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MPPT Algorithm Based Bidirectional DC-DC Converter Using Solar PV Array

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ABSTRACT

An integrated system of Bidirectional DC/DC Converter with Solar PV module and DC load has been proposed in this paper. The main aim of this paper is to meet the load demand at every instant of time by keeping the DC bus voltage constant with the help of Bidirectional DC/DC converter integrated with the Solar PV module also to implement the MPPT algorithms to track the maximum power from the solar PV array. This converter can operate with Perturb and Observe algorithm based soft- switching. Soft switching is provided to reduce the losses and stresses on switches. In BIDC we have a high gain output through the solar array which is charging the EV battery and gives the high performance of the battery. In the proposed system improve the performance and suitable to connect the multilevel inverters due to the presence of different inputs at different voltage levels., which is also used to improve the efficiency of bidirectional dc/dc converter and reduced switching loss, switching stress. The PV module is operated at maximum power point using MPPT technique. Perturb and Observe method of MPPT has been used in this paper. The solar PV array fed EV battery with the bidirectional DC-DC converter are modelled and simulated using MATLAB Simulink and the results are shown in the paper.

Keywords— Bidirectional DC/DC Converter, Solar PV, Arduino UNO microcontroller

I. INTRODUCTION

The purpose of Bidirectional DC/DC Converter is to help maintain the terminal load voltage constant, despite varying irradiance level, while employing MPPT. Perturb and Observe algorithm is used as the MPPT method. The Bidirectional DC/DC Converter can operate both as a buck converter as well as a boost converter, thereby managing the power flow between PV array, battery and load.

In case of sufficient solar insulation level, PV arrays supply the load requirement and the surplus power is directed to the battery Through the Bidirectional DC/DC Converter to charge it and hence the converter operates in buck mode.

If the solar insolation level is not high enough to fulfill the load requirement, for example during night or rainy season, then in that case, the energy stored in the battery must be delivered to the load through the Bidirectional DC/DC Converter, thereby operating in boost mode. Therefore, the dual mode DC/DC converter must be able to handle the energy flow in both the directions and hence operate in buck as well as boost mode according to the load requirement and the solar power available at that moment. A DC bus acts a point for integration of Bidirectional DC/DC Converter with the PV array and the load.

The proposed architecture augments the charging capability which becomes fast and highly efficient as it consumes power directly from the PV module. Efficient delivery of power to the load by providing a constant voltage at the terminal of load is the primary function of the proposed system.

II. PROPOSED SYSTEM

Figure 1 shows the block diagram consisting of an energy storage system in the form of a battery combined with the Bidirectional DC/DC Converter which integrates it to the PV system and variable DC load. The purpose of Bidirectional DC/DC Converter is to help maintain the terminal load voltage constant, despite varying irradiance level, while employing MPPT. Perturb and Observe algorithm is used as the MPPT method. The Bidirectional DC/DC Converter can operate both as a buck converter as well as a boost converter, thereby managing the power flow between PV array, battery and load. In case of sufficient solar insulation level, PV arrays supply the load requirement and the surplus power is directed to the battery Through the Bidirectional DC/DC Converter to charge it and hence the converter operates in buck mode. If the solar insolation level is not high enough to fulfill the load requirement, for example during night or rainy season, then in that case, the energy stored in the battery must be delivered to the load through the Bidirectional DC/DC Converter, thereby operating in boost mode. Therefore, the dual mode DC/DC converter must be able to handle the energy flow in both the directions and hence operate in buck as well as boost mode according to the load requirement and the solar power available at that moment. A DC bus acts a point for integration of Bidirectional DC/DC Converter with the PV array and the load. The proposed architecture augments the charging capability which becomes fast and highly efficient as it consumes power directly from the PV module. Efficient delivery of power to the load by providing a constant voltage at the terminal of load is the primary function of the proposed system.

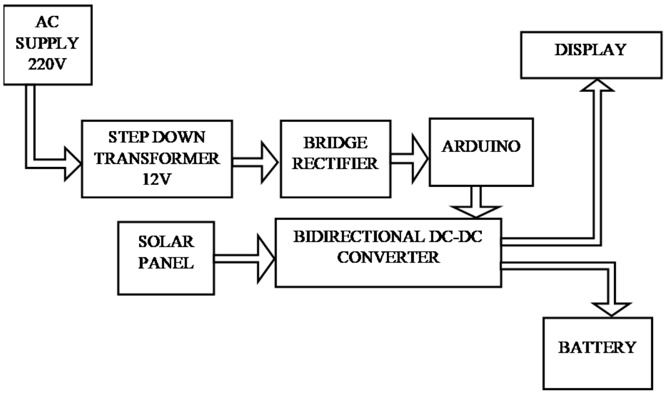

Fig. 1 Block diagram of Proposed System

Bidirectional DC/DC Converter

Bidirectional DC/DC converter is a converter which has the ability of conducting in both the directions between two DC points at different voltage levels. In order to provide power to the variable DC load continuously, and that too in an energy fluctuating natured renewable energy-based system, energy storage systems such as batteries are coupled with this converter having bidirectional power flow capability to compensate this power fluctuation [10]. Therefore, a bidirectional DC/DC converter is simply an electronic circuit or electronic device that converts a source of direct current (DC) from one voltage level to another and is capable of handling power flow in both the directions [9]. Basically, it is a combination of both buck and boost converters and hence it is also called a dual mode or dual switch DC/DC converter. Switched-mode DC-to-DC converters convert one DC voltage level to another, which may be higher or lower, by storing the input energy temporarily and then releasing that energy to the output at a different voltage. The storage may be in either magnetic field storage components (inductors, transformers) or electric field storage components (capacitors) [8]. Switching conversion is more power efficient (often

75% to 98%) than linear voltage regulation, which dissipates unwanted power as heat [10].

DC/DC Boost Converter

A switched mode DC/DC converter is connected in cascade to the output terminal of the PV panel and the duty cycle is set by MPPT to step up the voltage as desired [5]. The DC link capacitor connected across the boost converter regulates the output voltage and maintains it at a constant magnitude irrespective of the variation in the surrounding temperature or the solar irradiance level [1].

III. PROPOSED DESIGN

The basic concept of MPPT algorithm based bidirectional dc-dc converter using solar pv array. The design is as follows:

A. ARDUINO MICROCONTROLLER

A micro-controller is a small computer on a single integrated circuit containing a processor core, memory, and programmable input/ output peripherals The important part for us is that a micro-controller contains the processor (which all computers have) and memory, and some input/output pins that you can control.

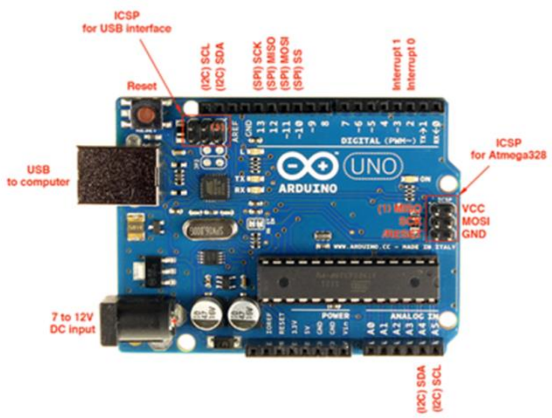

Fig. 2 Block diagram of Proposed System

Often called GPIO – General Purpose Input Output Pins).We will be using the Arduino Uno board. This combines a micro-controller along with all of the extras to make it easy for you to build and debug your projects. The Uno is a microcontroller board based on the ATmega328P. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz quartz crystal, a USB connection, a power jack, an ICSP header and a reset button. It contains everything needed to support the microcontroller.

B. TRANSISTER(TIP-122):

It is a Darlington braces NPN transistor. It works like an ordinary NPN transistor, but as it consists of a Darlington pair it has a decent collector current assessment of nearby 5 amperes and it's gain is around 1000. This transistor is famous for its higher gain of current which 1000 and it uses higher current at collector which is 5 amperes. Due to its higher gain of current and huge collector current (IC), it is used in such loads which use higher current and its uses for such submissions which required higher amplification. This transistor consumes less voltage only five volts across base and emitter, therefore, it can be effortlessly organized by a Logical expedient such as a microcontroller. Though precaution has to do to check if the logic expedient can supply up to 120 mA. So, if you are eyeing for a transistor which can be effortlessly organized by a Logical expedient to modification high power consuming loads or to intensify higher current then this transistor can be a perfect option for your solicitations.

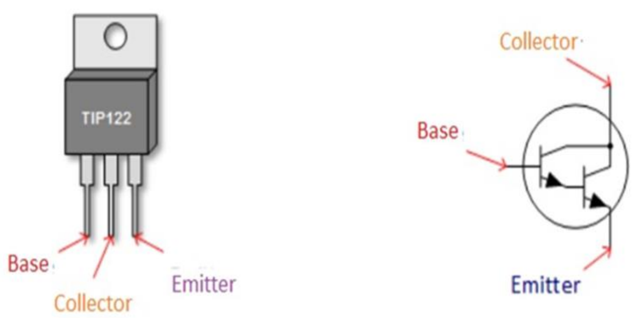

Fig. 3 TIP 122 Transistor

C. SOLAR PANEL:

Solar panel refers to a panel designed to absorb the sun's rays as a source of energy for generating electricity or heating. Photovoltaic modules use light energy (photons). Sun to generate electricity through the photovoltaic effect. The majority of modules use wafer-based crystalline silicon cells or thin-film cells. The structural (load carrying) member of a module can either be the top layer or the back layer. Cells must also be protected from mechanical damage and moisture. Most modules are rigid, but semi-flexible ones are available, based on thin-film cells. The cells must be connected electrically in series, one to another. Externally, most of photovoltaic modules use MC4 connectors type to facilitate easy weatherproof connections to the rest of the system.

Modules electrical connections are made in series to achieve a desired output voltage and/or in parallel to provide a desired current capability. The conducting wires that take the current off the modules may contain silver, copper or other non-magnetic conductive transition metals. Bypass diodes may be incorporated or used externally, in case of partial module shading, to maximize the output of module sections still illuminated.

Fig. 4Solar panel

D. PN JUNCTION DIODE(1N4007):

A p-n junction diode is two-terminal or two-electrode semiconductor device, which allows the electric current in only one direction while blocks the electric current in opposite or reverse direction. ... The p-n junction, which is formed when the p-type and n-type semiconductors are joined, is called as p-n junction diode.

1N 4007 these types of diodes allow only the flow of electrical current in one direction only. So, it can be used for the conversion of AC power to DC. 1N 4007 is electrically compatible with other rectifier diodes and can be used instead of any of the diode belonging to 1N400X series. 1N-4007 has different real-life applications e.g., freewheeling diodes applications, general purpose rectification of power supplies, inverters, converters etc. You can download 1N4007 Datasheet by clicking below button.1N 4007 has two pins in total i.e., anode and cathode respectively.

A properly labeled pin diagram of any device results in better standing of the user. I have made a completely labeled diagram of 1N-4007 diode along with its animation. The complete pinout diagram along with animation, symbolic representation and the real image of 1N 4007 is shown in the figure below.

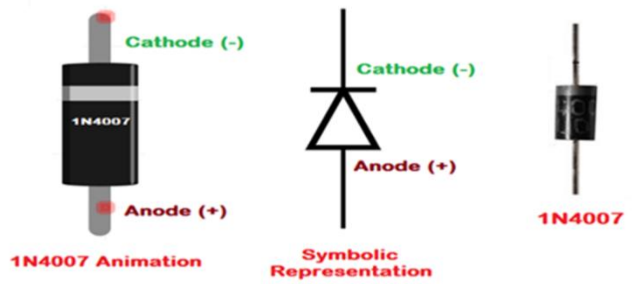

Fig. 5 PN Junction Diode

IV. SIMULATION

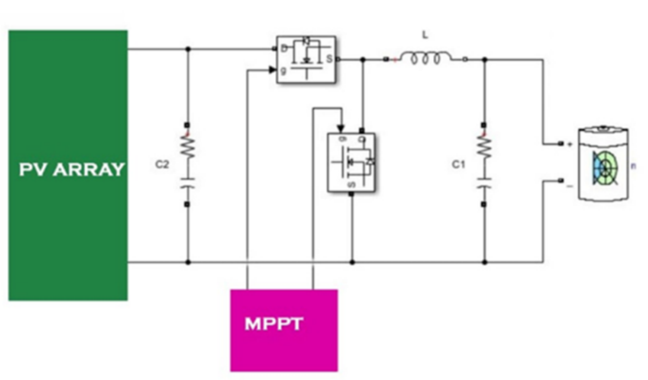

Fig.6 Simulation block diagram

Our project starts with renewable energy source solar pv array where we give the inputs of irradiance and temperature from that we can have the output dc current which is of distorted and various volt. In that we use bidirectional dc-dc converter on giving mpptpwm signal we can make the maximum power from the solar PV array. We use pertube and observe algorithm for mppt to gain the max power. From that we are charging the EV battery. feeding mppt PWM to the MOSFET of bidirectional dc-dc otherwise known as buck - boost converter.

V. MAXIMUM POWER POINT TRACKING

The most popular method used to monitor and improve efficiency of solar panels is Maximum Power Point Tracking, or MPPT. MPPT is measuring the power of the solar panel at given intervals and making sure it is always at its maximum power. A measurement is taken from the solar panel and the power is calculated. After a specified interval, another measurement is taken. These two measurements are compared, and adjustments are made to the solar panel to ensure that the most recent measurement will lead to the maximum power.

Most solar trackers move with regard to the angle of the sun, and do not constantly calculate power. Linak, for example, has two different types of solar tracking systems that both use integrated control actuators. The solar panels can either move 180 degrees (single axis) or can tilt in all different angles using dual access. First Solar and Solar Flexrack have similar trackers that follow the movement of the sun throughout the day. These trackers are controlled by MPPT controllers. Controllers such as the MPPT Tracer Solar Charge Controller are installed and read a solar panel. Based on the information read, all solar panels are adjusted to follow the sun's path.

VI. PERTURB AND OBSERVE

The most commonly used MPPT algorithm is P&O method. This algorithm uses simple feedback arrangement and little measured parameters. In this approach, the module voltage is periodically given a perturbation and the corresponding output power is compared with that at the previous perturbing cycle. In this algorithm a slight perturbation is introduce to the system. This perturbation causes the power of the solar module various. If the power increases due to the perturbation then the perturbation is continued in the same direction. After the peak power is reached the power at the MPP is zero and next instant decreases and hence after that the perturbation reverses as shown in Figures 7 and 8.

When the stable condition is arrived, the algorithm oscillates around the peak power point. In order to maintain the power variation small, the perturbation size is remain very small. The technique is advanced in such a style that it sets a reference voltage of the module corresponding to the peak voltage of the module. A PI controller then acts to transfer the operating point of the module to that particular voltage level. It is observed some power loss due to this perturbation also the fails to track the maximum power under fast changing atmospheric conditions. But remain this technique is very popular and simple.

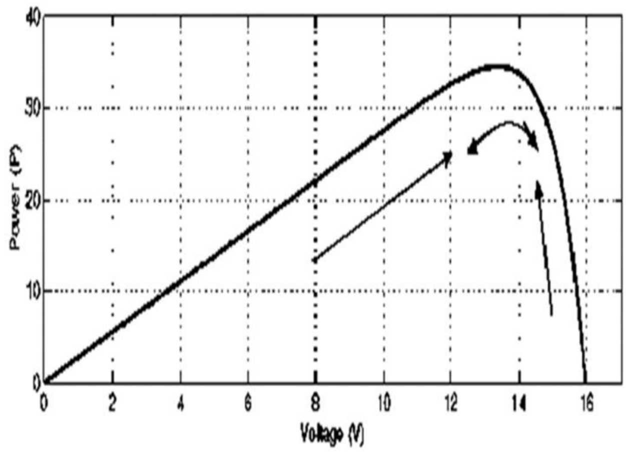

Fig.7 Graph Power versus Voltage for Perturb and Observe Algorithm

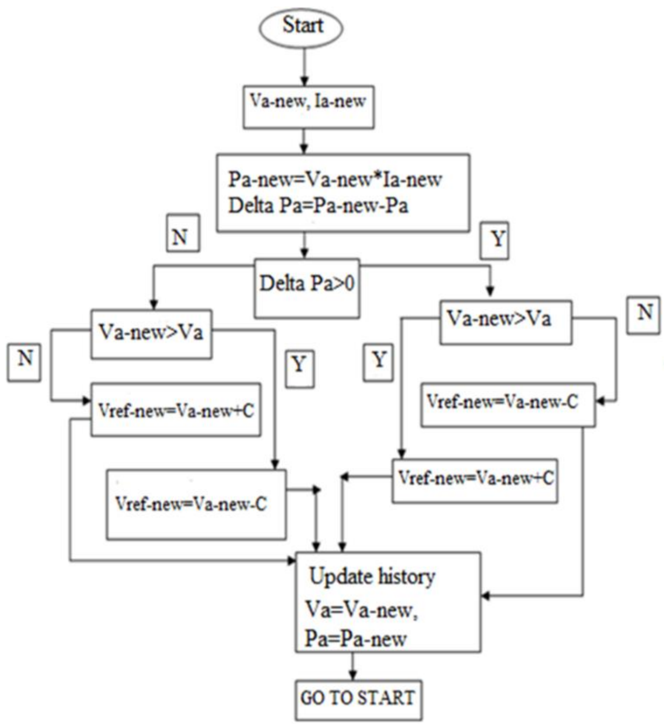

Fig.8 Flowchart of P&O method

VII. SIMULATION RESULTS

The simulation of the proposed system is carried out in MATLAB/SIMULINK software.

The below figure shows the proposed simulation circuit of PV panel in which fixed temperature of 25o C has been taken and varying irradiance level is 1000/m2. Current and voltage is taken as an input to the MPPT sub circuit which are then evaluated according to MPPT algorithm and the desired gating signal is fed to the boost converter. The current and voltage are changed into discrete values, the present and past values of current and voltage are multiplied respectively to obtain the present and past values of power. Then (Pn-Pb) and (Vn-Vb) is calculated where Pn and Pb are new and previous power and Vn and Vb are new and previous voltage values.

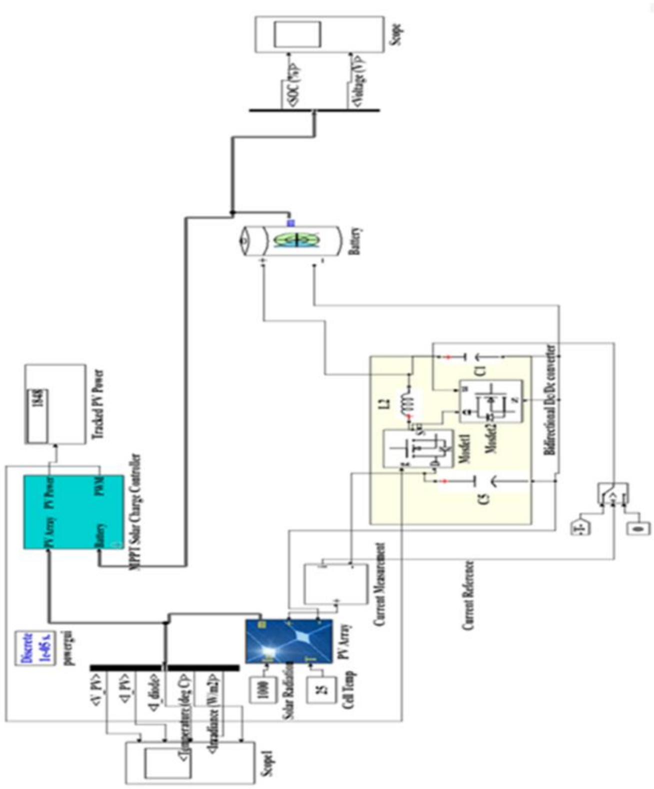

Fig. 9 Simulation Circuit Diagram

The difference of voltage and power are multiplied, if the product is positive i.e. either both are positive or both are negative then the output voltage is increased and if the product is negative i.e. either difference in voltage is negative or difference in power is negative the output voltage is increased in order to maximize the power output of solar panel in accordance to perturb and observe algorithm.

The circuit of Bidirectional DC/DC Converter in which there are 2 MOSFET switches – MOSFET1 and MOSFET2. By appropriate gating of these switches, we can control their operation in buck and boost mode. In the control mechanism the reference voltage has been taken as 12V and the switching occurs at 25 kHz. When switch 1 operates the power is transferred from dc bus to battery otherwise when switch 2 operates the power is transferred from battery to load.

It consists of solar PV module, boost converter, Bidirectional DC/DC Converter and battery which are connected to load. The load is increased at an interval of 1 second during simulation by choosing different resistors. Due to the variation in the level of solar irradiation the output of the solar PV module changes. To convert the wide range of DC output voltage into a steady voltage on DC bus, a DC link capacitor is used in the system. Similarly, the charging and discharging of battery may be readily realized by controlling the converter. In the simulation circuit there are 2 modes of operation,

1. First when the load power is supplied only by solar PV module in case of sufficient solar power and surplus power is directed to the battery.
2. Second when power is supplied by combination of battery and solar power in case of insufficient solar power supply.

As the load requirement is low and solar power is sufficient to supply the load, the battery current is positive i.e. solar power supplies the load as well as charges the battery but as the load requirement increases, the solar power is not able to supply the load, so the battery also supplies the power to the load.As the load requirement goes on increasing after every 1 second, the battery current is seen to be going more and more negative i.e. the battery supplies more and more power.

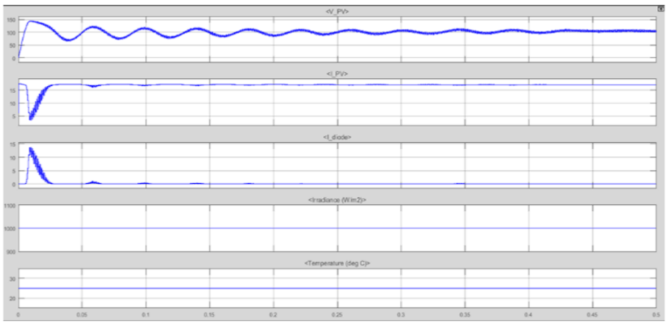

Fig. 10 Solar Irradiance Level,Load Power and Solar Power, Load Voltage Profile

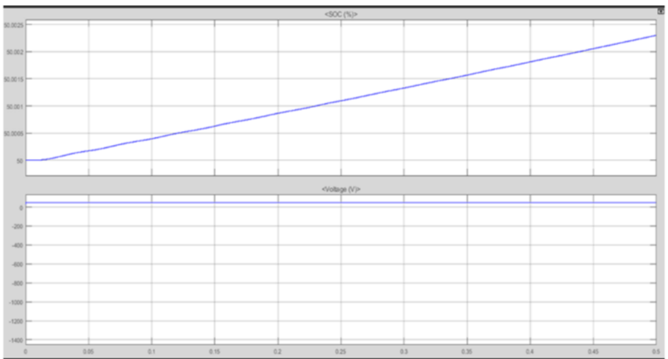

Fig. 11Efficiency, Battery Current

S. No	Components	Specifications
1	Bidirectional Switching Frequency	25Khz
2	PWM Switching Frequency	1000Hz
3	Battery Voltage	48V
4	Solar PV Power	250W
5	Bidirectional Capacitor	1000e-6mF
6	Bidirectional Inductor	10e-3mH
7	Internal Diode Resistance	0.01Ohms
8	Battery Rated capacity	200Ah

Table: 1 Simulation Setup Parameters

VIII. CONCLUSION

The main objective of this paper is to develop the control circuit of Bidirectional DC/DC Converter with MPPT controller for photovoltaic system to analyze its performance.The simulation study is done on MATLAB/SIMULINK. The simulation results clearly show that the MPPT tracks the maximum power point effectively. The result shows that during charging, the power is effectively transferred to the battery and similarly during discharging, the power is transferred back to the supply. The result shows that the battery. Overall results are encouraging and indicate the trends towards a reliable system. The proposed topology is suitable to apply soft switching reduce the losses and stresses on switches. So, the converter efficiency is increase and performance is soothing.

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