

Flexible PV mounted on a fabric-covered vehicle shade in Jeddah, Saudi Arabia: can natural motion prevent dust buildup?

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Abstract— An array of flexible triangular PV modules was installed on a fabric car shade canopy in a car park in Jeddah, Saudi Arabia. The performance, estimated from temperature-corrected short circuit currents for each sub-array on the four faces of the shade, were monitored for a period of six months in order to determine the performance degradation over time due to accumulation of dust. It was hypothesized that the natural motion of the fabric canopy due to the wind would cause the flexible modules to move, and this might in turn prevent the build-up of dust on the modules.

In practice, the motion was not sufficient to remove the dust, the build up of which resulted in a performance degradation on all four faces, converging with time on around 60% of the peak recorded performance. Rare rainfall events observed during the measurement period did result in significant, albeit temporary, performance improvements.

Keywords—Photovoltaics, Saudi Arabia, Rooftop, Flexible PV, Car shade, Car park

I. INTRODUCTION

IN HOT ARID CLIMATES, fabric covered shades are commonly used in car parks for protecting vehicles from excessive temperature, sunlight and dust. This represents a huge opportunity for deploying photovoltaic (PV) arrays at scale, particularly at facilities with large outdoor car parks, such as universities [1]. Flexible PV modules can be integrated into new shade fabric covers or retrofitted to existing ones. However, hot arid climates also pose a problem for PV installations in the form of dust deposition resulting in performance degradation over time. Previous



Fig. 1. Typical vehicle shade: steel cantilever frame with stretched fabric canopy [1].

work by the authors on a rigid structure car shelter with conventional glass encapsulated PV modules found that water-based cleaning systems were effective at maintaining PV performance, but added additional cost [2]. Could the motion of flexible PV mounted on fabric due to wind be sufficient to counteract dust deposition and therefore save capital and running costs of solar PV car shading solutions? This would help to improve the challenging economics of PV arrays in the low electrical tariff context of Saudi Arabia [3-5].

This work was the first evaluation carried out on these specific semi-flexible solar PV systems installed on fabric canopies in Saudi Arabia and aimed to quantify the performance reduction over time due to dust and other factors, in the context of varying environmental conditions.

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Fig. 2. Comparison of water cleaned/non-cleaned rigidly fixed PV modules [2].

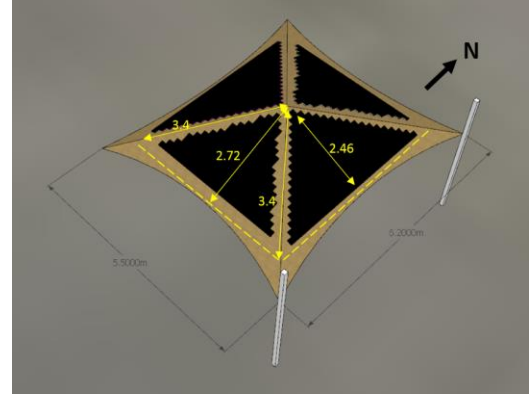


Fig. 3. Layout of flexible PV modules installed on a typical vehicle shade at KAU, Jeddah.

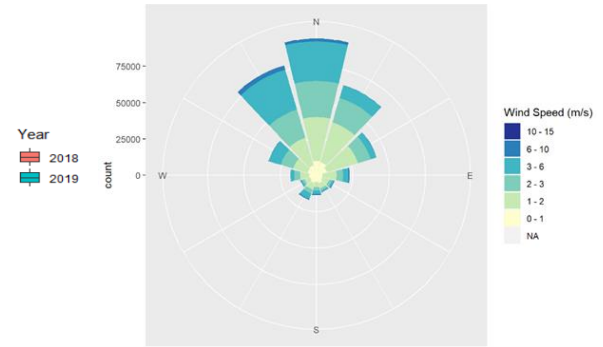
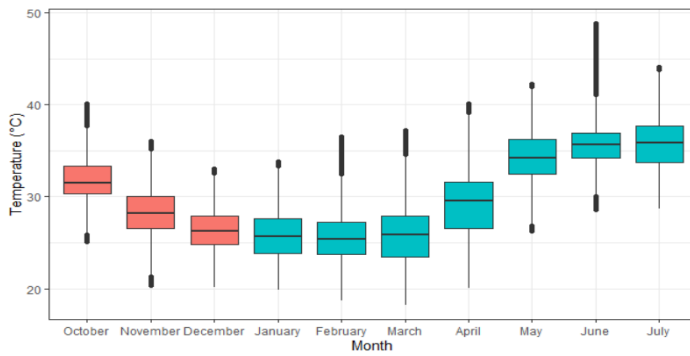


Fig. 4. (a) Temperature variation and (b) wind rose from the car park location at King Abdulaziz University, Jeddah

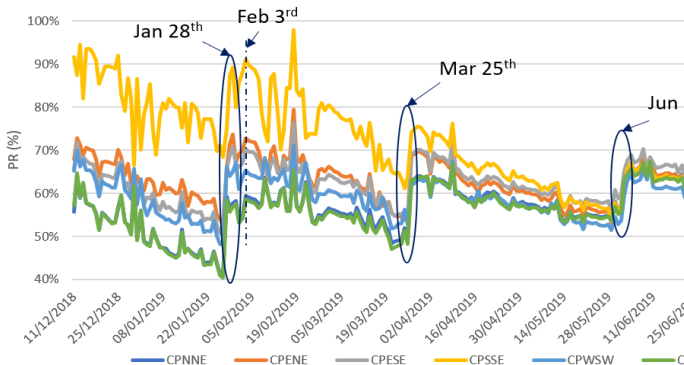


Fig. 5: Variation of weather-corrected performance ratio at noon from Dec 2018-Jul 2019, indicating rainfall events (ellipses) and manual cleaning event (dashed line). Note SSW and WNW sub-arrays did not return data due to faulty connections.

II. METHODOLOGY

The experimental setup was located in a car park at King Abdulaziz University in Jeddah, Saudi Arabia. It consisted of a single car shade canopy of typical design with square-based pyramid shape ($L=6.2 \text{ m} \times W=5.5 \text{ m} \times H=1.1 \text{ m}$) fabric stretched over a steel frame. On the fabric were mounted using rivets and washers a set of thermoplasticencapsulated semi-flexible PV modules (see Fig. 3, 5 and 6). On each of the four faces of the canopy, two sub-arrays were formed of 8 custom-made triangular

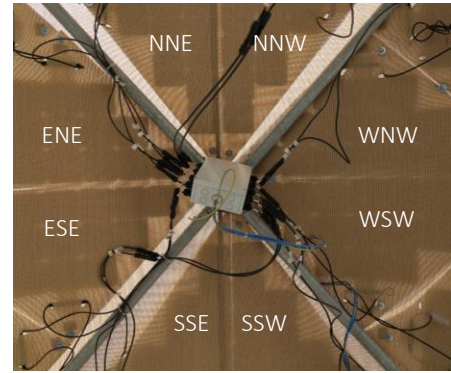


Fig. 6: View from underneath canopy, indicating the eight sub-arrays of the semi-flexible PV array, with current shunts mounted in junction box underneath the canopy.

modules, each of 16 cells (49 Wp). The total nominal capacity of the 8 sub-arrays mounted on the canopy was $8 \times 391 \text{ W} = 3.13 \text{ kWp}$. The short-circuit current of each sub-array was measured by 4-wire shunts and logged at 1 minute intervals initially over the course of six months.

In order to remove any possible effect of shading from nearby buildings, short circuit current averaged from 11:50 to 12:10 (+03:00) each day. This value was then normalized by rated short circuit current and in-plane irradiance, and corrected for ambient temperature variation (using method described in [6]) to give a performance ratio (PR).

Weather data was from a co-located weather station (ambient temperature, irradiance and wind speed). Rainfall events were identified from the records of a depth

sensor located in a nearby rain fed tank, and corroborated with media reports. Fig. 4 indicates predominantly northerly winds with mean monthly wind speed 2.0-2.6 m/s. Peak ambient temperature during the measurement period was 49 °C.

III. RESULTS AND DISCUSSION

The performance of the solar PV system, in terms of the performance ratio (PR) introduced in Section II, temperature corrected short circuit current per incident radiation at noon, was correlated with significant weather events and manual cleaning events (see Fig. 7). Six of the eight sub-arrays (named after the direction with respect to north) returned data, with SSW and WNW not returning due to loose connections. Weather events during the measurement period included January 28th, March 25th, and June 2nd, 2019. The first event was the most significant with 19.80 mm of rain, causing widespread disruption [7], whereas the second and third were much smaller instances. Furthermore, on February 3rd, the PV systems were cleaned manually.

It can be seen from Fig. 7 that the performance ratio gradually degrades between rainfall (or manual cleaning) instances. The average degradation percentage was 1.50% per week in the northern PV systems while the east and west side had 2.8% and 2% respectively. Lastly, the southern PV system registered a value of 4.10% per week making it the fastest rate of performance decrease.

For example, one rain event resulted in an overall average performance improvement of 19%.

IV. CONCLUSIONS

The significance of these results is that, while rain events helped to restore performance of canopy-mounted PV, the flexing and movement of flexible PV modules mounted on a fabric structure due to wind action was not enough on its own to remove dust in this context and there is therefore an appreciable drop on performance of the canopy over time. Consequently, in order to exploit the opportunity of car shades for PV, dust removal methods will need to be incorporated into future installations.

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