SOLA9001-Photovoltaics

Stand-alone Power System Design

Otway, Victoria
Project Type: Commercial

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1. Executive Summary

The project aims to design and develop a reliable and cost-effective off-grid solar power system for a Tourist Lodge located at Cape Otway, Victoria (-38.83°S,143.512°E) as shown in Figure1. The design to achieve this goal starts with assessing the AC and DC Load requirement and usage in Winter and Summer Months respectively. The standalone PV system is designed under the Australian Standard AS/NZS4509.

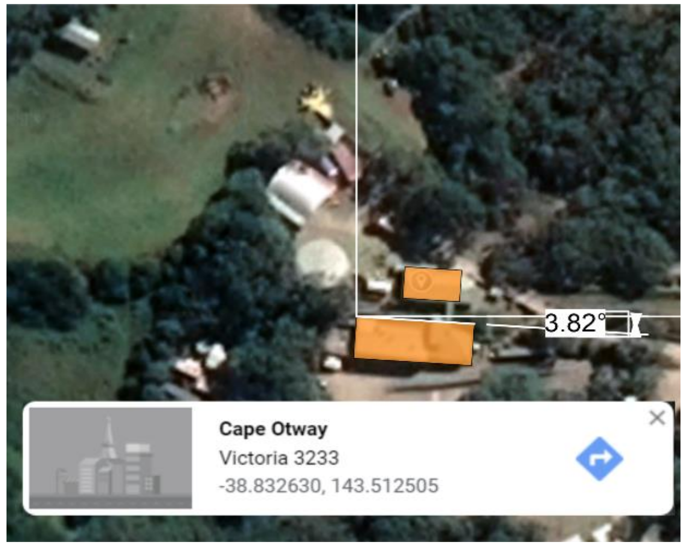


Figure 1: Location of the site

The Design considerations of the Project include:

- Effective and efficient Solar Power Generation through optimized panel orientation and installation.
- Maintaining a Reliable Power supply to the building across the year.
- Complying with local standard norms in Design and Wiring.
- Ensuring a lower Levelized Cost of Energy across the lifetime of the standalone system installation.

The overall nameplate details of the Standalone photovoltaic system are given in Table 1.1.

Project Type		Commercial
Average Daily Load		38621.25 Wh
System Voltage		48V
Days of Taxonomy		4 Days
Battery		Greensun 200Ah 48V LiFePo4
PV Module		Trina Solar TSM-510DE18M
Inverter		Growatt SPF8KTHVM
DC/DC Converter		Helios Power DCW100-24FT-P9200 Helios Power DCW500-48-12FT

Table 1.1 Nameplate Details of the system

The Standalone Power system is designed as an AC Coupled System as shown in Figure 1.2. The AC Coupled System is designed such that the complexity of connections and the conversion losses are minimal.

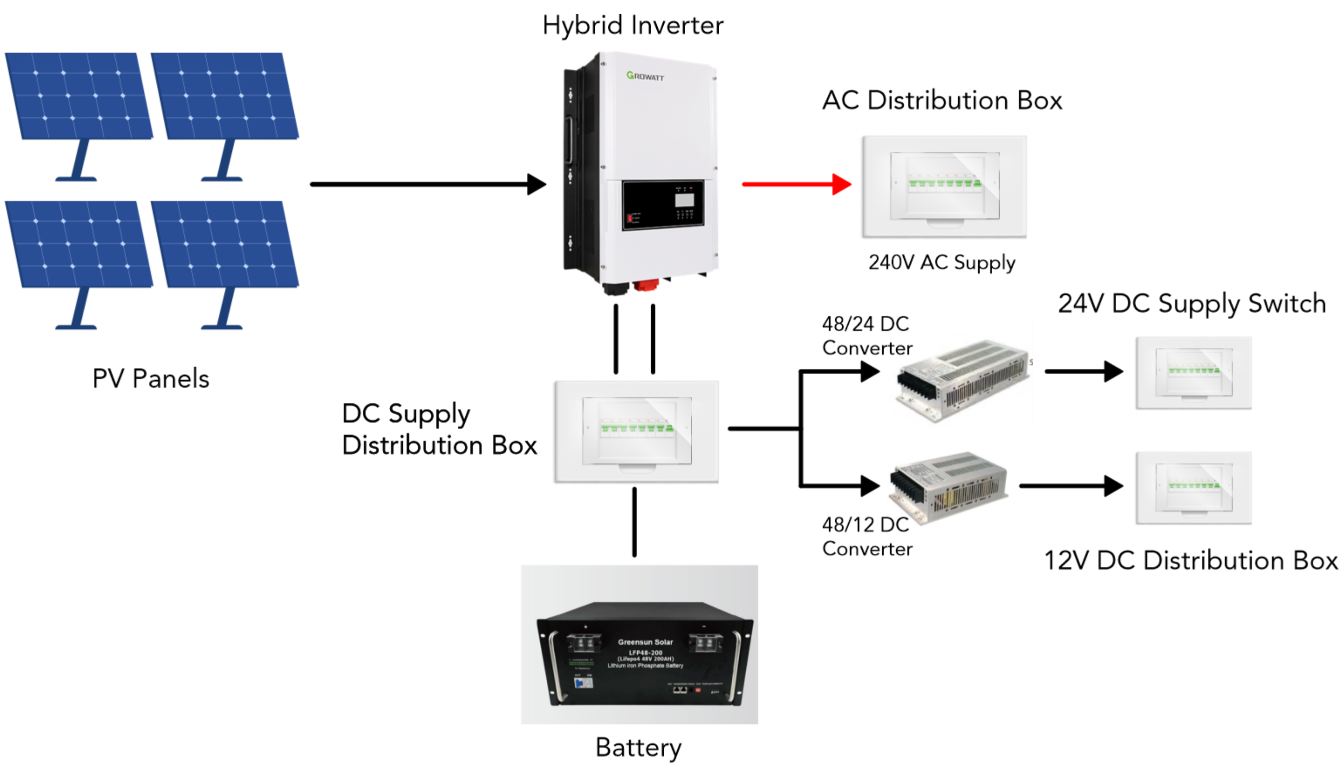


Figure 1.1 Block Diagram of AC Coupled Standalone Power System

2. Load Assessment

Electric Load Assessment is a fundamental part of energy management. The Load Assessment is performed for DC and AC systems based on the requirement stated as shown in Table 2.1 and Table 2.2. The Energy assessments are performed for Winter/Dry Months (Apr, May, Jun, Jul, Aug, Sep) shown by A1 and A4 and for Summer/Wet Months (Oct, Nov, Dec, Jan, Feb, Mar) shown by A2 and A5 from Table 1.1 and Table 1.2 respectively, to understand the energy demand of the system across the year. The DC and AC loads are chosen with high energy efficiency ratings to reduce the overall effective load in the system.

DC Load Assessment									
Appliance	Quantity	Rated Capacity		Winter or Dry Season		Summer or Wet Season		Contribution to max Demand	Comments
		Power	Voltage	Usage (hrs)	Energy (Wh)	Usage (hrs)	Energy (Wh)		
Indoor Lights	40	15	12	7	4200	7	4200	600	Switched ON for 7 hours/day
Outdoor Lights	10	15	12	24	3600	24	3600	150	Switched ON throughout the day
Modem	1	20	12	24	480	24	480	20	Switched ON throughout the day
Wifi Booster	20	5	12	24	2400	24	2400	100	Switched ON throughout the day
Laptop	2	45	24	14	1260	14	1260	90	Switched ON for 14hours/day
Daily Load Energy d.c. loads (Wh)				**A1**	**11940**	**A2**	**11940**		
Maximum d.c. demand (W)							**A3**	**960**	

Figure 2. 1 DC Load Assessment

AC Load Assessment													
Appliance	Quantity	Rated Capacity		Winter or Dry Season		Summer or Wet Season		Power Factor	Contribution to max Demand	Max Simultaneous Load*	Surge Factor	Potential VA	Design VA
		Power	Voltage	Usage (hrs)	Energy (Wh)	Usage (hrs)	Energy (Wh)						
Refrigerator	1	160	240	24	1000	24	1000	0.6	267	1	7	1866.7	1867.0
Electric Kettle	1	1500	240	1.5	2250	1.5	2250	1	1500	1	1	1500.0	1500.0
Microwave	1	2000	240	1	2000	1	2000	0.8	2500	1	1	2500.0	2500.0
Vacuum Cleaner	1	1500	240	1	1500	1	1500	0.8	1875	1	3	5625.0	5625.0
TV	21	60	240	0.75	945	0.75	945	0.8	1575	7	1	525.0	525.0
Bar Fridge	21	80	240	24	13650	24	13650	0.6	2800	7	7	6533.3	6534.0
Daily Load Energy				**A4**	**21345**	**A5**	**21345**						
Maximum AC. demand (W)								**A6**	**10517**				
Surge Demand											**A7**	**18550.0**	**18551.0**

Figure 2. 2 AC Load Assessment

With the load Assessment performed for DC and AC Loads, the Contribution to max demand for AC and DC loads is represented by A3 and A6 from Table 1.1 and Table 1.2 respectively, which is then used to calculate the power contribution of loads to maximum demand in the circuit. The surge power of AC loads is determined by using the surge factor [1] , and is calculated as shown in A7 from Table 1.2; this is caused due to the initial surge current of the inductive motors in AC appliances.

The above calculations can be found in the **T1 Load Analysis**

3. Battery Sizing and Selection

Battery Management plays a key role in an off-grid power system. The Daily Average Load and the Daily Ampere Hour calculated are shown in Table .1. Based on the Average Daily load, the DC system voltage is set to 48V (Rule of thumb). Hence the Daily Ampere Hour requirement of the system is calculated as shown in B2. The calculated data of the required battery capacity could be used to size our battery.

Battery Sizing				
			Winter	Summer
Daily Load Energy	Wh	DC	11940	11940
	Wh	AC	21345	21345
Maximum Demand	W	DC	960	
	W	AC	10516.67	
Average Daily Load	Wh		36195.68	36195.68
Daily Amphere Hour	Ah		754.08	754.08
Average Load Current	A		31.42	31.42
Max Demand Current	A		239.10	
Surge Demand Current	A		386.46	

Figure 3. 1 Daily Average Load and Required Battery Capacity

Required System Parameters		
System Voltage:	**V**	**48**
Inverter Efficiency:		**0.88**
Days of Autonomy:	**Days**	**4**
DoD:	**%**	**0.8**

Figure 3. 2 System Parameters

The Daily Ampere Hour value from B2 is used to size the battery. The average load current in Ampere is used to calculate the peak array current (to size the solar panel array) as shown in B3, to maintain battery SoC above the Battery Depth of Discharge.

Make:		**Voltx**	**Giant Power**	**Giant**	**Greensun**
Type		LiFePO4	Carbon Lead	LiFePO4	**LiFePO4**
Voltage:	V	24	2	12	**48**
Rated Capacity:	Ah	100	480	170	**200**
Nominal Voltage:	V	25.6	1.75	12	**48**
Max Charge Current:	A	100	120	100	**100**
Discharge Current		100	120	100	**100**
Max Discharge Current (5s):	A	200	1000	200	**250**
Life Cycle		2000	2600	5000	**6000**
Dod	%	0.8	0.6	1	**0.8**
Required Battery	Ah	3770.38	5027.18	3016.31	**3771**
No.of Battery Needed	n	38	11	18	**19**
No. Battery in Series	n	2	24	4	**1**
No. Battery in Parallel	n	38	11	18	**19**
Total number of Batteries	n	76	264	72	**19**
Max Charge Current					
Max Discharge Current	A	3800	1320	1800	**1900**
Max Discharge Current 5s	A	7600	11000	3600	**4750**
Cost/Battery	$/n	849	349	925	**2334.15**
Efficiency		0.95	0.85	0.95	**0.98**
Total Cost for Battery		**$64,524.00**	**$ 92,136.00**	**$66,600.00**	**$44,348.85**
Cost/Ah		**17.1**	**18.3**	**22.1**	**11.8**

Figure 3. 3 Battery Capacity Calculation and Comparison

Battery Capacity is calculated using the days of Autonomy (Figure 3.2) [2] [3] [4] specified under the Australian Standard AS/NZS4509 and the depth of discharge of the chosen battery.

Batteries from a set of manufacturers have been shortlisted and compared (Figure 3.3) to ensure system compatibility and reliability over its functions. The battery charge cycles have been one of the important factors when choosing the battery to ensure longer service life. The required battery capacity is calculated based on the Rated Capacity (Figure 3.3), Days of Autonomy T_{aut} =4 (For a Solar PV System), and battery depth of Discharge (Dod) (Figure 3.3).

A set of battery models were shortlisted in which the required Battery Size and the total number of batteries were calculated as shown in Table 3.2 to choose the most effective battery that could be used in the system. Based on the cost per Ah stored, the life cycle of the battery, and the performance **Greensun 48V 200Ah [5]** battery was chosen. The cost per Ah of storage was relatively lower in the chosen battery as shown in Figure 3.3 and the battery charge cycles were relatively high compared to other batteries. Hence a battery bank with 19 Cells connected in parallel is formed to have an overall capacity of 3771Ah. The overall discharge current and peak discharge current (5s) are within the design requirements.

The above calculations can be found in the **T2 Battery Sizing**

4. Tilt Angle and Orientation of Panel

Month	Direct Normal Insolation (W/m2)	Direct Horizontal Insolation (W/m2)	No.of Days	Average Daily Global Insolation (kWh/m2)	Daily Load (kWh/day)	Insolation/ Load
1	136573	94550	31	7.46	38.62	0.193
2	118137	77786	28	7.00	38.62	0.181
3	106824	71886	31	5.76	38.62	0.149
4	79596	50198	30	4.33	38.62	0.112
5	62930	38837	31	3.28	38.62	0.085
6	57683	32223	30	3.00	38.62	0.078
7	39096	39140	31	2.52	38.62	0.065
8	44360	53474	31	3.16	38.62	0.082
9	52645	69879	30	4.08	38.62	0.106
10	82228	84936	31	5.39	38.62	0.140
11	113913	101738	30	7.19	38.62	0.186
12	130651	98449	31	7.39	38.62	0.191
		Average Daily Insolation		**5.05**		

Figure 4. 1 Average Insolation on a Horizontal Plane across a year

Panel Orientation		
Latitude	°	-38.83
Lowest Output	kWh/m2	2.52
Month		7
Day Number		196
Declination Angle	°	21.51
Altitude Angle	°	30
Tilt Angle	°	60

Figure 4. 2 Optimal Panel Orientation

Based on the given weather data of the location [6], the cumulative Insulation per m square is calculated per month which is then used to calculate the ratio of insulation and Load. It is observed that the insolation to load ratio is minimum in July (2.52kWh/m2) as shown in Figure 4.1. Therefore, the tilt angle of the solar panel is optimized for the month with the least cumulative insolation. The Declination Angle δ and Altitude Angle α are calculated to get the optimal Tilt angle of the panel β=60° Figure 4.2. The azimuth angle of the panel is set based on the orientation of the rooftop from true north as shown in Figure 1.

The above calculations can be found in the **T3 Panel Orientation**

5. Solar Insolation on the Panel

With the calculated Panel Tilt angle and Azimuth angle, the insolation on the panel at the given location and orientation is calculated on an hourly basis. With the given irradiance data of the location, the declination angle, and Hour Angle (HRA) is derived to calculate the Direct Normal Irradiance (DNI) on the solar Panel at the given time. The Diffused Horizontal Irradiance (DHI) is calculated based on the optimum tilt angle derived. The Global Irradiation on the panel is the sum of DNI+DHI. The hourly data is aggregated to day-wise data to size the PV array of our system.

The calculations can be found in **T4 Irradiance**

6. PV Array Sizing

The PV Array sizing is estimated with the help of Peak Array Current which is > 5Times Average Load Current. The aggregated Global Insolation on the Panel is used to calculate the Daily Generated Ah by the photovoltaic system. The State of Charge of the battery is calculated for each day. The PV Array is sized by increasing the peak current, increasing in daily generated Ah. The peak current and tilt angle of the array is varied and fixed when the SoC of the battery is above the Rated Depth of Discharge (DoD). With the peak Array current to be **470A** and a tilt angle of **30°,** the power output of the photovoltaic system maintains the SoC above the rated Dod as shown in Figure 5.1 and Figure 5.2.

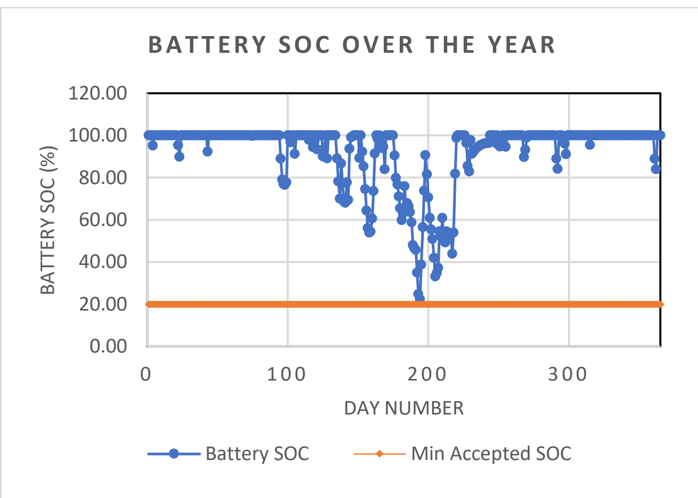


Figure 5.1 Battery SoC over the year

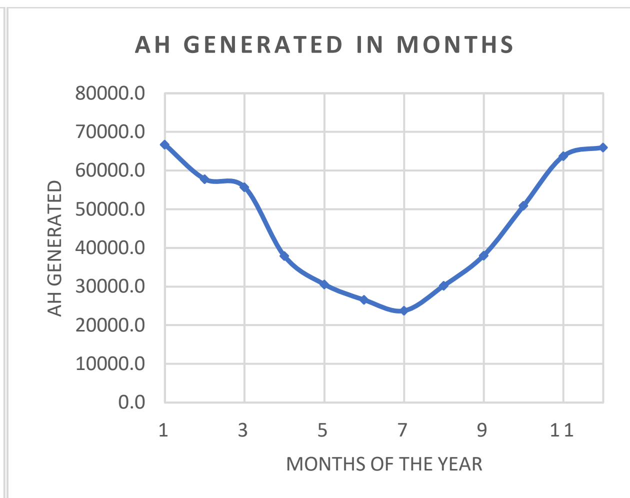


Figure 5.2 AH Generated in Months

With the panel array current, the PV array of the standalone system is scaled. Estimating the number of modules in the PV array is dependent on the type of charge controller used. On considering the performance of PWM and MPPT charge controller over price, the number of modules is calculated. It is observed that to overcome the worst performing months of June and July, the Peak array current is significantly increased to operate the battery above minimum SoC levels.

Taking the financial aspect into consideration, the battery level is optimized to reduce the initial cost and is overcome by increasing the number of PV panels (Peak Array Current).

The calculations can be found in **T5 SOC**

7. Photovoltaic Panel Selection

Temperature Derated Values of Module		
Minimum Temperature on Solar Cell	°C	4.9
Maximum Temperature on Solar Cell	°C	63.5
Maximum Power @Tcell (min)	W	481.90
Minimum Power @Tcell (max)	W	392.02
Minimum Isc @ Tmin	A	12.32
Maximum Isc @Tmax	A	12.61
Minimum Voc @ Tmax	V	47.09
Maximum Voc @Tmin	V	54.72
Minimum Vmp @ Tmax	V	37.55
Maximum Vmp @Tmin	V	46.15

Figure 7. 1 Temperature Derated values of TSM510DE18M

Figure 7. 2 Trina Solar TSM510DE18M

The photovoltaic panels have evolved to produce increased output. Looking on to the cost-effective panel in terms of performance in the longer-term, efficiency, and cost, **TSM-510DE18M [7]** offered the lowest cost/W of **$0.65/W** with a comparatively higher panel efficiency. Also considering the ambient temperature of the location, the minimum, and maximum temperature is 4.9°C and 38.5°C, and the temperature derating on the panel is minimal (NOCT Coefficient of Pmax=-0.34%/°C, Voc=-0.25%/°C, Isc=-0.04%/°C). The temperature derated values are calculated as shown in Table 7.1 to be used for MPPT controller sizing.

The calculations can be found in **T6 Solar and Inverter Scaling**

8. Hybrid Inverter Scaling and Selection

From the Load Assessment, we could observe that the total average load contributed by AC loads is greater than compared to DC Loads hence an AC Coupled Design is implemented in this standalone PV system. To reduce unnecessary conversion losses, a hybrid inverter is chosen for this standalone power project. A hybrid inverter has the functionality of an MPPT solar charge controller storing excess solar energy in a battery system and an intelligent inverter that converts DC from the battery to AC loads with efficiencies of >98% and >88% respectively.

The first step begins with the scaling of no. of modules in the PV array which is dependent on the Peak Array Current, System Voltage, Module Power, and the efficiencies of inverters and other subsystems. Therefore the number of PV modules is calculated (Figure 8.1).

Considering the scale of the technical requirements of the project with an input PV Array power of (70x510W), **Growatt SPF8 KTHVM** [8] is selected. It caters to the energy needs, is compatible with the battery system voltage, and eases the financial burden on the project by reducing the number of converters to be purchased in its absence. The derated temperature ratings of the PV Module with the details of the MPPT controller on the inverter are used to set the PV array dimension as shown in Table 8.1.

Figure 6. 1 Growatt SPF 8 KTHVM

MPPT Charge Controller and PV Array Matching			Safety Margin
No.of modules	n	70	
Max input Voltage		150	142.5
MPPT Range	V	60	66
	V	145	137.75
Min. number of modules in series		1.89	2
Max. number of modules in series Vmp		2.84	3
Max. number of modules in series Voc		2.48	2
Max. number of modules in parallel		9.52	9
Max number of Modules		14.53	14

Table 6. 2 MPPT Charge Controller and PV Array Matching

The safety margins are calculated for the hybrid inverter to function as an MPPT Charge controller, and the minimum and the maximum number of panels to be connected in series and parallel are calculated as shown in Figure 6.2. As per the calculation, a PV array is designed to have 2Panels in Series to form a string and 7 Parallel Strings as shown in Figure 6. 2. Hence to account for the demand, 5 such strings with Inverters connected in parallel are designed as shown in Figure 6.3.

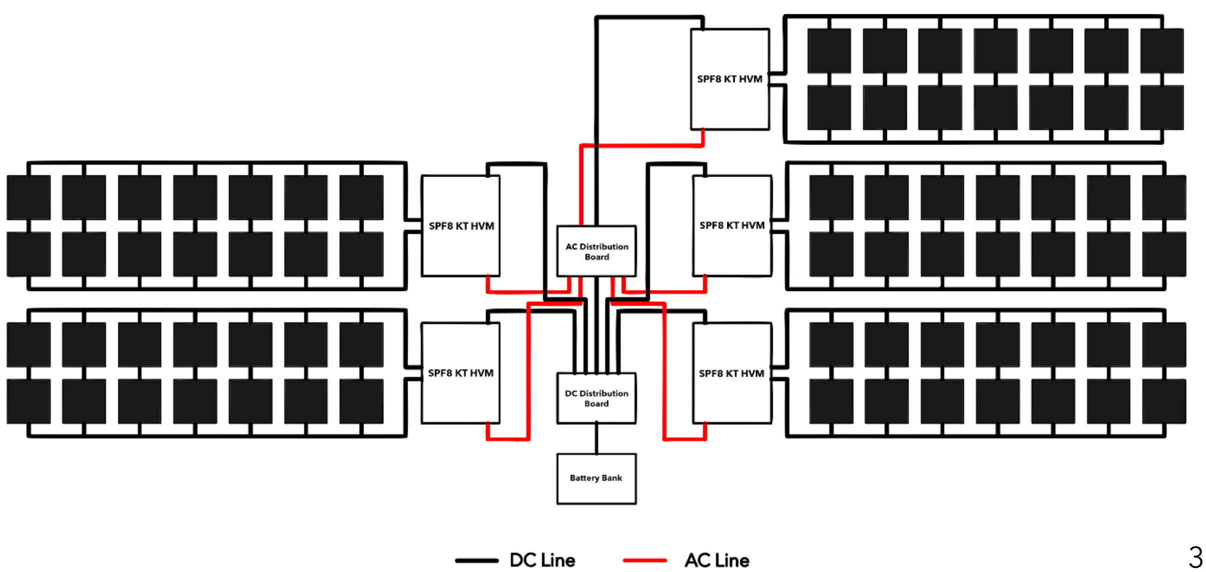


Figure 6. 3 Parallel Connection of Hybrid Inverters

9. DC/DC Converter Design:

Voltage Regulator Design			Selected Model
48/24V Converter	W	90	**DCW100-24FT-P9200**
Normal DC Current	A	1.875	Power:96W
Maximum Required DC Current	A	1.875	Input:20-60V Output:24V
48/12V Converter	W	445	DCW500-48-12FT
Normal DC Current	A	9.271	Power:500W
Maximum Required DC Current	A	18.125	Input:48V Output:12V

Figure 9. 1 DC/DC Regulator Design

As per the DC load requirements Figure 2.1 the around 455W [9] load operates at 12V and a 90W [10] load operates at 24V. To convert the battery voltage to 48V, two sets of DC/DC Buck converters are used to satisfy the requirements. The selection of the same has been shown in Figure 9.1

The calculations can be found in the **T2 Battery Sizing**

10. Safety and Surge Protection Devices

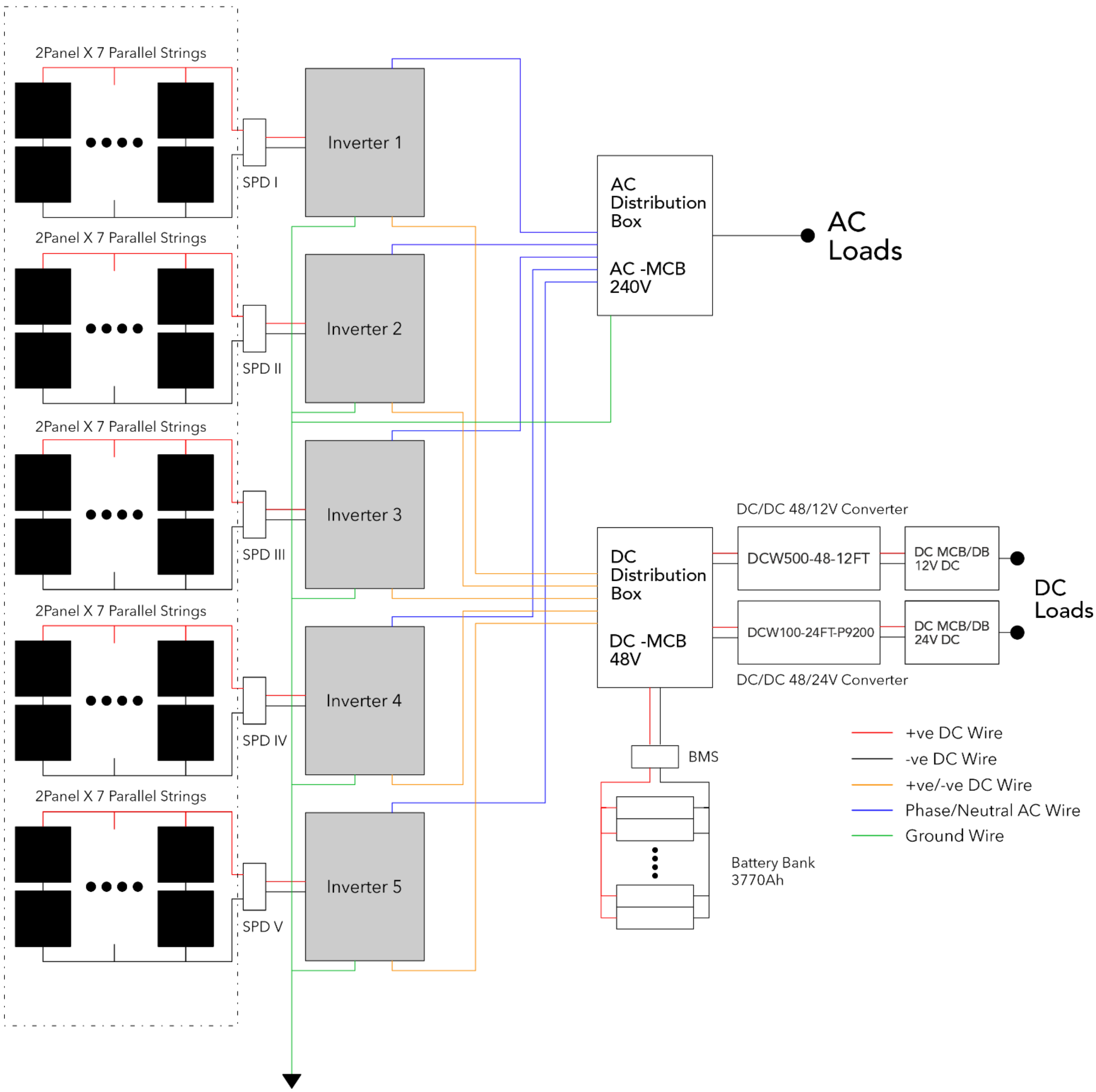
The standalone photovoltaic system is designed as per the safety standards of Australian Standard AS/NZS4509 [13]. The cabling size has been determined based on the usage, voltage, and current profiles. The diameter of the wires has been shown in Figure 10.1

Cabling					
HV DC Wiring	mm	25	**HA AC Wiring**	mm	10
Nominal System Voltage	V	96	Nominal System Voltage	V	96
Max Current in Wire	A	89.00	Max Current in Wire	A	150.00
Voltage Drop in Cable		2.157	Voltage Drop in Cable		6.4
LV DC Wiring	mm	2.5	**LV AC Wiring**	mm	2
Nominal System Voltage	V	24.00	Nominal System Voltage	V	1.50
Max Current in Wire	A	2.00	Max Current in Wire	A	14.00
Voltage Drop in Cable		12.00	Voltage Drop in Cable		0.214285714

Figure 10. 1 Calculation of Wire Diameter

Surge protection devices such as isolators are used between PV Modules and the inverters to avoid a high surge in current due to thunderstorms. AC and DC Miniature Circuit Boards are used in respective Distribution Switch Boxes. Thereby avoiding the overloading effect on inverters. The AC components such as inverters and AC Distribution boxes are earthed/grounded. The battery bank is controlled using a Battery Management System to avoid overcharging of batteries and is used to effectively trickle charge.

Standalone PV System Wiring



11. PV Performance

The overall PV Performance across the year could be determined by calculating the Monthly yield.

Month	No.of Days in month	Average Solar Insolation on Panel	Mean Max Temp	Derated Power	Monthly Yield	Ideal Energy Yield	Capacity per month
		kWh/m2/day	°C	(kWh)	(kWh)	(kWh)	(kWh)
January	31	5.50	17.35	25.55	4359.61	6091.73	26560.8
February	28	5.28	20.59	25.26	3733.10	5276.96	23990.4
March	31	4.46	17.40	25.54	3533.96	4939.01	26560.8
April	30	3.37	15.91	25.68	2593.43	3605.40	25704.0
May	31	2.52	13.69	25.88	2024.47	2792.54	26560.8
June	30	2.26	12.43	26.00	1765.91	2425.18	25704.0
July	31	1.96	11.10	26.12	1586.34	2168.57	26560.8
August	31	2.49	11.90	26.04	2013.38	2759.93	26560.8
September	30	3.24	12.48	25.99	2528.23	3472.71	25704.0
October	31	4.20	13.36	25.91	3371.68	4645.57	26560.8
November	30	5.43	14.78	25.78	4203.65	5820.81	25704.0
December	31	5.45	15.51	25.72	4341.45	6027.17	26560.8
			Average	25.79	3004.60	4168.80	26061.00
				Yearly	**36055.22**	**50025.57**	**312732.00**

Figure 11. 1 PV Performance across the year

The aggregated Monthly yield is the product of the average solar insolation of panel (kWh) with the Size of the PV Array (kWH) and the derated Power (kWh). This data provides us with the actual production of energy from the panels including the derated conditions that include the mismatch effect, soiling loss (5%) [11], system efficiencies, and effect of cell temperature. A summation of the monthly yield would provide us with the yearly yield of the PV system. The Ideal Energy yield is the production of energy from PV panels without the consideration of losses and derated Power as shown in Figure 11.1.

Performance Ratio	**0.7207**	
Capacity Factor	**0.12**	
Specific Yield Ratio	**1.01**	kWh/m2

Figure 11. 2 Performance Ratios

The Performance ratio is calculated as the ratio of monthly yield with the Ideal Energy Yield which is 0.7207 as shown in Figure 11.2. The capacity factor is calculated as the ratio of Capacity per month and the Monthly Yield which is 12.1%. The specific yield is the annual energy generated per kWp installed which is 1.01kW/m2.

The above calculations are shown in Figure 11.2. The monthly yield of the Designed PV system across the year is shown in Figure 11.3 and the Ideal Energy yield of the Designed PV system across the year is shown in Figure 11.4

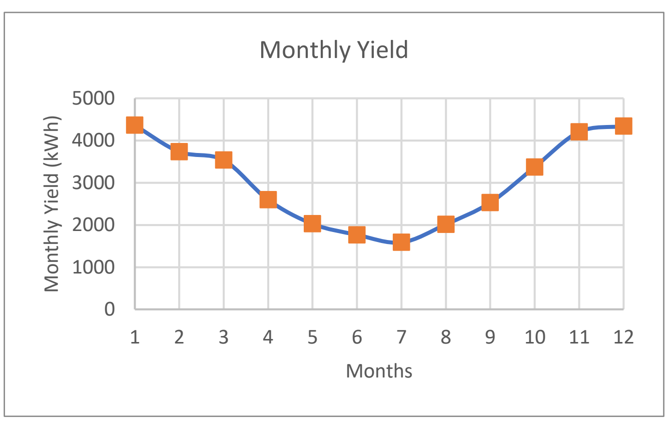


Figure 11. 3 Monthly Yield Across the year

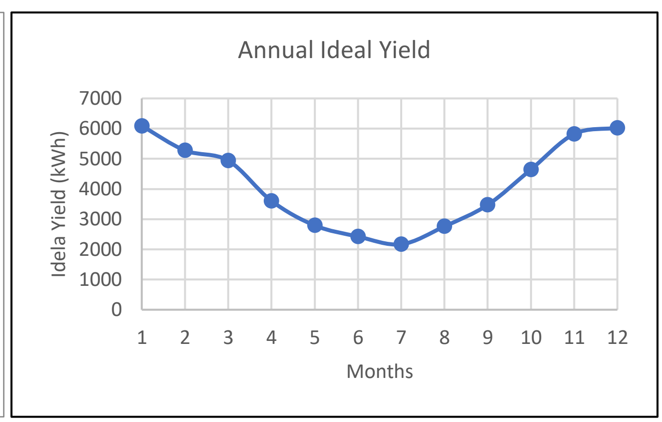


Figure 11. 4 Ideal Energy Yield Across the year

12. PV Cost Estimates

The major parts contributing to the budget of a standalone solar project are the Cost of components and the Installation Cost. The components of the system are carefully selected based on two criteria, Performance/cost (AUD) and the life cycle of the product. Hence the designed system would consist of better-performing components functioning over a larger period. The prices mentioned in Figure 12.1 are referred from online retail. Assuming a slash of 5% price in retail products for dealers, the components are purchased based on the procured rate.

The project is designed to be implemented throughout 21days. This project demands the presence of 1 Senior Solar Installation Technician [E12], 2 Solar Installation Technicians [E13], and 2 Electricians [E14], and the project is governed by a Project Manager. [E15]

Components	Qty	Unit	Actiual Rate	Procured Rate	Amount	Warranty	Design Life
TSM-510DE18M	**42**	**Nos**	**315**	**$ 299.25**	**$ 12,568.50**	25yrs	25yrs
Solar PV Panel							
Aluminium Alloy Frame	**21420**	**A$/W**	**0.085**	**$ 0.085**	**$ 1,820.70**		
Mounting Rack Bracket							
Frame and Kits							
Wiring and Surge Protection Devices					**$ 4,473.42**		-
DC 70mm 110Degree	100	$/m	25.39	$ 24.12	$ 2,412.05		
AC Cables 2.5mm	20	$/m	1.76	$ 1.67	$ 33.44		
SPD-DC Isolators	5	Nos	146	$ 138.70	$ 693.50		
DC MCB	5	Nos	42.44	$ 40.32	$ 201.59		
AC-MCB	2	Nos	42.23	$ 40.12	$ 80.24		
Distribution Boards	4	Nos	277	$ 263.15	$ 1,052.60		
Connectors							
Battery Storage Systems					**$ 47,328.85**		
GreenSolar 200Ah 48V Battery	19	Nos	2725	$ 2,334.15	$ 44,348.85	10yrs	20yrs
Air Conditioning	1	Nos	1560	$ 1,560.00	$ 1,560.00		
Aluminium Battery Racks	1	Nos	1420	$ 1,420.00	$ 1,420.00		
Inverters/Converters					**$ 8,246.79**		
Growatt SPF8KTHVM	3	**Nos**	**2558.61**	$ 2,430.68	$ 7,292.04	10yrs	-
DCW100-24FT-P9200	1	**Nos**	**280**	$ 261.25	$ 261.25		
DCW500-48-12FT	1	**Nos**	**749**	$ 693.50	$ 693.50		
Total Amount					**$ 74,438.26**		

Figure 12. 1 Cost Estimated for Components

The Installation Costs are mentioned in Figure 12.2 and the Cost of work hours is set based on the data provided by Glassdoor at Victoria State. The overall project cost before company margin is estimated to be 93,125.8A$ including the component cost, Installation cost, Site preparation, and cost of Logistics. With a company margin of 20% (19298.85A$), the overall project cost is estimated to be 115,793.11 A$ The calculations for the same are shown in Figure 12.3.

Installation Costs	Personnels	Work Hours	Rate	Amount
Senior Installer Technician	1	32	$ 60.00	$ 1,920.00
Solar Installer Technician	2	58	$ 51.00	$ 5,916.00
Electricians	2	80	$ 43.00	$ 6,880.00
Project Manager	1	100	$ 35.00	$ 3,500.00
Total Amount				**$ 18,216.00**

Figure 12. 2 Installation Costs for the Project

Overall Project Cost	Margin	Amount
Components		$ 74,438.26
Installation Cost		$ 18,216.00
Site Preparation and Logistics		$ 3,840.00
Margin	**20%**	**$ 19,298.85**
Total Amount		**$ 1,15,793.11**

Figure 12.3 Overall Cost for the Project

13. PV Economics

The economics of a standalone photovoltaic system is expressed in terms of the payback period and the Levelised Cost of Electricity. With an initial investment of 115,793.11 A$ towards the development of a standalone PV system, the annual savings are calculated to be 3742.60A$ as shown in Figure 13.1. Considering the annual maintenance cost of 1350A$ per annum the simple payback period of the PV system is estimated around 61.3 years as shown in Figure 13.2.

Annual Savings	Load (kWh)	Rate	Amount
Usage Savings		$/KWh	
Daily Average Load	36.196	0.245	$ 8.87
Annual Load	13220.00	0.245	$ 3,238.90
Annual Supply Savings		**$ 1.38**	**$ 503.70**
Total Savings			**$ 3,742.60**

Figure 13. 1 Annual Savings

PV Economics	Investment
Overall Project Cost	**$ 1,15,793.11**
Components	
Installation Cost	
Site Preperation Cost	
Annual Operating Cost	**$ 1,350.00**
PV Panel Cleaning	
Battery Health Check	
Simple Payback Period	61.30

Figure 13.2 Maintenance Cost and Payback Period

On calculating the Levelised Cost of Electricity of the system for a lifetime of 25years, the Maintenance cost and the upgrade costs (Replacement of Components beyond Service Life) is been discounted at a rate of 3.10%/year [12] as per the Local State discounting rate of 2022. The lifetime power generated is been degraded at a rate of 0.8%/year (given). Calculating the overall cost of investment in the lifetime and overall yearly yield in the lifetime, the Levelised Cost of Electricity of the system is calculated as 0.25$/kWh.

In comparing the actual cost of electricity from the grid, the LCOE is closer to that of the grid. In comparison with a scenario of deploying transmission lines to the locality, the initial investment price to set up transmission lines and transformers would drastically increase the relative LCOE hence the designed system is optimized to provide a minimal LSOE compared to that of other sources.

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Appendices

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