NUMERICAL SIMULATIONS OF A NEW DESING OF PIN INSULATORS

Alessandro DADAM
Celesc Distribuição S.A. – Brazil
alessandropd@celesc.com.br

Aline SALUM
Lactec – Brazil
aline.salum@lactec.org.br

Edemir KOWALSKI
Lactec – Brazil
edemir@lactec.org.br

Fábio RICHART
Lactec – Brazil
fabio.richart@lactec.org.br

Guilherme SILVA
Lactec – Brazil
cunha@lactec.org.br

Rodrigo QUADROS
Lactec – Brazil
rodrigo.quadros@lactec.org.br

Signie SANTOS
Lactec – Brazil
signie@lactec.org.br

Vitoldo SWINKA
Lactec – Brazil
vitoldo@lactec.org.br

ABSTRACT

Although pin insulators are designed to have a long operating life, many factors can reduce their life and consequently the quality of power supply, reliability and availability. Among the main factors, one of that causes the most failures in distribution lines is the accumulation of pollutants that lead to the phenomenon of superficial electrical tracking. In order to study the pollution accumulation, simulations were carried out on the air flow around the pin insulator of distribution lines, in order to verify, from the point of view of the characteristics of the flow, which model presents, comparatively, a better performance. The numerical simulations were made in ANSYS® FLUENT® 18.1 software, by finite-volume method and k-omega turbulence model SST (shear stress transport). Among the methodologies of analysis: streamlines, pressure field and velocity field; the pin insulator model, which in all methods showed superior performance, was the pin insulator of 4 ribs, comparatively with the conventional model and the one with 3 ribs.

INTRODUCTION

Pin insulators of distribution lines, as well as those of transmission lines, are designed to have reliability over long periods of operation. However, although mechanically and electrically this is true for the insulation component material, pollution in many environments can cause accidents. This is because pollution, both in terms of dust, salinity and humidity can cause the superficial electronic tracking, reducing the expected insulation effect for an insulator, which may cause a short circuit, among other problems. In transmission lines, pollution is the second cause of electrical problems in transmission lines, behind only lightning. However, the damage caused by pollution is about an order of magnitude higher than natural accidents. In this way, the purpose of the numerical study performed in this paper is to verify if the proposed insulator models, in relation to the commonly used models, have a better performance to avoid superficial tracking, increasing the reliability of the electrical distribution network assets. The numerical simulations were carried out based on three-dimensional models of the insulators. Three types of insulators were selected for the numerical simulations to represent the currently used model in comparison to two other models designed to reduce the possibility of superficial electrical tracking, being the insulator model of 3 and 4 ribs.

Pollution accumulation onto a solid surface

In [1] the theoretical analysis of deposition of colloidal particulates occurs mainly in regions of stagnation point flow, that is, places where they present zero velocity in any direction. We also analyzed the effects of mass transfer by convection and the electromagnetic attraction forces, given by DL (double layer) or double electric or diffuse layers. In this study, the authors correlate the deposition of colloidal particulates as a function of convection and double layer at points of stagnation of the flow within the viscous boundary layer, demonstrating a significant increase in the deposition of particulates at these points.
Similar to [1], [2] performed studies of pollutant deposition and the dynamic of small spherical particles as bubbles, droplets, etc. In [2], the analysis of deposition of pollutants were developed to vertical flows and stagnation point flow. The analysis was performed for small particles, both for the smaller and higher density, demonstrating the different behaviors due to the weight of the particle. Thereby demonstrating the character of particle accumulation occurs mainly in the regions of stagnation point flow, as well as in the center and periphery of the vortices.
In addition to the theoretical studies for the deposition of particulates, experiments were carried out on the accumulation of pollutants in an urban environment in Australia and concluded that the accumulation occurs intensely shortly after a period of rainfall and during the dry weather has its rate of deposition decreased, due to the humidity and surface electric charge and size of the particles [3]. Depending on the size of the particles, the trend is for a reduction in particulate size in an urban environment during a dry season, changing the dynamics pollution deposition.

Recently, several studies have been carried out in an effort to gain a better understanding of how pollutants disperse and accumulate on solid surfaces. Among these studies, numerical studies, respectively, using turbulence models as k-omega SST and LES (Large Eddy Simulation) are presented in [4] and [5]. In both studies, modified turbulence models were used to simulate the dispersion of pollutants in the microscale in an urban environment.

METHODOLOGY

In order to verify the pollutant accumulation regions, computational simulations of fluid flow (air) around the insulators were performed, considering a uniform horizontal wind speed of 5 m/s. The numerical simulations were performed in three dimensional models of the insulators according as shown in Figure 1.

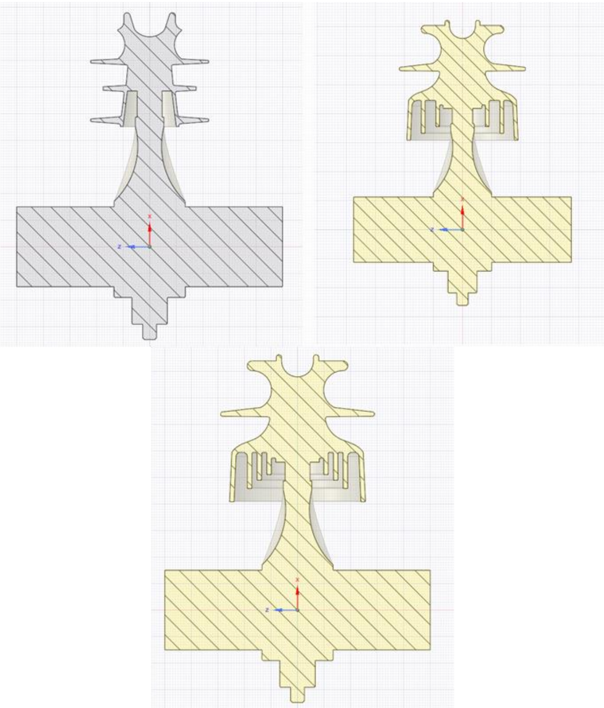

Figure 1. Pin insulator models: Conventional model (top left), 3 ribs (top right) and 4 ribs (bottom).

Three different models were used in the numerical simulation, being: the conventional model, the pin insulator with 3 ribs and the model with 4 ribs. The software ANSYS® FLUENT® (version 18.1) was used to perform the numerical simulations. The following considerations were used:

Numerical resolution method: finite volume model;

Discretization: second order upstream;

Domain: adjacent control volumes with variable dimension mesh (Figure 2);

Turbulence model: k-omega SST;

Transient simulation;

Time step: 0.0005 s;

Mesh: tetrahedral (3-D).

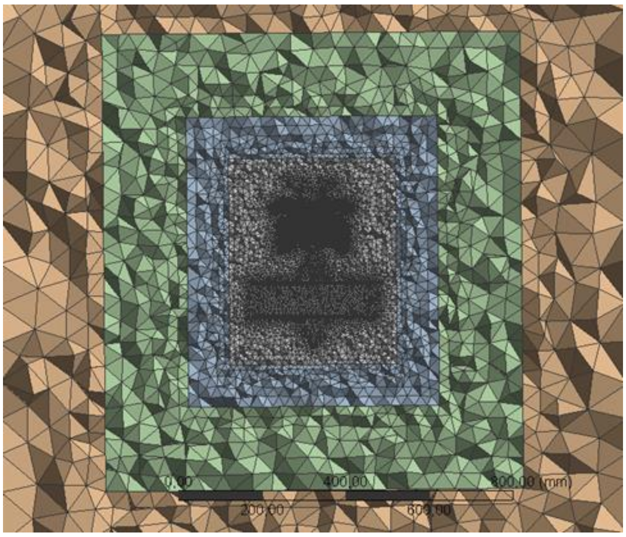

Figure 2. Variable mesh size.

RESULTS

Three types of analysis were made based on the numerical simulations:

Streamlines: The color scale used in the the flow velocity was: greater the speed (near the upper limit) more reddish and lesser the speed (near the lower limit) more bluish. In this type of analysis, data are sought on the proximity and quantity of streamlines in the lower part of the pin insulator, looking for regions where stagnation points may occur;

Pressure field: the pressure field is a scalar field and represents the locations where stagnation point flow may or may not occur. For this type of analysis, only the negative values were used in the color scale, that is, the values of gauge pressure below atmospheric pressure. This indicative can represent the regions, which due to the geometry of the insulator, can generate the stagnation point flow and thus the accumulation of pollutants, such as: dust, salinity and humidity;

Velocity field: representation of the magnitude of the velocity field (vector). For the study carried out, the velocity component was considered only in the vertical direction, which would be responsible for the flow and transportation of pollutants into the ribs of the pin insulator.

Streamlines

In **Erro! Fonte de referência não encontrada.** the streamlines close to the surface of the pin insulators are shown. Cuttings were made in the three-dimensional model to visualize the streamlines inside the insulators. In a qualitative way, the existence of streamlines closer each other indicates a greater fluid flow. Thus, the absence of streamlines in certain pin insulator ribs can qualitatively indicate that there is little or no circulation of pollutants carried by the wind.

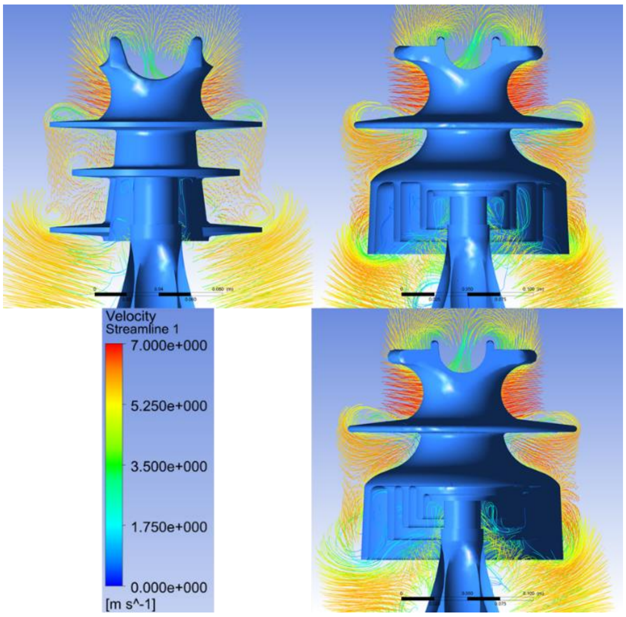

Figure 3. Streamlines over the pin insulator. Conventional model (top left), 3 ribs (top right) and 4 ribs (bottom).

Pressure Field

The flow pressure field is shown in the Figure 4.

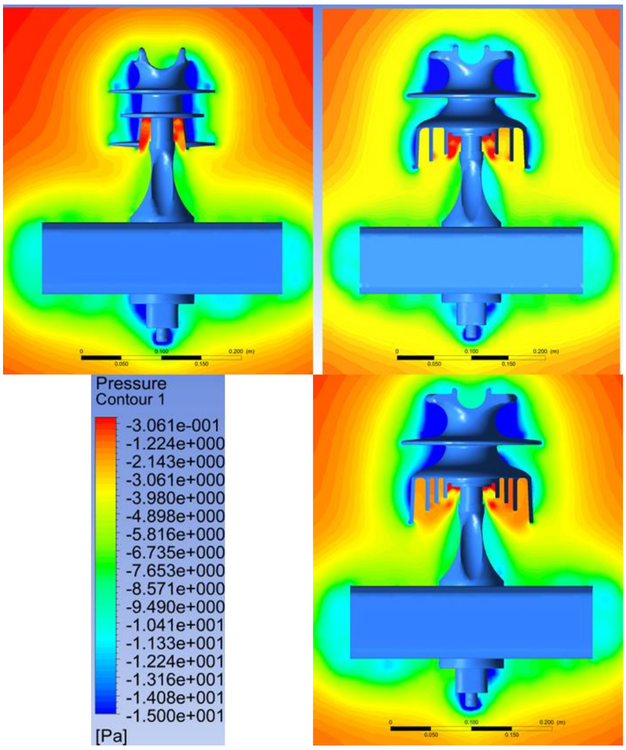

Figure 4. Pressure field over the pin insulator. Conventional model (top left), 3 ribs (top right) and 4 ribs (bottom).

Like the streamlines, the pressure field has a lower intensity in the lower parts of the pin insulator (into the ribs) for the 4 ribs model. For this model, the pressure into the ribs are closer to atmospheric pressure than other models. This means that the flow is not easily moved to this region, reducing the pollution accumulation. In addition to this, there is a higher number of openings and thus a larger contact area with the air flow and pollutants compared to the other models. This reduces the pollution concentration over the surface, not only by the pressure field, but also by increasing the area exposed to the same volume of fluid.

Velocity Field

In order to analyze the velocity field in a judicious way, the velocity field was divided into two parts, the positive or upward velocity and the negative or downward velocity. This division, which was done using only the values of the vertical velocity, had as objective the analysis of the flow in the ribs of the pin insulators.

Vertical Upward Velocity

The velocity field referring to the upward vertical velocity is shown in Figure 5.

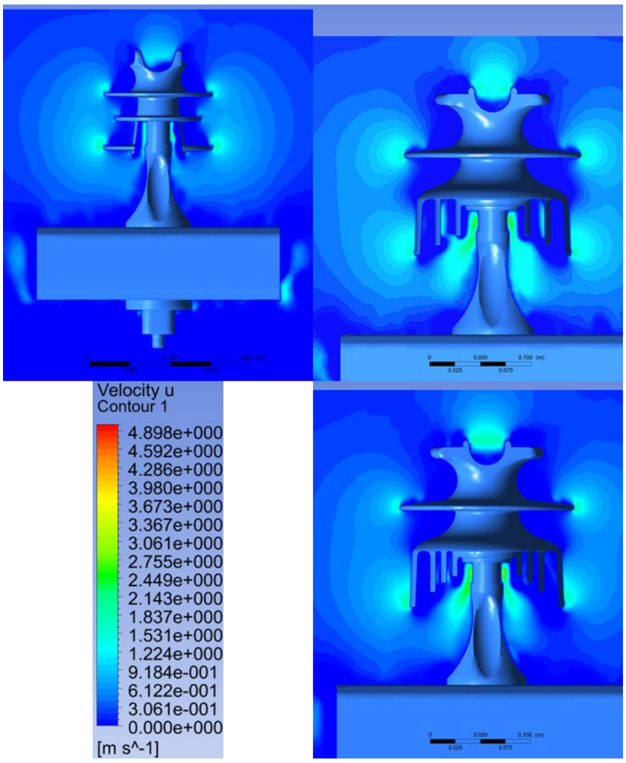

Figure 5. Velocity field over the pin insulator (positive values). Conventional model (top left), 3 ribs (top right) and 4 ribs (bottom).

The blue areas represent the location where the velocity in the vertical direction is zero or negative (if the upward direction is considered as positive). As was verified by the streamlines and pressure field, the 4 ribs model has openings where there is no upward flow. In this way, there is less probability that pollutants are carried through the wind into these regions.

Vertical Downward Velocity

The downward velocity field was shown in the Figure 6. The velocity field with negative values, i.e., the downward vertical velocity represents the portion of the flow which has a tendency to move away from the ribs of the pin insulator. The red areas represent the locations where the velocity in the vertical direction is zero or positive (if the downward direction is considered as negative). In this condition, any color other than red represents the regions at which there is air flow and pollutants going out of the pin insulators.

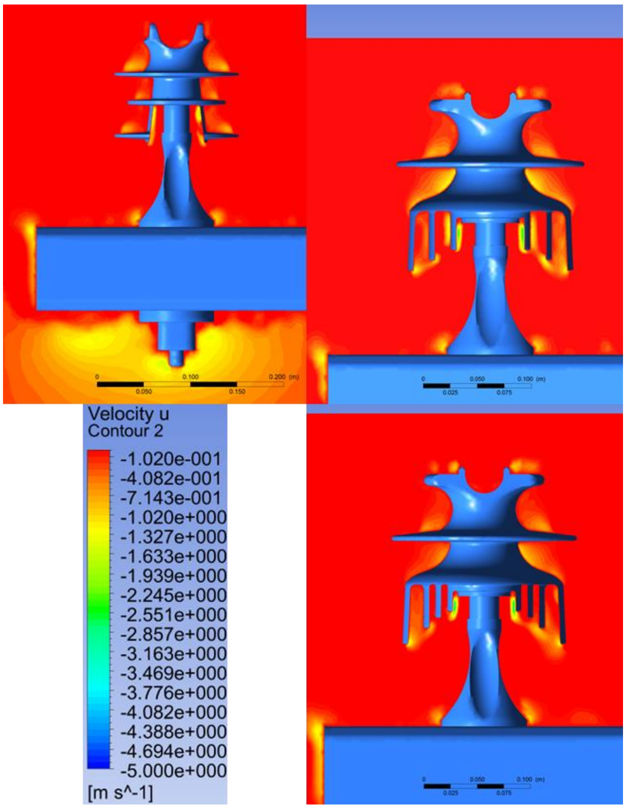

Figure 6. Velocity field over the pin insulator (negative values). Conventional model (top left), 3 ribs (top right) and 4 ribs (bottom).

CONCLUSIONS

For the three previously applied methodologies, being: streamlines, pressure field and velocity field; a better performance, from the point of view of flow was observed for the 4-ribs pin insulator model. This model presents conditions in which there is reduced accumulation of pollutants in relation to the other models. Although it is not possible to investigate by the methods used an accumulation of total pollutants that will be deposited on the surface, but it is clear that the model with the largest number of ribs underneath the pin insulator allows a reduction of the circulation of pollutants in its lower part, possibly reducing the occurrence of the effect of electrical surface tracking.

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