

INVESTIGATION OF INDOOR PERFORMANCE OF DUST ACCUMULATION ON SOLAR PHOTOVOLTAIC MODULE

M.PALPANDIAN

Dept. of EEE, Sethu Institute of Technology,
Pulloor, Virudhunagar, Tamil Nadu, India-626 115.
mpalpandian18@gmail.com
+91 97895 12115

M.SANTHI

Department of EEE, Solamalai College of
Engineering, Madurai, Tamil Nadu, India
santhi_nelson@rediffmail.com
+91 98432 79085

Abstract: In this study, the effects of dust accumulation on the solar photovoltaic (PV) module are investigated. The dust particles attenuate the incoming solar radiation, leads to reduction in surface transmittance and increase in temperature. The MATLAB simulation is used to demonstrate the effect of dust deposition on the PV module. The experiment is aimed to investigate the effects of four artificial air pollutants such as soil, cement, talcum powder and salt under indoor condition. The experimental result shows that there is a considerable reduction in the performance of PV module, which has linear relationship with the physical properties of dust particles. The increase in operating temperature and voltage reduction of PV module is investigated at indoor test conditions.

Key words: Photovoltaic module, Dust deposition, Operating temperature.

1. Introduction

The growth of solar PV technology has been rapidly increasing from the past few years due to the identified environmental issues and progressive decrease in the price of PV module per MW [1, 2]. The PV cell converts the incident irradiation into electrical energy by using the effect of semiconductors [3, 4].

The efficiency of the PV module depends on the solar irradiation incident on the surface of the PV module. The dust particles suspended in the atmosphere attenuates the incident solar radiation on the surface of the PV module, which leads to increase in temperature. The attenuation of incident solar irradiation depends on the type of deposition of dust particles. Since the dust effect is solely site-dependent, it is associated with local air pollution and the environment condition where the PV system is installed.

This study is organized in the following manner: In section 2, the effect of atmospheric air pollutants which attenuate the surface transmittance and factors influencing the dust deposition on PV module is analyzed. In section 3, demonstrate single diode PV model and the effect of dust on the performance of PV module in MATLAB simulink environment. In section 4, indoor experiment investigates the effects of deposition of artificial air

pollutants such as soil, cement, talcum powder, salt on the surface and operating temperature of PV module.

2. Effect of Dust Deposition on Efficiency of PV Module

The solar radiation is absorbed by atmospheric particles, which are reflected by water vapor, air molecules, dust and other contamination and scattered backwards [5]. The scattering of solar radiation reduces the direct irradiation and increases the diffuse irradiation [6-8]. The urban receives less solar radiation compared to rural areas and a decrease in solar attenuation depends on the nature of pollutants and quantity [8 -11]. Rainfall and wind may remove the particles which are suspended in the atmosphere [12, 13].

Depending upon the incident solar radiation of the PV module the efficiency of the PV module varies [9]. The deposition of dust particles on the surface of the PV module will attenuate the solar radiation and degrade the efficiency of PV module [14, 15]. Jiang Lu et al. investigated the impact of dust deposition on the efficiency of PV module under solar radiation ranged from 300 to 760 W/m² and found that the output efficiency varied from 4.4% to 11.6% [16].

The efficiency of the PV module depends on the semiconductor material, module design and environmental conditions [17]. The efficiency of PV modules ranges from 10 to 13% and the efficiency of the installed PV modules may further reduced by 10 to 25% due to the losses in the inverter, wiring, partial shading and soiling [4, 6]. The effect of wind plays a major aspect in the deportation of dust particles and the efficiency of PV module depends on the bonding strength of force between the surface of module and physical properties of dust particles [18, 19, 20].

2.1. Effect of dust deposition on the surface transmittance on PV module performance:

Appels, Muthirayan [21] observed that the percentages of reduction of surface transmittance and solar panel output power are almost equal in monocrystalline and

polycrystalline solar PV panel. During the short wave length, the dust deposition reduces the light transmittance [22]. Al-Hasan [20] has demonstrated that the increase in dust deposition results in increase in reflection of light intensity and the reflectance increases at longer wavelength. The transmittance reduction in the PV module depends up on the size of the dust particles [23, 24].

2.2. Effect of partial shading due to dust deposition on PV module performance:

The deposition of dust on the surface of the PV module may lead to partial shading. The partial shading leads to non-uniform irradiation on the PV array and the partial shaded PV cells consume power from the other non-shaded PV cells. The bypass diodes are connected in anti-parallel across PV cell to provide alternate path for the current flowing in the shaded PV cell [25]. The power losses in the shaded cells are dissipated as heat and it results in increase in temperature of the PV module. It leads to hot-spot [26, 27, 28]. The dust deposition on PV module increases the temperature up to 10°C. It causes small increment in short circuit current and decrement in open circuit voltage.

2.3. Effect of tilt angle and dust deposition on PV module performance:

The dust deposition on the surface of PV module decreases with increase in tilt angle and it results in the reduction of transmittance. The amount of dust deposition on the PV system depends on the tilt angle and the orientation of the PV system. The PV modules facing south are mainly affected by soiling. The transmittance reduction depends upon the dust deposition in coincidence with the tilt angle as well as the location of the site with respect to wind direction [24, 29].

The dust deposition density is measured at various tilt angles after 7, 15, 23 and 30 days of revelation. When the period of revelation is fixed, the density of dust deposition reduces with increase in tilt angle. If the tilt angle is fixed, the density of dust deposition increases with the addition of revelation periods [29].

Elminir [29] found that at the same tilt angle, equal amount of dust deposition on PV module installed at different orientations. As the tilt angle increases, the dust tends to roll-off and the increasing rate of dust deposition density reduces down and saturates earlier. The low density of coarse particle leads to partial shading when compared to deposition of fine dust particles. Thus, when the dust deposition density goes from 15.84 to 4.48 g/m², the resultant transmittance reduces from 52.54% to 12.38%.

2.4. Factors influencing dust deposition on PV Module:

The dust deposition on the PV module occurs in three ways: occult deposition, dry deposition and wet deposition. The occult deposition takes place, if the polluted water droplet in fog and clouds causes dust deposition in high cloudy areas [13]. The high humidity which enhances the dust deposition on the PV module surface [18, 30], leads to the formation of cluster [7] and adhesion on this surface is strengthened by evaporation [20, 24].

Under dry condition, how long the wind carries the dust particles are determined by the physical characteristics of dust particles and they are finally deposited on the surface of the PV module [12, 31]. The wind destruction of dust particles causes the charging of dust particles during take-off. The electrostatic force which occurs on the charged dust particles, leads to Coulomb force of attraction or repulsion based on the polarity of charge particle and charge distribution. Attractive force enhances the dust deposition and repulsive force causes the dust to freeze out in air by wind [23]. Thus, the wind effects influence the dust particle deposition on PV module depending on tilt angle, wind speed, direction of wind flow and nature of dust particles [4, 15, 24, 32, 33].

The wind velocity also affects the dust sedimentation and deposition characteristics. The time taken for the sedimentation of dust coating formed by low speed wind is longer than the high-speed wind. At low speed, small dust particles merge to form macro dust particles and form continuous dust coating, which results in the reduction of light transmittance on the surface of the PV module [32]. Under dry weather, fine dust particles deposited on the surface of PV module can be easily washed away by rain and minimum dust accumulation occurs after rainfall [34].

During wet deposition process, rain drops along with air pollutants are deposited on the PV module [12]. Zorrilla-Casanova [30] demonstrated that under long dry periods, dust deposition causes losses of irradiance. Elminir, García, and Kimber [24, 35, 36] have found that high optical losses occurs under the low rainfall condition. Elminir, Ghitas [24] have observed that the removal of dust by rain leads to power peaks in the PV module. The rainfall plays a major role in influencing the deposition of dust on the PV modules. The small amount of rainfall causes less natural cleaning of PV module and during that condition, the dust will turn into mud [37]. The frequent rainfalls will runoff the dust particle on the PV module [38].

The performance of PV module is highly affected by the finer particle than coarse particle of similar type [15, 23]. Hegazy [29] has demonstrated that only fine particle settled on the surface is installed at large tilt angle ($\beta > 50^\circ$). Based on the characteristics of dust particles, accumulation of sand particles inclines to form cluster. The sand particles bounce on the surface of the PV module and delay the formation of cluster. The single layer dust particles will be blown off by the wind but the cluster will be shattered and they will resettle on the surface. Sand particles bounce on the glass surface before settling and hence, cluster formation is delayed [18]. Thus the performance of the PV module is mainly affected by the dust deposition. The dust deposition is solely site dependent, where as the angle of incidence is depends on the PV orientation.

3. SINGLE DIODE PV MODEL

3.1 Modelling of Single

The mathematical description of I-V characteristics for an ideal PV cell from the theory of semiconductor is represented by a coupled non-linear equation (1) [39, 40]

$$I = I_{pv} - I_o \left[\exp\left(\frac{qV}{aKT}\right) - 1 \right] \quad (1)$$

Where I_{pv} is the light current generated by the PV cell, I_D is the Shockley diode equation, $I_{o,cell}$ is the reverse saturation of the diode [A], q is the electron charge [$1.60217646 \times 10^{-19}C$], k is the Boltzmann constant [$1.3806503 \times 10^{-23}J/K$], T [K] is the temperature of the p-n junction, and a is the diode ideality constant.

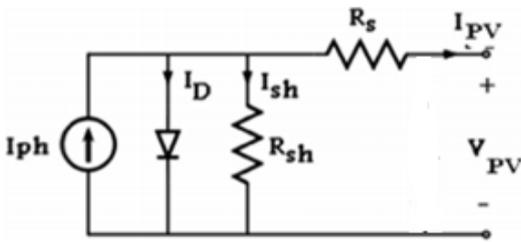


Fig. 1 Equivalent circuit of a PV cell

The Fig.1 shows the equivalent circuit of the practical PV cell. The practical PV module consists of several PV cells grouped together, which include the series resistance (R_s) and parallel resistance (R_p). The single diode PV model composed of a current source and a parallel diode. The single diode PV model has been used by the several authors in previous works due to its simplicity and accuracy. The I-V characteristics of

a practical PV module by including the R_s and R_p is given by (2)

$$I = I_{pv} - I_o \left[\exp\left(\frac{V + R_s I}{V_{ta}}\right) - 1 \right] - \frac{V + R_s I}{R_p} \quad (2)$$

$$V_t = \frac{N_s K T}{q} \quad (3)$$

V_t is the thermal voltage of the PV module with N_s are number of PV cells connected in series. The PV cells are connected in series and parallel to obtain the required to obtain the required voltage and current. The practical PV module may acts as a voltage source or current source based on the operating point. The practical PV module has high influence of R_s when the PV module operates in the voltage source region and R_p has high influence in current source operation. The ideal PV module has R_s is zero and R_p is infinity. The practical PV module has very low value of R_s and very high value of R_p . The R_s is the sum of internal resistance and R_p occurs due to the leakage current of the p-n junction. Some authors have neglected the R_p to simplify the model and R_s due to its very low value. The value of diode constant a can be chosen by empirical analysis. Many author found out the ways to estimate the exact value [40, 43]. Usually the diode constant can be randomly chosen between 1 and 1.5 depends on other parameter of I-V characteristics.

The current generated by the PV module linearly depends on incident solar irradiation is found by using the (4) [14, 41] at any temperature as given below

$$I_{pv} = I_{sc} \left(\frac{G}{G_n} \right) \quad (4)$$

$$I_{sc} = I_{pv,n} + K_I \Delta T \quad (5)$$

$$\Delta = T - T_n \quad (6)$$

$I_{pv,n}$ is the current generated by the PV module at Standard Test Condition (STC), T and T_n – actual and nominal temperatures in Kelvin, K_I – short circuit current temperature co-efficient ($A/^\circ K$), G and G_n – actual and nominal solar irradiation in W/m^2 . From the (4) and (5)

$$I_{pv} = (I_{pv,n} + K_I \Delta T) \frac{G}{G_n} \quad (7)$$

$$I_{o,n} = \frac{I_{sc,n}}{\exp(V_{oc,n}/aV_{t,n}) - 1} \quad (8)$$

$I_{o,n}$, $I_{sc,n}$, $V_{oc,n}$, $V_{t,n}$ represents diode saturation

current, short-circuit current, open circuit voltage and junction thermal voltage at nominal conditions respectively. Since saturation current varies with change in operating temperature and the performance of the single diode PV model can be improved by considering the (14) with the effects of voltage/temperature coefficient (KV) and current/temperature coefficient (KI).

$$I_o = \frac{I_{sc,n} + K_I \Delta T}{\exp[(V_{oc,n} + K_V \Delta T)/aV_{t,n}] - 1} \quad (9)$$

The saturation current of the PV model depends on the device operating temperature, recombination in the PV cell and inversely proportional to material quality. The Voc depends on Io and has less variation with Isc. The maximum power of PV module (Pmax,m) is estimated from the I-V model of the (2) at maximum power point. The expression for Pmax,m is as given below.

$$P_{max,m} = V_{mp} \times I_{mp}$$

$$= V_{mp} \left\{ I_{pv} - I_o \left[\exp\left(\frac{q}{KT} \times \frac{V_{mp} + R_s I_{mp}}{a N_s}\right) - 1 \right] - \frac{V_{mp} + R_s I_{mp}}{R_p} \right\} \quad (10)$$

where Vmp – maximum voltage at maximum power point and Imp – maximum current at maximum power point.

The value of Rp can be obtained by rearranging (10) as follows

$$R_p = \frac{V_{mp} + (V_{mp} + R_s I_{mp})}{\left\{ V_{mp} I_{pv} - V_{mp} I_o \exp\left[\frac{((V_{mp} + I_{mp} R_s)/N_s a)}{(q/KT)}\right] \right\} + V_{mp} I_o - P_{max,m}} \quad (11)$$

The optimum value of Rs and Rp are found by Newton Raphson methods, with the initial value of Rs is zero and the initial value of Rp,min is given by [42].

$$R_{p,min} = \frac{V_{mp}}{I_{sc,n} - I_{mp}} - \frac{V_{oc,n} - V_{mp}}{I_{mp}} \quad (12)$$

With the optimum value of Rs and Rp, the light generated current can be given as

$$I_{pv,n} = \frac{R_s + R_p}{R_p} I_{sc,n} \quad (13)$$

The impact of low value of Rs will reduce the performance of the PV model. If the value of Rp is decreased, open circuit voltage will drop and with increase in Rs causes the short circuit current to drop and there by decreases the output power. The impact of Rp is high at low irradiation condition, since there will be low PV current.

Table. 1 Specifications of a PV module at STC (1000 W/m2 and 25° C)

Parameters	Values
Maximum Power (P _{max})	40W
Maximum Power Voltage (V _{max})	18.0V
Maximum Power Current (I _{max})	2.22A
Open Circuit Voltage (V _{oc})	21.5V
Short Circuit Current (I _{sc})	2.44A
Temperature coefficient of V _{oc}	-0.36 %/K
Temperature coefficient of I _{sc}	+0.06 %/K

The effects of dust accumulations on the PV module can be depicted as given below (14) [4, 45-46]

$$I_{mp,dust} = I_{mp} \left[\frac{I_{pv} - d}{I_{pv}} \right] \quad (14)$$

Where Imp and dust are the current generated by the PV module under dust condition and d is dust factor.

3.2 Simulation Results

The single diode PV model (1-14) is simulated in MATLAB simulink environment for the PV model given in Table 1. The I-V characteristics of PV module for the change in irradiation (Fig.2) are analyzed. Under the short circuit condition, the maximum current generated by a PV module is short circuit current and is equal to current generated by the PV module. The open circuit voltage represents the voltage drop across the diode and it increases logarithmic with the incident irradiation. Hence the current generated by the PV module depends on the incident solar irradiation. For the decrease in solar radiation there is a slight reduction in open circuit voltage with respect to decrease in short circuit current. The saturation current of the PV model depends on the operating temperature and inversely proportional to material quality. The open circuit voltage depends on saturation current and has less

variation with short circuit current. With increase in operating temperature, the open circuit voltage decreases and the short circuit current increases which results in power generated by the PV module decreases.

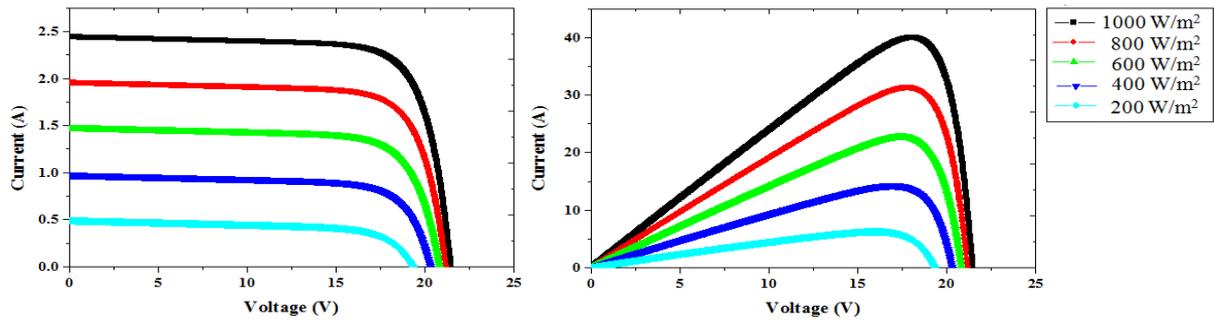


Fig.2 I–V and P–V characteristics of PV module under variable irradiation.

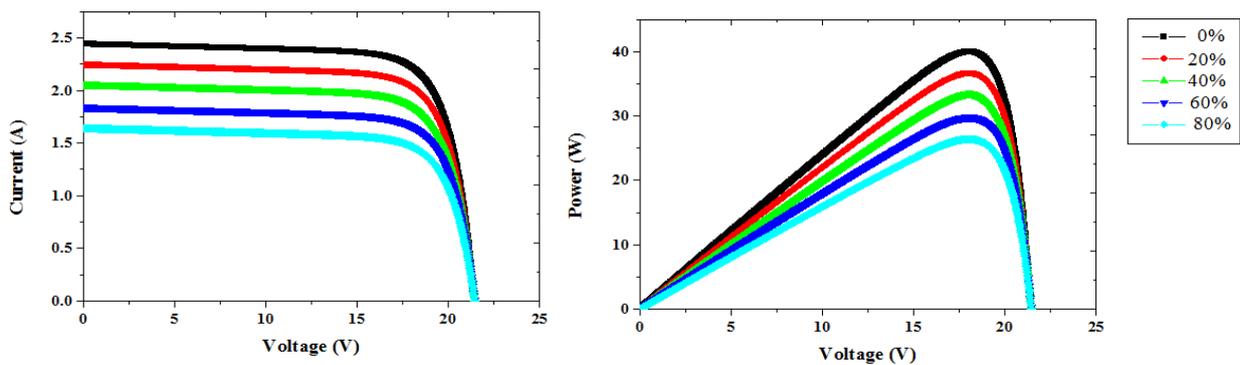


Fig.3 Effect of dust on I–V and P–V characteristics of PV module under simulation

The I–V and P–V characteristics of PV module at different dust deposition (20%, 40%, 60%, 80%) are shown in Fig. 3. It is realized that the dust deposition will degrade the performance of PV system. The increase in dust deposition attenuates the incident solar insolation. The open circuit voltage remains unchanged for the different dust deposition, while the PV current decreases significantly.

4. EXPERIMENT OF TEMPERATURE EFFECTS ON PV MODULE UNDER INDOOR CONDITION

To analyze the impact of dust deposition on the surface of PV module, a 1000W long-arc xenon lamp is intended to simulate uniform indoor solar radiation at 30W/m². The PV module produces maximum power of 40W with an area of 307.05 cm². A 30Ω rheostat is connected at the output of the PV module. The measuring instruments are used to measure the voltage and current. The surface temperature of the PV module is measured at specific point by using infrared thermometer.

The natural dust is replaced by artificial dust (soil,

cement, talcum powder and salt) and they are uniformly scattered on the surface of the PV module.

The initial temperature of PV module is maintained at 31± 1° C throughout the experiment. At the starting of the experiment, cleaned PV module is placed under the xenon lamp for 10 min.

The intention of measuring the temperature repetitively with the help of clean PV module is to assure the same initial point of temperature of the PV module with dust deposition. The temperature of the PV module is interrelated to the light intensity, initial temperature, environmental temperature and time of experiments. The surface temperature of the PV module is measured at specific point throughout the experiment to assure that the temperature at a specific point is same for all the experiments.

The PV module is under long-arc xenon lamp and temperature of PV module is measured at specific point between the third and tenth minutes. The experiments are repeated for different types of dust

deposition on the surface of the PV panel. The voltage, current and temperature are measured by the measuring instruments [47].

5. RESULTS AND DISCUSSION

The light luminance of 1000W long-arc xenon lamp is fixed for the experiment. At each time before starting the experiment the initial temperature of PV module is maintained at $31 \pm 1^\circ\text{C}$. Before the conduction of the experiment, the PV module has been tested for five times on the dust free environment and the performance of the PV remains almost the same (Table. 2).

The weights of soil dust particles are 0.1g, 0.2g, 0.3g, 0.4g, 0.5g and 0.6g and the variations of temperature with time under different weights of soil dust particles are shown in Fig.4 and Table. 3. The Table.4 represents the temperature of PV module with cement deposition. The weights of cement dust particles are 0.1g, 0.2g, 0.3g, 0.4g, 0.5g and 0.6g and the variations of temperature with time under different weights of cement particles are shown in Fig.5. The weights of talcum powder particles are 0.1g, 0.2g, 0.3g, 0.4g, 0.5g and 0.6g and the variation of temperature with time under different weights of talcum particles are shown in Fig.6 and Table. 5. The weights of salt particles are 0.1g, 0.2g, 0.3g, 0.4g, 0.5g and 0.6g and the variations of temperature with time under different weights of soil dust particles are shown in Fig.7 and

Table. 6.

With increase in artificial dust deposition (sand, cement, talcum powder and salt), attenuate the light illuminance. At the beginning of the experiment, the operating temperature increases gradually and the increasing rate slows down with increase in time. The temperature of PV module increases and the voltage of PV panel gradually decrease. The deposition of sand, cement and talcum powder over heats the PV module than the salt.

The clean PV module produces the voltage of 17.93V and the weights of soil deposited are 0.1g, 0.2g, 0.3g, 0.4g, 0.5g and 0.6g which cause reduction in output voltage of 2.53%, 6.00%, 14.01%, 16.53%, 21.80% and 33.16% respectively. The clean PV module produces the voltage of 17.59 V and the weights of cement deposited are 0.1g, 0.2g, 0.3g, 0.4g, 0.5g and 0.6g which cause reduction in output voltage of 2.23%, 7.74%, 14.56%, 17.80%, 24.62% and 30.02%, respectively. The clean PV module produces the voltage of 17.85V and the weights of talcum powder deposited are 0.1g, 0.2g, 0.3g, 0.4g, 0.5g and 0.6g and they cause reduction in output voltage of 3.58%, 6.94%, 14.04%, 21.30%, 27.56% and 34.72%, respectively. The clean PV module produces voltage of 17.83 V and the weights of salt deposited are 0.1g, 0.2g, 0.3g, 0.4g, 0.5g and 0.6g and they cause reduction in output voltage of 4.10%, 5.56%, 12.74%, 16.10%, 22.27% and 25.86%, respectively.

Table. 2 Voltage, current and power measurement of dust free solar PV module

Parameter's	Exp-1	Exp-2	Exp-3	Exp-4	Exp-5
V_{oc} (Volt)	18.57	18.81	18.86	18.8	18.75
I_{sc} (A)	0.7	0.7	0.7	0.7	0.7
V_{mp}(Volt)	17.68	17.25	17.47	17.85	17.68
I_{mp}(A)	0.6	0.6	0.6	0.6	0.6
FF (%)	81.60	78.60	79.39	81.38	80.82
η(%)	5.76	5.62	5.69	5.81	5.76
P_{max} (W)	10.60	10.35	10.48	10.71	10.60

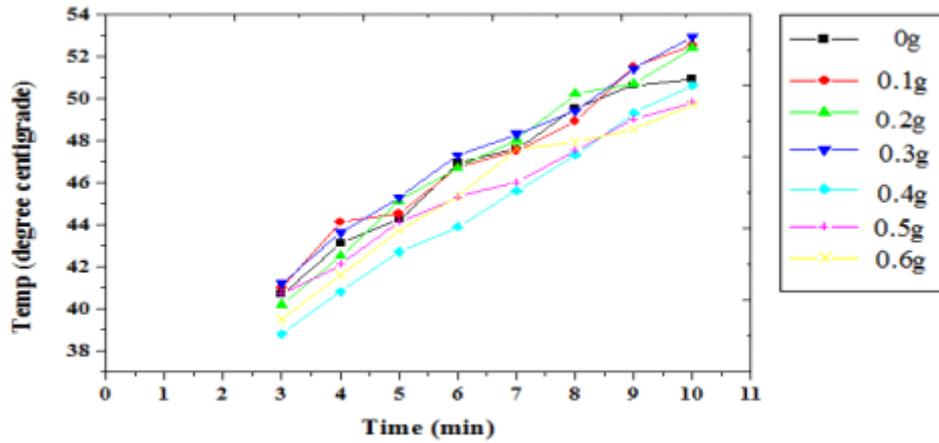


Fig.4 Operating temperature of the PV module with different weight of soil.

Table. 3 Temperature measurement of PV module with different weight of soil

Weight of dust (g)	0	0.1	0.2	0.3	0.4	0.5	0.6	
Time (min)								
Temperature (°C)								
	3	40.7	41	40.2	41.2	38.8	40.7	39.5
	4	43.1	44.1	42.5	43.6	40.8	42.1	41.6
	5	44.2	44.5	45.1	45.3	42.7	44.1	43.7
	6	46.9	46.7	46.7	47.3	43.9	45.3	45.3
	7	47.6	47.5	48.0	48.3	45.6	46.0	47.6
	8	49.5	48.9	50.2	49.4	47.3	47.5	47.9
	9	50.6	51.5	50.7	51.4	49.3	49.0	48.5
	10	50.9	52.5	52.4	52.9	50.6	49.8	49.7
Output voltage (V)		17.85	17.40	16.78	15.35	14.90	13.96	11.88

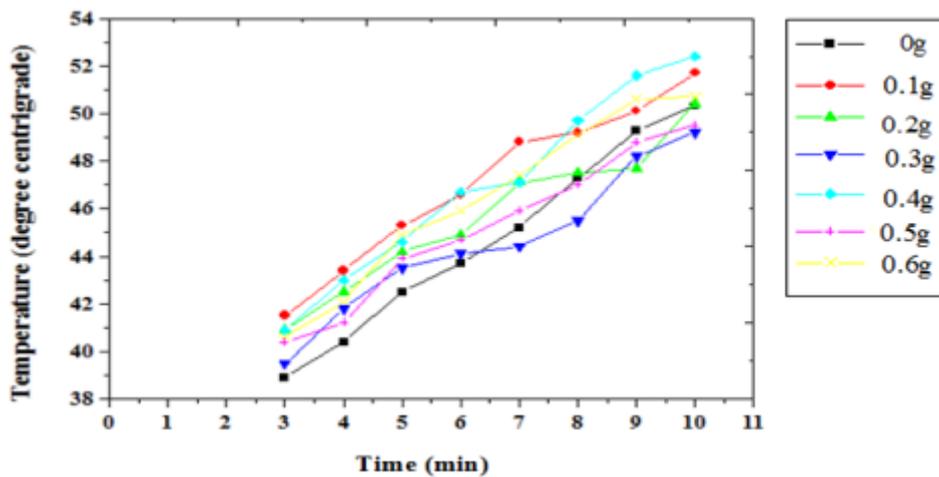


Fig.5 Operating temperature of the PV module with different weight of cement.

Table. 4 Temperature measurement of PV module with different weight of cement

Weight of dust (g)	0	0.1	0.2	0.3	0.4	0.5	0.6	
Temperature (°C)	Time (min)							
	3	38.9	41.5	40.9	39.5	40.9	40.4	40.6
	4	40.4	43.4	42.5	41.8	43.0	41.2	42.1
	5	42.5	45.3	44.2	43.5	44.6	43.9	44.9
	6	43.7	46.6	44.9	44.1	46.7	44.7	45.9
	7	45.2	48.8	47.1	44.4	47.1	45.9	47.4
	8	47.3	49.2	47.5	45.5	49.7	47.0	49.1
	9	49.3	50.1	47.7	48.2	51.6	48.8	50.6
	10	50.3	51.7	50.4	49.2	52.4	49.5	50.7
Output voltage (V)	17.59	17.20	16.43	15.03	14.46	13.26	12.31	

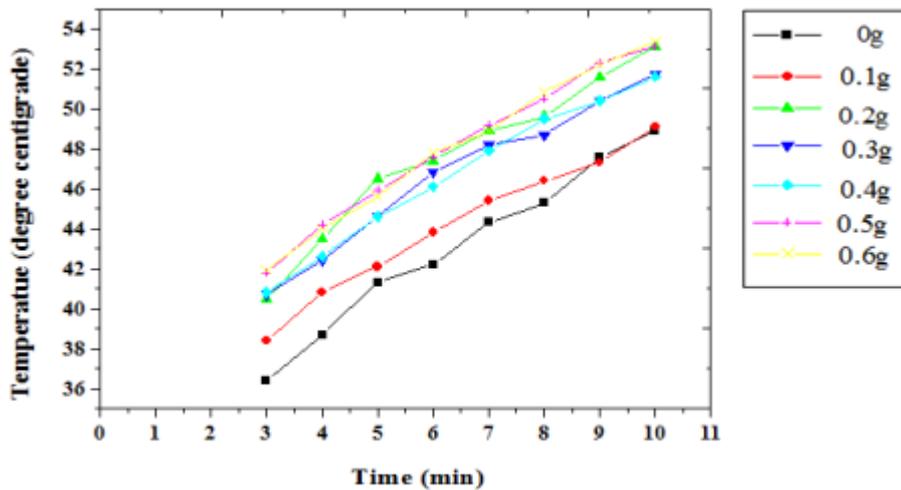


Fig.6 Operating temperature of the PV module with different weight of talcum powder.

Table. 5 Temperature measurement of PV module with different weight of talcum powder

Weight of dust (g)	0	0.1	0.2	0.3	0.4	0.5	0.6	
Temperature (°C)	Time (min)							
	3	36.4	38.4	40.5	40.7	40.8	41.8	41.9
	4	38.7	40.8	43.5	42.4	42.6	44.2	44.0
	5	41.3	42.1	46.5	44.6	44.6	45.9	45.6
	6	42.2	43.8	47.4	46.8	46.1	47.6	47.8
	7	44.3	45.4	48.9	48.2	47.9	49.2	48.9
	8	45.3	46.4	49.6	48.7	49.5	50.5	50.8
	9	47.6	47.3	51.6	50.4	50.4	52.3	52.2
	10	48.9	49.1	53.1	51.7	51.6	53.1	53.4
Output voltage (V)	17.85	17.25	16.65	15.38	14.08	12.96	11.68	

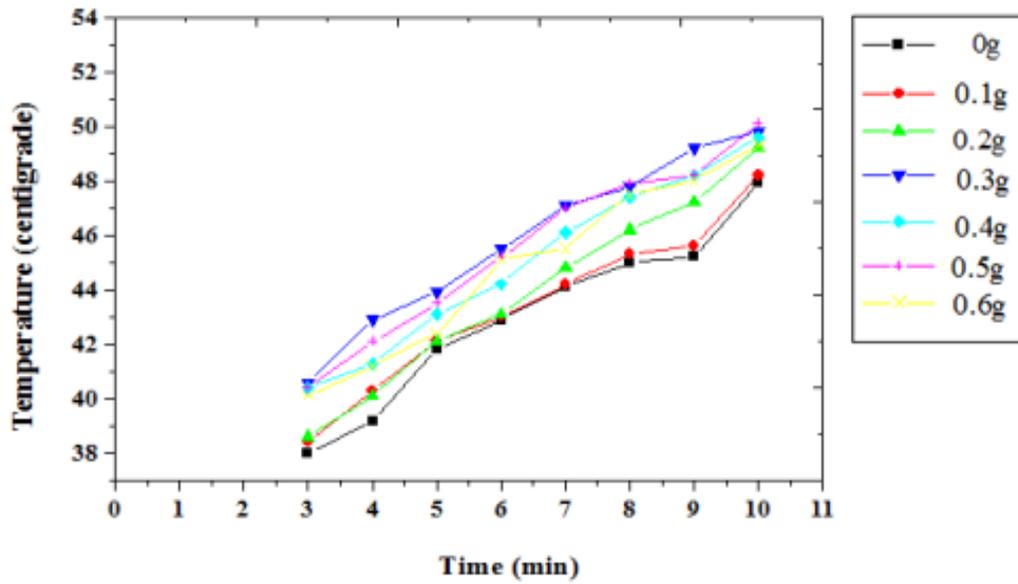


Fig.7 Operating temperature of the PV module with different weight of salt.

Table. 6 Temperature measurement of PV module with different weight of salt

Weight of dust (g)	0	0.1	0.2	0.3	0.4	0.5	0.6	
Temperature (°C)	Time (min)							
	3	38	38.4	38.6	40.6	40.4	40.4	40.1
	4	39.2	40.3	40.1	42.9	41.3	42.1	41.2
	5	41.8	42.1	42.1	43.9	43.1	43.5	42.4
	6	42.9	43	43.1	45.5	44.2	45.2	45.1
	7	44.1	44.2	44.8	47.1	46.1	47	45.5
	8	45	45.3	46.2	47.8	47.4	47.9	47.5
	9	45.2	45.6	47.2	49.2	48.2	48.2	48
	10	47.9	48.2	49.2	49.8	49.6	50.1	49.3
Output voltage (V)		17.83	17.10	16.84	15.56	14.96	13.86	13.22

5. CONCLUSION

In the present work, the impacts of dust deposition on the surface of the PV module and the factors influencing the dust depositions are investigated. The transmittance reduction in the PV module depends on the size of the dust particles, and it causes increase in temperature and decrease in voltage of PV module. The reduction in voltage depends on the physical characteristics of dust deposition. The MATLAB simulation is carried out to verify the effect of dust on the performance of PV module. The indoor experiment is carried out and the performance of PV is recorded. The operating temperature of the PV module is severely affected by the deposition of dust particle. The deposition of sand, cement and talcum powder over heats the PV module than the salt. The voltage of the PV panel decreases with increase in density of dust deposition.

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