Electric Field and Potential Distribution of Porcelain Insulator using FEM Method

B Mallikarjuna, K N Ravi, V Muralidhara, N Vasudev

Abstract: ***The porcelain insulators are investigated with the high voltage transmission line in outdoor condition. The MATLAB finite element simulation are used here to test the performance of the porcelain. The PDE software is helpful in modelling the porcelain insulator in two dimensional. The pollution layer in the porcelain assumed to be uniform. The simulation demonstrates the electric field and potential distribution in the porcelain insulator. The porcelain insulators have higher field distribution near to the high voltage line. The results are represented as graphs. The MATLAB 2017b comes with preinstalled PDE tool. In this paper the PDE tool is used for the results and analysis.***

Keywords **:** ***Porcelain, Insulators, MATLAB PDE tool, Finite element method***

I. INTRODUCTION

The power system reliability is one of the important security criteria to operate the power system reliable [1,3]. Generally ceramic insulators are used in power transmission lines for the insulation purpose. The insulators are facing problem as it is installed in the outdoors. The pollution is one of the major problems while installing the insulators [2,5]. In industrial and dustier or polluted area there is a commonly one layer is available on the insulator. The dry insulator usually remains unchanged. Due to rain another layer is formed with dust and this makes some leakage current [4]. This leakage current is responsible for the arcing and creates a flashover of the insulator [7]. So, determining the electric field around the surface is very important. This can help in the detection of faulty insulators [6]. Many other insulator related literatures [8-26] are helpful to make the model. This paper deals with the porcelain insulator electric field and potential field is analyzed with the high voltage and added pollution layer simulated in PDE software of MATLAB. The results are described in the upcoming sections.

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II. STATEMENT OF PROBLEM

The power system requires a detailed simulation study before it is implemented. There are many simulation studies available to design the power system parameters like electrical quantities such as Voltage rating, current rating, power rating of the varies devices. And also studying the impact of fault like security studies. But any of these described studies not including the physical parameters and environmental parameters. So, there is a problem in power system reliability when the transmission system insulators are placed in the out space. It has many impacts like due to rain, dust and temperature effects. To analyse these effects we go for Partial Differential Equation modelling of the devices which can analyse the electromagnetic effects with temperature change.

III. PROPERTIES OF THE MATERIALS

The insulators are usually manufactured with two components. The porcelain and glass which are dielectric components and used at the caps and pins. The housing of the insulators is built with the glass and porcelain and it has the better elative permittivity. To support the mechanical strength of the insulator her it requires the crimped fitting of dielectric material. The porcelain material and glass are the perfect insulator which has the les conductivity. The thickness of the pollution layer also added in the simulation and which is added to the conductivity of the material. It is assumed that it is spread over uniform on the insulator. The pollution layer conductivity of the pollution layer is taken from [9] which is a practical laboratory value. The parameters used in the insulator is depicted in Table I.

Table I: Porcelain and Glass insulator Dimensions

Material	Relative permittivity, ε_r	Conductivity, σ(S/m)
Air	1.0	$1*10^{-15}$
Porcelain	4.2	$1*10^{-14}$
Glass	4.2	$1*10^{-14}$
Steel	1.0	$1.45*10^{6}$
Cement	2.09	$1*10^{-14}$
Pollution layer	81	$600*10^{-6}$

The 50Hz and 11 kV system is used as the energized at the cap point of the insulator which is a high voltage level. The IEC 60507 standard says that the insulator in dry and wet condition the rms value is same. The 0V or ground is at the lower pin point. the air region is also considered larger and it also influences the insulator profile.

IV. RESULTS AND DISCUSSION

The finite element analysis is the predictive computer analysis for structures applied with vibrations, loads, heat and any other physical effects. This method makes the solutions to the boundary value problems with physics of PDE. It makes the geometries into computer grid or meshes or fill it will small triangles.
Then the models are converted into PDE equation.
Then solves for the required physical structural analysis. The formula given below is the structural equation of the porcelain insulator structure. The formula is set as give below to implement the side view of the insulator.

$$set\ formula = R1 + P1 + R2 + E1 + R3 + E2 + P2 \quad (1)$$

After doing the analysis the PDE equation used shown below,

-div(epsilon*grad(V))=rho, E=-grad(V), V=electric potential **(2)**

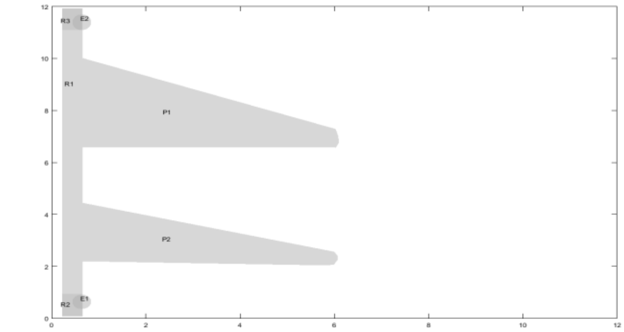

Fig .1 Modelling of porcelain insulator in PDE tool

Figure 1 shows the Modelling of porcelain insulator in PDE tool. The Figure 2 shows Discretization of PDE tool using MATLAB. Figure 3 shows the Intense Discretization of PDE tool using MATLAB. Here P1 and P2 are the shapes represented in the diagram. E1 and E2 are the circles. R1, R2 and R3 are the rectangles. The equation (1) shows the combination of the shapes create the porcelain insulator. The figure 2 shows the triangle shape fill in the diagram of the insulator. The more connected area is the point of strong porcelain and lightly connected area is of less density. The figure 3 shows more intense discretization of the PDE analysis. This result analyses the electric field of the insulator, potential field of the insulator and potential vector field. The electric field shows the high dense color as the more density in the electric field. Light color shows the less density of the electric field. The potential field shows the magnetic flux circles of the diagram. Here also dense color shows the high-density magnetic field. And vector field shows the director of the electric field. And 3D diagram shows the height of the vector field.

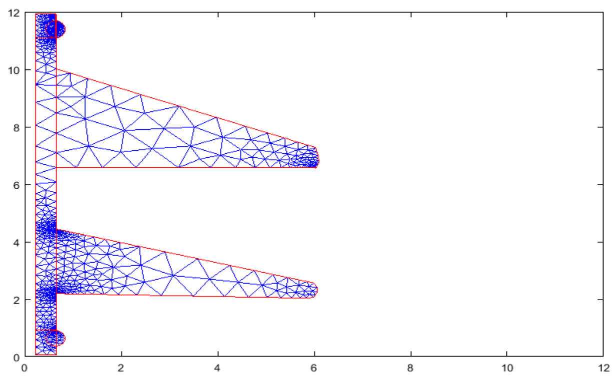

Fig. 2 Discretization of PDE tool using MATLAB

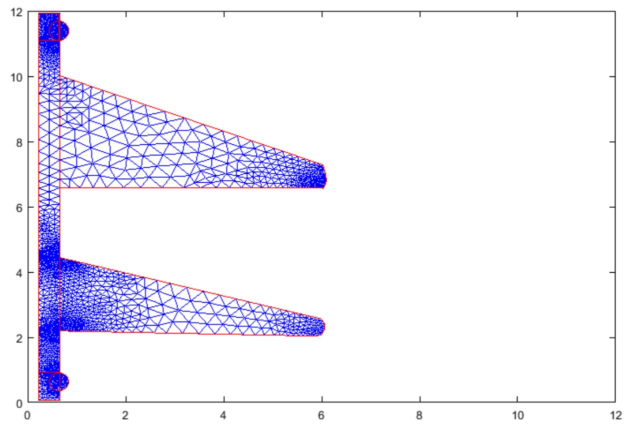

Fig. 3 Intense Discretization of PDE tool using MATLAB

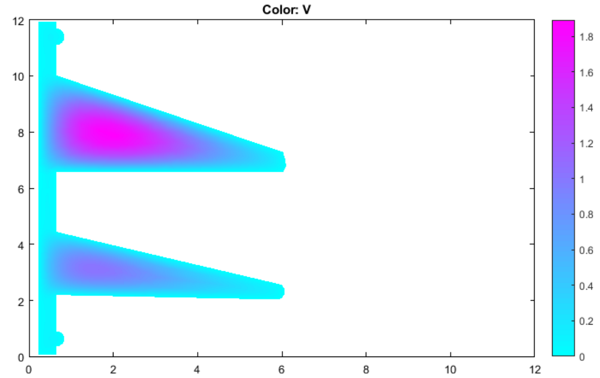

Fig 4 Electric Field of the insulator in PDE

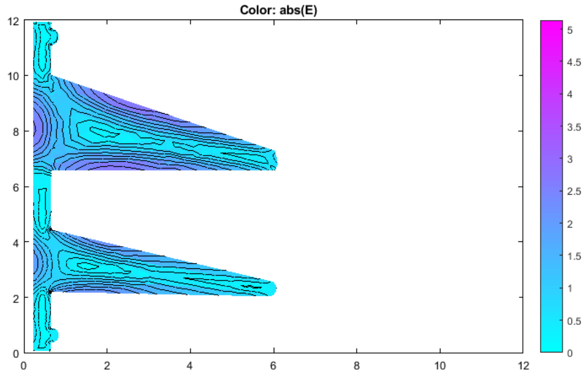

Fig 5 potential field in PDE

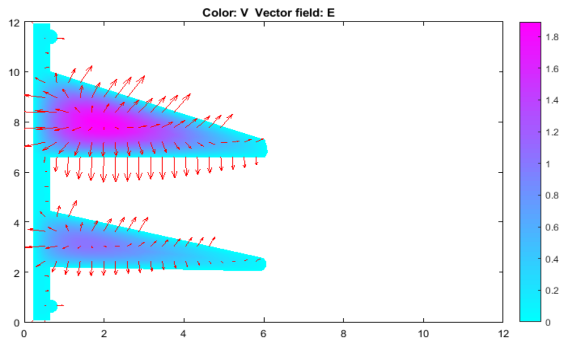

Fig 6 Electric Vector Field in V

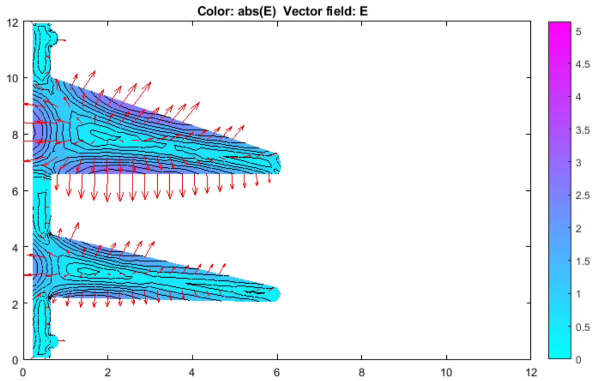

Fig 7 potential of electric field and vector field

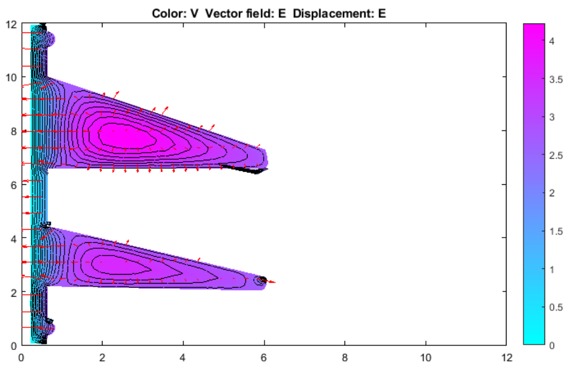

Fig 8 Displacement of field

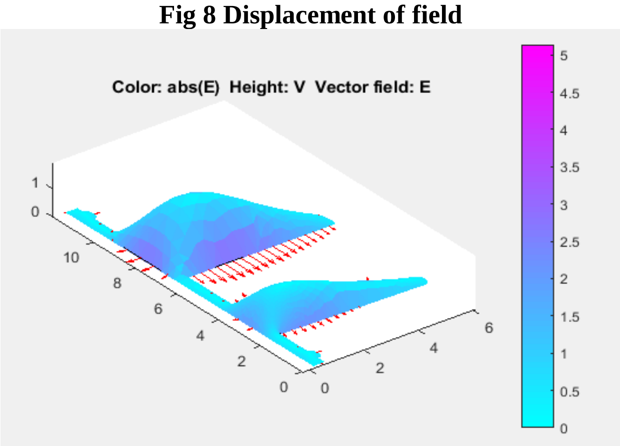

Fig 9 3D view of the insulator with VECTOR field

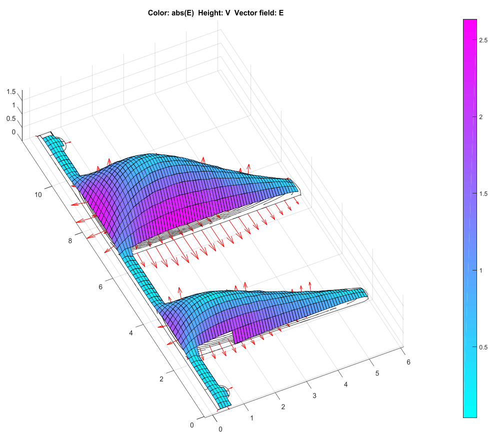

Fig 10 3D view of the insulator with potential field and vector field

Figure 4 implements the Electric Field of the insulator in PDE. From the figure more density of electric field is available at the area P1. Figure 5 shows the potential field in PDE.it shows that the center point of the P1 and P2 is more in magnetic field. Then the Figure 6 shows the Electric Vector Field in V. it shows the vector field of electric field is perpendicular to the P1 and P2 shapes and it penetrated towards the rectangle R1, R2 and R3. The Figure 7 shows the potential of electric field and vector field as single figure. Figure 8 implements the Displacement and electric field. Figure 9 3D view of the insulator with potential field. Figure 10 shows the 3D view of the insulator with potential field and vector field. These 3D shapes shows the complete awareness about the shapes considered as insulator. And it can be seen that red color is not shown in the electric and potential fields. This shows that the porcelain material is good at the insulation of the Electric transmission system.

V. CONCLUSION

For the testing the laboratory conditions are added in the simulation with an ideal model. For the polluted, wet and dry conditions the insulator surface is considered as tangential. The denser colored area is identified as the polluted region of the insulator. From the graphs the property of the insulator can be identified before the practical implementation.

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