Transient Thermal Conduction Analysis of High Voltage Cap and Pin Type Ceramic Disc Insulator Assembly

R. D. Palhade[1], V. B. Tungikar[2], G. M. Dhole[3] and S. M. Kherde[1]

[1]Department of Mechanical Engineering,
Shri Sant Gajanan Maharaj College of Engineering, Shegaon, Dist-Buldhana,
Pin- 444 203, (MS), India,
[2]Department of Production Engineering,
Shri Guru Govind Singhji Institute of Engineering & Technology, Nanded,
Pin- 431 606, India
[3]Department of Electrical Engineering,
Shri Sant Gajanan Maharaj College of Engineering, Shegaon, Dist-Buldhana,
Pin- 444 203, India
[1]palhaderd@gmail.com

Abstract

Use of high temperature conductors is being considered by more and more electric utilities as a means to increase transmission line capacity. Hence there is a need to investigate temperature rise of transmission line insulators when the current carried by the line conductor is high. This has raised questions regarding the effect of these increased temperatures on the performance of all components attached to the conductor, including the insulators. This paper presents the results of finite element simulation of transient thermal conduction analysis to determine the temperatures reached at various locations on the conductor attachment hardware, end fittings of cap and pin type ceramic disc insulator assembly by using commercially available software Ansys-11. Remarkable temperature rise was not observed at porcelain and cement of insulators in spite of the high conductor temperature, suggesting almost no reduction in electrical and mechanical characteristics of insulators for short period of time but for longer period of time and varying environmental conditions there might be development of high temperature and chances of affects of this high temperatures of conductor on the insulator assembly and end fittings of insulator.

Keywords: *Transient thermal conduction, Finite element analysis, High conductor current, Temperature rise, ceramic insulator assembly*

1. Introduction

The insulator that we talk about here is an electrical insulator because it is used to block or retard electrical current. Obviously insulator means a substance that blocks or retards the flow of electrical or thermal current. Thus outdoor insulator is the insulator for outdoor application. Electric power delivery from the generation site to the consumer uses overhead conductors for long transmission. Conductors are mostly operated at high voltage in order to minimize losses during transmission and distribution, and it also needs support along the way to keep it at a certain height and to keep it isolated from earthed supports. Insulators have a major role to isolate the conductor from the support. They are also used as a support of the conductor itself. Hence, they have to have good insulation properties and also be mechanically strong. The insulator itself is an important role to protect the more expensive apparatus involved in the power system. They act as first protection and have to fail first when over-voltages propagate along the line. They need good electrical and mechanical performance in order to withstand the wide range of conditions that occur. These conditions include environmental, mechanical, thermal and electrical stress on the insulator.

Unfortunately, the combinations of many variable environmental parameters which influence an insulator's behavior over its lifetime are difficult to artificially simulate. To detection and replacement of faulty insulators on power transmission lines is of great importance for the safe operation of the power system. Appropriate shape and dimensioning of insulators in electrical equipment must provide sufficient thermal and electrical strength and the required minimum effect of temperature and insulation resistance during the whole lifetime of insulator. The main concern of the subsequent insulation design is the steady-state voltage strength, flashover, impulse and mechanical tension, temperature developed at pin and conductor interaction *etc*. This requires knowledge of the mechanisms leading to insulation failure and its dependency on material, shape of an insulator, dimension of an insulator, electrode spacing and voltage etc.

Power utility companies are requested to transmit more power to meet the growing demand. However, it is difficult to construct new transmission lines from economical and environmental points of view. Considering such circumstances, upgrading of the capacities of existing lines seems a solution to meet the requirement. Up-grading the line voltage of existing transmission lines results in some technical problems. It is thus very necessary to investigate the possibility of increasing the current carrying capacities of the lines. Stability, voltage and other factors need to be considered in the determination of the current carrying capacity of a conductor. In past study reported, the current carrying capacity of a conductor is principally militated by its thermal limits. Sag, loss in tensile strength of conductor, the degradation at the conductor joints and/or compression clamps, etc. are all thermal limiting factors [1]. Also reported the tolerable sag and loss in tensile strength for the existing aluminum conductor steel reinforced (ACSR) by simulation based on probabilistic approach using actually recorded climatic data when the current capacity of the conductor is increased [2]. It is mentioned in CIGRE technical brochure, the operation of conductors at high temperatures will obviously result in higher operating temperatures for all hardware components connected to the conductors, including the insulators and insulator parts [3].

The results of theoretical and experimental approaches to this subject regarding temperatures of measuring points of an insulator assembly, conductor and conductor clamp at the equilibrium for a conductor current of 2000 A are measured and noted the temperatures of pin, cement, cap and porcelain [4]. In various study, it is mentioned that, insulators are continually subjected to mechanical and electrical stresses which depend on the characteristics of the line. These stresses become critically high under exceptional environmental conditions. The choice of the insulator must be made by considering: The characteristics of the electrical network, the degree of reliability, the accepted limits of inconvenience operation, the environment and the effects of aging on the insulator [5-7].

It is also reported the results of a study of temperature distribution in the body of insulation, based on the ac conductivity of RIP insulation. A method of computing the maximum thermal voltage of this system is also given [8]. Very recently reported the thermal behaviour of the distribution line porcelain insulators when the line's conductor current is high, a laboratory condition in a simulation program (ANSYS) was created considering the structure and geometry of porcelain insulator based on finite element analysis and working out distribution maps of temperature changes. The considerable temperature rise was not observed at insulators in spite of the high conductor temperature [9]. S. W. Han, *et al.*, [10] described some basic performance tests and accelerated ageing test by cool-heat cycling methods and thermal mechanical performance test methods on alumina porcelain insulators (new and aged) used for transmission lines in Korea. There were no failures reported in electrical and mechanical performance tests such as high voltage strength, flashover voltage, impact strength, *etc.*, in any of the samples.

Considerable efforts have been made during past years on computer aided numerical methods like FEM, FDM and BEM. Using these numerical methods, the mechanical and electrical characteristics of ceramic material affected by the force, tension, temperature and electrical load can be easily evaluated [11]. The electrical and thermal performance of a contaminated polymer insulator is performed. The electric field is determined by using the (FEM) technique, while the temperature distribution along the insulator surface is calculated by solving the heat transfer differential equation numerically with the aid of the finite difference method (FDM) [12]. Y.T. Keum, *et al.*, [13] described the finite element simulation of ceramic electric insulators for analyzing the heat and moisture transfer in the drying process and overloading conditions in suspending cable weight. The guideline of precise design of ceramic insulators is proposed regarding the redesign of the insulator geometry. The FE method was used to calculate the complex ac field in polluted insulators. The polluted insulators constitute a very heterogeneous insulating system, including cases in which $\omega\varepsilon >> \sigma$ as well as cases in which $\sigma >> \omega\varepsilon$ [14]. Subba Reddy B, *et al.*, [15] made an attempt to study accurately, the potential and electric field distribution for different types of ceramic disc insulators by using computer simulations carried out by commercially available software package. U. Schümann, *et al.*, [16] have been presented the results of 2D and 3D Finite Element calculations of the electrical field distribution along a 420 kV suspension insulator set arrangement. This study used different design parameters of the composite insulator and of field control devices (corona rings) were varied. The maximum values of the electrical field stress in the area of the live line end of the set were evaluated in detail. Recently the research work were carried out to analyze the effect of structural, thermal & the electrical charge distribution load individually applied over the insulator assembly by using computer simulation. The effects of these loads on the disc type line, tension insulator assembly by modeling of 2D axi-symmetric Finite Element analysis model in software Ansys-09 presented & compared to the possible experiments [17]. In the recent paper, describe the electric field surrounded the ceramic insulator; also the leakage currents of insulator are measured by using the finite element analysis (FEA) program Quick field [18].

In most of published literature, has been reported operation of conductors at high temperatures will obviously result in higher operating temperatures for all hardware components connected to the conductors, including the insulators and insulator fittings. However it is necessary to find out the effects of this high temperature on the insulator assembly and its components over the period of time. In this paper, presented the findings of computer simulation of transient thermal conduction finite element analysis on the cap and pin type high voltage ceramic disc insulator assembly by using commercially available software Ansys-11. The primary objective of present work is to validate experimentally measured temperatures in above sited literature at the insulator end fitting/rod interface by computer simulation technique using finite element method. Then to determined if these temperatures result in any concerns about the long term mechanical and electrical performance of the insulators. It should be noted that this paper could also be informative for the maintenance work of power utility companies facing unexpected high current in case of fault, *etc*.

2. Analytical Treatment

The idea of simple heat transfer processes affecting the temperature of a line insulator is shown in Figure 1. The mathematical expressions are given by

$$C\frac{dT}{dt} = P_{in} + P_s - P_{out} - P_c - P_r$$

$$P_c = D_c\left(T - T_0\right)$$

$$P_r = D_r\left(T^4 - T_0^{\,4}\right)$$

Where C is the heat capacity of an insulator, T is the temperature of an insulator, T_0 is the ambient temperature, t is time, D_c is the coefficient of dissipation by convection, and D_r is the coefficient of dissipation by radiation. P_{in} is the heat conducted to an insulator from clamp, P_s is the heat conducted to the insulator by solar radiation, P_{out} is the heat conducted to the next insulator from the insulator of interest, and P_c and P_r are heat dissipated from the conductor by convection and radiation, respectively. Temperature of the insulator can be obtained by solving the equation numerically, for example, by finite element method. The above speculation will be informative to see the qualitative tendency of the phenomenon, [4].

3. Experiment Setup

As per the Osamu Fujii, *et al.*, [4] a few experimental results of temperature measurement of insulators have been reported, where conductor was heated by passing hot oil in a pipe with simulated size of a line conductor (Verbal Presentation by a French Delegate at a CIGRE-2000, [19]) or by using high direct current(CIGRE-2001), [20]. Comparing with these two approaches, an experiment using alternating current of power frequency is considered more favorable because the condition seems close to the actual service condition. In this case, actual standard conductor can be used and effect of eddy current loss in the ferrous clamp and bolts can be automatically included. The details of experimental set up used by Osamu Fujii, *et al.*, [4], is given partly in Figure 2, having the following elements.

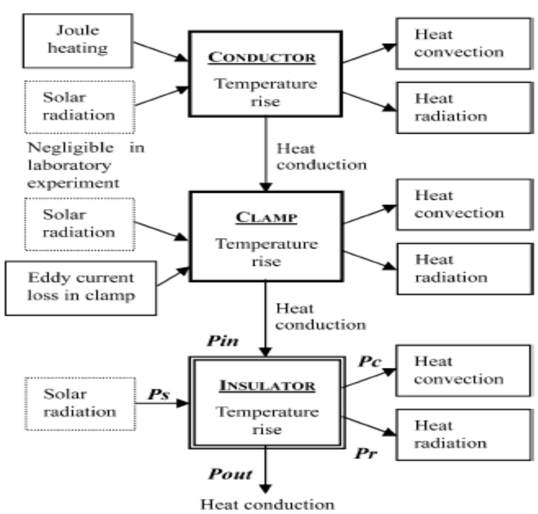


Figure 1. Block Diagram of Heat Transfer

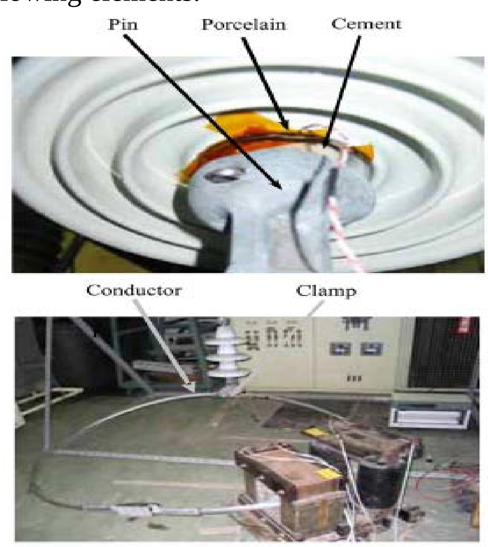


Figure 2. Location of Thermocouples

Five thermocouples were used to monitor surface temperature at: 1) conductor 10 cm apart from the clamp; 2) the clamp; 3) the pin of the insulator closest to the conductor; 4) cement between the pin and porcelain of the insulator; and 5) porcelain 10 cm apart from the pin. The ambient temperature was also measured with another thermocouple. Constant alternating current of 50 Hz up to 2000 A was supplied to the conductor by using two current transformers and time variations of the temperature at the five points described above were monitored continuously with a hybrid recorder. The experiments were carried out indoors and the effects by wind and solar radiation seemed negligible. The temperature recorded by this experimental set up at the pin were given as an input to the finite element transient thermal conduction simulation model and the temperature distribution, thus obtained at other points (locations) in the insulator assembly from computer simulation were found to be closely matching the experimental results.

4. Insulator Assembly Model Adopted for Investigation

In this present study, the single ceramic disc cap and pin type ceramic/porcelain insulator is chosen. A schematic of the ceramic insulator disc assembly and actual photograph is shown in Figure 3 and Figure 4 respectively. The design of cap and pin type Ceramic insulator, essentially consists of a malleable/ductile iron cap, malleable/forged iron pin and a ceramic/porcelain shell. The cap and pin of the insulator is fixed to the ceramic shell with the help of Portland cement. A bituminous coating is applied to the pin to prevent corrosion. Figure 1 shows the geometrical characteristics of the pin-and-cap ceramic disc insulator assembly such as its diameter (d), height (h) and creepage distance (cd). The diameter and height are 320mm and 170 mm respectively. The creepage distance, which is the shortest path between two conductive parts (or between a conductive part and the bounding surface of the equipment) measured along the surface of the insulation, is 540 mm.

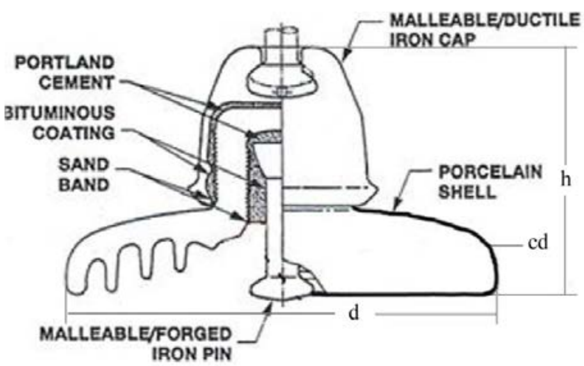


Figure 3. Schematic of the Insulator Assembly Model Adopted for the Study

Figure 4. Photograph of Cap-Pin Type Disc Insulator Assembly

4.1. Insulator Assembly Model Adopted for the Transient Thermal Conduction Simulation

The symmetry of the insulator assembly was exploited when creating the finite element model, resulting in axi-symmetric two dimensional problems and alleviating the need for computationally expensive three dimensional modeling. The model is generated with the help of key points later joined by straight lines and then forming 2-D area model, as shown in Figure 5.

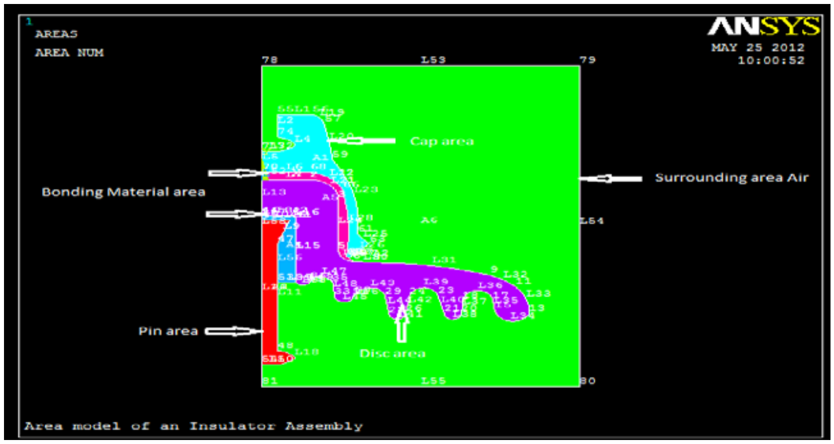


Figure 5. 2-D Axis-Symmetric Area Model of Pin-and-Cap insulator Assembly

In this paper commercially available FE software ANSYS 11 is used for the 2D axis-symmetric calculations. The insulator assembly is meshed using the thermal solid, Quad 8 node 77 planes, which is the element that has one degree of freedom, temperature, at each node. The 8-node elements have compatible temperature shapes and are well suited to model curved boundaries. The applied model consists of 2636 nodes and 863 elements as shown in Figure 6.

Figure 6. Meshed Model of Pin-and-Cap Insulator Assembly

The element input data includes eight nodes and thermal material properties as given in Table 1. Transient thermal conduction finite element analyses are performed. The modeled insulator assembly consists of cap (malleable/ductile iron), pin (malleable/forged iron), disc (ceramic/porcelain), bonding material (cement) and surrounding air. The supporting structures, conductors and other accessories are not modeled in the present work.

Table 1. Thermal Properties of each Component of Cup-and-Pin Insulator Assembly

Sr. No.	Assembly Component Name	Material	(K) W/m^{0}K	(Cp) J/Kg^{0}K	(ρ), kg/mm^3 (10^{-9})
1	cap	Malleable cast iron	45	460	7300
2	Bonding material	Portland cement	0.29	1070	2320
3	disc	Ceramic/porcelain	2.5	710	3800
4	Pin	Forged steel	54	490	7860
5	Surrounding	Air	0.023	1012	1.0

(K-Thermal conductivity, Cp-Specific heat, ρ-Density)

4.2. Loading and Boundary Conditions

A thermal load of temperature 73.6^{0}C is applied on the all nodes of pin, whereas 30^{0}C is applied on line (boundary) nodes of cap, partly cement and disc and the initial temperature over all nodes is considered 27^{0}C [4] as shown in Figure 7. The load step time is considered as 300 seconds and other conditions as number of sub steps, maximum and minimum number of step were specified as per experimental conditions. Then transient thermal conduction analysis was performed and the results for nodal temperature, nodal gradient vector, nodal flux vector, temperature vs time and temperature vs distance are plotted and analyzed.

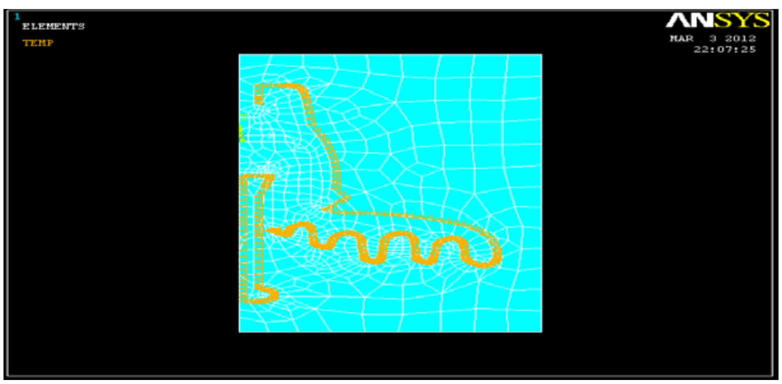


Figure 7. Shows the Loading and Boundary Conditions Applied over the Model

5. Results and Discussions

Finite element transient thermal analysis determines temperatures and other thermal quantities that vary over time. Engineers commonly use temperatures that a transient thermal analysis calculates as input to structural analyses for thermal stress evaluations. A transient thermal analysis follows basically the same procedures as a steady-state thermal analysis. The main difference is that most applied loads in a transient analysis are functions of time. To specify time-dependent loads, we can either use the function tool to define an equation or function describing the curve or then apply the function as a boundary condition, or we can divide the load-versus-time curve into load steps.

In order to investigate temperature rise of transmission line insulator when the current carried by the line conductor is high. It is essential to know the temperature distribution over the insulator assembly & its effects over various parts of insulator assembly. Excess heating of insulator is anticipated due to higher conductor current which may reduce electrical & mechanical characteristic of the insulator. Figure 8 and Figure 9 show the nodal temperature distribution at each position of thermal equilibrium (temp 73.6^{0}C, initial temperature 30^{0}C). and distribution of thermal gradient over the insulator assembly.

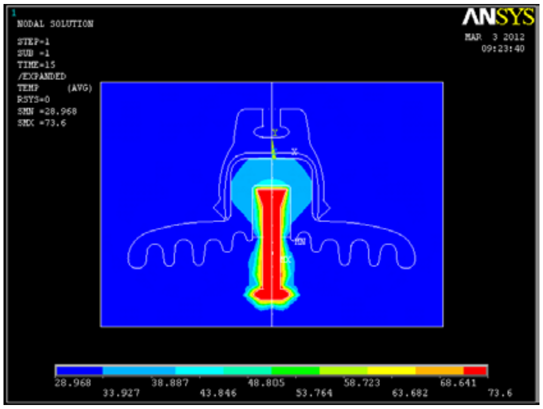


Figure 8. Nodal Temperature Distribution in Insulator Assembly

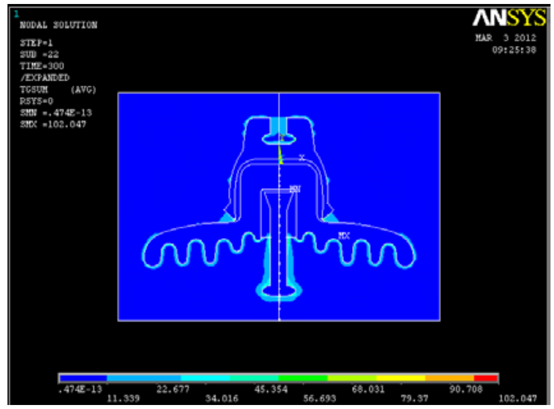


Figure 9. Thermal Gradient over the Insulator Assembly

In the design of cap and pin type ceramic disc insulator, Portland cement is used in order to fill the space between porcelain & metal hardware, where the cement acts as a compression-resistant agent. Thus the compression strength of cement at an elevated temperature is of interest in the present study. The most important environmental factor providing cement expansion was a temperature. Because the components of insulator had a different thermal expansion coefficients, when the temperature difference happened in each parts of porcelain insulator, the moistures in air penetrated into interface between porcelain and cement. As a result its react with cement chemical compounds as illustrated in above, then cement was expanded. Generally cement was contracted after curing due to a water contact, so cement was hardened. But during ageing moistures in air penetrate into cement and react with cement chemical contents, and then cement is expanded again.

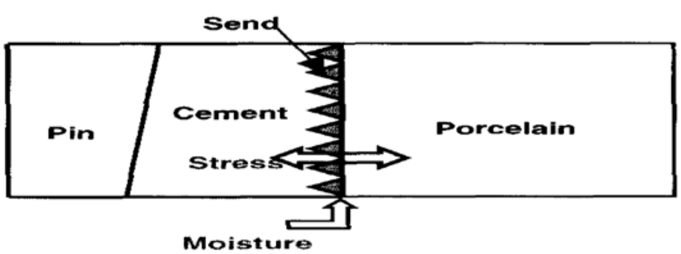


Figure 10. The Process of Contraction and Expansion of Cement with Ageing Time

Figure 10 showed the typical process of contraction and expansion of cement with ageing time. It was known that the displacement from cement contraction or expansion gives serious mechanical stress to cement and porcelain body [21].

Figure 11 showed the simulation result regarding the cement displacement with temperatures. In normal porcelain insulators were applied in environment temperature of below 100°C. But in order to assure the deterioration quality of cement, the expansion property should be tested in the autoclave with 216°C in the case of the standard such as ASTMC 151. According to Figure 11 it could be seen that the cement displacement changes with linear according to temperature, then the cement displacement was about 0.05% at room temperature, but when increasing to 400°C, it was over 0.10%. These result had an analytic meaning comparing to other researches in which given cement expansion artificially in the aspect of approaching methods [10].

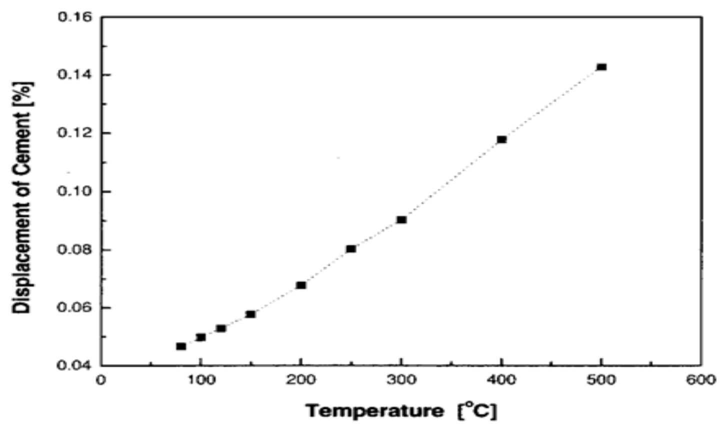


Figure 11. The Cement Displacement with Temperatures

In the present analysis, the transient thermal conduction finite element analysis is done by taking the input temperature 73.6^{0}C. By considering temperature change by solar radiation & wind negligible. A past study indicates that the highest temperature of an insulator is about 50^0 C in most cases when being directly exposed to the sun [12]. The maximum temperature is shown at the pin area and space between the porcelain and pin area i.e. in cement area. Temperature shown over the other part of the insulator assembly gradually decreases as shown in Figure 8. The same was reflected in the graph plotted between the temperature verses distance of an insulator assembly as shown in Figure 12.

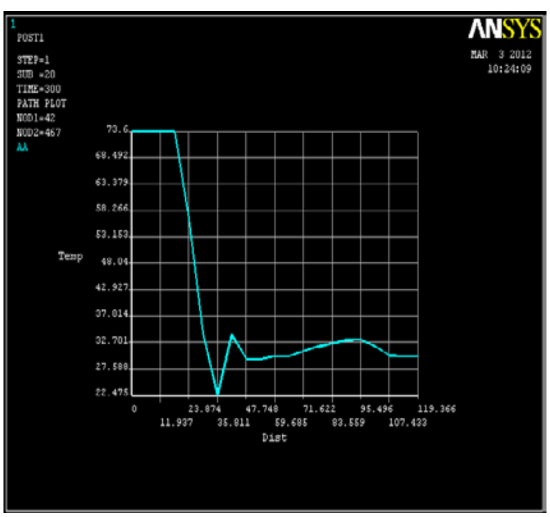


Figure 12. Temperature Variation of Distance over an Insulator Assembly

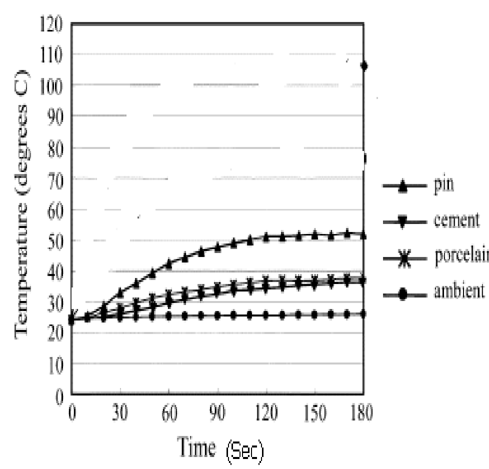


Figure 13. Temperature Variation of Time over an Insulator Assembly

Figure 13 shows time variations of temperatures at measuring points in terms of nodes, which were obtained for present transient thermal conduction analysis, without considering the thermal equilibrium state for the time period of 300 second. Temperatures of pin, cement, and porcelain are much lower compared with that of the conductor, indicating that most of the heat generated at the conductor is dissipated by convection and radiation. These result of the transient thermal finite element analysis through computer simulation, in this paper matches between 92 to 95 % with the experimental results obtained by [7]. It is observed in Figure 14; the thermal flux produced for the given temperature is shown mainly over the cement area, although temperature variation over given time in cement area is very small, it can be seen from Figure 15. But for safer working of an insulator assembly it is required to consider the mechanical and electrical strength of insulators at elevated temperatures. It has also to be considered as the insulator operated for varying mechanical loads of (45, 65kN) and electrical loads of (1000, 1500 2000 Amps.) *etc*.

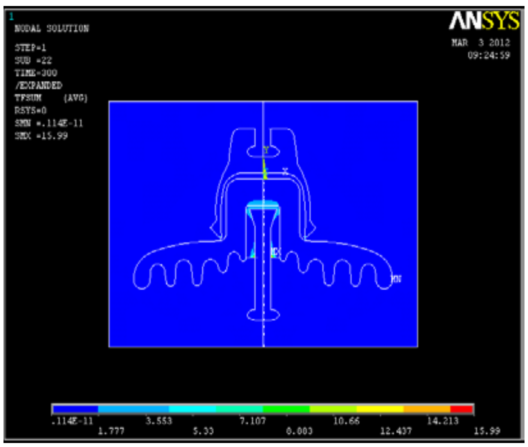


Figure 14. Variation of Nodal Flux Vector over Insulator Assembly

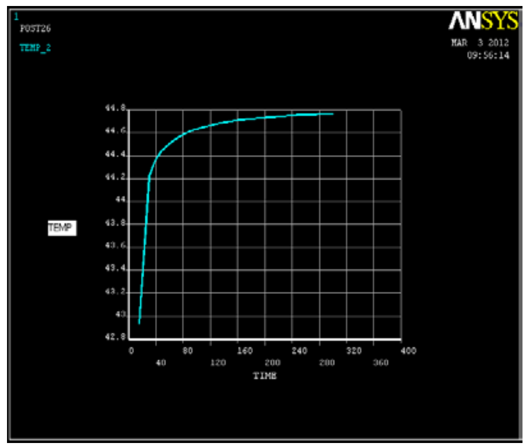


Figure 15. Temperature Variation of Time in Cement Area

It could be safely said that the temperature is not high enough to significantly affect the performance of insulator assembly for short duration. However over prolong period (continuous) loading and due to variable atmospheric and pollution condition, this may degrade the bonding characteristics of cement, leading to failure of insulator assembly.

6. Conclusion

In this paper a comprehensive transient thermal conduction finite element analysis of 11kV single pin and cap type ceramic disc insulator assembly has been presented. The high temperature produced in current carrying conductor is not enough to transfer over an insulator assembly component during a short period of time. So it could be safely said that the temperature is not high enough to significantly affect the performance in terms of mechanical and thermal characteristics of an insulator assembly for short duration. However over prolonged period (continuous) and electrical, mechanical loading, further due to variable atmospheric condition and environmental pollution, this may degrade the bonding characteristics of cement, even disc material which is basically brittle in nature leading to failure of insulator assembly. This study may lead to an optimized design, development and performance of cap-pin type disc porcelain insulator and assembly components. The feasibility of simulation results obtained is already validated experimentally in mentioned references. The computer simulation results obtained using finite element method software, thus can avoid costly and time consuming experimental setups.

Acknowledgements

The authors wish to acknowledge the help and guidance received from Dr. M.A. Beg, Professor, Prof. S. R. Paraskar, Associate Professor, Department of Electrical Engineering, Shri Sant Gajanan Maharaj College of Engineering, Shegaon-444203, India and Prof. P. M. Ardhapurkar, PhD scholar, IIT, Bombay and Head, Department of Mechanical Engineering, SSGMCE, Shegaon, India. Also the kind support received from Mrs. Harsha S. Patil, Assistant Professor, Department of Applied Sciences and Humanities, SSGMCE, Shegaon in preparing the manuscript of the paper.

References

[1] Y. Mizuno, H. Nakamura, K. Adomah and K. Naito, "Assessment of thermal deterioration of transmission line conductor by probabilistic method", IEEE Trans. Power Del., vol. 13, no. 1, **(1998)**, pp. 266-271.

[2] K. Adomah, Y. Mizuno and K. Naito, "Probabilistic assessment of the sag in an overhead transmission line", Trans. Inst. Elect. Eng. Jpn., vol. 120-B, no. 10, **(2000)**, pp. 1298-1303.

[3] "Considerations relating to the use of high temperature conductors", CIGRE Technical Brochure, vol. 331, **(2007)**.

[4] O. Fujii, Y. Mizuno and K. Naito, "Temperature of Insulator as Heated by Conductor", IEEE transactions on power delivery, vol. 22, no. 1, **(2007)**, pp. 523-526.

[5] J. J. Taylor and A. D. Lantz, "Insulator design and application as influenced by different service environments", CIGRE, no. 211, **(1960)**.

[6] P. J. Lambeth, J. S. T. Looms, M. Sforzini, C. Malaguti. Y. Porcheren and P. Calaverie, "International research on polluted insulators", CICRE, no. 33.02, **(1970)**.

[7] R. Cortina and J. P. Rynders, "The performance of insulators subjected to direct voltage in polluted conditions-service experience", CIGRE Study Committee Collosium, Brazil, Section V, **(1981)**.

[8] N. S. Jyothi, T. S. Ramu and Manoj Mandlik, "Temperature Distribution in Resin Impregnated Paper Insulation for Transformer Bushings", IEEE Transactions on Dielectrics and Electrical Insulation, vol. 17, no. 3, **(2010)**, pp. 931-938.

[9] P. I. Lerantzis, P. T. Tsarabaris and N. J. Theodorou, "Study of Thermal Behaviour of Porcelain Insulators with the Finite Element Method", Materials and Applications for Sensors and Transducers, **(2011)**, pp. 245-248.

[10] S. W. Han, H. G. Cho and G. H. Park, "Stress Simulation on Suspended Porcelain Insulators with Cement Displacement", Transactions on Electrical and Electronic Material,vo1. 4, no. 3, **(2003)**, pp. 19-24.

[11] V. T. Kontargyri, I. F. Gonos, I. A. Stathopulos and A. M. Michaelides, "Simulation of the Electric Field on High Voltage Insulators using the Finite Element Method", Electromagnetic Field Computation, 12th Biennial IEEE Conference, **(2006)**.

[12] G. Xu and P. B. McGndh, "Electrical and Thermal Analysis of Polymer Insulator under Contaminated Surface Conditions", IEEE Transactions on Dielectrics and Electrical Insulation, vol. 3, no. 2, **(1996)**, pp. 289-298.

[13] Y. T. Keum, J. H. Kim and B. Y. Ghoo, "Computer aided design of electric insulator", Journal of Ceramic Processing Research, vol. 1, no. 1, **(2000)**, pp. 74-79.

[14] E. Asenjo S., N. Morales O. and A. Valdenegro E, "Solution of Low Frequency Complex Fields in Polluted Insulators by Means of the Finite Element Method", IEEE Transactions on Dielectrics and Electrical Insulation, vol. 4, no. 1, **(1997)**, pp. 10-26.

[15] B. Subba Reddy, N. A. Sultan, P. M. Monika, B. Pooja, O Salma and K. V. Ravishankar, "Simulation of Potential and Electric Field for High Voltage Ceramic Disc Insulators", 5th International Conference on Industrial and Information Systems, ICIIS-2010, India, **(2010)** July 29-August 01, pp. 526-531.

[16] U. Schümann, F. Barcikowski, M. Schreiber, H. C. Kärner and J. M. Seifert, "FEM Calculation and Measurement of the Electrical Field Distribution of HV Composite Insulator Arrangements", 39th CIGRE session, Paris, France, **(2002)**, pp. 25-30.

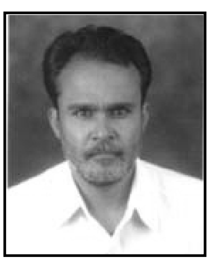
[17] R. D. Palhade, V. B. Tungikar and G. M. Dhole, "Finite element analysis of disc type line tension insulator assembly in terms of structural, thermal and electrical load distribution", International Conference on Frontiers in Mechanical Engineering, FIME-2010, NIT Surathkal, India, **(2010)** May 20-22.
[18] S. Mahmood Faisal, "Simulation of Electric Field Distribution on Ceramic Insulator Using Finite Element Method", European Journal of Scientific Research ISSN 1450-216X, vol. 52, no. 1, **(2011)**, pp. 52-60.
[19] "Verbal Presentation by a French Delegate at a CIGRE WG22.03 Meeting", Vichy, France, **(2000)** August 25-26.
[20] "High temperature conductors and their effect on composite insulator mechanical performance", CIGRE, no. 67.01, **(2001)**.
[21] J. S. T. Looms, "Insulators for high voltages", IEE power engineering series; London: Peter Peregrinus, no. 7, **(1988)**, pp. 276.
[22] ANSYS® software Release-11 (2011), Ansys SAS IP, Inc.

Authors

R. D. Palhade is an Associate Professor in Mechanical Engineering Department at Shri Sant Gajanan Maharaj College of Engineering, Shegaon, India. He received his B. E. (Production Engineering), DBM and PG-DMM from Sant Gadge Baba Amravati University, Amravati, India, and M. Tech in Mechanical Engineering of specialization Manufacturing Processes Engineering, from Indian Institute of Technology, (IIT) Kharagpur, India. He has presented more than 15 papers in International/National Journal, an international conference & national conference. He is member of Institute of Engineers (India), (IE), Kolkata and Indian Society of Technical Education, New Delhi (ISTE).

Dr. V. B. Tungikar received M. Tech in Mechanical Engineering of specialization (Machine Design) from Indian Institute of Technology, (IIT) Kharagpur in 1992 and Ph. D from SRTMU, Nanded in 2003. Currently he is working as a Professor and Head (Workshop), Department of Production Engineering, SGGS Institute of Engineering & Technology, Vishnupuri, Nanded, India. He has published more than 20 papers in international refereed journals, International conferences, national journals and national conferences. He reviewed a book on Machine Design,

Published by Pearson education, India in 2007.



Dr. G. M. Dhole received M. Tech. (I.P.S) from Visvesvaraya National Institute of Technology, Nagpur, India, and Ph.D. degree in Electrical Engineering from S.G.B. Amravati University, Amravati, India. He has published more than 50 research papers in different International and National Journals and Conference Proceedings. His main research interest includes power system planning, operation and control, intelligent methods, and its applications in power system, VLSI and Embedded design. He is IEEE, IACSIT, IE and ISTE member. He is presently working as a professor in Electrical Engineering Department, at Shri Sant

Gajanan Maharaj College of Engineering, Shegaon, (India).

Dr. Sanjay M. Kherde is Professor in Mechanical Engineering at the SSGM College of Engineering, Shegaon, India. He holds BE and MIRPM degrees from Amravati University and Post graduation from NITIE, Mumbai and Ph.D. from SGB Amravati University, Amravati, India. His current research interests include optimization, scheduling, public transportation and IT application in regional and local models of health care delivery and technology assessment. He has published more than 24 research papers in different International and National Journals and Conference Proceedings.