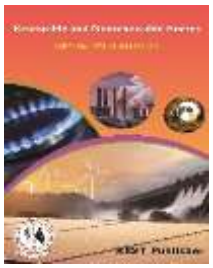
Renewable and Nonrenewable Energy

Vol: 5(1), 2026

REST Publisher; ISBN: 978-81-948459-2-8

Website: https://restpublisher.com/book-series/ese/

DOI: https://doi.org/10.46632/rne/5/1/19



Dust Removal Methods for Solar PV Panels -A Review

***K Kalyani Radha, B Omprakash**

JNTUACEA, Ananthapuramu, Andhra Pradesh, India.

*Corresponding Author Email: *radha.mech@jntua.ac.in*

Abstract: *Solar energy is generated when sunlight is used to produce electrical energy. Photovoltaic modules use solar cell, which converts solar radiation into direct electricity. It is necessary to keep the photovoltaic panels cleaned regularly to gain the maximum power output from the sun. It is inexorable that such things as bird droppings, dust, pollen and mud will collect on the photovoltaic (solar cells) modules. Because of these things the performance and power efficiency of PV panel will decreases rapidly. If the photovoltaic cells not clean properly, so it is unable to collect the maximum sunlight from the sun radiation, then automatically the produced electricity is also reducing. This estimates the power losses up to 30% to 40% of maximum power consumptions. Generally, dust on the solar panels quite natural. The aim of the proposed system is to develop a microcontroller and actuators based cleaning system that can able to clean the solar modules when the power efficiency of modules reduces morning times. This system can reduce the power losses up to 10% of maximum power consumption.*

Keywords: *PV module, microcontroller, actuators, efficiency, dust, performance*

1. INTODUCTION

The word photo voltaic is derived from photo, the Greek word for light and volt, relating to electricity, photo voltaic cells are made-up of a material known as semiconductors, the most commonly used semi-conductor material in solar panel is silicon. When the light falls on the solar panel. It strikes directly to the solar cell; this cell absorbs the solar radiation. These solar cells convert radiation into direct electric current, each photo voltaic cell in the solar panel can generate 0.5 volts of maximum current. The maximum power can be achieved by placing these cells In-series and in-parallel can increase the total current. When manufacturing a solar panel, it is necessary to place an anti-reflective coating such as glass plate is susceptible to dust from the surrounding

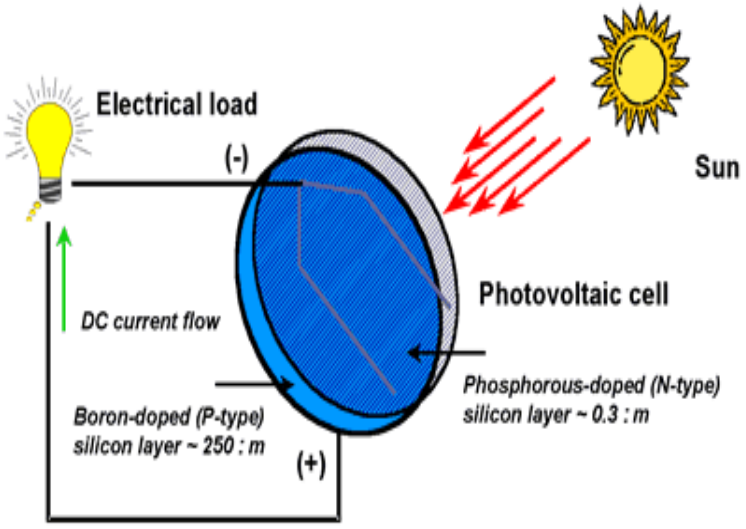


FIGURE 1. Photovoltaic cell receiving the light from sun and converting it into electricity

Environment. When this plate becomes dirty, thus power efficiency of PV panels will reduce. *Objective:* The main objective of the project is to find out the effects of dust and removing dust by using ARM microcontroller programmed and gear motor based cleaning system *Article domain:* This article belongs to Solar PV panel cleaning system and also about how the dust effect efficiency of panel.

2. BRIEF SUMMARY OF ARTICLES

Hotel and Woertz et al., were amongst the pioneers investigating the impact of dust on solar systems. They recorded a maximum degradation in collector performance of performance of 4.7%. Into dust accumulation on a solar village PV system near Riyadh indicated a 32% reduction in performance after 8 months. An experiment to investigate the effect of Aeolian thus deposition on photovoltaic solar cells by Dirk Goose showed that the deposition of fine airline dust particles on the glazing of PV cells significantly affected the performance of such cells. This experiment was conducted in investigate the effect of wind velocity and air Berne dust concentration on the drop of PV cell performance caused by dust accumulation. M. Moon. (Google Association) et al., (one of the world's well known organization in the information technology) studied the effects of dust and solar panels of a 1.6MW. The company made a comparison on two different sets of solar panels in Google campus first one is flattered panel and the second one is tilted, dirt accumulates on top of the flat panels whereas rain washes away most dirt on the tilted ones and leaves some accumulation in the corners. A Google team cleaned them up as part of this experiment, 15 months after the installation of the panels. For the flat panels the cleaning resulted in double energy output overnight. However, for the tilted panels, the difference was found to be relatively small. There is difference of 2% current reduction relative to both the type of panels. H.P Garg et al., conducted an experiment in Rourke, India, that dust accumulation on a glass plate tilted at 45° would reduce the transmittance by an average of 8% after an exposure period of 10days. It was observed that about 2.5g/m²/day of dust were collected b/w April and June. Further investigation on the effect of dust accumulation on the tilted solar panels revealed a reduction in plate transmittance ranging from 64% to 17%, for tilt angels ranging from 0° to 60° respectively after 38days of exposure. The flat panel observed reduction of 30% in useful energy gain after 3 days of dust accumulation. Salami Hamaul, Saudi Zine, Rahman Abdallah et al., conducted an experiment which illustrates the testing of a photovoltaic module (ISOFOTON I-100/24) under real operating conditions. The tests were carried out under different solar radiation, cell temperature and air mass conditions, where different I- V characteristics were taken, for efficiency determination as a function of irradiance, cell temperature and air mass. The STC efficiency was found to be 8.96% corresponding to an STC module output power of 65.6W. An efficiency maximum of 9.093% was found at 800w/m2. The efficiency linearly decreases with temperature and air mass. F. Mejia, J. Kleist, J. L. Bosch et al., conducted Soiling is the accumulation of dust on solar panels that causes a decrease in optical efficiencies of CSP systems. However, geographically widespread data is only available for solar photovoltaic (PV) systems. The changes in efficiency of a large commercial site (86.4 kid) was quantified during the summer dry period over the course of 2010 with respect to rain events observed at a nearby weather station (3.4 km away) and using satellite solar resource data. Soiling losses were found to be 0.21% per day. The site was observed to have a decrease in efficiency from 7.2% to 5.6% during a 108-day dry period in the summer at which point a rain event occurred that recovered most of the lost efficiency going back to 7.1%. Kaifeng NING, Japing CHEN et al., with the increasingly shortage of conventional energy, solar energy, as one kind of an inexhaustible, and pollution-free clean source of energy, became the first choice of renewable energy. In different working circumstances, the system could work in different working modes: calendar-check tracking mode, four-quadrant detector tracking mode and night mode. Practical experiments show the system could meet the demands of detection accuracy, lower power, and higher reliability. Hiroyuki kawamoto and Takuya shipmate et al., conducted electrostatic cleaning method on solar PV panel. A unique cleaning system has been developed by utilizing an electrostatic force to remove sand from solar panels. A single-phase voltage is applied to parallel wire electrodes embedded in a cover glass plate of a solar panel. It was demonstrated that more than 80% of the adhering sand was repelled from the surface of the slightly inclined panel, and the output power generated by the solar panel was recovered up to 80% after the cleaning operation. The power consumption of this system is virtually 0. This technology is expected to increase the efficiency of mega solar power plants constructed in deserts at low latitudes. The device will be suitable for mega solar power plants constructed in deserts because it is potentially inexpensive, needs virtually no power, and operates automatically without water and other consumables. Xiao long Lu, Qi hang, Jinhua Hu et al., conducted automatic cleaning on the solar PV panel by using Piezo electric actuator. A linear piezoelectric actuator based solar panel cleaning system is designed, fabricated and characterized. In linear piezoelectric actuator, to elliptical motions of driving feet or employ to drive the vibrator and the wiper. Exciting by the driving voltage of 100Vo-p at resonance, the prototype actuator works well at both the forward and backward operation. The experimental results indicate that a proper pressure force between the wiper and panel and longer panel width perpendicular to wiping direction are beneficial to the energy gain improvement. Due to the use of linear piezoelectric actuator, the cleaning system has the merits such as light weight and compact structure just like other piezoelectric systems. K. Srinivas Rao, Mahesh et al., has conducted solar panel tracking system to capture the more solar energy. This project is designed with ARM&TDMI processor does the job of fetching the input

from the sensor and gives command to the motor to run in order to tackle the change in the position of the sun. It reports a "LPC2148 based improved structure of solar tracker". The monitoring controller based on the closed loop algorithm is designed and implemented with ARM7 TDMI processor based LPC2148 controller in embedded system domain. Experimental work has been carried out carefully. Maximum current achieved and that can be obtained by solar panel. Solar trackers are devices used to orient photovoltaic panels, reflectors, lenses or other optical devices towards the sun. Since the sun's position in the sky changes with the seasons and time of the day, trackers are used to align the collection system to maximize energy production. Ravi Tejano et al., has conducted automatic cleaning system and tracking system of solar PV modules. This automated system is implemented using 8051 microcontrollers 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. In this experiment the PV module efficiency increased about 30%. Hussein A Kazembe, Tamer Khatri, K. Copian et al., conducted experiment how the dust effect on multi-crystalline PV module was investigated for indoor and outdoor conditions. The PV module performance has been tested under the deposition of different pollutants (red soil, ash, sand, calcium carbonate, and silica). The aim of the conducted experiment is to identify the effect of dust on the voltage and output power of PV modules. According to the obtained results, a drop of PV module's voltage and output power is observed when dust particles are deposited on the PV module depending on the mass accumulated, and the type of pollutant. Moreover, larger reduction occurs when the PV module's temperature is increased. In addition to that, keeping the PV modules clean and cool, results efficient system performance. Amirah afiqah bent armed et al., conducted an experiment Solar power is one of environment friendly power source. It is characterized by being highly dependent on the radiation level which is function of sun position at the sky. As it is a single axis tracker, the tracker will follow the Sun in East-West movement. While, a smart sun tracking is a system develop to make sure that the PV module always perpendicular to the sun for maximum extraction. To control the single axis rotation, the circuit is programmed to fulfill a minimum and maximum requirement value from the PV module. When the amount of radiation on the module is not between the required values, power window motor will rotate until it reaches a point where the produces voltage is acceptable. As for cleaning purposes, a mechanism consists of sliding brushes has been developed. The mechanism works with the help of gravity which when the module inclined, the brushes will slide to the same direction of the module and clean the module surface. The automated cleaning system is implemented to prevent the formation of dust on the module surface. It is to make sure that the module can extract maximum capacity of solar power. Yen-Mo Chen, AlexQ.Huang et al., were conducted an experiment with a three-port dc–dc converter integrating photovoltaic (PV) and battery power for high step-up applications. The topology includes five power switches, two coupled inductors, and two active-clamp circuits. The coupled inductors are used to achieve high step-up voltage gain and to reduce the voltage stress of input side switches. Two sets of active-clamp circuits are used to recycle the energy stored in the leakage inductors and to improve the system efficiency. Therefore, the control scheme of the proposed converter provides maximum utilization of PV power most of the time. As a result, the proposed converter has merits of high boosting level, reduced number of devices, and simple control strategy. Experimental results of a 200-W laboratory prototype are presented to verify the performance of the proposed three-port converter. Gabriele Lybrand, Jived Narnia, Huaibei Yu et al., were conducted an experiment on solar panels automatic cleaning system The design that was decided upon by our group consists of a mechanism, which behaves much in the way of a wiper blade on a car, to clean the solar panel. This "wiper blade" is fitted with an electrostatic cloth, attached to a servomotor, interfaced with, and operated by the Basic Stamp 2 (BS2). In addition to this, a dust detecting system is used to determine when it is best to clean the panels. This means that the energy is not wasted by always cleaning the panels or by having the efficiency reduced because of dirt. Finally, an emergency system is equipped to provide an automatic shut off in the form of a button and a digital thermometer. Salim, A. A., F. S. Hurrian, Imamura M.S et al., studied about the failure of open-circuit modules. SOLERAS photovoltaic power system (PVPS) on which became operational in seep 1981A series of current voltage (I-V) tests and other analyses eventually uncovered a number of (PV)modules that have resulted in open circuit type failure in the four cell group, or a half module. As of august 1984, the estimated number of these defective modules in the PV field was 152. In that 340 modules need repairs. In addition to failure analyzing there is a plan to continue the monitoring of the rate of failure and analyzing the failure mechanisms is presented. Mohammad S. El-Shobokshy, Filmy M. Hussein et al., studied the effects of dust accumulation on the surface of photovoltaic cells were experimentally investigated. The dust deposition density in g/m2 of panel surface area was determined in each test run. The effect of dust deposition density on the short circuit current, output power and the fill factor was determined and discussed. It was concluded that dust accumulation considerably deteriorates the performance of the photovoltaic cells. J. K. Kalel's · M. Capsule. Et al., conducted an experiment on one of the least analyzed side effects of atmospheric air pollution is the degradation of PV-panels' performance due to the deposition of solid particles varying in composition, size and type. In the current study, the experimental data concerning the effect of three representative air pollutants (i.e. red soil, limestone and carbonaceous fly-ash particles) on the energy performance of PV installations are analyzed. According to the results obtained, a considerable reduction of PVs' energy performance is recorded, depending strongly on particles'

composition and source. Subsequently, a theoretical model has been developed in order to be used as an analytical tool for obtaining reliable results concerning the expected effect of regional air pollution on PVs' performance. Furthermore, experimental results concerning the dust effect on PVs' energy yield in an aggravated – from air pollution – urban environment are used to validate the proposed theoretical model. Edward Leonardo Vidal et al., has conducted an experiment on Two photovoltaic technologies are compared with regard to the energy yield, performance ratio and their level zed cost of energy. The global tilted solar irradiation reached mean values of 8.6 kW h/m2 day in summer and 6 kW h/m2 day in winter demonstrating the high irradiation available. The performance ratio of thin films decreased due to the dust accumulation at a rate from −4.2 to −3.7%/month for decreasing temperature and from −4.8 to −4.4%/month for increasing temperature. For multi crystalline silicon modules, the degradation rates were −2.4 to −1.8%/month for decreasing temperature, and −6.2 to −3.7%/month for increasing temperature. It was concluded that the electricity costs were 14.48 cents€/kW h and 15.65 cents€/kW h for thin film and mc-Si, respectively. Thus, the thin films had more benefit after cleaning than multi-crystalline modules. J. Relaycaron, BodoLittmann et al., The optical loss caused by the accumulation of dirt and other contaminants on solar collectors is the third most important meteorological input, after insolation and air temperature that determines energy yield in a photovoltaic power plant. The test setup includes several First Solar plane-of-array modules that are allowed to accumulate natural contaminants, and several controls held clean by regular washing. This study reveals clear region-specific soiling trends as well as insight into the amount of rainfall required for full recovery of module performance. Soiling rates of up to 11.5% per month are observed in heavy agricultural areas. As little as 0.5 mm of rainfall is sufficient to completely clean a dirty frameless module in regions with lighter soiling rates. Jian Zhu, Chin-Mei Hsu et al., conducted an experiment here for the first time; we demonstrate novel Nano-dome solar cells, which have periodic Nano scale modulation for all layers from the bottom substrate, through the active absorber to the top transparent contact. We demonstrate Nano dome devices with a power efficiency of 5.9%, which is 25% higher than the flat film control. The Nano dome structure is not in principle limited to any specific material system and its fabrication is compatible with most solar manufacturing; hence it opens up exciting opportunities for a variety of photovoltaic devices to further improve performance, reduce materials usage, and relieve elemental abundance limitations. Lastly, our Nano dome devices when modified with hydrophobic molecules present a nearly super hydrophobic surface and thus enable self-cleaning solar cells. James R. Gayer and Marla E. Perez-Davis et al., conducted experiment on the results of dust on panel because of soil, during the Martian soil storm. Samples were tested both initially clean and initially dusted. The samples were exposed to clear and dust laden winds, with velocities varying from 23 to 116 m/s, and attack angles from 0' to 90'. Abrasion is negligible at 0°, and increases to a maximum at 90°. Occultation is more of a problem with small particles, whereas large particles (unless they are agglomerates) cause more abrasion. John K. Kalel's, Alexandra Koala and Marina Capsule et al., conducted experiment on effect of soiling by natural pollution affects panels and to calculate loss of efficiency of cell. Specifically, the performance of two identical PV-panel pairs is compared, after the exposure of one of them to natural air pollution, over a certain period. A systematic series of experimental measurements under variable ambient conditions is conducted in order to indicate any differences between the power output and the efficiency of the panels. According to the results obtained, the presence of dust considerably deteriorates the PV-panels' performance (i.e. 0.4% efficiency reduction in absolute terms), even within a short period of panels' outdoor exposure (i.e. one month) without cleaning. H. Patel, and V. Agarwal et al., proposed Current-voltage and power-voltage characteristics of large photovoltaic (PV) arrays under partially shaded conditions are characterized by multiple steps and peaks. The proposed algorithm works in conjunction with a DC-DC converter to track the GP. In order to accelerate the tracking speed, a feed forward control scheme for operating the DC-DC converter is also proposed, which uses the reference voltage information from the tracking algorithm to shift the operation toward the MPP. The tracking time with this controller is about one-tenth as compared to a conventional controller. All the observations and conclusions, including simulation and experimental results, are presented. N. Barzun et al., studied solar tracking system. A novel method, which will automatically track the sun's position. By using this method, the solar tracker can be successful in maintaining a solar array at a sufficiently perpendicular angle to the sun. Solar tracking is by far the easiest method to increase overall efficiency of a solar power system for use by domestic or commercial users. By utilizing this simple design, it is possible for an individual to construct the device themselves. A.K. Sabena and V. Dutta et al., Single Axis Solar Tracking System prototype models successfully developed. The system is able to track and follow Sunlight intensity in order to collect maximum solar power regardless of motor speed. The unique of developed system, motor speed is not critical consideration because the DC-geared motor offers low output rated speed and high output rated torque. Therefore, any types of DC-geared motor can be used for this system regardless of motor speed controller unit as long as the speed and torque of the motor are following the given specification. The constructed system model can be applied in the residential area for alternative electricity generation especially for non-critical and low power appliances A. Zahedi et al., In this paper, the author presents the latest development and the results obtained from a project of an integrated renewable energy and energy storage (IREES) system. The IREES system, which is a total renewable energy based electricity supply system, finds so many applications as it can be used as a large-scale power supply being connected to national grids as well as a small scale power supply for remote areas. Findings and results arising from this research project will be of practical value for both power suppliers and people as energy users as this system not only conserves energy but also helps preserve the environment. M. Drift, P.J. Preset al., This paper presents a new solar irradiance model for the estimation of the solar radiation on façades of buildings in urban environments. A model and a computer tool, using Visual Basic Application of Excel, have been developed to analyze in detail the radiation on façades. It can

be used to determine, in a very intuitive, easy and fast way, using solar radiation contour maps, the best areas for the installation of photovoltaic systems. Finally, using the data obtained by the solar irradiance model for an application example, the electricity production of a photovoltaic system located at the selected façade is analyzed and discussed. Rappels, B. Muthirayan et al., The effect of dust settlement on the efficiency of photovoltaic modules was measured. To gain a deeper insight into the problem the physical properties of the collected dust were examined using a scanning electron microscope (SEM). The results show a constant power loss between 3% and 4% for the optimal tilt angle and regular rainfall. Rain seems to have little cleaning effect on smaller dust particles (<; 10 am), but on bigger particles (like pollen, ~60 am) the effect was clearly visible. S. Armstrong and W.G Hurley et al., This paper investigates the effectiveness of maximum power point tracking (MPPT) and proposes a quantitative measure of MPPT efficiency. Using a vector methodology to track the direction and path of the sun throughout the day, the optimal solar tracking angle and angle of incidence of the sun's rays are derived. The solar arrays output power is monitored, under sunny sky conditions, with and without the use of maximum power point tracking in order to study the difference in efficiencies and to quantify the benefits of maximum power point tracking. The paper presents result for the efficiency of MPPT under fixed horizontal solar panel conditions and optimal solar tracking. C. Jaen, J. Pouf, G. Capella. C. Jaen, J. pouf, G. Capella et al., Nowadays power supply systems based on photovoltaic cells have two main drawbacks; even the primary energy is free and renewable. They are production cost and efficiency. In order to increase their efficiency, it should be interesting that the energy transfer between cells and load was done at maximum level. In this paper, the use of a sun tracker system is presented as an additional improvement applied to a photovoltaic installation that works under a maximum power point tracking (MPPT) control technique. A 50 W-prototype has been assembled. Some experimental results are also included in order to validate the whole system M. Schnitzler, P. Johnson et al., One of the most critical inputs to a photovoltaic (PV) energy model is the solar data set, which establishes the site's irradiance and weather variability. For long-term energy estimates, the solar data set are expected to represent the long-term climatologically conditions on-site. a. The results of a research study conducted at nine locations throughout the United States show that both the magnitude and the distribution of input solar data sets affect energy. The value of on-site solar data collection and its ability to reduce uncertainty from between 2% to 5% is presented, as demonstrated from a case study from a site in the United States Desert Southwest. N. Kishore, M. Valsalva et al., This paper discusses the modeling of single-diode photovoltaic cell to estimate the maximum power with respect to changes in environmental factors that affects its efficiency performance. The parameters, i.e. resistances for the modeling of PV cell are determined for nonlinear I-V characteristics to replicate the maximum power point. These values are determined at various environmental factors like; dust, solar radiation intensity, shadow, temperature and wind velocity.

3. PROPOSEDSYSTEM

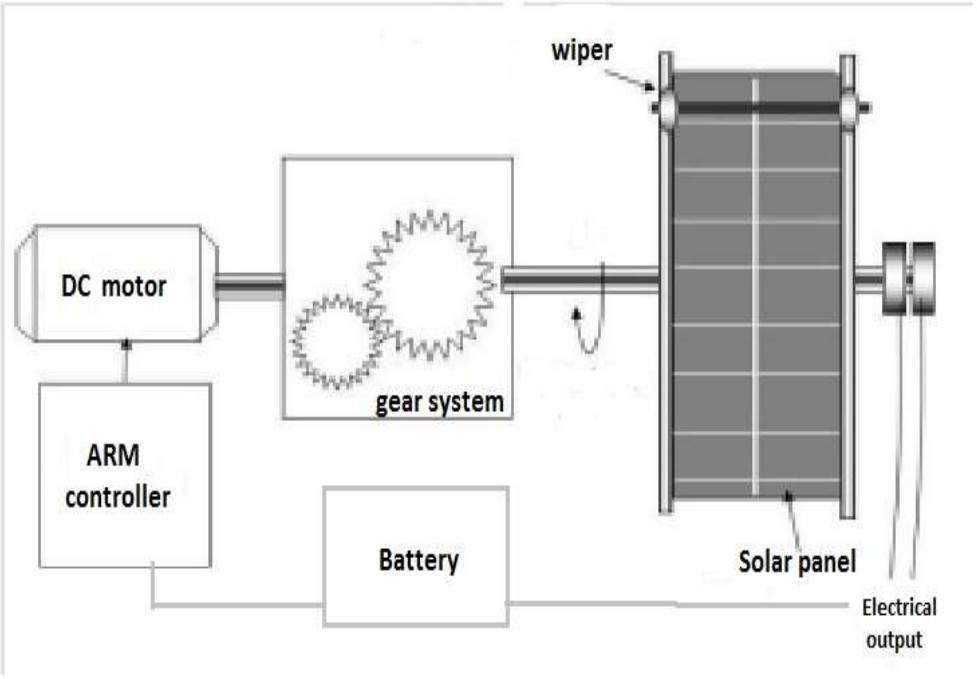


FIGURE 2. Proposed system circuit

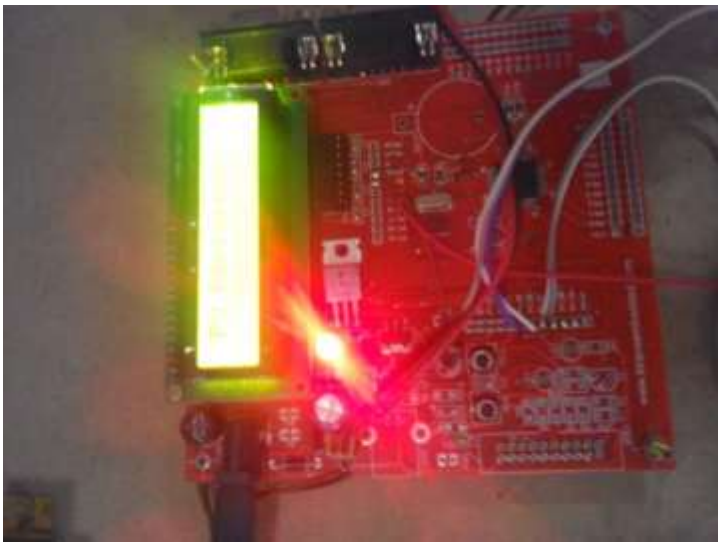


FIGURE 3. Microcontroller used in the circuit (ARM Controller)

The above system used in present project. The complete system shown in fig4which contain solar panel arranged with wiper, gear motor and micro-controller which is also known as ARM. This is connected to gear motor which can move wiper. ARM is programmed to sense the dust and detect the reduction in voltage then wiper starts cleaning. Voltage values can be observed on LCD which is shown in Fig3.

FIGURE 4. Solar panel and total setup used in proposed system

4. RESULTS

Observations: Most of the above projects proved that there is significant loss of power up to 40% and suggested methods proved to reduce this loss. The developed methods prove that the efficiency of solar panel can be increased up to 30%. Some of the above methods explain about how dust effect on the panel and some explains how to improve the performance by using different cleaning methods.

5. CONCLUSION

The effects of presence of dust were studied using artificial dust (falling leafs, husk, talcum powder). The dust has a major impact on performance and efficiency of the solar panel. The reduction in the peak power generates can be up to 30%, under greater irradiation the effects of dust can be slightly reduced but not negligible. Hence, in practice microcontroller and actuator based architecture in order to ensure the highest performance of PV panel under different irradiation levels. By studying the above methods selecting microcontroller and gear motor based solar panel cleaning system which is not mentioned in above methods. This is easily maintainable and low-cost. Power consumption is also less for this process.

REFERENCES

[1]. M. C. Hottel and B.B Woertz, "Performance of flat plate solar heat collectors" ASME Trans.,

[2]. M. Moon (2009) Google studies How dirt affects solar panel efficiency. PC Magazine: Good clean Tech. Available: www.goodcleantech.com/2009/08/google_studies_how_dirt_affect.php.

[3]. H. P Garg," Effect of dirt on transparent covers in flat-plate solar energy collectors". *Solar Energy congress, New Delhi, pp.960- 964*

[4]. Shaharin Anwar sulaiman "Influence of dirt accumulation on performance of PV panels" *The International Conference on Technologies and Materials for Renewable Energy, Environment and Sustainability, TMREES14*

[5]. Saadi Zinea, Rahmani Abdellah, Soualmi Hamoua "Efficiency of PV module under real working conditions "

[6]. F. Mejia, J. Kleissl, J. L. Bosch, "The effect of dust on solar photovoltaic systems" *The International Conference on Technologies and Materials for Renewable Energy, Environment and Sustainability, TMREES14*

[7]. Hiroyuki kawamoto and Takuya shibata, "Electrostatic Cleaning system for Removal of sand from solar Panels"

[8]. Xiaolong Lu, QiZhang, Junhui Hu, "A linear piezo electric actuator based cleaning system"

[9]. K. Sreenivasa Rao, M.Mahesh, 2012. *International Journal of Modern Engineering Research. (IJMER) www.ijmer.com*

[10]. Ravi Tejwani, "360° SUN TRACKING WITH AUTOMATED CLEANING SYSTEM FOR SOLAR PV MODULES", *978-1- 4244-5892-9/10/$26.00 ©2010 IEEE*

[11]. "SMART SUN TRACKING WITH AUTOMATED CLEANIN SYSTEM FOR PV MODULES" AMIRAH AFIQAH BINTI AHMED

[12]. Kaifang NING, Jiping CHEN, Tao YU, Guanhua ZHOU, Xingfeng CHEN, Guolin YU, "Design of the Attitude Automatic Adjusting System for the Solar Panel " *978-1-4244-9600-6/11/$26.00 ©2011 IEEE*

[13]. E. M. Al-Qubaisi, M. A. Al-Ameri, A.A.Al-Obaidi, "Microcontroller Based Dust Cleaning System for a Standalone Photovoltaic System"

[14]. Hong-Chan Chang, Cheng-Chuan Chen "Implementation of a Power Supply with the Characteristics of Solar Panels under Partially Shaded"

[15]. P. Vasijev, A. Struckas, S. Borodinas, A. Rotmanas, "*Ultrasonic Cavitations Research in Thin Flowing Liquid Layer" 10.1109/ULTSYM.2012.0213*

[16]. Liza Boyle, Holly Flinchpaugh, Michael Hannigan, "*Impact of Natural Soiling on the Transmission of PV Cover Plates", 978-1-4799-3299-3/13/$31.00 ©2013 IEEE*

[17]. Marcelo A. Perez, Jaime Zapata*," Analysis of Short-Term and Long-Term Characteristics of PV Power Production" 978-1-4799-2399-1/14/$31.00 ©2014 IEEE*

[18]. N. Barsoun, "Implementation of a Prototype for a Traditional Solar Tracking System", the Third UKSim European Symposium on Computer Modeling and Simulation, pp. 23-30, 2009.

[19]. A.K. Saxena and V. Dutta, "*A versatile microprocessor- based controller for solar tracking", IEEE Proc., 1990, pp. 1105 – 1109*.