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DESIGN OF 250W HYBRID SOLAR SYSTEM FOR OFF-GRID AS WELL AS ON GRID SYSTEM WITH NET METERING

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Abstract: A hybrid design of solar system for off-grid as well as on-grid system is explained in this paper. The system has been designed in order to get the maximum efficiency by implementing maximum power point tracking (MPPT) concept with the help of DC-DC converter. The net metering concept has been used to track the power taken from or given to utility which is controlled by Arduino microcontroller that senses the voltage and current and controls the operation of the system.

Keywords: *Solar, Charge controller, MPPT, DC-DC converter, Battery, Inverter, Net Metering, Arduino.*

I INTRODUCTION

One of the most important sources of renewable energy nowadays which have caught the attention of many is the 'Solar Energy' and it is through harnessing this energy thatwe are meeting some of our energy demands. For the design of the solar PV power generation system, when the loaddemand is certain, the main principle is to make full use of solar energy, try to minimize capacity of PV array and storage battery as far as possible and ensure the normal operation of the load in continuous rainy weather conditions.

PV generation system should operate at its maximum power point (MPP) to increase system efficiency. Therefore, MPP tracking is very crucial for PV power generation systems to operate at the maximum power point as much as possible at any time. However, the MPP also changes with the irradiation level and temperature due to the nonlinear characteristics of PV modules. A charge controller is an essential part of nearly all power systems that charge batteries,whether the power source is PV, wind, hydro, fuel, or utility grid. Its purpose is to keep your batteries properly fed and safe for the long term. A charge controller is a regulator that goes between the solar panels and the batteries.

The inverter is composed of power electronics devices,which mainly convert direct current (DC) to alternating current (AC). In addition to this, the inverter also has other useful features, such as cutting off the circuit to avoid being breakdown by surge current, charging the batteries, saving the data and applying the maximum power point tracking (MPPT) to improve the efficiency of power generation. The PV inverter is not only inherited from inverter but also able toget the most out of the solar cells besides doing system protection tasks.

Net metering is a billing system that allows customer tosell their electricity to electric utility generated by solar panels. While net metering policies vary by state, customers with rooftop solar system usually are credited at the full retail electricity rate for electricity they sell to electrical utilities. The full retail electricity bill includes not only the cost of power but also all of the fixed cost of the poles, wires, meters,advanced technologies and other infrastructure that makes the electric grid safe, reliable and able to accommodate solar system. Through the credit or payment they receive net- metered customers effectively avoid paying these costs of the grid.

Arduino controls the whole operation of the proposed system.

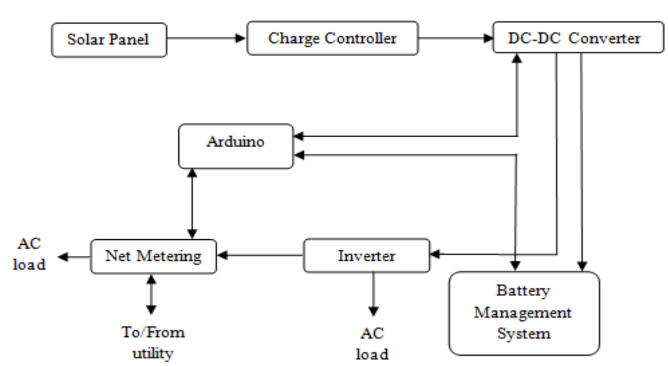


Fig.1 Block diagram of proposed system

Fig.1 shows the block diagram of the proposed system. This paper describes a design of hybrid solar system suited to

Indian scenario. The design implemented in this paper paves way to effectively and efficiently co-ordinate to utilization of both solar as well utility grid supply.

II PROBLEM STATEMENT

Solar and wind energy have gained significance over theyears and they have been supplementing conventionalsources of energy in various countries throughout the world.In a country like India, Where the power supply isintermittent and schedule power cuts occur regularly, use ofrenewable source of energy is indispensable. Energy derivedfrom these sources stored in appropriate storage systems provide backup during load shedding period. Variousalgorithms and designs have already been implemented foreffective use of stand-alone solar PV system. When this power provided by stand-alone is insufficient to charge thebatteries or to supply the load, an additional source can beappend to this system will enhance the reliability of thesystem. Some systems entirely depend on the grid utility forcharging of batteries incurs high losses. Considering the problem of reliability of grid supply, this system proves to be inefficient. So a hybrid system that uses both solar energyand grid supply as and when required will charge the batteryfast and will also provide a continuous power supply. Thiswould also reduce the losses significantly.

III BASIC OBJECTIVE OF THE PROPOSED SYSTEM

The thesis is basically focused on the design of the hybrid solar system, which includes:

A) Implementation of MPPT to obtain maximum efficiency

B) Effective battery charging system

C) Net-Metering

IV METHODOLOGY

A. A hybrid solar system

The solar system can be designed for off-grid system in which the load is supplied by the solar PV system which is intermittent in rainy seasons. So the other way is the hybrid system in which load can be supplied from both solar system and also from grid supply which increases the reliability of supply also reduces the losses that incurred due to stand alone system.

B. Design

1. Load Assessment:

TABLE I. System Load and Specification

Sr.No.	Individual load	Number of individuals	Rating in watt	Hours of usage
1.	CFL	4	15	8
2.	Fan	2	75	6
3.	Laptop	1	40	2

Therefore,

Total connected load = $(4 \times 15) + (2\times 75) + (1\times 40) = 250W$

Now, Total watt-hour rating of system

$= (15\times 4\times 8) + (2\times 75\times 6) + (1\times 40\times 2) = 1460Wh$

2. Inverter Sizing: Depending on the load the size of inverter is calculated. The required power from inverter is 1460 Wh/day. Inverter size should be taken 20% to 30% more than the connected load.

Hence, Inverter size = $250 + (250\times 30\ \%) = 325W$

The required inverter rating is 325W or by market availability.

3. System Voltage Selection: System voltages are generally 12V, 24V, 48V,….etc. The system voltage is selected by the requirement of the system. As our system load is small, we will take 12V as the system voltage.

4. Battery Sizing: Battery size is calculated by taking the output of inverter plus losses in the inverter taken into consideration. Assuming inverter efficiency as 85%, then

$$\text{Wh/day} = \frac{1460}{0.85} = 1717.65$$

For 12V system,

$$\text{Battery Ah rating} = \frac{1717.65}{} = 143.13\text{Ah} \cong 145\text{Ah}12$$

Thus, Battery rating is 145Ah, 12V.

Autonomy: The autonomy defines the battery backup when there is no supply neither from solar nor from grid. Depth of discharge is used to determine the autonomy. Assuming lead acid battery having 50% depth of discharge. Then to supply load for a day battery rating required is

$$= \frac{145}{} = 290\text{Ah/day}0.5$$

Assuming we want backup for 2 days, then battery size required = $(290\times 2) = 580Ah$

Considering the rating of battery required as 600Ah for two days of backup.

5. PV Sizing: PV module is sized by considering the battery efficiency, solar radiation of location at which system to be implemented. Let's assume battery efficiency of 80% then, power to be supplied by PV module is

$$= \frac{1717.65}{0.8} = 2147.06\text{Wh/day}$$

Now, considering the solar radiation of location is 5KWh/ m^2 /day. Then solar panel size to meet this load is

$$\overset{2147.06}{} = \frac{}{5} = 429.41W$$

Taking the PV panel rating as 500Wp, 12V.

6. Charge controller selection: It is selected based on the Power output and voltage of solar panel. Therefore,

= 500 — = 41.667A12

Considering 20 % loss in electronic components. Charge controller rating = (41.667 × 20 %) = 50A, 12V.

C. Implementation:

1. Charge controller: The output of solar panel is fed to the charge controller. Then the charge controller regulates the current and voltage to suit the requirement.

2. DC-DC converter: This is basically a buck-boost dc-dc converter used to maximize the efficiency of the system. When the power output of the solar panel is not as per the requirement then dc-dc converter performs buck-boost function to adjust the power to the required value which in turn maximizes the system efficiency. This buck and boost actions are control through the Arduino. The flowchart of this operation is shown in Fig.2.

3. Battery charging system: The hybrid system uses both solar and grid supply to charge the battery. This switching between the power supplies is based on preset thresholds that are set in the microcontroller. When these thresholds are met, the Arduino microcontroller generates appropriate commandsto switch the relay accordingly, allowing solar power and/or utility grid supply to charge the battery. The threshold values are set in terms of the percentage of battery charge or the battery voltage levels. The 12V solar tubular battery used in this design can be charged to a maximum voltage level of 14.5V and can retain a voltage level of 1O.5V when fully discharged. The threshold level has been set at 80% of the battery voltage for the range of 10.5V to 14.5V. The charging of the battery can be divided into two stages based on the preset threshold value.

   Stage 1:0 % - 80 %: This stage denotes the charging of the battery to 80 % of the maximum voltage level from the fully discharged state. The battery voltage level is constantly measured using a voltage sensing circuit and the Arduino microcontroller has been programmed such that when the battery voltage level goes below 13.7V which corresponds to 80% of the maximum level, it generates a command to switchthe relay from normally open state to normally closed state allowing the battery to charge from the solar PV and utility grid supply simultaneously.

   Stage 2:80% - 100% : When the battery is charged up to 80% of its maximum voltage level, the Arduino microcontroller generates commands to switch the relay back to normally closed state and block the utility grid supply. At this stage, the battery is charged only from the solar PV. The flowchart for the control strategy explained above is given in fig. 3.

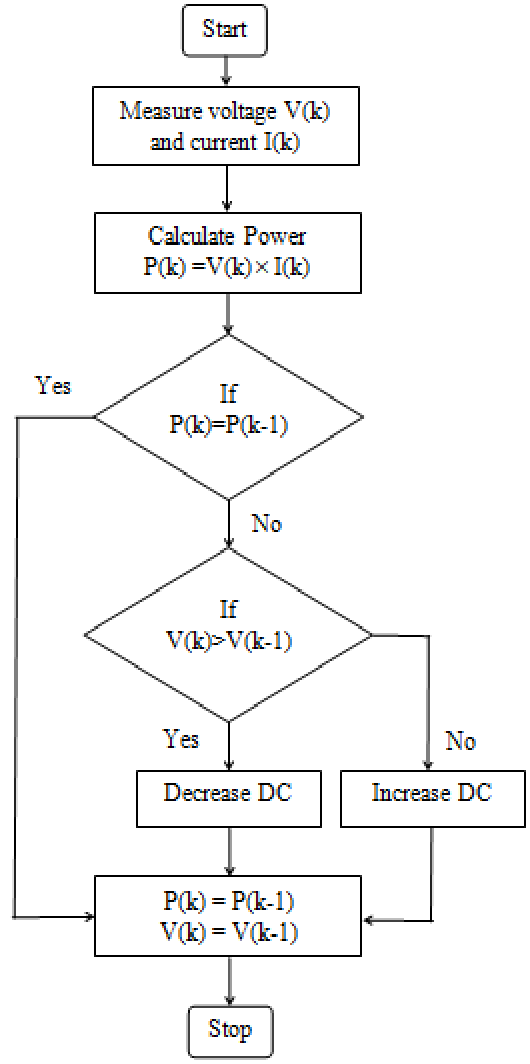


Fig.2 Flowchart for MPP

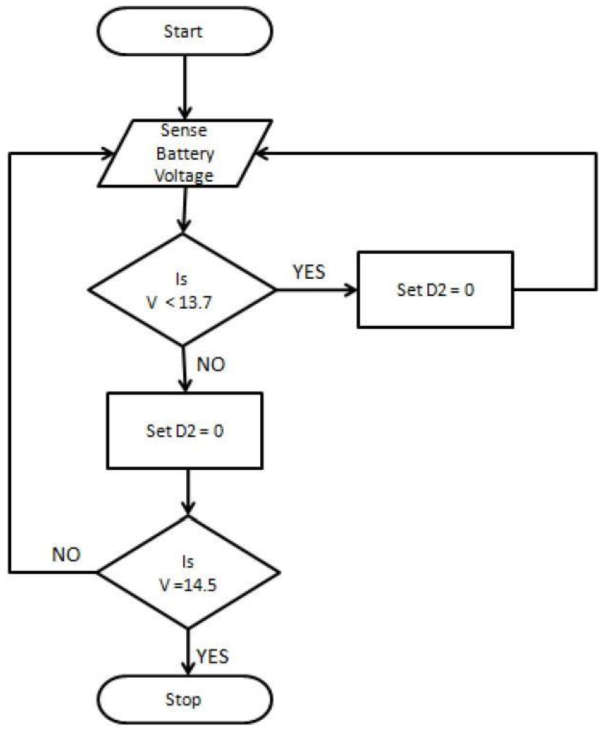


Fig.3 Flowchart for battery charging

4. *Inverter:* A grid tied inverter is used which converts the dc current into ac current to supply the load.

5. *Net-Metering:* Net meter is used to measure the net energy between the grid to load and the excess energy from any renewable energy sources that fed to the grid.

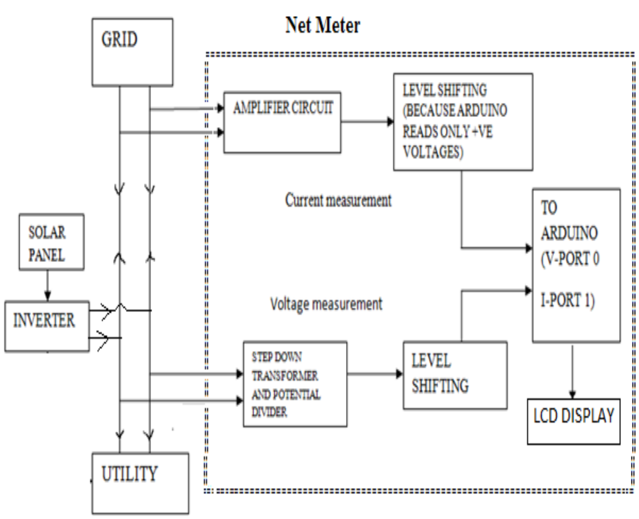


Fig.4 Block diagram of net meter

The proposed system consists of a voltage and current measuring circuit, power supply unit, amplifiers (OpAmp IC 741), regulators (LM 7809) and processing unit. The voltage and current measuring circuit feeds the corresponding instantaneous values of voltage and current as an input to Arduino. Arduino calculates the net energy by using instantaneous values of voltage and current. The net output energy is displayed through LCD which is interfaced with Arduino. Fig.4 shows the block diagram of proposed netmeter.

6. *Arduino Microcontroller:* An Arduino ATmega328 microcontroller has been used to monitor and control the operation of the dc-dc converter, Net-meter and battery charging system. The current sensor senses the current, the voltage sensor senses the voltage and they fed the result into Arduino and therefore Arduino compares them with the preset instruction and changes accordingly to extract the result.Arduino receives the voltage and current parameters from sensors and by the program burned into the Arduino microcontroller it controls the operation of buck-boost converter to obtain maximum efficiency.

7. *Simulation of dc-dc converter:* The dc-dc converter used is buck-boost converter

I) Calculation of converter parameters:

Input voltage 12-18volt. Taking the maximum voltage for the calculation of parameter.

Output voltage 12v, 2.77amp

By using the output equation $Vo = \frac{(D\times Vs)}{(1-D)}$, where D is the Duty cycle D is calculated to be 0.48.

D > 0.5 ------Boost mode

D < 0.5 ------Buck mode

Is =source current, 41.67Amp. Similarly by using this formula $Is = \frac{(Io\times D)}{(1-D)}$, output current is calculated,

Io = 45.1425Amp.

The value of Inductance as calculated is given as $L = \frac{(D\times Vs)}{(Fs\times \Delta I)}$,

Therefore, L= 249µH.

And the value of Capacitance is taken as $C = \frac{(Io\times D)}{(Fs\times \Delta V)}$

Therefore, C= 362µF

The switching frequency is chosen as Fs = 10 KHz with Time period $T = 0.1\times 10\times e^{-3}$.

II) Simulation model: The simulation model of a buck-boost converter is shown in fig.5.

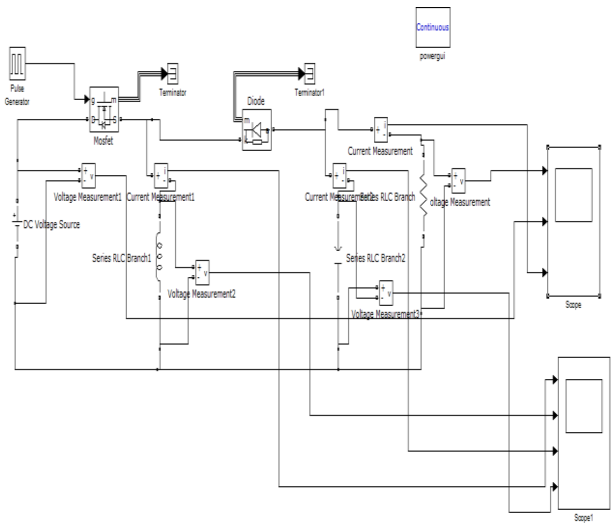
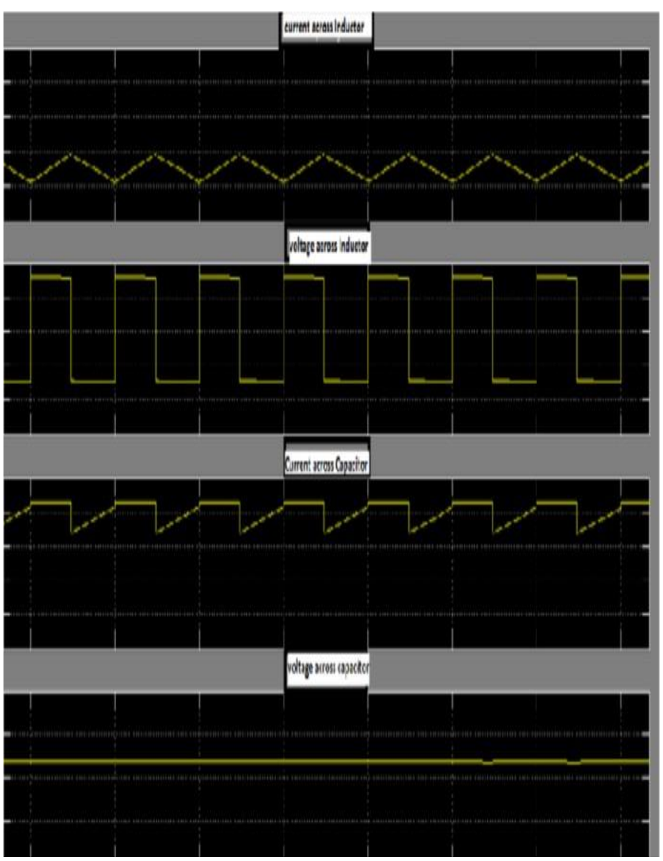


Fig.5 Simulation model of buck boost converter

III) Results of simulation: The results of simulations are obtained by applying the voltage which is 18V as it is the maximum voltage that a solar panel can produce. The simulation result shows the voltage and current across load, capacitor and inductor as shown in fig.6.



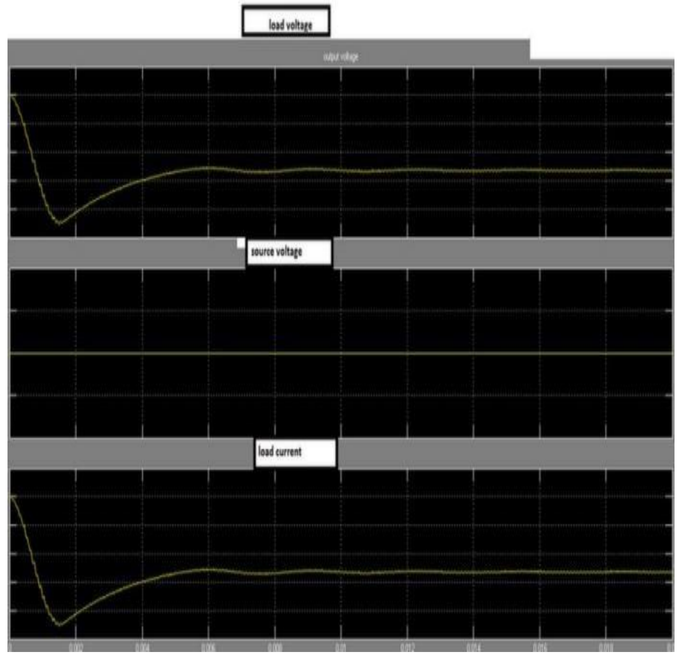


Fig.6 Simulation results of buck-boost converter

V RESULTS

The design of 250W system is done in this paper, based on it the specifications of various components of the proposed system are shown in table II.

Table II. System components and their specifications

Components	Specifications
Solar panel	500Wp
Charge controller	50A,12V
Battery	600Ah,12V
Inverter	325W

VI CONCLUSION

The hybrid solar system design of solar has been done utilizing both solar power and grid supply suited to Indian scenario. The use of Arduino microcontroller has simplified the control and enhanced the efficiency of the system. The use of dc-dc (buck-boost) converter has increased the efficiency of the system and it gives the constant voltage and power to the system. The prerequisite for varying the threshold setting has ensured enhanced flexibility of the system. Battery voltage based switching using Arduino has simplified the operation of the system.

The use of net meter helps to know about the total consumption of the energy from grid supply as well from solar panels. It can be inferred from the above hybrid solar system is much suited for those areas where both grid supply and solar irradiation is available.

REFERENCES

[1] R. Szweda, "Renewable energy applications in the Indian subcontinent,"Photovoltaics Bulletin, vol. 2003, pp. 7-9, 2003.

[2] M. Sarkar, et al., "Issues relating to energy conservation and renewable energy in Bangladesh," Energy for Sustainable Development, vol. 7, pp. 77-87, 2003.

[3] Lawrence L. Kazmerski, Solar photovoltaics R&D at the tipping point: A 2005 technology overview, Journal of Electron Spectroscopy and Related Phenomena,Vol.150,No.2-3,105-135,2006.

[4] Wang Xiuhua, Miao Xinfa, Zhang Mingzhu. Single-phase inverter research for intelligent double closed-loop [J]. Power supply technology. 2015139

[5]M. A. Salam and S. A. Khan, "Transition towards sustainable energy production – A review of the progress for solar energy in Saudi Arabia," Energy Exploration and Exploitation, vol. 36, no. 1. SAGE Publications Inc., pp. 3–27, 01-Jan-2018.

[6] Jaya Vasita, Akash Davda, Real-Time Performance Analysis and Operation & Maintenance Experience of Photovoltaic Generating plant in Western India; International Journal of Science and Research (IJSR) 2017; vol. 6,1pp. 1657-1665

[7] A.K Mishra, Anil Kumar Dubey, C.B Tripathi, Prahsant baredar Lala Tripathi."Renewable energy: An overview of its contribution in current energy scenario of India," Renewable and Sustainable energy reviews, pp. 226-223, July 2016.

[8] Hisham Mahmood, Dennis Michaelson and Jin Jiang: "Control Strategy for a Standalone PV/Battery Hybrid System", 38th Annual Conference of the IEEE Industrial Electronics Society (IECON201 2), Montreal, PQ, 25-28 October 2012.

[9] Eric Yep. (20 1 1, March). india's Widening Energy Deficit [Online]. Available:http://blogs.wsj.com/indiarealtime/2011103/09/indias-widening-energy-deficit

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