Innovative Low Cost Cleaning Technique for PV Modules on Solar Tracker

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Abstract – **This paper presents an innovative low cost cleaning technique for photovoltaic panels on a bi-axial solar tracking system from Helioslite. This competitive solution exploits the motion of the tracker and the gravity effect. The cleaning tests were carried out and validated using an optimal design of the cleaning system prototype. These have been achieved using a locally developed prototype of the Helioslite bi-axial tracker. As a perspective and before proceeding to the realization of the cleaning system in real dimensions, other tests should be conducted in order to ensure the effectiveness of this innovative cleaning system.**

Keywords - Soiling; Energy productivity; Solar Tracker; Cleaning system; PV Panels; gravity effect.

I. INTRODUCTION

Improving the performance of photovoltaic installations is an important topic that researchers around the world are trying to study and develop. Several studies on the energy efficiency of PV panels have shown that the use of the solar tracker can significantly increases the productivity of PV modules [1]. As for example the performance of PV modules installed on a biaxial tracker could incrases by 40% compared to the ones installed on a fixed system [2].

Over time, the performance of PV installations can be reduced because of the increase in soiling rate which exceeds 20 % in desert area [3]. The solar panels mounted on the tracker can be cleaned naturally by the effect of tracking (falling particles during the tracker's movement) or by the effect of rain. But, unfortunatly, this type of cleaning is insufficient especially in desert areas where the soiling phenomenon is more pronounced. Hence the need to develop other corrective and economic cleaning solutions. In order to improve the electrical performance of the PV panels, there are several cleaning techniques such as:

- The GECKO robot which cleans PV panels using a telescopic arm monitored by a truck [4].
- ECOPPIA is a dry cleaning technique for photovoltaic panels, that saves water and removes up to 99 % of the dust [5].
- SOLARWASH is equipped with treads to increase the contact surface and that allow to ensures up to 25% increase in production [6].
- PURAQLEEN it is a purified water cleaning system that allows regular maintenance of solar panels [7].

However, these cleaning systems required a very high investment, a control operator, water and conventional energy.

There are also preventive solutions based on the coating of the PV modules surface with agents preventing or mitigating the accumulation of soils on them. Nevertheless, they still under research and still have the problem of degradation.

In this context, we propose a new low cost cleaning technique which is a corrective and a preventive solution at the same time. Corrective because it is applicable after the deposition of soils but preventive because it avoids the adhesion of particles to the surface of the PV modules. This cleaning solution operates using the force of gravity by exploiting the orientation of the tracking system.This paper presents a description of this new cleaning technique as well as the results of the first tests conducted on it.

II. FUNCTIONAL ANALYSIS

Before starting the system design, a functional analysis is essential. It allows to analyze the product from the customer and the designer point of view in order to determine the service functions to be ensured by this product.These service functions present constraints for the designer, which determines the constructive solutions. We present in the following section some diagrams that summarize our approach for designing the cleaning system.

A. Horned Beast Diagram

The horned beast diagram is a tool of functional analysis of the need which makes it possible to express our need and to highlight our study. It also presents the different large parts directly related to the cleaning system (figure 1).

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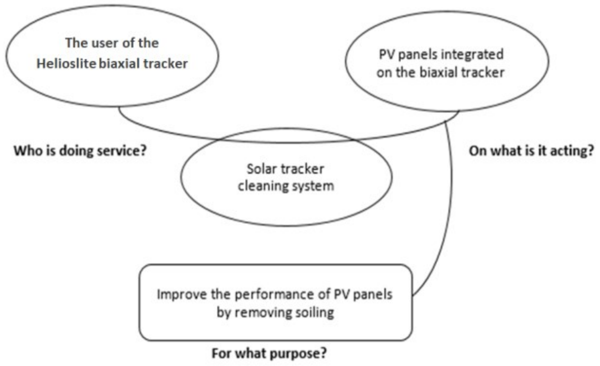

Figure 1. Horned beast diagram of the system

B. Octopus Diagram

The octopus diagram is a graphical representation of the interactions of the product with its environment (figure 2)

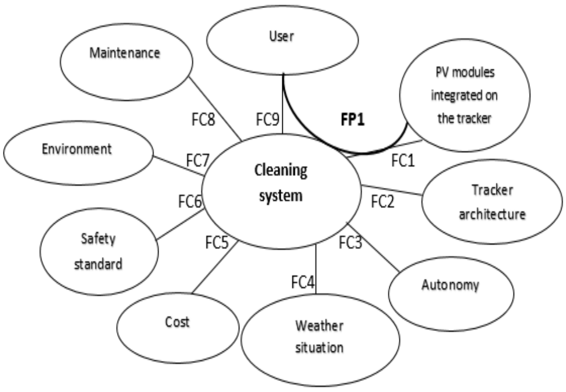

Figure 2. Presentation of the Octopus Diagram

This diagram is aulways followed by the identification of service functions:

FP1: Allowing the user to clean the entire surface of the PV panel of the solar tracker.
FC1: Protecting PV modules
FC2: Respecting the architecture of the tracker
FC3: Being perfectly autonomous
FC4: Being Adapted to weather conditions
FC5: Being less expensive
FC6: Respecting safety standards
FC7: Respecting the environment
FC8: Being easy for assembly
FC9: Being aesthetic

C. Functional Specifications

The approach and the results of the Functional Analysis of Needs are summarized in the Functional Specifications (CDCF) which focuses on the Service Functions. Table 1 shows the criteria of the service functions. The last step of the functional analysis is based on the extraction of the possible technical solutions of the cleaning system. Each service function has its technical functions as well as its constructive solutions. The next step is to develop a prototype of cleaning technique to validate the feasibility and the effectiveness of this new cleaning solution.

Table 1. Functional specifications

Code	Service Function	Criterion
FP1	Allow the user to clean the entire PV panel surface of the solar tracker by the gravitational effect.	- Effectively remove the soiling. - Frequency of cleaning.
FC1	Protect PV modules.	- Avoid the formation of glass cracks. - Avoid mechanical shocks. - Avoid shading on the PV panel.
FC2	Respect the architecture of the tracker.	- Consider the dimensions of the panel and Tracker. - Optimal design.
FC3	To be completely autonomous.	- Move autonomously along the surface of the PV panel by the gravitational effect.
FC4	Adapted to the weather conditions.	- Resist to corrosion. - Being rigid. - Being robust.
FC5	To be less expensive.	- Price.
FC6	Respect safety standards.	- Meet the safety standards.

III. BIAXIAL TRACKER PROTOTYPE

Before starting the realization of the cleaning system in real dimensions, its validation using reduced dimensions is essential for testing its feasibility and for better developing its design. In order to meet this main objective, we decided to design and realize a prototype of the biaxial tracker of Helioslite by reproducing the same real mechanism. The system stability was an essential criterion to produce a flexible movement. Aesthetic part was also taken into account in the system form. Fig.3 shows the biaxial tracker of Helioslite (a) as well as the final design of the biaxial mini tracker prototypethat that have been designed locally at home laboratory (b).

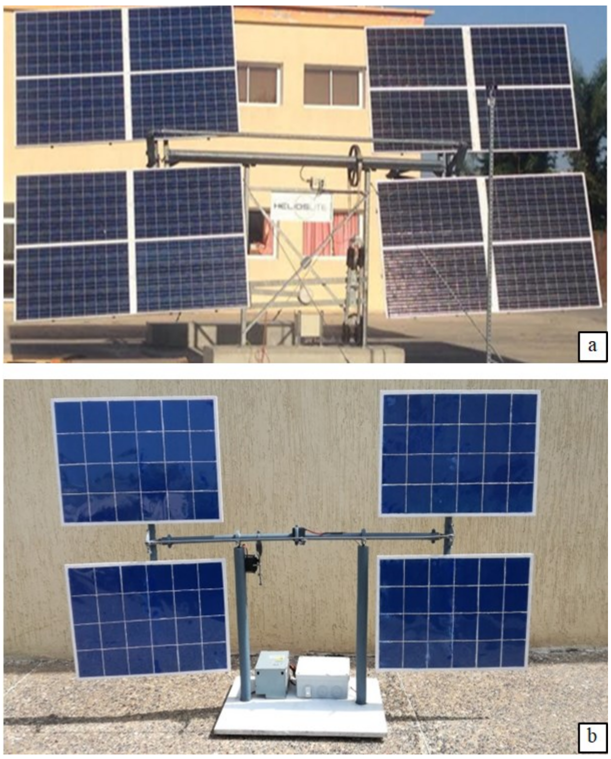

Figure 3. a) Biaxial Tracker of Helioslite. b) Prototype of Helioslite biaxial tracker

The control of this mini tracker was carried out by an Android application installed on the smartphone via the Bluetooth connection while exploiting some electronic tools, such as: the Arduino, the Servomotors and the Bluetooth receiver, in order to execute the same real mechanism of the commercialized Helioslite biaxial solar tracker. Fig.4 shows a monitoring platform consisting of buttons to provide orientation by the determination of the rotation angle.

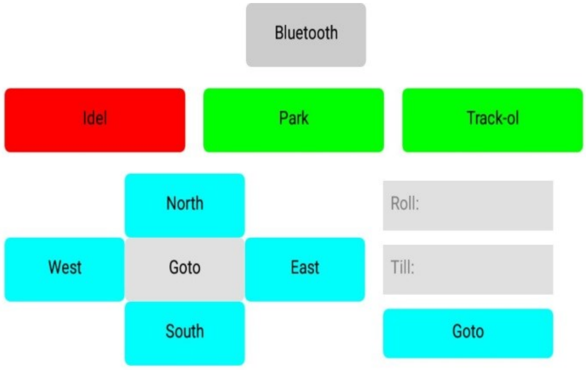

Figure 4. Monitoring interface of the prototype

IV. REALIZATION AND TESTS

A. First cleaning solution and its test

This cleaning technique is based on the use of a translation system with ball guide including a skirting board with a brush to clean the deposited soils on the panel surface.

Figure 5. First cleaning system

The new cleaning solution will be less expensive since it works using just the force of gravity during the movement of tracking system. However, it was less practical since it blocks during its movement on the surface of the prototype's panel. After a few attempts to clean up the artificial soils, we found that the cleaning brush used was less satisfactory, since the wiping of the soiling was very weak and incomplete as shown in Fig 6. As a result, we decided to develop another cleaning system avoiding the problems of the first one by using a more practical linear guide and a more efficient cleaning brush.

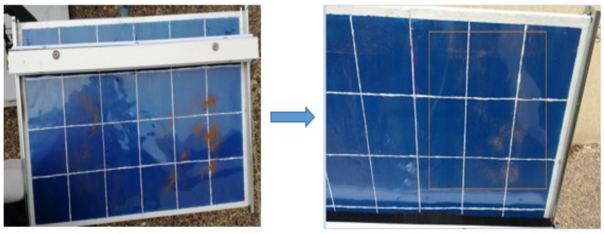

Figure 6. First cleaning solution and test

B. Second cleaning solution and its test

This second solution presents a simple design that moves over the entire surface of the panel using a roller guide. The microfiber cleaning brush has been used to remove any type of dust accumulated on the panel surface while protecting the surface of the solar glass.

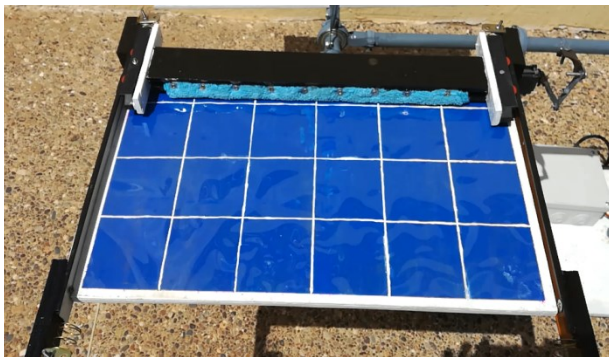

Figure 7. Second cleaning system

After integrating the system in the prototype tracker, we noticed that the movement of the cleaning system was more convenient and more fluid. During the movement of the mini tracker there was no blocking of the cleaning system in its extremities. According to the cleaning tests carried out using the artificial soils, we found that the second cleaning technique ensures the brushing and the wiping of the soiling. The results of the dirt removal were very satisfying and remarkable as presented in Fig 8.

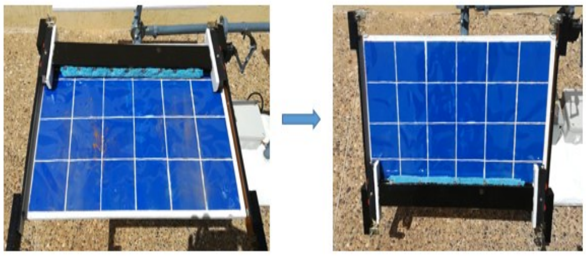

Figure 8. Second cleaning solution test

C. Comparison with other techniques

The new cleaning technique is specially designed to be autonomous, adapted to the tracker's architecture and to respect safety standards. In this section, we present a comparison between this new cleaning solution and other existing techniques to show its several advantages (Table 2).

Table 2. Comparison between the cleaning solution and other existing solutions [4 - 7]

New cleaning solution	Existing solutions
Independent and fully autonomous cleaning technique	Need for an operator for control and guidance
Preservation of conventional energy resources	Energy need for alimentation
Very high cleaning frequency	Less frequent cleaning
Preservation of hydraulic resources	Very important water need
Operation using the force of gravity by exploiting the tilting of the solar tracker	Starting requires the exploitation of different conventional energy sources (especially for robotic cleaning systems)
Simple and easy system for assembly and disassembly	Relatively complicated especially for robotic systems

Our main goal is to take advantage of the cleaning tests to develop a better low-cost cleaning technique integrated in the biaxial tracker in order to eliminate perfectly the soils. The following steps consist in designing the cleaning system according to the real dimensions of the solar tracker to evaluate the cleaning results. The cleaning frequency will be twice a day depending on the tilting of the solar tracker panels. Therefore, the removal of dirt will be more effective in an autonomous, reliable and less expensive way.

V. CONCLUSION

The objective of the present work is the design of a new cleaning solution of PV modules in order to improve their performance. This system is destined for the biaxial tracker of Helioslite. A functional analysis was studied in three parts; need analysis, functional analysis of need and technical functional analysis to determine constructive solutions. A biaxial tracker prototype was realized to carry out cleaning tests and to improve the cleaning system design.

The tests of the first cleaning system were not satisfactory. The problems encountered after these tests were overcome in the second solution which has given satisfying results. As a perspective and before proceeding to the realization of the cleaning system in real dimensions, other tests should be conducted in order to ensure the effectiveness of this new cleaning system.

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