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WIND LOAD CASES IN THE DESIGN OF THE PLATFORM OF AN AZIMUTHAL TRACKER

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***Abstract*—**Photovoltaic (PV) solar to electric power conversion efficiency can be improved by using dual axes solar tracking systems which allow positioning of the PV platform perpendicular on the sun rays. An azimuthal tracker has two independent rotational movements related to a vertical axis for the azimuthal rotation and a horizontal axis for the altitudinal rotation. Main loading on the structure of the platform comes from wind. The mobility of the platform and changes in wind velocity and direction create several load cases that must be considered in design of such structures. This paper presents the wind action evaluation and load cases resulted as possible cases of calculus of PV platforms. Finally, numerical application for an existing platform is presented.

***Keywords*—**Tracker, platform, wind load, load case

I. INTRODUCTION

AS stated in EC 20/20/20, due to the potential of reducing the consumption based on fossil fuels by using renewable energy systems, these sources are promoted at European level. An important direction is represented by the implementation of photovoltaic (PV) systems. They are increasingly used to convert solar energy into electric energy, by PV effect. In order to improve the energy efficiency of photovoltaic conversion a reliable option is to orientate the panels towards the sun, method which is called “Tracking” [1], [2].

The tracking systems must allow an accurate positioning of the PV platforms towards the sun for maximizing the radiation falling, ideally perpendicularly, on the PV surface. For maximizing the quantity of solar radiation received by the platform surface, dual axes solar tracking systems are mostly used, an energetic increase up to 40% being achieved [3].

The most used solution of dual axes tracking system is the azimuthal tracker [3], [4]. Fig. 1 presents the general diagram of such a tracker. It has two rotational axes: a vertical fixed axis and a horizontal mobile axis. Rotation around the vertical axis is setting the azimuthal orientation angle ψ^* and rotation around the horizontal axis is setting the elevation orientation angle α^*.

Rotations around both axes must be performed in several sequences during each day, for a precise daily solar tracking.

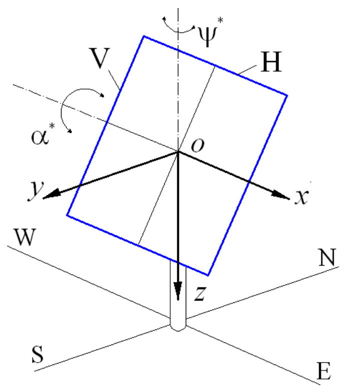


Fig. 1. General diagram of an azimuthal solar tracking system.

Being a mobile system, with specific functioning positions, running conditions (slow and sequential movements, high efficiency and precise mechanisms, outside running conditions etc.) and specific loads (wind, snow etc.), the design process involves some particular elements. The embodiment design must be performed considering the safety rules imposed by both civil engineering (Eurocode – building constructions) and mechanical engineering. This paper is dealing with elements of dimensioning the platform of a tracker, considering wind load. An analysis of standards reffering to wind action is performed and an evaluation of possible wind load cases that must be considered in calculus of tracked platforms is presented. Finally, an example of numerical calculus is presented.

II. LOAD FROM WIND ACTION

Solar trackers are working outside, with the main loads coming from wind. Wind action is evaluated by pressures or by forces; its effect on structures is depending on wind parameters (mean velocity, turbulence characteristics, dynamic factor), structure characteristics (shape, size, orientation) and location [5] - [9].

Standards like EN 1991-1-4 [5] and ASCE/ SEI 7-05 [6] present calculus procedures related to the wind loads determinations. There is also a specific Romanian standard [7], based on EN 1991-1-4. The Spanish Standard NBE-AE 88 [8] presents a model of wind action on inclined open surfaces very similar with the tracking systems for PV platforms. All these standards can be used to determine wind load on tracked PV platforms, even if they are not especially dedicated.

Following, the most relevant aspects of [5] and [6] for determining wind loading on open tilted surfaces are presented.

The wind force F_w acting on a structure or a structural component may be determined, according to Eurocode 1 [5], for a height less than 15 m, by using expression

$$\mathbf{F_w = c_f \cdot q_p \cdot A_{ref}}, \tag{1}$$

where: c_f is the force coefficient; q_p – velocity pressure; A_{ref} - the reference area of the structure or structural element.

The velocity pressure relation is

$$\mathbf{q_p = \frac{1}{2} \cdot \rho \cdot v_p^2}, \tag{2}$$

where v_p is the peak wind velocity and ρ is the air density, which depends on altitude, temperature and barometric pressure to be expected in the region during wind storms. The recommended value for ρ is 1.25 kg/m^3.

From all the analysed standards, the legally applicable in Romania are the European standard (Eurocode) [5] and the Romanian standard [7]. The model given for the buildings roofs is not valid due to the fact that the roof is not considered as an open surface. Models similar with the case of PV platforms are the canopy model - for tilt angle up to 30 degrees, and the signboards model - for vertical positions (90 degrees tilt angle). Due to the limited range of tilt angle, both standards are not covering all the wind load cases for solar tracking platforms.

Russian standard [9] of wind actions on buildings presents distribution of pressure coefficients on the surface of sheds roofs, similar to Eurocode canopies model. As in the previous cases, this case is not covering the whole range of tilt angles needed for the wind action model on tracking PV platforms.

The American standard [6] provides model for tilt angles between 0 and 45 degrees, with values significantly higher than those presented in Eurocode.

Smaller values are presented in the model of NASA report [10], for range of tilt angles of 20 to 6 degrees.

The Spanish Standard NBE-AE 88 [8] presents a model for the whole range of tilt angles (0-90 degrees), with values close to those from Eurocode, for canopies with tilt angles up to 30 degrees. Values of the pressure coefficients are given for different wind direction (front wind or back wind) and wind angles α (see the diagram from Fig. 2. and values from Table I) [8]. This is covering the whole cases specific to tracking systems [11].

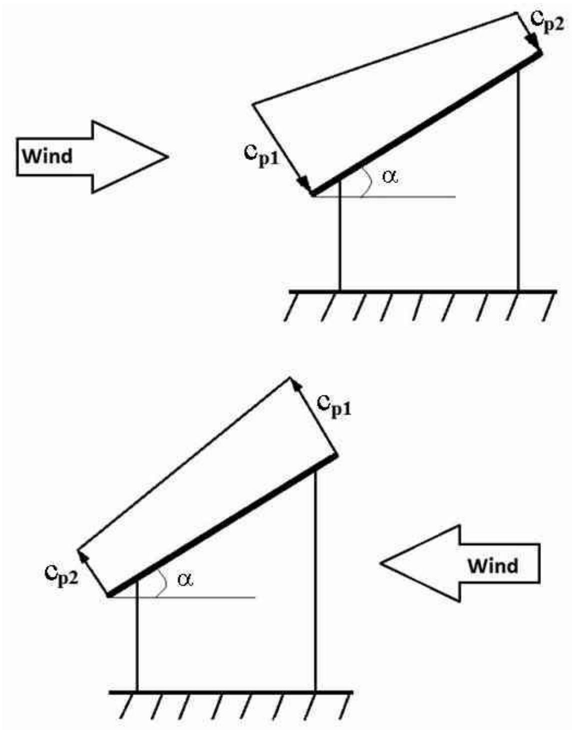


Fig. 2. Pressure coefficients and distribution diagram on PV platforms.

TABLE I
PRESSURE COEFFICIENTS FOR OPEN PLATFORMS

Symbol	Value						
α (degrees)	0	10	20	30	40	50	60-90
c_{p1}	0	0.8	1.2	1.6	1.6	1.4	1.2
c_{p2}	0	0	0.4	0.8	0.8	1.0	1.2

In the general case of trapezoidal distribution of pressure, the force coefficient can be calculated based on the limit pressure coefficients c_{p1} and c_{p2} (see Fig. 2) with relation

$$\mathbf{c_f = \frac{(c_{p1} + c_{p2})}{2}}. \tag{3}$$

The tilt angle mentioned in all standards is actually the wind angle (angle between wind direction and structure surface) considering the horizontal direction of the wind. Wind angle is not always the tilt angle of the platform. Even for horizontal terrain, there can be consider a deviation of wind direction of ±10 degrees relative to the horizontal direction [8]. It must also be consider the case of lateral wind, when wind angle has nothing to do with the tilt angle of the platform. This is why the angle α from Table I is the wind angle and must not be assimilated with the tilt angle or elevation orientation angle α* of the platform of the tracker (see Fig. 1).

III. Wind Load Cases

The calculus of the platform of a tracking system should be the starting point for dimensioning the structure [4] due to the fact that the weight of the platform will further influence all the other calculations.

The main load cases for platform dimensioning must consider the wind angle towards the platform, wind velocity and wind direction. The system must track the sun for a limited wind velocity v_{lim}. For higher wind velocity, the system takes a safety position with horizontal platform. In the safety position, wind load must consider the maximum peak wind velocity v_{max} (maximum wind velocity on the specified region over the last 30 years, according to Eurocode 1 [5]). The limited wind velocity v_{lim} should be around half of the maximum peak wind velocity v_{max} given by standards.

Based on a comparison between all possible loading cases, looking for maximal loads resulted from specific platform positions, wind angle, direction and velocity, the following Load Cases (LC) have been determined for calculus of platforms (Fig. 3.):

1) LC1 – vertical platform, wind angle 90 degree, Oy direction, constant pressure, peak wind velocity $v_p = v_{lim}$ (LC1a – front wind, LC1b - back wind);
2) LC2 – vertical platform, wind angle 30-40 degrees, lateral wind Ox direction, trapezoidal pressure, peak wind velocity $v_p = v_{lim}$ (LC2a – lateral front wind, LC2b – lateral back wind);
3) LC3 – tilted platform, wind angle 30-40 degrees, Oy direction, trapezoidal pressure, peak wind velocity $v_p = v_{lim}$ (LC3a – front wind, LC3b – back wind);
4) LC4 – safety position horizontal platform, wind angle 20 degrees, upside, Oy direction, trapezoidal pressure, peak wind velocity $v_p = v_{max}$; and
5) LC5 – safety position horizontal platform, wind angle 20 degrees, upside, lateral wind Ox direction, trapezoidal pressure, peak wind velocity $v_p = v_{max}$.

The coordinate system of the platform is the one presented in Fig. 1. The dimensions of the platform are: V – vertical dimension and H – horizontal dimension.

IV. Design Example. Conclusion

The general embodiment solution of the azimuthal tracking system with one slew drive and one linear actuators developed at the Solar Park of ProDD Research Institute of Transilvania University of Braşov is presented in Fig. 4. (a – 3D model, b and c – views of the physical prototype. Design stages are presented in [4].

The tracker is consisted of a fixed pillar 1, on which the slew drive 2 is assembled. On the driven part of the slew drive, the rotational element 3 is assembled creating the azimuthal (vertical) rotational axis. The horizontal rotational axis is made between element 3 and platform 6, with bearings 5. 3D modelling of the tracker is an instrument for optimization, allowing easy analysis and simulation of different solutions [12].

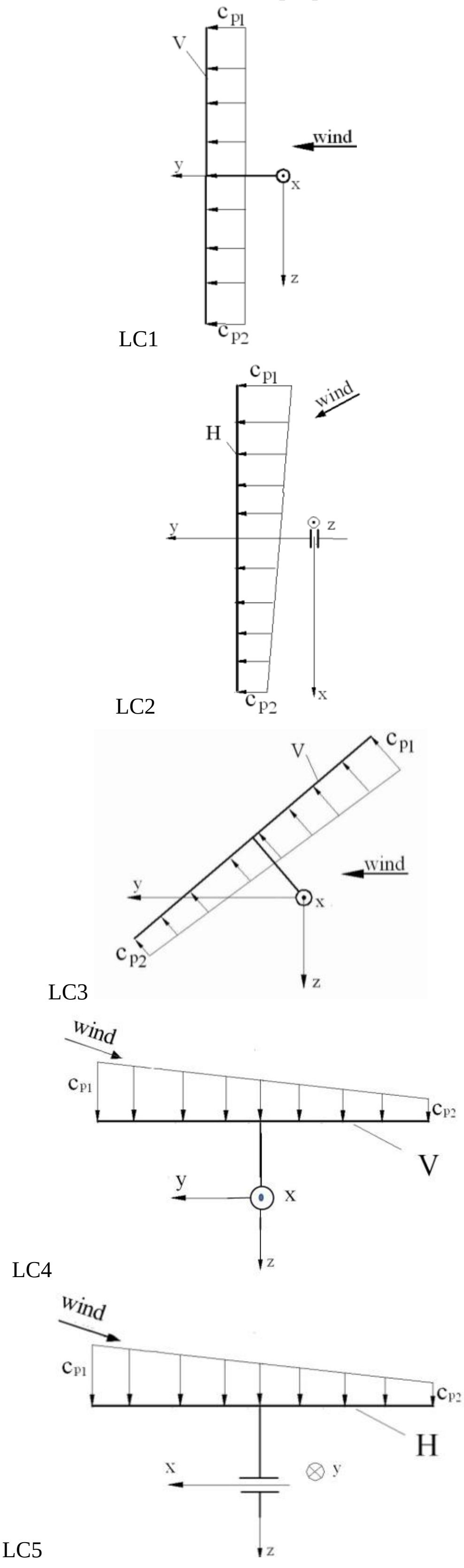
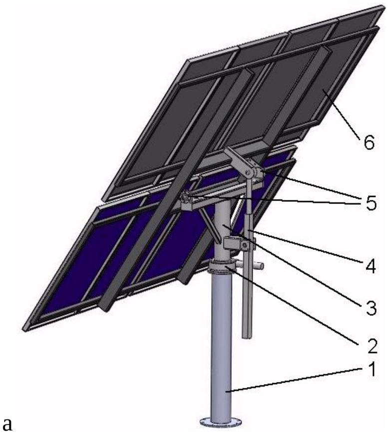


Fig. 3. Wind load cases for PV platforms calculus.

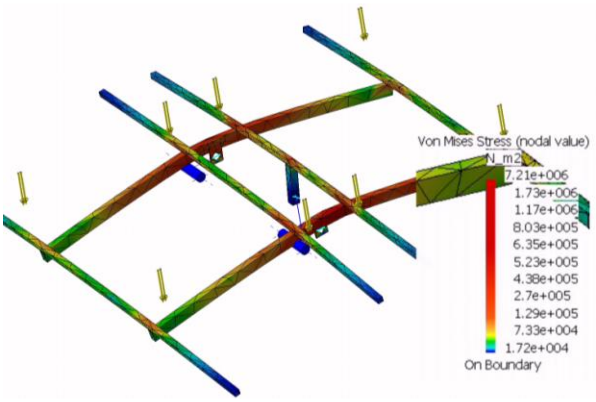
For example, Fig. 5 presents the results of FEM analysis on the beam structure of the platform for LC1a (a–Von Misses stresses, b–translational displacements).



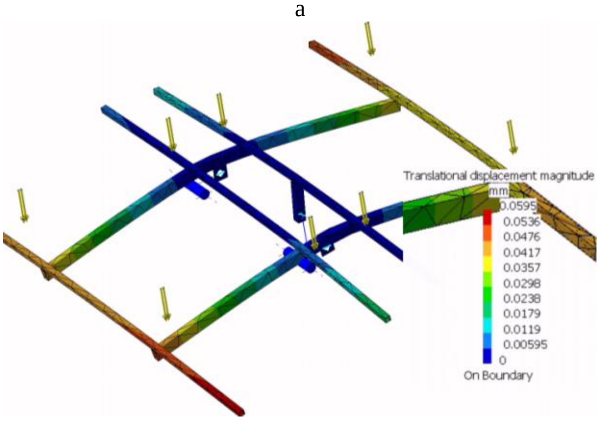
a

b c

Fig. 4. Components of the azimuthal tracker driven by one slew drive and one linear actuator.



a



b

Fig. 5. FEM Analysis.

Materials and sections of the beams of the platform structure must be chosen from conditions of strength and stiffness. FEM analysis of the platform has the aim of checking the structure for maximum stresses and for maximum deformations. It must be performed for all the wind load cases presented above, considering also the dead weight of the structure.

REFERENCES

[1] H. Mousazadeh, "A review of principle and sun-tracking methods for maximizing solar systems output," *Renewable and Sustainable Energy Reviews*, no. 13, 2009, pp 1800-1818.
[2] T. Huld, M. Suri, D. Dunlop, "Comparison of Potential Solar Electricity Output from Fixed-Inclined and Two Axis Tracking Photovoltaic Modules in Europe," *Progress in Photovoltaics: Research and Applications* 16, 2008, pp. 47-59.
[3] R. Messenger, J. Ventre, "Photovoltaic Systems Engineering", 2nd ed., London. CRC Press, 2004, pp. 179-189.
[4] R. Velicu, "Dual axes PV tracking system with rotational and linear actuators," *Annals of the Oradea University. Fascicle of Management and Technological Engineering*, vol. X (XX), no. 1, 2011, pp. 115–120.
[5] EN 1991-1-4, "Eurocode 1: Actions on Structures. General Actions - Part 1-4: Wind Actions," 2004.
[6] ASCE/SEI 7-05, "Minimum Design Loads for Buildings and Other Structures," *American Society of Civil Engineer*, 2006.
[7] NP-082-04, "Eurocode 1: Design Code. Bases of Design and Actions on Buildings. Action of Wind," 2004 (in Romanian).
[8] NBE-AE/88, "Actions on structures," 1988 (in Spanish).
[9] GOST 27751-88 P.5, "Wind Loads. Annex 4," (in Russian), 1988.
[10] R. D. Miller, O. K. Zimmerman, "Wind Loads on Flat Plate Photovoltaic Array Fields," *Boeing Engineering and Construction*, 1981, pp. 94–97.
[11] I. Scaletchi, I. Visa, R. Velicu, "Modeling Wind Action On Solar Tracking PV Platforms, "*Bulletin of The Transilvania University of Brasov, Series I - Engineering Sciences*, vol.3 (52), 2010, pp. 115–122.
[12] C. C. Gavrila, "A Transversal Coupling 3D Modeling," *Annals of the Oradea University, Fascicle of Management and Technological Engineering*, vol. XII, (XXII) 2013, no. 1, 2013, pp. 133–137.