# Dual mode DC-DC Power Converter for Solar Battery Charger

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***Abstract***

*Solar charged battery systems provide power supply for complete 24 hours a day irrespective of bad weather. By adopting the appropriate technology for the concerned geographical location, we can extract a large amount of power from solar radiations. More over solar energy is expected to be the most promising alternate source of energy. The global search and the rise in the cost of conventional fossil fuel is making supply-demand of electricity product almost impossible especially in some remote areas. A power converter is a key technology in the applications of solar power generation. This work proposes a new solar battery charger. The solar battery charger is composed of two solar modules and a dual-mode DC-DC power converter. The operation of dual-mode DC-DC power converter is divided into two modes. One is the switched series/parallel operation of solar modules, and the other is the parallel operation of solar modules. It is suitable for the solar application because of expanding the input voltage.*

***Keywords*** **-** *Power Converter, Dual Mode, Solar Radiation, Solar Modules, Solar battery*.

## I. INTRODUCTION

It is well-known that the world is facing a major threat of fast depletion of the fossil fuel reserves. Most of the present energy demand is met by fossil and nuclear power plants. A small part is met by renewable energy technologies such as the wind, solar, biomass, geothermal, etc. There will soon be a time when we will face a severe fuel shortage. As per the law of conservation of energy, "Energy can neither be created, nor be destroyed, but it can only be converted from one form to another". Most of the research now is about how to conserve the energy and how to utilize the energy in a better way. Research has also been into the development of reliable and robust system to harness energy from non-conventional energy resources. Among them, the solar power sources have experienced a remarkably rapid growth in the past 10 years. This is pollution free source of abundant power**.**

The solar energy has attracted more interest. The solar cell is a semiconductor device which converts the energy of sunlight to an electric energy. The price of the solar cell drops obviously and continuously because of mass production and technological

progress. The solar cell array will generate a dc power when sunlight shines. However, the output dc power of solar cell is irregular and dependent on the operating conditions, such as: temperature, light intensity and material, and it cannot supply load directly. Since output voltage and current of single solar cell is low, several solar cells should be connected in parallel and in series to be a solar module. The output power of solar module is proportional to the irradiance level. It can be found that the higher temperature will result in the lower output power of solar module.

Battery will generate an electrical power by an electrochemical reaction, and it is charged by electrical energy to reduce the chemical energy for cyclical use. Accordingly, the battery is an important energy storage element, and it is widely applied to the portable electronic products, electric vehicles, and back-up power systems. Conventionally, the battery is charged from the utility through a grid-connected battery charger. However, sunlight exists everywhere and is free such that the solar battery charger is attractive. A DC-DC power converter should be inserted between the solar module and the battery.

### *A. Literature Review*

The work in [1] presents the study of bidirectional DC to DC converter and comparing with the various existing method techniques. The proposed converter is designed in the manner of closed loop control. By using a controller, we can obtain a high output voltage and high gain by controlling the duty cycle of switches. The DC/DC converter is constructed by a buck-boost circuit, which is operated as a buck circuit when charging and a boost circuit when discharging. So we can use many power related systems, which improves efficiency, lower losses and higher performance.

The energy storage devices are necessary to the stand alone PV generation system [2]. Lead acid battery which performance is specially designed is suitable for PV generation application. The battery charging and discharging control with the max power of PV array is the key point to increase efficiency of the generation system. In this paper, the new system configuration with parallel battery charger is

designed. The conversion steps are decreased and system conversion efficiency is increased. The two module MPPT coordinate control is designed to increase PV utilizing efficiency. According to the different battery characteristics, the battery management is optimized for better performance and longer life time. The performance and total efficiency of PV generating system can be improved for stand-alone application. The experimental results of the prototype verify the effectiveness of proposed protocol and strategy.

The Objectives of this work is to study the performance analysis power monitoring between the photovoltaic panel and battery by connecting the dual mode input in automatic series/parallel mode. To compare the output power from the boost converter when operated in series mode and parallel mode.

## II. PV ENERGY CONVERSION SYSTEM

### *A. Off-Grid PV Energy System*

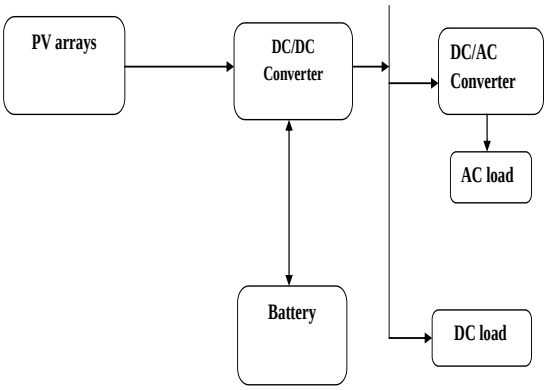
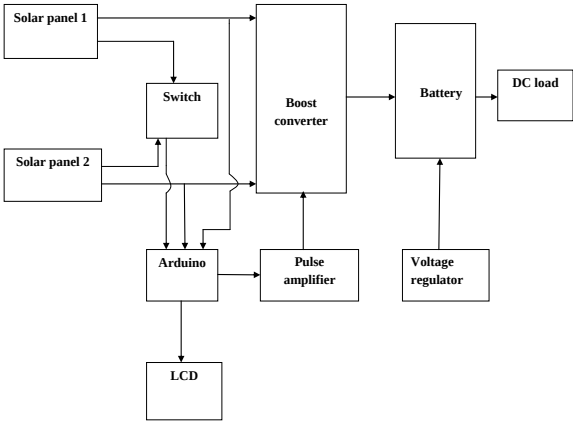



**Fig 2.1: Basic off-Grid PV Energy System**

The off-grid PV system shown in figure 2.1 are usually used in rural or remote areas, where the grid is not available or not accessible. The off-grid systems can be further divided into two sub-categories: domestic and non-domestic applications. In the former the PV system is used to provide electricity for small communities, where connection to the power grid is not feasible. Usually small PV systems (<5KW) are used for household applications together with an energy storage unit and back-up system. In the latter, the PV system is used t energize a single industrial or agricultural load that is not connected to the grid, such as water pump, traffic light or telecommunication equipment. A battery unit is used to store energy. An off-grid PV energy system consists of a solar array connected to DC-DC converter, a battery bank and an optional DC/AC inverter can be used.

### *B. Basic Block Diagram*

Figure 2.3 shows the power circuit of proposed solar battery charger. The solar battery charger is composed of two solar modules and a dual-input DC-DC power converter. The two solar modules are connected to the dual mode ports of dual-mode DC-DC power.




**2.2: Basic block diagram**

Fig 2.2 shows the schematic diagram representation of dual mode DC-DC power converter. It mainly consists of photovoltaic panel as non-conventional energy source, DC-DC boost converter, Arduino, Microcontroller board, DPDT relay, LCD, Pulse amplifier, Voltage regulator. The arrangement also consists of battery which acts as a conventional energy sources.

### *C. Operating Principle*

#### *a) Circuit Diagram*

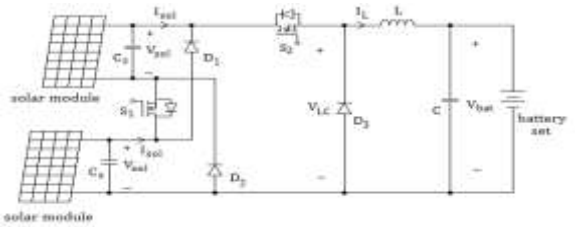



**Fig. 2.3: Power Circuit diagram of project**

converter and the output of dual-mode DC-DC power converter is connected to a battery set. The dual-mode DC-DC power converter is composed of two power electronic switches (S1 and S2), three diodes (D1, D2 and D3) and a low-pass filter (L and C). The dual-mode DC-DC power converter integrates two types of boost power converter. When the power electronic switch S2 is still in the on state and the power electronic switch S1 is switched in high-frequency pulse-width modulation (PWM), the dual-mode DC-DC power converter is operated as the first type boost power converter. The solar battery charger is operated in the switched series/parallel mode, and

two solar modules will be alternately connected in series and in parallel according to the state of power electronic switch S1 to charge the battery set.

The proposed solar battery charger is operated in the switched series/parallel mode when the voltage of battery set is higher than the voltage of single solar module but smaller than two times the voltage of single solar module. The operation circuit of solar battery charger is shown in Fig. 3 where two solar modules are considered as the same. The power electronic switch S1 is switched in high-frequency PWM. When the power electronic switch S1 is in the on state, the operation circuit of solar battery charger is shown in figure 2.4 (a). The two solar modules are connected in series.

***b) Switched Series/Parallel Mode***

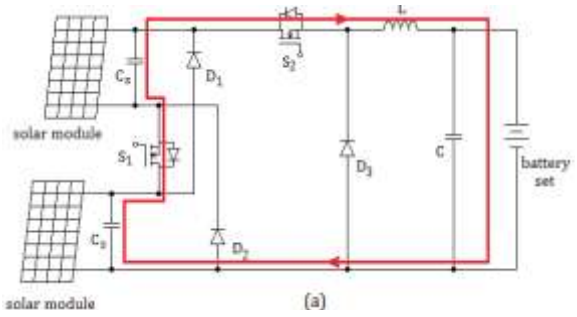



**Fig 2.4: Switched series/parallel mode**

The voltage across the input of low-pass filter is two times the voltage of solar module. The change rate for the inductor current of low-pass filter is

$$\frac{dI_L}{dt} = \frac{2Vsol - Vbat}{L} \quad \text{.....(1)}$$

operation circuit of solar battery charger under the switched series/parallel mode ,fig (a) the power electronic switch S1 is in the on state, fig (b) the power electronic switch S1 is in the off state. Where Vsol and Vbat are respectively the voltage of solar module and the battery set, and L is the inductor of low-pass filter.

***c) Parallel Mode***

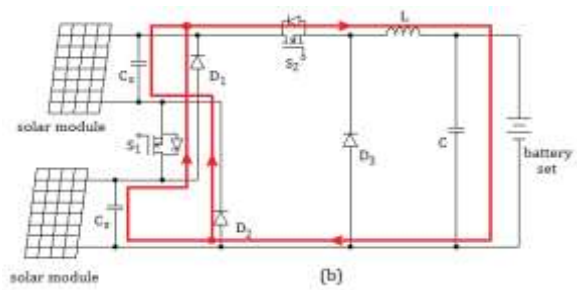



**Fig 2.4: Parallel mode**

The proposed solar battery charger is operated in the parallel mode when the voltage of single solar module is higher than the voltage of battery set. The dual-mode DC-DC power converter is similar to a conventional buck power converter while the input voltage is the voltage of single solar module. The power electronic switch S1 is still in the off state and the power electronic switch S2 is switched in high figure 2.4(b) operation circuit of solar battery charger under the parallel mode, fig(a) the power electronic switch S2 is in the on state, fig (b) the power electronic switch S2 is in the off state frequency PWM. When the power electronic switch S2 is in the on state, the operation circuit of solar battery charger shown in fig (a) . The voltage across the input of low-pass filter is the voltage of solar module. The change rate for the inductor current of low-pass filter is:

$$\frac{dI_L}{dt} = \frac{Vsol - Vbat}{L} \quad \text{.....(2)}$$

## III. Hardware Implementation of proposed work

### *A. Components Used*

| Components | Type/range | Quantity |
|---|---|---|
| Photovoltaic panel | 12W | 2 |
| Boost Converter | 13V | 1 |
| DPDT relay | 12v,285 ohm | 1 |
| Arduino | 5V,16 PIN | 1 |
| Battery | 12 V | 1 |
| Capacitor | 1000e-6F | 8 |
| Resistor | 1K | 4 |
| MOSFET | 7471 | 1 |
| Power Supply | 12v | 1 |
| Inductor | 40 turns | 1 |
| LCD | 16x2 | 1 |
| LED | - | 1 |
| Voltage Regulator | - | 3 |
| Pulse Amplifier | L293D | 1 |
| Diode | Semiconductor | 5 |

### *B. Practical setup of the proposed work*

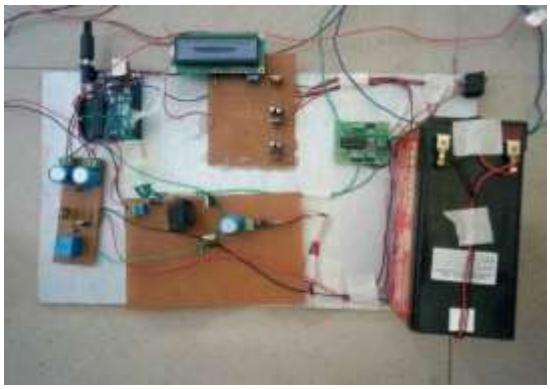


**Fig.5: Practical setup of the proposed work**

### *C. Working*

When sunlight falls on the photovoltaic panel, these uses light energy from the sun to generate electricity through photovoltaic effect so we get DC voltage .The voltage which is available from the solar array is variable and less. In order to obtain constant voltage DC-DC converter is used the voltage generated by array is less. It can be increased by interfacing it with boost converter which considerably steps up the output voltage which could meet the demand of power. The microcontroller is programmed to generate the firing pulses with fixed duty cycle using PWM techniques.

It has inbuilt microcontroller and A/D converter. The arrangement also consists of Arduino board it consists of 14 digital input /output pins. MOSFET pulses pin connected to output of the pulse amplifier and is input is connected to pin 10 of the arduino board. The pin 12 of board acts a toggle switch pin. The arrangement also consists of DPDT relay acts as a decision making device that detects abnormal or fault conditions and initiate actions. It is connected to the switch S1. On the other side the battery is used as conventional energy sources which connected to the converter.

When the voltage is high the panels are connected in series. When the voltage is below 6v it will automatically connected in parallely through switch S1 .It will boost up the generated voltage and generated voltage is stored in a battery. It is verified both by experimentally with a laboratory prototype.

## IV. RESULTS AND DISCUSSION

The solar module is kept out from morning 8:00AM to 5:30PM. Most of the time the modules were connected in parallel in between 10:00AM to 4:30PM. Early morning and late evening the solar modules were connected in series. The variation of individual panel voltage of affects the output power from the boost converter.

| Time | Mode S-series P-parallel | Boost i/p voltage from solar panel | Individual panel voltage | Input current | Vo | Io | Power Po |
|---|---|---|---|---|---|---|---|
| 8:00 | S | 8.4 | 4.2 | 0.38 | 13.2 | 0.24 | 3.192 |
| 9:00 | S | 11.6 | 5.8 | 0.41 | 13.6 | 0.34 | 4.756 |
| 9:30 | P | 8.2 | 8.2 | 0.76 | 13.1 | 0.55 | 7.22 |
| 10:30 | P | 10.6 | 10.6 | 0.8 | 13.4 | 0.63 | 8.48 |
| 11:30 | P | 12.8 | 12.8 | 0.86 | 13.6 | 0.80 | 11 |
| 12:30 | P | 17.2 | 17.2 | 1.4 | 17.2 | 1.4 | 24.08 |
| 1:30 | P | 16.8 | 16.8 | 1.34 | 16.8. | 1.33 | 22.5 |
| 2:30 | P | 13.6 | 13.6 | 1.2 | 13.6 | 1.2 | 16.32 |
| 3:30 | P | 11.4 | 11.4 | 0.84 | 13.2 | 0.72 | 9.56 |
| 4:30 | P | 8.1 | 8.1 | 0.76 | 13.6 | 0.45 | 6.14 |
| 5:00 | S | 11.2 | 5.6 | 0.41 | 13.1 | 0.35 | 4.59 |
| 5:30 | S | 8.3 | 4.15 | 0.36 | 13.2 | 0.23 | 3.11 |

The solar battery charger is operated in the switched series/parallel mode, and two solar modules will be alternately connected in series and in parallel according to the state of power electronic switch S1 to charge the battery set. The parallel connection of solar modules has high power output and it can charge the battery very fast.

## V. Advantages and Applications

### *A. Advantages*

- Enhanced Energy independence and security.
- Reduced local distribution losses.
- Increased reliability.
- Lower operation and maintenance cost.
- It will reduce the power bill.
- It is comparatively easier to install.

- Eliminates the transportation and delivery cost.
- The battery is charged very fast.
- It is more efficient.

**5.2 Applications**

- Hybrid power system.
- Home automation.
- Healthcare.
- Smart metering.
- Agriculture.
- PV with backup generator power.
- **Utility-scale power production.**

## VI. CONCLUSIONS

A power converter is a key technology in the applications of solar power generation. A new solar battery charger is proposed in this paper. The proposed solar battery charger is composed of two solar modules and a dual-input DC-DC power converter. The operation of dual-input DC-DC power converter is divided into the switched series/parallel operation of solar modules and the parallel operation of solar modules. The salient feature of the proposed solar battery charger is that both the voltage variation across to the input of low-pass filter and the voltage variations of each switching operation for the power electronic switches S1 and S2 are reduced as compared with the conventional solar battery charger regardless the operation mode of dual-input DC-DC power converter. Hence the passive elements of dual-input DC-DC power converter can be reduced. In addition, the proposed solar battery charger can perform the functions of MPPT to harvest the maximum power of solar module. The experimental results verify that the proposed solar charger can reduce both the voltage variation across the input of low-pass filter and the voltage variations of each switching operation for the power electronic switches S1 and S2 and trace the maximum power of solar module. The proposed device is prototype which accepts 230V but in future it can be apply for higher version like 11KV and more 11KV .This project can be implemented for single phase therefore reducing complexity of hardware development. It can also be implemented for different loads, different control strategies and for smart grid.

## ACKNOWLEDGEMENT

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