Numerical simulation by mixed convection of a MV / LV substation

in the city of Bechar (southwest of Algeria)

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Abstract : Due to the significant increase in summer's temperature particularly in Saharan zone (city of Bechar), the electric power substations in medium voltage to the low voltage (MV / LV) installed by electricity and Gas distribution companies (Sonelgaz) undergo additional stress compared to those installed in the north, because of overheating which leads to outages Electric unexpected for consumers

To this end, the present work is to a numerical study of a type of public distribution station which includes a transformer and taking into account the outside temperature measures by the weather station of ENERGARID laboratory.

The objective of this study is to analyze the results of the distribution of temperature, aeration of the position and the flow of air to the interior of the post.

The use of digital Fluent CFD code that is designed to deal with such physical problem.

Thereafter we will also analyze the influence of some key system settings and find the best solutions or propose a new architecture of positions.

Keywords : MV / LV substation, Saharan climate, mixed convection, numerical simulation

1. Introduction

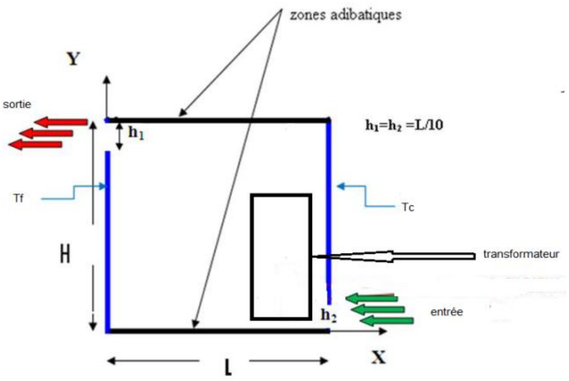
In recent decades the heat transfer by convection mixed has been subject of numerous theoretical, numerical and experimental investigations. Mixed convection in rectangular spaces is a very important subject of investigation for its presence in various industrial applications such as cooling of electronic components, heat loss in the solar collectors and the ventilation of rooms and buildings . The laminar regim of forced or natural convection has limited value because the number of Reynolds or Grashof / Rayleigh square must not exceed a certain threshold [2-3]. The heat transfer by mixed convection has a considerable interest for technological applications such as chemical deposition of thin layers and cooling of electronic parts [4-10]. A large number of numerical and experimental studies carry on heated or insulated tubes mixed convection[11-16]. Most of these studies consider the bidimensional case with vertical tubes. They studied the effect of the adimensional numbers on the behavior of flow in mixed convection. The effect of the inclination was considered by [17] and [18] in 3D which assume that the flow has a predominant direction in order to simplify the Navier Stokes.

To overcome this problem, a small numerical study of heat transfer by convection mixed was conducted with the objective of finding the best solutions for already installed items and propose a new architecture of posts adapted to climatic conditions of southern Algeria .

The main constraints are overheating which reduces the life of plants and cause detrimental stoppages to customers and the deterioration of the contacts due to fouling by sand.

2. Geometric Configuration

This is an electric power processing station for the public distribution of length L = 3.4m and height H = 2.8m, equipped with two openings same heights h1 = h2 = 0.44m. One is located at the bottom for admission of air and the other at the top for the hot air outlet. The wall near the transformer is at a warm temperature Tc and the other wall kept at a cold temperature Tf, too, the floor and the ceiling of the post are supposed thermally insulated. The post contains a transformer size (e1 = 1.7m,e2 = 1.85m). The boundary conditions of the post are taken from bechar climate data.



Geometric Configuration

To simplify the problem, it is assumed that:

- The fluid is Newtonian and incompressible.
- Heat transfer by radiation is negligible.
- The heat dissipation by viscous friction is neglected.
- The Boussinesq approximation is considered.
- The flow is bidimensional.

3. Mathematical Model

a. Continuity equation

$$\frac{\partial \rho}{\partial t} + \frac{\partial}{\partial xj}(\rho Vj) = 0 \qquad (1)$$

Considering presidents assumptions, the equation is written in Cartesian coordinates as :

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 0 \qquad (2)$$

b. Momentum equations of X, Y directions

Considering the variation of viscosity with temperature, projections conservation equation of the quantity of movement are written following Ox and Oy respectively as:

following Ox :

$$\rho 0\left(\frac{\partial u}{\partial t} + \frac{\partial}{\partial x}(uu) + \frac{\partial}{\partial y}(uv)\right) = \frac{-\partial P*}{\partial x} + u\left(\frac{\partial}{\partial x}\left(\frac{\partial u}{\partial x}\right) + \frac{\partial}{\partial y}\left(\frac{\partial u}{\partial y}\right)\right) \qquad (3)$$

following Oy :

$$\rho 0\left(\frac{\partial v}{\partial t} + \frac{\partial}{\partial x}(uv) + \frac{\partial}{\partial y}(vv)\right) = \frac{-\partial P*}{\partial y} + u\left(\frac{\partial}{\partial x}\left(\frac{\partial v}{\partial x}\right) + \frac{\partial}{\partial y}\left(\frac{\partial v}{\partial y}\right) + \rho 0 g\beta(T - T0)\right) \qquad (4)$$

c. Energy equation

This equation expresses the conservation of the total energy of the system; it is written :

$$\rho Cp\frac{\partial T}{\partial t} = \frac{\partial}{\partial xi}\left(K\frac{\partial T}{\partial xi}\right) + \tau ij\frac{\partial vi}{\partial xi} \qquad (5)$$

Let :

$$\phi = \tau ij\left(\frac{\partial Vi}{\partial xi}\right) \qquad (6)$$

Where ⧫ means the viscous dissipation function which represents the degradation of indoor heat forces.

In the case where the function ⧫ is neglected (according to our hypotheses), equation (5) can be written in cartesian coordinates as:

$$\frac{\partial T}{\partial t} + \frac{\partial}{\partial x}(uT) + \frac{\partial}{\partial y}(vT) = \alpha\left[\frac{\partial}{\partial x}\left(\frac{\partial T}{\partial x}\right) + \frac{\partial}{\partial y}\left(\frac{\partial T}{\partial y}\right)\right] \qquad (7)$$

Where $\alpha = K / \rho\ Cp$ is the thermal diffusivity of the fluid.

The initial and boundary conditions:

The previous system of equations must be solved under certain specified conditions

to the input :

$U = V_{max}$; $V = 0$; $T = T_f$ (5)

to the output :

Outflow (all gradients are taxed null except that of pressure)

Hot walls:

$U = V = 0$; $T = T_C$ (6)

Vertical walls:

$U = V = 0$; $T = T_f$ (7)

Horizontal walls (adiabatic)

$$u = v = \frac{\partial T}{\partial x} = 0 \qquad (8)$$

The numerical procedure used in this work is that of finite volume. It involves the integration of differential equations of mathematical model on finite control volumes for the corresponding algebraic equations. The SIMPLE algorithm was chosen for the coupling speed pressure in the Navier Stokes equations on a staggered mesh . Convective terms in all equations are evaluated using the scheme apwind1er order. In order to follow any changes in hydrodynamic and thermal fields, we used a uniform mesh.

4. Results and discussion:

4.1 Distribution of flow and temperature field:

Figure (2) shows the streamlines and isotherms inside the transformer station for an input speed V min = 0.3 m / s. the airflow at the station is characterized by the appearance of several vortex. The big party of this air recirculation is lending the wall and the heating body which explains why the transfer of heat by conduction is more dominant than that by convection.

The temperature distribution confirms the structure of the flow which is intense in the vicinity of the transformer, there is also warming of the air inside the post that gets trapped due to low air flow at the exit of the station .

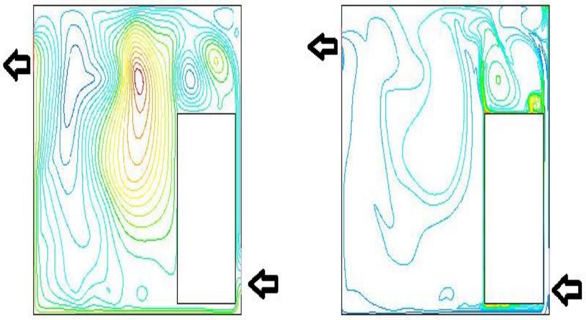


Figure 2: The streamlines left and isotherms right for Vmin = 0.3 m / s

The streamlines and the isothermas inside the station of the transformer for an input speed Vmax = 7.9 m / s are shown in Figure (3). The flow of air to the interior of the station changes his structure for higher input speeds, which indicates the appearance of large vortices begotten by a faster air circulation due to air change. By cons, there is always the small air recirculation zones above the transformer caused by the evacuation of very heat flow by the transformer, and the hot fluid is at the top of the post.

The temperature distribution always follows the airflow, in the case of high speeds we see that the isotherms of the post divided into two areas ; the first is at the bottom of the post where is parallel to transformer and the second is located above the transformer representating the hottest layer inside the post. In addition, it is concluded that the heat transfer by convection is more important than that by conduction.

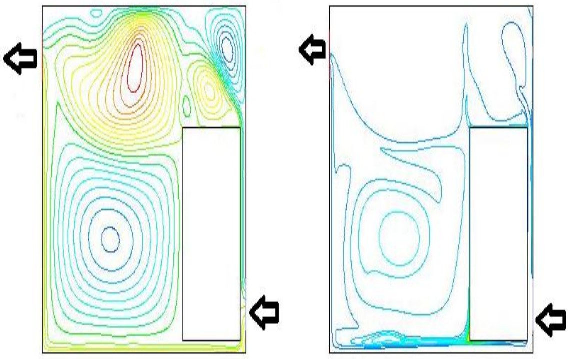


Figure 3: The streamlines left and isotherms right for Vmin = 7.9 m / s

4.2 Temperatures and speeds Profiles:

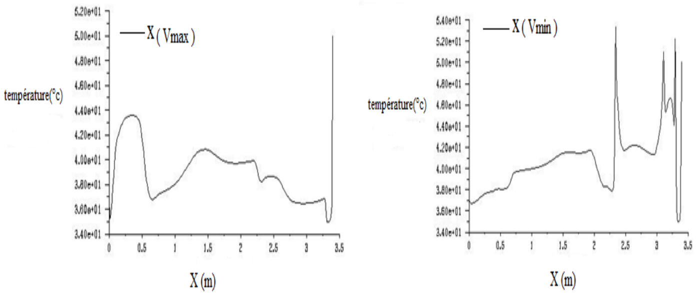


Figure (4): temperature profile for Y = 2 m

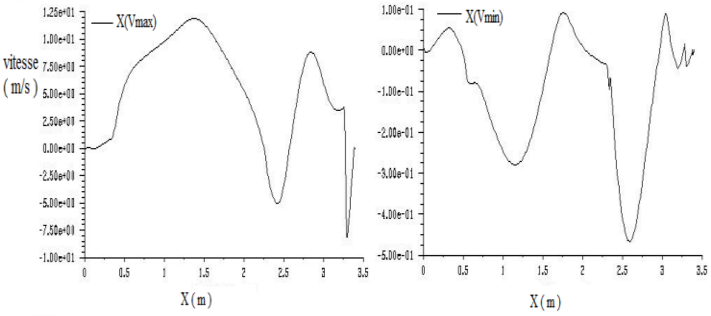


Figure (5): speed profiles for Y = 2 m

Figure (4) illustrate the evolution of the temperature on the line Y = 2m for speed Vmax = 7.9 m / s and V min = 0.3 m / s ; the temperature distribution compliant to the circulation of the fluid which is noted that the temperature does not exceed the ambient emperature (Ta = 45 ° C)) throughout the area in parallel of the transformer. In the case of low speeds, we see an increase of temperature until Tc = 54°C just after the position X = 2.3 m (near to the transformer) to stabilize until almost the hot wall what characterizes that the heat transfer is dominated by conduction. By against for the high speeds and because of the renewal of air the temperature increases rapidly from the position X = 3.3 m to reach the hottest value which explains that the transfer by convection is predominant.

The profile of the average vertical velocity at a height of Y = 2 m to a maximum speed and a minimum other is shown in Figure (5). A brusque decrease of the vertical velocity is noted to reach minimum values at about X = 0.5m and for different values of Ri. However the maximum speed values are met in the range 0.8 < X < 2.5 (near of heating corps). These values indicate where the fluid particles follow the streamlines in ascending and descending movement.

5. Conclusion

The study presented in this work is on laminar mixed convection in an electrical transformer station intended for the public distribution, equipped with two openings and a transformer. The vertical left lateral wall of the post is carried to a cold temperature and the right wall (near heating body) is subjected to a hot temperature, while the other walls are considered to be adiabatic.

For our numerical simulation we presented the streamlines and curves of the isothermal with speed is maximum on the one hand and on the other minimal.

It is found that much of the air recirculation in the post is lending the wall and the heating also the air circulation is faster if the input speed is higher following the renewal of air. Moreover it is concluded that the temperature distribution follows and complies the airflow.

Finally ; we see that the heat transfer by conduction is predominant if the speed i slow ; by against in high speed case the transfert by convection is more important.

Nomenclatures

g Gravitational acceleration [m / s2]

H Height of the cavity [m]

L The cavity length [m]

h1 length of evacuation [m]

h2 Length of entry [m]

e1 The thickness of the heating element [m]

e2 The height of the heating element [m]

U, V velocity vector Components [m / s]

Greek symbols

λ Thermal conductivity [W / mK]

μ Dynamic viscosity [Kg M-1 / s-1]

υ Kinematic viscosity [m2 / s]

ρ Density [kg / m3]

Δ Temperature difference [K]

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