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INFLUENCE OF THE LATITUDE ON THE ORIENTATION EFFICIENCY OF A PSEUDO-EQUATORIAL SOLAR TRACKING SYSTEM

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Abstract: *The aim of this paper is to present, based on numerical simulations, the results of optimizing the location of a sun tracking mechanism for maximal efficiency. The system was designed, constructed and optimized considering specific implementation conditions of the Braşov-Romania area and can be used for both types of solar systems, photovoltaic and thermal ones.*
Key words: *photovoltaic, tracking, mechanism, latitude, efficiency*

1. INTRODUCTION

The efficiency increase of solar systems is an important target set for the future. This goal can be reached through different paths; an important one is the use of tracking mechanisms with fixed-predefined or sensor-based orientation program. Literature widely analysis tracking systems referring to the fundamental aspects related to the orientation algorithms and to the input solar radiation on tracked solar systems, (Diaconescu et al. 2007; Abu-Khadera et al. 2008).

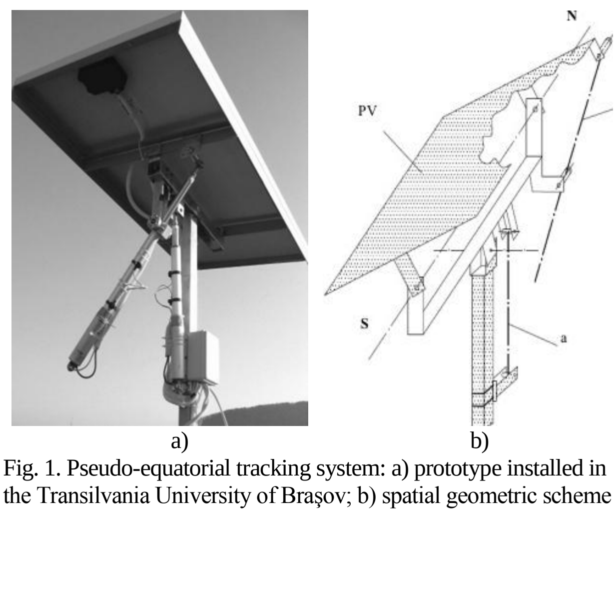
Previous work reported on the design and optimization of a novel pseudo-equatorial solar tracking systems (Fig. 1), using predefined orientation programs (Burduhos 2009). This paper further expands these results, aiming to determine the latitudes (locations) where the tracker could be optimally used.

2. INPUT DATA

2.1 Direct Solar Radiation

All simulations presented in this paper, for estimating the orientation efficiency, are based on the direct solar radiation (available and received).

As a prediction model for the solar radiation, the *Meliss* model was used, able to determine the direct solar radiation R_d [W/m^2] based on the hour, the day of the year and the atmospheric conditions typical for the area:



a) b)

Fig. 1. Pseudo-equatorial tracking system: a) prototype installed in the Transilvania University of Braşov; b) spatial geometric scheme

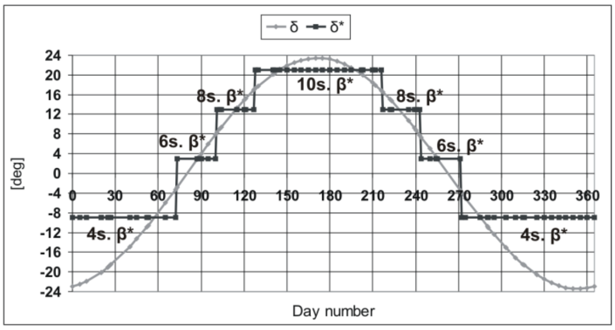


Fig. 2. The division of the year in intervals by approximating the annual variation of the declination angle (δ) with a 6-steps-line (δ*) (β* represents the number of daily steps)

Interval / number β* steps	γ*	β* steps in the morning	morning local hours (the afternoon hours are considered symmetrical)
N= 73…100 N= 244…271 6 steps	42.5º	63º; 40º; 19º; 0º	8:39 *(9:59)*; 10:03 *(11:23)*; 11:24 *(12:44)*
N= 101…127 N= 217…243 8 steps	32.5º	64º; 47º; 31º; 16º; 0º	8:13 *(9:33)*; 9:22 *(10:42)*; 10:24 *(11:44)*; 11:28 *(12:48)*
N= 128…216 10 steps	24.5º	64º; 50º; 36º; 24º; 12º; 0º;	7:54 *(9:14)*; 8:54 *(10:14)*; 9:55 *(11:15)*; 10:43 *(12:03)*; 11:36
N= 272…724 4 steps	54.5º	50º; 24º; 0º	9:36 *(9:55)*; 11:18 *(11:37)*;
		in the afternoon data are symmetrical	

Tab. 1. Optimal annual orientation program during one year

$$R_d = 1367 \cdot [1 + 0.0334 \cdot \cos(0{,}9856^o \cdot N - 2.72^o)] \cdot \exp\left(-\frac{T_R}{0.9 + 9.4 \cdot \sin\alpha}\right) \quad (1)$$

where: N is the day number of the year, α is the altitude angle depending on the hour, while T_R is an atmospheric coefficient, with values between 1, …, 5.

Using this relation and considering the direct radiation measured in Braşov-Romania, the local atmospheric coefficient T_R was evaluated having 3 as the mean annual value.

2.2 The Step Orientation Program

Considering relation (1) and a minimum acceptable orientation efficiency, based on Matlab numerical simulations for the Braşov-Romania conditions, the year was divided in 6 annual intervals (Fig. 2) having the orientation program as described in Table 1.

2. SIMULATION PREREQUISITES

The locations for which the solar tracking system reaches an optimal efficiency were calculated based on numerical simulations using Matlab and (1); at different latitudes the variation of the orientation efficiency (energy of direct solar radiation normally received by the orientated surface / available energy of direct solar radiation) was further evaluated for an entire year.

The following simplified conditions were considered:

- a clear, cloudless sky;
- latitudes between 1º−89º N, because the northern and southern hemisphere are symmetrical;
- the optimal diurnal movements from Braşov were considered for all latitudes, while the elevation movement has been corrected according to the latitude;
- due to the fact that a comparative analysis is hardly influenced by the variation of the atmospheric coefficient T_R, this was considered for all latitudes 3.

4. SIMULATIONS

Initially, due to the long simulation durations in Matlab, tests were done only for the first half of an year, with a temporary distance of 10 days and a latitude angular distance of 11º. These parameters could not sufficiently describe the variation in the orientation efficiency; this is why in the next step simulations were made throughout the whole year with a temporary distance of 5 days (Fig. 3).

As Fig. 3 shows, in the interval 67º−89º N the curve of the orientation efficiency modifies its bending. Further simulations with latitudes between 84º−89º N and a latitude angular distance of 1º (Fig. 4) show that this phenomenon occurs at 85ºN; at this latitude the difference between the angular stroke of the tracking system and the duration of the day becomes evident.

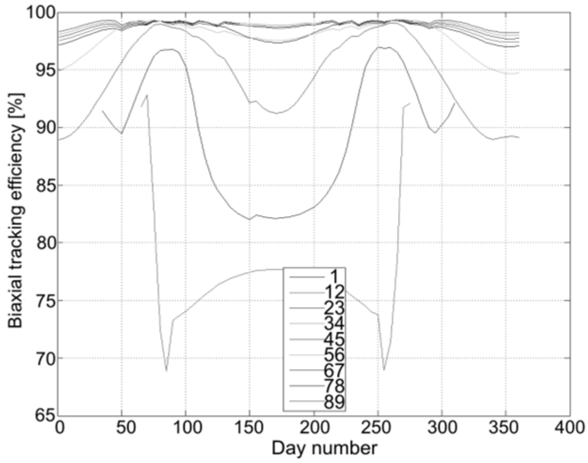


Fig. 3. Orientation efficiency variation of the pseudo-equatorial tracking system in the northern hemisphere, during a year, with a 5-day temporary distance

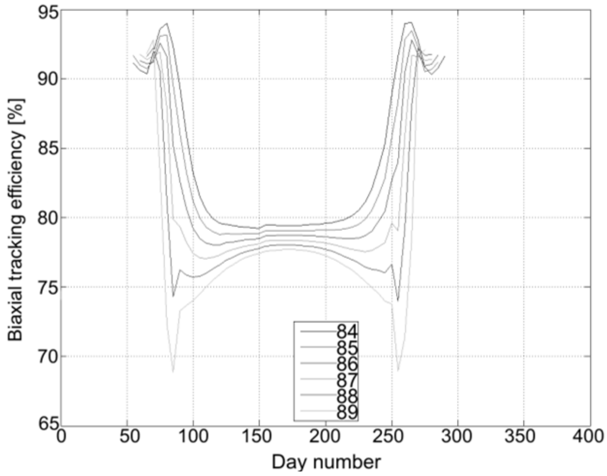


Fig. 4. Orientation efficiency variation of the pseudo-equatorial tracking system in the northern hemisphere, during a year, with a 5-day temporary distance between 84º – 89º N latitudes

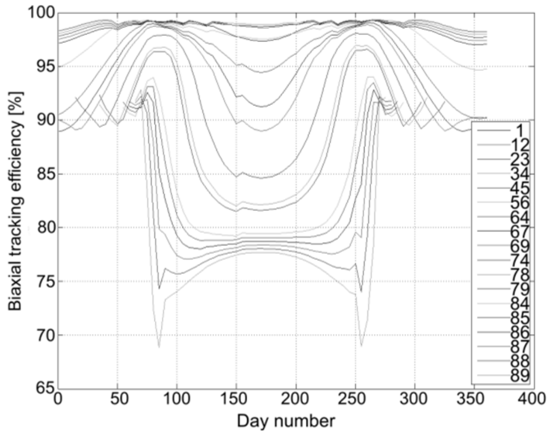


Fig. 5. Orientation efficiency variation of the pseudo-equatorial tracking system in the northern hemisphere, obtained from all numerical simulations

5. CONCLUSION

From the global diagram (Fig. 5) and the interpretation of the obtained curves the following conclusions can be stated:

- the pseudo-equatorial tracking system is especially efficient at latitudes below 56ºN because in this interval the orientation efficiency is higher than 95%;
- because the southern hemisphere is symmetrical to the northern one, the pseudo-equatorial orientation can be used in locations between 56ºS and 56ºN;
- at higher latitudes the use of the system is not justified, at least for two reasons: a) the system has high efficiency only during the spring and autumn and b) the polar night phenomenon which appears over 74ºN.

6. ACKNOWLEDGEMENTS

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7. REFERENCES

Burduhos, B., (2009). *Optimization of Pseudo-Equatorial Tracking Mechanisms Used for Increasing the Conversion Efficiency of Individual Photovoltaic Modules*, PhD. Thesis, Braşov

Diaconescu, D.; Vişa, I.; Burduhos, B.; Popa, V. (2007). On the Sun-Earth Angles used in the Solar Trackers' Design. Part 2: Simulations, *Annals of the Oradea University, Fascicle of Management and Technological Engineering*, Vol. VI (XVI), pp. 842-849, ISSN:1583-0691

Meliss, M. (1997). *Regenerative Energiequellen – Praktikum*, Berlin Heidelberg, Springer, ISBN 3-540-63218-2

Mazen, M., Abu-Khadera; Omar, O., Badranb; Salah, Abdallah; (2008). Evaluating Multi-Axes Sun-Tracking System at Different Modes of Operation in Jordan, *Renewable and Sustainable Energy Reviews 12*, pp. 864–873

Olchowik, J.M.; Tomaszewski, R.; Adamczyk, J.; Gulkowski, S.; Cieslak, K.; Zabielski, K.; (2008). Four Years Exploitation Analysis of the Hybrid Solar System in South-Eastern Poland Conditions, *Proceedings of 23rd European Photovoltaic Solar Energy Conference and Exhibition*, pp. 3084-3087, Valencia

Sharan, A.M.; (2008). Variation of Energy Conversion Efficiencies of Stationary Photovoltaic Systems with Latitudes, *Energy & Environment Vol. 19 Issue 5*, pp. 679-689