CHAPTER – 6

Study of 50 kWp Rooftop PV Systems:
A Case Study
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6.1 Introduction:

The solar cell technologies based on Si-wafer are generally referred as the first generation technologies while the cell technologies based on thin film are referred as the second generation technologies. The primary objective of development of thin film technologies is to reduce the cost of PV Modules. In this work Cd-Te thin film solar cell will be fabricated with the cheapest technique to get efficient and low cost solar cell.

The state of Odisha receives an average solar insolation of about 5.5 kW per sq. meter. At this rate the average capacity utilization factor is expected to be about 19%. Keeping this in view the State offers a levelized tariff of Rs 17.80 per kWh over a period of 25 years. Again the solar cell technologies can be categorised to Si- Wafer solar cell and heterojunction solar cell (thin film solar cell)[75].

6.2 Solar Power Plant:

The main objective is to study the generated voltage and power in roof top Solar PV station of 50KWp and to connect the load requirements in KIIT Campus. Figure 6.1, represents a rooftop Solar PV station of 50KWp at KIIT Campus, Bhubaneswar.

Figure 6.1: 50kWp roof top PV system of KIIT
6.3 Block Diagram of Grid Integrated Solar Power Plant:
The basic components of grid integrated solar power plant are as follows: PV arrays, Inverter, Transformer, Load, Meter, Protective devices, Other devices etc.

![Block Diagram of Grid Connected PV System](image.png)

6.4 Module Specification: HSTBF24230P (Poly Crystalline Solar Module)

![Polycrystalline Solar Module](image.png)

<table>
<thead>
<tr>
<th>Company</th>
<th>HHV Solar PV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type</td>
<td>Standard</td>
</tr>
<tr>
<td>Model No.</td>
<td>HSTBF24230P</td>
</tr>
<tr>
<td>Technology</td>
<td>Polycrystalline</td>
</tr>
<tr>
<td>Maximum Power, $P_p$</td>
<td>230W</td>
</tr>
<tr>
<td>Open Circuit Voltage, $V_{oc}$</td>
<td>36.90V</td>
</tr>
<tr>
<td>Short Circuit Current, $I_{sc}$</td>
<td>8.15A</td>
</tr>
<tr>
<td>Rated Voltage</td>
<td>30.55V</td>
</tr>
<tr>
<td>Rated Current</td>
<td>7.53A</td>
</tr>
<tr>
<td>Maximum System Voltage</td>
<td>1000V</td>
</tr>
<tr>
<td>Output Tolerance</td>
<td>± 3%</td>
</tr>
<tr>
<td>Cell Temperature</td>
<td>25°C</td>
</tr>
<tr>
<td>Dimension of Module</td>
<td>1650mm x 987mm x 42</td>
</tr>
</tbody>
</table>
6.5 PV Array Designing:
Number of PV modules is calculated as per load demand. The no. of inverter, combiner box and other equipments is needed to complete the whole designing. It is required to find the followings.

a) The no of module to be accommodated on both roof top and facade can be calculated by the following formula,
No. of module accommodation = (Total usable area) ÷ (area of a selected PV module).

b) To design the array there are some parameter to check. The most important thing to choose proper inverter and combiner box. So that, they can withstand the PV modules’ voltage and current.

6.5.1 Calculation:
MPPT voltage range of the Inverter = 425V to 875V
Power rating of inverter = 50kW
Inverter rated voltage = 900V
So maximum current in the inverter = 50,000/900 = 5505b Amp
Open circuit voltage of the Module = 36V
There are 20 modules in series. So open circuit voltage of the series combination = 36.0 × 20 = 720V.
As 720V is within MPPT voltage range of the inverter, So Maximum voltage of the Module = 30.55 V
Inverter MPPT voltage range: 425V-875V
(425V-875V)/ 20= 21.25-43.75 (Maximum power voltage of the Module = 29.60V)
So, maximum power voltage is in the voltage range of the Inverter.
50kW inverter current rating: Inverter rated voltage = 900V
Maximum Current = (50000/900) = 55.55A

6.5.2 Number of inverter calculation
No of inverter = Total no of module/(no. of module in series in a string × no. of parallel string) = 220/(20 × 11) = 1

6.5.3 Number of combiner box
As combiner box is equal to the number of inverter, So, only one combiner box is required.

6.5.4 Plant Capacity
It may be calculated by= No. of modules × Maximum Power = 220 × 230Wp = 50,600Wp
**6.5.5 Power Generation**

It may be calculated by:

Total Calculated Energy = \[
\frac{\text{No. of Modules} \times \text{Max. Power (Wp)} \times \text{Solar irradiance (in kWph/m}^2/\text{day}) \times \text{No. of days}}{1000}.
\]

<table>
<thead>
<tr>
<th>Month</th>
<th>No. of Modules</th>
<th>Max. Power (Wp)</th>
<th>Solar irradiance (in kWph/m$^2$/day)</th>
<th>No. of days</th>
<th>Total Calculated Energy in kWph</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>220</td>
<td>230</td>
<td>4.5</td>
<td>31</td>
<td>7058</td>
</tr>
<tr>
<td>February</td>
<td>220</td>
<td>230</td>
<td>5.2</td>
<td>28</td>
<td>7367</td>
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<td>March</td>
<td>220</td>
<td>230</td>
<td>5.7</td>
<td>31</td>
<td>8941</td>
</tr>
<tr>
<td>April</td>
<td>220</td>
<td>230</td>
<td>6.2</td>
<td>30</td>
<td>9411</td>
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<td>May</td>
<td>220</td>
<td>230</td>
<td>6.1</td>
<td>31</td>
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<td>June</td>
<td>220</td>
<td>230</td>
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<td>30</td>
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<td>July</td>
<td>220</td>
<td>230</td>
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<td>31</td>
<td>6054</td>
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<td>August</td>
<td>220</td>
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<td>3.7</td>
<td>31</td>
<td>5803</td>
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<td>220</td>
<td>230</td>
<td>4.09</td>
<td>30</td>
<td>6208</td>
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<td>220</td>
<td>230</td>
<td>4.5</td>
<td>31</td>
<td>7058</td>
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<td>220</td>
<td>230</td>
<td>4.4</td>
<td>30</td>
<td>6679</td>
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<td>December</td>
<td>220</td>
<td>230</td>
<td>4.6</td>
<td>31</td>
<td>7215</td>
</tr>
</tbody>
</table>

**Total Power generated**

80946 kWph

**6.5.6 Extra Power Generated**

Extra power generated is the difference between total power generated and field power or power consumed.

\[
\text{Extra Power Generated} = (80946 - 4890) \text{ kWph} = 76056 \text{ kWph}
\]

\[
\% \text{ power generated} = \left(\frac{\text{Extra Power Generated}}{\text{Total power generated}}\right) \times 100
\]

\[
= \left(\frac{76056}{80946}\right) \times 100 = 93.9\%
\]

The total extra power generated is about 93.9%. The reason behind this is the losses occurred in the system. The loss may be occurred due to dust on the module or copper loss/wire loss or shading or increase in temperature or change in intensity etc.
6.5.7. Experimental result

An experiment was done at KIIT campus by considering one PV module from the 50kWp plant. The experiment was done by considering difference irradiance level.

The I-V (current-voltage) curve of a PV string (or module) describes its energy conversion capability at the existing conditions of irradiance (light level) and temperature. Conceptually, the curve represents the combinations of current and voltage at which the string could be operated or ‘loaded’, if the irradiance and cell temperature could be held constant. Figure 6.4 and figure 6.5 shows the I-V characteristics and PV characteristics in different irradiance level. The fill factor is approximately 0.75 which is use in the calculation above. The maximum power obtained from the solar cells varies between 29V to 30V when solar irradiation changes from 600 W/m² to 1200W/m².

![I-V Curve](image)

Figure 6.4: I-V Characteristics of solar module installed at KIIT

![P-V Curve](image)

Figure 6.5: P-V Characteristics of solar module installed at KIIT
6.6. Rooftop Power generation:

The load curve for Rooftop power generation from the different Inverter for the month of January is given below. The inverters are placed in different hostel buildings, academic building, vocational building etc.. The figure shows from 6.6 to 6.14, that the output from each inverter with respect to solar generation for the load connected to it.

Figure 6.6 shows a no load on 13\textsuperscript{th} January and maximum load of 95kWh occurs on 24\textsuperscript{th} January in Hostel 1.

![Figure 6.6: Power generation for the Month of January from the inverter Hostel-1](image)

Figure 6.7 shows a minimum load of 42kWh on 15\textsuperscript{th} January and maximum load of 95kWh occurs on 24\textsuperscript{th} January in Hostel 2.

![Figure 6.7: Power generation for the Month of January from the inverter Hostel-2](image)
Figure 6.8 shows a minimum load of 35kWh on 15\textsuperscript{th} January and maximum load of 82kWh occurs on 24\textsuperscript{th} January in Hostel 3.

![Figure 6.8](image)

Figure 6.8: Power generation for the Month of January from the inverter Hostel-3

Figure 6.9 shows a minimum load of 27kWh on 20\textsuperscript{th} January and maximum load of 71kWh occurs on 12\textsuperscript{th} January in Hostel 4.

![Figure 6.9](image)

Figure 6.9: Power generation for the Month of January from the inverter Hostel-4

Figure 6.10 shows a minimum load of 29kWh on 15\textsuperscript{th} January and maximum load of 78kWh occurs on 23\textsuperscript{th} January in Dining Hall 1.

![Figure 6.10](image)
Figure 6.10: Power generation for the Month of January from the inverter: Dining Hall-1

Figure 6.11 shows a minimum load of 30kWh on 15\textsuperscript{th} January and maximum load of 73kWh occurs on 24\textsuperscript{th} January in Dining Hall 2.

Figure 6.11: Power generation for the Month of January from the inverter: Dining Hall-2

Figure 6.12 shows a minimum load of 35kWh on 15\textsuperscript{th} January and maximum load of 78kWh occurs on 16\textsuperscript{th} January in Vocational Building.
Figure 6.12: Power generation for the Month of January from the inverter: Vocational Building

Figure 6.13 shows a minimum load of 14kWh on 27th January and maximum load of 73kWh occurs on 12th January in Academic Building.

Figure 6.13: Power generation for the Month of January from the inverter: Academic Building

Figure 6.14 shows a minimum load of 12kWh on 27th January and maximum load of 69kWh occurs on 12th January in Academic Building 1.
6.7 **Summary:**

In this chapter, different characteristics of output current (I) vs voltage (V) and output power (P) vs voltage (V) of the module (230Wp) installed at 50 kWp Solar PV Station at KIIT campus has been drawn to realize the energy conversion capability of the module in the existing conditions of the module. Again, a study on 50kWp solar PV station at KIIT campus has been made incorporating the output voltage of inverter annually. From the case study at KIIT Campus it was found that Solar PV station not only gives supply to campus but also it connects with the online grid. It was concluded that there has been most significant role of solar PV system in India by connecting utility grid in which more amount of energy can be generated and consumed.