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Automated Cleaning System for Solar PV Modules with Sun Tracking

Dr.K.Kalaiselvan[1], T.R.Arunkumar[2], A.Deeparasan[3], M.Thirumalesh[4] and R.Vijay[5]
[1-5]Er.Perumal Manimekalai College of Engineering/Electrical and Electronics Engineering, Hosur, India
Email: kalai123selvan@gmail.com, arunkumarram12344@gmail.com, deepaarasan94@gmail.com, thirumaleshmurugan@gmail.com & vijayviji0499@gmail.com

***Abstract*—The solar PV modules are generally employed in dusty environments which are the case in tropical countries like India. The dust gets accumulated on the front surface of the module and blocks the incident light from the sun. It reduces the power generation capacity of the module. The power output reduces as much as by 50% if the module is not cleaned for a month. In order to regularly clean the dust, a sun tracking- cum- cleaning system has been designed, which not only tracks the sun but also cleans the modules automatically. This automated system is implemented using 8051 microcontroller which controls the stepper motor coupled with the gear box (40:1 ratio).This mechanism does not require any sensor or synchronization for tracking the sun. While for cleaning the PV modules, a mechanism consists of a sliding brushes has been developed. In this mechanism, the solar panels make a rotation of 360o in a day, which results in sliding of cleaning brushes twice over the PV modules. In terms of daily energy generation, the presented tracking-cum- cleaning scheme provides about 30% more energy output as compared to the flat PV module (module kept stationary on ground) and about 15% more energy output as compared to PV module with single axis tracking. The implementation and working of 360o sun tracking system with automatic cleaning is described in this paper.**

***Index Terms*— single axis sun tracking, automatic cleaning, dust deposition, PV Module.**

I. INTRODUCTION

In order to maximize the amount of radiation collected the amount of radiation collected by a solar collector, the tracker must follow the sun throughout the day. But, if the environmental conditions in which the solar PV modules are installed, like tropical climate around the equator, significant amount of dust gets deposited on PV modules, as shown in Figure 1. The regular cleaning of PV modules is required in tropical climate which adds to the cost of operation and maintenance of the PV systems. The settled dust, if not cleaned, affects the performance of the solar PV module by shading the front surface. It has been observed that the reduction in energy output from a PV panel with dust could be as much as 50%, when the modules are not cleaned for 30days.

A. Implementation Of The Sun Tracking And Self-Cleaning Of Solar Pv Modules

Sun tracking systems are designed in a way to track the solar azimuth angle on a single axis. In single axis tracking system the collector is rotated around only one axis, the sun moves tracing an angle from the sunrise to

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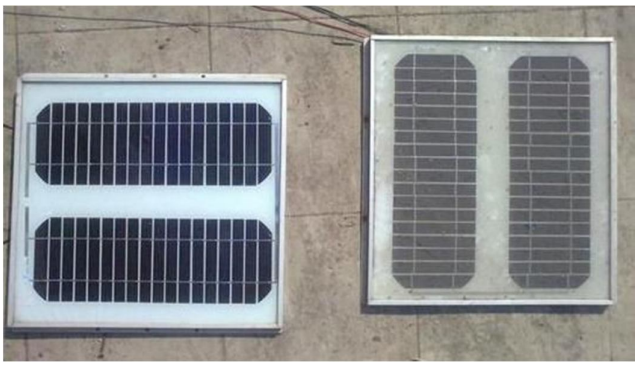

Figure 1. Image of cleaned and dusty module

the sunset. This angle traced by the sun is called the azimuth angle (γ) is defined as the angle between the lines due south and projection of normal to the collector as shown in Figure 2. Here we have used vertical axis with movement in the east-west (E-W) direction. The automated cleaning and tracking systems are implemented using a stepper motor, gear box (40:1), shaft, and sliding rod solar PV modules and circular metal rings for contacts as shown in Figure 3. The control of the stepper motor and the cleaning arrangement is done using a microcontroller.

The implementation of Sun tracking cum cleaning mechanism for Solar PV module is explained in the two steps (A and B) mentioned in next paragraph.

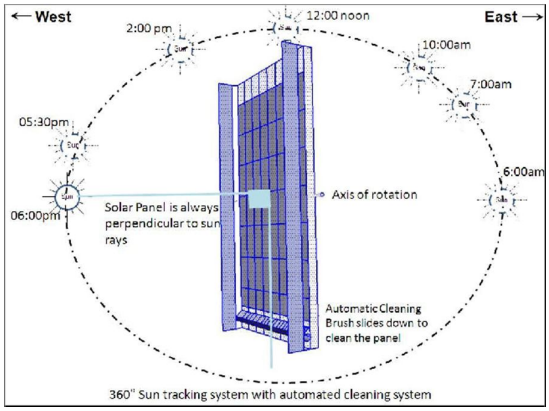

Figure 2. Schematic representation of Azimuth angle (γ) and Inclination angle (β)

A. Tracking Mechanism

A single axis tracking of the solar PV module is implemented along with the automated cleaning mechanism. For tracking the sun, the module is made to rotate 360o angle in a day, i.e. one rotation in 24 hours. The module starts its rotation from vertical position at the time of sunrise facing towards east (perpendicular to ground) and rotates at the rate of 15° per hour as shown in Figure 4.

This tracking mechanism is based on the angle of rotation of earth around its own axis. The time for rotation of earth around its own axis is 24 hours which is equal to the tracking time of this system. This system is always in synchronization with the rotation of earth without any extra component because, this system starts at the time of sunrise and goes on and on as earth rotates on its own axis. That is the reason this tracking system does not require any sensor or extra component for synchronization like any other tracking system.

B. Cleaning Mechanism

The automated cleaning mechanism is implemented using brush, rod & sliding wheels as shown in Figure 5. The brush is fitted in the rod. The rod is fitted with the wheels at both the ends, which are fitted in the channel in which they rotate. When panel comes in a vertical position at 6 am and 6 pm the brush fitted on the rod rotates on the panel from upwards direction due to gravity and cleans the panel two times in a day. In this way the cleaning mechanism works.

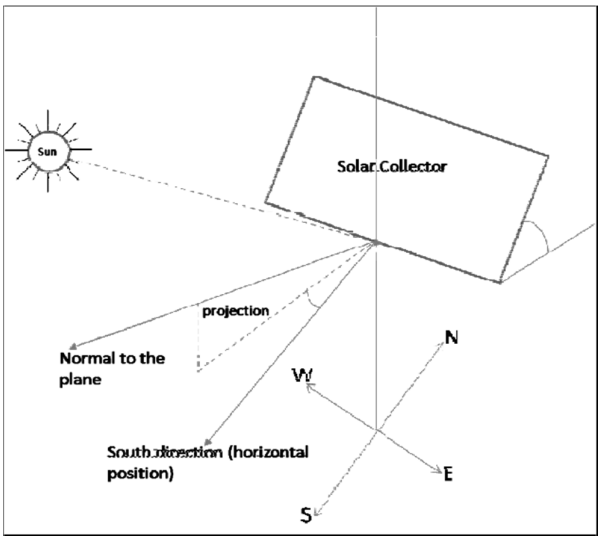

Figure 3. Metal Ring Contacts

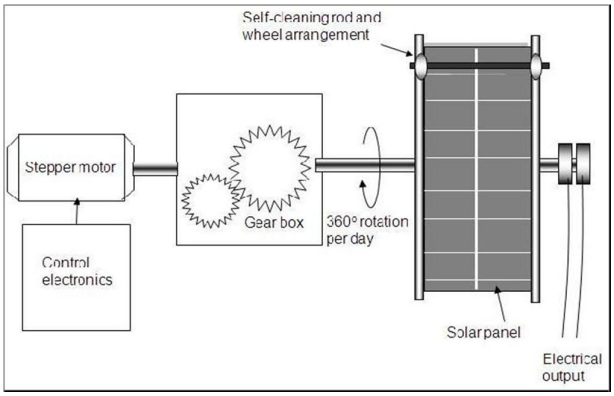

Figure 4 Schematic diagram of Sun tracking and automatic cleaning of solar PV modules

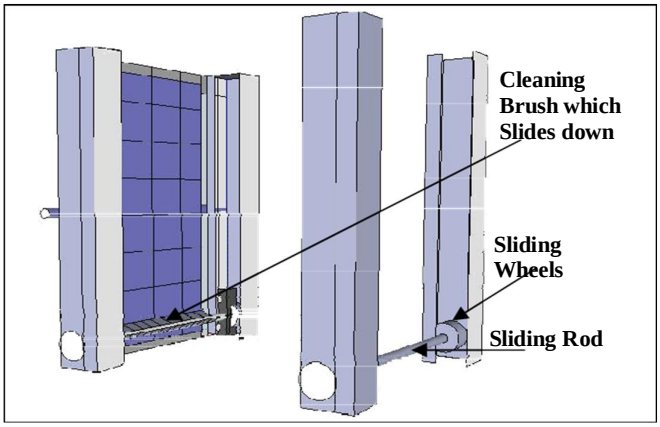

Figure.5. Sliding Rod and Wheel arrangement

The proposed Sun tracking and self-cleaning of solar PV modules are a complete product and can be implemented with any existing solar PV system. This arrangement has capacity to enhance the energy output of the system and reduces the maintenance required for regular cleaning of the PV modules. This system cleans the modules twice in a day automatically.

II. RESULTS

To observe the effectiveness/performance of tracking system some experiments were conducted. The experiments consisted of measuring the performance of the solar PV modules which are (case1) dusty,(case2) cleaned and (case3) tracked as well as cleaned modules. The energy output performance of PV modules has been measured under following three cases:-

Case 1: Kept stationary without cleaning (Dusty) Vs Kept stationary but manually cleaned regularly (Cleaned)

Case 2: Kept stationary but manually cleaned regularly (Cleaned) Vs Kept in this tracking system with automatic cleaning (Tracked as well as cleaned)

Case 3: Kept in this tracking system with automatic cleaning (Tracked as well as cleaned) Vs Kept stationary without cleaning (Dusty)

The comparison of energy output for three different cases is presented in Table I.

TABLE I PERCENTAGE GAIN IN ENERGY OUTPUT FOR VARIATIONS SITUATION

Percentage gain in energy output		
Case 1	Case 2	Case 3
14.7	15.8	30.6

Comparison of cost of power generation through SPV for particular station like Mumbai:-We have estimated the cost of power generation at particular station like Mumbai for three different systems (with module efficiency 14%) similar to the above cases the power plant system with modules kept

Case 1: Stationary but not cleaned

Case 2: Stationary but manually cleaned

Case 3: Tracked and automatically cleaned with this system

TABLE II POWER GENERATED IN ONE YEAR FROM 1MW POWER PLANT

Power generation and its cost			
	Case 1	Case 2	Case3
Averaged Units per day generated (Kwhr/MW)	3600	4400	5000
Cost /per unit (USD $)	26 Cents	22 cents	19 cents

Table II shows the Average number of units generated per day from 1MW power plant and the generation cost per unit of electricity in cents. The difference between the generation costs is quite significant.Graph of performance index of module:-

Comparison between the performances of dusty and stationary panel with the tracked and automatically cleaned panel which is our tracking system as shown in Figure6.

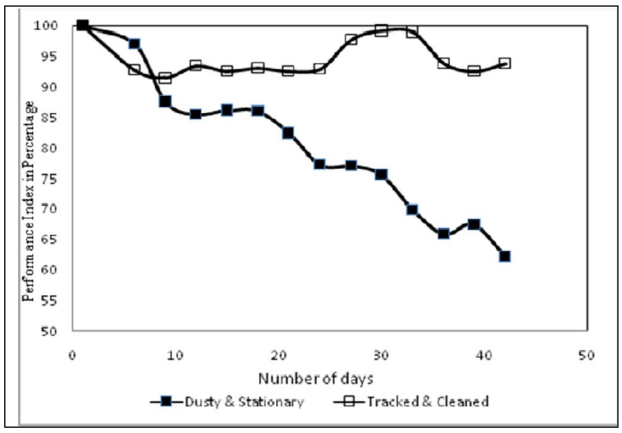

Figure 6 Graph of comparison of dusty and stationary, tracked and cleaned the around 45 day's period

The above graph is performance index vs. number of days which shows that the performance of the panel which is not cleaned had decreased approximately up to 50% in approximately 50 days, where as the performance of panel kept with this tracking-cum-cleaning system remains almost the same.

III. Conclusion and Future Work

A novel mechanism of sun tracking with automatic cleaning of PV modules is presented and cleaning mechanism of the PV modules consists of sliding brushes, which slides over module and cleans it twice a day, wherein PV panel makes a rotation of 360^{o} in a day. It is observed that the daily energy generation of a flat PV module (kept stationary on ground) increases by about 30% and 15% for case of tracking-cum-cleaning and just single axis tracking, respectively. This demonstrated the effectiveness of tracking-cum-cleaning mechanism.
The mentioned tracking-cum-cleaning system is most suitable for today's industrial need. The difference is quite significant as we can see from Table 2 the difference in number of units generated per day and cost of per kWhr.
Above system can be kept inclined in the north or the south direction accordingly to achieve better energy generation from the PV modules of given wattage ratings. This system can extend to two axis tracking by rotating one axis manually and other axis automatically as rotated in this system since this mechanism does not require any sensor or synchronization for tracking the sun. The other axis (north-south) can be rotated on daily or monthly basis. This axis can also be implemented manually or automatically using motor, microcontroller etc. The cleaning mechanism can also improved by making some arrangement for rotating the brush on the panel for still more improved cleaning.

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