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Wind Action Analysis on Different Structures of Photovoltaic Systems Installed on Flat Rooftops of Buildings

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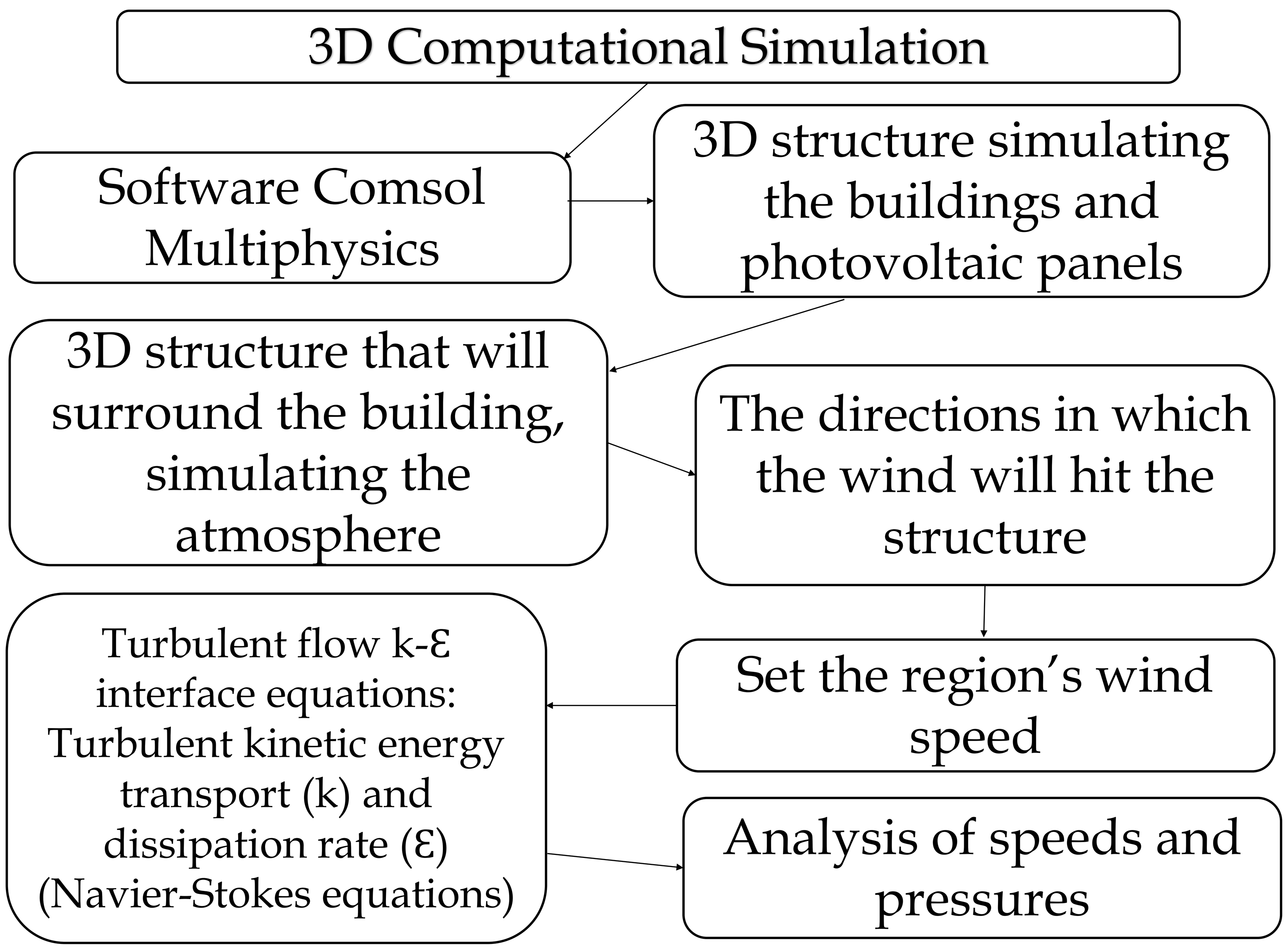
Abstract. This paper aims to analyze the velocities and pressures that the wind exerts in three different configurations of photovoltaic systems installed on flat rooftops of buildings. The Finite Elements Method is used to perform thirty computer simulations for different wind speeds and directions. From the obtained results analyzes of the maximum and minimum values of pressure and velocity on the surface of structures and the building are performed. Thus, it is possible to identify the necessary precautions regarding materials and installation so that structure is safe and does not result in accidents and material economic damage.

1. INTRODUCTION

The increase in installed capacity of photovoltaic systems in Brazil in 2018 represents fifty percent of a total of 2,4 GW of installed capacity today. Most of the installations are tied to distributed micro and mini generation, which correspond to electric power generation systems with ab installed capacity of 75 kW or les, and above 75 kW and les tan or equal to 5 MW, respectively. In this context, a stimulus is observed that the systems are installed on the gr-nd or integrated into the buildings. In the latter case, for buildings in the design phase it is already possible to predict the mechanical loads that the photovoltaic system Will exert on the roofs of the buildings. In the case of existing buildings, assessments are required on the mechanical carrying capacity of the system to be installed [1], [2], [3].

In this context, studies are conducted to analyze the effect of wind on flat roofs of buildings. Therefore, the characteristic wind values in Brazil are evaluated, based on ABNT NBR 6123 – Wind Forces in Buildings [4], in order to parameterize computational simulations that allow the analysis.

2. METHODOLOGY



2.1. Simulation schema

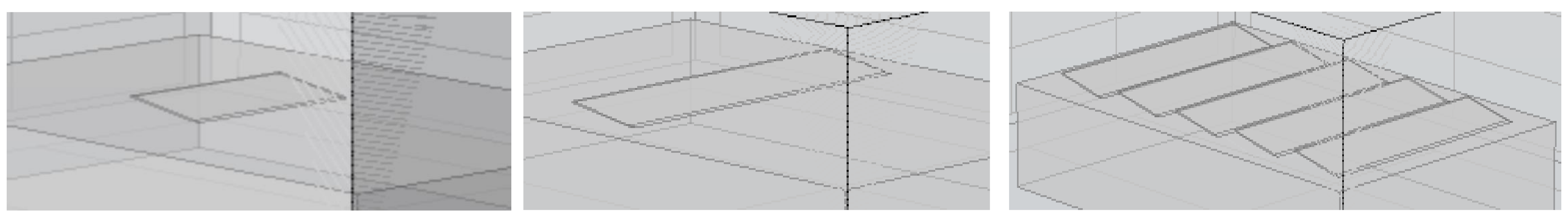


Fig. 1. Rooftop plan with photovoltaic panel structures

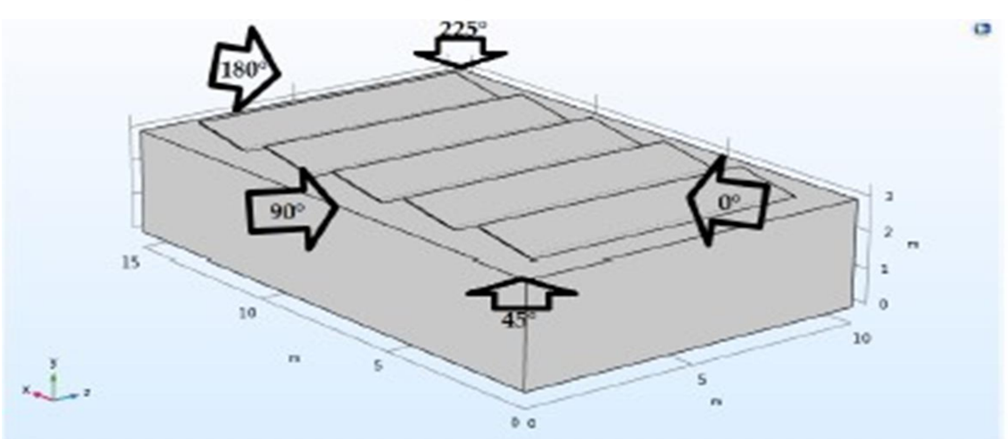


Fig. 2. Wind flow directions

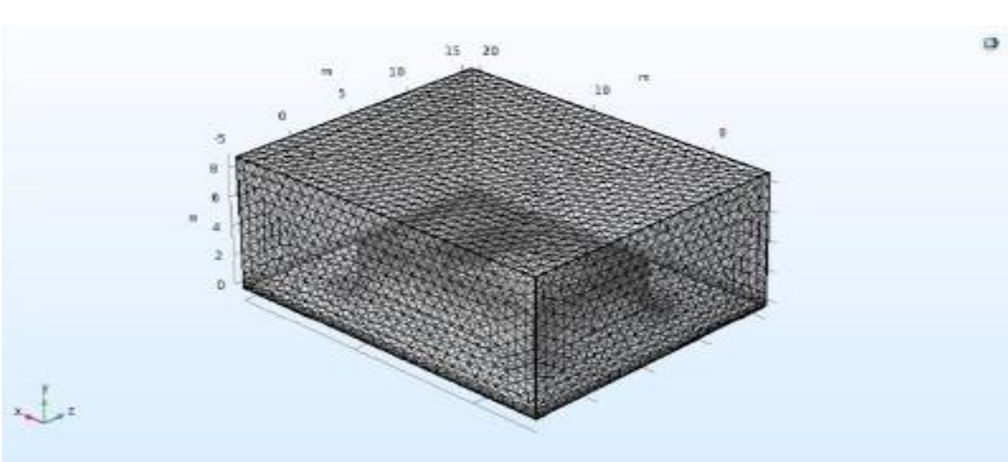


Fig. 3. Mesh produced for given geometry

Wind velocity = 35 m/s or 50 m/s;

- Define the velocity of the local wind (minimum and maximum);
- Apply that velocity in one of the five directions (Fig. 2);
- Select the Navier-Stokes equations;
- Create the mesh (Fig. 3);
- Take the worst situation;
- Verify the pressure and the surface speed;

- Evaluate photovoltaic systems structures with varying amounts of panels, defining the occupation of the available coverage area (Fig. 1);
- Identify the effects of wind velocity by assessing the pressures exerted on the panels and the fixation structures on the panels;
- Identify the worst situations involving wind speed and direction in photovoltaic system structures installed on flat roofs of buildings (Fig. 2);
- Apply the Finite Element Method [5] to obtain wind pressure on the structures of photovoltaic systems (Fig. 3).

3. RESULTS

The Computer simulations are performed for three different panels structures, with five different wind directions, and at speeds of 35 m/s and 50 m/s, resulting in a total of thirty simulations. Due to lack of space, only part of the graphic results obtained with the highest velocities and pressures are presented. In this case the structure with five sets of eight photovoltaic panels on plan rooftops showed the worst case with wind direction ate 225º.

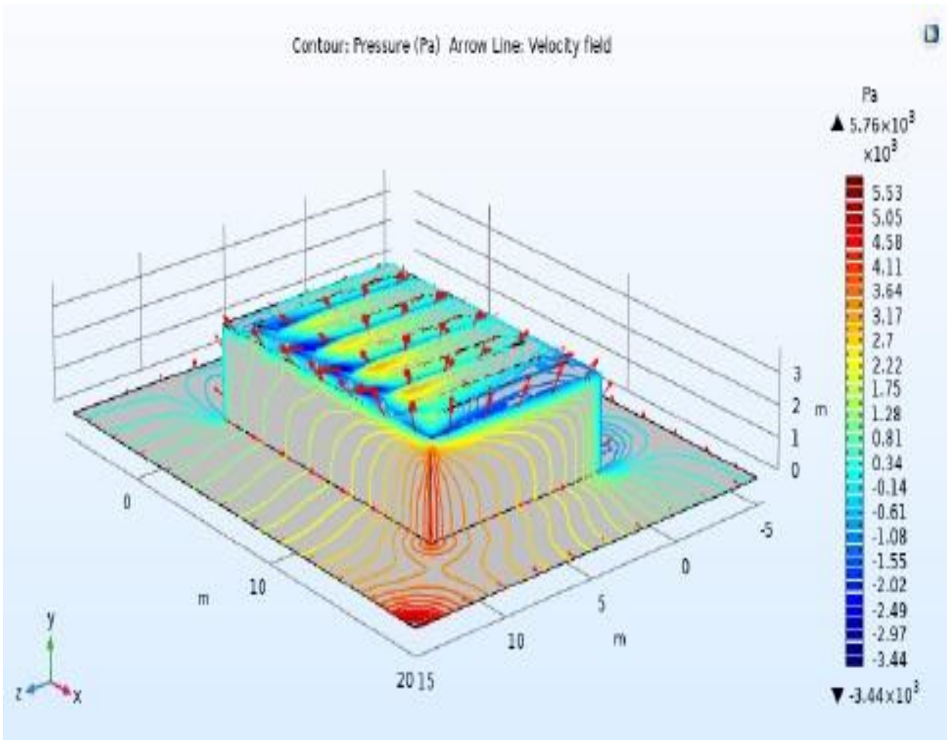


Fig.4. Wind pressure acting on the building at 225º

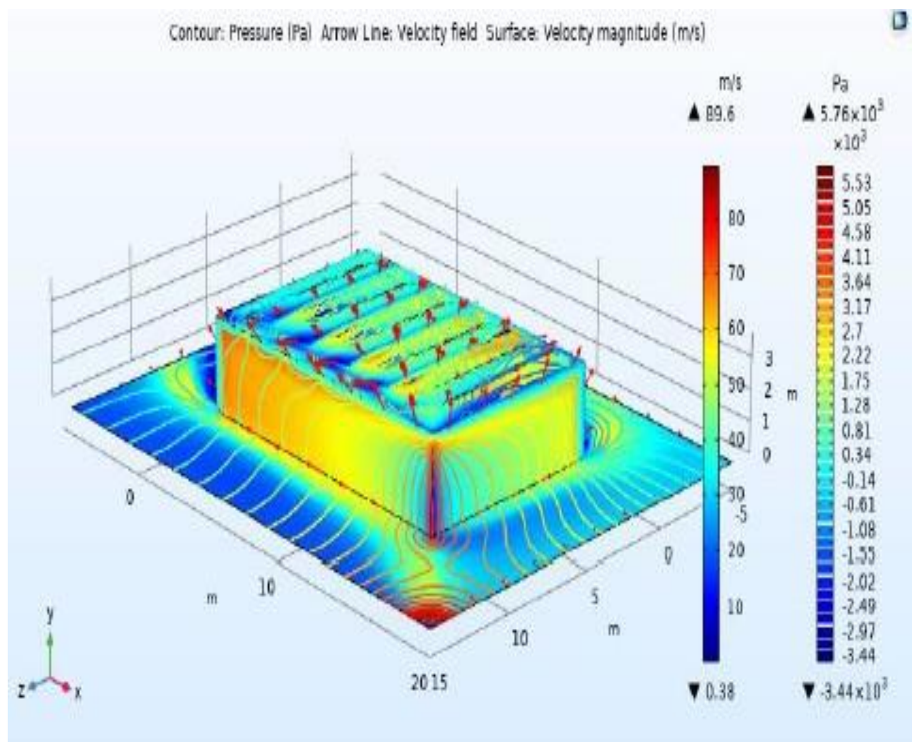


Fig.5. Surface speed at 225º direction

For these wind conditions on the building the maximum identified pressure is $5.76*10^3$ Pa (equivalent to a pressure of 587.36 kgf/m^2) and the minimum pressure is $-3.44*10^3$ Pa (equivalent to a suction pressure of 350.78 kgf/m^2). The greatest pressures are exerted on the panels closest to the roof edge where the wind initially hits the structure. This feature can be seen from the yellow color on the panels surface. Thus, the maximum pressure on the panels is $2.7*10^3$ Pa (equivalent to 275.35 kgf/m^2) and the minimum pressure is $-2.02*10^3$ Pa (equivalent to a suction pressure of 205.95 kgf/m^2) (Fig. 4).

As for the velocities on the surface of the analyzed structure, in the xz plane, these vary from 89.6 to 0.38 m/s, acquiring higher values at the edges of the building (Fig. 5) and at the bottom of the panels, due to the obstacle they represent for wind circulation.

35 m/s	Speed (m/s)		Pressure (Pa – kgf/m^2)	
Direction	Maximum	Minimum	Maximum	Minimum
0°	49.9	0.02	$-0.21*10^3$Pa – -21.41 kgf/m^2	$-1.33*10^3$Pa – -135.62 kgf/m^2
45°	74.4	0.06	$0.73*10^3$Pa – 74.43 kgf/m^2	$-0.49*10^3$Pa – -49.96 kgf/m^2
90°	50.3	0.16	$-0.27*10^3$Pa – 27.53 kgf/m^2	$-1.14*10^3$Pa – -116.25 kgf/m^2
180°	50.4	0.01	$0.15*10^3$Pa – 15.29 kgf/m^2	$-1.12*10^3$Pa – -114.21 kgf/m^2
225°	89.6	0.38	$2.7*10^3$Pa – 275.32 kgf/m^2	$-2.02*10^3$Pa – -205.98 kgf/m^2
50 m/s	Speed (m/s)		Pressure (Pa – kgf/m^2)	
0°	71.9	0.03	$-0.09*10^3$Pa – -9.17 kgf/m^2	$-2.06*10^3$Pa – -210.06 kgf/m^2
45°	107	0.22	$0.23*10^4$Pa – 234.53 kgf/m^2	$-0.18*10^4$Pa – -183.55 kgf/m^2
90°	77.3	0.04	$-0.65*10^3$Pa – -66.28 kgf/m^2	$-1.83*10^3$Pa – -186.61 kgf/m^2
180°	72.6	0.02	$0.3*10^3$Pa – 30.6 kgf/m^2	$-1.95*10^3$Pa – -198.84 kgf/m^2
225°	129	0.54	$0.55*10^4$Pa – 560.84 kgf/m^2	$-0.32*10^4$Pa – -326.31 kgf/m^2

Table I – Results of the simulations of the structure with five sets of eight photovoltaic panels at 35 and 50 m/s speeds

4. CONCLUSIONS

From the results obtained for different wind intensities and directions the wind in the 225° directions are responsible for the largest forces acting on the structures to pull the structures fixed on the flat rooftops. Thus, it can be concluded that software based on the finite element method assists in the analysis of wind effects on photovoltaic structures installed on building roofs. It can still be stated that studies involving the sloping roofs and the materials used to fix the metal structure and photovoltaic panels are necessary. And finally, from the results, it is affirmed about the necessity of the proper fixation of the structure in order to withstand the intense pressure exerted by the wind, especially in the rear of the panels, minimizing possible damages and accidents.

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