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DUAL AXES PV TRACKING SYSTEM WITH ROTATIONAL AND LINEAR ACTUATORS

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Abstract: The tracking systems for PV platforms must allow an accurate positioning of the PV panels towards the sun moving on the sky. The dual axes azimuthal solar tracking system which is the subject of this paper allows two independent rotational movements related to the following axes: a vertical axis for the azimuthal rotation (driven by a rotational actuator) and a horizontal axis for the altitudinal rotation (driven by a linear actuator). This paper is presenting the construction of the PV tracking system and some of the main issues that must be solved in the design of such a tracking systems.

1. INTRODUCTION

PV platforms are an important category with technological and economical implementation possibilities with a great potential of reducing the consumption based on fossil fuels. They are increasingly used to convert solar energy into electric energy, by photovoltaic effect.

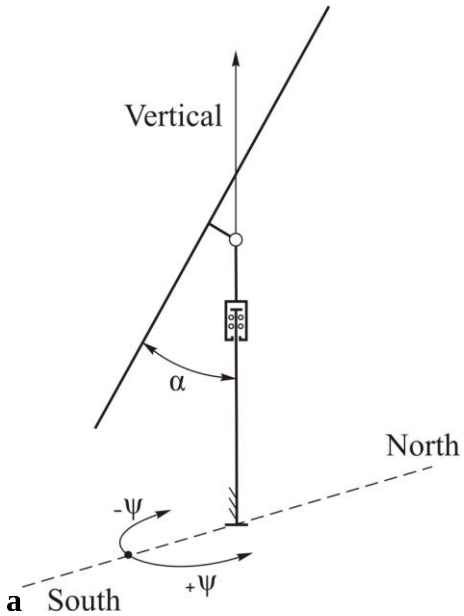
The tracking systems must allow an accurate positioning of the PV platforms towards the sun for maximizing the radiation falling, ideally perpendicularly, on the PV surface. For maximizing the quantity of solar radiation received by the platform surface, dual axes solar tracking systems are mostly used, an energetic increase up to 40% [3, 5] being achieved. Therefore, the interest in research, innovation and implementation of dual axes systems becomes higher.

This paper is presenting the construction of a dual axes tracking system called azimuthal tracker [6]. Figure 1,a presents the general diagram of an azimuthal tracker. It has two rotational axes: a vertical fixed axis and a horizontal mobile axis. Rotation around the vertical (azimuthal) axis is setting the azimuthal ψ orientation angle and rotation around the horizontal (elevation) axis is setting the α elevation orientation angle. Rotations around both axes must be performed in several sequences during each day, for a precise daily solar tracking.

The design process involves some particular elements coming from the fact that the tracker is 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.) acting on specific loading cases. The embodiment design must be developed considering the safety and dimensioning rules imposed by both civil engineering (Eurocode - building constructions) and mechanical engineering.

2. CONSTRUCTION OF AN AZIMUTHAL TRACKER WITH ROTATIONAL AND LINEAR ACTUATOR

The azimuthal tracking system with one slew drive and one linear actuators has been developed at the Solar Park of ProDD Research Institute of Transilvania University of Braşov. The elements of the general embodiment solution are presented in Figure 1,b.



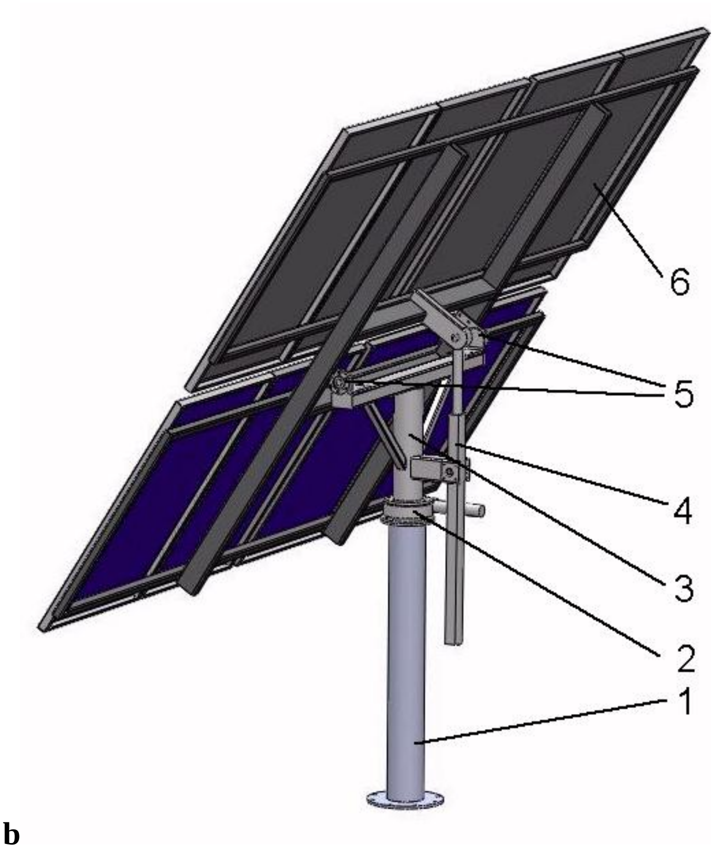


Figure 1. Azimuthal solar tracking system (a- general diagram, b- construction of tracker driven by one slew drive and one linear actuator)

The construction stays on a fixed pillar 1, on which the slew drive 2 is assembled. The slew drive is an assemble electrical motor - speed reducer with warm gear. On the driven part of the slew drive, the rotational pillar 3 is assembled. The azimuthal (vertical) rotational axis is created and actuated by the slew drive 2. The horizontal rotational axis is made between element 3 and platform 6, with bearings 5. The platform has a structure made with aluminium rectangular tubes, while the rest of the structure (elements 1 and 3) is made of steel.

The seasonal movement (angle α – see Fig. 1,a) is performed with the screw-nut linear actuator 4, with the cylinder attached with a bearing to the rotational element 3 and with the head of the piston attached to a bearing on the platform 6. Both bearings are sliding bearings

The construction of the azimuthal (vertical) rotational axis is based on a special bearing, as seen in Figure 2. The bearing makes the link between the two rotating elements of the slew drive (warm wheel on the bottom side and pinion with attached casing on the upper side). Such a bearing is taking not only radial and axial forces (F_{rad}, F_{ax}) but also a tilting moment M_k.

Figure 3 presents a longitudinal section through the bearings of the seasonal rotational axis. Double sealed self aligning ball bearings are used for this rotational axis. The section from figure 7, presents only the left bearing of the bearing mounting. As it can be seen from the bearing mounting diagram, the system is axially fixed at one side (left side), while the other side is axially free. The right side is basically identical with the left side excepting the shoulder and the elastic ring holding the outer ring of the self aligning ball bearing.

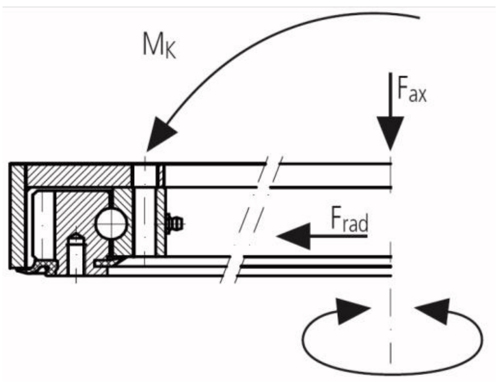


Figure 2. Azimuthal rotational axis

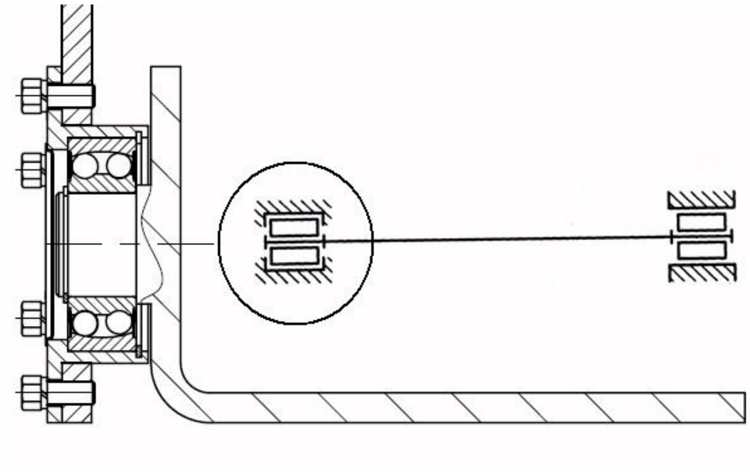


Figure 3. Elevation rotational axis

3. ELEMENTS OF EMBODIMENT DESIGN

The embodiment design [4] of such a structure starts from product design specifications (PDS). The main elements of the PDS are the following:

- The system is treated as a civil engineering construction since it will be placed outside, part of a solar park;
- As a mobile system it should have a safe functioning between precise determined static positions;
- The material is common steel for the main structure and aluminium for the support of the PV panels;
- The tracker has a medium size (approx. 1.5 – 2 kWp) with a platform thet must sustain 8 PV panels, interchangeable, with dimensions l x L in the range: l = 850...1000 mm; L = 1400...1600 mm, so l_{max} = 1000 mm and L_{max} = 1600 mm; panels will be placed on two rows of four resulting a maximum vertical dimension V = 2L = 3200 mm and a maximum horizontal dimension H = 4l = 4000 mm;
- There are considered the specific loads of the Braşov region, where the tracker will be placed: maximum wind speed v_{max} = 30 m/s, elements of seismic loads (max. 7.5 Richter, top period T_s = 0.7 s, seismic coefficient k_s = 0.2);
- For the 45° latitude (location of Braşov), the platform must be rotated on the following ranges of the two angles: α = 0 … 67.5°, ψ = -90 … 90°;
- Considering wind action as creating the main loads on the structure, a safety position with horizontal platform (α = 90°) must be performed in case of high wind velocity;
- The temperature range of mobility is -5 … 50°, but with minimum temperature (static position) of -30°.

A tracking program must determine the position of the platform, for each moment during an year, in order to get higher conversion efficiency. It is ideal to position the panels surface perpendicular to sunrays, but this is only possible with continuous movement around the two axes of the tracker. The common solution is tracking in sequences (higher number of sequences for summer season than for winter and higher number of sequences for azimuthal rotation than for elevation rotation).

Solar trackers are working outside, with the main loads coming from wind.

The wind force Fw acting on a structure or a structural component may be determined, according to Eurocode 1 – Wind actions [2], for a height less than 15 m, directly by using expression

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

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

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

where v_p is the peak wind velocity and ρ is the air density, which depends on the 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.

EN 1991-1-4 [2] standard presents calculus procedures related to the wind loads determinations, without covering the specific case of trackers. The Spanish Standard NBE-AE 88 [1] presents a model of wind action on inclined open surfaces very similar with tracking systems. Values for pressure coefficients are given for different wind direction and angle between wind direction and platform surface (see the calculus diagram from Figure 2). Wind angle is not necessarily the tilt angle of the platform.

In the general case of trapezoidal distribution of pressure, the force coefficient can be calculated depending on the limit pressure coefficients c_{p1} and c_{p2} (see Fig. 4) with relation

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

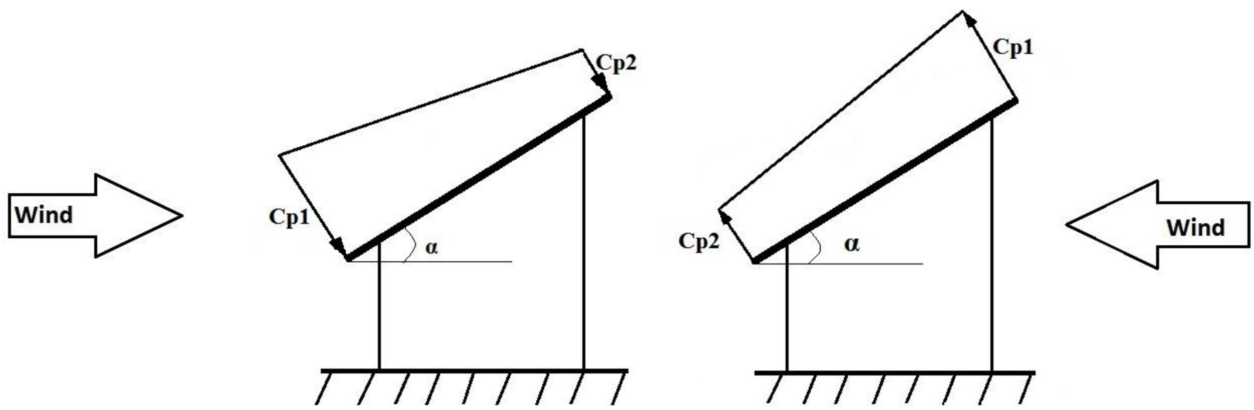


Figure 4. Pressure coefficients and distribution diagram on PV platforms

For the location of this tracker in Braşov, Romania, the system must track the sun for a maximum wind velocity of 15 m/s. For higher wind speed, the system must take a safety position with horizontal platform. In this position, it must take wind load considering the peak wind velocity (of 30 m/s on the specified region over the last 30 years, according to Eurocode 1 – Wind actions [2].

The weight of the panel together with all the parts (frame) directly attached to the panel is G = 2800N. Weight of the mobile part (platform) must be as smaller as possible in order to diminish the loads on elements.

The main loading cases [6] for structure dimensioning must consider the tilt angle of the platform, wind velocity and wind direction. Based on a comparison between all possible loading cases, four Loading Cases have to be considered for these constructions of trackers (Figure 3):

- LC1 - vertical platform, back wind perpendicular - constant pressure, wind angle 90°, peak wind velocity v_p = 15 m/s;
- LC2 - vertical platform, back wind lateral - trapezoidal pressure, wind angle 50°, peak wind velocity v_p = 15 m/s;

- LC3a - horizontal platform, front wind lateral Oy direction - trapezoidal pressure, wind angle 20°, peak wind velocity v_p = 15 m/s;
- LC3b - horizontal platform, front wind lateral Oy direction - trapezoidal pressure, wind angle 20°, peak wind velocity v_p = 30 m/s;
- LC4a - horizontal platform, front wind lateral Ox direction - trapezoidal pressure, wind angle 20°, peak wind velocity v_p = 15 m/s.
- LC4b - horizontal platform, front wind lateral Ox direction - trapezoidal pressure, wind angle 20°, peak wind velocity v_p = 30 m/s.

As it can be seen, only the extreme positions of the platform determine the peak loads. There can be defined static situations (when there is no movement on actuators) and dynamic situations (when there is movement on actuators). Loading cases LC1 and LC2 refer to both dynamic and static situations, while LC3a and LC4a refer to dynamic situations LC3b and LC4b only refer to static situation.

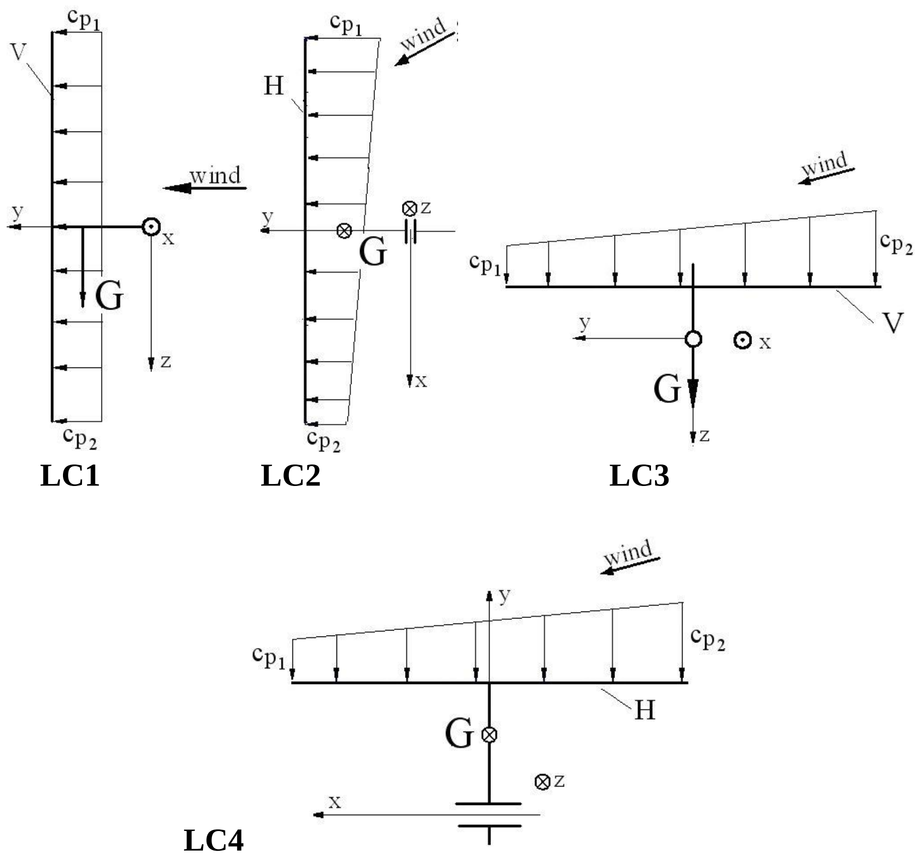


Figure 4. Main loading cases of PV trackers

4. CONCLUSION

Based on the above presented elements of embodiment design of azimuthal trackers, few conclusions can be drawn:

- Outside working conditions, relative low rotational speed, impose very simple bearing solutions, reliable but also with less maintenance;
- Only static calculations must be performed for the elements of the tracker; bearing must be calculated based on static loading capacity;

- Loads on bearings are very different depending on working position, wind speed and direction. There are situations with important radial forces and very small axial forces and in other situations the axial forces are important with no radial forces.
- Very high tilting moments and also axial forces on the azimuthal rotational axis of azimuthal trackers impose special constructions. The solution from figure 8, even if reliable and simple, is less used since the existing constructions of slew drives (see fig. 6) assure a reliable solution of rotational axis, together with a low speed actuator;
- For azimuthal trackers, the bearings from the elevation rotational axis (Figure 7) are subject to important radial forces and no axial forces;
- High tilting moments on the horizontal axis of azimuthal trackers impose higher distance between bearings (solution from Figure 7). In this case, since there are no axial forces, radial deviations of the two bearings can be compensated by using self aligning bearings, bearings with lower capacity to take axial forces;
- When structures are using materials with different thermal elongation coefficients, due to temperature differences between seasons, bearing mountings most compensate thermal elongation (Figure 7).

These conclusions are mended as guidance for designers of azimuthal tracking systems.

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