Effect of Transient Performance Changes on Photovoltaic Modules Output

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Aims and Objectives

Aim
The main aim of this research is to study the effect of transient performance changes on photovoltaic modules output.

Objectives
This research seeks to know;
1. the main cause of PV output transients together with their relationship with transients in solar irradiance;
2. when the effect of transient performance changes on photovoltaic modules would be noticed;
3. the significant information required about a PV module before characterising its transient behaviour.

Methodology

The data used in this study is a daily detailed data set (from July 01 -15, 2018) from the installed roof-top solar photovoltaic (PV) array at Dublin Energy Lab (DEL), Grangegorman. This array consists of 42 PV modules with arrangements: 4 strings of 2×10 and 2×11 of 250Watts each with maximum PV power system of 10.5 kilowatts peak (kW_p).

The total area of surface for the PV module generator is estimated as 68.3m^2 with each of the modules having area capacity of 1.63m^2. From the online data loggers of the installed PV-CS Grangegorman, the following files were generated: Grid feed-in (kWh), daily yield (kWh) and Power output (kW).

These data were analysed to find the effect of daily transient performance changes, PV output generation (kW), hourly solar radiation (Wm^{-2}), hourly efficiency and hourly performance ratio using suitable formulas.The performance ratio was calculated using global solar radiation obtained from historical for the Dublin Airport meteorological station.

Results and Discussion

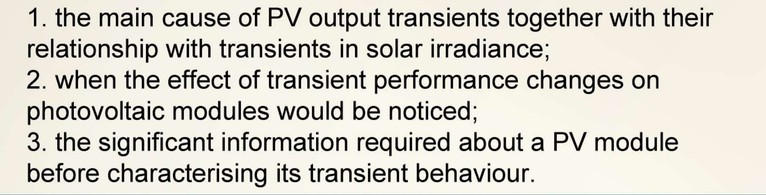


Figure 1: A 3-D Clustered Column plot showing a gradual reduction in hourly efficiency of PV output in the absence of solar radiation (that is, when plotted with respect to Day).

In Figure 1, the highest hourly efficiency of the PV recorded was about 17.36% on the third (3rd) day and thereafter, it finally declined to 3.25% on the last day (15th). The decrease in efficiency of the PV output may be as a result of low solar radiation caused by unexpected shading (Li, 2016) and weather conditions (Osterwald et al, 2002).

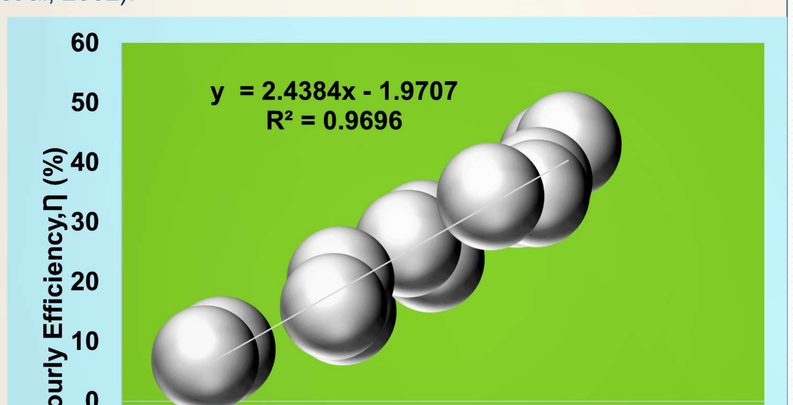


Figure 2: A 3-D Bubble plot showing an increase in hourly efficiency with respect to increase in hourly solar radiation.

Figure 2 is quite an opposite of Figure 1. This is because as the solar radiation increases, the efficiency of the PV output also increases given a positive value of gradient, m (2.4384). This is explained by the proportion of variation, R^2. The R^2 value is 0.9696, that is, about 97% of the variability in hourly solar radiation is accounted for by the straight-line fit to hourly efficiency.

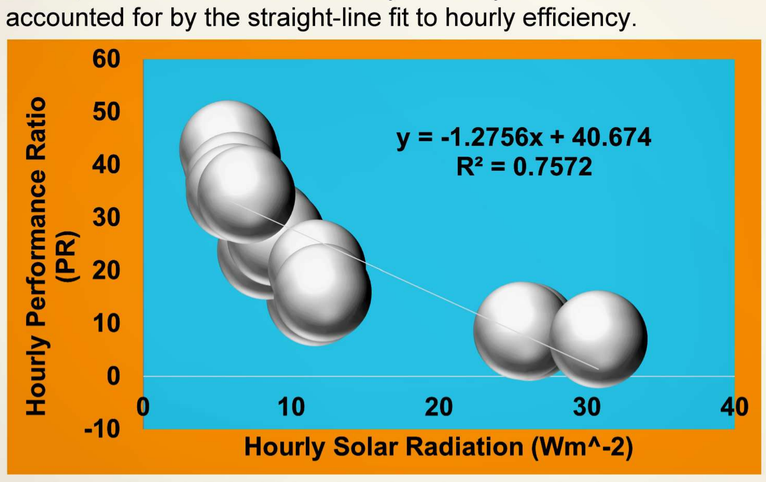


Figure 3: A 3-D bubble plot showing a gradual reduction in hourly performance ratio (PR) of PV output

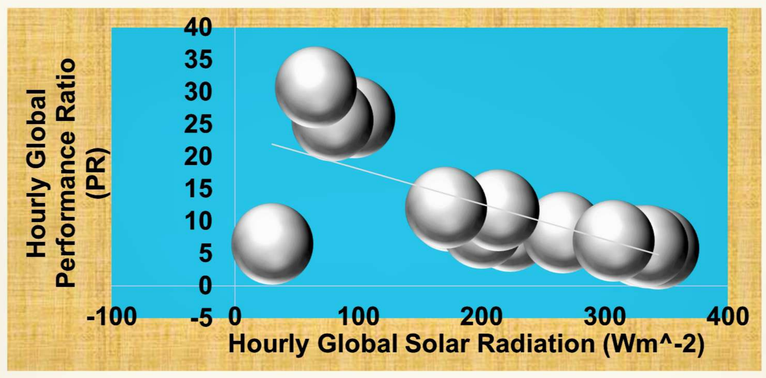


Figure 4: A 3-D bubble plot showing the effect of Global radiation reduction in hourly performance ratio (PR) of PV output.

Figure 3 and Figure 4 shows the hourly performance ratios (PRs) estimated from the daily detailed data set (from July 01-15, 2018) from the installed roof-top solar PV array in Grangegorman and daily global radiation from July 01-15, 2018 at Dublin Airport from the online historical data (https://www.met.ie/climate/available-data/historical-data#). Their gradient, m, and proportion of variation, R^2 values have shown clear distinctions in terms solar radiation generation. For instance, the hourly performance ratio (PR) of roof-top solar PV array (real system) with gradient, m, value = -1.2756 and R^2 value = 0.7572, that is, about 76% of the variability in hourly solar radiation is accounted for by the straight-line fit to hourly performance ratio (PR). This is because 0.7572 is close to 1 while hourly PR for global solar radiation with gradient, m, value = -0.0544 and R^2 value = 0.4942, that is, about 49% of the variability in hourly solar radiation is not accounted for by the straight-line fit to hourly global PR.

Further illustration on this comparison can be seen in Figure 4 where the hourly global radiation data (Wm^{-2}) for Dublin Airport obtained from the historical data increases in multiple times than that of the hourly solar radiation (Wm^{-2}) data obtained from installed PV array (real system) at Grangegorman.

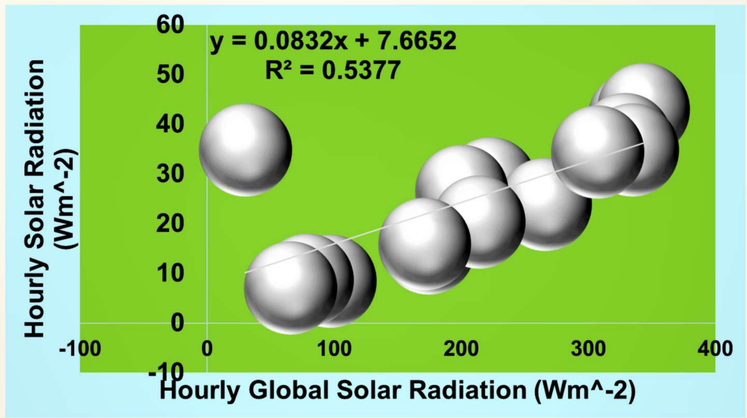
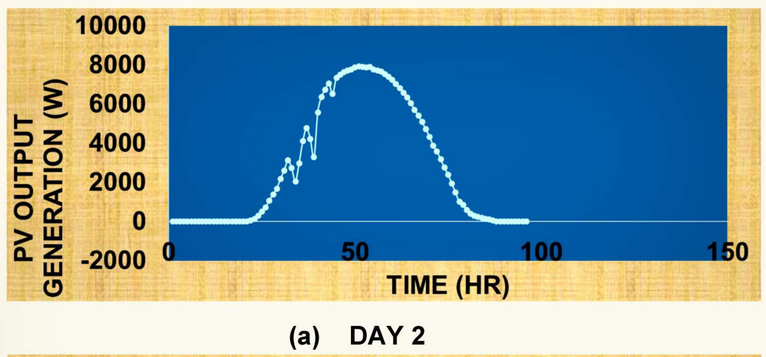
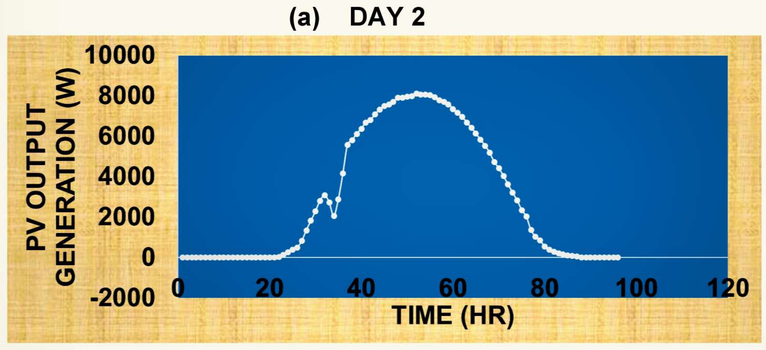


Figure 5: A 3-D bubble plot showing the hourly solar radiation versus hourly global solar radiation from July 01-15, 2018.

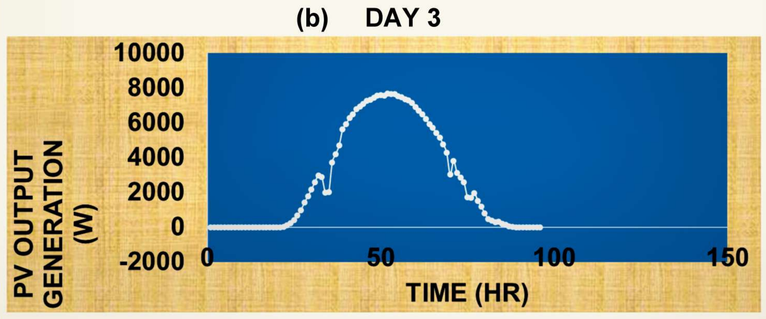
Figure 5 illustrates a 3-D bubble plot of hourly solar radiation of the real system (installed roof-top PV system) versus hourly global solar radiation of the historical data from the Dublin airport. The positive value of the gradient, m (0.0832) indicates that the hourly solar radiation of the real system is in proportion with hourly global solar radiation. The low value of R^2 is due to the decrease in R^2 value of the hourly global solar radiation (as seen in Figure 4).



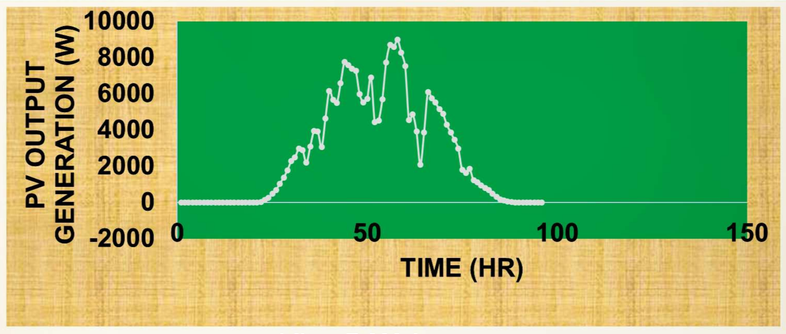
(a) DAY 2



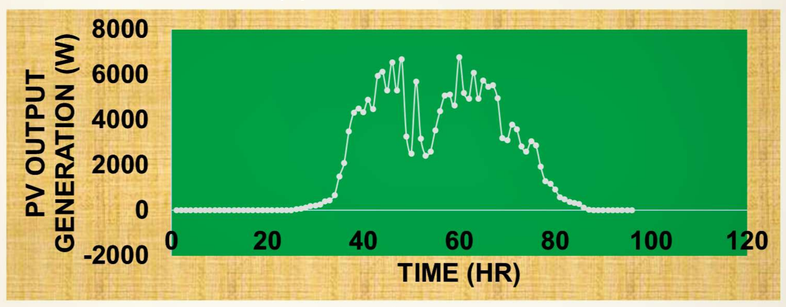
(b) DAY 3



(c) DAY 4



(d) DAY 1



(e) DAY 5

Figure 6: Graphs showing the effect of daily transient performance changes on PV modules output

The PV output generation in Figure 6 (a, b, c) shows a parabolic curve which indicates a clear, sunny day. This parabola intersected at the horizontal (time-axis) during sunrise and sunset and would be maximum around solar noon (NREL, 2009). The PV output generation plots in Figure (d,e) contains distortions that have changed them from their perfect parabolic shapes. These distortions or changes are known as **Transients in solar irradiance** and these are caused by over-passing clouds that shade the area of the surface when travelling in front of the sun. Such transients in PV output generation correspond to random solar irradiance increments and reductions throughout the day (NREL, 2009).

Conclusion

The effect of transient performance changes were verified from the distorted peaks of the PV output generation, variations in hourly efficiencies (when plotted against Day and Hourly Solar Radiation), distinctions in R^2 values, reductions in hourly PRs for the installed PV array at Grangegorman (real system) and hourly global radiation of the Dublin Airport obtained from the online historical data using the values from their negative gradients. positive gradient value obtained when hourly solar radiation of real system is plotted against hourly global radiation of Dublin Airport.

Also, more comparison was drawn from the positive gradient value obtained when hourly solar radiation of real system is plotted against hourly global radiation of Dublin Airport. The low value of R^2 is due to the decrease in R^2 value of the hourly global solar radiation. It was noticed that hourly solar radiation values of the real system reduces more readily than the hourly global solar radiation values as being distinguished with the values of their gradients. This is because there are more meteorological checks at the airport which prevents obstruction or shading of all kinds and therefore making such location more better for solar PV panels installations.

Therefore, the PV performance variations were analysed as seen in all the plots.

Acknowledgements

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