MODELLING OF THE WIND EFFECT ON A DOUBLE-TRACKING PV PLATFORM

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The objective of the paper is the assessment of the wind load applied to a real photovoltaic (PV) platform installed on a site situated in Brasov, Romania. The platform has a double-tracking axis mechanism, which allows the rotation of the platform depending on the sun position, in order to gather the maximum solar yield to produce electricity. The 3D numerical investigations were performed by using the software COMSOL Multiphysics. The results were represented graphically, in terms of pressure fields along the PV platform disk, depending on the seasonal and daily angle of inclination relatively to the two axes of platform rotation.

Keywords: PV platform, wind load, modelling in COMSOL Multiphysics.

1. Introduction

The objective of the paper is the assessment of the wind load applied to a real photovoltaic (PV) platform installed on a site situated in Brasov, Romania, which belongs to the Transilvania University. The platform has a double-tracking axis mechanism which allows the rotation of the platform depending on the sun position, in order to gather the maximum solar yield to produce electricity. The study was performed by 3D numerical simulation using COMSOL Multiphysics software [1], a finite element method based computer code, using a common solver for the study of several problems that require resolution of partial differential equation systems.

2. Computational methodology

The tests were performed on a 3D, 1:1 geometrical scale model of the platform. They permitted us to compute airflow around the platform and assess loads exerted by the wind for different positions of the platform with respect to the direction of incoming wind.

The final purpose of the simulations was to compute the forces and moments acting on the pillar sustaining the platform in the case of strong winds

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[2]. Integration of pressure values over the platform surface permitted us to compute the three components of the resulting force with respect to the three directions defined in the numerical solver.

The following step in our study would be to add a temperature conditions on the boundaries of the platform, as well as on the inlet and outlet of air boundaries, in order to be able to compute heat exchange between the platform and surrounding air, in different seasonal conditions. This is of great importance in the functioning of the PV panels mounted on the platform. It is well known that overheating or overcooling the PV panels has an important influence on their efficiency in transforming solar energy into electricity. This is the next step of our project and will be presented in another paper.

3. Description of the PV platform and simulations hypothesis

The PV platform is composed by a disk with 5m diameter containing several types of PV panels; this disk is sustained by a 5.4m high pillar. The connection between the pillar and the disk is made by a 0.8m long cylinder articulated around two axes, thus permitting the double-tracking movement of the disk, in order to gather the maximum solar radiation to produce electricity (Fig.1).

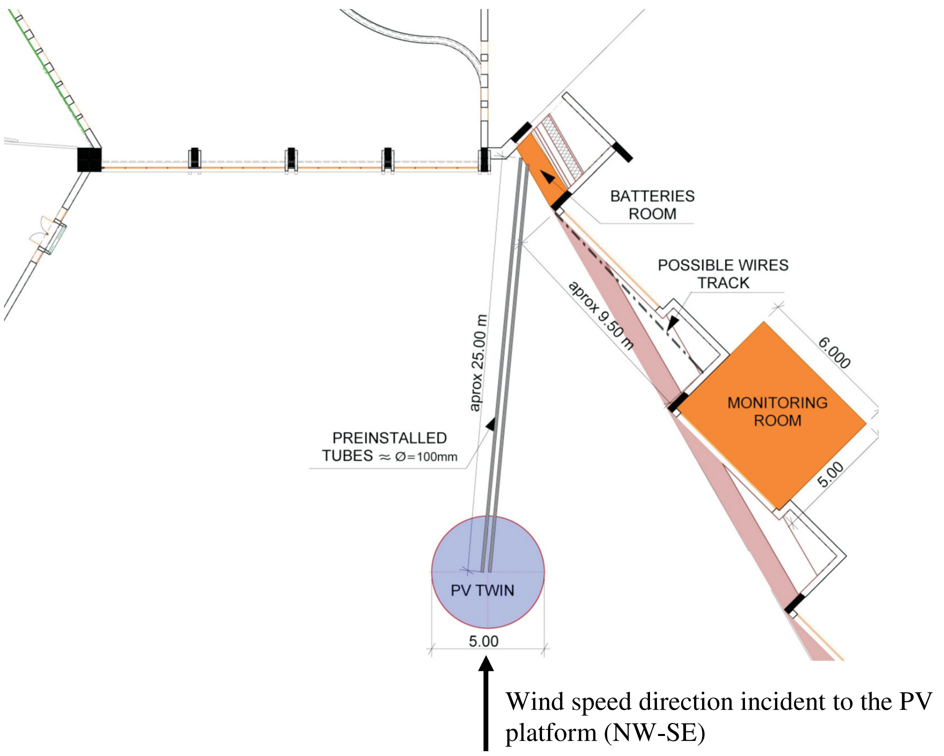

Fig. 1. Elevation on the PV platform mounted on the “Collina”, Transilvania University of Brasov

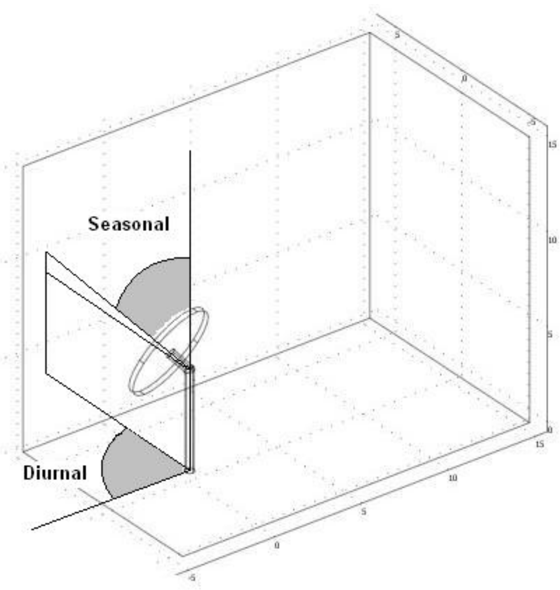

Fig. 2. Computing domain with diurnal angle & seasonal angle considered in the simulation

The numerical modelling of the wind behaviour along the PV platform was based on the following hypothesis:

- the reference wind speed for Brasov town (v_{ref}), according to the Romanian standard SR 10101/20-90 [3], was 22m/s at 10m above the ground;
- wind velocity distribution with height was a power low profile of the form:

$$v_H = v_{ref}\left(\frac{H}{10}\right)^{0.2}, \tag{1}$$

where H represents the height at which wind velocity (v_H) is calculated. The power coefficient of 0.2 corresponds to plane ground, without important obstacles;

- the dominant wind direction for the simulations was considered NW-SE (North West – South East). It resulted from the real meteorological data available for Brasov. Other directions were not considered in the simulations, because it has been observed very rarely within the weather data records that winds exceeding 20m/s have different directions;
- the numerical 3D model of the platform (including the group ”pillar-cylinder-disk”) was constructed within the COMSOL Multiphysics environment (see Fig.2). The computing domain was set to 4 platform diameters long, 2 platform diameters wide and 3 platform diameters high [4]. The resulting mesh consisted of

about 16000 tetrahedral elements and 2300 triangular boundary elements, yielding a total of 123000 degrees of freedom;

- all simulations were performed under a stationary flow regime and the airflow was considered turbulent. The turbulence model used was the $k-\varepsilon$ one;
- air density was taken constant, independent of temperature and equal to 1.2kg/m^3 and the air dynamic viscosity corresponding to this temperature was considered equal to $1.7\cdot10^{-5}$Pa·s.

The boundary conditions used were: air inlet with the velocity profile varying with height as described above (on the left hand side of Fig. 2); air outlet with no viscous stress (on the right hand side of Fig. 2); rough wall computed with the logarithmic wall function with an offset of $h/2$ on the bottom of the domain (see Fig. 2); all other boundaries were set to symmetry boundary.

Several pairs of inclination angles, such as diurnal angle and seasonal angle were simulated, in order to assess the air movement and pressure distributions under different positions of the double-tracking platform (see Fig. 2 and Table 1); for each of these pairs of angles, we introduced the platform geometry in the COMSOL Multiphysics environment, in order to simulate the air movement throughout the calculation domain.

Table 1

Pairs of diurnal angle and seasonal angle (reported to horizontal plan) used in simulations

Day of the year	Diurnal angle reported to South	Hour of the day	Diurnal angle reported to South	Hour of the day	Seasonal angle
1-72	48	04:00	-23	12:51	54.5
	23	10:01	-48	14:37	
	0	11:37	48	21:00	
73-100	64	04:00	-19	12:55	42.5
	41	08:52	-41	14:16	
	19	10:22	-64	15:46	
	0	11:43	64	21:00	
101-127	76	04:00	-18	12:56	32.5
	55	07:51	-36	14:10	
	36	09:14	-55	15:26	
	18	10:30	-76	16:49	
	0	11:44	76	21:00	
128-216	80	04:00	-16	12:53	24.5
	62	07:10	-30	13:58	
	46	08:27	-46	15:02	
	30	09:38	-62	16:13	
	16	10:42	-80	18:10	
	0	11:47	80	21:00	
217-243	76	04:00	-18	12:56	32.5
	55	07:51	-36	14:10	
	36	09:14	-55	15:26	
	18	10:30	-76	16:49	

	0	11:44	76	21:00	
244-271	64 41 19 0	04:00 08:52 10:22 11:43	-19 -41 -64 64	12:55 14:16 15:46 21:00	42.5
272-366	48 23 0	04:00 10:01 11:37	-23 -48 48	12:51 14:37 21:00	54.5

4. Numerical results

The results of our study were represented graphically, in terms of pressure distributions along the PV platform disk, depending on the seasonal and daily angle of inclination relatively to the two rotation axes of the platform. Finally we calculated the resultant pressure forces (F_x, F_y and F_z) applied to the platform disk, in all cases (Table 2).

Table 2

Force components F_x, F_y and F_z of the resultant pressure force acting on the PV platform disk

Diurnal angle reported to South	Seasonal angle reported to horizontal plane	F_x (N)	F_y (N)	F_z (N)
48 23 0	54,5	-7109 -7098 -7192	3703 1943 -26	3394 4591 5040
64 41 19 0	42,5	-5044 -5199 -5244 -5249	4531 3384 1706 7	2221 3924 4990 5271
76 55 36 18 0	32,5	-3288 -3394 -3489 -3528 -3532	4299 3766 2823 1507 -2	1084 2654 3871 4617 4821
80 62 46 30 16 0	24,5	-2209 -2302 -2426 -2459 -2517 -2442	3558 3356 2885 2047 1129 19	643 1796 2809 3550 3975 4100

An example of the pressure distribution over the PV platform surface is given in Figure 3, for the pair: diurnal angle = 48º and seasonal angle = 54.5º.

In Figures 4 to 7, we presented the variations of the total pressure force (F) components (F_x, F_y and F_z), upon the diurnal and seasonal angles.

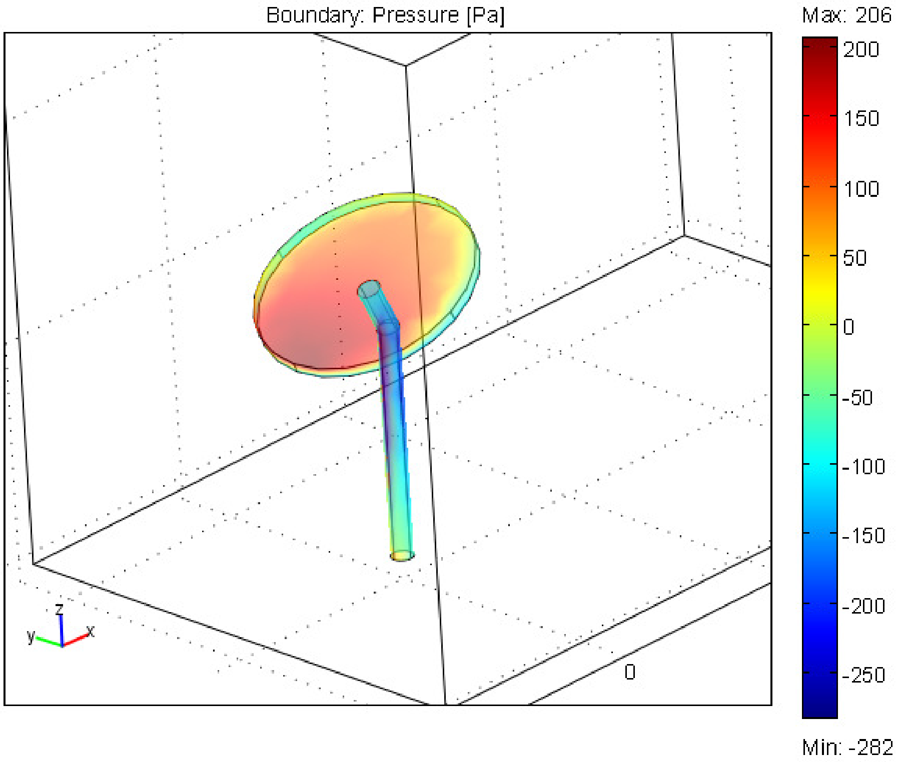

Fig. 3. Pressure distribution over the PV platform contour for the pair: diurnal angle = 48º and seasonal angle = 54.5º

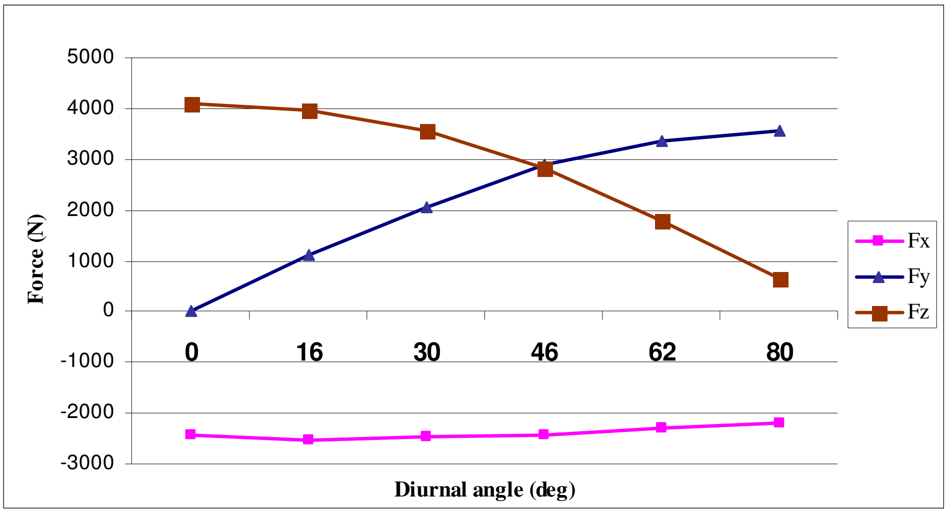

Fig. 4. Variation of F_x, F_y and F_z upon the diurnal angle, for a seasonal angle α = 24.5º

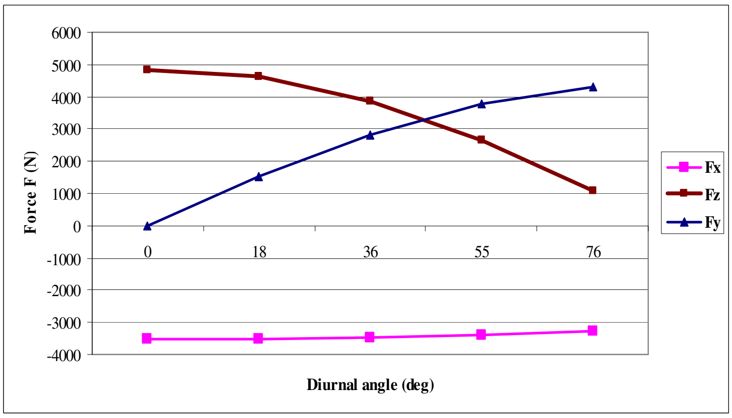

Fig. 5. Variation of F_x, F_y and F_z upon the diurnal angle, for a seasonal angle $\alpha = 32.5^o$

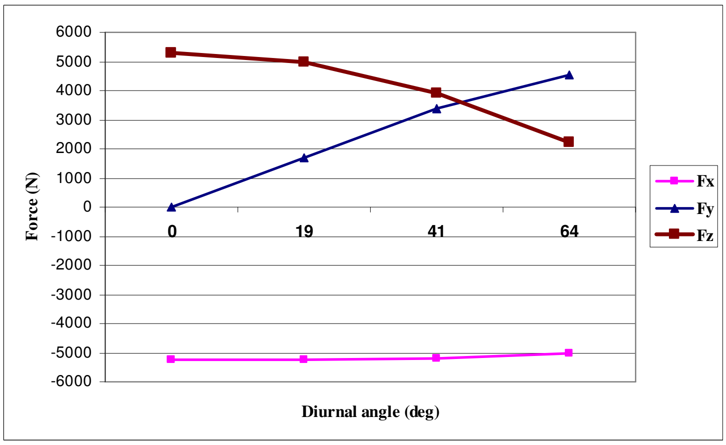

Fig. 6. Variation of F_x, F_y and F_z upon the diurnal angle, for a seasonal angle $\alpha = 42.5^o$

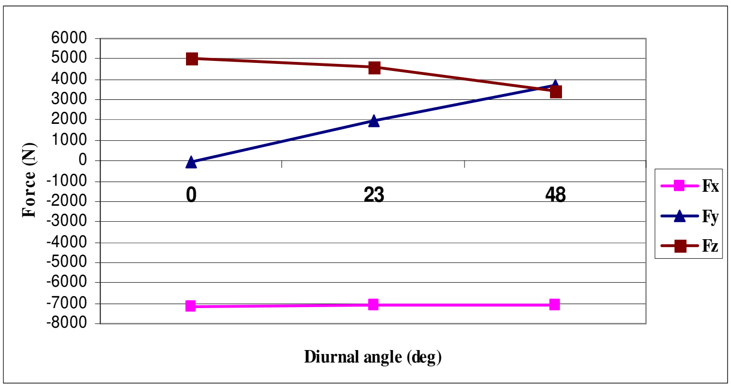

Fig. 7. Variation of F_x, F_y and F_z upon the diurnal angle, for a seasonal angle $\alpha = 54.5^o$

5. Conclusions

By analysing the values of the pressure force component F_y for all cases investigated, we notice that this force is approximately nil for a diurnal angle equal to 0º; this behaviour could be explained by wind speed direction, which is normal to the disk plane and there is no lateral stress along the *Oy* axis to the disk; when the diurnal angle is no nil, the lateral stress force F_y grows as the diurnal angle becomes bigger, and the vertical force F_z diminishes consequently. In the same time, the component F_x remains constant for all diurnal angles, but its values depend strongly with the seasonal angles. The component force F_x is negative (opposite to wind direction) for all the studied cases, which denotes that the platform disk is submitted to a positive torsional momentum M_y, which tends to rotate the platform disk clockwise; the structural calculations of the platform should be also take into account, this stress being caused by the wind influence.

The application point of the resultant force on the disk (*F*) cannot be found exactly from the COMSOL Multiphysics simulation results, but from the visual approach of the pressures distribution graphics, it appears that this point is placed under the supporting point of the disk centre, corresponding to the disk connection point to the articulated cylinder designed for the disk rotation.The vertical force component F_z is always positive (ascendant force) and tends to “pull up” the disk along the vertical axis *Oz*.

The model we created can be used in the case when a more complete study of wind effects on the platform for other incident directions is needed, allowing numerical modelling of air flow around the platform, as well as pressure distributions on it to be computed accurately.

6. Acknowledgements

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