STUDY OF SOLAR PANEL CLEANING SYSTEM TO ENHANCE THE PERFORMANCE OF SOLAR SYSTEM

[1]Akhil Mishra, [2]Ajay Sarathe
National Institute of Technical Teachers Training and Research, Bhopal

Abstract: In this paper we review the various concepts to handle energy demand around the world. The use of unconventional sources is increasing rapidly for many applications. Some unconventional sources of energy are solar, wind and geothermal which are inexhaustible. Solar energy is abundant in nature and is being used for many applications like street lighting , house hold appliances(cooking), water heating, agricultural and industrial purposes. One of the ways to harness solar energy is done by using solar photovoltaic panels. The limitation in proper use of solar energy is its efficiency. The factors which affect efficiency are like dust, humidity, temperature etc. Electrical parameters of solar panel are sensitive to accumulated dust density and will affect the transmittance of the solar panel thereby reduce its overall efficiency. To deal this problem, it is necessary to clean the solar panels regularly. One of the method is to enhance the efficiency of solar panel is by removing the dust accumulated on solar panel. Cleaning of solar panels is a difficult task. The conventional way to clean the solar panels is washing them manually but it is not reliable and economical. In this regard review of various techniques is done which are currently being used to increase the efficiency or performance of these solar panels.

Keywords: solar panel, cleaning efficiency, PV panels, Photovoltaic cell, plate efficiency

---

1.0 INTRODUCTION

The ability of Solar panels to absorb the sunlight as a source of energy and it is used to generate electricity or heat. Solar panel is designed in such a way such that it can generate maximum output whether it is used to generate electricity or any other purpose. A photovoltaic (PV) module contains many of the PV cells it contains near about 6x10 photovoltaic solar cells. Photovoltaic modules represent the electrical phenomenon array of a electrical phenomenon system that generates and provides star electricity in industrial and residential applications. Each module is rated by its DC output power beneath commonplace check conditions (STC), and generally ranges from a hundred to 365 Watts (W). The potency of a module determines the world of a module given constant rated output – AN V-E Day economical 230 W module can have doubly the world of a 16 PF economical 230 W module. There are a number of commercially on the market star modules that exceed potency of twenty-two and reportedly conjointly surpassing pure gold A single solar module can produce only a limited amount of power; most installations contain multiple modules. A electrical phenomenon system usually includes Associate in Nursing array of electrical phenomenon modules, Associate in Nursing electrical converter, electric battery pack for storage, interconnection wiring, and optionally a star following mechanism. The foremost common application of star panels is star water heating systems. The worth of alternative energy has continuing to fall in order that in several countries it's cheaper than normal fuel electricity from the grid (there is "grid parity"). Electrical phenomenon modules use light-weight energy (photons) from the Sun to get electricity through the electrical phenomenon impact. The bulk of modules use wafer-based crystalline semiconductor cells or thin-film cells. The structural (load carrying) member of a module will either be the highest layer or the rear layer. Cells should even be shielded from mechanical injury and wetness. Most modules are rigid; however semi-flexible ones are on the market, supported thin-film cells. The cells should be connected electrically nonparallel, one to a different. Externally, most of photovoltaic modules use MC4 connector's type to facilitate easy weatherproof connections to the rest of the system. Modules electrical connections are made in series to achieve a desired output voltage and/or in parallel to provide a desired current capability. The conducting wires that take the current off the modules may contain silver, copper or other non-magnetic conductive transition metals. Bypass diodes may be incorporated or used externally, in case of partial module shading, to maximize the output of module sections still illuminated.

1.1 SOLAR HOTSPOT

Solar hotspots are the regions characterized by an exceptional solar power potential suitable for decentralized commercial exploitation of energy with the favourable techno-economic prospects and organizational infrastructure support to augment solar based power generation in a country.

1.2 ENERGY SOURCES –

Various source of energy like coal, gas, hydro, nuclear, renewable, diesel and their some of them are going to be exhausted within few years.

- **INSOLATION** - Solar energy incident on earth surface**.**
- **PHOTOVOLTAIC CELL-**Photovoltaic cell is an electrical device that converts the energy of light directly into electricity by the photovoltaic effect

1.3 PRINCIPLE OF PHOTOVOLTAIC CELL

Sunlight striking the photovoltaic cell is absorbed by the cell. The energy of the absorbed light generates particles with positive or negative charge (holes and electrons), which move about or shift freely in all directions within the cell. The electrons (-) tend to collect in the

N-type semiconductor, and the holes (+) in the P-type semiconductor. Therefore, when an external load, such as an electric bulb or an electric motor, is connected between the front and back electrodes, electricity flows in the cell.

1.4 EFFECT OF DUST ON PV PANEL

Accumulation of dust from the outdoor environment on the panels of solar photovoltaic (PV) system is natural. There were studies that showed that the accumulated dust can reduce the Performance of solar panel, accumulated dust on the surface of photovoltaic solar panel can Reduce the system's efficiency by up to 50%.

2.0 CLEANING METHODS FOR PV PANEL'S

2.1 NATURAL REMOVAL OF DUST

The natural powers are employed to remove the dusts, such as wind power, gravitation and the scour of the rainwater. The effect of this method is not very well. It is seen that the solar cell array can be turned to vertical or oblique position to remove the dusts easily when early morning, late evening, night and a rainy day. However, the rotation of the large solar cell array is very difficult.

2.2 MECHANICAL REMOVAL OF DUST

The mechanical methods remove the dusts by brushing, blowing, vibrating and ultrasonic driving. The brushing methods clean the solar cell with something like the broom or brush that were driven by the machine was designed just like windscreen-wiper. However, firstly, because of the small size and the strong adhesively of the dusts, the cleaning method is inefficient. Secondly, the abominable working environment of the solar cell makes the maintenance of the machine difficult. Then, due to the large area of the solar cell array, the cleaning machine is powerful. Lastly, the surfaces of the solar cell maybe were damaged by the brush when wiping. The blowing method cleaning the solar cell with wind power is an effective cleaning one except the low efficiency, high energy-consumption and the unsatisfactory maintainability of the blower.

2.3 ELECTROSTATIC REMOVAL OF DUST

If there are a high potential on the surface of the solar panels, the charged and uncharged dusts will be attract to the panels because of the electrostatic forces. Then, the dust particles will be charged by the solar panels finally, so they have the same electric charge and the electrostatic forces between them are repulsion. At last, the dust particles will float away the solar panels. However, this strategy cannot be used in PV system, because of the effecting of the rain on earth.

[1] Kutaiba-Sabah et.al in the experiments which is previously done, dust accumulation for the solar panels being investigated for a long period of time that is approximately for one year. The experiments have been done in different countries which have climate conditions of the dusty weather. Those countries are Iraq, Egypt and UAE. The solar panels were never cleaned, initially for one month, and then for two months and so on. The results were there was a decreasing in the transmittance of the solar panels, which is emphasize the effect of accumulated dust, even though the changing in the tilt angel which is in concurrence with the dust deposition on the panels. A well designed auto cleaning system to clean the solar panels will be added to the panels to keep the transmittance of the solar planes fixed approximately and to reduce the cost- of periodic cleaning. Actually, there are many benefits from such a project. First, economical benefit, where there is no more money will be paid to a cleaning agency. Second, it is time saving, where there is no time will be spent to clean those solar panels. Besides that, recurrently cleaning will make sure that the solar panel works with a good transmittance. Finally, safety and health of workers in sites. Since robots are capable of working in perilous environments, more dangerous operations are being handled by robots.

[2] Anglani et.al Mirror cleaning for concentrated solar thermal (CST) systems is an important aspect of operation and maintenance (O&M), which affects solar field efficiency. The cleaning process involves soil removal by erosion, resulting from droplet impingement on the surface. quite a few studies have been conducted on the dust accumulation and CSP plant reflectivity restoration, signifying that parameters such as nozzle diameter, jet impingement angle, interracial distance between nozzles, standoff distance, water velocity, nozzle pressure and others factors influence the extent of reflectance restoration . In this paper our main objectives is to identifying the optimized cleaning strategies suitable for CST plants, able to restore mirror reflectance by high-pressure water-spray systems through the enhancement of shear stress over reflectors' surface. In order to evaluate the forces generated by water-spray jet impingement during the cleaning process, fluid dynamics simulations have been undertaken with ANSYS CFX software.

[2] Zhou et.al the self-cleaning technology for solar cell array can promote efficiency of electricity produced and protect the solar cell. The methods of dust-removal, such as natural means, mechanical means, self-cleaning Nano film, and electrostatic means are presented in this paper. Although some methods for self-cleaning have been mentioned by many researchers, especially, the application for lunar and Martian exploration, less research about self-cleaning for the solar cell array has been performed. Synthesizing the above-mentioned method, the best strategy of removal-dusts for solar cell array is electric curtain.

[3] Halbhavi et.al the solar PV modules are usually employed in dusty environments which are the case in tropical types of 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 reducing of power output as much as by 50% if the module is not cleaned for a month. In order to regularly clean the dust, a automatic cleaning system has been designed, which senses the dust on the solar panel and also cleans the module automatically. This automated system is implemented by using the 8051 microcontroller that controls the DC gear motor. This mechanism consists of a sensor that is light dependent resistor (LDR). While for cleaning the PV modules, a mechanism consists of a sliding brushes has been developed. The losses of the output power of the fixed solar panel at a tilt angle (35) is about 25% of the rated yield and can be higher depending on the dust form. The dirt and bird drop make a hot spot in the panel, and it can make temporary fail in the panel.

[4] Huang et.al this paper presents an intelligent solar panel cleaning system that utilizes a fuzzy logic controller. The output voltage of the solar panel is applied to compute whether to activate the cleaning mechanism. Both the direction and position of the system is set by using a light sensor that is parallel to the direction of the sunlight. The data from the light sensors, combined with fuzzy logic control software developed using Lab VIEW, determine the control commands (stop, forward, and reverse) for the stepper motors controlling the cleaning process. The cleaning process, which is going to be frequent until the power output from the solar panels is sufficient, is performing in real time to keep the power generating capacity of the solar cells. The projected solar panel cleaning system is based on fuzzy logic control. According to our research, no solar panels currently on the market are equipped with cleaning devices.

[5] Mondal et.al the solar photovoltaic (SPV) panel's efficiency depends upon the quantity of solar irradiance and the spectral content. SPV panels are being largely used because of their economic and environmental qualities. The performance of SPV panels getting tainted due to

factors like air pollution, bird droppings, dust, snow accumulation, etc. An automatic and integrated solar panel cleaning robotic arm (SPCRA) with four-degrees of freedom has been designed to overcome the above factors. The arm has two prismatic and two revolute joints. SPCRA has unique end effectors with a water sprinkler, air blower and a wiper installed as a single unit on it. We have discussed the cleaning technology using an electromechanical system for SPV. The system has been analyzed and optimized for high effectively. The external system developed does not affect the actual performance of SPV, since it is not coupled with the panels. As the tests were conducted on 50 Watt SPV panels, the efficiency development value is less.

[6] Ballal et.al Sun is a low cost source of electricity and instead of using the generators; solar panel can convert direct sun rays to electricity. Conventional solar panel is fixed with a certain angle, limits their exposure area from the sun due to Earth rotation. In pursuing to get the maximum energy is converted from the sun, an automatic system is required which should be capable to continuously rotate the solar panel at constant rate. The automatic solar tracking system solves this problem. There are single axis trackers and dual axis trackers. In this paper we will discuss PLC based dual axis tracker. Dual axis trackers have two degrees of freedom that act as axes of rotation. PLC based input and output (I/O) configuration is used as the hardware along with the analyzing unit of photosensitive resistance for detecting the ray strength and then shifts the panel towards the maximum output from the sun. Stepper motor arrangement is used to rotate the panel to the desired position.

[7] Zorrilla-Casanova et.al the dust accumulation on the surface of a photovoltaic module decreases the radiation attaining in the solar cell and then losses in the generated power produced. Dust not only reduces the radiation on the solar cell, but also changes the dependence on the angle of incidence of such radiation. This work presents the results of a study carried out at the University of Malaga to quantify losses caused by the accumulation of dust on the surface of photovoltaic modules. Our results show that the mean of the daily energy loss along a year caused by dust deposited on the surface of the PV module is around 4.4%. In long periods lacking rain, every day energy losses that can be higher than 20%. In addition, the irradiance losses are not constant throughout the day and are strongly dependent on the sunlight incident angle and the ratio between diffuse and direct radiations. In such type of work we have studied earlier in common the energy losses due to accumulated dust on the surface of photovoltaic modules.

[8] Gheitasi et.al Use of renewable energy sources in New Zealand such as photovoltaic (PV) panels has been increasing over the last few years. The Thames energy group is planning to explore the possibility of using a more sustainable energy. Alkhaldi Mohammed, a Wintec student did a study to install 327 kw PVs system over the Thames hospital roof which has an area of 2950m,2 and another Wintec student Alnajrani Hassan, did a study to install 11064 KW PV systems with an area of 99576m2 to cover the needs of Thames domestic houses. However, with Thames being near the coast, and surrounded by forest, there were some environmental issues affecting the PV output, such as dust which accumulated from pollen and sea salt. This project was to maintain the PVs to generate power at high efficiency.

3.0 EXISTING RESEARCH EFFORTS

[9] Mukadam et.al we designed and built an automated self-cleaning solar panel. The panel detects the occurrence of an impediment shading a cell, and actuates a cleaning mechanism that cleans off the impediment and consequently, restores the panel to normal capacity. To power the cleaning mechanism, we built our own power supplies which are supplied by a 12V battery. The fully assembled system was able to detect a shaded cell from debris. Furthermore, it initiated the wiper motion down and up the panel to clear the debris. Also, the system maintained the battery charged when there was no cleaning and sufficient power was available. More importantly, the project decreased the daily energy lost compared to the case where the PV panel was left shaded for an entire day.

[10] Kokila et.al Solar panel has gained its importance in our day to day life as a replacement for conventional electricity. The solar panel converts the solar energy into heat or electrical energy. Due to the accumulation of dust on the surface of the solar panel, the incident light is blocked from the sun. This reduces power generation and the power output of the system by 50%, if the module is not cleaned for a long period of time. The proposed system aims at overcoming the problem by a timer based automatic cleaning system which cleans the solar panel regularly in the dusty environment. The proposed system gives more efficient storage of power that is generated using the solar panel by frequent cleaning of the solar panel.

[11] Glasser et.al The solar photovoltaic collection at the Miller Auditorium is a 50 kW DC system that has been depending on five seasonal angle adjustments and no cleaning measures to reach at the mean value of 64.7 MWh annual energy generation from the time of 2012. This amount of energy generation yields $7,046 in annual energy savings based on current market pricing for end use electricity of $0.1089/kWh. The existing adjustment plan is based on seasonal tilts accounts for annual costs between $760 and $848, but the actual adjustments have historically not taken place according to the existing plan. The investigation pointing on maximizes the net energy outcomes of the Miller collection by studying low cost approaches to roll schedules and panel cleaning. Cleaning test groups are designed to determine feasibility and panel cleaning cost effectiveness with respect to pollen, dust, and accumulation of soiling. Industry standard practices for defensive panel continuation frequently neglect panel cleaning and therefore do not consider the potential impacts on the system performance.

[12] Greenough et.al the objective of Project SPACE is to form an automated solar panel cleaner that will address the unfavorable soiling impact on commercial photovoltaic cells. Particularly, we assumed to generate a device that increases the maximum power output of a soiled panel by 10% (recovering the amount of power lost) while still costing under $500 and operating for up to 7.0 years. A successful design should operate without the use of water. This will going to help solar panel arrays to achieve a production output closer to their maximum potential and set aside companies on costs associated energy generation. The present apparatus uses a brush cleaning system that cleans on set cleaning cycles. The device uses the combination of a gear train (with 48 pitch Delrin gears) and a 12V DC motor to spin both a 5.00 foot long, 0.25 inch diameter vacuum brush shaft and drive two sets of two wheels. The power source for the drive train is a 12V deep cycle lead-acid battery.

[13] Sensarma et.al for close to three decades, tapping the energy from the sun has always had great potential but large scale utilization has faced many bottlenecks. in the midst of many bottlenecks are cost of technology, energy storage, solar power distribution and daily/seasonal changeability of solar resources. In the present initiative, we address these challenges under three broad research themes of solar energy capture, distribution and storage. We recommend initializing a solar energy research cooperative with the following objectives:

a) We will establish a technology demonstrator 1 MW (peak) solar power station in two phases. It will supplement electricity requirement of IITK campus during day time (8 hrs) and thus help in reducing dependence on grid power. This will also generate useful data for future implementation of such projects in the region.

b) Modules in the solar power station will be used for research and as test platforms for large scale solar energy technologies.

c) We will initiate new and enhance the existing programs for long term research & development in solar power generation, storage, distribution, management and policy making in the institute.

[14] Zelun Li et.al the self-cleaning technology for solar cell array can promote efficiency of electricity produced and protect the solar cell. The dust removal method, such as natural way, mechanical way, self-cleaning Nano film, and electrostatic way are presented in this paper. Even though some methods for self-cleaning have been mentioned by many researchers, If the surfaces of the solar cell array were covered with a pellucid self-cleaning Nano film, it will keep clean. The self-cleaning Nano film is made of super hydrophobicity material or super-hydrophobic material. That is means the self-cleaning mechanism of the Nano film involve two strategies. The popular super hydrophilic film is TiO2, which has hydrophobicity and photo catalytic activity. The self-cleaning method consists of two stages. The first one is photo catalytic process which TiO2 film reacts under the ultraviolet light, and split the organics dirt.

[15] Mani et.al Most of the oil reserves peaking and coming climate change are seriously driving the solar photovoltaic's (PV) adopted as a sustainable renewable and eco-friendly alternative. Enduring material research has up till now to find a breakthrough in considerably raising the conversion efficiency of profitable PV modules. The PV systems installation for optimum yield is mainly dictated by its geographic location latitude and existing solar insolation and installation design such as tilt, orientation and altitude to maximize solar exposure. On the other hand, once these parameters have been addressed appropriately, there are other depending factors that arise in determining the system performance (efficiency and output). Dust is the lesser recognized factor that considerably influences the performance of the installations of PV. This paper provides an appraisal on the current status of research in studying the impact of dust on PV system performance and identifies challenges to further pertinent research.

[16] Sulaiman et.al Dust accumulation from the outside environment on the solar photovoltaic (PV) panels system is natural. There were studies which showed that the accumulated dust can minimize the performance of solar panels, but the results were not evidently quantified. The purpose of this research was to study the dust accumulation effects and then analyze the performance of solar PV panels. Experiments were conducted by utilizing dust particles on solar panels with a steady power light source, to conclude the resulting electrical power generated and efficiency. The effect of presence of dust was studied using artificial dust (mud and talcum) under a constant irradiance conducted in an indoor lab. Dust has consequences on the solar PV panel performance. The decline in the peak power generation can be equal to 18%. It was also given away that under larger irradiation; the effect of dust became somewhat minimized but not negligible.

[17] Ramachandra et.al Solar hot spots are the regions characterized by an incomparable solar power potential apposite for decentralized saleable energy exploitation. Identification of solar hot spots in a vast geographical expanse with dense habitations helps to meet escalating power demand in a decentralized, efficient and sustainable manner. This statement focuses on the evaluation of resource potential with changeability in India consequential from high resolution satellite derived insolation data. Data investigation reveals that almost 58% of the geographical area potentially represents the solar hot spots in the country with more than 5kWh/m2/day of annual average Global insolation. A techno economic investigation of the solar power technologies and a forthcoming minimal utilization of the land existing within these solar hot spots exhibit their enormous power generation as well as emission reduction potential.

[18] Sabah et.al in the previously done experiments, dust accumulation for the solar panels has been researched for a long period of time which is approximately about a year. The experiments have been prepared in different countries which is having climate conditions of the dusty weather. Those countries are Iraq, Egypt and UAE. The solar panels were not at all cleaned, at first for one month, then next for two months and so on. The results were like there was a decreasing effect in the transmittance of the solar panels, which is emphasizing the effect of accumulated dust, although the changing in the tilt angel which is in conjunction with the dust deposition on the panels. Actually, there are many benefits from such a project. First, economical benefit, where there is no more money will be paid to a cleaning agency. Next, it is time reduction, where there is no time will be spent to clean those solar panels.

[19] Biswas et.al this paper presents a design of solar tracking system driven by 12V or 24V DC motor controlled by a microchip 'Intelligent Drive unit IBL2403'. The projected double axis rotation solar tracker ensures the optimization of solar energy conversion to electrical energy by the orientation of 'titanium-oxide' PV panels in synchronization to the hemispherical position of the Sun. The hemispheroidal three dimensional rotational axle moves the PV panel along the Sun path. Efficient cooling system and dust control mechanism has been designed for maximum efficiency. Normally silicon based PV cells having 13% of conversion rate of solar to electrical energy, but the Titanium-oxide PV (ToPV) panels having 32% of conversion rate.

[20] Kawamoto et.al an improved cleaning system has been developed that uses electrostatic force to remove sand from the surface of solar panels. A single-phase high voltage is applied to parallel wire electrodes embedded in the cover glass plate of a solar panel. It has been verified that more than 90% of the adhering sand is repelled from the surface of to some extent inclined panel after the cleaning action. The performance of the system was further improved by improving the electrode configuration and introducing natural wind on the surface of the panel, even when the deposition of sand on the panel is extremely high. The power consumption of this system is virtually zero. An improved cleaning system for removal of the sand that accumulates on solar panels using electrostatic force has been developed. This system is suitable for use in mega solar power plants constructed in deserts at low latitudes because it is potentially inexpensive, requires virtually no power, and operates automatically without water and other consumables.

[21] Bansal et.al the energy or efficiency produced by solar photovoltaic modules is related with the Sun's available irradiance and spectral content, as well as other factors like environmental, climatic, component performance and inherent system. These dust, dirt and bird droppings are the major reasons for the solar photovoltaic system underperformance. This paper discusses a comprehensive overview of dust problem and the recent developments made on automated cleaning system for solar photovoltaic modules which give brief overview on techniques like electrical, mechanical, chemical and electrostatic.

[22] Kulkarni.al the solar PV modules are generally employed in dirty environment which is the case in tropical countries like India. The dirt 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 dust accumulation on the surface of a photovoltaic (PV) module decreases the radiation getting the solar cell and produces losses in the generation of voltage and power. Dust not only decreases the radiations on the solar cell, but also changes the dependence on the incidence angle of such radiation. According to the research, the daily energy loss along a year caused by dust deposited on the surface of the PV module is around 4.4%. In long periods with no rain, every day energy losses can be more than 20 %.

[23] Nazar et.al the recent upsurge in the demand of PV systems is due to the fact that they produce electric power without hampering the environment by directly converting the solar radiation into electric power. Solar energy is totally natural, it is considered as a clean energy source. So the study on increasing the efficiency of solar panel is very compulsory. In this paper I have discussed a variety of methods of efficiency improvement of solar panel. We can advance efficiency of solar panel by utilizing solar tracker with panel which constantly tracks sunlight throughout the day to get highest solar energy. Second method to advance the efficiency is a dust cleaning. Dust is barrier between sunlight and solar panel. Third method is cooling technique. As panel temperature increases output voltage of solar panel that decreases panel cooling is necessary for the improvement of efficiency.

[24] Patil et.al the aim of this paper is to give an innovative concept to handle energy demand around the world is increasing rapidly for many applications. Renewable sources of energy are solar, wind and geothermal which are inexhaustible. Solar energy is abundant in nature and is proving its existence for many applications like street lighting, house hold appliances, water heating, agricultural and industrial purpose. One of the way to harness solar energy is done by using solar panels. Limitation of solar energy is its efficiency for any application due to the factors like dust, humidity, temperature etc. Electrical parameters of solar panel are sensitive to accumulated dust density and will affect the transmittance of the solar panel thereby reduce its efficiency. In order to overcome this problem, it is necessary to clean the solar panels regularly.

[25] Burke et.al a successful design should operate without the use of water. This will help solar panel arrays achieve a production output closer to their maximum potential and save companies on costs associated energy generation. The goal of Project SPACE is to create an automated solar panel cleaner that will address the adverse impact of soiling on commercial photovoltaic cells. The results of the analysis on the drive shaft show a maximum deflection at 4.41 degrees. This deflection will occur at the end farthest away from the motor. The maximum deflection before the beam plastically deforms was calculated to be roughly 62 degrees. The calculation can be found in Appendix 1. Our analysis shows that the drive shaft can handle the torque of the motor. This analysis was performed on a single gear from a larger gear train. A complete analysis of every gear is recommended to ensure adequate part performance.

[26] Kawamoto et.al given the idea of using the electrostatic force to remove sand. A single-phase high voltage is applied to parallel wire electrodes embedded in the cover glass plate of a SPV. It has been shown by them that more than 90% of the adhering sand is repelled from the surface of the slightly inclined panel after the cleaning operation of panels. They give the idea that the performance of the system was further improved by improving the electrode configuration and introducing natural wind on the upper surface of the panel, even when the accumulation of sand on the panel is extremely high. After the experiment they have analysed that power consumption of this system is virtually zero. This technique is expected to increase the effective efficiency of mega solar power plants.

[27] Sabah et.al Performed experiments in different countries which have climate conditions of the dusty weather. Some of those countries are Iraq, Egypt and UAE. The solar panels which were there were never cleaned, first for one month, second for two months and so on. The results were that there was a decrement in the transmittance of the SPV Panels, So they emphasized on the effect of accumulated dust, even though the changing in the tilt angel of the panel which is in conjunction with the dust deposition . A well designed auto cleaning system to clean the solar panels will be introduced to the panels to keep the transmittance of the solar planes fixed approximately and to reduce the cost of periodic manual cleaning**.** Frequently automatic cleaning will ensure that the solar panel works with a good transmittance over the year.

[28] Sulaiman et,al, Studied the effects of dust accumulation on the performance of SPV panels. Experiments were performed using dust particles on solar panels with a constant-power light/ radiation source, to determine the resulting electrical power generated and efficiency by these SPVs. The effect of presence of dust particles was studied using artificial dust (mud and talcum) under a constant irradiance. They have conducted experiments in an indoor lab. Dust has reducing effect on the performance of solar PV panel. The reduction in the peak power generated by the SPVs up to 18%.

Some of the researcher had done work to increase the efficiency of work solar plate. They used the different techniques for cleaning the solar panel; some of the researcher has used different acid to clean panels. Some of the research work is conclude in table below

S. No.	Paper title	Author	Published year	Remarks
1	Project SPACE: Solar Panel Automated Cleaning Environment	Matt Burke	2016	3.5% improvement in the efficiency
2	design and implementation of microcontroller based automatic dust cleaning system for solar panel	Satish patil	2016	1.6 – 2.2% improvement by regular cleaning
3	Microcontroller Based Automatic Cleaning of solar panel	S. B. Halbhavi	2015	25% Losses due to tilt angle of 35’ and further more due to dust
4	An Integrated Design of an Auto Clean and Cooling Smart PV Panel	Sumit Das	2014	Titanium-oxide PV (ToPV) panels have a 32% conversion rate.
5	Electrostatic cleaning system for removal of sand from solar panels	Hiroyuki Kawamoto	2014	Use of electrostatic force to remove sand from the surface of solar panels
6	Self-Cleaning Solar Panels to Avoid the Effects of Accumulated dust on Solar Panels Transmittance	Kutaiba Sabah	2013	Improvement in transmittance by use of self cleaning solar panels

3.1 CONCLUSION

From the above study it is analysed that as the surface of the solar panel clean, solar ray falling on the plate are more utilized to convert in to work. So it is found that as the surface of the plate maintained clean the efficiency of the solar panel get also increase. So it is necessary to clean the surface panel of plate at regular interval. Some of the methods are given-

1. High potential of solar energy or solar hotspots are present in India.
2. The efficiency of SPV can be increased by various techniques
   - Solar tracking of SPV plates
   - Removal of dust from the SPV surface
3. Dust accumulation on SPV may reduce its efficiency up to 50%. Some methods used to remove dust from surface are as follows,
   i. Natural removal of dust
   ii. Mechanical removal of dusted cleaning of these array
   iii. Electrostatic removal of dust
   iv. Electro mechanical removal of dust

4. So to increase the efficiency of the SPV array we must timely remove the dust from its surface of insulation. Automated cleaning of this array is preferred because it may increase the efficiency of SPV array up to 20% No manual interference so the running cost of cleaning system is less.

REFERENCES

[1] Hiroyuki Kawamoto, Takuya Shibata (2015) Electrostatic cleaning system for removal of sand from solar panels. Journal of Electrostatics 73 (2015) 65e70.

[2] Monto Mani, Rohit Pillai (2010) Impact of dust on solar photovoltaic (PV) performance: Research status,challenges and recommendations. Renewable and Sustainable Energy Reviews 14 (2010) 3124–3131.

[3] Gaofa He, Chuande Zhou, Zelun Li (2011) Review of Self-Cleaning Method for Solar Cell Array. International Workshop on Automobile, Power and Energy Engineering16 (2011) 640 – 645.

[4] T.V. Ramachandraa, RishabhJain, GauthamKrishnadas (2011) Hotspots of solar potential in India. Renewable andSustainableEnergyReviews 15 (2011) 3178–3186.

[5] Shaharin A. Sulaiman, Haizatul H. Hussain, Nik Siti H. Nik Leh, and Mohd S. I. Razali (2011) Effects of Dust on the Performance of PV Panels. International Journal of Mechanical, Aerospace, Industrial, Mechatronic and Manufacturing Engineering Vol:5, No:10, 2011.

[6] Satish patil, Mallaradhya H M (2016) design and implementation of microcontroller based automatic dust cleaning system for solar panel. international journal of engineering research and advanced technology (ijerat) issn: 2454-6135 special volume. 02 issue.01, may-2016.

[7] Amit Kumar Mondala & Kamal (2015) A brief history and future aspects in automatic cleaning systems for solar photovoltaic panels. Advanced Robotics, 2015 Vol. 29, No. 8, 515–524, http://dx.doi.org/10.1080/01691864.2014.996602.

[8] Burke, Matt Greenough, Ryan Jensen, Daniel and Voss Elliot, "Project SPACE: Solar Panel Automated Cleaning Environment" (2016).Mechanical Engineering Senior Theses.

[9] Shaharin A. Sulaiman, Haizatul H. Hussain, Nik Siti H. Nik Leh, and Mohd S. I. Razali I (2011)

[10] Effects of Dust on the Performance of PV Panels. World Academy of Science, Engineering and Technology International Journal of Mechanical, Aerospace, Industrial, Mechatronic and Manufacturing Engineering Vol:5, No:10, 2011.

[11] Kutaiba Sabah, Sabah Nimma Faraj (2013) Self-Cleaning Solar Panels to Avoid the Effects of Accumulated Dust on Solar Panels Transmittance. International Journal of Science and Research (IJSR), India Online ISSN: 2319-7064.

[12] Sumit Das,Ashutosh Mohanty,Aritra Dey,Aniruddha Biswas (2014) An Integrated Design of an Auto Clean and Cooling Smart PV Panel. International Journal of Innovations in Engineering and Technology (IJIET) Vol. 4 Issue 1 August 2014 ISSN: 2319 –1058.

[13] Rupali Nazar (2015) paper title: improvement of efficiency of solar panel using different methods. International Journal of Electrical and Electronics Engineers ISSN- 2321-2055.

[14] S. B. Halbhavi,S. G. Kulkarni,Dr. D. B. Kulkarni (2015) Microcontroller Based Automatic Cleaning of Solar Panel. International Journal of Latest Trends in Engineering and Technology (IJLTET) Vol. 5 Issue 4 July 2015 ISSN: 2278-621X.

[15] Francesco Anglani,,John Barry,Willem Dekkers (2016) A numerical study on high-pressure water-spray cleaning for CSP reflectors. AIP Conference Proceedings 1734, 160001 (2016); doi: 10.1063/1.4949242.

[16] Cong-Hui Huang (2014) applying fuzzy logic controller to intelligent solar panel cleaning system. Journal of Marine Science and Technology, Vol. 22, No. 6, pp. 716-722 (2014) DOI: 10.6119/JMST-014-0321-8.

[17] Matt Burke, "Project SPACE: Solar Panel Automated Cleaning Environment"(2016). Mechanical engineering senior theses.

[18] Satish patil “design and implementation of microcontroller based automatic dust clean in system for solar panel” international journal of engineering research and advanced technology ISSN: 2454-6135 volume. 02 issue.01, may-2016

[19] S. B. Halbhavi `` Microcontroller Based Automatic Cleaning of solar panel`` International Journal of Latest Trends in Engineering and Technology ISSN: 2278-621X Vol. 5 Issue 4 July 2015

[20] Rupali Nazar`` improvement of efficiency of solar panel using different methods International Journal of Electrical and Electronics Engineers ISSN- 2321-2055 (Volume 07, Issue 01, June 2015

[21] Amit Kumar Mondal `` A brief history and future aspects in automatic cleaning systems for solar photovoltaic panels`` Advanced Robotics, Vol. 29, No. 8, 515–524, 2015

[22] Sumit Das ``An Integrated Design of an Auto Clean and Cooling Smart PV Panel`` International Journal of Innovations in Engineering and Technology ISSN: 2319 – 1058 Vol. 4 Issue 1 August 2014 80

[23] Hiroyuki Kawamoto ``Electrostatic cleaning system for removal of sand from solar panels`` Journal of Electrostatics 73 (2015) 65e70 science direct

[24] Kutaiba Sabah ``Self-Cleaning Solar Panels to Avoid the Effects of Accumulated Dust on Solar Panels Transmittance ``International Journal of Science and Research, India ISSN: 2319-7064 Volume 2 Issue 9, September 2013

[25] Shaharin A. Sulaiman ``Effects of Dust on the Performance of PV Panels` International Journal of Mechanical, Aerospace, Industrial, Mechatronics and Manufacturing Engineering Vol:5, 2011

[26] T.V. Ramachandra ``Hotspots of solar potential in India`` Renewable and Sustainable Energy Reviews 3178–3186 7april 1011 Science direct

[27] Gaofa He ``Review of Self-Cleaning Method for Solar Cell Array`` International Workshop on Automobile, Power and Energy Engineering Procedia Engineering 640 – 645 science direct

[28] Monto Mani Impact of dust on solar photovoltaic (PV) performance: Research status, Challenges and recommendations ``Renewable and Sustainable Energy Reviews 3124–313 July 2010 science direct