Environmental Effects of Dust Deposition on Solar PV Panels in the Surface Mining Industry

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Abstract

This paper highlights a study of Solar Photo-Voltaic (PV) energy system from the environmental impact analysis and its effects point of view and the enhancement factors affecting the Solar Photovoltaic (PV) module by the tilt angles variation on power output of MPPT and dust accumulation on solar PV panel. The Efficiency of solar PV energy system from the environmental impacts in Mining Industry and also a Laboratory study is also conducted and a specific investigation on dust deposition effect on the solar photovoltaic (PV) panel, its power loss and overall efficiency of the solar panel are made. The Scanning Electron Microscope (SEM) analysis carried out for the collected dust samples, and obtained images are also analyzed. A specific investigation on dust samples like Iron ore, Coal, Limestone, Sandstone of different weights, and three different irradiation levels of 500,700,900W/m^2 is done and the following data collected. In this study, measuring of voltage current, power in the solar photovoltaic (PV) panel is also done. According to the accumulation of dust particles on the solar panel the minimum power of the solar panel is observed for deposition of Coal dust on the solar PV panel and the maximum power of the solar PV panel is observed for deposition of Iron ore dust on the solar PV module.

Keywords: *Scanning Electron Microscope, dust deposition, irradiation levels voltage, current, power*

I. INTRODUCTION

Now a days, most of the electrical energy has been generated by using conventional energy sources like coal, nuclear, gas, petrol, and diesel. This affects the environmental conditions and depletion of traditional energy sources. So, this has led to research on some alternative energy sources like solar, wind, tidal, biomass, and geothermal [1]. These are natural sources, which are refilled over some time, and the power generated from these sources is called renewable energy sources.

Generating electrical energy from renewable power sources has many advantages like [2] pollution free, reliable, inexhaustible, lower maintenance, and availability everywhere[3]. Nonconventional power sources are also called renewable energy sources. The solar photovoltaic (PV) cells comes under renewable energy sources, it converts the solar energy into electrical energy. Therefore, electrical power is produced by PV cells with the help of sun light is called solar energy[4]. The most used material in the PV cell is silicon. In PV cell, the sun light falls on the surface of the cell, which results in exciting the electrons in the cell and generation of an electric voltage and current. The performance of the solar panel greatly influenced by environmental factors like available radiation from sun, temperature, Mining dust, Relative humidity, direction of wind speed [5]. Because of airborne dust particles on the surface of the PV module, blocking of solar irradiation is happened.

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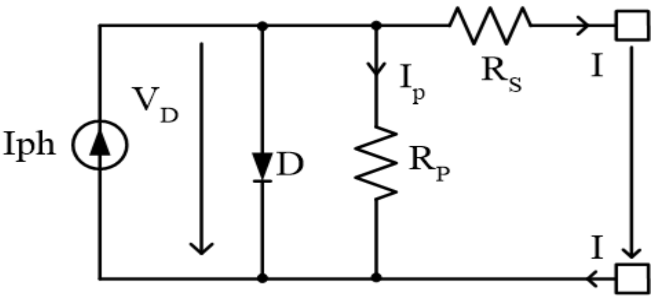

Figure 1: Single diode equivalent circuit of Photovoltaic cell

- I_{ph} = Photo or light generated current (A),
- V_d = Voltage through diode (A),
- R_S = Series resistance (Ω).
- R_p = Parallel resistance (Ω),
- D = Diode,
- I =Current.

2.Photovoltaic cell

The term "photo" means light, and "voltaic" means electricity. Thus, a PV cell is a device which directly converts light into power. At present, there are broadly two types of PV cell materials, such as crystalline PV cells and thin-film PV cells. Crystalline PV cells are of three kinds: mono-crystalline PV cells (Mono-Si), polycrystalline PV cells (p-Si), and Gallium Arsenide (GaAs) PV cells. Similarly, thin-film PV cells of different types, such as amorphous silicon PV cells (a-Si), Cadmium Telluride PV cells (CdTe), Copper Indium Gallium Selenide PV cells (CIS/CIGS) and organic PV cells (OPC) [14].

Photovoltaic cells generate heat by converting sunlight to electricity. The electric current produced depends on solar irradiation. A PV cell can make around 0.5 to 0.8V. Because of the tiny PV cells change, solar PV panels contain distinct Photovoltaic cells connected in series and parallel.

3. Impact of Environment on the Photovoltaic System

3.1 Temperature effect on the photovoltaic system

In the photovoltaic system, usually, the solar cell is the best at low temperatures. In high heat, semiconductor properties change resulting in increased current, and significant decrease in the voltage too. Impact of temperature on PV cell efficiency can be traced to influence on Current (I), and Voltage (V) as maximum power given by [11]

$$P_m = V_m I_m (FF) V_{oc} I_{sc} \qquad (1)$$

where FF is called Fill factor, V_{oc} is called open circuit voltage, I_{sc} is called short circuit current, V_m= maximum voltage, I_m is called maximum current.

3.2 Impact of humidity on the photovoltaic system:

In this impact of moisture on the Solar panel system, [12]which obstructs extreme variation in the power generated system, indirectly in the photovoltaic system,[6] it makes the device work less efficiently than it could have without it. Humidity can decelerate efficiency in two ways:

- In this first efficiency way, tiny water droplet like beads of sweat reflects sunlight away from solar cells. This process reduces the amount of the sun hitting the solar panel to produce electricity.
- In this second efficiency way, in consistent hot, humidity climatic weather, degrade the solar panels lifetime. It is for a combination of both thin-film modules cells and crystalline silicon cells, in case cadmium telluride (thin film) of the PV cell it can perform in the tropical climatic condition [13].

3.3 Impact of dust on the photovoltaic system

In the process of mining, the large amount of dust comes from the process of mining at mineral mines site from following mining activities like Heavy Earthmoving Machinery [HEMM], drilling, blasting, etc. In this process, a large number of tiny dust particles will generate from the mining process. This type of dust Pm_{10} is also called a particulate matter. This type of dust is produced by HEMM when the soil got disturbed, and the wind blows from over bare ground and stockpiles in the mine area [6]. Dust accumulation is one of the significant factors affecting the solar panel efficiency. Especially in remote mining areas where weather conditions are going to effect, the solar panels performance.

4. Description of the Experiment:

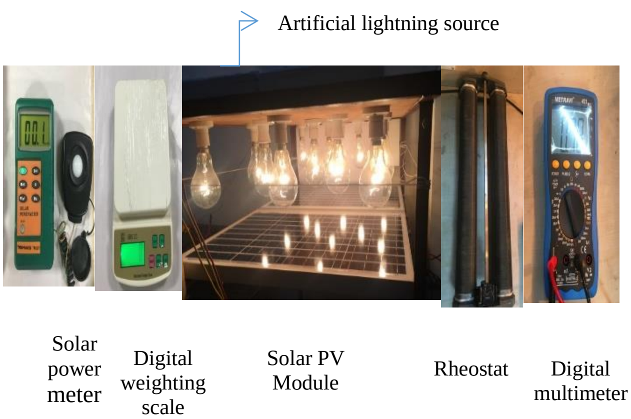

Figure 2: Experimental setup used in the present study

4.1 Description of the present study

In this Investigation, four mine dust samples are collected from the surface mining where solar panels are installed in the mine. For this experiment, 40W Polycrystalline photovoltaic panel is mounted on a stand to carry out an experimental study various equipment required for the study are: 1) 40W Polycrystalline PV module (Make: LUMINOUS), number of cells= 36, the material used in the PV technology is Aluminum. This is placed under artificial light representing sunlight. For artificial lighting, 16 number of electrical bulbs each (200W) are used. This acts as artificial lighting. 2) Digital Multimeter (Make: METRAVI-451) is used to find the voltage, current, temperature for this experiment and load Resistance of 100(ohms). 3) Solar power meter (Make: TENMARS TM-207). 4) Cooling fan (230V), 5) Banana type connecting pins as per requirement (2A Capacity). 6) Dust samples: a) Iron ore b) Coal c) Limestone d) Sandstone. 7) Digital weighing machine (Make: SRS-120) used for the dust samples' weight. With the help of a flour mesh with the sieve size approx. (15-20mm) dust samples were spread uniformly on the Polycrystalline photovoltaic panel under artificial lighting source. After evenly spreading the dust samples of different weight, at different irradiation levels 500,700,900W/m^2, the results are collected.

5. I-V and P-V characteristics of series and parallel connected PV modules by variation of radiation and temperature for series and parallel connected PV modules.

Photo voltaic panels can be connected in either series or parallel combinations to increase the voltage or current capacity of solar array. However, the solar panels are connected, the upper hand corner will always be the maximum power point (MPP) of the array. From this we can find fill factor and efficiency of solar panels.

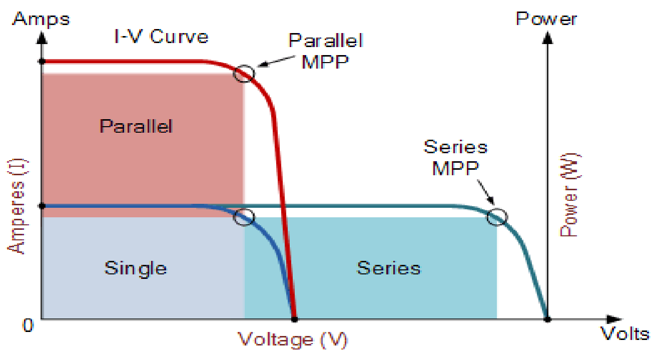

Figure 3: I-V Characteristics of series and parallel connected PV module

By the variation of radiation and temperature for series and parallel connected PV Modules we observed in the Figure 4 and 5 the I-V Characteristics of parallel and P-V Characteristics of parallel are both connected PV modules with constant temperature of 30°C and different irradiance levels of 1002 W/m^2 and 508 W/m$^{2.}$

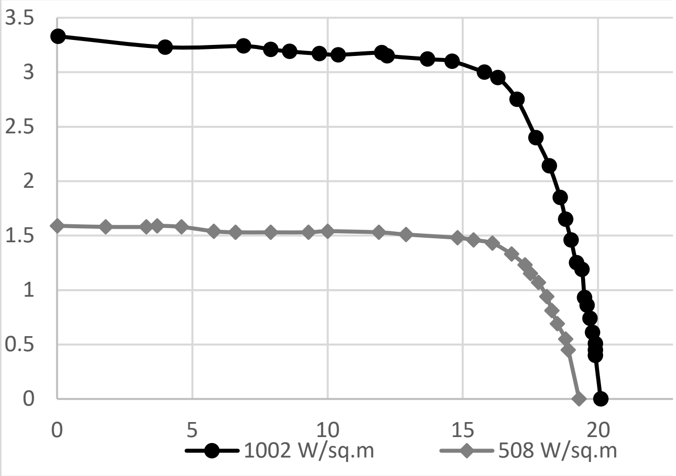

Figure 4: I-V Characteristics of parallel connected PV Modules with constant temperature of 30°C and irradiance of 1002 W/m^2 and 508 W/m^2

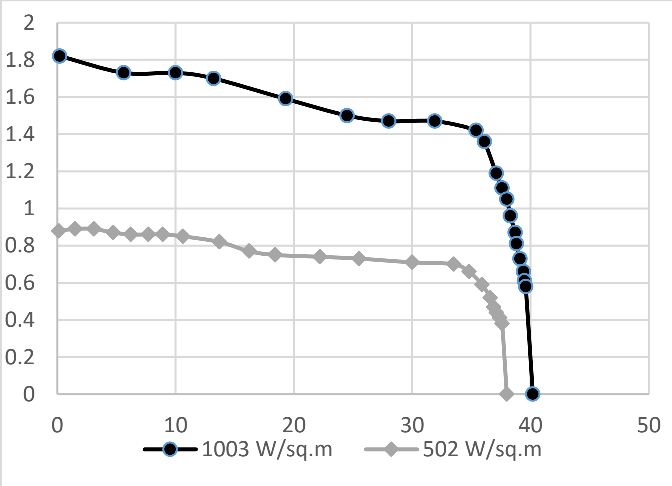

Figure 5: I-V Characteristics of series connected PV Modules with constant temperature of 29°C and irradiance of 1003 W/m^2 and 502 W/m^2

Figure 6: Solar PV Modules Installed at Mine

6. Solar Power Generation at Mine

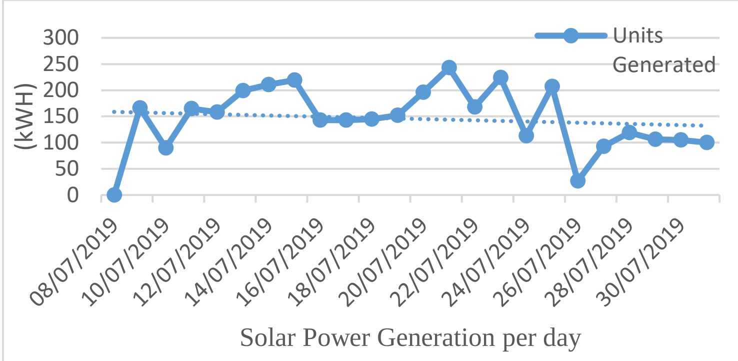

Figure 7: Solar Power Generated per day

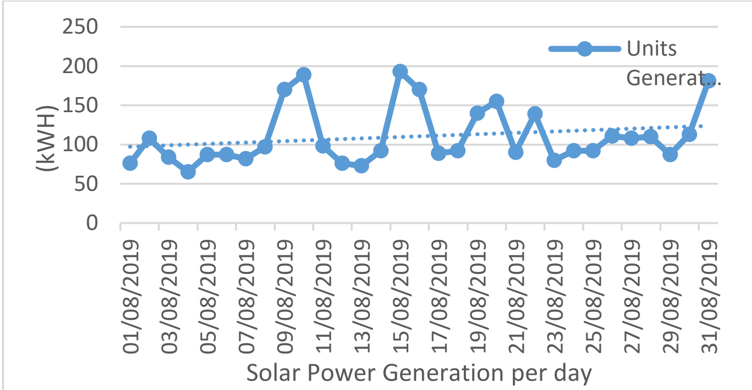

Figure 8: Solar Power Generated per day

6.1 Monthly Load Profile of Solar Power Generation

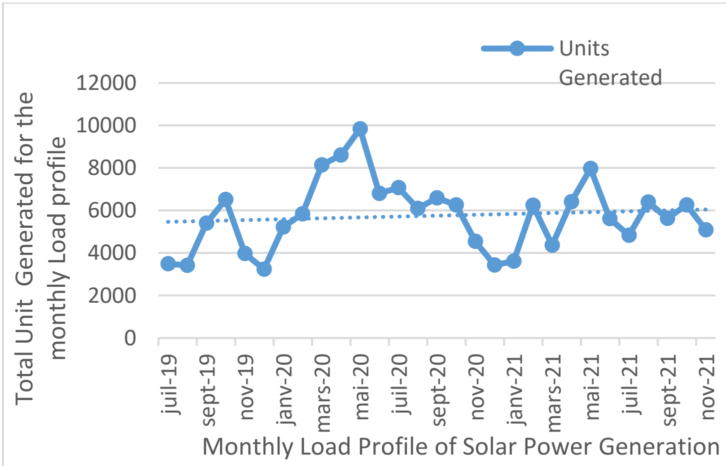

Figure 9: Monthly Load Profile of Solar Power Generation in Mines

Based on the Solar power generation in mines we have observed from the figures (7 to 9). power generation per day. In every month we have observed that maximum 200 plus units are generated per day and minimum 50 plus units are generated in few days this is because of the Environmental conditions in the Mining areas such as (solar radiation, temperature, dust, humidity etc.) Especially in few months we observed the days are cloudy, heavy rainfall, wind speed because of this generation unit is getting low.

7. Characterization of Collected Dust samples

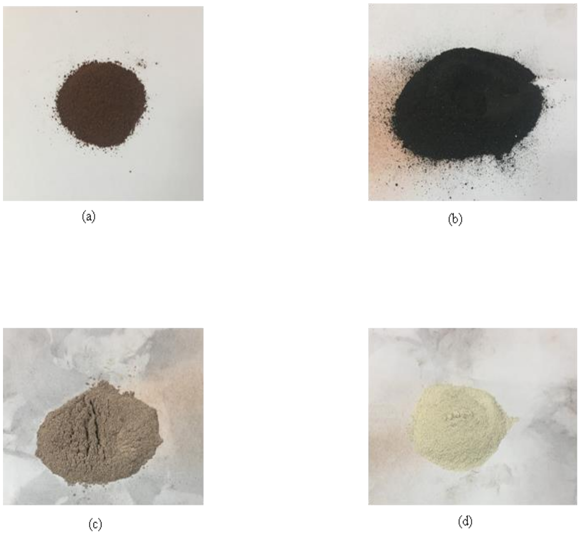

Figure 10: Collected dust samples presently used in experimental study (a) iron ore (b) coal (c) limestone (d) sandstone

7.1 Surface Morphology of Dust Samples

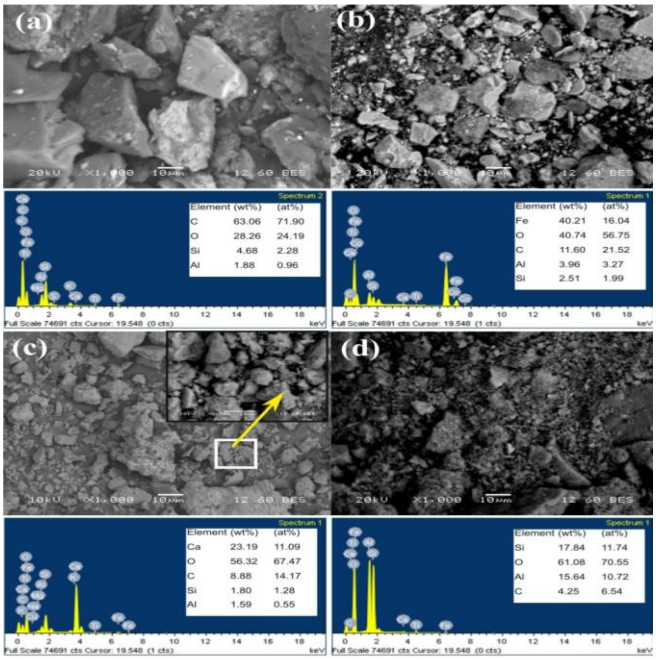

Figure 11: SEM images of the collected dust samples presently used in experimental study (a) iron ore (b) coal (c) limestone (d) sandstone

Scanning Electron Microscope was used to Examine the surface Morphology of collected dust from the mines. Figure:4 reveals the surface morphology of the collected dust particles from the SEM images it can be observed that the dust collected from the mines was dominated by very fine and silt particles.

7.2 Microstructure study of dust powders

Figure 11(a-d) shows the SEM micrographs and EDS spectra of coal, iron ore, limestone, and sandstone powders. It has been observed from the Figure (d) that the dust powder particles are irregular in shape and are in various sizes. This distribution of particle sizes and shapes influences the dust's shading effect on the PV module surface and the power output[83]. The coal and iron ore powders in Figure 11 (a) and (b) contain particles with an average length of 30.82µm, 13µm, respectively. The limestone and sandstone powders in Figure 4(c) and (d) contain very fine particles with agglomerations. It has been observed from the EDS analysis of the powders, the major constituents in coal, iron ore, limestone, and sandstone are carbon (71.90 weight %), iron (40.21 weight %), calcium (23.19 weight%), and silicon (17.84 weight %), respectively. The oxygen present in all powders in higher content with 20-60 w%, carbon, aluminum, and silicon are present nearly (2- 10) weight%.

8. Conclusion

In this experimental study, different mine dust samples of different weights are used at three irradiance values of 500, 700, 900 W/m^2 used to get the output of the Solar panel in terms of current (I), voltage(V), and power (W). In this study, dust samples are taken for the analysis of power output results. PV module outputs like voltage, current, and power are observed with four different mine dust samples.

According to the Data observation at Iron ore 80g weight sample, the maximum power loss of 68.50, 66.45 and 57.51% have been observed at three different irradiation levels of 500, 700, 900W/m^2 have been found. For Coal dust, 80g weight sample the maximum power loss of 97.75, 97.31, and 97.90% is observed at three different irradiation levels of 500, 700, 900W/m^2 have been found,

For the limestone 80g weight sample, the maximum power loss of 85.65, 85.53 and 87.74 % have been observed at three different irradiation levels of 500,700,900W/m^2 have found. For the Sandstone 80g weight sample, the maximum power loss of 80.72, 83.99 and 82.75% saw at three different irradiation levels of 500,700, 900W/m^2. The maximum power loss in percentage found in the Coal dust sample at three different irradiation levels of 500,700,900W/m^2. Due to the high density of coal dust power loss increased in the PV module.

In the observation of 20g of accumulated coal dust on the solar panel, it can reduce its power loss up to 66.29%, for 80g of accumulated coal dust on the solar panel. It can reduce its power loss up to 97.75%for 500W/m^2. For the same dust particle with different irradiance 700W/m^2 80gm of accumulated coal dust power loss up to 97.33% for the same coal dust particle with different irradiance 900W/m^2 for 80 gm of accumulated coal dust on PV module can reduce up to 97.90%.

In addition, from Images of SEM analysis, as shown in Fig (4), the coal dust sample is found with tiny particles in size of all samples taken in the experimental study. It indicates that finite dust particles are also going to affect the performance of the solar PV module. Different types of dust samples are collected from different Remote mining areas. In addition, it refers that the tiny dust sample size of the particle is inversely proportional to power loss in the solar PV module.

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