2 STRINGS OF 13 YL250P-29b PANELS

PAPUA NEW GUINEA - OFFGRID SYSTEM

<table>
<thead>
<tr>
<th>PANEL SPECS.</th>
<th>BATTERY BOX</th>
<th>BATTERY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pmax 250W</td>
<td>LENGTH 1400mm</td>
<td>1000AH</td>
</tr>
<tr>
<td>Impp 8.39A</td>
<td>DEPTH 850mm</td>
<td>48V</td>
</tr>
<tr>
<td>Vmpp 29.8V</td>
<td>WIDTH 950mm</td>
<td></td>
</tr>
<tr>
<td>DIM-1640mm X 990mm</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

BATTERY BOX
### System Design & Engineering Calculations

#### Circuit 1

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Load in Watts</td>
<td>1339</td>
<td>Watts</td>
</tr>
<tr>
<td>Days of Autonomy</td>
<td>3</td>
<td>Days</td>
</tr>
<tr>
<td>System Voltage</td>
<td>24</td>
<td>Vdc</td>
</tr>
</tbody>
</table>

#### Solar Module Specs

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Power</td>
<td>250</td>
<td>Watts</td>
</tr>
<tr>
<td>Maximum Voltage</td>
<td>29.8</td>
<td>Volts</td>
</tr>
<tr>
<td>Maximum Current</td>
<td>8.39</td>
<td>Amps</td>
</tr>
<tr>
<td>Open Circuit Voltage</td>
<td>37.6</td>
<td>Volts</td>
</tr>
<tr>
<td>Short Circuit Current</td>
<td>8.92</td>
<td>Amps</td>
</tr>
<tr>
<td>Temperature Coefficient of $P_{\text{max}}$</td>
<td>-0.42</td>
<td>%/°C</td>
</tr>
<tr>
<td>Temperature Coefficient of $V_{\text{oc}}$</td>
<td>-0.32</td>
<td>%/°C</td>
</tr>
<tr>
<td>Temperature Coefficient of $I_{\text{sc}}$</td>
<td>0.05</td>
<td>%/°C</td>
</tr>
<tr>
<td>Power Tolerance $f_{\text{man}}$</td>
<td>-0/+5</td>
<td>W</td>
</tr>
</tbody>
</table>

#### Environment Conditions & Losses

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>De-rating factor for direct $f_{\text{dirt}}$</td>
<td>2</td>
<td>%</td>
</tr>
<tr>
<td>Peak Sun Hours</td>
<td>4.53</td>
<td>Hrs/day</td>
</tr>
<tr>
<td>Design Maximum Ambient Temperature</td>
<td>30</td>
<td>°C</td>
</tr>
<tr>
<td>Design Minimum Ambient Temperature</td>
<td>17</td>
<td>°C</td>
</tr>
<tr>
<td>Site Maximum Ambient Temperature</td>
<td>30</td>
<td>°C</td>
</tr>
</tbody>
</table>
The Temperature derating factor is determined as follows:

\[ f_{\text{temp}} = 1 - [\gamma \times (T_{\text{cell,eff}} - T_{\text{stc}})] \]

- \( f_{\text{temp}} \): Temperature de-rating factor (dimensionless)
- \( T_{\text{cell,eff}} \): Cell temperature at standard test conditions 25°C
- \( T_{\text{stc}} \): Average daily cell temperature in °C
- \( \gamma \): Power temperature coefficient per degree Celsius

\[ T_{\text{cell,eff}} = T_a + 25^\circ C = 28^\circ C + 25^\circ C = 53^\circ C \]

\[ f_{\text{temp}} = 1 - \left[ \frac{0.42}{100} \times (53 - 25) \right] = 0.882 \]

The Temperature derated Output of module is determined as follows:

\[ P_{\text{mod}} = P_{\text{stc}} \times f_{\text{man}} \times f_{\text{temp}} \times f_{\text{dirt}} \]

- \( P_{\text{mod}} \): De-rated Power output of the module in Watts
- \( P_{\text{stc}} \): Rated Module output under Standard Test Conditions (STC)
- \( f_{\text{man}} \): Manufacturing Tolerance (as per manufacturers datasheet)
- \( f_{\text{temp}} \): De-rating factor for temperature (dimensionless)
- \( f_{\text{dirt}} \): De-rating factor for dirt (dimensionless)

\[ P_{\text{mod}} = 250 \times 1.02 \times 0.882 \times 0.98 = 220.41 \text{Watts} \]
To determine the number of modules in the array to meet the daily design energy demand is calculated as follows:

\[
N = \left( \frac{E_{tot} \times f_o}{P_{mod} \times H_{tilt} \times \epsilon_{pvss}} \right)
\]

- \(E_{tot}\): Total Daily design Energy Demand
- \(f_o\): Efficiency of the PV Sub-system (dimensionless)
- \(P_{mod}\): De-rated power output of the module in Watts
- \(H_{tilt}\): Peak Sun Hours for the specified tilt angle
- \(\epsilon_{pvss}\): Oversupply co-efficient (dimensionless) – we have designed the system with 25% oversupply

\[
E_{tot} = (290W \times 2x24Hrs \times 3\text{dys}/7\text{dys}) + (200Wx8\text{Hrs}) + (9Wx16x5\text{Hrs}) + (15Wx24\text{Hrs}x3\text{dys}/7\text{dys}) + (3000\text{Wh})
\]

\[
E_{tot} = 11440\text{ Wh/day}
\]

\[
N = \left( \frac{11440\text{Wh} \times 1.25}{220.41 \times 4.50 \times 0.80} \right) = 18.02\ldots\text{round off to 18 panels}
\]

Since our design is based on MPPT analysis, we will look at an MPPT controller which can handle 18x250Wp=4500Wp

Controller chosen: Controller 1 - 1 x 60A Tri-Star MPPT
Controller 2 - 1 x 60A Tri-Star MPPT
Controller 3 - 1 x 60A Tri-Star MPPT

Array Configuration:

- 6 panels per controller
- 2 strings of 3 panels in series per controller (See schematic attached)

The controllers will have synchronized charging to the battery with a meter Hub.
Battery Calculations

To determine the size of Battery Bank to meet the daily design energy demand is calculated as follows:

\[ C_x = \left( \frac{E_{tot}}{AV_{dc}} \right) \times \left( \frac{T_{aut}}{D.O.D} \right) \]

Battery Bank at 80% depth of discharge and 3 days back up:

\[ C_{10} = \left( \frac{11440}{24} \right) \times (3 / 0.8) = 1787.5 \text{ AH Bank} \]

**System Configuration:**

18 x 250W Panels

1800Ah@24V Battery bank
Cable sizing and Voltage drop calculations

- Length of DC cable $l_{DC\, cable} = 10\, m$
- Maximum power point current of panel $I_{MP} = 8.39\, A$
- Maximum power point voltage of array $V_{Array\, max}$...Refer to calculation below

$$V_{Array\, max} = No.\, of\, panels\, \{V_{mp} - [V_{vmp} \times (T_{min} - T_{STC})]\}$$

$$V_{Array\, max} = 80.025\, V$$

Determining cross sectional area of the array cable

$$A_{DC\, cable} = 2 \times l_{DC\, cable} \times I_{MP} \times \rho / V_{drop} \times V_{Arraymax}$$

$$A_{DC\, cable} = 2 \times 10\, m \times 8.39 \times 0.0183 / 0.01 \times 80.025 \times \ldots \ldots \, (1\%\, voltage\, drop\, assumed)$$

$$A_{DC\, cable} = 3.83\, mm^2 \ldots \ldots \, 4\, mm^2\, SD1\, cable\, would\, be\, suitable$$

Determining cross sectional area of Battery charging cable

$$A_{DC\, cable} = 2 \times l_{DC\, cable} \times I_{DC\, bat} \times \rho / V_{drop} \times V_{Batsys}$$

$$A_{DC\, cable} = 2 \times 5\, m \times 60 \times 0.0183 / 0.01 \times 24 \times \ldots \ldots \, (1\%\, voltage\, drop\, assumed)$$

$$A_{DC\, cable} = 45.75 \ldots \ldots \, 50\, mm^2\, PVC\, cable\, would\, be\, suitable$$

Determining cross sectional area Inverter DC cable

$$A_{DC\, cable} = 2 \times l_{DC\, cable} \times I_{DC\, inv} \times \rho / V_{drop} \times V_{Inverterdc}$$

$$A_{DC\, cable} = 2 \times 5\, m \times 105 \times 0.0183 / 0.01 \times 24 \times \ldots \ldots \, (1\%\, voltage\, drop\, assumed)$$

$$A_{DC\, cable} = 80.08\, mm^2 \ldots \ldots \, 80\, mm^2\, PVC\, Battery\, cable\, chosen$$
Inverter Selection calculations

AC Load

\[(16 \times 9W \text{ LED lights}) + (2 \times 290W \text{ Oxy Concentrator}) + (200W \text{ desktop}) + (1 \times 15W \text{ Oximeter}) + (650kWh/yr) = 1339 \text{ W}\]

The oxygen concentrator will have a surge for very short period of time, so we need to make sure that the inverter chosen can supply that surge for a short period, usually 1 second.

In this case the inverter size chosen is a **2500VA 24V TBS Inverter**. Refer to attached datasheet for specs.

Protection Equipment Sizing

DC breakers:

PV breaker sizing

Rated PV breaker Voltage

\[V_{OC \text{ array max}} = \text{No. of panels} \times \left( V_{OC} - [V_{OC}(T_{min} - T_{STC})]\right)\]

\[V_{OC \text{ array max}} = 3 \times \left( 37.6 - \left[ \frac{0.32}{100} \times 37.6(50 - 25) \right] \right) = 104.96V\]

\[V_{PV \text{ Breaker}} = 103.78V \ldots \text{Approx 125Vdc rated PV Breaker}\]

Rated PV Breaker Current

\[I_{PV \text{ Breaker}} = 1.25 \times I_{sc \text{ array}}\]

\[I_{isolator} = 1.25 \times 8.92A\]

\[I_{isolator} = 11.15 \ldots \text{Approx 16A rated PV breaker required}\]

Battery Charging Breaker

Rated voltage to be 24Vdc as per battery bank voltage

Rated current= 1.25% x Rated controller current= 1.25% x 60A= **75A** Breaker

Inverter DC Side Breaker

For a 2500VA 24V TBS Inverter:
Inverter surge power/system voltage = 5500W/24V = 229.17A...**250A HRC Fuse**

**Inverter AC Side Breaker**

Inverter AC surge power/AC system voltage = 5500W/240 = 22.9.....**32A Main Switch**

**Yearly Average Energy Yeild**

Overall system efficiency

\[
 f_{\text{system}} = f_{\text{inv}} \times f_{\text{voltdropACDC}} \times f_{\text{dirt}} \times f_{\text{temp}} \times f_{\text{man toil}}
\]

\[
 = 0.93 \times 0.98 \times 0.98 \times 0.91 \times 1
\]

\[
 = 0.812......81.2\%
\]

Expected yearly output of the system

\[
 E_{\text{avg}} = \text{No. of panels} \times P_{\text{mod. rated}} \times \text{peak sun hours} \times 366 \text{ days} \times f_{\text{system}}
\]

\[
 = 18 \times 220.41W \times 4.53 \times 365 \times 0.812
\]

\[
 = 5.33 \text{ MWh/year}
\]
Solar panel configuration at Keripia Health Centre, Western Highlands Province, PNG