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AN OVERVIEW OF CRITIQUE OF POWER LOSS DUE TO AMASSMENT OF DUST ON SOLAR PANELS

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ABSTRACT

This paper represents the brief literature review in realm of degradation of solar photovoltaic panel performance. It would not be prejudiced to say that solar photovoltaic technology is emerging as prime source of energy in many countries. A huge amount of growth has been observed in the installed capacity of solar photovoltaic power plants every year. Unfortunately, low efficiency of solar panels is the biggest barrier in development of this technology. Researchers all around the globe are toiling to increase its efficiency at the manufacturing stage but it seems to be equally vital to operate the solar panels at its maximum efficiency. Therefore, it is very important to savvy the factors that are responsible in the degration of solar photovoltaic performance under the real time weather conditions. This review represents a list of that factors and their affect on the efficiency of solar panels.

Keywords:solar photovoltaic; power loss ; dusting; soiling ; performance degradation

I. INTRODUCTION

In last few years, solar photovoltaic technology has flourished with rapid pace world widely. Solar PV has started to play a vital role in electricity generation in some countries as the decline in costs have made non subsidized solar photovoltaic generated electricity cost competitive with fossil fuels in a increasing number of locations around the world. In 2015, solar PV generation made another record year for growth, with an estimated 50 GW installed for a total global capacity of about 227 GW [1]. China has maximum installed capacity in the world and it surpassed Germany in year 2015. Germany was on top in total installed capacity from last many years. China, Japan, and the United States rated for the enormous majority of new capacity. An approximated 22 countries had enough capacity at end-2015 to fulfill more than 1% of their electricity demand, with some handsome higher shares in some countries (e.g., Italy 7.8%, Greece 6.5% and Germany 6.4%). In addition, world's largest grid connected solar PV power plant is located in Chain, Longyangxia hydropower-solar power mix PV power plant has installed capacity of 850MWp [2]. The 320MWp of phase-I was completed for power generation in 2013 and the 530MWp of phase-II was fully put into operation in July 2015. The average everlasting electricity production of the plant is 1,303GWh. Trend of electricity generation from solar

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PV panels is increasing day by day but its high cost investment and low efficiency are two biggest threats to this technology. In fact, low efficiency is the major cause of its immense money investment. Due to low efficiency (18-21%), large numbers of panels are required to generate a particular amount of energy. Consequently, hike in the capital investment of solar photovoltaic power plant. A lot of research has reported to increase its efficiency at manufacturing level but another challenge in this field is to extract the maximum power output under the real time operating environment of the panel.

II. MAJOR FACTORS AFFECTING THE EFFICIENCY OF SOLAR PV PLANTS

Firstly, Low efficiency is one of biggest issue in PV technology. Scientists and researchers all over the world are endeavoring a lot to improve the efficiency of solar panels. It is very important to get maximum power output from the installed capacity. Solar radiation and cell temperature are the two factors, which affect the performance of solar panels. Besides, there are plethora of other factors, which affect the output power of solar panels such as the reliability of other components of the complete system and other environmental conditions. Fig 1 tells us the list of various factors that affects the solar power plants output energy.

2.1 NAME PLATE DC RATING

The It is also known as sticker DC power rating of solar panel in the standard test conditions (1000 W/m^2, 25 C ^{o}) , which implies that particular solar panel will produce its maximum power in such standard conditions but there might an error between the actual field performance and name plate rating.

2.2 *DIODE AND CONNECTION LOSS*

The main role of bypass diodes in PV system is to sustain PV modules in partial shading conditions because due to partial or full shading, hot spot on the solar panel can be created which will definitely cause rise in temperature and heat loss. To mitigate such problem bypass diodes are usually used but these bypass diodes can cause one form of connection loss known as power loss in the system [3]. The other type connection loss in PV system happens where PV modules and other electrical components are connected together to form PV arrays, known as resistive loss.

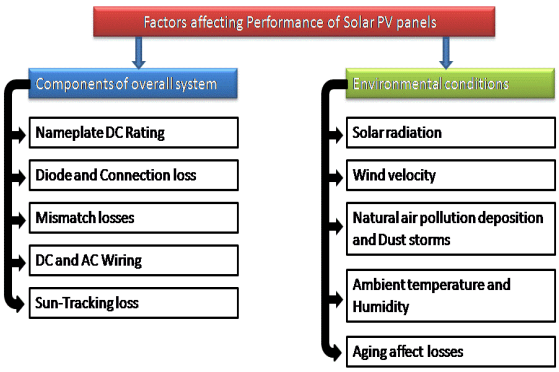

Fig. 2. Various factors affecting performance of solar PV power plants

2.3 MISMATCH LOSS

A mismatch loss study on an actual installation has been conducted on a real photovoltaic plant operating in the Italian region of Puglia by Lorente et al.[4].They found a very small mismatch loss in the small PV plant of 40

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modules; furthermore the ordering does not influence so much the loss in this case. Instead, the loss in the larger array of 320 modules is bigger and the ordering method presents a more significant influence.

2.4 DC AND AC WIRING

These losses consist of the resistive losses of the cables and wires used throughout the whole PV plant.

2.5 SOLAR TRACKING LOSSES

Solar tracking systems would probably hike the efficiency of a PV module, but it is really important to investigate when and where. This investigation has done by Eldin et al. [5]. It has been found that the addition in electrical energy generation with the help of tracking the sun is about 39% in case of a cold city. While the production in electric energy does not exceed 8% in case of a hot city as, due to overheating of the PV panels. However, if the energy needed for running the tracking system, which ranges from 5% to 10% of the energy generated, is included in this analysis then tracking the sun will not be feasible in hot countries.

2.6 SOLAR RADIATION

Solar PV power plant's performance is highly sensitive to environmental conditions. Solar radiation is always unpredicted and variable for any particular location. Hence it dramatically varies the output of solar PV power plants.

2.7 HUMIDITY, TEMPERATURE AND WIND VELOCITY

In analyzing the effect of humidity, two factors need to be considered. The first factor is the effect of water drops on the irradiance level of sunlight and the second factor is humidity entrance to the solar cell enclosure. Reference [6], Mekhilef S. et al. revealed that humidity degrades I_{sc} but has insignificant effect on V_{oc}. The power output or efficiency drops because water vapors scatter the solar radiation incident on solar panel. In the second approach to the humidity effect on solar cell's performance, moisture ingression has studied. It has been observed that the high content of water vapour in the air causes encapsulate delamination. Ahmad N. I. et al. examined the effect of high temperature on the performance of large scale solar power plant [7]. It was found that the short circuit current, gradually increased with marginal changes, while the open circuit voltage, V_{oc} decreased linearly when the temperature increased. Due to this effect the maximum power output, P_{max} as well as its efficiency was linearly reduced once the temperature increased. Regarding the wind speed impact, which is often neglected, it plays a crucial role in decreasing modules' temperature and accordingly increase in their efficiency. Kaldellis J.N. et al. performed experiments at two different locations to understand the impact of wind speed on the performance of solar PV power plant [8]. They found modules' efficiency temperature coefficient is estimated to be about -0.30% per ^{0}C for the installation at Ligourio and -0.44% per ^{0}C for the installation at Chania. Wind speed and ventilation at Ligourio is far better than Chania. Finally, they investigated the impact of wind speed on the thermal loss coefficient for the case of Ligourio, with the estimated 7-10 W/m^2 K per m/s.

2.8 AGING AFFECT LOSSES

The proposed life cycle of solar is around 25 years by manufactures. Therefore, it is obvious falls in efficiency of solar panel with respect to its age. To evaluate the rate of degradation of solar panel Kaplanis S. et al.

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performed experiment on the BP c-Si PV modules [9]. They concluded that a progressive degradation of 11% within a period of just more than 20 years has been effected, under the real time placement of solar panel.

2.9 DUST DEPOSITION LOSSES

Higher wind speed may lead to heavy dust deposition on solar panel, which also causes huge impact on the performance of solar PV panels. Soiling losses represent to power loss resulting from snow, ash, dust and other particles that cover the surface of the PV module. Dust is a narrow layer that covers the surface of the solar array, which reduces the fall of solar radiation into the solar panel. The typical dust particles are less than 10 µm in diameter but this depends on the location and its environment.

The map of the world has shown in Fig 2 with the dust intensity in different colours. The darker colour indicates the higher level of dust. India lies in Zone 3 in this map, which means dust intensity around it, is in the range of 44-96 mg/m^3 [10].

III. CRITICAL STUDYING IN DUST

Soiling means not only dust deposition, but also surface adulterate by plant products, soot, salt, bird droppings, and growth of organic species, adversely affecting the optical performance. Dust deposition on solar collector surface depends upon two major factors. First is the location of the

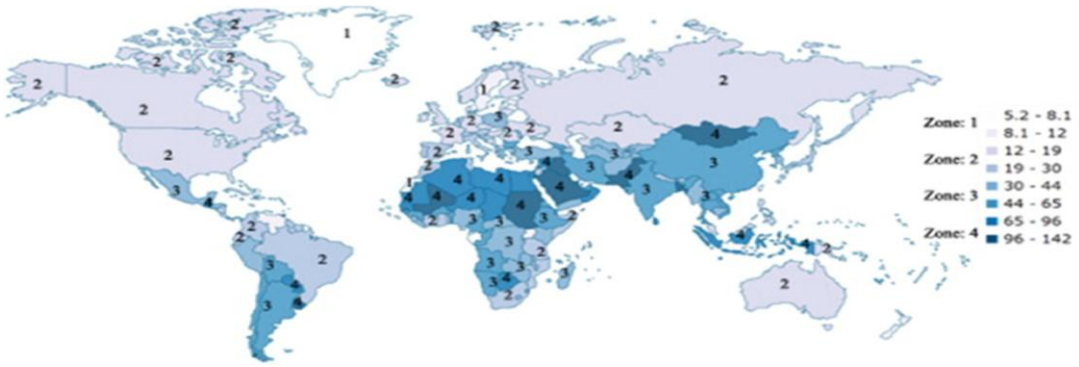

Fig. 2. Example Dust intensity around world (mg/m^3) [10]

solar plants and secondly site's local environmental conditions (i.e. Weather condition). The other factors are tilt angel, dust density, wind speed and type of dust particles [11].

To find the causes and impacts of dust deposition on solar energy collector began 75 years ago. In 1942, Hottel et al. were originated to investigate the impact of dust on solar collector. They revealed that a 1% degradation in thermal flat-plate collector's performance attributed to dust/dirt accumulating on a glass plate tilt at an angle of 30^0 in extreme weather conditions of the United States of America [12]. After the gap of three decades in 1974, Garg H.P. investigated the affect of dust on the transparent cover of the flat- plate energy collector [13]. He found the dirt correction factor for glass plate was 0.92 with tilt angle 45^0 and the correction factor was greater for plastic film than glass cover. It attracted the other scientists around the world. With the growth of solar technology, researchers started to calculate the reduction in efficiency of solar PV panels due to dust deposition.In 1977, Maag C.R., did experiment on solar photovoltaic panel to analyze its performance under the

real time weather conditions [14]. It was the first study to understand the affect of soiling on performance of solar photovoltaic collector. He found variation in short circuit current with deposition of dust. Hoffman A.R., with Maag C.R. also published a project report "Photovoltaic module soiling studies May 1978 – October 1980".in this report, they performed many experiments on various sites of United States throughout the years [15]. They found significant degradation in electrical performance ranging from 2% to 60% depending upon the time and site but they did not gather information regarding dust density and also performed indoor experiments under the artificial solar radiation to find out the degradation in performance without considering temperature constraint. Although tilt angle plays a crucial role in amount of dust deposition but tilt angle was also fixed to 30^0 throughout the experiment period in that study. Nahar N.M. et al. focused on tilt factor in their research work and they found the affect of dust deposition was more, when glass cover placed at zero degree tilt angle as compared to 90^0 tilt angle [16]. Although, they used natural way of dust deposition but they did not calculate the dust density. They performed their experiment for short period of time. Hence, it is very difficult to rely on their results. Besides, they did their experiment on reduction in solar radiation not on degradation in electrical performance. El-Shobokshy M. S. et al. was the first team, which showed the reduction in electric power with respect to amount of dust density [17]. They found 12% reduction in output power due to 253 g/m^2 dust density but the way of dust deposition was artificial. Moreover, they performed an indoor experiment with the help of solar simulator under the controlled standard test condition and compared the result with specification sheet provided by the manufacture. To maintain standard test conditions in laboratory were really difficult so indoor experiment was also doubtful. To eliminate, this doubt, Al-Hasan A.Y. et al. performed an outdoor experiment and they calculated 33% reduction in output power of solar PV panel with respect to deposition of 1 g/m^2 dust density with fixed tilt angle 30^0 but the way of dust deposition was again artificial [18]. Hence, it was again really difficult to judge the performance of solar panel under real and natural weather conditions. Elminir H.K.et al. and El-Nashar A. M. placed the glass cover in outdoor environment for 210 days at different tilt angle and finally, found the reduction in solar radiation through the glass cover in the range of 12.38- 52.54%[19-20]. They also calculated the amount of dust density but experiment on glass cover was not enough to evaluate the performance of solar PV panel under extreme weather conditions. In their research work, few scientists opted almost same methodology. They performed outdoor experiment with using pair of solar PV panels [21-25]. The way of dust deposition was also natural. In most of the research, the dust deposition period was limited to 56 days and results were also varied a lot according to location. They main reason behind the variation in the results might be due to less number of observations and short period of experiment. Some researchers showed immense interest in size and type of deposited dust particles [26-30]. They performed indoor experiments, either depositing dust artificially or naturally and they found different results with different type of dust particles. Therefore, it is also one of the important factors, which also need to consider in dust deposition affects field of studies. Rao A. et al. performed the indoor and outdoor experiment to validate their results more precisely but the way of dust deposition was artificial. Hence, calculation of actual performance degradation was again not possible [31]. Kalogirou S.A. et al. did a unique experiment. They deposited a wet artificial dust and performed an outdoor experiment [32]. They found 42% reduction in output power of solar PV panel. Hence, it also important to study the degradation in performance of solar PV panel due to wet dust deposition in winter season

III. CONCLUSION

In the above brief literature survey, it has been observed that dust affects a lot on the performance of solar panels. To calculate the reduction in efficiency, different kinds of methodology were being adopted by the researchers. But for precise results, outdoor experiment with long period of experiment should be adopted. In addition, experiment should be repeated frequently.

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