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A preliminary study of the degradation of large-scale c-Si photovoltaic system under four years of operation in semi-arid climates

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ABSTRACT

We report the preliminary results of the degradation study of large-scale photovoltaic (PV) system installed using 1006.74 kWp crystalline silicon (c-Si) PV array. A linear least square (LLS) fitting method is adopted, and the degradation rate (DR) is calculated for the four years based on monitored operational data in semi-arid climates of India.

Introduction

In the current PV market, most widely used modules are crystalline silicon based due to their higher efficiencies and stability factors. But the question of reliability and life time are the crucial issues as they will be operating under different climatic conditions [1–3]. Even though the c-Si modules are widely accepted, the behavior under real time operating conditions typically when exposed to outdoors is still not fully understood especially for the Indian weather conditions. Hence, this article aims to provide a degradation preliminary assessment based on monitored data for understanding the behaviour of c-Si based PV plant under four year outdoor exposure.

Methods

The DR (%/year) of the c-Si based 1006.74 kWp PV system is evaluated by means of an LLS fitting method of the performance ratio by using \( DR = \frac{100 \times (a/b)}{a} \). Here, ‘a’ is the slope of the line and ‘b’ is the intercept of the trend line obtained for monitored energies in \( Y = a \times X + b \) equation [4–8].

Results and discussion

The 1006.74 kWp c-Si PV power plant is shown in Fig. 1. Fig. 2 depicts the monthly performance ratio (PR) during four years of operation under semi-arid climates of India (site details Latitude: 16.3°N, and Longitude: 77.6°E) [9]. The PR annual averages observed are 76.46%, 75.73%, 74.98% and 71.37% for 2012, 2013, 2014, and 2015 respectively. For each year the corresponding trend lines are estimated and identified using the LLS fitting method, see Fig. 3.

Table 1 summarizes the evaluated DR of the 1006.74 kWp c-Si PV system for the period of assessment. A negative degradation rate denotes a lowering of the performance beginning from the third year (−0.30%). Keeping this in view, maintenance is done in finding out the reason for it and enough measures are taken to limit this by introducing water cooling of PV, regular checks related to dust cleaning etc. Indeed
a degradation of −0.17% is observed for the fourth year, quite low compared to the previous years, demonstrating the maintenance actions effectiveness. DR results of this study are within the comparable range of National Renewable Energy Laboratory consolidated study of all the previous studies conducted in different climate regions on global level [10].

Conclusion

The article reported the degradation rates of large scale c-Si PV array under semi-arid climates of India. For each year under the monitored period performance ratio and corresponding DR is evaluated. The reported DRs for the PV plant are in the range of −0.30% to −0.17% starting from the third year of its operating and they are within the range as per the previous studies conducted in different areas.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.rinp.2019.01.032.

References


Table 1

Degradation rate for each year of operational data.

<table>
<thead>
<tr>
<th>Year</th>
<th>Regression Equation</th>
<th>a</th>
<th>b</th>
<th>DR</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012</td>
<td>Y = 1.11 X + 75.73</td>
<td>1.11</td>
<td>75.73</td>
<td>0.18</td>
<td>First financial year (FY) of the plant</td>
</tr>
<tr>
<td>2013</td>
<td>Y = 2.35 X + 76.46</td>
<td>2.35</td>
<td>76.46</td>
<td>0.37</td>
<td>Second FY without issues in operation</td>
</tr>
<tr>
<td>2014</td>
<td>Y = −1.89 X + 74.98</td>
<td>−1.89</td>
<td>74.98</td>
<td>−0.30</td>
<td>Third FY with few additional issues</td>
</tr>
<tr>
<td>2015</td>
<td>Y = −1.00 X + 71.37</td>
<td>−1.00</td>
<td>71.37</td>
<td>−0.17</td>
<td>Fourth FY after enough maintenance</td>
</tr>
</tbody>
</table>

Fig. 2. Performance ratio for 1006.74 kWp c-Si PV array for a period of 4 years in semi-arid climates.

Fig. 3. LLS method applied to each year operational data.

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