DUAL AXES PV TRACKING SYSTEM DRIVEN BY ONE LINEAR ACTUATOR

Radu Velicu[1]
[1]Transilvania University of Braşov, Department of Product Design and Robotics,
rvelicu@unitbv.ro

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Abstract: The dual axes solar tracking system which is the subject of this paper allows two linked rotational movements related to the following axes: a vertical axis for the azimuthal rotation and a horizontal axis for the altitudinal rotation. It uses only one linear actuator in order to perform the rotation around the vertical axis (input) and a closed chain in order to link the rotation around the horizontal axis to the input rotation. This paper is presenting the construction of the PV tracking system and some of the main aspects that must be considered in the design of such a tracking systems.

1. INTRODUCTION

The PV tracking systems are used with the PV platforms in order to maximise the conversion of solar energy into electric energy, by photovoltaic effect. They 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.

This paper is presenting the construction of a dual axes tracking system called azimuthal tracker [6]. Figure 1,a presents the general diagram of a dual axes 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. In the case of the azimuthal tracker which is the subject of this paper, the two rotations are coupled by a closed linkage. The driving rotation is the azimuthal one while the elevation rotation is depending on it. Input rotation must be performed in several sequences during each day, for a precise daily solar tracking.

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.

2. CONSTRUCTION OF AN AZIMUTHAL TRACKER DRIVEN BY ONE 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.

The construction stays on a fixed pillar 1. The mobile rotational pillar 2 can rotate relative to the fixed pillar, creating the azimuthal (vertical) rotational axis. The horizontal rotational axis is made between element 2 and platform 3, with bearings 4. The platform 3 has a structure made with aluminium rectangular tubes, while the rest of the structure (elements 1 and 2) is made of steel.

The platform is attached to the ground through the beam 5 and two spherical joints 6. Pillar 7 is fixed on the ground.

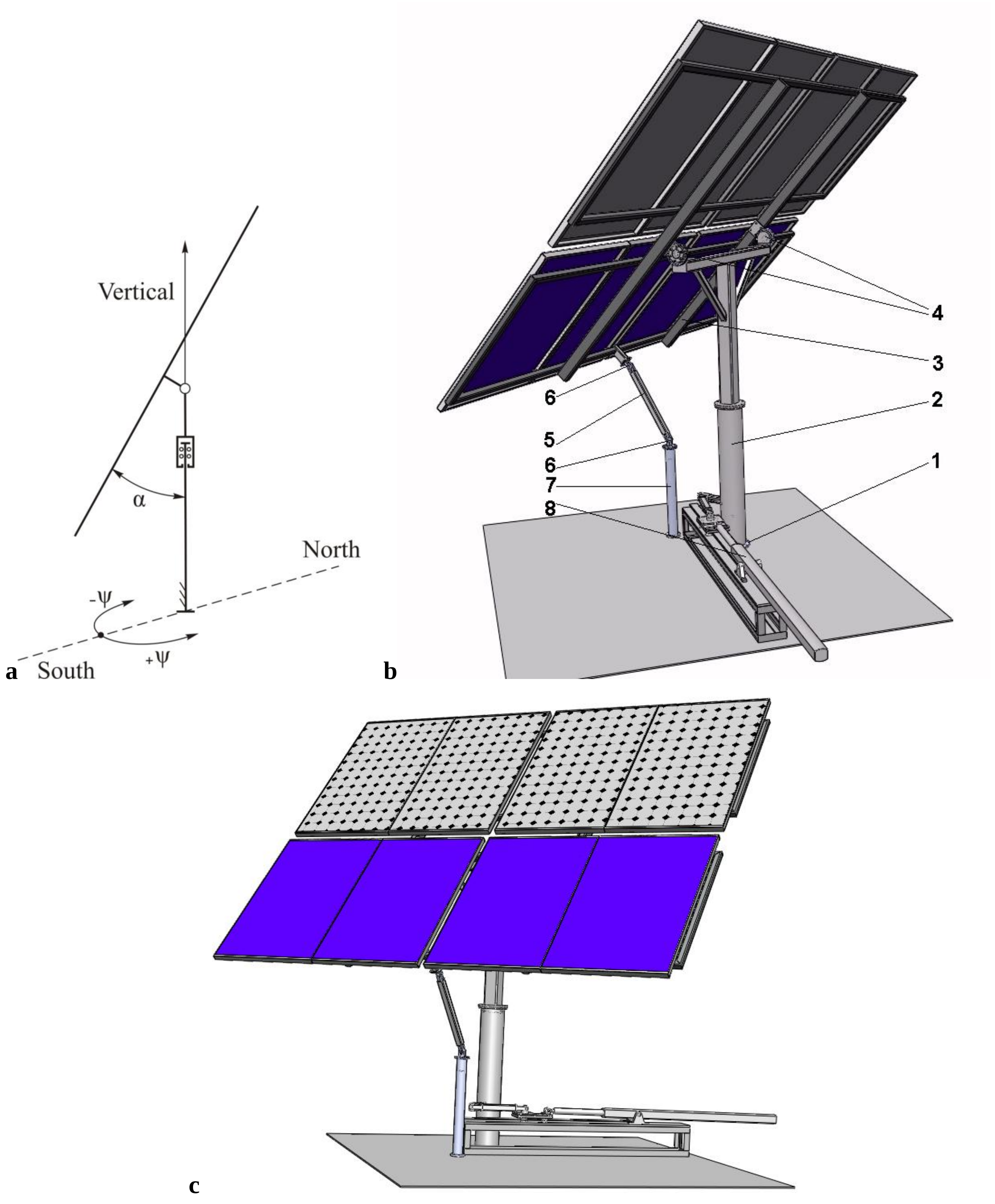


Figure 1. Azimuthal solar tracking system (a- general diagram, b, c - construction of tracker driven by one linear actuator)

The system is driven by the linear actuator 8, acting on the rotational pillar 2 with a crank mechanism. Figure 2 presents the construction of the driving system. It is raised from the ground on a metallic support 9 on which the linear guide 10 is placed. The linear actuator is attached with a rotational joint 11 on the metallic support and with another rotational 12 on the carrier of the linear guide. The rotational joints 13 and 14 of the crank mechanism are simple bolt joints.

Figure 3 shows the construction of the bearing mounting from the vertical (azimuthal) rotational axis between the fixed pillar 1 and the rotational pillar 2. It's an "O" mounting using two double sealed radial ball bearings (A and B). Bearing B is mainly taking an axial load coming from the weight of the structure. The main load on bearing A is a radial load coming from wind action on the platform.

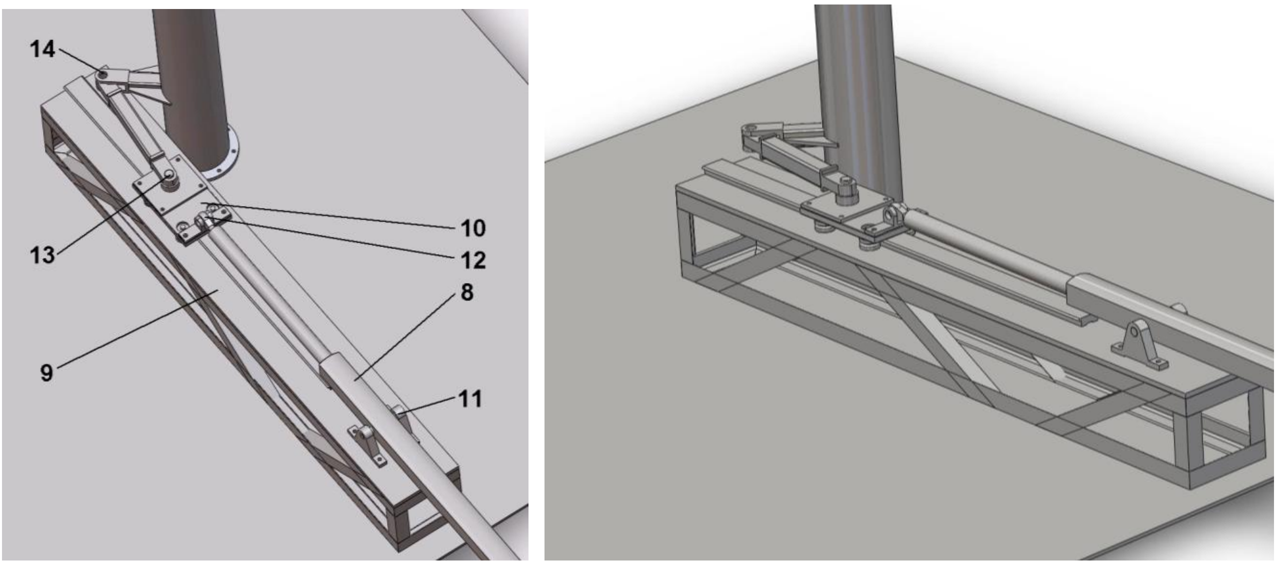


Figure 2. Driving system

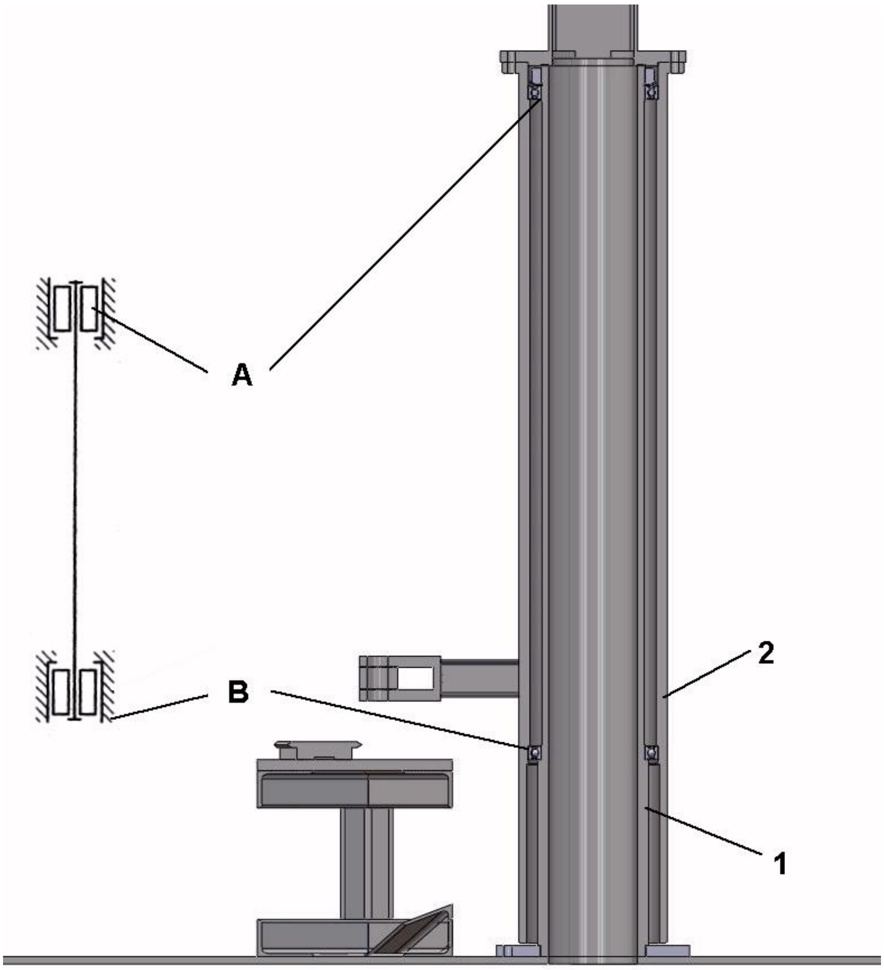


Figure 3. Azimuthal rotational axis

Figure 4 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.

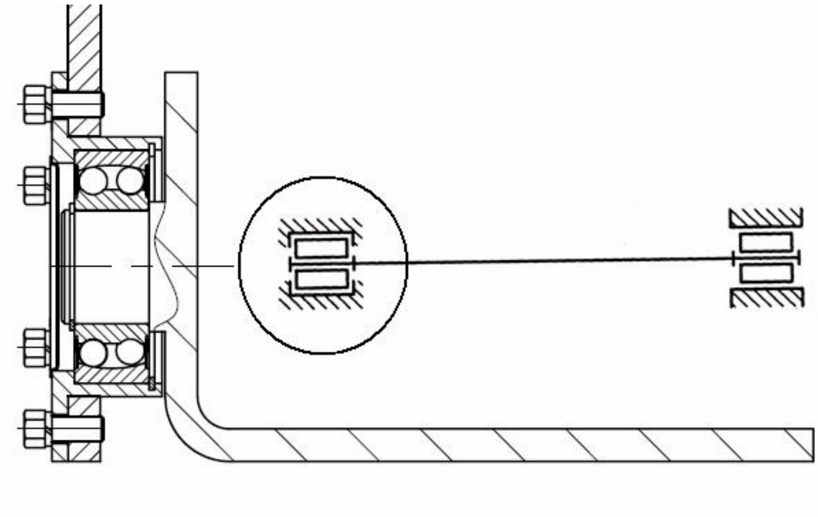
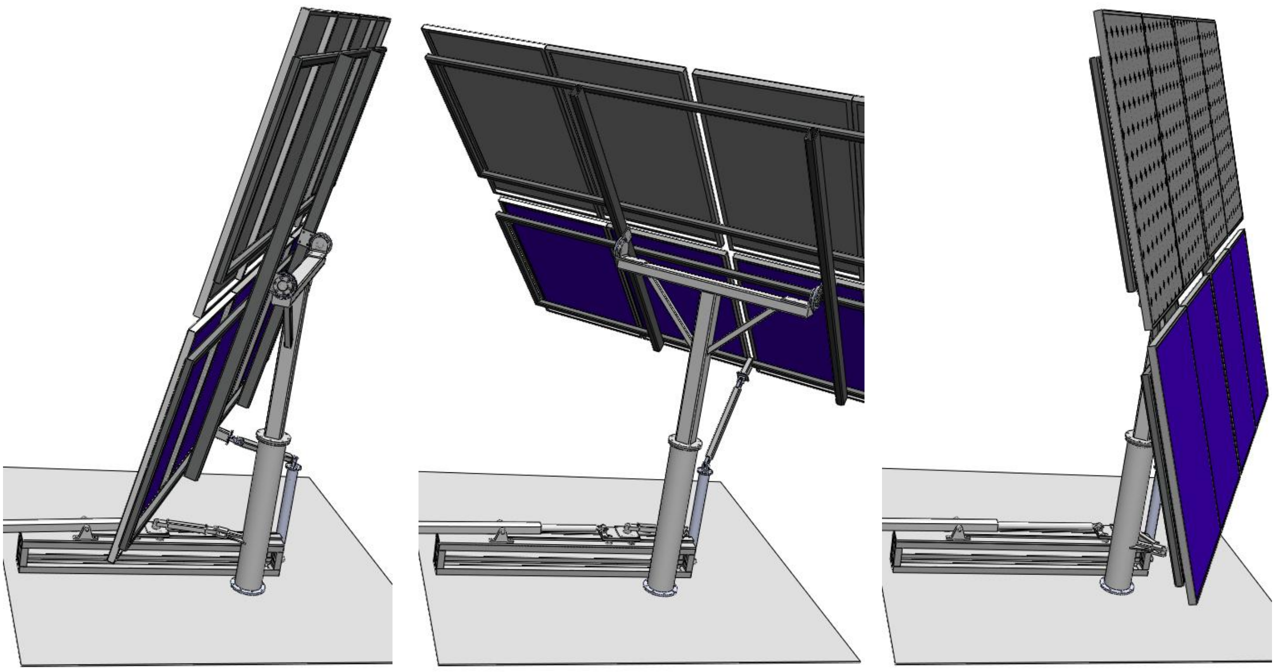


Figure 4. Elevation rotational axis

Figure 5 presents three extreme positions of the tracker: a – sunrise (platform oriented to east), b – noon (platform oriented to south), c – sunset (platform oriented to west).



a b c

Figure 5. Extreme positions of the tracker (a – sunrise, b – noon, c – sunset)

3. ELEMENTS OF EMBODIMENT DESIGN

A tracking program must determine the position of the platform, for each moment during an year, in order to get higher conversion efficiency. Dimensions of the closing link must be chose according to this. The common solution is tracking in sequences. Tilt angle of the platform varies in the range: α_{min} =15º, α_{max} =50º.

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

The wind force F_w 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

$$F_w = \frac{1}{4}(c_{p1} + c_{p2})\rho v_p^2 A_{ref}, \quad (1)$$

where: $c_{p1,2}$ are the limit pressure coefficients; ρ is the air density, which depends on the altitude, temperature and barometric pressure; v_p is the peak wind velocity; A_{ref} - the reference area of the structure or structural element.

Since EN 1991-1-4 [2] standard is not covering the specific case of trackers, the tracker designers refer to the Spanish Standard NBE-AE 88 [1] which 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 6).

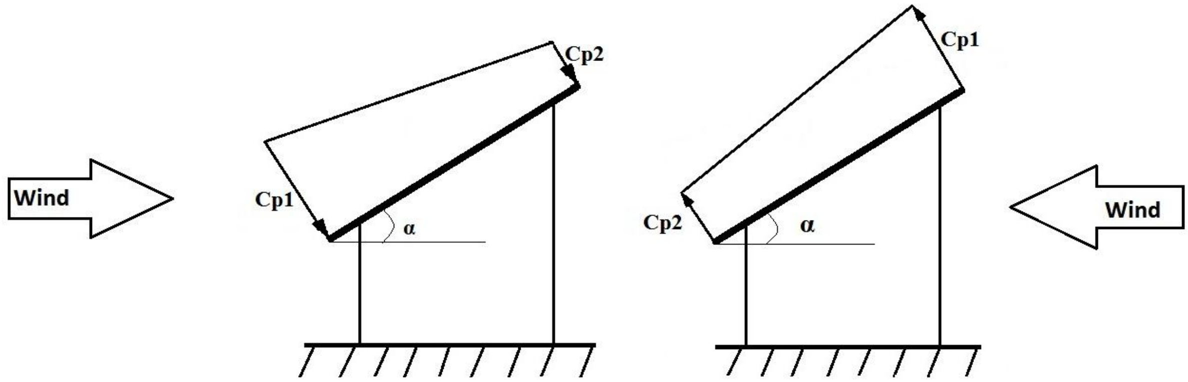


Figure 6. Pressure coefficients and distribution diagram on PV platforms

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 the safety position which is orientation to south. 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 main loading cases for structure dimensioning must consider the tilt angle of the platform, wind velocity and wind direction [6]. Based on a comparison between all possible loading cases, four Loading Cases have to be considered for these constructions of trackers (Figure 7):

- LC1a – platform with tilt angle α_{min} =15º, back wind, peak wind velocity v_p = 15 m/s (see Figure 7, a);
- LC1b – platform with tilt angle α_{min} =15º, side wind, peak wind velocity v_p = 15 m/s (see Figure 7, b);
- LC2a – platform with tilt angle α_{min} =50º, back wind, peak wind velocity v_p = 30 m/s (see Figure 7, a);
- LC2b – platform with tilt angle α_{min} =50º, back wind, peak wind velocity v_p = 30 m/s (see Figure 7, b).

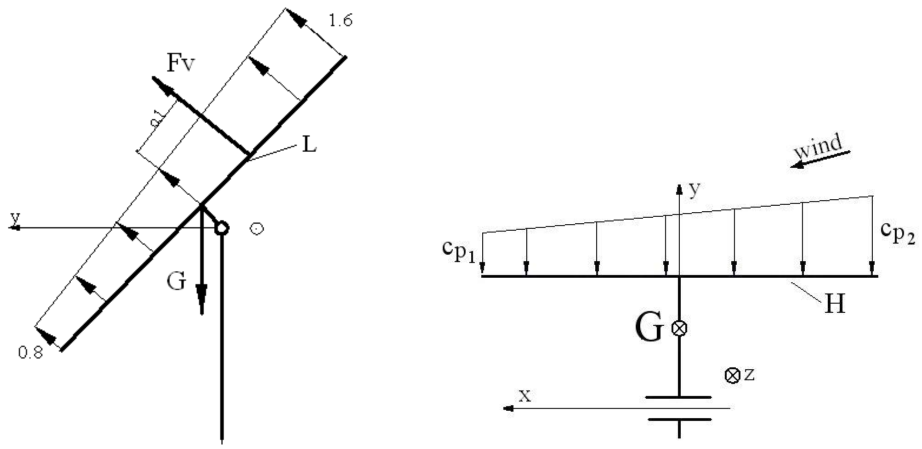


Figure 7. Main loading cases of PV trackers

4. CONCLUSION

Based on the above presented elements of embodiment design of azimuthal trackers [4], 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. For the bearings of the vertical (azimuthal) axis there are situations with important radial axial forces (loading cases LC1a, LC1b, LC2a and LC2b) and in other situations the axial forces are important with no radial forces (when wind speed is zero).
- Very high tilting moments and also axial forces on the azimuthal rotational axis (Figure 3) impose large distance between bearings, with bigger radial force on bearing B;
- The bearings from the elevation rotational axis (Figure 4) are subject to important radial forces and no axial forces (loading cases LC1a, LC2a) or radial forces and axial forces (loading cases LC1b, LC2b).

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

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