

Using Steam to De-Ice Energized Substation Disconnect Switch

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Abstract—A new de-icing technique that uses steam to de-ice energized disconnect switch has been developed. Electrical tests confirmed the insulating properties of steam. De-icing tests were conducted and successfully completed on energized equipment. Based on these results, a steam-based industrial version of a de-icer is now in the process of being manufactured.

I. INTRODUCTION

The recent extreme ice storms in province of Quebec (Canada), in particular that of 1998, revealed an important problem with the switching performance of disconnect switch, which cannot be easily ensured when there is an accumulation of ice of 20 mm or more. When severe icing is followed by a period of cold, the entire disconnect switch assembly (jaws and mechanism) is jammed by the ice. This causes extensive delays to isolate equipment such as lines and transformers requiring servicing or repairs. Substation operators are seeking a solution to this problem.

Some background information is presented as well as an overview of the main de-icing techniques. The use of steam for de-icing de-energized equipment is then presented, followed by the steam-based de-icing of energized equipment, mainly disconnect switch. An actual application for cleaning equipment at a 25-kV substation is reviewed, followed by a remotely operated prototype which was subjected to laboratory tests. The development of an industrial version of the steam-based de-icer is covered in the conclusion.

II. OVERVIEW OF DE-ICING TECHNIQUES

There are several techniques available for de-icing equipment. One such method uses CO₂ pellets to clean [1] and de-ice insulators much like using sand blasting equipment. This method is good but very costly and abrasive.

One of the most widespread methods involves the use of a high-pressure jet of hot water [2]. This method is very efficient for de-icing aircraft, fire hydrants, water pipes,

etc. It is very simple and quick to use. However, large quantities of water and power are required and operators are splashed by the water, which is problematic. This technique is difficult to use to de-ice energized equipment outdoors due to the increased conductivity of hot water, the effects of wind on the proper dispersal of the water stream, and the required minimal safety approach distances.

Another useful technique involves infrared technology [3], used to de-ice aircraft in hangars. Under indoor conditions it is very efficient. However, its efficiency outdoors is reduced due to climatic elements (e.g. wind, cold temperatures, freezing rain). In order to de-ice energized equipment, a safe approach distance must also be met, which further reduces the efficiency of the technique.

Glycol-based liquids are also used for de-icing purposes. However, they are generally electrically conductive and would present a hazard when de-icing energized equipment. There would also be a risk of short-circuiting the post insulators through the effects of conductive liquid runoff that has been contaminated by minerals on the surface of the ice. It would also be important to collect these liquids for environmental purposes, which entails non-negligible costs.

Another technique is steam-based de-icing, which is an improved version of the hot water method. Steam-based de-icing is frequently used by Quebec municipalities. It is efficient for de-icing fire hydrants, water pipes, the ground, and cabinets. The technique is simple to use and low in cost. Operators are not splashed by the water. This technique was therefore retained in view of further evaluation of de-icing applications for energized and de-energized equipment.

III. STEAM-BASED DE-ICING OF DE-ENERGIZED EQUIPMENT

The first steam-based de-icing tests were conducted inside a cold environmental chamber at a temperature of -12°C. A portable steam generator producing 49 kg (110 lbs) of steam an hour at a pressure of 3 bars (45 psi) was used to generate the steam.

A complete single phase 145-kV disconnect switch unit was covered with ice at various joints. A mechanical load

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was applied at the pivot, simulating an opening operation. A load cell was used to measure the applied forces. During the de-icing operation, the recording of the forces allowed the exact moment of release of the opening mechanism to be known. Temperature sensors (thermocouples) installed prior to the icing operation showed the temperature at which the ice-covered mechanisms were freed.

In general, the moving parts of the disconnect switch were covered with 30 mm of ice. The release times ranged from 15 to 60 seconds and corresponded to the release in mechanical stress. In addition, during the release it was noted that the temperature of the mechanisms being de-iced exceeded 0°C, which indicated that the ice was becoming more fragile and that there was reduced ice-metal adherence. It was therefore not necessary to de-ice the entire piece of equipment to allow the disconnect switch to open. Figures 1a and 1b show the results of complete de-icing of the disconnect switch jaw. The de-icing process took less than two minutes.



Figure 1a: Ice-covered jaw



Figure 1b: Jaw de-iced using steam

IV. USING STEAM TO DE-ICE ENERGIZED EQUIPMENT

It was previously shown that steam can efficiently de-ice de-energized equipment. However, prior to using this technique to de-ice energized equipment, the steam must be electrically characterized and adequately directed.

Tests without ice were carried out at Institut de recherche d'Hydro-Québec (IREQ) high-voltage laboratory. Figure 2a shows the test setup. A jaw from a 145-kV disconnect switch was installed on a 1-m-long porcelain post insulator. The jaw was energized with AC voltage ranging from 0 to 150 kV. Various isolated steam

tubes 1 to 3 metres in length were used to direct the steam. An isolated manipulator was designed to direct the steam tube and develop safe approach procedures (Figure 2a,b). The tests allowed the conductivity of the steam to be maintained at less than 1.5 $\mu\text{S}/\text{cm}$. The electrical isolation of several types of steam tubes directing the steam was checked up to a voltage of 150 kV by measuring the leakage current. The best performing tubes were identified.

The second step consisted in using steam to de-ice energized equipment. Tests were conducted in an environmental chamber at the atmospheric icing pavilion at Université du Québec à Chicoutimi (Canada). The test setup, steam tube manipulator and steam generator were the same as those used at IREQ's laboratory (Figure 2a,b). This environmental chamber has an ice production system, a voltage source of 125 kV AC and allows a minimum temperature of -30°C.



Figure 2a: Test assembly



Figure 2b: Steam jet

Figure 3 shows the test object subjected to an accumulation of freezing rain during 2 hours and 20 minutes. The ice thickness is about 50 mm (measured

directly) on the post insulator and represents a substantial accumulation. The ice thickness on the jaw exceeds 50 mm. All of the skirts have been bridged by the ice. This constitutes a very severe condition for the post insulator's electrical isolation.



Figure 3: De-icing test on the jaw of an energized disconnect switch.

The following procedure was used and is based on icing UQAC method [4] in melting regime

- Accumulation of ice at 70 kV AC (phase-to-neutral) and environmental chamber temperature of -12°C during 2 hours and 20 minutes;
- 20 minutes of cooling while de-energized to freeze any water on the post insulator;
- Heating of the room, applied voltage of 70 kV;
- When the water runs over the ice or the ambient temperature is around 0°C , the voltage is increased until it reaches the test voltage, which is between 80 and 95 kV;
- Measure the post insulator leakage current and the temperature of the jaw blade;
- Once the maximum leakage current is obtained on the post insulator, purge the steam tube and direct the steam jet over the disconnect switch jaw;
- Thaw out the jaw;
- Once the temperature of the blade attains about 55°C (measured by optical thermocouple) and there has been no post insulator or steam tube flashover, the test has been successfully completed.

Figure 3 also shows a typical steam-based de-icing test. It was found that at the start of de-icing with steam the water that runs off cleans the surface pollutants present on the whole column, thus reducing the conductive current and preventing flashovers. Nine de-icing tests were conducted and no flashover occurred. All the tests were therefore successfully completed. The de-icing process took about 5 minutes. The technique can also be used to remove contamination from the ice on post insulators and for fully de-icing an energized post insulator.

V. OTHER APPLICATIONS: CLEANING ENERGIZED EQUIPMENT

The steam-based technique can also be used to clean other types of energized equipment [5]. During the 2003 winter coldest period, a substantial accumulation of contamination was noted on some 25-kV insulators. The substation could not be shut-down such the insulators could not be cleaned. The steam-based de-icing technique was therefore used to clean the energized insulators (see Figures 4a and 4b). The type of pollutants involved were strongly adhering to the insulator surface. Despite these inconveniences, the surface of the insulators was successfully cleaned within a reasonable period of time while ensuring the safety of maintenance personnel and the integrity of equipment. As the work was done on energized equipment, service continuity was maintained. Since the method involved the use of directed steam, the cleaning could be done during the winter at -20°C and with 40 km/h winds.



Figure 4a: Steam cleaning



Figure 4b: Steam jet

VI. REMOTE CONTROLLED PROTOTYPE OF THE STEAM-BASED DE-ICER

An industrial prototype of the de-icer was manufactured in 2003 (see Figure 5). It includes a remote-controlled, isolated telescopic mast 16 m in length (fully extended). It is also made up of an isolated steam hose, on the outside of the mast, which deploys synchronously with the mast. The prototype can be used to de-ice equipment rated 145 to 330 kV.

Dielectric strength tests for the mast and steam hose

assembly (see Figure 5) were conducted between two electrodes spaced 2.7 m apart reproducing the geometry of a 330-kV disconnect switch. The upper electrode is supplied in voltage (60 Hz or switching overvoltage) and the lower electrode is connected to electrical ground through a 1000-Ω resistive shunt or directly for the overvoltage tests. The characteristics of the dielectric tests are listed in Table I. During tests under wet conditions, the conductivity of the rain ranged from 15 μS/cm to 45 μS/cm. The precipitation rate was 1.5 mm/min.

The steam was generated by a mobile boiler capable of producing 135 kg (300 lbs) of steam an hour at a pressure of 6.2 bars (90 psi). A steam hose was used to connect the boiler to the mast's isolated steam hose.

The leakage current during the power-frequency withstand tests (60 Hz) was measured on the mast grounding side using the 1000-Ω shunt. A 2.5 mA/100 kV current was measured. This current was stable and corresponded to the inter-electrode capacitive current

The mast and steam hose assembly successfully passed the tests listed in Table I. They withstood the specified voltage levels.



Figure 5: Dielectric tests (prototype)

TABLE I
DIELECTRIC TESTS

Type	Level	Duration	Results
60-Hz power frequency (dry)	400 kV	15 minutes	Withstand (successful)
60-Hz power frequency (wet)	240 kV	15 minutes	Withstand (successful)
Switching impulse (wet)	850 kV	10 pulses	Withstand (successful)

VII. CONCLUSION

The new steam-based de-icing method is efficient, simple to use and present little risk to safety. An industrial version of the de-icer is at the design and development stage and will allow disconnect switch, or various 330-kV equipment, to be de-iced while energized. The device will have its own energy supply and will be installed on a utility truck to make it mobile.

VIII. REFERENCES

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