Backtracking Algorithm for Single-Axis Solar Trackers installed in a sloping field

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Backtracking Algorithm for Single-Axis Solar Trackers installed in a sloping field

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ABSTRACT
In this paper we present a backtracking algorithm that improves the energy production of a single-axis solar tracker by reducing the shadow caused by neighboring panels. Moreover, the proposed algorithm can operate in any field slope avoiding the necessity of correcting the field slope where the solar tracker is placed. This is an important feature once it will reduced the time and the manpower during the solar tracker setup. The results have shown that the algorithm presents a similar performance comparing to similar algorithms that were designed only for horizontal fields.
Keywords- PV Panels; Solar Trackers; Backtracking Algorithms; Solar Position; Renewable Energy.

I. INTRODUCTION

The renewable energies is an important topic nowadays. This kind of energy is obtained from natural resources, such as: sun, wind, water and geothermal energy. In recent years the photovoltaic (PV) energy has been a growing bet in Europe [1]. Therefore, the European Union (EU) decided to design measures to transform Europe into a highly efficient society. The main goal is to fulfill several demands until 2020, known as "20-20-20" which has the following meaning: a 20% reduction in EU greenhouse gas emissions from 1990 levels; raising the share of EU energy consumption produced from renewable resources to 20%; a 20% improvement in the EU's energy efficiency. Therefore this action plan will intend to control and reduce energy demand and will reduce the population dependency on oil resources.

Using PV panels is one possible way to obtain the energy that nature provides us by transforming the solar radiation into electricity. The photovoltaic panels can be configured in two different ways: using a static panel where the angle of solar radiation incidence is variable along the day; or using a solar tracker, where the panel will always follow the position of the sun [2]. Both configurations are feasible, however the solar trackers will present much higher efficiency. Nevertheless, the solar trackers are not a 100% effective system because there might be situations in which the solar trackers are not prepared for them. One of these situations is the incident shadow on the panels caused by neighboring panels in the tracker. This paper will justify the application of an algorithm that will address this issue and therefore improve the solar tracker efficiency.

II. BACKTRACKING ALGORITHM

The backtracking algorithm is used to prevent the shadowing effect on the PV panels. This effect will occur in the early morning and late afternoon mainly due to the sun lower elevation. By applying a backtracking algorithm, the PV plants will improve the system efficiency once all the panel area is exposed to solar radiation. Figure 1 presents an example without backtracking algorithm, as can be seen there is a panel region that it is not receiving sunlight due to the shadow produced by inclination angle of the adjacent panel.

Figure 2 presents an example with backtracking algorithm implementation. In this case the shadow effect is solved by reducing inclination angle of the adjacent panel. Note that this not optimal panel inclination will reduce the theoretical system efficiency without shadow [3, 4, 5]. In conclusion of backtracking algorithm, as the sun goes around, the algorithm makes the correction of the inclination angle of the PV panels in order to avoid the shadowing effect.

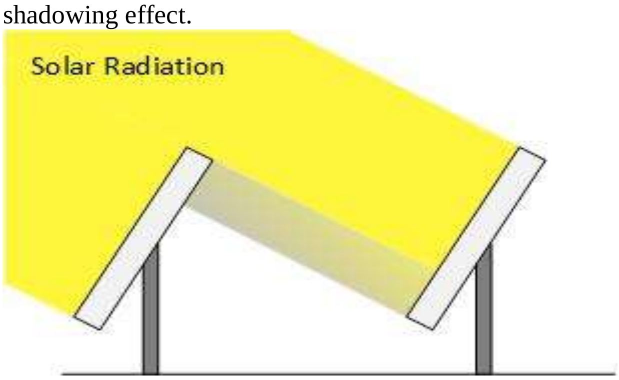

Figure 1: Solar trackers without Backtracking Algorithm.

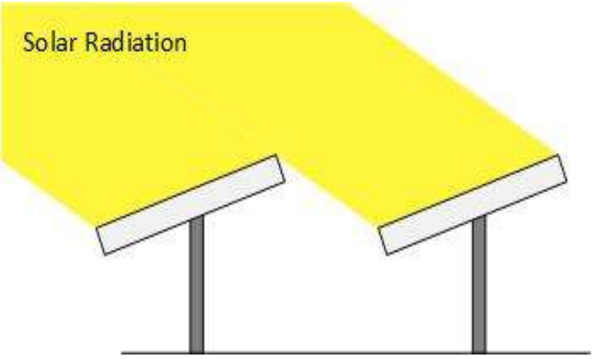

Figure 2: Solar trackers with Backtracking Algorithm.

There are several backtracking algorithms already developed for this purpose namely the algorithms proposed by Dorian Schneider [3], E. Lorenzo [4], Dan Weinstock and Joseph Appelbaum [5]. These algorithms were only designed for the case where the solar tracker is placed in a horizontal field, imposing that during of the solar tracker setup, a slope field must be turned horizontal increasing the setup time and cost especially for large solar plants.

III. PROPOSED BACKTRACKING ALGORITHM

The proposed backtracking algorithm was developed based for a single-axis solar tracker, making use of trigonometric equations. Considering the two dimensions projection presented in Figure 3, the backtracking coefficient b is obtained by the following expression:

$$b = \frac{d.\sin(\beta - \alpha)}{w} \qquad (1)$$

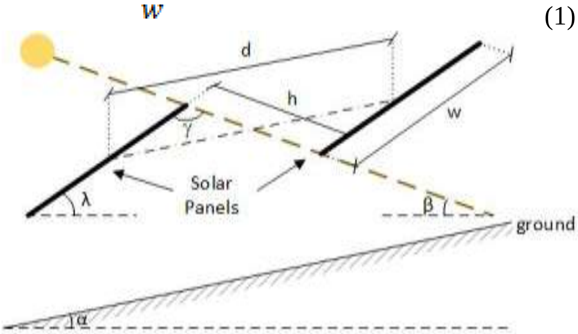

Figure 3: Solar projections of PV panels.

The backtracking coefficient b depends on the distance between panels (d), the width of each panel (w), the incidence angle of the sun radiation (β) and the field slope angle (α). For the case that b is less than 1 this means that shadowing effect will occur and therefore the backtracking must be applied. On the other hand when b is greater than 1, the panel will follow its ideal inclination without backtracking. Note that the sun incidence angle β can be obtained through a solar positioning algorithm, like for example the SPA algorithm [6]

The inclination angle of the panel that avoids the shadowing effect can be obtained by:

$$\theta = 180 - \gamma - \beta + \alpha \qquad (2)$$

for $\beta < 0$ (during the morning period) and by:

$$\theta = \gamma - \beta + \alpha \qquad (3)$$

for $\beta > 0$ (during the afternoon period), where γ is obtained through the law of sines in a triangle using the following development:

$$\begin{cases} \sin(\beta - \alpha) = \dfrac{w}{h} \\ \sin\gamma = \dfrac{d}{h} \end{cases} \Rightarrow \gamma = \arcsin b \qquad (4)$$

IV. RESULTS

In this section are presented two examples to test the proposed backtracking algorithm performance. The first example uses two PV panels of 1 m wide placed 1.2 m apart (w=1m; d=1.2m) in the same solar tracker axis in a horizontal field.

Figure 4 shows the evolution of the solar panel inclination angle using the proposed algorithm. As we can observe in Figure 5, the solar tracker is performing backtracking for a coefficient b less than 1. When the coefficient exceeds this value, it means that the panel is following the normal procedures (without backtracking), because the solar incidence on the panel will not cause shadowing effect.

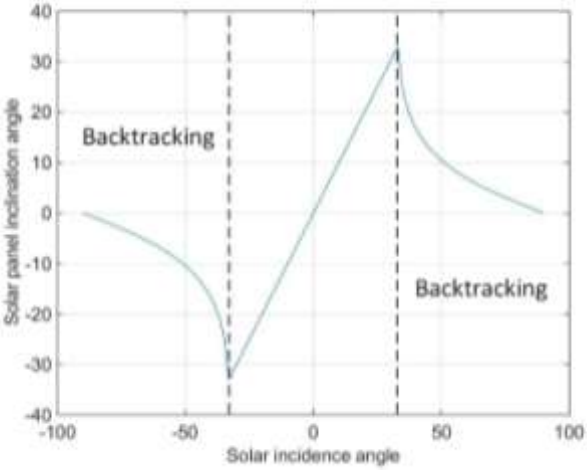

Figure 4: Inclination angle of the solar panel (spacing between panels: 1.2 m).

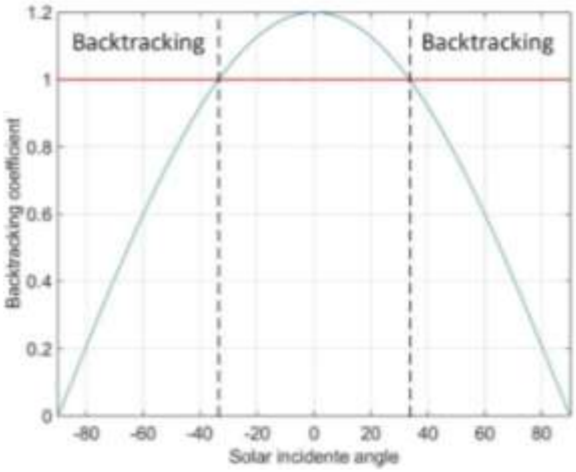

Figure 5: Backtracking coefficient (spacing between panels: 1.2 m).

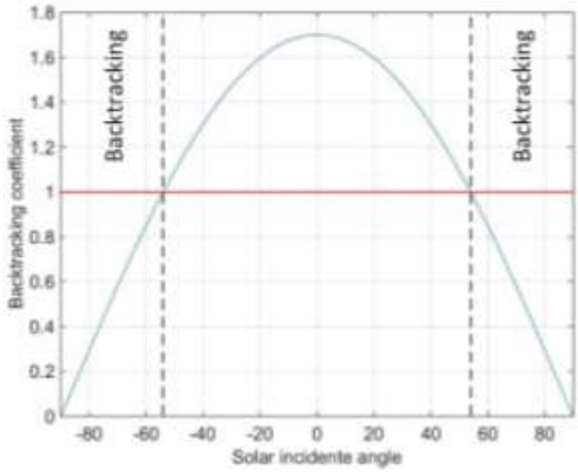

Figure 7: Backtracking coefficient (spacing between panels: 1.7 m).

Figures 6 and 7 show the same previous approach but now with panels 1.70 m apart instead of 1.20 m. As can be seen in this case there was a change in the range of backtracking coefficient value, however the threshold backtracking/no-backtracking remains with the coefficient (b = 1). As a result of this, it can be concluded that the normal follow up period without backtracking will be greater.

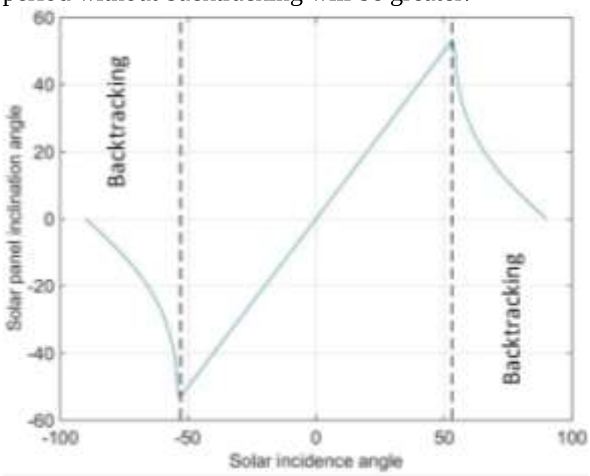

Figure 6: Inclination angle of the solar panel (spacing between panels: 1.7 m).

Figure 8 compares the proposed algorithm with the algorithm developed by Weinstock and Appelbaum for a space between panels of 1.2m. As can be seen the both algorithms presents similar results. Netherless, the backtracking coefficient used in each algorithm presents several differences, because as long as the algorithm of Weinstock and Appelbaum need to change the threshold point each time the spacing between panels changes, the proposed algorithm will do it automatically.

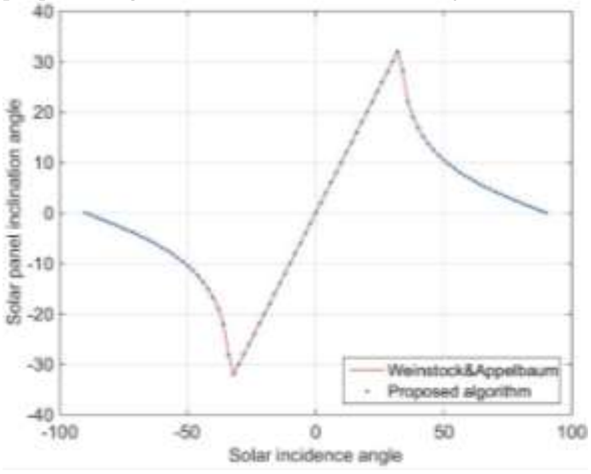

Figure 8: Inclination angle of the solar panel for both algorithms (spacing between panels: 1.2 m).

For the second example the solar tracker will placed in a 10º slope field (α=10º). In this case the solar tracker will behave differently due to its ground inclination. Figure 8 shows the evolution of the solar panel inclination angle using the proposed algorithm. As we can observe in this case the solar tracker reference is 10º because its resting position is parallel to the ground.

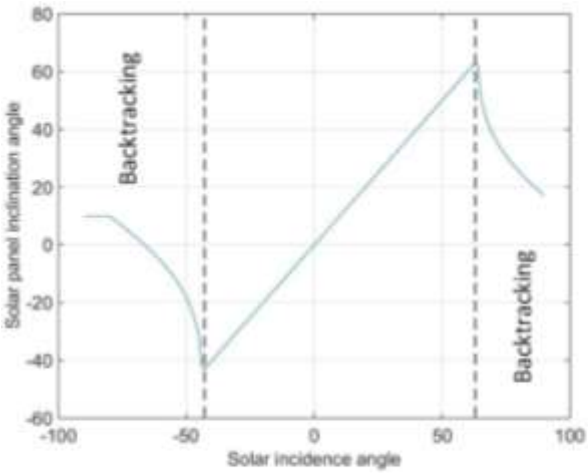

Figure 9: Inclination angle of the solar panel (spacing between panels: 1.7 m; ground slope: 10º).

V. CONCLUSIONS

The backtracking algorithms are a very useful tool in the implementation of PV plants using solar trackers due to the improvement of the energy production efficiency. The proposed algorithm has proven to be a very versatile in terms of a PV implementation setup by not imposing that the ground of the tracker must be horizontal as other similar algorithms do. Moreover, the proposed algorithm presents a similar performance when compared with a similar algorithm for a tracker placed in a horizontal ground. In relation to the backtracking coefficient the range of values change depending on the park settings, being due to the fact that keeping the same point backtracking\no-backtracking border (b = 1). Otherwise it was necessary to measure this parameter for each case study, as the algorithm of Weinstock and Appelbaum does.

REFERENCES

[1] Maria Teresa Silva Pereira de Macedo Grijó, “O Impacto da Produção de Energia Solar Fotovoltaica no Crescimento Económico,” Master Thesis, Faculty of Engineering, University of Porto, 2014.

[2] S. Deepthi, A. Ponni, R. Ranjitha, and R. Dhanabal, “Comparison of Efficiencies of Solar Tracker systems with static panel Single- Axis Tracking System and Dual-Axis Tracking System with Fixed Mount,” Int. J. Eng. Sci. Innov. Technol. IJESIT, vol. 2, Mar. 2013.

[3] D. Schneider, “Control algorithms for large scale, single axis photovoltaic trackers,” 16th Int. Stud. Conf. Electr. Eng., 2012.

[4] E. Lorenzo, L. Navarte, and J. Muñoz, “Tracking and back-tracking,” Polytechnic University of Madrid (IES-UPM), 2011.

[5] D. Weinstock and J. Appelbaum, “Diffuse Irradiance and Tracker Simulations,” Sandia Natl. Lab., May 2013.

[6] I. Reda and A. Andreas, “Solar Position Algorithm for Solar Radiation Applications.” National Renewable Energy Laboratory, 2008.