Insulators for cold urban areas: The problem of Road Salt

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It seems odd that a professor located in one of the hottest region in the world should write an article about an issue that is associated with the opposite end of temperature scale. This article is warranted due to the increasing number of users who are experiencing a less than satisfactory performance of insulators in winter due to road salt. We have started a research project at Arizona State University that is being funded through an industry-utility-university consortium PSERC, Power Sytems Engineering Research Center. Rest assured, we are not trying to reproduce winter conditions in Sunny Arizona, rather, we are more concerned with the effect that the road salts have on insulators, both ceramic and composite.

Background Information: In order to permit safe passage for pedestrians and vehicles during winter months, the sidewalks and roads in urban areas are salted at regular intervals. The goal is to prevent ice formation on these surfaces and to deice the surfaces as quickly as possible. The application of salt lowers the freezing point of the road/sidewalk surfaces and thus delays ice formation. It is interesting to note the huge quantities of salt used in North America. For example, **USA uses about 15 million tons and Canada 4-5 million tons every year**. Some of this will get deposited on the insulator surface by natural agents such as wind, and from the movement of vehicles on these streets. Considering that we classify any amount over 0.1 mg/cm^2 on the insulator surface as heavy pollution, it should not be surprising that the performance of insulators in cold climates is an important issue.

Several types of salts are used for deicing. The most common is rock salt (sodium chloride) as it is inexpensive. It lowers the freezing point of the surface to a few degrees. Other chemicals such as calcium chloride and magnesium chlorideare also used. These work better than sodium chloride. For example, calcium chloride works below 20^o F (-8^o C), and effective for lower levels of relative humidity (42%) when compared with sodium chloride (72%). A mixture of salts such as rock salt mixed with calcium chloride, calcium magnesium acetate (CMA) are also used. These are claimed to be much more effective, cause less corrosion and are environmentally friendlier when compared to rock salt, however they more expensive than rock salt.

Calcium chloride, magnesium chloride and CMA are also used in a liquid form. Experience has shown that the liquid lasts longer as the liquid adheres well with the road surface, provides wider coverage and also is easier to apply. There are a number of application tools that have been developed. This method of deicing is clearly favored by the road authorities and the number of users is increasing. The electric power authorities are not too happy with this situation. One reason is that the deicing material is hard to remove and does not wash off easily with water. So if it were to be deposited on an insulator surface it would remain there for a much longer time than rock salt. Utilities serving the metropolitan areas of Denver, Chicago and others are complaining of increased incidences of wood pole fires and insulator flashovers during the winter months. Whether this is solely due to the deicing liquid chemicals is hard to say at this stage due to lack of comprehensive scientific data.

In order to address this issue, a research project was initiated at ASU. Several types of porcelain, silicone rubber and EPDM rubber composite insulators have been installed near major highways in Chicago. There are several objectives of this program: (1) to determine the pollution severity caused by the road salt in terms of conventional ESDD (equivalent salt deposit density), (2) to determine the cleaning action of natural agents like rain and wind, and (3) explore new methods of characterizing contamination severity and (4) use all of the above information to predict if and when utilities to engage in washing programs to maintain continuity of power delivery.

The program is initially intended to address issues related to distribution and subtransmission (< 69 kV) line insulators. Eventually the scope will be expanded to include station insulators.

Initial Results: We considered three types of deicing chemicals, rock salt (NaCl), solid calcium chloride and liquid calcium chloride. These were applied to a standard porcelain insulator (5.75" X 10", leakage distance of 310 mm) using a slurry consisting of kaolin in water. The porcelain insulator was dipped into this slurry in order to get a uniform layer on the surface. By a process of trial and error the amount of NaCl, solid calcium chloride and liquid calcium chloride content in the slurry was adjusted so that the conductivity of a known area of the insulator was more or less equal. The ESDD value was measured to be about 0.17 mg/cm^2 for the three different types of salts. The insulator was allowed to dry overnight.

The surface resistance of these insulators was monitored in a fog chamber using ultrasonic fog. The guidelines for the measurement of surface resistance were consistent with the IEEE Task Force Publication [1]. The voltage used for the measurement was 2 kV_{rms}. Fig. 1 shows the variation in surface resistance. It can be seen that there is a wide variation in the rate at which these salts go into solution and this aspect of solubility is well known. The insulator contaminated with liquid calcium chloride goes into conduction almost immediately upon turning on the fog generator. Another important observation is that while the final value of the surface resistance approaches a similar value which should be expected as they have a similar ESDD to start with; the rate of decrease of surface resistance is different for the three chemicals. One can readily argue that unless a significant amount of moisture is present on the insulator surface, the solid calcium chloride and to a lesser extent rock salt is not a serious concern to insulator performance. However the same cannot be said for liquid calcium chloride. Its presence on the insulator surface can rapidly lead to increased leakage current and possible flashover.

Flashover Voltage Calculation With Computer Simulation: A computational model was developed to predict flashover voltage of insulators for line and station applications. The model is an advancement over existing models in that it includes the effect of shed bridging due to moisture (in liquid, ice or snow form). The flow chart that depicts the major steps in the model is shown in Fig. 2. A full mathematical treatment of the model is beyond the scope of this article and will be presented elsewhere. Shed bridging is a real issue with porcelain/glass insulators used in stations where the distance between sheds is about an inch. For line insulators employing the cap and pin design there is about a 6 inch spacing between the various bells, hence bridging due to water from rain or fog is usually not an issue. Shed bridging is possible under ice or snow conditions and must be considered in the context of pollution of insulators in cold places in during winter.

For the purpose of evaluating the effect of the various deicing chemicals on the flashover voltage, a standard 5.75”X 10” porcelain bell with 310 mm leakage distance, was considered. Fig. 3 shows the calculated flashover voltage for ESDD = 0.15 mg/cm^2. It can be seen that the deterioration in the contamination performance is far more serious for liquid calcium chloride than with the other two salts.

A further deterioration in insulator performance will occur in the case of porcelain insulators used in station due to shed bridging. Fig. 4 shows two varieties of station posts used for 230 kV systems, the 900 kV BIL unit is more common, but there are several utilities that use the 750 kV BIL units. Figs. 5 and 6 show the calculated flashover voltage. The shed spacing is about 1 inch. The ESDD is assumed to be 0.15 mg/cm^2. Insulator A has a BIL of 750 kV and a leakage distance of 132”. Insulator B has a BIL of 900 kV and a leakage distance of 165”. It can be seen that the 132” insulator will flashover with liquid calcium chloride even without shed bridging. The 165” leakage unit will offer satisfactory performance as long as there is no shed bridging. To assume that this will always be true is not practical. If shed bridging is considered, even this insulator will fail if the contaminant is liquid calcium chloride. However for sodium chloride, the insulator can be expected to perform satisfactorily for this level of contamination. Should the contamination severity increase or if more sheds were to be bridged then even this insulator would flashover.

Shed bridging can be avoided by increasing the shed spacing, but this will impact the leakage distance. Obtaining the required leakage distance while maintaining sufficient shed spacing requires the use of alternate diameter sheds, taller insulators, or using hydrophobic materials like silicone rubber. All of these are possible options for new construction. However for improving the performance of existing insulators in such locations, insulator coatings like RTV silicone rubber is one available choice.

Presently studies are being conducted to quantify the impact of the different chemicals on composite insulators using either silicone rubber or ethylene propylene rubber materials for the housing. In case of silicone rubber, important questions like impact on hydrophobicity retention and recovery are being addressed, as is the ease with which these chemicals can be removed from the insulator surface.

SUMMARY: Deicing chemicals can cause serious degradation in insulator performance. While liquid calcium chloride is increasingly preferred by road authorities for their virtues, utilities have good reasons to be worried about the performance of insulators especially in stations. It is desirable that utilities work closely with the road authorities to ensure that we are all able to drive safely and be assured that a warm home awaits us on those miserable winter days.

Figures

Fig. 1: Variation of Surface resistance with time of wetting in the fog chamber. The surface resistance is expressed as Meg Ohm/cm of leakage distance.

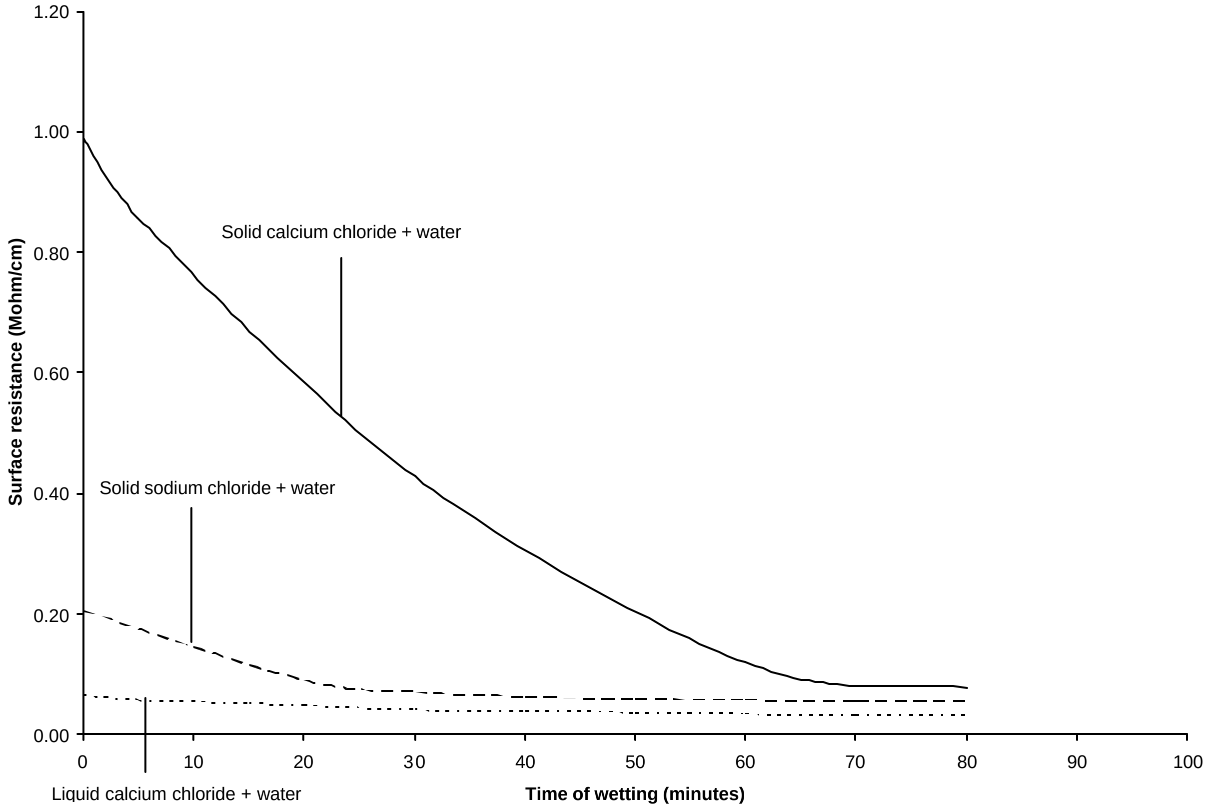


Fig. 2: Flowchart of Theoretical Model for Flashover Voltage Calculation.

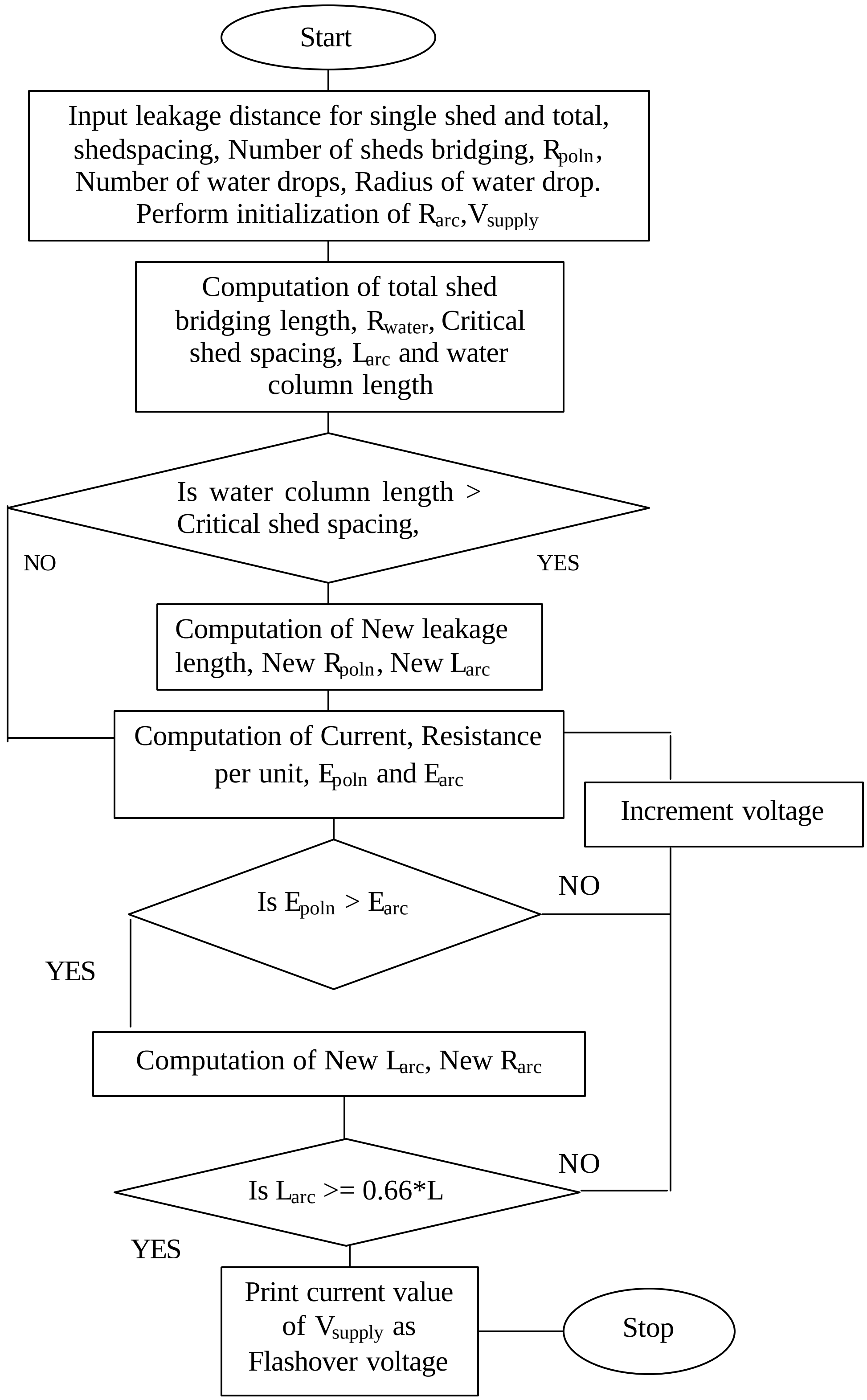


Fig. 3: Flashover voltage calculation for a single standard porcelain bell (5.75”X 10”) with 310 mm leakage distance.

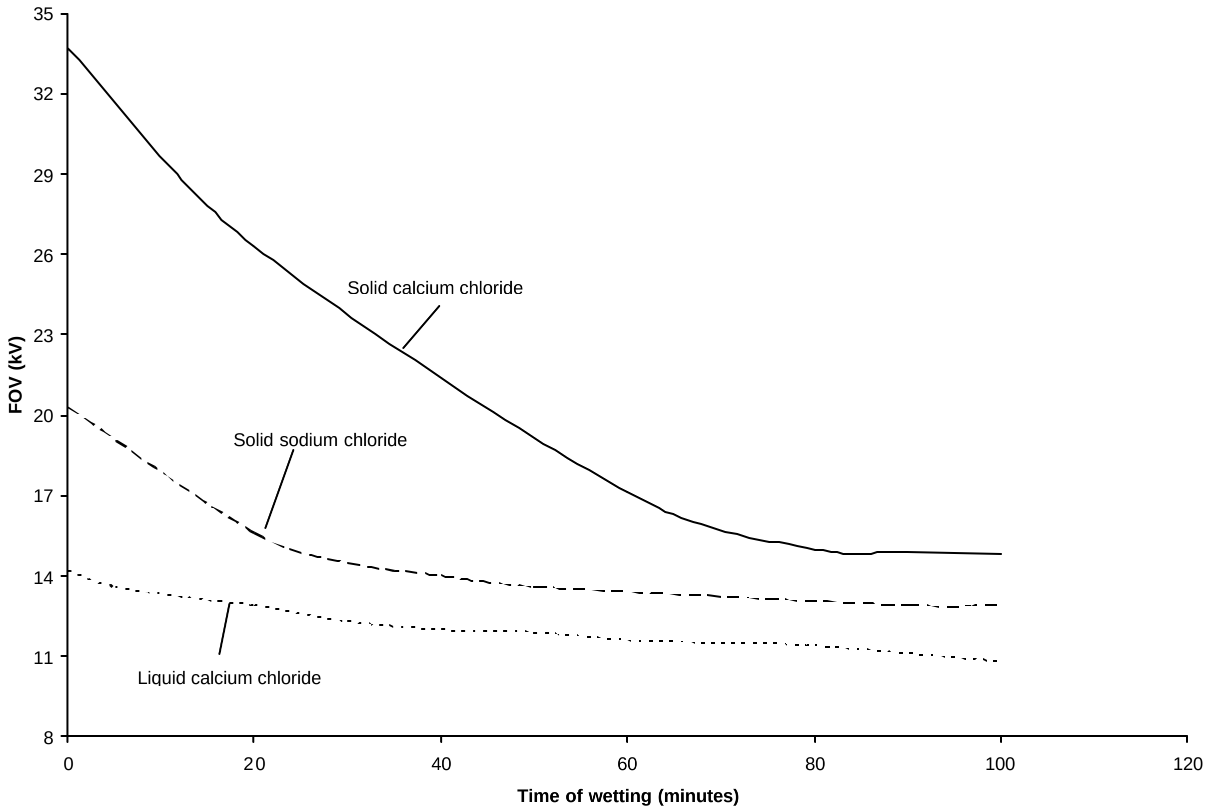
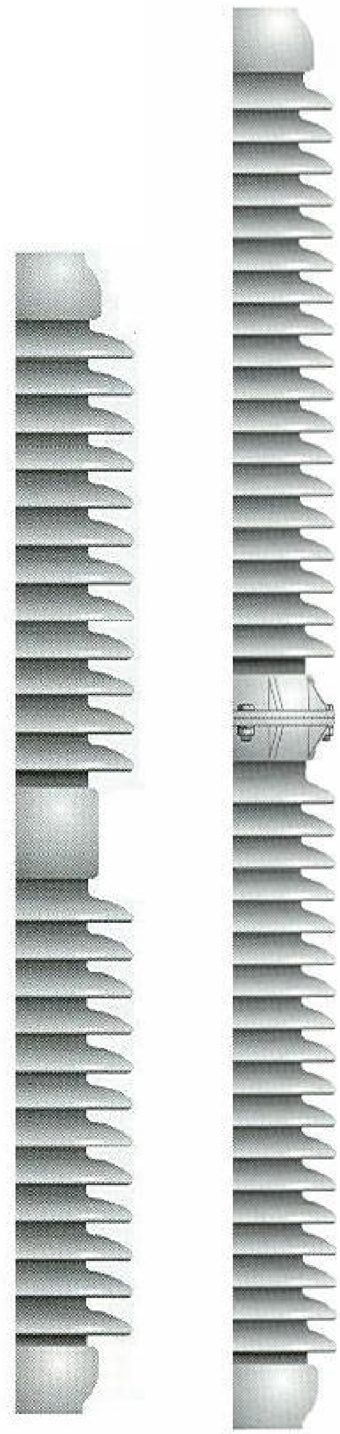


Fig 4: Two types of post insulators used for 230 kV systems. (a) 750 kV BIL with leakage distance = 132” and (b) 900 kV BIL with Leakage distance =165”.



(a) (b)

Fig. 5: Calculated flashover voltage of 132” leakage distance post for liquid calcium chloride and solid sodium chloride salts with ESDD= 0.15 mg/cm^2.

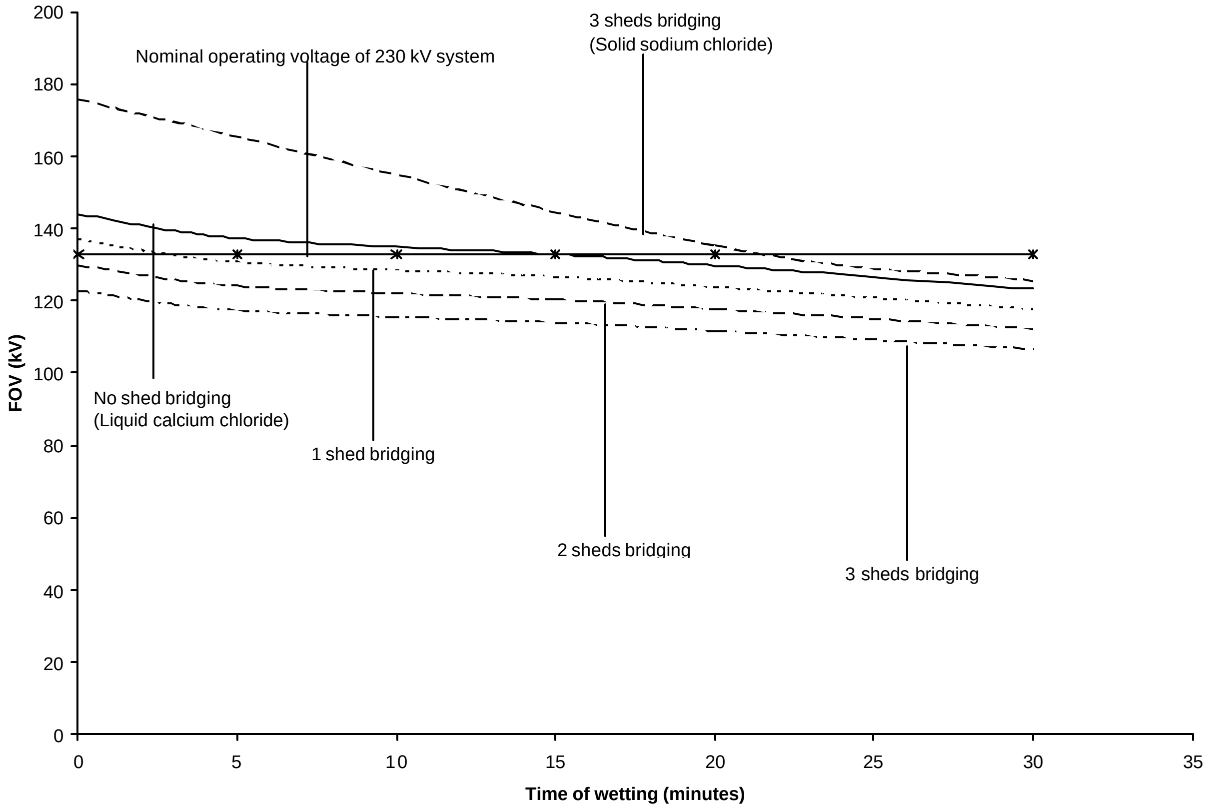


Fig. 6: Calculated flashover voltage of 165” leakage distance post for liquid calcium chloride with ESDD= 0.15 mg/cm^2. The flashover performance with sodium chloride is better and hence is not shown.