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Implementation of Switching Circuit between Grid and Photovoltaic system with fixed and Movable Tracking

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Abstract : The objective of this paper is to design a DC to DC converter, inverter and power switching circuit for integrating the photovoltaic system to the grid. Achieve a stable output voltage of 230V AC,and to switch the power supply between the city electrical system and the designed solar photovoltaic system. Movable and static tracking systems are discussed. In that Movable solar tracking system is considered to get higher efficiency compared to static solar tracking method. The output from the PV panel is given to boost converter and inverter. Inverter output is given to load. The switching circuit is used to switch the city electric grid power to solar power and vice versa according to the availability of solar energy. When the capacity of the solar panel and the storage battery is insufficient for the load, the power switch will automatically switch to the municipal city electricity. Therefore, the load can be utilized throughout the day.
Keywords : PV Array, Grid integration, Microcontroller, tracking system, boost converter, switching system.

1. Introduction

Solar energy is the energy that comes from the sun. Every day the sun radiates an enormous amount of energy. Like other stars, the sun is a big gas ball consisting of mostly hydrogen and helium. The sun generates energy in its core by a process called nuclear fusion. During nuclear fusion, the sun's extremely high pressure and hot temperature causes hydrogen atoms to come apart and their nuclei to fuse or combine. Some matter is lost during nuclear fusion. Only a small portion of the energy radiated by the sun into space strikes the earth (one part in two billion). Yet this amount of energy is enormous.

The efficiency of the system with fixed panel is compared with movable tracking system. In movable tracking, the solar panel receives sunlight and can generate the maximum power at the time. When the solar energy generating capacity is insufficient, the electricity will be provided by the storage battery. When the capacity of the solar panel and the storage battery are insufficient for the load, the power switch will automatically switch to the municipal city electricity. Therefore, the load can be utilized without any discontinuity. The hardware design of the existing solar energy collector system can be replaced with movable tracking system in order to provide higher efficiency at lower cost. Solar energy is the most abundant and uniformly distributed among all the available non-conventional sources. Even though technology for trapping solar energy is already in existence, the process can be further improved to increase its efficiency. Solar energy is freely available, needs no fuel and produces no waste. It helps in maintaining pollution free environment. Moreover, solar power is renewable. The sun will keep on shining anyway, so it makes sense to utilize it.

A photovoltaic system is based on the ability of certain materials to convert the radiant energy of the sun into electrical energy. The total amount of solar energy that lights a given area is known as irradiance (G) and it is measured in watts per square meter (W/m^2). The instantaneous values are normally averaged over a period of time, so it is common to talk about total irradiance per hour, day or month. Of course, the precise amount of radiation that arrives at the surface of the Earth cannot be predicted with high precision, due to natural weather variations.

The design, development, and evaluation of a microcomputer-based solar tracking and control system (TACS) was discussed in[1]. It was capable of maintaining the peak power position of a photovoltaic (PV) array by adjusting the load on the array for maximum efficiency and changed the position of the array relative to the sun. At large PV array system installations, inverters were used to convert the dc electrical output to ac for power grid compatibility. Tracking and control system performs the adjustment of inverter or load for achieving maximum array output. Another important function of the system was the tracking the sun's irradiance for concentrating arrays. The TACS also minimized several other problems associated with conventional shadow-band sun trackers such as their susceptibility to dust and dirt that might cause drift in solar alignment. It also minimizes the effects of structural war page or sag to which large arrays might be subjected during the day.

Microprocessor and microcontroller based automatic position control scheme in discussed in[2]. They had designed for controlling the azimuth angle of an optimally tilted photovoltaic flat type solar panel or a cylindrical parabolic reflector to get the illuminating surface appropriately positioned for the collection of maximum solar irradiance. The proposed system resulted in saving of energy. It was designed as a pseudo tracker in which step tracking scheme had been used to keep the motor idle to save energy. The tracking system was not constrained by the geographical location of installation of the solar panel since it was designed for searching the Maximum Solar Irradiance in the whole azimuth angle of 360° during the locking cycle. Temporal variations in environmental parameters caused by fog, rain etc., at a distance from the location where panel was mounted, did not affect proper direction finding.

The automatic sun tracker was implemented with a dc motor and a dc motor controller. The solar energy conversion unit consist of an array of solar panels, a step-up chopper, a single-phase inverter, ac power source and a microcontroller based control unit. High efficiency was achieved through the automatic sun tracker and the MPP detector. In this system, the MPP detection and the power conversion were realized by using the same hardware circuit. In the existing MPP detectors, the detection of the MPP was achieved by using analog computing, comparing, and holding. In contrast to the existed ones, in the new system, MPP was detected by software which was embedded in a microcontroller[3-8]

2. Proposed System

The proposed system consists of a fixed or movable solar tracking system, DC-DC boost converter, inverter, switching circuit and master control circuit for inverter and boost converter. From fig 1. The power generated from the solar panel is stored in the battery. Boost converter takes the input from the Battery and boosts the voltage as per our requirement. The output of the boost converter is connected to the inverter to convert DC voltage into AC voltage. AC voltage is given to load.

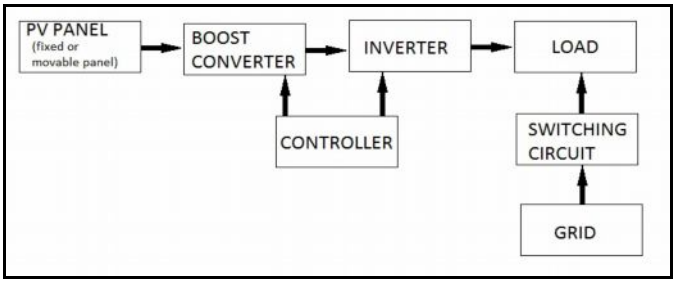

Fig. 1 Block diagram of the proposed system

2.1 Movable solar Tracking system

In this method the solar panel is moved according to the sun's direction to trap 75% to 80% of the solar energy. Automatic solar tracking is required for moving the panel. This movable tracking system consists of small and less complicated control circuits. The output of the light sensor controls the operation of the geared motor. The control circuits consume less power and easy to implement with available electronic components.

Geared motor is controlled by an electronic controller. In the existing system maximum energy from the sun is received only from 11 am to 2 pm, because solar panel is always kept tilted at 30°north and charges a small alkaline (12 volts) battery. A new method has been introduced, where sunlight is tracked from morning 6 am to 6 pm by moving the solar panel along with the movement of the sun using geared motor which is controlled by an electronic control circuit. On implementation of the proposed system, at least 30% extra energy will be trapped compared to the existing system. [10-15].

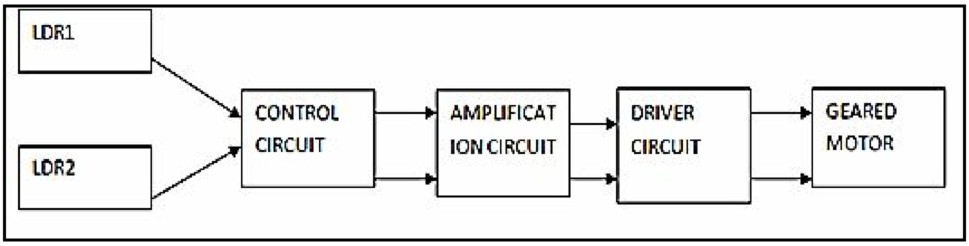

Fig. 2 Movable Tracking system

Conventional solar panels tilted and rigidly fixed at a certain angle, limits their area of exposure to the sun during the entire course of the day. Therefore, the average solar energy trapped is not maximized. Solar tracking systems are essential for solar energy based power generation systems. The control circuit is used to sense the light falling on the LDR. When the control circuit senses the light it closes the switch in the circuit. The LDR and a trim pot form a voltage divider which is used to apply bias to a transistor. As the LDR changes resistance the change in potential is detected by the circuit and the relay is activated.

Table 1Comparison of fixed and movable tracking

Fixed panel tracking		Movable panel tracking	
Time	**Voltage**	**Time**	**Voltage**
8.00 AM-12.00 PM	3.8	8.00 AM-12.00 PM	4.4
12.00 PM-4.00PM	4.2	12.00 PM-4.00 PM	5

2.2 DC-DC Boost Converter

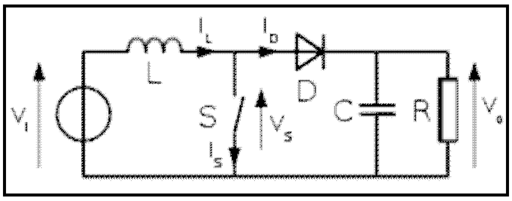

Fig. 3 Boost Converter

When the switch is closed, current flows through the inductor in clockwise direction and the inductor stores the energy. Polarity of the left side of the inductor is positive. When the switch is opened, current will be reduced as the impedance is higher. Therefore, change or reduction in current will be opposed by the inductor. Thus the polarity will be reversed. As a result two sources will be in series causing a higher voltage to charge the capacitor through the diode D. If the switch is cycled fast enough, the inductor will not discharge fully in between charging stages, and the load will always see a voltage greater than that of the input source alone when the switch is opened. The blocking diode prevents the capacitor from discharging through the switch. During the On-state, the switch S is closed, resulting in an increase in the inductor current.

In the Off-state, the switch is open and the only path offered to inductor current is through the flyback diode D, the capacitor C and the load R. This results in transferring the energy accumulated during the On-state into the capacitor. The input current is the same as the inductor current. So it is not discontinuous as in the buck converter and the requirements on the input filter are relaxed compared to those of a buck converter.

2.3. Inverter

Fourier analysis reveals that a waveform, like a square wave, that is anti-symmetrical about the 180 degree point contains only odd harmonics, the 3rd, 5th, 7th, etc. Waveforms that have steps of certain widths and heights can attenuate certain lower harmonics at the expense of amplifying higher harmonics. For example, by inserting a zero-voltage step between the positive and negative sections of the square-wave, all of the harmonics that are divisible by three (3rd and 9th, etc.) can be eliminated. That leaves only the 5th, 7th, 11th, 13th etc. The required width of the steps is one third of the period for each of the positive and negative steps and one sixth of the period for each of the zero-voltage steps. Changing the square wave as described above is an example of pulse-width modulation (PWM). Modulating, or regulating the width of a square-wave pulse is often used as a method of regulating or adjusting an inverter's output voltage. When voltage control is not required, a fixed pulse width can be selected to reduce or eliminate selected harmonics. Harmonic elimination techniques are generally applied to the lowest harmonics because filtering is much more practical at high frequencies, where the filter components can be much smaller and less expensive. Multiple pulse-width or carrier based PWM control schemes produce waveforms that are composed of many narrow pulses. The frequency represented by the number of narrow pulses per second is called the switching frequency or carrier frequency. These control schemes are often used in variable-frequency motor control inverters, because they allow a wide range of output voltage and frequency adjustment also improve the quality of the waveform.

Multilevel inverters provide another approach to harmonic cancellation. Multilevel inverters provide an output waveform that exhibits multiple steps at several voltage levels. For example, it is possible to produce a more sinusoidal wave by having split-rail direct current inputs at two voltages, or positive and negative inputs with a central ground. By connecting the inverter output terminals in sequence between the positive rail and ground, the positive rail and the negative rail, the ground rail and the negative rail, then both to the ground rail, a stepped waveform is generated at the inverter output. This is an example of a three level inverter: the two voltages and ground.[9-11].

2.4. Control Circuit

PIC16F877 has 5 basic input/output ports. They are usually denoted by PORT A, B , C , D, and PORT E . These ports are used for input/ output interfacing. In this controller, "PORT A" is only 6 bits wide, PORT B, C,D are 8 bits wide, PORT E has width of 3 bits. All these ports are bi-directional. The direction of the port is controlled by using TRIS(X) registers (TRIS A used to set the direction of PORT-A, TRIS B used to set the direction for PORT-B, etc.). Setting a TRIS(X) bit '1' will set the corresponding PORT(X) bit as input. Clearing a TRIS(X) bit '0' will set the corresponding PORT(X) bit as output.

3. Simulation and Results

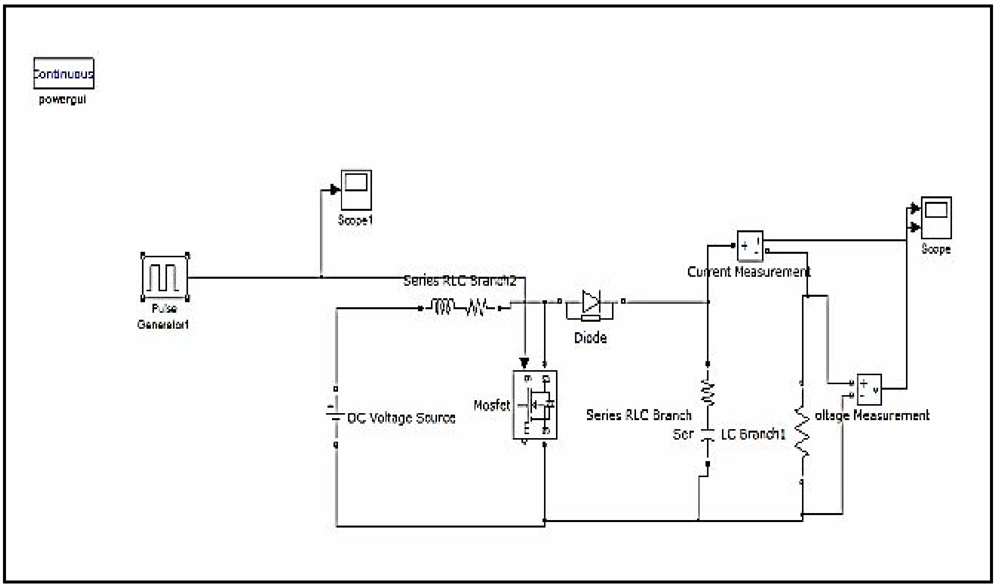

Fig. 4 : simulink model of boost converter

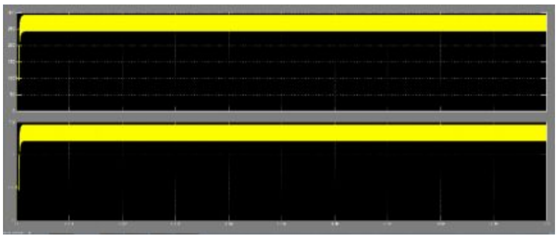

Fig .5: Result for boost converter

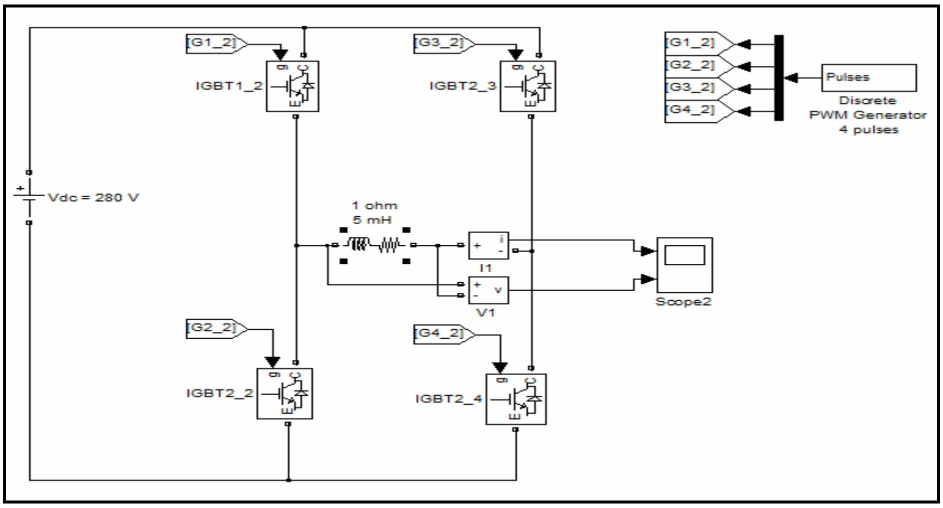

Fig. 6: Simulink block for inverter

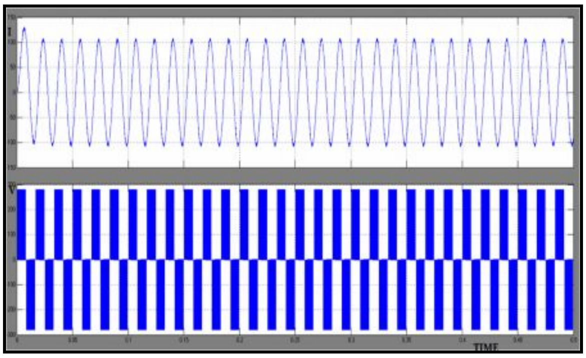

Fig. 7: Inverter output voltage.

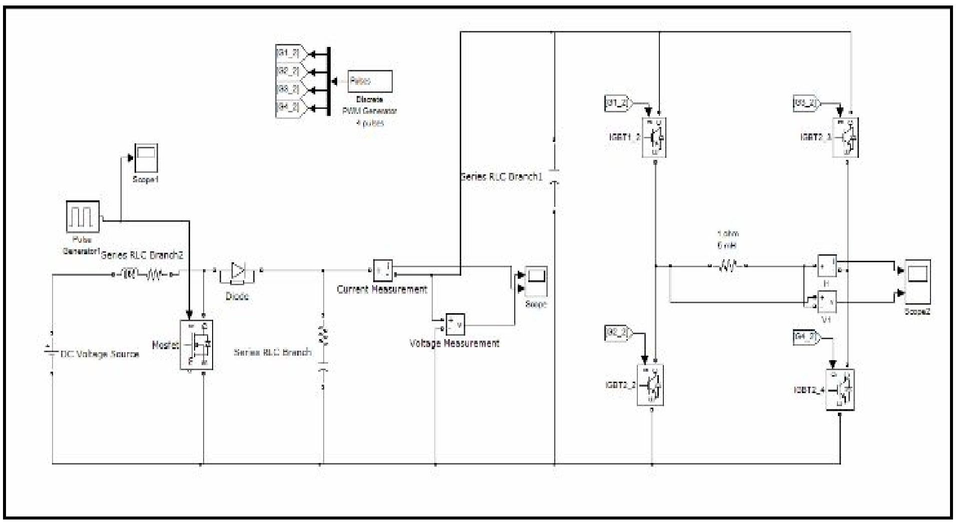

Fig. 8: Simulink block for boost converter integrated with inverter

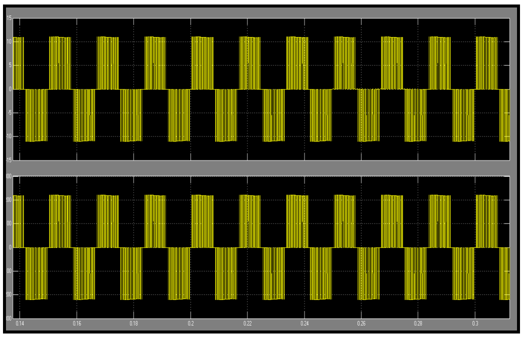

Fig. 9: Result for boost converter with inverter

Fig. 10: Solar panel arrangement

Solar panel parameters are 3w panel, 18 solar cells with each cell voltage of 0.5-0.7 V. The Output voltage of the panel varies from 8.5V to 10.5V.Solar panel is a packaged, connected assembly of photovoltaic cells. The solar panel can be used as a component of a larger photovoltaic system to generate and supply electricity, in commercial and residential applications. Each panel is rated by its DC output power under standard test conditions, which typically ranges from 100 to 320 Watts. The efficiency of a panel determines the area of a panel for the same rated output. For an example, 8% efficient 230 Watt panel will have twice the area of a 16% efficient 230 Watt panel. Because a single solar panel can produce only a limited amount of power, most installations contain multiple panels. A photovoltaic-system typically includes an array of solar panels, an inverter, a battery and/ or solar tracker and interconnection wiring. Solar panel receives irradiance from sun and provides the output voltage in the form of DC. The DC voltage from the panel is given to the DC-DC boost converter. Control circuit is used to generate the pulses to stepper motor drive for rotations and generate the pulses to turn on the switches in boost converter and inverter. The pulses generated from the PIC microcontroller has an amplitude of 5V only, but the turn on voltage of switch is 12V, so the amplifier circuit amplifies 5V to 12V. Buffer IC (CD3040) is used to match the signal level between different stages. They also boost the signal, enabling it to travel through long cables or through bunch of pedals. Opto-coupler (MO2E1310) is used for separation and intensification of a signal. Typical examples are relays which require higher current than microcontroller pin can provide. Usually, Opto-coupler is used for separating microcontroller supply and relay supply. In case of a breakdown, optocoupled part of device stays safe in its casing, reducing the repair costs. Transistor (CK100) is used for amplify the voltage 5V to 12V. Darlington pair is used because it is a compound structure consisting of two bipolar transistors (either integrated or separated devices) connected in such a way that the current amplified by the first transistor is amplified further by the second one. This configuration gives a much higher common emitter current gain than each transistor taken separately and, integrated devices take less space than two individual transistors because they can use a shared collector. Capacitor (1000µf, 25V) is used for filtering the pulsating DC.

Fig.11: Movable solar tracking model

The proposed system consists of a small and less complicated control circuit which is supplied with the output of light sensors and based upon these inputs it controls the operation of the geared motor. Also, the circuits consume less power and are easy to implement with available electronic components. A photovoltaic module or photovoltaic panel is a packaged interconnected assembly of photovoltaic cells, also known as solar cells. A typical silicon PV cell is composed of a thin wafer consisting of an ultra-thin layer of phosphorus-doped (N-type) silicon on top of a thicker layer of boron-doped (P type) silicon. Regardless of size, a typical silicon PV cell produces about 0.5 – 0.6 Volt DC under open-circuit and no-load conditions. The current (and power) output of a PV cell depends on its efficiency and size (surface area), and is proportional to the intensity of sunlight striking the surface of the cell. The photovoltaic module, known more commonly as the solar panel, uses light energy (photons) from the sun to generate electricity through the photovoltaic effect.[4-7]

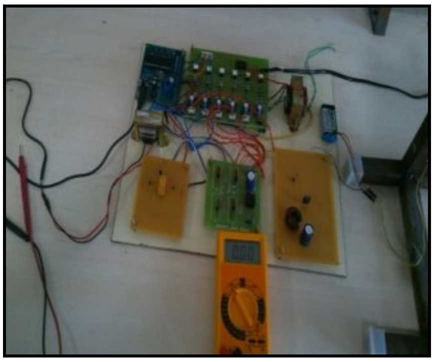

Fig. 12: solar power conversion circuit

Solar panel output is DC voltage. This DC voltage is input to the Boost converter, Boost converter boosts the voltage. Boosted voltage is input to the inverter, inverter converts the DC voltage into AC voltage. Control circuit produce pulses (5V) to turn on the switches. Amplification circuit will amplify the 5V of AC voltage into 12V of AC to turn on the switches in boost converter and inverter. [15-21]

4. Grid Integration

The automatic control of switching through the Solar panels and the city grid is employed in order to avoid the storage battery from being exhausted and closed. It reduces the utilization of power from conventional energy sources. In the proposed system Darlington circuit with the relay and photosensitive resistance are used to achieve the switching. When the circuit needs high input impedance, or large current gain, two cascaded transistors are used to build the Darlington amplifier. So the relay combine with the use of Darlington transistors are simple, easy and inexpensive to build such automatic switching circuit. Public contact of relay is represented by COM. When the COM interlinked with those for the B-point, relay coil is not powered often called as NC (normally close). While those who do not usually interlinked with the COM as the A point, often called as NO (normally open). When at no power, COM is the same as NC. But when the current flows through the coil, the coil will produce magnetic suction under the armature, making NO and COM interlinked. Therefore, as long as we control the coils with the power or not, and can take advantage of the relay contact to control the circuits on or off. Therefore, when solar power is sufficient, its output voltage is connected to the NC, the city grid is connected to NO. Light-sensitive resistors are used, because of low price. The photosensitive resistors are commonly made of Cadmium sulfide (CdS). When the light is strong, the resistance decreases and vice versa.

Fig. 13: Prototype model for solar power system

The movable solar tracking is inter connected to conversion system. When the capacity of the solar panel and the storage battery are insufficient for the load, the power switch will automatically switch to the municipal city electricity, therefore, the load can be utilized for throughout the day. The output 230V AC can be supplied to the general household load for use. Finally, after getting the solar power, turn off the city grid power and utilize the power generated from the solar cells.[18-19]

5. Conclusion

In this paper the small scale hardware model of a low cost automatic solar energy tracking system has been designed and successfully implemented. Analysis and design of solar photovoltaic energy converter, the circuit structure designed to include DC to- DC converter, DC-to-AC Inverter and its integrity in order to achieve the final goal of stabilizing the AC output. Also, it includes the switching circuit to switch between the city grid and solar panels. Under the independent mode of operation, this system can directly convert the solar power into a 50 Hz, AC voltage to provide to the small household load. The experimental data verify this feasibility.The designed system requires minimum maintenance with a practically good level of improvement in system efficiency for the comparatively low cost. Further the efficiency of the solar power conversion can be increased by replacing the Z-source inverter in place of boost converter and voltage source inverter. Z-source inverter has single stage conversion and performs both the functions of boost converter and inverter. If large capacity of PV panels are used the generated power utilized by the load and excess power can be given to the grid.

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