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Modeling and Simulation of an off Grid PV system for with Battery Backup for Remote and Rural Area Network

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Abstract **- Solar PV systems are now popular everywhere in world. These systems generates electricity to meet the demands along with conventional resources but also electrifying the rural areas where grid facility not available. In this paper an off grid PV system for a domestic load (a house load) modelled and simulated in matlab.**

1. INTRODUCTION

Solar off grid PV system so called because there is no grid connection available and PV system work independently. For a house load an off grid PV system have components like modules, battery (if battery backup), controller converter and inverter (as most of appliances are running on AC). For whole system design it is necessary to estimate the load and then each component is selected as per ratings.

2. Load Estimation

In a house following appliances are common and table 1 shows appliances with their rating and load estimations.

Table 1 – Load estimations

LOAD	WATTS	QUANTITY	HOUR/DAY	TOTAL WATTS	TOTAL WATTS-HOUR/DAY
TV	150	1	6	150	900
CFL	20	4	10	80	800
REFRIGERATOR	500	1	12	500	6000
FAN	40	3	8	120	720
COMPUTER	150	1	2	150	300
TOTAL				960≅ 1000	8720≅ 8800

So a house load is = 1 kW or 8800 Wh/day

For 1 kW load following PV components are required as shown in table 2.

Table 2 – PV Components and their ratings

COMPONENT	DESCRIPTION	RESULT
Load	Estimated	1 kW
PV array	Size	2.5 kW
	Total panels	10
	In series	2
	In parallel	5
	Panel power	295 Wp
Charge controller	Capacity	52
	Number of controller	3
Inverter	Size	1.25 kVA

The PV panel or module has following specifications:

Table 3 – PV module specifications

Parameter	Value
Peak power	295 watts
Module Efficiency	14.7%
Peak power voltage	36.51 volts
Peak power current	8.08 amps
Open circuit voltage	44.78 volts
Short circuit current	8.30 amps
Number of cells	72 cells
Max. System voltage	1000 volts DC

3. PV ARRAY MODELING

PV array in matlab Simulink is a mathematical model which uses the equations of equivalent circuit model of solar cell. This PV array configure according to requirement of model. Figure shows a PV array:

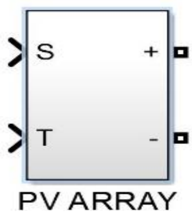

Figure 1 – PV array subsystem

4. BUCK CONVERTER MODELING

A buck converter with fixed duty cycle is modeled to give constant output DC of 48V. The circuit and Simulink model of buck converter shown in figure below:

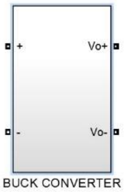

Figure 2 – Buck converter subsystem

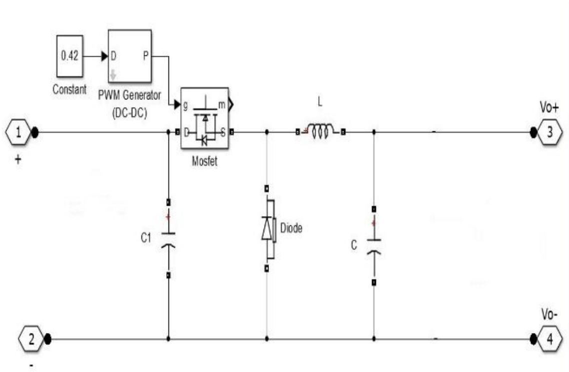

Figure 3 – Buck converter model

Here values of inductor (L), capacitor (C), duty cycle (D) and PWM switching frequency (F_s) are:

$L > 0.0056\, H$ $\quad$ $C = 1.56e^{-7} f$

D = 0.42 and $\quad$ $F_s = 10000\, H_z$

5. INVERTER MODELING

Here all the appliances need AC power for their working so the inverter is necessary in the system which gives AC output with desired level (120V/230V). Inverter in this model build by using PWM technique. Sine wave and triangular wave is compared to generate PWM which used to switching on/off semiconductor switches and DC input is converted in to AC. A transformer for step up of converted AC is used to get desire AC voltage level (230V here). Below figure shows inverter model in matlab.

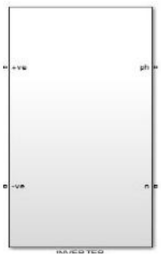

Figure 4 – Inverter subsystem

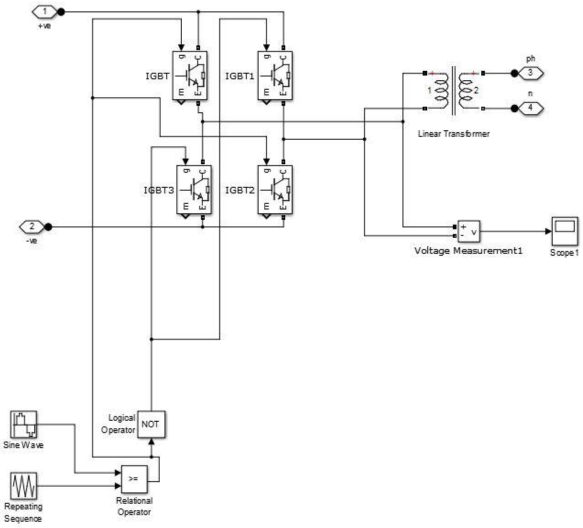

Figure 5 – Inverter model

6. OFF GRID PV SYSTEM MODEL WITH NO LOAD

The models of PV array, Buck converter and Inverter is connected to make an off grid PV system model. Figure below shows the PV system in Matlab Simulink without load.

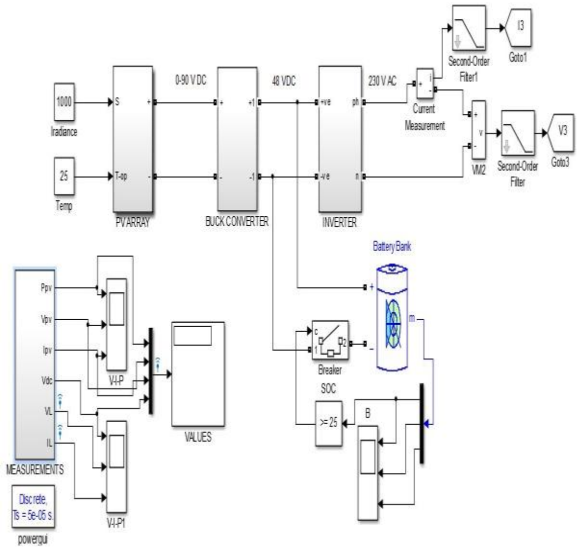

Figure 6 – PV system Simulink model without load

At no load and standard operating conditions (1kW/m^2 irradiance and $25^o C$ operating temperature) following results are obtained.

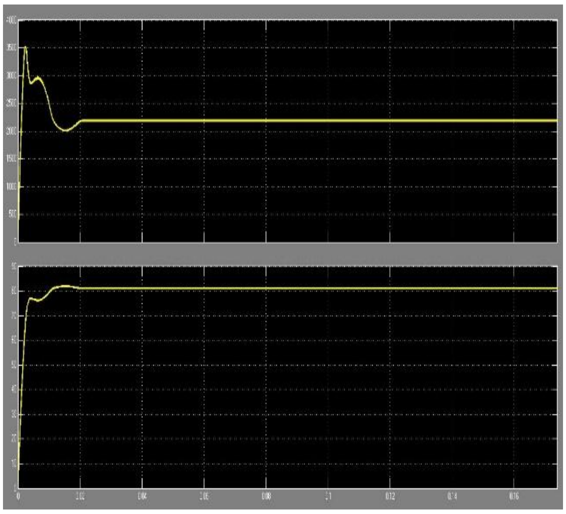

Figure 7 – Output Power & Voltage of PV array

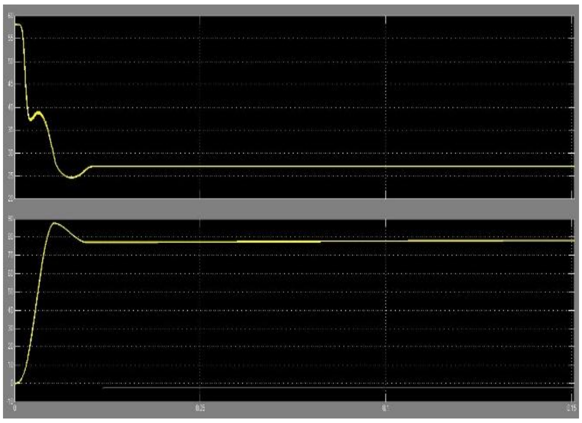

Figure 8 – PV array current & Buck converter output

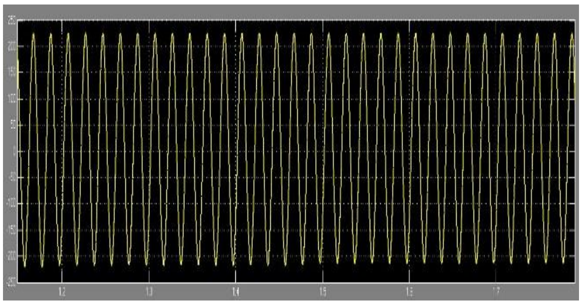

Figure 9 – Inverter Output

7. OFF GRID PV SYSTEM WITH LOAD

Now model is connected to 1 kW load which is estimated in table 1. Figure shows the model with load and results obtained from simulation. These results are taken at standard operating conditions (1 kW/m^2 Irradiance and 25^oC operating temperature of array).

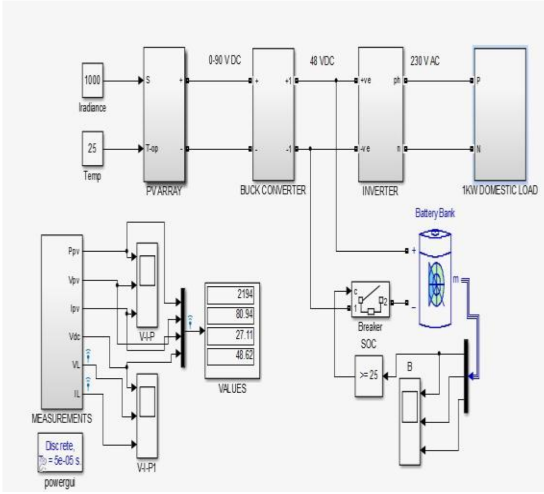

Figure 10 – PV system with load

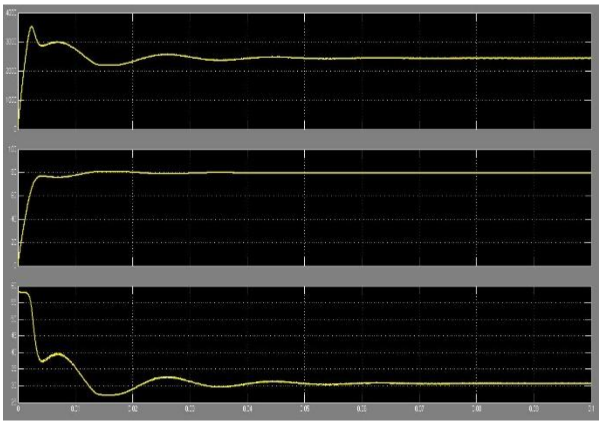

Figure 11 – Output Power, Voltage & current of PV array

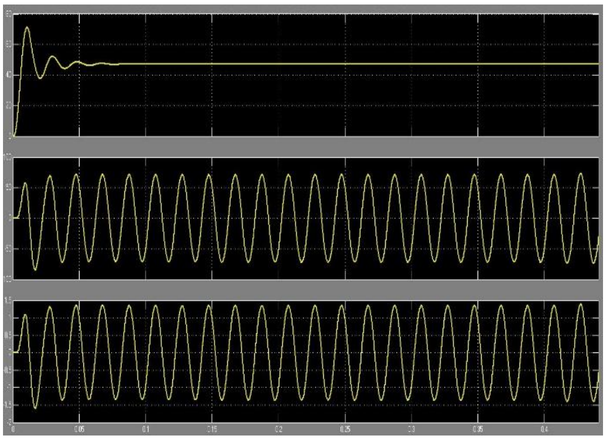

Figure 12 – Buck converter & inverter (across load) output

8 BATTERY OPERATION

Battery in the off-grid system is for supplying load when there is no sun irradiance on the solar panels. Battery charged from array when load is less and excess power is generated by array and battery discharge through load when there is no power from the array. To prevent the under discharging of battery state of charge is monitored and when it less than 25% battery disconnected form the load by breaker. Below figure shows the battery in the PV system simulation.

9 CONCLUSION

This study presents a simple but efficient off-grid photovoltaic system for a domestic load that can meet the daily load demands. The results show that the average daily load requirement of a house of 8800 Wh/day. In order to meet this load demand, an array of 10 solar panels required. Modeling and simulation of system shows the results for load and no load conditions at standard operating conditions.

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