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SLEWING RINGS FOR LARGE SIZE SOLAR PANELS. A CASE STUDY

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ABSTRACT

This paper presents a computer optimization algorithm for internal geometry of slewing rings manufactured at SIRCA S.A,. already used in large size solar tracker power plant. The model takes into account the sun position on the sky and the wind speed effect. The internal geometry of the slewing ring considers the geographic position of the solar panel by using the specific country solar and wind maps, respectively. The proposed slewing rings for single and double axes solar trackers ensures the optimization of converting the solar energy in electricity by a correct orientation of the PV panel.

Keywords: PV panel, slewing rings, wind speed effect

1. INTRODUCTION

According to Tudorache and Krewindler [1], the solar tracker may be classified as a function of the number of rotation axes and orientation type. From the point of view of number of rotations axes, there are solar tracker systems with one axes and with two axes. With no wind effect, the solar tracker with a single-axes seems to be the best economic solution for small PV power plants. But the wind effect has to be always tacken into account. According to [2], solar PV modules and panels work best when their absorbing surface is perpendicular to the suns incoming rays. The position of the sun in the sky can be plotted using two angles,azimuth and zenith, the angle of the solar panel orientation relying on these two values. From the point of view of the orientation model, there are solar tracker systems with a computed PV panel trajectory and also with online computed trajectory. The last solution may be superimposed with the online wind information, as well as to prevent the panel destruction and the orientation system failure. There are many types of electronic devices used to command the PV panel, as for example, sensors for the light intensity. For a single rotation axes two independent light sensors and separate measurement can be used according to [1]. For two rotation axes PV panel, two devices may be connected. The shadow effect can be used for the two degrees of freedom of the PV. For the large solar tracker power plant, the shadow effect has to be taken into account, especially for large dimension PV panels. According to Groumpos AND Khouzam [3], when the solar array are arranged in multiple rows of panels, the first row suffers a reduction of power output, even when sufficient spacing is provided between rows. The reduction in the output power occurs because the neighbors, especially during sunset and sunrise. The distance between row panels also influences the external load transmitted to the slewing ring when the wind force acts on the panel. This phenomenon is given by a shielding effect [4, 5] and has to be taken into account. According to [6], when designing the site layout, the following aspects are important: choosing row spacing to reduce inter-row shading and associated shading losses, choosing the layout to minimize cable runs and associated electrical losses, allowing for a sufficient distance between rows for access and maintenance purposes, selecting a tilt angle that optimizes the annual energy yield according to the latitude of the site and the annual distribution of solar resource, orientating the modules to face a direction that yields the maximum annual revenue from power production.

Tracking Systems, Solar Resources and Orientation Angles of a PV Panel

Dual-axis tracking systems are able to track the sun more precisely than single-axis systems. Depending on the site and precise characteristics of the solar irradiation, trackers may increase the annual energy yield by up to 27% for single-axis and 37% for dual-axis trackers [6]. Site selection and planning of PV power plants require reliable solar resource data. Power production linearly depends on the plane of array irradiance, at least to a first approximation. The solar resource of a location is usually defined by the values of the global horizontal irradiation, direct normal irradiation and diffuse horizontal irradiation, as defined below. Figure 1, generated by [10], shows the solar path diagram for a specific location on the planet.

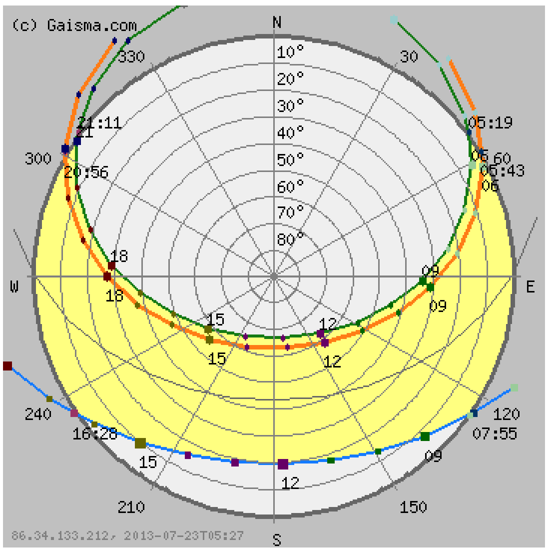
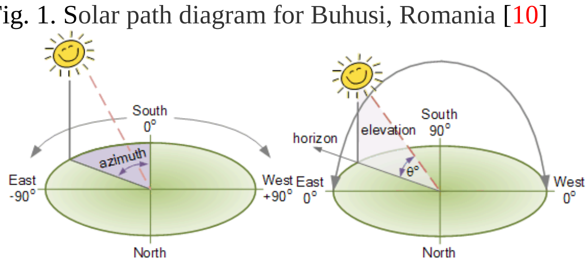


Fig. 1. Solar path diagram for Buhusi, Romania [10]



Azimuth Orientation Zenith Orientation

Fig. 2 [2]

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The solar map include Azimuth and Zenith orientation, as defined in Fig. 2. In this case, the target is Buhusi, a city indentified as latitude +46.71 (46°42'36"N) **and l**ongitude +26.72 (26°43'12"E)

Sun path diagram (also known as "solar path diagram", "sun chart" or "solar chart") is a visualization of the sun's path through the sky. The solar elevation and azimuth over the period of a full year can be plotted onto a solar chart. A sun chart enables to locate the position of the sun at any time of the day, during any month and for any location, making solar panel orientation much easier. This path is formed by plotting azimuth (left-right) and elevation (up-down) angles of the sun in a given day to a diagram [7].

According to diverse studies, the wind and insolation maps are presented in figure 3 and 4, respectively. According to [7], some results are presented in Figures 5 and 6, for the selected location.

Wind Load Calculations on PV Panel

The effect of wind speed in PV panel on the slewing ring, combined with angle for altitudinal rotation is to create axial, radial and tilting moment. The orientation directions are indicated in Figures 7 and 8 and the wind effect in the slewing ring load chart is suggested in Fig. 9.

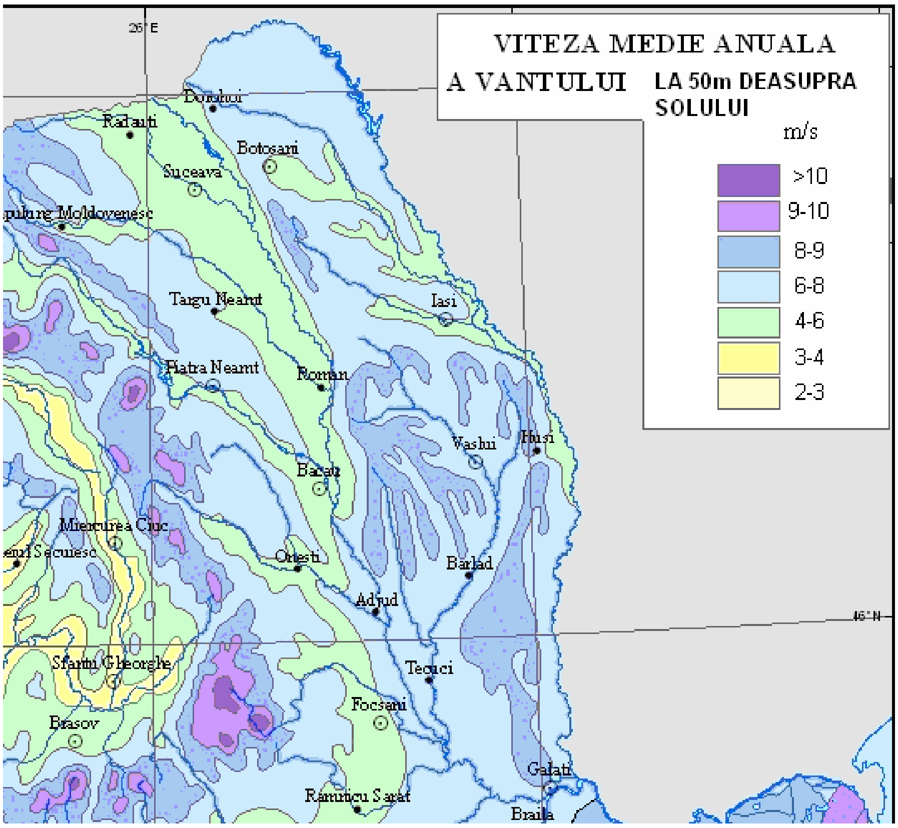

Fig. 3. Wind map. The average wind speed, at 50 m above the sole [8]

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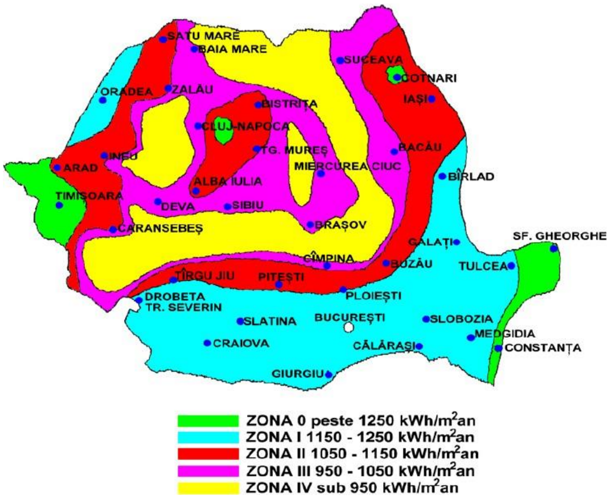

Fig. 4. Insolation map for Romania [9]

According to [4, 5], the wind force effect on a plate positioned perpendicular to the wind direction can be approximate as

$$F_p = A \cdot C_f \cdot q \qquad (1)$$

where F_p is the wind load, in N, A is the effective frontal area of the part under consideration, in m^2, C_f is the shape coefficient in thewind direction for the part under consideration and q is the wind pressure corresponding to the appropriate design condition, in N/m^2. q depends on the wind speed and may have a high value when storm exists. In this case, the maximum surface exposed to the wind effect is given by F and B parameters used to describe the PV panel dimensions, as is indicated in figures 7 and 8 [11]. Usually, $F/B<5$ and, in this case, $C_f \approx 1.2$ [4, 5]. Figure 9 shows a sample from the computer code, developed at Sirca in order to compute the slewing rings used in PV panels. According to [7], the insolation and wind speed is given in Table 1.

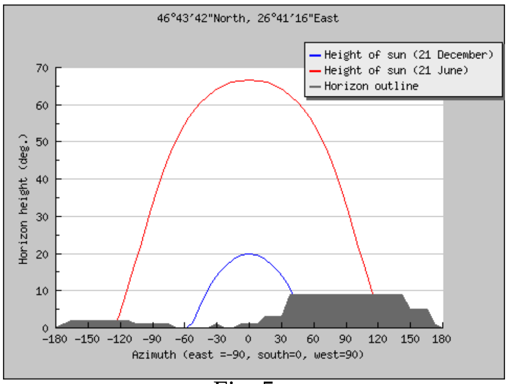

Fig. 5.

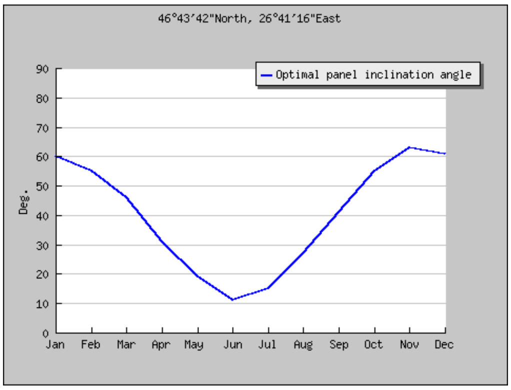

Fig. 6.

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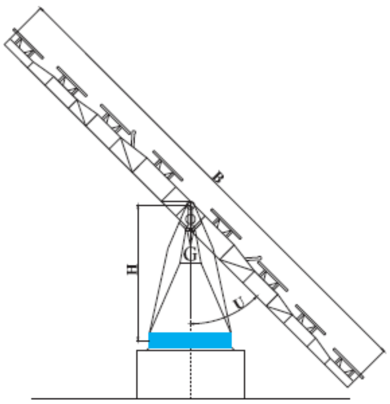

Fig. 7. [11]

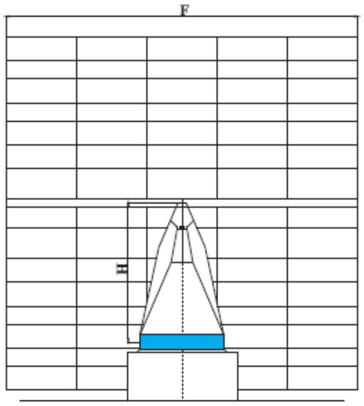

Fig. 8 [11]

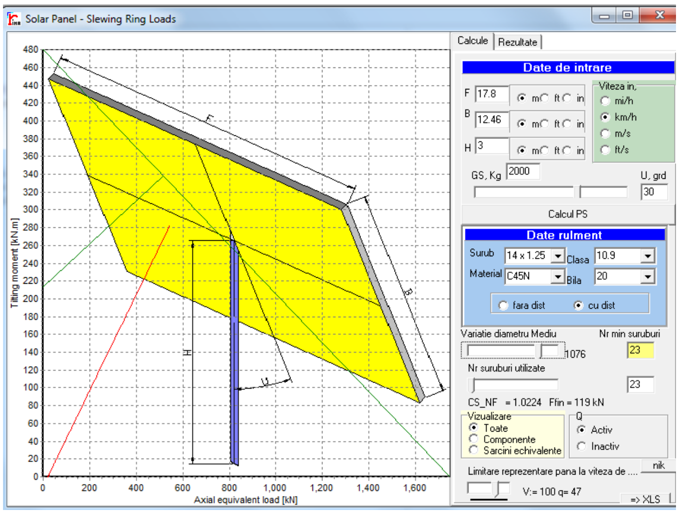

Fig. 9. Example of analysis for the wind speed of 100 km/h

Table 1. These data were obtained from the NASA Langley Research Center Atmospheric Science Data Center; 2002 [7]

Month	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Insolation, $kWh/m^2/day$	1.22	1.96	2.90	3.92	5.05	5.36	5.40	4.79	3.33	2.17	1.30	0.97
Wind speed, m/s	6.33	6.33	6.86	5.95	5.10	4.97	4.56	4.61	4.97	6.35	6.25	6.49

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The relation between the wind speed, in km/h, and the dynamic pressure of the wind, in N/m^2, is

$$q = 0.048 \cdot v^2 \qquad (2)$$

Usually, the maximum wind speed values are 2,5 times greater than the normal wind speed, for the red and orange codes. For Buhusi area, the maximum wind speed for orange code is 60 km/h. With all these assumptions and considering the optimal panel inclination angle (acute angle between wind and surface), it results that maximum force acting on the PV panel due to the wind and the solar panel inclination can be approximated as:

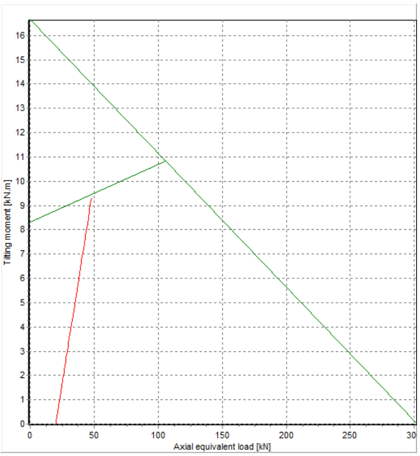
$$F = F_p \cdot cosU \qquad (3)$$

where U=π/2 – the tilt angle.

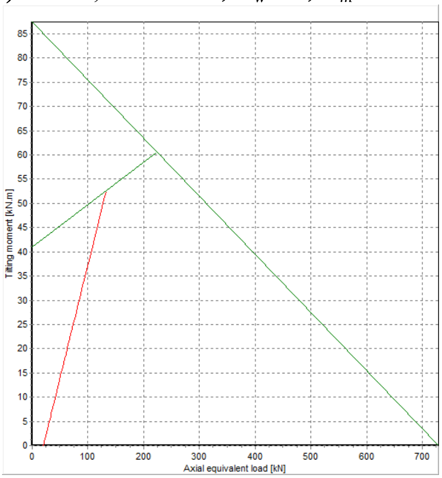
There are many studies regarding the forces acting in PV panels, as for example [12-14]. If F=17.8 m, B=12.46 m, H=3 m, G_p=2000 kg, the wind speed and tilting PV panel produce a load distribution that can be supported by a slewing ring having the pitch diameter D_m as is presented in Fig. 10.

Discussions and Conclusions

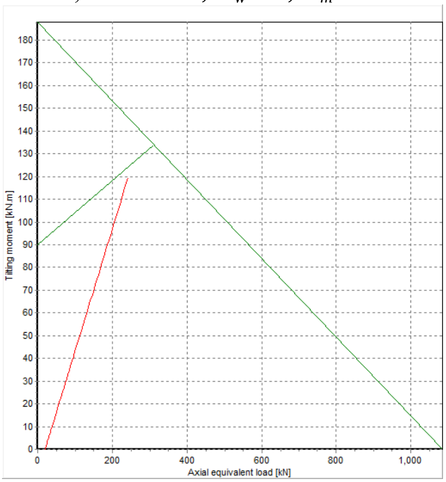
A computer code was developed at SIRCA in order to assist PV panel projecting process, taking into account the GPS target (Buhusi, in this case), using the meteorological data. The computer code takes into account the PQS analysis. Wind speed, GPS position of a target and the Zenith orientation influence the base slewing ring dimensions. The computer program assists the technical projections and can assure a low cost project for the mechanical structure. Figure 9 shows a print-screen from the program, for U=30°, v=100 km/h, D_w=20. In this case, the slewing ring diameter has to be around 1076 mm. For latitude +46.71 (46°42'36" N) and



a) U=76°, v=60 km/h, D_w=20, D_m=200



b) U=55°, v=60 km/h, D_w=20, D_m=458 mm



c) U=30°, v=60 km/h, D_w=20, D_m=670 mm

Fig. 10. D_m – pitch diameter as a function of the wind speed and the tilt angle U

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longitude +26.72 (26°43'12" E), a slewing ring with D_m=670 mm can be used for the worst conditions. If the maximum wind speed tends to 100 km/h, a single axe PV panel slewing ring will be designed with a pitch diametr of D_m=1076 mm. If a dual axis PV panel with on-line control is used, allowing for modifying the tilt angle, a slewing ring of 200 mm pitch diameter can satisfy the problem by temporary turning the PV panel in order to reduce the exposed area to the wind directions. The second axis of PV panel can be fixed, but a large slewing ring can be used or can be modified, using a second slewing ring or a turntable (hydraulic or mechanic) system. An economic analysis has to be performed for optimizing the PV panel cost.

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