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Developing an Automatic Dust Cleaning Unit to Improve the Photovoltaic Panels Productivity

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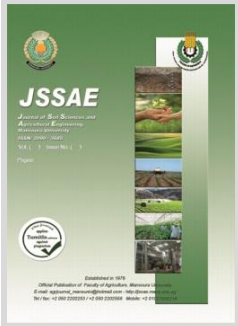

ABSTRACT

Egypt has one of the best weather conditions for producing renewable energy in the world. As a result, there has been a proven market pull for solar energy in the region in a growing clean energy export market as clean energy. Solar energy maintenance is relatively low comparing to other power generation sources. Although, less maintenance is required, the important factor that reduces its generation according to accumulate dust on solar PV modules. Dust accumulation effectively reduces the energy yield of solar panels. So, the current paper deals with the locally designed automatic cleaning mechanism for solar PV modules. The designed mechanism consists of an electronic solar module that automatically cleans the solar module at the required rate. without requiring water to clean the solar module. This cleaning mechanism is also suitable for pole mounted street lighting systems where daily manual cleaning is not possible and could be more costly. Six months later from start experiments, the obtained results of PV panel recorded maximum value of volts, current and power were 18.1 V, 0.85 Amp 15.39 Watts respectively for cleaned one while it was decreased up to 8.87 V, 0.425 Amp and 3.77 Watt for the un-cleaned respectively. The use of the developed cleaning unit improves the energy produced from PV panel by 42.32% compared to the control.

***Keywords*:** PV panel, automatic, dust cleaning

INTRODUCTION

Solar panels are important and more popular around the world. The energy produced by solar panels is related to the available solar radiation and spectral content, as well as other factors such as environmental performance, climate, component performance, and the inveterate system. The accumulation of dust and debris particles on the surface of the PV panels negatively affects their performance. Cleaning dirty panels with commercial detergent can be time consuming, expensive, and dangerous for the environment, or even corrode the frame of the PV systems. Ideally, the PV systems should be cleaned every week to maintain maximum efficiency, especially pole mounted street lighting systems, which are not cleaned continuously in addition to the presence of some challenges in cleaning process, the most difficult are few stop the traffic within cities, other challenge is the difficulty in cleaning the solar cells on street lighting poles regularly. The dust accumulates on the solar panel system surfaces through different purpose thereby recording the incident sunlight onto the solar panel system reducing transmittance; it results in a reduction of power generation capacity of the solar panel system. As per analysis, the output power of the panel is reduced by 50%. *Das et al. (2017)* found that the cleaning dusts on panels using labor per one month are expensive. Moreover, this process consumes more time, water and energy usage. Accordingly, a development cleaning system has been designed, which senses the dust on the solar panel and also cleans the module automatically. For cleaning the solar panel system, a mechanism consisting of sliding brushes has been developed. In periods of every day energy generation, the given development cleaning scheme extend about 30% more energy output as compared to the dust accumulated solar panel system. *Divyavani et al. (2018)* added that PV module efficiency is limited because of the dust, humidity and temperature. The eligibility of solar panel system was studied before and after cleaning for the surface of solar panels system after day, week and month. The results indicated that solar panel system efficiency frequently increased after cleaning. Thus the developed model increases the solar panel performance. *Kulkarni et al. (2018) and Manju et al. (2018)* indicated that the power output reduces by 50% if the PV systems are not cleaned after one month. So development cleaning system has been designed to clean the dust on the PV automatically. *El-Sybaee et al. (2018)* found that the dust deposition decrease the record of solar radiation which is falling on the solar panel and creates shadow effect. With the passage of time the density of dust on the panel increases and reduces the electric power of the solar panel. The data showed power reduction of up to 51.12 %. The efficiency of the solar photovoltaic panel system was reduced from 15.9 to 7.88 % for clean and unclean modules, respectively. *Sivan et al. (2017)* found that the average performance of solar panel systems is affected by the accumulation of dust on them. While many factors affect the amount of energy a solar panel system will produce. Experts agree that dirty solar panels do not produce energy compared to clean panels, where the loss rate reaches 50% due to dust accumulation. *Mishra and Sarathe (2017)* He added that the accumulation of dust on solar panel systems reduces their efficiency by up to 50%. Therefore, to increase the efficiency of solar panel systems, we must remove dust in a timely manner from our solar panel systems. Automated cleaning of this array is preferred as it may increase the efficiency of the solar panel systems by up to 20%. *Patil and Mallaradhya (2016)* found that the mean performance of PV systems is recorded to be increased by about 1.6% to 2.2%

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if cleaning every day. Hence, the upgraded PV systems increase the performance. so it should be cleaned with an effective cleaning technique. Changing ambient weather conditions such as storms and rain, especially the desert environment, this leads to the formation of cement particles over the PV systems, which prevents the solar radiation from reaching the solar panel systems. *Brahmbhat (2018).* In the dry months, the removal of cement particles from the solar energy systems is very difficult, thus affecting the performance of the solar system systems. Hence, solar panel systems must be kept clean. Therefore, the main objective of this research is to provide an effective, economical and simple automatic cleaning mechanism to remove dust from all solar panel systems.

MATERIALS AND METHODS

The investigated constriction was identified at roof of Test and Research Station for Tractor and Farm Machinery, Alexandria, Egypt (Latitude 33.74 N and 72.83 E).

System Components

An automatic cleaning system with new technology is used to clean the gather dust on the solar panel system surface every day, especially on the lighting poles as shown in the Figures 1 and 2. The investigated system includes the following parts:

Solar panel: A 20 Watts PV mono-crystalline panel having short circuit current of one Amp and open-circuit voltage (VOC) 18.6 Volts with dimensions 0.42 X 0.57 m is identified. Two solar panels were used, one with cleaning unit and the other conducted as a control unit. Both of the panels were kept under natural conditions and were tested 168 days from 1st May 2018 to 15th October 2018 between 8.00 am and 17.00 pm. The system location is on a rack facing towards the south with a fixed tilt angle of 31°.

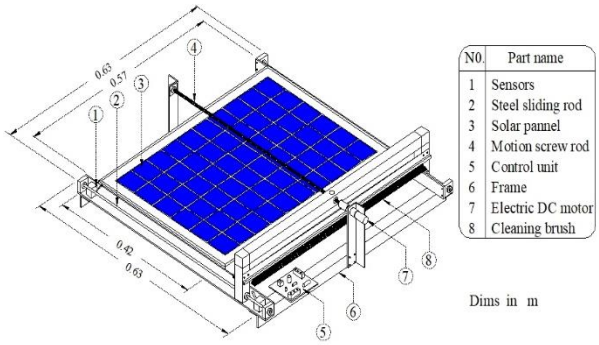
Electronic unit: It includes "DC" motor, Arudino board, timer circuit, power supply and sensor.

- **The "DC" motor** (12 V, 100 rpm; 0.5- 1.0 A) was conducted on the base of cleaning trolley. The speed of "DC" motors was conducted on the base of cleaning trolley. The speed of "DC" motors can be striped over a wide reach by using a variable supply voltage.
- **Arduino board** is a microcontroller board based on the ATmega328P (datasheet). It has 14 digital input / output pins (of which 6 can be used as PWM outputs), used as control unit, that sent a signal to timer, consequently to motor. It is considered the mind of the control system.
- **Timer circuit** model L298N can be constant according to the desired operation of the brush. For normal environment conditions, the timer is adjusting once per 24 hours.
- **Sensors** are located at the two ends of brush stroke that reflects the movement of the DC motor as soon as the touches the sensors.
- **Power supply** is a chargeable battery of 12 V used to supply the system with energy.

Cleaning trolley: it is designed to easily slide on two steel sliding roods placed on the base of the solar panel. The trolley frame made from angle and rod iron parts are linked together. The brush bar (0.57 m wide) was fixed and connected to easily change at the lower surface of trolley. The center of the trolley frame is fixed with a screw bolt and nut. The nut is welded on the trolley frame.

Working principle

- According to the dimensions 0.42 * 0.57 meters of the used flat panel, the solar panel cleaning system was made of brushless DC motors, and tooth brushes controlled by signal created by Arduino.
- A DC motor was installed on the cleaning trolley, to give rotational movement which is converted into linear movement by the rack system.
- The cleaning trolley moves every 24 hours to perform the cleaning process, which takes about 60 seconds, as the brush moves on the along the solar panel a distance of 57 cm between the two sensors and back again to the starting point controlled by Arduino, and thus cleaning the solar panel systems.



N0.	Part name
1	Sensors
2	Steel sliding rod
3	Solar pannel
4	Motion screw rod
5	Control unit
6	Frame
7	Electric DC motor
8	Cleaning brush

Fig. 1. Solar panel cleaning system

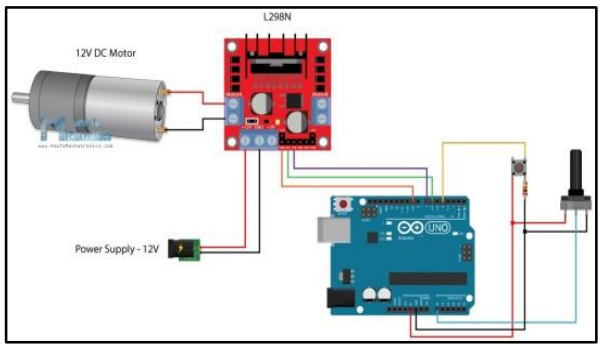


Figure 2. Complete structure of the designed System

Devices used

The red and blue DC voltmeter as shown in Fig. (3) was used to measure the voltage and current at various loading conditions and digital multi meters (with an accuracy of ± 1% for DC current and ± 0.09% for the DC volt) along the variable resistance (30W) was used to measure current and voltage without load.

A solar power meter Lutron (model: SPM-1116SD) was used to measure the solar radiation on a horizontal surface every 30 minutes.

Environment Meter Model: EM-9300SD, was used to measure temperature, relative humidity, luminous intensity and wind speed both on the screen.

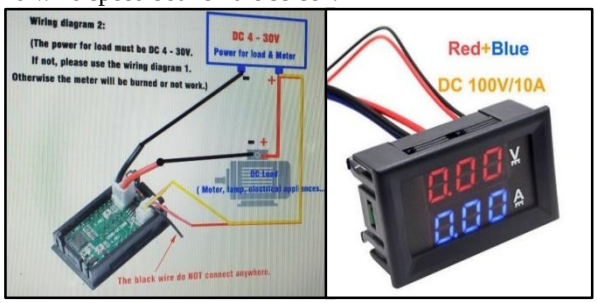


Fig. 3. A red and blue DC voltmeter circuit

The module parameters were calculated using the following equation. (*Dayal and Sudhakar 2013*).

$$p_{max} = I_{max} \, x \, V_{max} \quad \text{..... (1)}$$

$$\eta_{module} = \frac{p_{max}}{G \, x \, A} \quad \text{..... (2)}$$

Where:-

A = Actual area of module, m^2
G = Global solar irradiance, $W.h/m^2$
I_{max} = Maximum current, A
V_{max} = Maximum volt, V
η_{module} = Module efficiency, %
p_{max} = Maximum power, W

The power improvement of solar panel could be obtained as follows:

$$\text{Power improvement} = \frac{P_{cs} - P}{P_{cs}} \times 100 \quad \% \quad \text{..... (3)}$$

Where: - P_{cs} = Power of solar panel with cleaning system.
P = Power of solar panel without cleaning system.

RESULTS AND DISCUSSION

The experiment was carried out on two solar panels, the first panel without modification (control) and the second was development (cleaning system). Ambient temperature and solar radiation data were recorded every 30 minutes during the trial period, the minimum and maximum ambient temperatures ranged from 18.6 °C to 40.8 °C respectively. And the minimum and maximum intensity of solar radiation ranged from 133 to 1150 W/m^2.

Variation of current and voltage

Figure 4 shows the variation of current and voltage for the cleaned and un-cleaned surfaces for one to three weeks of dust deposition of PV panel. The results indicated that output volte and current decreased continuously with increasing accumulated dust every day.

The difference of PV panel volte and current between the cleaned and un-cleaned panels was very small in the first and second weeks. The difference in the voltage and current between the cleaned and un-cleaned PV panels began to relatively increase in the third week, due to dust accumulates on the solar panels through different sources and blocks the incident sunlight onto the module reducing transmittance; it results in a reduction of power generation capacity of the PV panel. It is obvious from Figure 4 that the value of volte and current is reduced considerably of the third week of dust deposition. The maximum value of volts was 18.55 V for clean surface while it was decreased up to 18.34 V for the dusty surface; the decrement after three weeks was about 1.15 %. Also, the maximum value of current was 0.84 Amp for the clean surface while it was decreased up to 0.80 Amp for the dusty surface; the decrement after four weeks was about 4.59%.

Figure 5 shows the variation of current and voltage for the cleaned and un-cleaned surfaces after two to six months of dust deposition over the surface of the solar panel. The results indicated that output volte and current decreased continuously with increasing the accumulated dust every day. It was obvious from Figure 5 that the value of volte and current is reduced considerably after two to five months of dust deposition. From these results, after two months the value of volte was 18.56 V for the cleaned surface while it was decreased up to 16.42 V for the dusty surface; decrement after two months was about 13.12%, and the value of current was 0.87 Amp for a cleaned surface while it was decreased up to 0.82 Amp for the dusty surface; the decrement was about 6.37%. Also, after six months the value of volte was 15.58 V for the cleaned surface while it was decreased to 10.32 V for the dusty surface; the decrement was about 50.95%, and the value of current was 0.89 Amp for the cleaned surface while it was decreased up to 0.81 Amp for the dusty surface; the decrement after five months was about 9.58%.

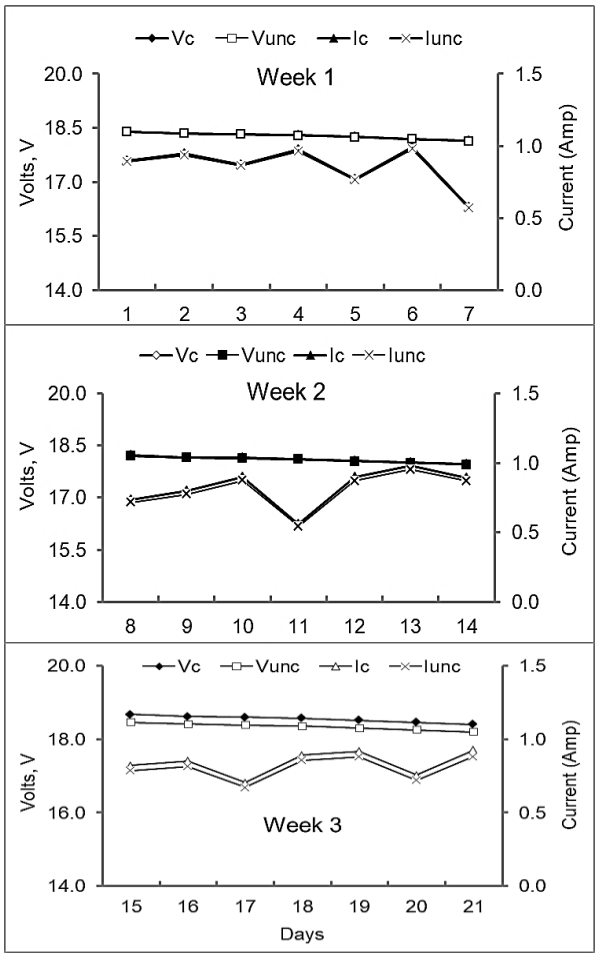


Fig. 4. Variation of current and voltage for the cleaned and un-cleaned surfaces after one to three weeks dust deposition.

The variation of current, voltage and power for the cleaned and un-cleaned panels of the end experimental period:

Figures 6, 7 and 8 show the variation of current, voltage, and power for the cleaned and un-cleaned panels after 168 days of dust deposition over the surface of PV panel. The results indicated that output volts, current, and power decreased continuously with increasing accumulated dust every day. The difference of PV panel volte and current between the cleaned and un-cleaned panels was very small at the first week and dramatically increased after six months. This results due to dust accumulates on to the solar panels through different sources and blocks the incident sunlight onto the module reducing transmittance. This results in the reduction of power generation capacity of the PV panel. It is obvious from Figures 6 and 7 that the value of volte is reduced considerably after 168 days of dust deposition.

The maximum value of volte was 18.1 V for the cleaned surface while it was decreased up to 8.87 V for the dusty surface and the minimum value of volte was 10.8 V for the cleaned surface while it was decreased up to 7.84 V for the dusty surface. Also, the maximum value of current was

0.85 Amp for the cleaned surface while it was decreased up to 0.425 Amp for the dusty surface, and the minimum value of current was 0.44 Amp for cleaned surface while it was decreased up to 0.32 Amp for the dusty surface.

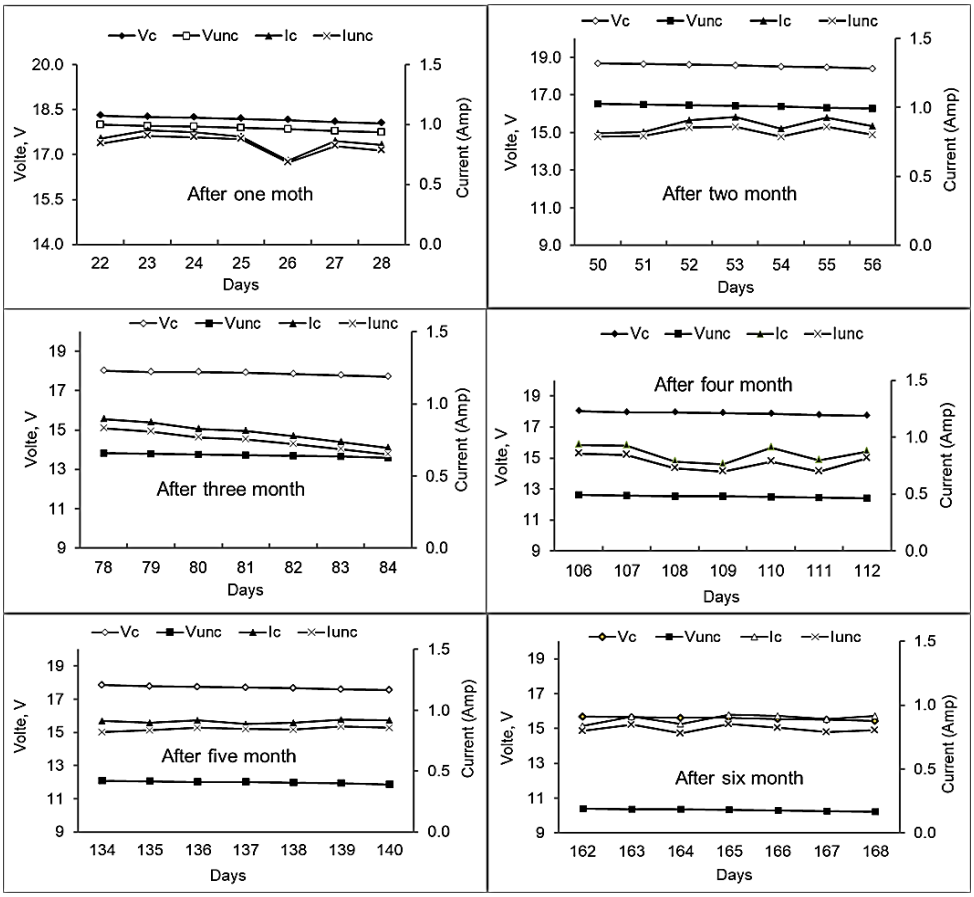


Fig. 5. Variation of current and voltage for the cleaned and un-cleaned surfaces after two to six months of dust deposition

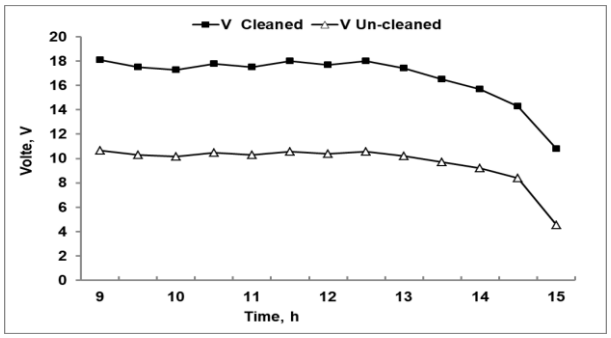


Fig. 6. Variation of voltage for the cleaned and un-cleaned surfaces at the end of dust deposition period (168 days).

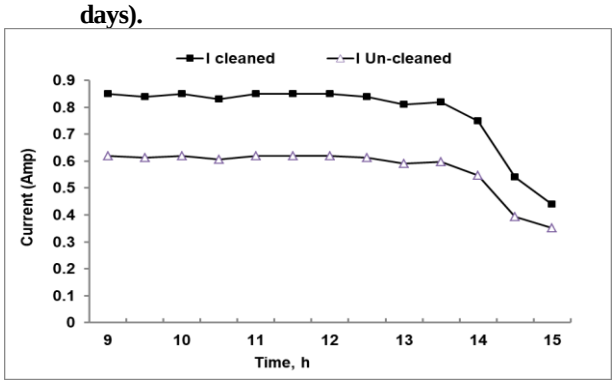


Fig. 7. Variation of current for the cleaned and un-cleaned panels at the end of dust deposition period (168 days).

It was obvious from Figure 8 that the value of volte was reduced considerably after 168 days of dust deposition. The maximum value of power was 15.39 Watts for the cleaned surface while it was decreased up to 3.77 Watts for the dusty surface, and the minimum value of power was 4.75 Watt for the cleaned surface while it was decreased up to 2.51 Watt for the dusty surface.

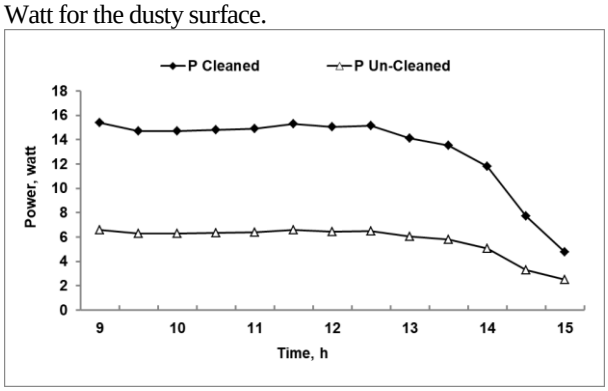


Fig. 8. Variation of power for the cleaned and un-cleaned panels at the end of dust deposition period (168 days).

Variation of power improvement for cleaned and un-cleaned solar panels

It was obvious from Figure 9 that the power improvement was reduced considerably from one to six months dust deposition. The maximum value of power improvement was 42.32 % found after six months while the

minimum value was 5.85 % after one month when using the developed cleaning system compared with the dusty surface.

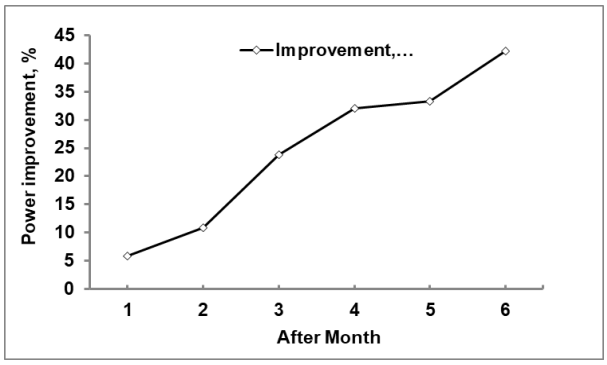


Fig. 9. Variation of power improvement for the cleaned and un-cleaned solar panels.

CONCLUSION

- Dust accumulates on to the solar panels surface through different sources and limits sunlight reducing transmittance, consequently reducing the capacity of power generating from PV panels.
- After the experiment of six months, the maximum values of volts, current and power were 18.1 V, 0.85 Amp 15.3 and 9 Watt for the cleaned surface respectively. However it decreased up to 8.87 V, 0.425 Amp and 3.77 Watts for the un-cleaned surface respectively.
- The use of the developed cleaning system improves the energy produced by the PV panels by 42.32% after six months compared to the control.

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تطوير وحدة تنظيف الأتربة آلياً لتحسين إنتاجية الألواح الكهروضوئية

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معهد بحوث الهندسة الزراعية – مركز البحوث الزراعية – جيزة

تتمتع مصر بإمكانات عالية من الطاقة الشمسية ، واستغلالها أمر حاسم للتنمية الوطنية المستدامة من خلال التخطيط الفعال للطاقة والاستقلال التدريجي عن الوقود الأحفوري ، مصر لديها واحدة من أكثر البيئات مواتية لأكبر إنتاج للطاقة المتجددة في العالم. ونتيجة لذلك ، ظهرت جاذبية سوقية للطاقة الشمسية في المنطقة في سوق التصدير المتنامي للطاقة النظيفة. تعد المحافظة على الطاقة الشمسية منخفضة نسبياً مقارنة بمصادر توليد الطاقة الأخرى، على الرغم من انها تحتاج إلى صيانة أقل ولكن لا يزال العامل المهم الذي يقلل من توليدها هو تراكم الغبار في الوحدات الكهروضوئية الشمسية، تراكم الغبار يقلل بشكل فعال العائد من ألواح الطاقة الشمسية. والهدف من البحث هو تطوير آلية للتنظيف التلقائي لوحدات الطاقة الشمسية الكهروضوئية. تتكون الآلية المطورة من وحدة إلكترونية تقوم تلقائيًا بتنظيف الالواح الشمسية بالمعدل المرغوب دون الحاجة إلى استخدام المياه لتنظيفها. وآلية التنظيف هذه تعتبر مناسبة أيضًا لأنظمة إضاءة الشوارع المثبتة على الأعمدة حيث لا يمكن إجراء التنظيف اليدوي اليومي لها. من النتائج المتحصل عليها وجد أنه بعد ستة أشهر من بدء التجارب ، بلغت القيمة القصوى للفولت والتيار و الطاقة 18.1 فولت و 0.85 أمبير و 15.39 وات للسطح النظيف ، وانخفضت إلى 8.87 فولت و 0.425 أمبير و 3.77 واط للسطح الغير نظيف واستخدم نظام التنظيف المتطور مقارنة بالسطح الغير نظيف ، يحسن الطاقة التي تنتجها الالواح الكهروضوئية بنسبة 42.32٪ بعد ستة أشهر من التجارب.