

DIFFERENT CHARACTERISTICS OF SEMICONDUCTING GLAZED INSULATORS AT ARTIFICIALLY POLLUTED CONDITIONS

Ghasem Ahrabian¹, Farhad Shahnia², Amin Lafzi³

^{1,3}Faculty of Electrical and Computer Engineering, University of Tabriz, Tabriz, Iran

²Eastern Azarbayjan Electric Power Distribution Company, Tabriz, Iran

¹ahrabian@tabrizu.ac.ir, ²shahnia@tabrizu.ac.ir, ³amin_lafzi@yahoo.com

Abstract-Semiconducting Glazed Insulators are one of the most efficiently used insulators in contaminant areas. Several electrical and mechanical tests take place under electrical and mechanical rests are carried out to foresee the operation of these insulators in regions with high pollution. In attention to plenty of such tests that each one is being tested with a special way and different electrical, mechanical and environmental specifications, adding the results up and analyzing them has a special importance. In this paper, comparing the operation of this kind of insulators with conventional porcelain insulators in different artificially polluted conditions and related indexes in determining the operation of these insulators in different conditions of pollution is achieved.

Keywords-Semiconducting Glazed Insulators, Withstand voltage, Flashover, Leakage current, Test

I. INTRODUCTION

Application of different kinds of insulators is based on different electrical, mechanical and economical conditions. The most important point which should be considered about insulators is the pollution effect on their operation according to the different environments. Most of insulators are used outdoors and the environment pollutions can cause their surface to be covered with dust or chemical materials in long time. In wet environments pollution causes reduction in surface impedance of the insulators by dissolving in water and dispersing on the whole surface of the insulators. Nowadays, Semiconducting Glazed Insulators (SGI) are being used accompanied by porcelain insulators in large amount while the results of their tests and experimental studies show the priority of SGI in comparison with others, especially in highly polluted areas. All over the world, different laboratories are conducting tests that each one takes place with a special method and for different polluted environments, where adding these results up has a special importance. The main ability of SGI in facing with negative effects of pollution and humidity is surface drying effect. Existence of surface conducting in insulator's glaze ends to leakage current in mA range and increasing its temperature to some degrees more than the ambient temperature. Insulator heating cause humidity

evaporation of the insulator surface and prevents local discharges to happen. Uniform potential distribution on SGI string is more monotonous than ordinary porcelain insulators.

II. SGI STRUCTURE

The structure of SGIs is the same as ordinary porcelain insulators but the most important difference is in their glaze. SGIs contain tin-oxide and amount of antimony with the other additive of niobium-oxide in ordinary glaze base. This additive was found effective to improve performance against glaze corrosion. In addition to the capacitance specification of SGI which is the same as the other insulators, SGIs have little conducting characteristic in their surface because of semiconducting glaze layer existence, meanwhile because of high surface impedance of conventional insulators, such a conductance in their layer is not seen. In Fig. 1 the schematic structure of a SGI is presented where their differences with ordinary porcelain insulators are shown in Fig. 2.

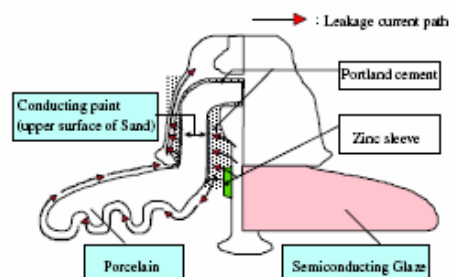


Fig. 1. Structure of SGI.

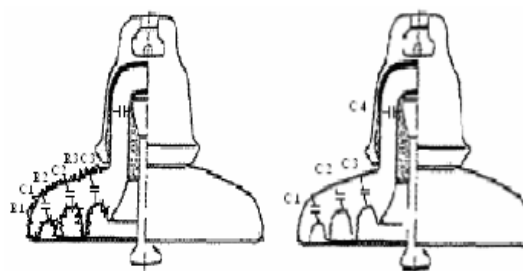


Fig. 2. Schematic image of ordinary porcelain insulator (right) and glazed porcelain insulator (left).

The application of SGI s is greatly suggested for areas with high pollution and humidity. The leakage current on the surface of convectional insulators flows on its surface and the rate of it increases as pollution and humidity increase and if on the surface of insulator there are dry bands, the leakage current follows its way through the air due to the low impedance of the air rather than the dry bands as shown in Fig. 3. In result partial discharges are created on the surface of insulator and their number might increase resulting in a flashover on the insulator. In SGIs, the leakage current will continue its path through the glaze of the insulator instead of flashover through the air which is caused because of insulator glaze low impedance as shown in Fig. 4. This fact prevents flashovers to happen which would end to better operation and longer life of insulators and succession in polluted and humid conditions.

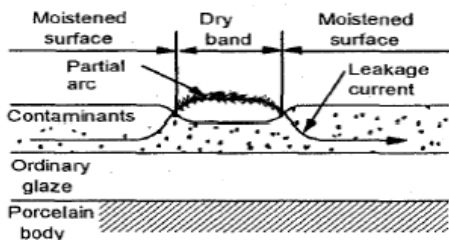


Fig. 3. Leakage current flow on the surface of contaminated ordinary porcelain insulators.

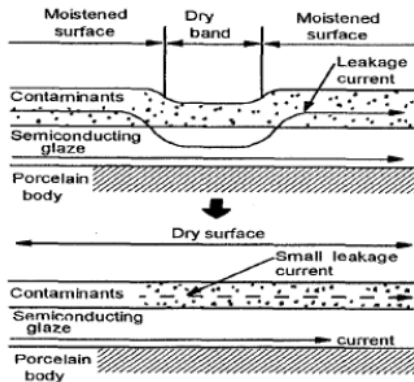


Fig. 4. Leakage current flow on the surface of contaminated SGI.

III. SGI WITHSTAND VOLTAGE

The results of different tests on the conventional porcelain insulators and SGIs prove the fact that SGIs have about 3 times higher impedance in comparison with ordinary porcelain insulators which will decrease to 2 times in heavy humid conditions as shown in Fig. 5.

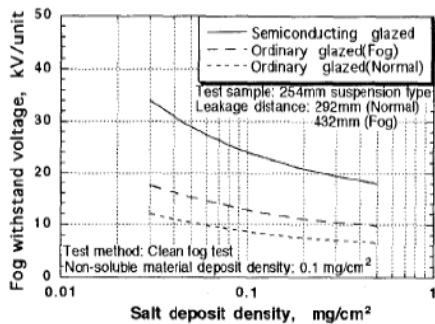


Fig. 5. Contamination withstand voltage of SGI.

So with comparison for different values of salt deposit density on different insulator surfaces, better operation of these insulators can be found out which suggests the application of these kinds of insulators in polluted regions with more confidence.

IV. SGI SURFACE IMPEDANCE

When the leakage current flows on the surface of insulators, the generated heat will cause a decrease in the surface impedance of the insulator since the thermal coefficient of semiconductor is negative and in result current will increase. As this condition continues there is probability of thermal runaway of the insulator. In order to prevent this, it is better to choose high surface impedance for insulator. But in attention to the current flow on insulator surface in order to its operation recovery and also increase the rate of withstand voltage, it is not possible to increase the impedance value so high, therefore the optimum value should be chosen which is about $13 \pm 5 \text{ M}\Omega$. In this case the leakage current value would be about 0.5-1 mA on the SGI surface. Therefore the withstand voltage variation of SGI with insulator surface impedance is as shown in Fig. 7.

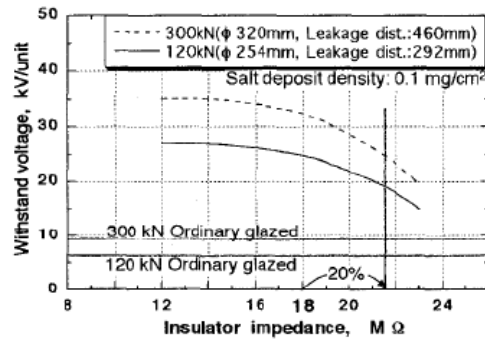


Fig. 6. SGI withstand voltage variation with insulator surface impedance.

Due to the surface impedance of the insulator, the leakage current flow on insulator surface will cause fatalities on its surface which result in an increase in insulator temperature in comparison with ambient temperature which is transferred to environment as heat. With an increase in impedance, leakage current on the surface of SGI decreases. This fact causes an increase in thermal stability of the insulator. Thermal runaway of withstand voltage will increase because the surface impedance is high. In fact, withstand voltage value will decrease. Therefore, these two characteristics will determine the optimum impedance. But the main parameter is the thermal runaway of withstand voltage. Because withstand voltage of SGI is higher than ordinary porcelain insulators under the pollution condition. Fig. 8 shows the SGI thermal runaway of withstand voltage with insulators surface impedance variations which increases with an increase in impedance value.

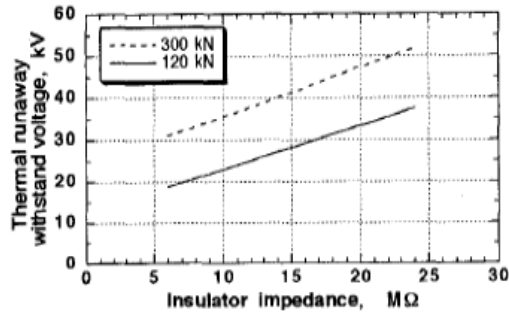


Fig. 7. SGI thermal runaway withstand voltage with insulator surface impedance.

V. SGI FLASHOVER VOLTAGE

In order to study and analyze the flashover voltage in SGIs several tests in the field of switching and lightning impulse stress are done on these insulators.

As shown in Fig. 8, flashover voltage variations of ordinary porcelain with environmental humidity are linear which for a definite humidity, the flashover voltage rate increases with temperature increase. But in SGIs a different behavior in different humidity is visible, as shown in Fig. 9 where in 10°C and 20°C the flashover voltage decreases as humidity increases. But in 30°C and 40°C the flashover voltage increases as humidity increases.

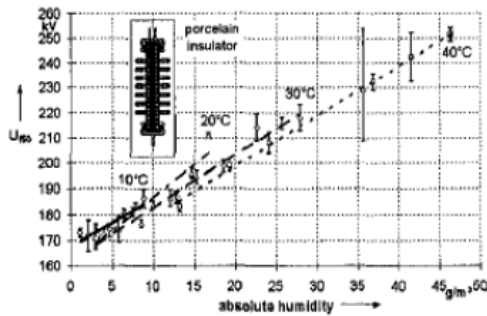


Fig. 8. Ordinary porcelain flashover voltage variations with absolute humidity at different temperatures.

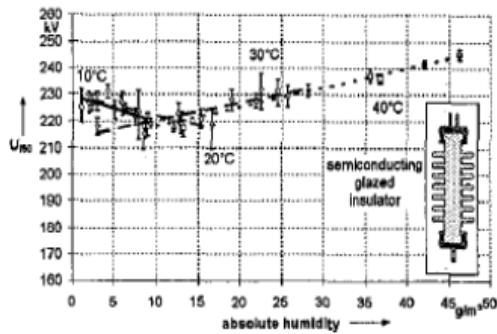


Fig. 9. SGI flashover voltage variations with absolute humidity at different temperatures.

Also comparing ordinary porcelain insulators and SGIs for a definite temperature, this major result is obtained that in low humidity for SGIs, flashover voltage value created by the switching impulse stresses is more than the same value for conventional insulators. But for very high amount of humidity (above 45 g/m³) flashover voltage value created by switching impulse stress for SGIs is less than the same value for conventional insulators which is shown in Fig. 10.

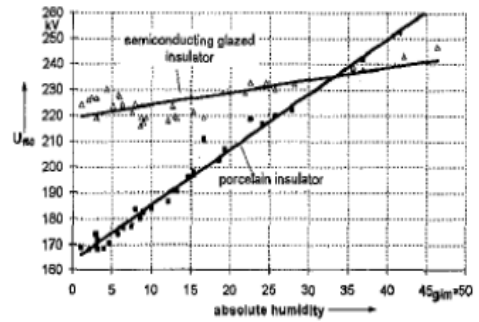


Fig. 10. Influence of the absolute humidity on the flashover voltage of SGI and ordinary porcelain insulator.

Flashover voltages created by lightning impulse stress in conventional porcelain insulators and SGI for different temperatures in terms of humidity changes are shown in Fig. 11. As shown in this figure, the flashover voltage value for an environment with constant temperature and humidity is higher for porcelain insulator with semiconducting glaze than the same value for ordinary ones.

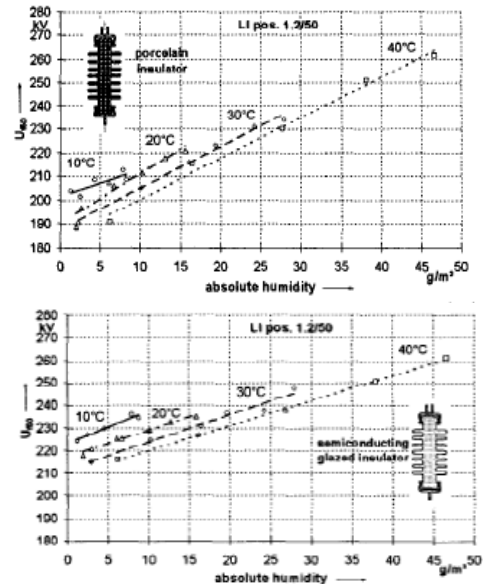


Fig. 11. Flashover voltage variations with absolute humidity for different temperatures for ordinary porcelain insulator (top) and SGI (bottom).

Also in Fig. 12, the flashover voltage by lightning impulse stress of these two insulators are shown which proves mentions the fact that in humidity above of 37 g/m³, the flashover voltage of conventional glazed insulator is more than SGIs.

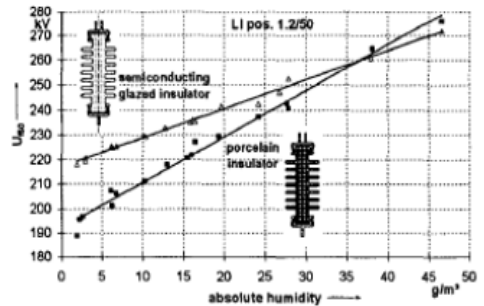


Fig. 12. Flashover voltage variations with absolute humidity of a SGI and ordinary porcelain insulator.

VI. SGI POTENTIAL DISTRIBUTION

Equivalent circuit of SGI string is shown in Fig. 13 which contains series connection of capacitors (capacitance characteristic of each insulator) and impedance (insulator surface electrical impedance). In each insulator string capacitance between the insulator units and conductor and insulator units and tower is effective in addition to capacitance of each insulator and in other words potential distribution along an insulator string formed by insulator units is not uniform because of leakage capacitors. In result, voltage drop on the line side units is more than the other units. This problem has decreased in SGIs, because in insulator strings formed by SGI unit, voltage distribution is more uniform than previous conditions because of low surface impedance voltage. This has led to the ability of decreasing the length of insulator string in the same conditions with ordinary porcelain. In addition this can also be greatly effective on decreasing the probability of corona discharge.

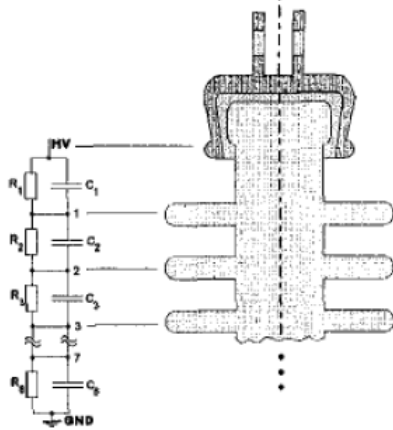


Fig. 13. Equivalent circuit of SGI string.

Voltage distribution of a 7 unit insulator string which has semiconductor glaze with the equivalent circuit of Fig. 13 for different switching impulse stresses is shown in Figures 14 and 15. As it is visible, for frequencies less than 1 kHz, the ohmic component of the voltage is prior but for frequencies higher than 10 kHz, voltage potential is capacitive. And so it is almost equal with voltage distribution in conventional porcelain insulators.

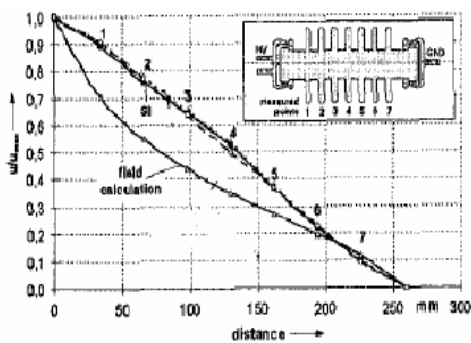


Fig. 14. Measured and calculated potential distribution for different voltage shapes.

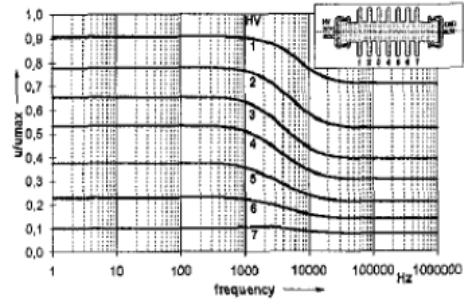


Fig. 15. Value of the potential at the tips of the sheds for different frequency of the driving voltage.

In Fig. 16 voltage distribution on the surface of SGI, effect of lightning voltage wave on insulation string in several frequencies is visible. As you see for low frequencies, in attention to the conductance of insulator semiconductor, voltage distributions show ohmic characteristics. But for high frequencies voltage distributions have capacitance behavior. Also the voltage distributions in 7 units of SGIs for several frequencies of lightning impulse voltage stress are shown in Fig. 17.

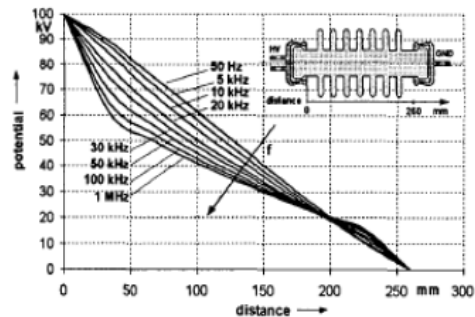


Fig. 16. Potential distribution along a SGI for different frequencies of the driving voltage.

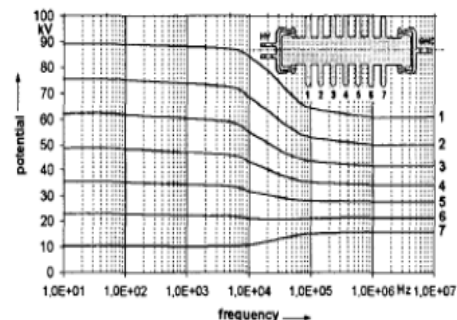


Fig. 17. Frequency response for the tip of each insulator shed for a driving voltage.

In order to make voltage distribution more linear on the insulator string, we can increase conductance of insulator semiconductor glaze 4 to 10 times, which causes an increase in surface leakage current of insulator 4 to 10 times. This increase in leakage current creates thermal instability problems in insulator, but as mentioned before an increase in value of insulator glaze conductance causes voltage distribution more linear in the insulator string and also increase in value of flashover voltage which is visible in Fig. 18.

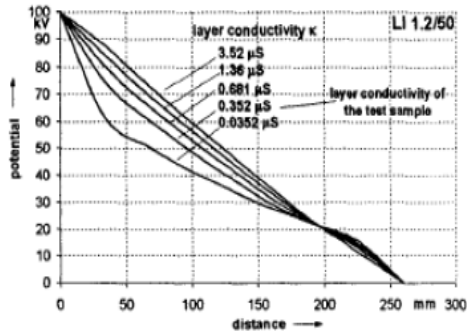


Fig. 18. Potential distribution along a SGI for different layer conductivities.

VII. CONCLUSION

Application of SGIs in highly polluted areas has been increase in the last few years in comparison with ordinary porcelain insulators and their application is highly recommended for the areas with high temperature and humidity. These insulators have higher flashover and withstand voltage at switching and lightning impulses and have a more uniformed voltage distribution along the insulator string in comparison with ordinary porcelain insulators. Better materials also are being studied nowadays for being used in their glaze so that their characteristics are improved at polluted areas.

VIII. REFERENCES

- [1] S. Matsuni, Y. Nakashima, F. Kasaki, O. Fujii, E. Matsuda, "State of the art of semiconducting glazed insulators for transmission lines in heavily contaminated area", *Proc. of 5th IEEE Int. Conf. on Properties and Application of Dielectric Materials*, May 1997, Korea.
- [2] A. Shinoda, H. Okada, M. Nakagami, Y. Suzuki, S. Ito, M. Akizuki, "Development of high resistance semiconducting glazed insulators", *IEEE Power Engineering Society General Meeting*, pp. 556-562, June 2005.
- [3] O. Elsaser, K. Feser, "Flashover behavior of semiconducting glazed insulators under positive switching impulse stress at different climate conditions", *IEEE Int. conf. on Electrical Insulation and Dielectric Phenomena*, pp. 711-714, 1999.
- [4] O. Elsaser, K. Feser, F. Messerer, "Flashover behavior of semiconducting glazed insulators under positive lightning impulse stress at different climate conditions", *IEEE Int. conf. on Electrical Insulation and Dielectric Phenomena*, pp. 203-206, 2000.
- [5] Y. Mizuno, K. Naito, "Voltage and temperature distribution along semiconducting glazed insulators strings", *IEEE Trans. on Dielectrics and Electrical Insulation*, Vol. 6, No. 1, pp. 100-104, February 1999.
- [6] K. Kato, S. Asaoka, T. Ikeda, "Wetting characteristics of various kinds of insulator", *Proc. of 6th IEEE Int. Conf. on Properties and Application of Dielectric Materials*, June 2000, China.