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Estimation of Electric Stress and Surface Potential for Traction Insulators

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Abstract—Traction insulators are solid core insulators widely used for railway electrification. Constant exposure to detrimental effects of vandalism, and mechanical vibrations begets certain faults like shorting of sheds or cracks in the sheds. Due to fault in one/two sheds, stress on the remaining healthy sheds increases, owing to atmospheric pollution the stress may lead to a flashover of the insulator. Presently due to non availability of the electric stress data for the insulators, simulation study is carried out to find the potential and electric field for most widely used traction insulators in the country. The results of potential and electric field stress obtained for normal and faulty imposed insulators are presented.

Keywords—shorted sheds; surface charge simulation method; surface field; surface potential; traction insulators.

I. INTRODUCTION

With the recent advances in technology, the electrification of railways has overpowered steam-run trains due to its higher speed and eco friendly nature. To provide flexible or rigid support for these overhead electric traction lines, traction insulators are widely used [1]. In overhead electrification systems, the supply of electricity is maintained through an overhead system of suspended cables known as the catenary with its auxiliaries like contact wire with a pantograph arrangement [2]. The maintenance of traction insulators is mandatory to ensure the proper functioning of electric trains.

Due to constant mechanical vibrations, vandalism and environmental effects the traction insulators are subjected to enhancement of electric stress, which may further lead to failure/flashover of the insulator. A fracture/crack once formed on the surface of the insulators propagates radially and in due course of time leads to mechanical/insulation failure of the insulators. Further accumulation of dust particles and moisture forms a conducting layer on the surface of the sheds which degrades the withstand capacity of the insulator. To understand the stress variations, it is important to study the electric field and potential distributions which occur during normal and faulty conditions. Currently there is no data available for the electric stress and potential distribution across the traction insulators used in the country. Hence a detailed simulation/experimental study is attempted in the present investigation.

II. NUMERICAL COMPUTATION

Over the years various numerical methods have been adopted for computation of potential and electric field for normal and faulty ceramic disc type insulator in a string [3-5].

Numerical methods are employed for electric field calculations for physical systems which are complex and cannot be solved analytically. Domain based methods like Finite Difference Method (FDM), Finite Element Method (FEM), and boundary based methods such as Boundary Element Method (BEM), Surface Charge Simulation Method (SCSM), and Charge Simulation Method (CSM) are some of the existing numerical methods. The problem under investigation is of open geometry (boundary) type, hence boundary based method SCSM would be very suitable, hence is selected for the study

The SCSM code [4-6] developed was suitably modified and employed for the present investigation. Galerkin's method has been employed owing to its higher accuracy [6].

Simulations study is conducted on normal and fault imposed on the insulators. Presently two types of faults were simulated:

- Crack Propagation- The profiles at different stages of crack propagation were simulated.
- Sheds shorted to create a fault- Three fault locations were chosen namely near ground end, near high voltage end and at the middle of the insulator.

Simulations were carried for 25kV ac system voltages for various traction insulators presently used in the country.

III. SIMULATION RESULTS

A. For healthy/normal traction insulator

Simulations were carried out for five different types of traction insulators whose details are listed in Table I. For brevity, results of one type of insulator in particular, namely Type A, are presented. Type A insulator is a stay arm traction insulator of 150 N. Fig 1 presents its basic profile. Fig. 2 and Fig. 3 show the plots of equipotential lines and electric potential respectively. It is seen from Fig. 3 and Fig.4 that the surface potential and electric field decreases from 25 kV at the line conductor end to zero at the ground end. Fig 5 depicts the bulk stress along the insulator. The volume/bulk stress is high at the line end conductor and near cap-cement-insulator junction.

TABLE I.
SPECIFICATIONS OF TRACTION INSULATORS USED FOR STUDY

Insulator	Creepage length (mm)	Height (mm)	Width (mm)	Weight (kg)
Type A	920	600	187	15
Type B	1090	600	200	17
Type C	920	580	187	15
Type D	912	547	115	8.6
Type E	880	636	135	19

Fig. 1. Type A insulator Profile

Fig. 2. Equipotential Lines Plot for Type A insulator

Fig. 3. Potential Plot for Type A insulator

Fig. 4. Surface gradient Plot for Type A insulator

Fig. 5. Volume/Bulk Stress Plot for Type A insulator

B. For fault imposed traction insulator

Simulations are carried out with faults imposed on the insulator. To generate fault, either some sheds were intentionally shorted or a crack/fracture initiated on the ceramic portion. A crack of length 3.1 mm was simulated as shown in Fig. 6. Fig. 7 and Fig.8 show the comparison of surface potential and surface field for normal and fault initiated condition. From the plots it is observed that a sharp rise of potential and as well as surface field was observed at the location of fractured portion of the insulator. Similarly, Fig. 9 and Fig. 10 present the comparison results for potential and electric stress for fault where two sheds from the line conductor end were shorted. This is assumed to happen in the field due to vandalism or other mechanical vibration. Fig.10 shows the continuous increase of surface field along the remaining insulator portion. In case of the above faults on the insulator aided with atmospheric contamination/pollution conditions the stress is likely to increase further leading to an ultimate flashover at nominal voltages.

Fig. 6. Type A insulator with crack

Fig. 7. Comparison of surface potential of type A for normal and fault

Fig. 8. Comparison of surface field of type A for normal and fault

Fig. 9. Comparison of surface potential of type A for normal and bottom 2 sheds shorted

Fig. 10. Comparison of surface field of type A for normal and bottom 2 sheds shorted

IV. EXPERIMENTATION

To verify the simulation results few experiments were carried out for normal /dry and wet conditions as per [8]. The experimental set up shown in Fig.11 consists of a main transformer, a regulating transformer, and a control panel. The High Voltage transformer is rated for 150 kV -2A/100 kV-3A/50 kV-6A, of 300 kVA. The input voltage to the transformer is 400V (is fed by two phase ac supply) and the input current rating is 750 A. The output of the test source is calibrated with a Siemens make standard reference potential transformer model: 20321/S16b, VTO II 55.

The experimental chamber consisted (5m× 5m×5m), where experiments for artificial pollution/rain can be carried out. Experiments were carried out on traction insulators for dry and wet/rain conditions.

The insulator performance was monitored for different voltage levels from a low value to 100kV. The leakage current measurements were also made using a Rigol make DS1042C, 2-channel, and 40MHz, 400MSa/s digital storage oscilloscope across a 50Ω resistor at the ground end.

The experiments were conducted for normal and as well as for wet conditions for different voltage levels. The leakage current pulses were seen to be significant during wet conditions. Fig. 12 and Fig.13 show the leakage current pulses for voltage levels 25kV and 70kV respectively. From the graphs it is seen that as voltage across the insulator was increased in steps, the leakage current pulses also increase in magnitude.

Fig. 11. Schematic diagram of experimental setup

Fig. 12. Performance of Type A insulator under wet condition for 25kV

Fig. 13. Performance of Type A insulator under wet condition for 70kV

V. CONCLUSIONS

Simulation study was conducted for five types of traction insulators presently being used in the country. The simulation results of surface potential, electric stress and bulk/volume conductivity are presented.

Two types of fault are initiated during the simulation studies, and it is found that the electric stress increases across the surface of the traction insulators.

The stress across the insulator was found to be high, when the location of the defect in the insulator is near the high voltage conductor (line end), and it is less when the defect in the insulator is located at the middle or near the ground end of the unit.

Preliminary experimentation was carried out on different types of traction insulators and the performance was monitored for dry/normal and wet conditions. The performance of the leakage current magnitude was monitored.

The field and potential data never existed for the traction insulators presently used in the country. Hence, it is believed that these results are presented for the first time and will be useful to the utility engineers.

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