

COMSOL Modelling of the Wind Effect on a PV platform

A.Georgescu *¹, A. Damian¹

¹ Technical University of Civil Engineering Bucharest

*B-dul Lacul Tei nr.124, sector 2, Bucharest, ROMANIA; email: andrei_georgescu2003@yahoo.com

Abstract: 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, which belongs to the Transilvania University. The platform has a double-tracking axis mechanism which allows the rotation of the platform disk depending on the sun position, in order to gather the maximum solar yield to produce electricity. The study was performed by numerical simulation using COMSOL Multyphysics, 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. The simulation results are outlined in the form of pressure distribution graphs over the platform disk, as well as in correlations between axial forces over the disk and diurnal angles related to Ox coordinates axis. 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 modeling of air flow around the platform, as well as pressure distributions on it to be computed accurately.

Keywords: Insert two to five keywords that are descriptive of the work presented in the paper. Separate keywords by commas.

1. Introduction

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. Integration of pressure values over the surface of the platform 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.

2. Description of the case study

The PV platform is composed by a disk with 5m diameter containing several types of PV panels, this disk is sustained by a 5,4 m high pillar. The connection between the pillar and the disk is made by a 0,8 m long cylinder articulated around two axis, thus permitting the double-tracking movement of the disk, in order to gather the maximum solar radiation to produce electricity (Figure 1).

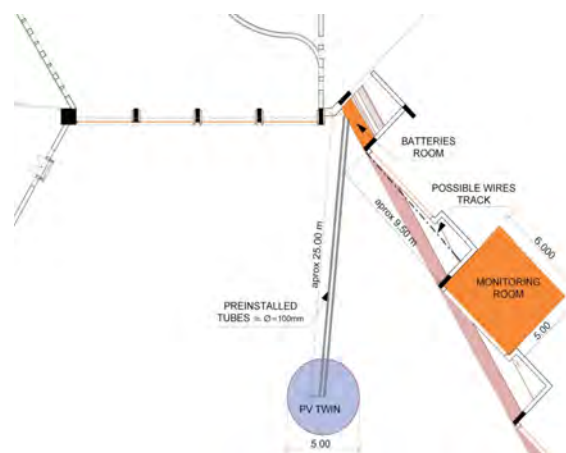


Figure 1: Elevation on the PV platform mounted on the Colina University of Brasov

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, was considered 22 m/s at 10 m above the ground

- wind velocity distribution with height was considered as a power law profile of the form:

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

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 20 m/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. The resulting mesh consisted of about 16000 tetrahedral elements and 2300 triangular boundary elements, yielding a total of 123000 degrees of freedom.

- All the simulations were performed under a stationary flow regime and the airflow was considered turbulent. The turbulence model used was the $k-\epsilon$ one.

- air density was taken constant, independent of temperature and equal to 1,2 kg/m³ and the air dynamic viscosity corresponding to this temperature was considered equal to 1,7*10⁻⁶ kg*m*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.

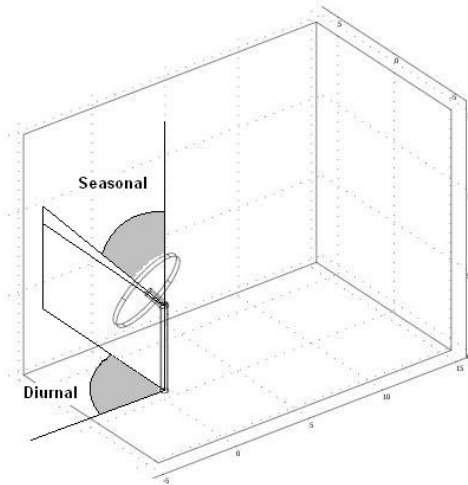


Figure 2: Computing domain with explanations on the “diurnal angle/seasonal angle” considered in the simulation

- several pairs of inclination angles, such as: “diurnal angle/seasonal angle” were simulated, in order to assess the air movement and pressure distributions under different positions of the double-tracking platform (see figure 2 and table 1).

Table 1. The pairs: “diurnal angle/seasonal angle” considered in the simulations

Day of the year	Diurnal angle reported to South	Hour of the day	Seasonal angle reported to horizontal plan
1-72	48	04:00	54,5
	23	10:01	
	0	11:37	
	-23	12:51	
	-48	14:37	
73-100	48	21:00	42,5
	64	04:00	
	41	08:52	
	19	10:22	
	0	11:43	
	-19	12:55	
101-127	-41	14:16	32,5
	-64	15:46	
	64	21:00	
	76	04:00	
	55	07:51	
	36	09:14	32,5
	18	10:30	
	0	11:44	
	-18	12:56	

101-127	-36	14:10	32,5
	-55	15:26	
	-76	16:49	
	76	21:00	
128-216	80	04:00	24,5
	62	07:10	
	46	08:27	
	30	09:38	
	16	10:42	
	0	11:47	
	-16	12:53	
	-30	13:58	
	-46	15:02	
	-62	16:13	
217-243	-80	18:10	32,5
	76	04:00	
	55	07:51	
	36	09:14	
	18	10:30	
	0	11:44	
	-18	12:56	
	-36	14:10	
	-55	15:26	
	-76	16:49	
244-271	76	21:00	42,5
	64	04:00	
	41	08:52	
	19	10:22	
	0	11:43	
	-19	12:55	
	-41	14:16	
272-366	-64	15:46	54,5
	64	21:00	
	48	04:00	
	23	10:01	
	0	11:37	
	12:51		
	-48	14:37	
	48	21:00	

3. Use of COMSOL Multiphysics

For each of these pairs of angles, we introduced the platform geometry in the COMSOL environment in order to simulate the air movement throughout the calculation domain.

4. 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.

An example of the pressure distribution is given in figure 3, for the pair: “diurnal angle=48°-seasonal angle=54,5°”

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

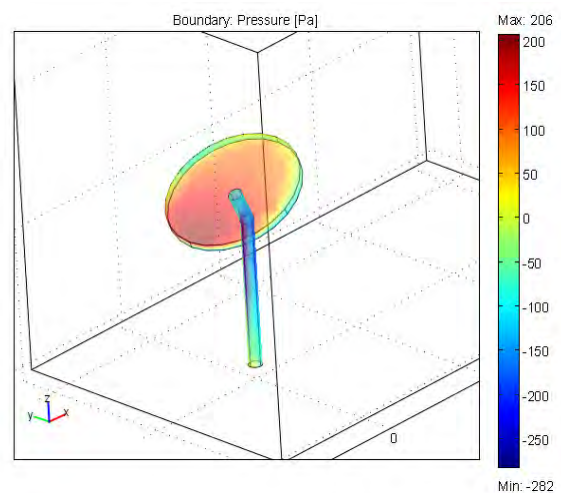


Fig 3: Pressure distribution over the PV platform contour for the pair: “diurnal angle=48°-seasonal angle=54,5°”

In the figures 4 to 7 we presented the variations of the total pressure force (F) components (F_x , F_y and F_z) with the seasonal and diurnal angles, as considered in the simulations.

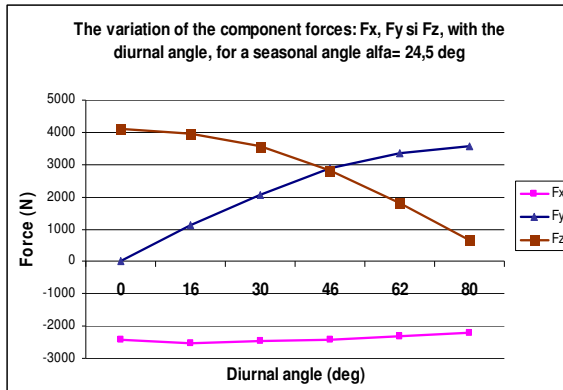


Figure 4

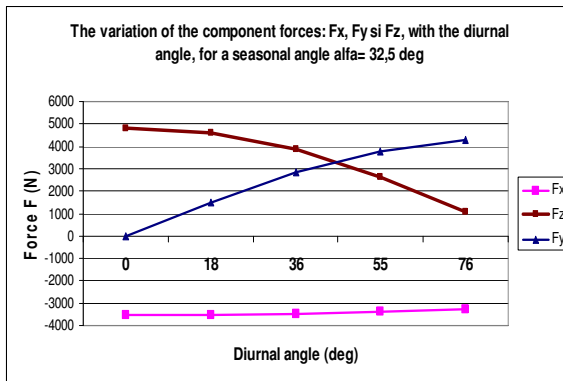


Figure 5

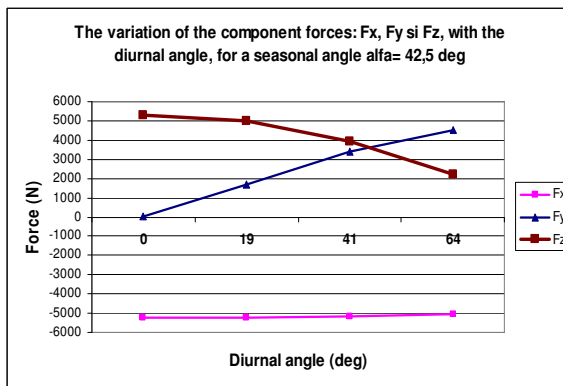


Figure 6

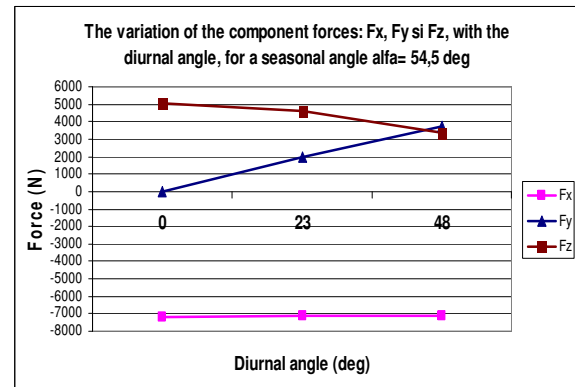


Figure 7

4. 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 0° ; 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 caused by the wind influence;
- The application point of the resultant force on the disk F cannot be found exactly from the COMSOL 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.

5. References

1. Hernández, J.A., Pavón, G., García, M.A., - "Analytical Solution of Mass Transfer Equation Considering Shrinkage for Modeling Food-Drying Kinetics", *Journal of Food Engineering*, **45**, 1-10, (2000).
2. Ben-Yoseph, E., Hartel, R.W., & Howling, D.,-"Three-Dimensional Model of Phase Transition of Thin Sucrose Films during Drying", *Journal of Food Engineering*, **44**, 13-22, (2000).
3. SR 10101/20-90 - "Acțiuni în construcții – încărcări date de vânt, Anexă națională" (Actions in constructions-loads due to wind. National Annex).
4. COMSOL Multiphysics ver. 3.4 – Users guide (2007)
5. Indicativ NP-082-2004 – "Cod de proiectare. Bazele proiectării și acțiuni asupra construcțiilor. Acțiunea vântului " (Design code. Basis of the design and impact on constructions. The effect of wind), published in M.O. Nr. 349 bis/25.04.2005.

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