SELF-CLEANING OF SOLAR PHOTOVOLTAIC: A CASE STUDY FOR IMPROVING THE PERFORMANCE OF SOLAR PHOTOVOLTAIC

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Abstract— The world's fear of global climate change has increased the severity of this energy crisis problem, while also creating an urgency to find alternative solutions. Due to decreasing system prices the market for PV systems is one of the most stable and fastest growing in the world. Shading and overheating of photovoltaic cells can result in a significant energy reduction of PV systems. Tilting and natural ventilation allows the buildup offine sand to be blown off from the PV array's surface. However, dust particles tend to gradually accumulate on the PV surface making the cleaning task more difficult and reduces the overall PV panel efficiency due to the combined effect of shading and heating. In this an original method to reduce effect of windblown sand and dust and increased PV temperature on photovoltaic arrays is described. The method consists of removing air blown dust from photovoltaic using forced air flow of cooled return air from existing air conditioning systems.

Index Terms— air blown dust, photovoltaic, efficiency, solar energy.

I. INTRODUCTION

Photovoltaic systems have the ability to directly convert sunlight to electrical energy, and they also have an environmentally compatible nature. Photovoltaic panels are constantly exposed to various types of weather and are thus a target for dirt, dust, industrial residues, atmospheric pollution, algae, moss, bird droppings, etc. The agents responsible for deterioration of the surfaces also include the chemicals used during cleaning. These form an excellent attraction for dirt and accelerate the deterioration process. This results the panel's surface prevents the sun's rays from filtering onto the panel's photovoltaic cells completely, reducing the solar performance and therefore efficiency. Current methods of cleaning reflective surfaces are expensive, interruptive, inefficient, and potentially damaging to collector surfaces. So an automated, efficient cleaning process that requires neither water nor moving parts to keep the solar collectors clean for maximum reflectance and energy output. [1].

II. PERFORMANCE OF SOLAR CELL

A. Factors Affecting the Performance of Solar Cell

As photovoltaic technology generates electricity from light, minor shading can result in a significant energy reduction. When a PV cell is shaded, it ceases to generate electricity and consequently acts as a high resistance and tends to be reverse-biased by other PV cells. Several factors significantly affect the solar array performance, such as operating temperature, solar intensity, sun angle, and I-V operating point (load matching for maximum power), the properties of the materials, and the gradual degradation of collectors resulting from accumulation of dust particulates. Crystalline silicon modules performance decreases due to temperature rise above 25^0C with a temperature coefficient of power drop of 0.35-0.65 % /K. Dessert gulf regions suffer from this problem the most. At noon time in summer, when the radiation intensity and the ambient temperatures are at their highest, a PV panel can reach temperatures up to 125 ^{0}C which is detrimental to both PV power and PV life [2].

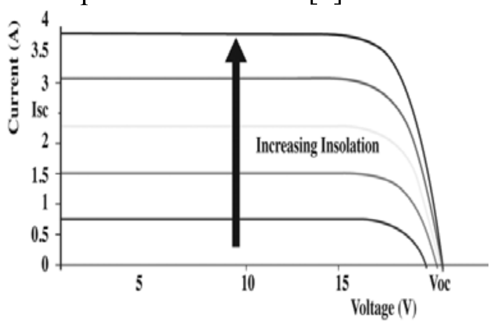

Fig.1 I-V characteristics at different solar intensities

PV cell's photocurrent is directly proportional to the solar intensity insolation and inversely proportional to temperature as shown by the I-V curves at different solar radiation intensities and temperatures.

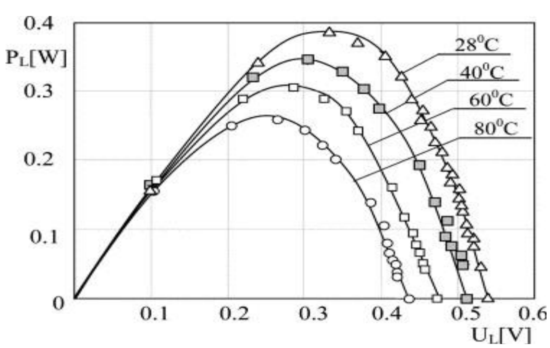

Fig. 2 Power output at different Temperatures of a PV cell

B. Dust Accumulation on Panels

Dust is a term generally applying to minute solid particles with diameters less than 500 mm. The characteristics of dust settlement on PV systems are dictated by two primary factors that influence each other, viz., the property of dust and the local environment. The local environment comprises site-specific factors influenced by the nature of prevailing (human) activities, built environment characteristics (surface finishes, orientation and height of installation), environmental features (vegetation type) and weather conditions. The property of dust (type – chemical, biological and electrostatic property, size, shape and weight), is as important as its accumulation/aggregation. Likewise, the surface finish of the settling surface (PV) also matters. A sticky surface (furry, rough, adhesive residues, electrostatic buildup) is more likely to accumulate dust than a less sticky, smoother one. The Fig 3 shows dust accumulation forming a heavy layer on solar module.

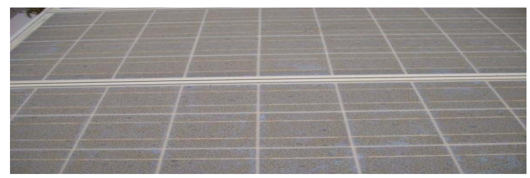

Fig.3 Solar module covered by heavy layer due to dust accumulation before cleaning

C. The Effect of Dust on Photovoltaic Module

Dust accumulation on PV arrays due to prolonged exposure to sandstorms may happen quite often in the desert regions thus causing minor shading on the PV module. Over time, as dust is deposited repeatedly, a thick layer of sand is formed on the surface making it harder for sunlight to penetrate through PV cover and reach the PV cell, thus decreasing the power output [3]. The problem becomes worse if the PV panel is placed horizontally to ground level as dust particles fall directly onto the panel, gradually covering it completely. Under dry weather conditions, the panel tilting to an optimal angle allows dust to slide off the smooth surface.

Dust and heat are the two most important problems faced in using PV cells in the desert gulf regions. Solving this coupled problem would greatly improve the acceptance of PVs as an alternative source of energy in the UAE and the Gulf region. Solar desalination plants in some of the middle-east countries like the solar desalination plant of Abu Dhabi suffers from the deposition of dust on its solar plates. With the time, the accumulated dust will affect the transmittance of the solar plates. The effect of the accumulated dust will be reduced with the increasing of tilt angle, since the tilt angle will affect the exposure time to the sunlight also. But the best way to eliminate the effect of the accumulated dust on the solar panels is to clean the panels. Cleaning the solar panels is also a problem. The normal way to clean the solar panels is washing them. But still also need time to spend or paying money to a cleaning agency. Actually, the cleaning should be frequently from time to time, and that is mean spending more and more money for cleaning. So this paper focused to construct a new method of Self-cleaning by using Forced Air Flow of Return Air from Air Conditioning Systems and suggests an original solution to the dust and temperature problem of PV cells which would improve the operating efficiency of PV arrays.

III. SELF-CLEANING METHODOLOGY

The effect of the accumulated dust will be reduced with the increasing of tilt angle, since the tilt angle will affect the exposure time to the sunlight also. But the best way to eliminate the effect of the accumulated dust on the solar panels is to clean the panels.

The best source of forced air flow in hot climate regions is the return air from air conditioning systems; as depicted in Fig 4. This applies to all roof top, roof-integrated or façade-integrated photovoltaic systems. There is an immense potential for the proposed technique in the UAE where air conditioning systems constitute the major electrical power load for most parts of the year, and where the buildings handle large amounts of air flow from the supply and return ducts. The air flow rates from the return ducts are function of the building envelop condition, building function and occupancy. A 5 m ceiling height with 3 air changes per hour (ACH) will accommodate 4.1 *l*/s of air flow from the supply duct per unit floor area. Provided that 50 % of the return air is being regenerated through a central chiller and the remaining 50 % exhausted to ambience through the return duct while assuming 50% percent of the roof area (assuming the roof area is same as floor area) is being covered by PV, it turns out that the same supply air flow rate, i.e. 4.1 *l*/s, will be available per unit area of the PV surface. In addition to removing dust accumulation from the PV, the cooled return air from air-conditioned spaces can also help remove huge amount of heat to keep the PV panel cooled and thus increase the PV power output.

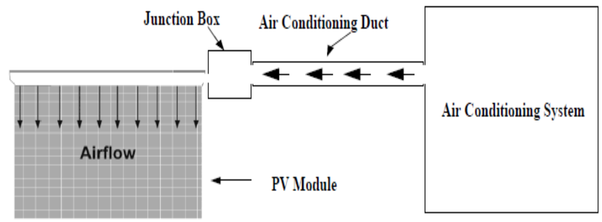

Fig.4 Conceptual diagram of the proposed method

The following equations are used for this methodology:

For building-integrated photovoltaic (BIPV), the panel temperature (Tp) is given by

$$T_P = T_a + \omega \left(\frac{0.32}{0.92 + 2\upsilon_f} \right) G_T \quad (1)$$

where Ta is the ambient temperature, υ_f is the free stream air velocity, ω is a coefficient depending on the PV mounting, and G_T is the solar irradiance in W/m2 on a normal surface. Table 3 lists ω values for different mounting conditions, with ω =1.2 for the current flat roof case.

The average daily temperatures on the PV panels are calculated based on the weather data. The average convection combined convective and radiative heat loss coefficient from a PV surface is obtained by

$$\bar{h}_c = 5. + 3.8\,\bar{\upsilon}_f \quad (2)$$

The same air flow rates cannot be guaranteed across the PV panel length so average convective and radiative heat transfer coefficient 'h_c' is calculated from average free stream air velocity 'υ_f' across panel length. The total heat removed (Q) from the PV surface is obtained by

$$Q = \bar{h}A(T_p - T_{air}) \quad (3)$$

Where T_p and T_{air} are the average PV panel and return air temperatures, respectively. The efficiency (η) of heat removal as a percentage of incoming radiation is obtained by:

$$\eta = \frac{Q}{G_T} \times 100 \quad (4)$$

IV. RESULTS

There is an immense potential for the proposed technique in the UAE where air conditioning systems constitute the major electrical power load for most parts of the year, and where the buildings handle large amounts of air flow from the supply and return ducts. This proposed method of Removal of Air Blown Dust from Photovoltaic Arrays Using Forced Air Flow of

Return Air from Air Conditioning Systems is applied in Al Ain, UAE and the results obtained was as follows

Table.1 Calculated PV Temperatures, Heat Removed of the Technique Based On Al Ain Weather Data

Month	G_T W/m²	T_a °C	V_f m/s	T_{air} °C	T_p °C	Q W/m²
Jan	662	23	1.5	30	46	216
Feb	606	26	1.5	30	47	230
Mar	711	28	1.5	30	49	254
April	628	35	2	30	53	314
May	719	40	2	30	61	417
Jun	663	44	2	30	63	448
Jul	587	45	2	30	62	431
Aug	660	42	2	30	61	420
Sep	674	38	1.5	30	59	395
Oct	747	36	1.5	30	60	400
Nov	709	28	1.5	30	50	277
Dec	623	26	1.5	30	46	213

The Table 1 gives the input weather data for Al Ain to measure the PV panel temperature, heat transfer coefficient and the overall heat removed from the panel assuming average weather conditions for each month and the variations of monthly average panel temperatures and the how much heat removed were calculated.

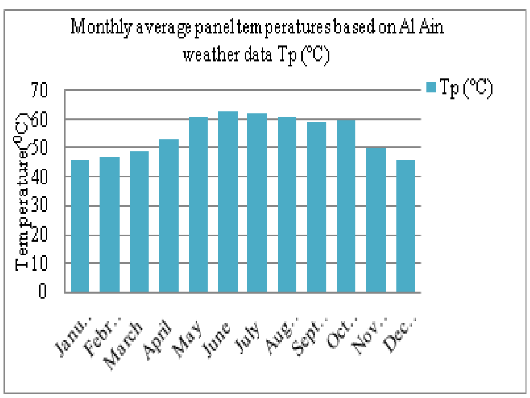

Fig.5 Monthly average panel temperatures based on Al Ain weather

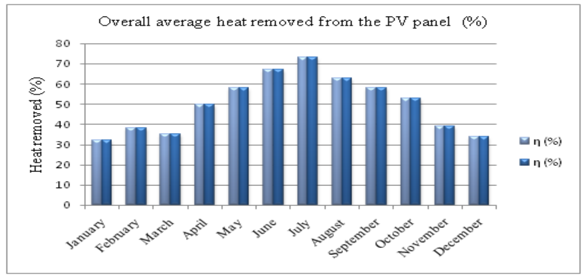

Fig.6 The expected overall average heat removed from the BIPV based on Al Ain weather data.

The overall average heat removed from the PV panel by convection through pre-cooled return air from the air conditioning system. Results show that a huge amount of incoming thermal energy can be removed reaching up to 73 % in July.

V. CONCLUSION

PV installation in desert region necessitates a regular cleanings to maintain an optimum performance. However, the accumulations of dirt objects on solar module have a significant, impact on output power and overall system efficiency. Dust accumulation on the surface of PV panels and their raised temperatures; greatly reduce the output power due to the reduction of glass transmittance and loss in cell efficiency. This is an original solution for the combined problem of dust and heat in desert climate. Using self-cleaning solar panels, especially in areas where water is scarce could overcome one of the significant challenges to achieving optimum results from the solar installation. It can be found that almost 73% of thermal energy removed and the overall efficiency is increased by this method.

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