PERFORMANCE EVALUATION OF CdTe PV MODULES UNDER NATURAL OUTDOOR CONDITIONS IN KUWAIT

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ABSTRACT: Performance of CdTe thin film photovoltaic modules under natural outdoor conditions in Kuwait is investigated in this study with particular emphasis on specific environmental parameters prevailing in hot desert locations; such as high ambient temperature, Aeolian dust, humidity, and scarcity of rain. Study results are expected to provide in-depth understanding of electrical performance of a promising thin film photovoltaic technology due to lack of such full studies in desert like environments, leading to improvements of simulations models, and hence better estimation of photovoltaic module yield. Study results also provides recommendations for cleaning the modules based on meteorological conditions instead of a fixed or variable cleaning schedule, leading to better utilization of water which is considered scare in hot desert environments.
Keywords: CdTe module, electrical properties, energy performance, thin film.

1 INTRODUCTION

Large photovoltaic plants in desert regions have the potential to complement fossil fuel to meet the growing energy consumption of the world population. It is thus necessary to study the performance of photovoltaic systems under desert like conditions such as high ambient temperatures and high dust accumulation on PV modules. In the present work, CdTe modules have been chosen because they are a suitable thin film technology for hot climates. The test system has been set up in Kuwait, where desert like conditions are met, data collection started in September 2009 and is expected to be completed before the end of this year.

2 Experimental set-up and procedures

2.1 Experimental set-up

Meteorological parameters such as global irradiance, diffuse irradiance, wind speed, wind direction, precipitation, rain events, ambient temperature, and relative humidity were all continuously measured. The rain event sensor was included to identify the start and stop time of rain, which is considered an important study parameter for monitoring very light rain or rain drizzles. This parameter is seldom recorded by precipitation sensors with commonly used sensitivity in most solar studies.

The photovoltaic module test stand as seen in Fig. 1 was custom made to house a multi-channel IV-curve tracer, a data logger, and an uninterruptable power supply. Twelve CdTe thin film photovoltaic modules of the type First Solar FS-275 were mounted on the stand with two modules on each tilt angle, ranging from flat to vertical between 0, 15, 30, 45, 60, and 90 degrees. The stand is divided into two wings orientated eastern and western. Photovoltaic modules were connected to the multi-channel IV-curve tracer by using a four-wire configuration to avoid voltage drop in cabling. Furthermore, all modules were fitted with temperature sensors for measurement of modules temperature. The sensor location was identical on all modules.

2.2 Procedure

Meteorological and photovoltaic module parameters were continuously measured, and recorded over one minute average values, providing a huge data bank for detailed transient studies. IV-curves were taken every 30 minutes.

Figure 1: Photovoltaic module test stand

Comparative performance of modules in relation to dust accumulation was carried out by cleaning photovoltaic modules on the eastern wing while modules on the western wing were kept unclean. Cleaning of eastern wing modules was carried out according to a predetermined cleaning schedule, whereas western wing modules were generally cleaned on the first day of the month.

The pyranometers were cleaned daily, either at night time during non-dusty days or at early morning hours to insure dust free pyranometer lens. The shadow ring adjustment bar was adjusted daily after sunset for the next day.

In addition 40 x 40 x 2 mm^3 glass samples were exposed outdoors on the test site on six tilt angles - flat, 15, 30, 45, 60 degrees, and vertical - to collect dust. Glass samples were removed on the last day of the month after one full month of exposure for spectroscopy analysis.

3 Meteorological data

During the test period starting from September 2009 till end of August 2010 the total global insolation was around 2,000 Wh/m^2, which ranks Kuwait as a high potential site for solar applications. The month of July recorded the highest global insolation at 7.4 Wh/m^2/day, the lowest was recorded during the month of December at 3.2 Wh/m^2/day. The month of September recorded the highest monthly clearness index at 68%, and 55% as the lowest during the month of December.

High ambient temperatures are generally experienced during summer months. The highest ambient temperature was recorded during the month of July at 51^{o}C and around 50^{o}C during June and August. The monthly average daily maximum ambient temperature for summer months was calculated around 45^{o}C. Fig. 2 shows monthly average daily insolation and ambient temperature.

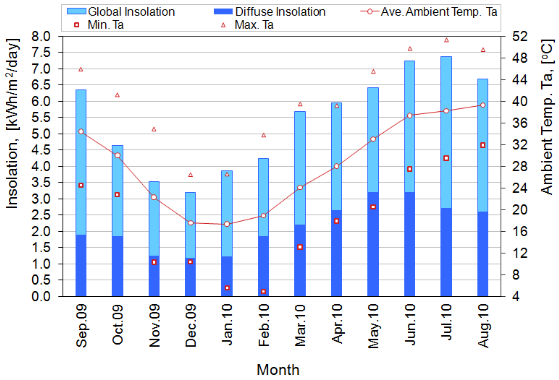

Figure 2: Monthly average daily insolation and ambient temperature (Sep.09 - Aug.10)

During the test period, no precipitation was recorded during the summer as expected. The month of November recorded the highest precipitation with a daily average of 1.9 mm/day, whereas the months of February and March recorded the lowest precipitation around 0.05 mm/day.

Relative humidity was monitored due to the major role it plays in forming a sticky dust layer on module surface. Rain free months recorded an average daily humidity around 30%, which is considered low. Nevertheless, the months of July and August recorded two days each of high humidity capable of transforming dry dust into clustered and sticky dust. Monthly average precipitation and relative humidity are shown in Fig. 3

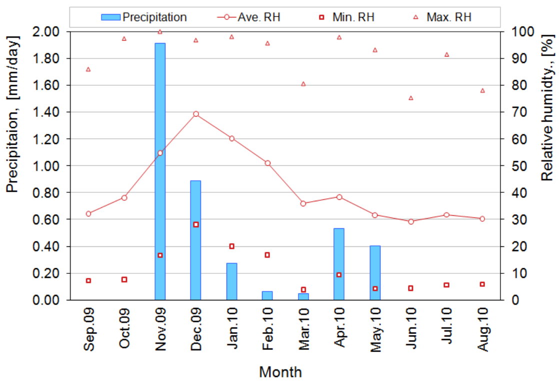

Figure 3: Monthly average daily precipitaion and relative humidity (Sep.09 - Aug.10)

4 Photovoltaic module performance

The photovoltaic modules were monitored from September 2010 till the end of August 2010. The power temperature coefficient of CdTe photovoltaic modules was calculated from IV-curves of clean modules. The results show an average value of -0.28%/ ^{o}C, which is slightly higher than the value given on the module data sheet state of -0.25%/ ^{o}C. Module efficiency under low irradiance levels (< 350 W//m^2) show slightly lower efficiency compared with high levels, this could be attributed to applying a fixed temperature coefficient.

During the months of April through August modules on the eastern wing were periodically cleaned, whereas modules on the western wing were cleaned only once at the beginning of the month. Figure 3 shows percentage loss in module yield on the last day of the month on 30 degree tilt angle. The month of May recorded the highest loss (-25%) because of heavy dust accumulation mainly due to presence of dusty rain. Fig. 1 shows photo taken on day 17. The month of June recorded the lowest loss with -6.6% due to absence high humid days. It was observed that air borne dust during the test period differs from previous results [1], in which the months of August and September had the highest dust accumulation.

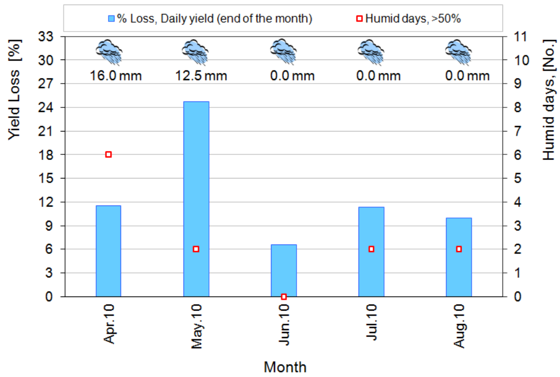

Figure 4: End of the month percentage loss in daily yield due to dust accumulation.

Fig. 4 shows average daily humidity during the month of July with percentage loss in daily yield for selected days with clean reference module, which clearly demonstrate an increase in losses after presence of high humidity on the 10th day. Slight improvements in later days after the 17th are attributed to dry dust accumulation which was naturally blown away by wind**.**

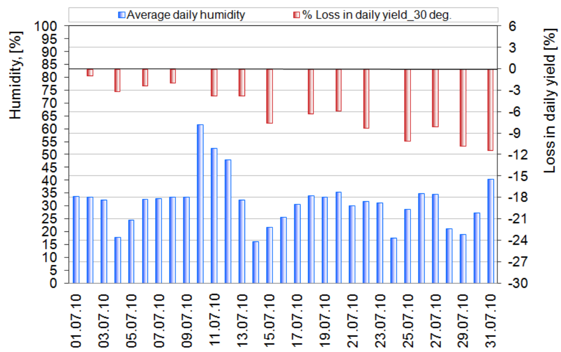

Figure 5: Average daily humidity and percentage loss in daily yield during Jul.10

5 Conclusions and remarks

Dust accumulation poses a serious problem to modules in a desert-like environment. Whereas dry dust is less detrimental, dust followed by light rain or high humidity can form a sticky layer on the module, particular on the modules of low inclination angles. The same applies to dusty rain. These layers remain on the surface and require cleaning of the modules.

Highest monthly losses due to dust accumulation were recorded in May from 4% for the vertical surface to 37% in Isc for the flat surface, mainly due to the presence of dusty rain or dry dust accumulation followed by light rain. Earlier observations have shown that yield losses can be even higher.

The dust accumulation on PV modules does not correlate directly with the quantity of air borne dust. Other factors such as relative humidity and rain events are equally important for the quantity of accumulated dust.

Module operating temperatures around 55^{o}C above STC were experienced, which amounts to substantial reduction in power and yield, hence PV technologies with lower power coefficients are more attractive for application in desert climates

6 Recommendations

To avoid high operating module temperature in the range or 20 - 25^{o}C above ambient temperature, it is highly recommended to use open air mounting structure.

Immediate cleaning is generally needed following dusty rain events even if accompanied by heavy rain, in addition to light rain events following dry dust accumulation. Cleaning in such cases requires using wet soft brushes to loosen the dust layer while spraying water.

However, since in desert-like environment cleaning with water is difficult to achieve, other ways of reducing the accumulation of dust have to be developed.

Module surfaces with dust repellent properties are one possibility to minimize dust accumulation and to increase the duration between cleaning events.

7 References

[1] H. AlBusairi and A. AlKandari (1987): Performance evaluation of Photovoltaic modules in Kuwait, Proceedings of International PVSEC-3, pp. 323-326