIA in polluted conditions and did not find significant reduction of flashover strength.

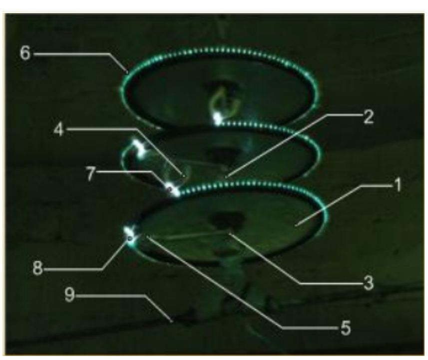

Figure 1. Example of a three-MCIA string (35 kV) during lightning impulse tests: 1 – sheds of insulating body; 2 – cap; 3 – pin; 4 – upper feed electrode; 5 – lower feed electrode; 6 – multi-chamber system; 7 – upper spark discharge gap; 8 – lower spark discharge gap; 9 – conductor.

The aim of the performed test was thus to compare the flashover performance of 220 kV glass cap-and-pin insulator strings with and without MCS under ice conditions.

II. Test Program

A. General

At present there is no IEC Standard for ice testing and thus the tests were performed according to the principles of STRI-developed Ice Progressive Stress (IPS) method, described in [3]. This method was accepted by the IEEE and was included in the recently published IEEE Standard [4]. This method was already used practically for the recommendations for the improvement of line insulation profile in ice areas of Norway [5] and for comparison of different options of breakers for ice areas in Sweden and Norway. This time the same method is applied to simulated specific ice environment in Russia.

B. Target ice parameters

Glazed ice thickness 30 mm was defined as target level of ice load in the area of possible application of MCIA. Calibration of exposure time for ice accretion on the insulators was thus performed until ice thickness 30 mm on the standard rotating cylinder, see Figure 2. The calibration was performed without voltage application. This calibration defined time for ice accretion (approximately 7,5 hours), which was used in all further tests.

Figure 2. Calibration of time for ice accretion on rotating cylinder (red arrow). Composite insulators were used to indicate the position of insulator strings.

Another important parameter during the test is the conductivity of melting ice (the so-called "dripping water conductivity") on the surface of the insulator (for example for Scandinavian conditions this parameter is estimated 100-200 µS/cm). This parameter was defined for specific Russian environment as the conductivity of applied water 100 µS/cm. This value fully corresponds to the IEEE requirements; see TABLE I. In terms of the conductivity of melting ice would be approximately 130 µS/cm.

TABLE I. EXPERIMENTAL CONDITIONS RECOMMENDED BY IEEE STANDARD [4] AND ACTUAL VALUES DURING THE TEST

Experimental conditions	**Recommended value**	**Actual value during the test**
Type	Glaze ice (clear ice) with icicles	Glaze ice (clear ice) with icicles
Thickness	5 mm to 30 mm on rotating cylinder	About 30 mm on rotating cylinder
Freezing water flux	60±20 $l/h/m^2$	Typically 65-75 $l/h/m^2$
Water conductivity σ_{20}	100 µS/cm at 20 °C	100 µS/cm at 20 °C
Air temperature	-5°C to -15 °C	-7°C to -10 °C
Precipitation direction	45°±10°	About 45°
Applied voltage	Service voltage stress	Maximum service stress

C. IPS test of insulator string without/with MCS

Ice was accreted on three insulator strings in parallel, first without MCS, during the time (approximately 7.5 hours) found in calibration phase. Maximum phase-to-ground operating voltage of 146 kV was applied during all time of ice accretion. This voltage corresponds to maximum operating voltage in Russia for the voltage class 220 kV.

After finishing of the ice accretion, insulators were tested, one at a time, by performing a rapid voltage increase up to flashover (Ice Progressive Stress, IPS method [3]). The voltage was increased at a constant rate of approximately 12 kV/s until flashover, which was quite in line with earlier practice [3].

The same test procedure as described above was applied for insulators equipped with MCIA.

D. Test set-up and test objects

The test objects correspond to the voltage class 220 kV and consisted of 14 cap-and-pin insulators of aerodynamic profile. In the first case these were insulators only, in the second case, the string was equipped by MCS.

Testing was performed in STRI climate hall, 18 m in diameter and 23 m in height, which was cooled down to about -10°C. During the testing, insulator strings were hung from a grounded beam 3 m above the floor. Voltage was applied at the bottom of the strings via horizontal tubes simulating conductors. The test voltage was supplied from a 550 kV test transformer located in the main high voltage hall and connected via wall bushing.

Each insulator was subjected to water spray from three separately controlled nozzles, mounted on poles placed approximately 3 m from the insulators. The set-up is shown in Figure 3.

Figure 3. Set-up for ice accretion on insulator strings.

III. TEST RESULTS

Individual flashover voltages and their averages are presented in Table 2. Examples of flashovers of insulators taken from video recordings are presented in Figure 4. For the illustration, view of insulators during development of ice accretion is presented in Figure 5. and Figure 6. for both insulator strings and the strings equipped with MCS.

TABLE II. RECORDED INDIVIDUAL FLASHOVER VOLTAGE VALUES

Test object	**String**	**Flashover voltage, kV**	**Average, kV**
Insulator string without MCS	No 1	220	236
	No 2	211	
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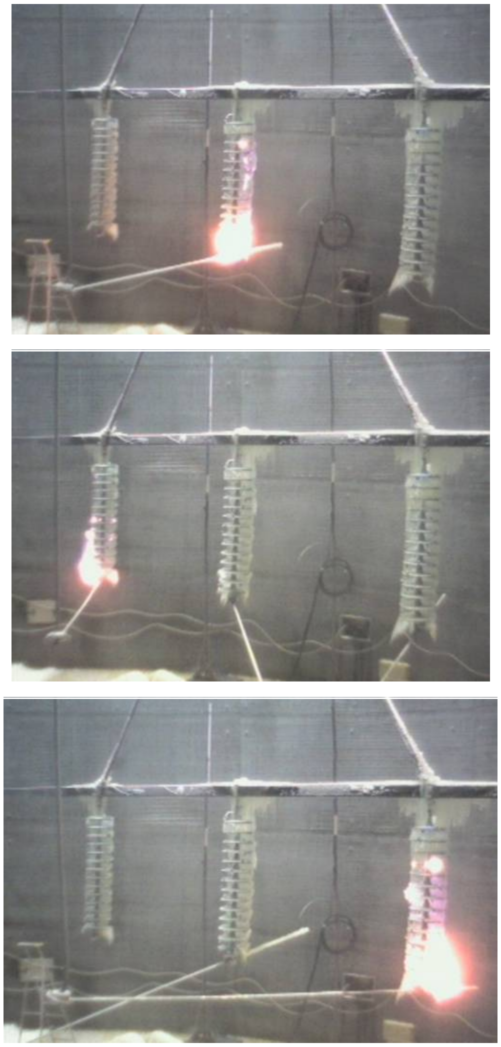

Figure 4. Examples of flashovers of insulators with MCS.

Figure 5. Development of ice accretion on insulators strings without MCS. Photos show examples after 5 h and 7 h of ice accretion.

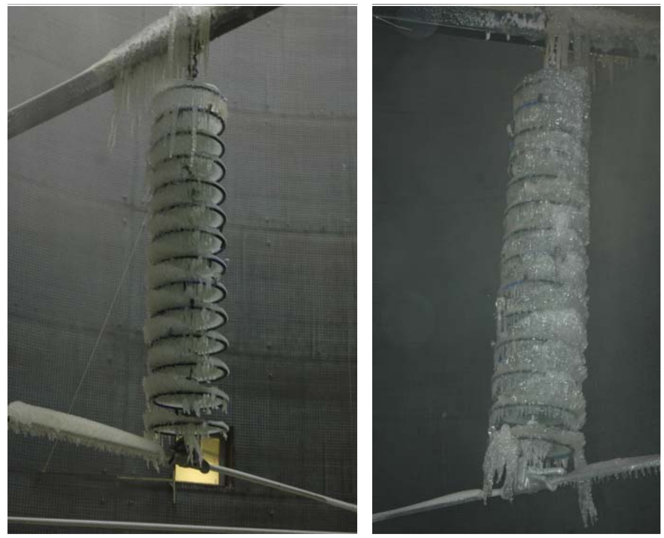

Figure 6. Development of ice accretion on insulators with MCS. Photos show examples after 5 h and 7 h of ice accretion.

IV. SUMMARY

Ice Progressive Stress test method was successfully used for the comparison of strings of cap-and-pin insulators with and without multi-chamber system (MCS). The test was performed for specific Russian environment defined as glazed ice 30 mm with 100 µS/cm of applied water conductivity.

The results showed that MCS does not reduce the electrical strength of insulator strings under such ice conditions. The average flashover voltages for the strings with/without MCS are approximately the same (236/230 kV) and are much higher than maximum operating voltage for 220 kV voltage class (146 kV phase-to-ground).

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