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Stand-Alone Solar PV System Design Calculations for Residential Applications

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***Abstract:** Today solar system installations are most common requirement for residential applications, so here it is summarized simple calculations for stand-alone residential applications with suitable examples with help of various capacity (i.e. 1kWp, 3kWp and 5kWp) of solar PV system designs. This paper can be helpful for the various levels of solar field professionals and solar design engineers.*
***Keywords:** Stand-alone, Solar PV module, Battery, Powe conditioning unit, kWh-units.*

I. INTRODUCTION

The most common solar PV systems are,

1) Grid connected solar PV Systems

These are completely different with stand-alone systems; these systems work whenever grid supply presents, then it gives the output supply. If grid fails NO-Output, it does not require battery bank, but grid supply is mandatory.
It is mostly recommended for city and town areas where the grid supply / utility supply is accessible.

2) Battery connected stand-alone Solar PV Systems

These stand-alone systems are more suitable for remote locations and wherever the grid supply is not accessible / not available areas. Battery banks are mandatory for these systems.
So, it is very clear that, for grid connected systems grid supply is the compulsory and for the battery connected (i.e. Stand-alone) systems battery bank is compulsory.

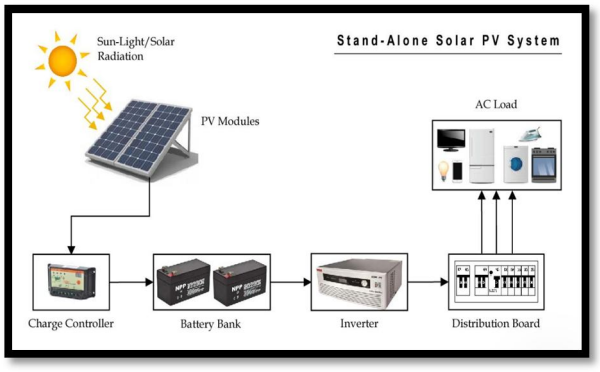

Fig.1: Stand-Alone Solar PV System

In stand-alone systems, sometimes charge controller (it is a charging unit, it charges the battery bank through the Solar PV panels) and inverter (it is a DC supply to AC supply converting system) units are combined into single unit called power conditioning unit (PCU).

II. MAIN EQUIPMENTS OF STAND-ALONE SOLAR PV SYSTEM

For stand-alone systems main equipment are the a) Solar PV Panels b) Battery bank c) Power Conditioning unit, it contains with charge controller and inverter.
All the above equipment is now adays readily available in the market. But its selection of rating / capacity is a challenging task for designers and installers. It is also mandatory to know customers, is the supply agency / company installing the proper rating of equipment or not, to fulfill our required kWh-unis.

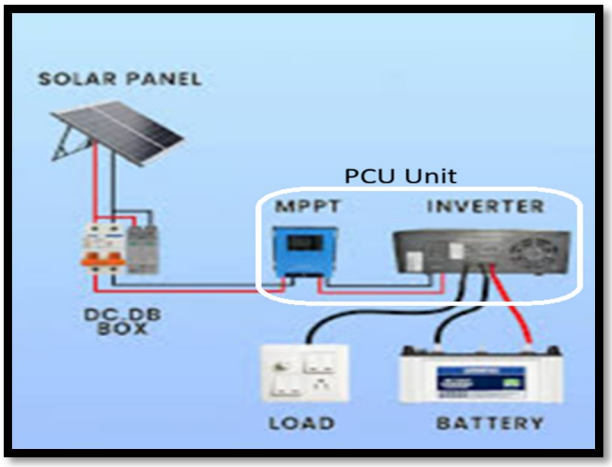

Fig.2: Equipment of stand-alone system

III. DESIGN CALCULATIONS FOR STAND-ALONE SYSTEM

To design a stand-alone battery connected system, there are some common assumptions that are taken into consideration for the various sizes of stand-alone solar PV systems are,

1. Selection of Battery Voltage (i.e. 24 / 48 / 110) V rating.
2. No. of average sunshine hours (i.e. 5.5 Hrs.) per day.
3. No. of units Consumption (i.e. kWh) per day.
4. Battery Capacity (Ah), Extra rating (i.e. 30%) consideration.
5. PV array size (kWp), Extra rating (i.e. 30%) consideration.
6. Inverter Cum Charge Controller / PCU, Extra rating (i.e. 50%) consideration then actual kW load.

A. 1kWp Stand - Alone System Calculations

Sl No	Loads	Watts	Select Quantity (Nos)	Select Usage (Hrs)	Total kilo Watts	kWh/Day (Units)
1	FAN	80	3	11	0.24	2.64
2	LED Lamp1	5	4	8	0.02	0.16
3	LED Lamp2	9	6	5	0.05	0.27
4	LED Lamp3	12	2	1	0.024	0.02
5	LED Lamp4	15	2	1	0.03	0.03
6	BULB	25	2	5	0.05	0.25
7	CFL	16	4	3	0.06	0.19
8	Load-1	500	1	0.5	0.5	0.25
					0.85	3.33

Fig. 3: Load connected for 1kWp PV system

Average Sunshine hours/day = 5.5 Hrs.
Selected Battery capacity = 24 Volts
Above table Total kW load = **0.85 kW**

1) Total No. of Units per day:

= **3.33 kWh.** ---------- (1)

2) Battery Capacity (Ah), calculations with 30% Extra:

= [(kWh per Day x 1000) / (Battery Voltage)] x [1.3].
= [(3.33 x 1000) / (24)] x [1.3]
= [(3330) / (24)] x [1.3]
= [138.75] x [1.3]
= **180.5 Ah** ……..… (2)

Fig. 4: PV Array pic for 1kWp system

3) PV Array size (Wp), calculations with 30% Extra:

= [{(Battery Capacity x Battery Voltage) / (Average Sunshine hrs.)} x 1.3] / [1000].
= [{(180.37 x 24) / (5.5)} x 1.3] / [1000]
= [{(4328.88) / (5.5)} x 1.3] / [1000]
= [{787.07} x 1.3] / [1000]
= [1023.18] / [1000]
= 1.0 kWp ……..……. (3)

4) Inverter Cum Charge Controller / PCU calculations, with 50% extra:

= [Total kW load] x [1.5]
= [0.85] x [1.5]
= 1.3 kVA ……..….. (4)

	Select Bat. Voltage(24/48/110)V	24			
	Avg. Sunshine Hrs / day	5.5			Results
1	No.of Units Consumption/Day		3.3	Kwh (Units)	
2	Battery Capacity(Ah),30% Ext.		180.5	Ah	
3	PV Array size (Wp), 30% Ext.		1.0	kWp*	
4	Inverter Cum Charg Controller / PCU		1.3	kVA	

Fig. 5: Summarized results for 1kWp system

B. 3kWp Stand - Alone System Calculations

Sl No	Loads	Watts	Select Quantity (Nos)	Select Time (Hrs)	Total kilo Watts	kWh/Day (Units)
1	FAN	80	6	7	0.48	3.36
2	LED Lamp1	5	6	8	0.03	0.24
3	LED Lamp2	9	8	5	0.07	0.36
6	BULB	25	4	6	0.1	0.60
7	CFL	16	6	3	0.10	0.29
8	Load-1	200	1	10	0.2	2.00
9	Load-2	100	2	4	0.2	0.80
10	TV	100	1	10	0.1	1.00
11	Load-3	1000	1	1	1	1.00
					2.28	9.65

Fig. 6: Load connected for 3kWp PV system

Average Sunshine hours/day = 5.5 Hrs.
Selected Battery capacity = 48 Volts
Above table Total kW load = **2.28 kW**

1) Total No. of Units per day:
= 9.65 kWh. ---------- (1)

2) Battery Capacity (Ah), calculations with 30% Extra:
= [(kWh per Day x 1000) / (Battery Voltage)] x [1.3].
= [(9.65 x 1000) / (48)] x [1.3]
= [(9650) / (48)] x [1.3]
= [201] x [1.3]
= 261.3 Ah ……..… (2)

3) PV Array size (Wp), calculations with 30% Extra:
= [{(Battery Capacity x Battery Voltage) / (Average Sunshine hrs.)} x 1.3] / [1000].
= [{(261.3 x 48) / (5.5)} x 1.3] / [1000]
= [{(12545) / (5.5)} x 1.3] / [1000]
= [{2281} x 1.3] / [1000]
= [2965] / [1000]
= 3.0 kWp (Approx.) ……. (3)

Fig. 7: PV Array pic for 3kWp system

4) Inverter Cum Charge Controller / PCU calculations, with 50% extra:

= [Total kW load] x [1.5]
= [2.28] x [1.5]
= 3.4 kVA …….. (4)

	Select Bat. Voltage(24/48/110)V	48			
	Avg. Sunshine Hrs / day	5.5			Results
1	No.of Units Consumption/Day		9.65	Kwh (Units)	
2	Battery Capacity(Ah),30% Ext.		261.3	Ah	
3	PV Array size (Wp), 30% Ext.		3.0	kWp*	
4	Inverter Cum Charg Controller / PCU		3.4	kVA	

Fig. 8: Summarized results for 3kWp system

C. 5kWp Stand - Alone System Calculations

Sl No	Loads	Watts	Select Quantity (Nos)	Select Time (Hrs)	Total kilo Watts	kWh/Day (Units)
1	FAN	80	8	6	0.64	3.84
3	LED Lamp2	9	6	7	0.05	0.38
4	LED Lamp3	12	3	5	0.036	0.18
5	LED Lamp4	15	3	4	0.045	0.18
6	BULB	25	5	4	0.125	0.50
7	CFL	16	6	2	0.10	0.19
8	Load-1	200	1	1	0.2	0.20
9	Load-2	100	1	0.5	0.1	0.05
10	TV	100	2	9	0.2	1.80
11	Air Condnr.	1500	1	6	1.5	9.00
					3.00	16.32

Fig. 9: Load connected for 5kWp PV system

Average Sunshine hours/day = 5.5 Hrs.
Selected Battery capacity = 110 Volts
Above table Total kW load = **3.0 kW**

1) Total No. of Units per day:

= 16.32 kWh. ---------- (1)

2) Battery Capacity (Ah), calculations with 30% Extra:

= [(kWh per Day x 1000) / (Battery Voltage)] x [1.3].
= [(16.32 x 1000) / (110)] x [1.3]
= [(16320) / (110)] x [1.3]
= [148.36] x [1.3]
= 192.9 Ah …….. (2)

3) PV Array size (Wp), calculations with 30% Extra:

= [{(Battery Capacity x Battery Voltage) / (Average Sunshine hrs.)} x 1.3] / [1000].
= [{(192.9 x 110) / (5.5)} x 1.3] / [1000]
= [{(21216) / (5.5)} x 1.3] / [1000]
= [{3857} x 1.3] / [1000]
= [5014] / [1000]
= 5.0 kWp ……..…….. (3)

Fig. 10: PV Array pic for 5kWp system

4) Inverter Cum Charge Controller / PCU calculations, with 50% extra:

= [Total kW load] x [1.5]
= [3.0] x [1.5]
= 4.5 kVA ……..….. (4)

	Select Bat. Voltage(24/48/110)V	110			
	Avg. Sunshine Hrs / day	5.5			Results
1	No.of Units Consumption/Day		16.32	Kwh (Units)	
2	Battery Capacity(Ah),30% Ext.		192.9	Ah	
3	PV Array size (Wp), 30% Ext.		5.0	kWp*	
4	Inverter Cum Charg Controller / PCU		4.5	kVA	

Fig. 11: Summarized results for 5kWp system

IV. CONCLUSION

In this design calculations, 30% extra (i.e. 1.3 times) considered for battery sizing and PV Array sizing and 50% extra (i.e. 1.5 times) considered for PCU calculations for best results of operation peak loads also.

All the calculations are designed for PV-array sizing only (i.e. kWp), not with connected load (i.e. kW) and not with PCU rating (i.e. kVA). The charge controllers are available inbuilt with PCU along with suitable current ratings.

Some of the easy thumb-rule tips for Stand-alone battery backup PV systems.

1) One day's kWh unit consumption divided into three will be the approx. required size of stand-alone solar PV system (i.e. kWp) capacity.
2) Every kWp system can generate approx. 3 to 4 kWh units per day.
3) Each kWh system requires approx. 6 to 8 Sq. meters of area for PV module installation.

Note: *In this article some of the pics are taken from internet source.*

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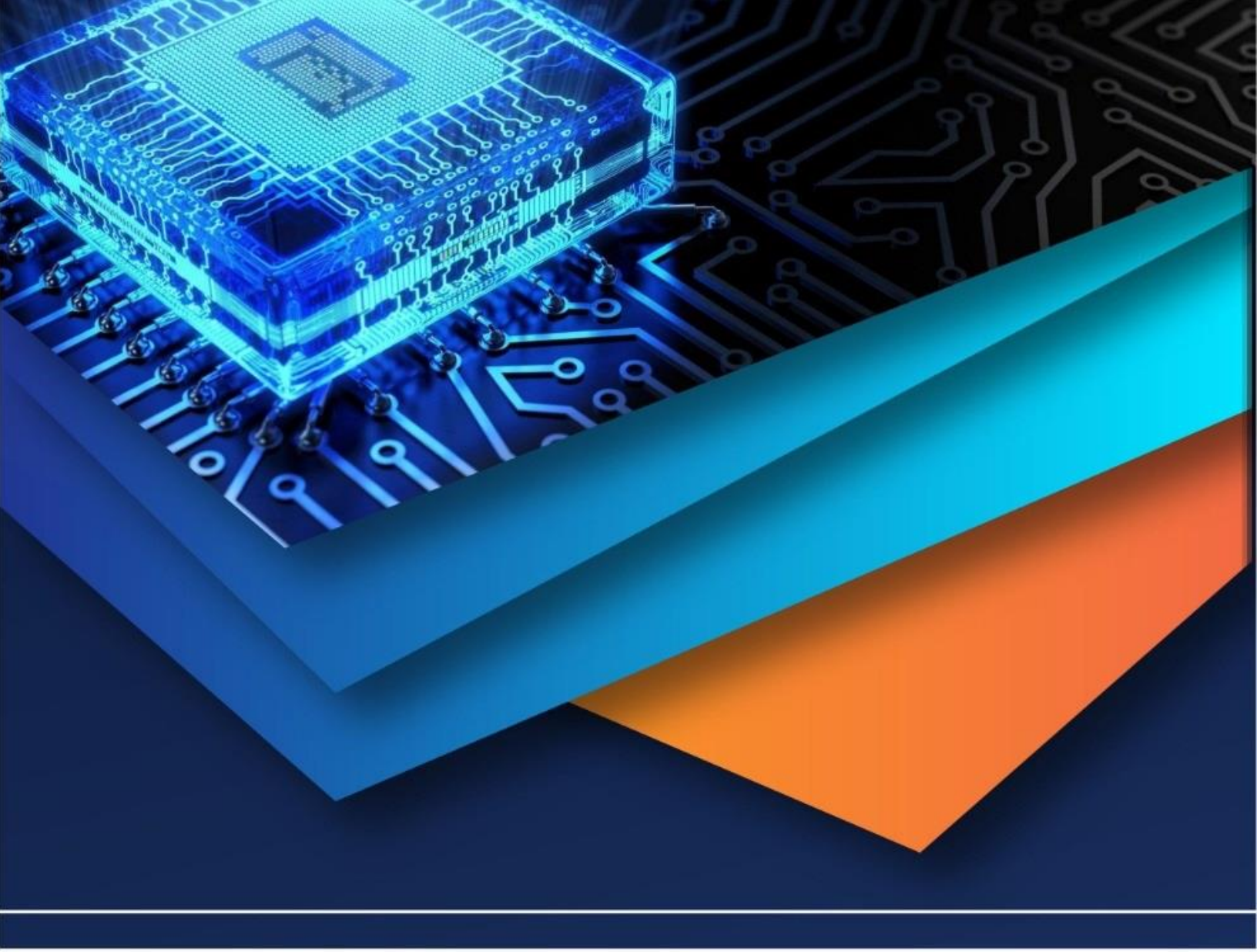

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