Design and Testing OFF Grid Photo Voltic System

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Abstract - In today's world the demand of energy is incredibly high and non- renewable resource such as ore, fossil fuel and nuclear fuel are not sufficient to meet this demand. Eventually renewable energy is a better choice. There is an increasing trend of using solar cell in the industry as well as to household appliance because solar energy is expected to play a prominent role in future smart grid as a distributed renewable source. For optimal and large-scale integration of solar energy several modeling software and computer program is used.

In this paper a stand-alone solar system of 2kW with battery backup, being located in Bangalore, its designed by using a MATLAB program named Simulation and one popular software AutoCAD. The energy harvested by PV modules and conversion of this energy into useable AC form using an inverter. Charge controller can be based MPPT or PWM type, the inverter helps in conversion of regular DC input to AC output which can be used by normal loads. The system can be utilized in the night by the use of storage devises like battery. The objective of the work is to Design to charge the battery and run the load. The inverters consist of Buck converter it converts variable DC to fixed DC and Half bridge inverter, inbuilt charge controller which regulates the harvested energy for charging the battery as well as to supply the loads during the day. The key design aspects for the selection of solar PV modules are battery selection and inverter selection are described.

***Key Words*: Renewable Energy, Off-Grid Power System, Maximum Power Point Tracking, Inverter, Battery, MATLAB-Simulink**

1. INTRODUCTION

Increased energy utilization and global pollution awareness have made green/renewable energy more and more valuable. Among several renewable energy resources, photovoltaic (PV) effect is the most essential and sustainable way because of abundance and easy accessibility of solar radiant energy around the earth [1]. The conversion of solar energy into electric energy is performed by means of photovoltaic cells.[2] One of the attractive features of the PV system is that its power output matches perfectly with the peak load demand. It produces more power on a sunny day when excessive load consumes more power from the grid.

There are three basic configurations of solar system [3]. Standalone system, grid tie system and grid interactive system. At present, PV power is extensively used in standalone power systems in remote villages, particularly in hybrid with diesel power generators. Its major components are PV module, charge controller, battery and inverter [4][5]

Batteries store the energy and provide a constant power source. Charge controller is used to control the flow of current into and out of the battery.[6] It prevents battery from overcharging and completely discharging. As most of the appliances are AC-voltage devices, inverter becomes an inevitable component of a stand-alone system.[7] Modern sine wave inverters exhibit low open-circuit loss, allow partial load operation and should have power surge protection, short term overload capacity for several minutes and low level of high-frequency interference in the output signal [8].

In this paper a stand-alone solar system of 2kWp is designed by using simulation analysis using MATLAB/SIMULINK. The off-grid PV System model is developed featuring PV module, dc-dc converter, Maximum Power Point Tracker (MPPT) method with applied Perstrub and Observation Algorithm, storage battery model, inverter, and communal load model. This developed off-grid PV system is expected able to supply energy demand as the communal. The average daily electricity power demand for this System is a minimum of 1.2 kWh.[9][10]

1.1 Stand Alone Based PV System

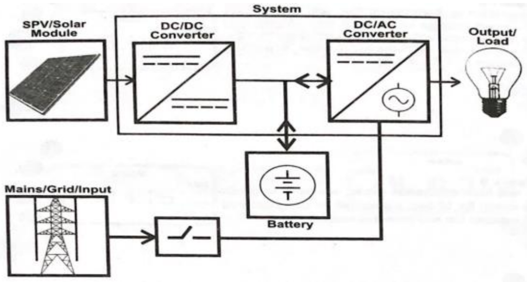

Fig.1. Block diagram of Standalone PV system

Stand-alone PV systems are designed to operate independent of the electric utility grid, and are generally designed and sized to supply certain DC and/or AC electrical loads. With an inverter it can also power AC load. For systems with no battery the energy is used immediately; only works when it's sunny, Systems with Battery Backup can supply power 100% of the time.[2]

In this project we are designing a Simulink model for standalone system in software called MATLAB. We are going to design a PV system having rating of 2000W, the charge controller is used to regulate the power going to the batteries.[2] Inverters are used to convert dc power into ac, whenever we want to connect to the ac load system. Here we are using Multilevel inverter which can produce seven level inverter waveforms because it has less harmonic distortion.

In stand alone system inverter is the brain of the system, the inverter operates in different-different mode like PCU Mode, Smart Mode, Hybrid Mode the selection of modes depend upon the priority of battery and load in this system PCU mode is operation.

PCU Mode: - In a solar PCU, solar charging of battery takes priority during the day. The Solar PCU controls the priority and optimally selects the source of charging. It comes with user selectable energy saver mode which allows the user to select the priority and save the bill. It also selects the source of AC output to be either from the Solar or inverter or the grid. In the Energy Saver Mode priority is given to Solar, the battery is charged first and also supports the inverter to power the appliances. Once the solar energy stops, the PCU starts consuming the stored energy from the battery.

2. MATHEMATICAL MODEL FOR GENERATION

A. Technical Analysis

1). Calculation of the number of solar panels: The method used for this calculation is based on the method described in reference [6] with some modifications. Total Energy consumed per day is shown as in equation (1)

$$E_{day} = \sum_{i=0}^{n} \frac{u_i \times p_i \times n_i}{1000} \quad (kWh) \qquad \text{.........................(1)}$$

Where i is the index for each type of load such as fan, lamp, TVTV, and so on, U_i = number of hours of use of device type i per day, P_i = power rating of device type i, n_i = number of device type i. To meet above requirements with solar power generation, efficiency and derating factors should also be considered. Thus, the total PV generation capacity required can be calculated as.

$$P_{PV} = \frac{E_{day}}{S_d \times d} \quad (kW) \qquad \text{..................................(2)}$$

where, Sd = the average duration of solar radiation, d = the derating factor is influenced by efficiency effects such as soiling the panels, lost wires, shadows, snow cover, aging, and so on. The typical value for Sd in Indonesia is 4.5-5.1 kWh/m2 / day, and d value is 80%. In this study average duration of sun exposure is 4.8 kWh/m2 /day based on available weather information in [5].

The number of PV panels required, calculated using equation (3)

$$nP = P_{PV}/P_O \qquad \text{...............................(3)}$$

where P_O is the power output capacity of each panel.

2). Calculation of the number of batteries required: Due to the difference between the variation of load power and solar power generation at any given time, the battery storage system is required to supply or absorb this variation. In system design, the battery along with the inverter system, placed between the rooftop PV panels and the load. To determine the size and number of batteries, methods based on [7] are used. The number of batteries (N_{bat}) is shown in Eq.(4)

$$N_{bat} = \frac{E_{day} \times n_d}{V_{bat} \times I_h \times DOD} \qquad \text{.........................(4)}$$

where n_d is the number of days required power reserves, V_{bat} is the voltage rating, I_h is the ampere-hour rating, and DOD is the depth of discharge of the battery system. Thus, equation (1)(4) represents a mathematical model for selecting the number of PV panels and batteries from the technical requirements of the load.

3). Calculation of size of inverter: Based on the block diagram shown in Figure 1 the inverter capacity is determined by the expected peak load demand. Peak load demand is estimated using the relationship between the connected load and the diversity factor (DF) of the load at which the diversity factor is the ratio of maximum demand to the total connected load.

$$P_{inv} = \sum_{i=1}^{n} \frac{P_i \times n_i}{DF} \quad (Watt) \qquad \text{.....................................(5)}$$

3. PROPOSED METHODOLOGY

Fig-2 shows the basic flowchart of the Standalone system work.

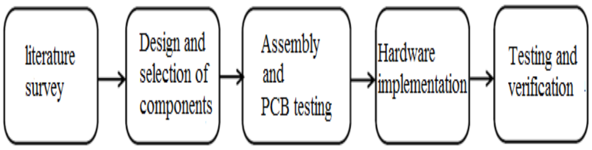

Fig -2: Methodology for health monitoring system

Literature survey- A literature survey is carried out for the selection of topology and techniques employed for efficient performance by comparing it with the traditional one.

Design and selection of components- The designing of Buck converter and Inverter, selection of the switching devices (MOSFET, design of output filter components and design of inductor. The tool used for design is "MATLAB Simulink" for schematics and simulation.

Assembly and PCB testing- PCB board is tested for the correct circuit paths and continuity is checked at different ground points. The selected components are assembled in the verified PCB according to the component designation.

Hardware Implementation- The assembled PCB is checked and the test setup is made for the analysis and testing purposes.

Testing and verification- The implemented converter is analyzed and the performance of the converter is tested under different input and output load conditions

4. SIMULATION DESIGN AND COMPONENTS

A). Solar PV

Solar PV which is used based on data on load needs and availability in the Indonesian market. Based on the existing reference the solar pv used is LEN 385 Wp, that has peak power 385 W. After calculated based on load requirements, the configuration used is 3 panels in parallel

Table-1: Specification of Solar PV

Parameter	Value
Maximum power	385 W
Module efficiency	21%
Vmp (V)	39.70
Imp (A)	9.85
Isc (A)	9.90
Voc (V)	48.45
Number of cells	72 Ncell

B). Solar Battery (C10)

The system designed is the Off-Grid system so that the topology requires energy storage media, which in this study the energy storage media used are batteries. In the system design that is designed, the capacity and configuration of the battery must be determined so that it can work according to system requirements. For system configuration, the number of batteries in a series arrangement (1 string) will determine its suitability with the system voltage (DC bus) which in both types of load the DC bus voltage value is the same, which is 24 V. In addition, the duration of the autonomy time of the system and the energy it takes effect on the size of the battery.

Table-2: Battery Specification

Nominal Voltage	12V
Capacity	150.0Ah @10hour to 1.80 V/cell
Dimension	191 x 210 x 681 mm
Operating Temperature Range	Discharge: -20 ~ 55°C (-4 ~ 131°F) Charge: 0 ~ 40°C (32 ~ 104°F) Storage: -20 ~ 50°C (-4 ~ 122°F)
Float Life	22 Years
Inner Resistance	0.5mΩ

In the simulation with MATLAB note the DoD value of the battery itself, in this simulation the battery DoD value is set at 80%

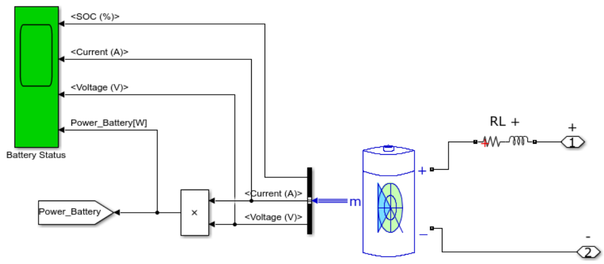

Fig -3: Battery Block Simulation

C). Inverter

The inverter used in this system is a single-phase inverter type with a control method with Pulse Width Modulation (PWM) technique, namely by comparing the sinusoidal signal with a triangle signal. So that from this comparison can give an on/off signal and can result in changing the DC signal to AC signal

Table-3: Solar Inverter specification

Capacity	2500 kV
Switching element	24V
Switching element	MOSFET
Maxx output current	6.8A
Grid charging current	5A-20A
Normal Frequency	50Hz
Maxx. PV power recommended	2000W
Maxx Solar current	70A

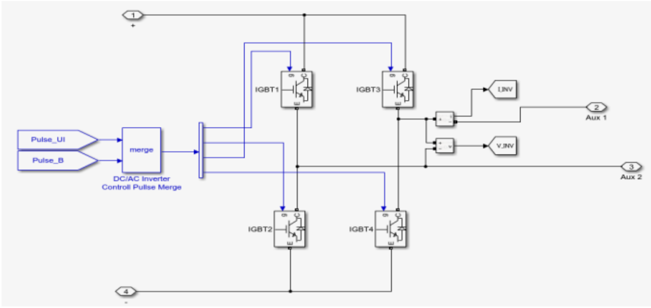

Fig -4: DC/AC Inverter Block Simulation

D). Simulation of PV System

In this project we are designing a Simulink model for standalone system in software called MATLAB. We are going to design a PV system having rating of 2000W, the Buck converter is used to regulate the power going to the batteries. Inverters are used to convert dc power into ac, whenever we want to connect to the ac load system. Here we are using Multilevel inverter which can produce seven level inverter waveforms because it has less harmonic distortion

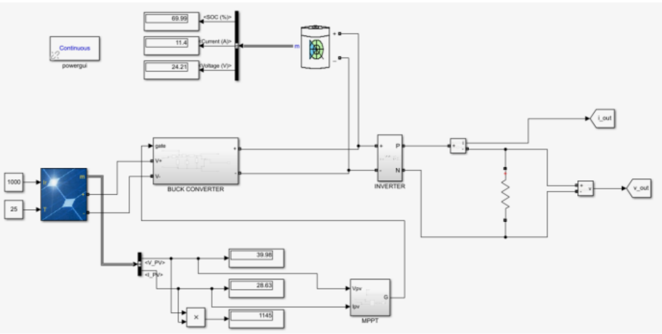

Fig -5: 2kW PV System Simulation

Simulation model of standalone PV system is shown in Fig.5, it shows PV module which can generate the electricity from the sun rays. Further it consists of the MLI system which can generate inverter waveforms.

5. RESULTS AND DISCUSSION

The simulation result for output voltage and output current is shown in Figure 6.

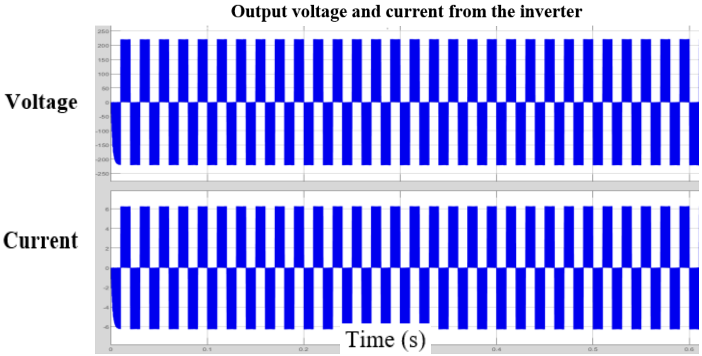

Fig -6: O/P V and I waveform from the inverter

The observed O/P V and O/P I is 230.V and 5.63A respectively. The effect of irradiance on current-voltage and characteristic curve is shown. From the figure, it can be concluded that when the irradiance is 1000W/m2, the output power of the solar panel is 380W. As the solar radiation decreases, the output power decreases also.

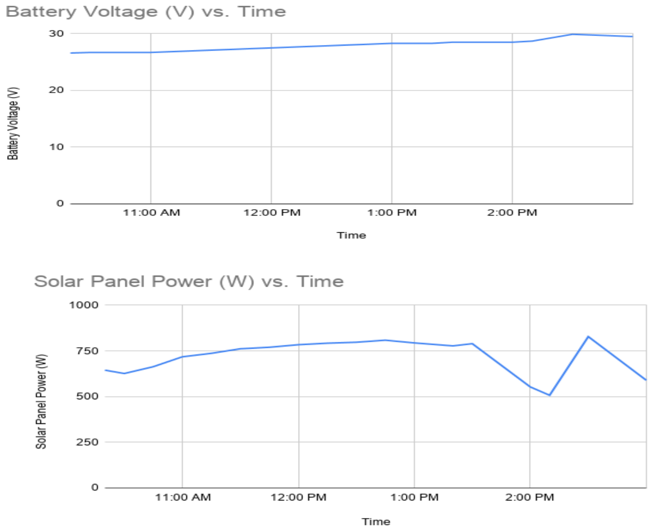

Fig -7: PV Power(W) vs Time for Charging Battery

Total time taken by the battery to charge from 20 percent to 80 percent SOC is around four and half hour

Table-5: Testing outcome while battery charging

Time	Solar Panel Voltage (V)	Solar Panel Current (A)	Battery Voltage (V)
10.20AM	28.4	22.7	26.6
11.20AM	27.7	26.6	26.9
12.20PM	28.5	27.8	27.7
13.20PM	28.8	27.0	28.3
14.20PM	28.9	27.7	29.9
15.20PM	30.7	19.2	29.5

The effect of irradiance on current-voltage and power voltage characteristic curve is shown in Fig. 8. From the figure, it can be concluded that when the irradiance is 1000W/m2, the output power of the solar panel is 1200W. As the solar radiation decreases, the O/P power decreases.

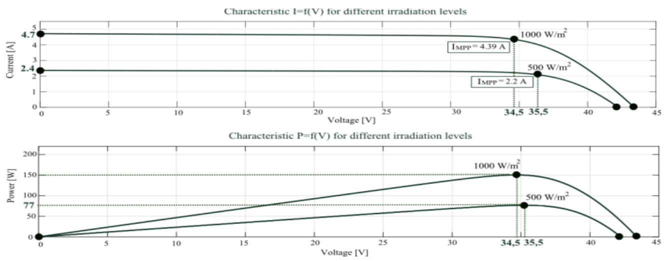

Fig -8: PV characteristics at different values of irradiance

6. CONCLUSION

Off-grid system design using MATLAB / SIMULINK is now possible. Energy sources such as Solar PV and Batteries can supply to the load based on the load profile. Scenarios that have been done show that the performance of the system is influenced by irradiation and temperature, because when the value of irradiation and temperature drops, solar PV will go up and down in supplying the load so that the battery will also be more volatile in supplying to the load. Sizing the system and specifications is considering the load estimation 2kh/day. The result reveals that a 1200W photo voltaic array with 3 modules of capacity, 385W each. The 12 V, 150 Ah batteries and an inverter of 2.6kVA with 24V DC input and a voltage regulator with current carrying of 6.8 A safely is needed.

The designed off grid photo voltaic system requires wires made up of copper with different areas of cross section like 4sqmm, 10sqmm & 2.5sqmm for connecting between PV module and battery, battery and inverter and inverter to load respectively. Installing off grid it means being independent of electricity suppliers. Off grid PV is an electricity power source which is renewable in nature and obtained from solar energy. In the project aims at development of an off grid solar inverter designed in MATLAB and is validated by the hardware. The system uses buck converter with MPPT control and half bridge single phase inverter to supply the power to AC load. The portable project is being tested in my collage.

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