International Journal on Applications in Information and Communication Engineering
Volume 2: Issue 11: November 2016, pp 4-9. www.aetsjournal.com ISSN (Online) : 2394-6237

Implementation of Solar Based Bidirectional Dc-Dc Converter with ZVS using PMDC motor

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Abstract**—** In this project presents a new non conventional energy source based bidirectional dc/dc converter for transfer the power in both directions. The nonconventional source of solar energy with Maximum Power Point Tracking is used to avoid the demand of electric power, which is inexhaustible and non pollution .The maximum power point traction is the combination of switch mode converter and Controller, which is used for extract the maximum power from the solar panel i.e., combination of boost converter and incremental conductance algorithm. Incremental conductance is one of the important techniques in this system and because of its higher steady-state accuracy .The output voltage of boost converter is stored in battery. A low cost, soft switched, isolated bidirectional dc/dc converter using only four switches was proposed for interconnect between two dc buses. That battery is connected to source side of bidirectional dc/dc converter and load side of bidirectional dc/dc converter is connected to the PMDC motor. Main concept in this project is transfer the power from source side to the load side and vice versa through the same bidirectional dc-dc converter and reverse power is stored in battery when PMDC motor acts as a generator. In the proposed system reduced the number of switch and used zero voltage switch are introduced, which is also used to improve the efficiency of bidirectional dc/dc converter and reduced switching loss, switching stress, easier thermal management. The results of proposed system are validated using MATLAB/Simulink.

Keywords**—** *Bidirectional DC/DC converter; boost converter; Maximum Power Point Tracker (MPPT); incremental algorithm; zero voltage switching (ZVS); permanent magnet dc motor(PMDC).*

I. INTRODUCTION

The Solar energy is the clean and sustainable energy, with long lifespan and a high Reliability. A solar cell is an electronic device which directly converts sunlight into electricity. A PV array consists of several photovoltaic cells in parallel and series connections. Parallel connection is responsible for increasing the current in the array whereas the series connections are responsible for increasing the voltage of the module.

A PV module is used efficiently only when it operates at its optimum operating point. The optimum operating point of a PV module depends upon varying the isolation levels, sun direction, irradiance, temperature and the load of the system. PV solar cells have relatively low efficiency ratings; thus operating at the maximum power point is desired for array will operate at the highest efficiency. The constant atmospheric conditions and load variables, it is very difficult to use all the solar energy without a controlled system. For the best performance, it becomes necessary to force the system to operate at its OOP. The solution for such a problem is to use a maximum power point tracking (MPPT) system. A MPPT is normally operated with the use of a dc-dc (direct current/direct current) converter. The converter is responsible for transferring maximum power from the solar PV module to the load.

Incremental conductance is one of the most widely using MPPT algorithms because it improves energy efficiency and provides steady state in output power with the help of boost converter. This method has two advantages over the P&O method especially that it stops updating the reference variable when the MPP is reached, thus reducing power oscillations. The maximum electrical energy of solar panel is stored in battery, which is connected to the input side of bidirectional dc-dc converter. Traditionally they were used for the motor drives for the speed control and regenerative braking.

The Bidirectional dc-dc converters are employed when the dc bus voltage regulation has to be achieved along with the power flow capability in both the direction. An isolation and non isolation is the different types of bidirectional dc-dc converter. The isolation type is providing safety; improve the efficiency then non isolation. *In this system soft switching technique is also used to improve the efficiency of bidirectional dc-dc converter, reduced switching stress.*

A Zero voltage Switching (ZVS) is one of the types of soft switching technique, during turn on voltage across the device is reduced to zero before the current increases. The load side of bidirectional dc-dc converter is connected to the Permanent Magnet dc motor (PMDC). The PMDC motor is essentially simple in construction, which takes power form the battery through bidirectional dc-dc converter drive the vehicle. If the vehicle goes down slope, The PMDC motor acts as a generator. This converts mechanical energy into electrical energy. The generation of electrical energy is stored in battery through the bidirectional dc-dc converter. In this process provide the energy saving purpose also.

II. BIDIRECTIONAL DC-DC CONVERTER

Bidirectional dc-dc converters serves the purpose of stepping up or stepping down and also same the voltage level transfer between its input and output along with the capability of power flow in both the directions. The attracted applications of Bidirectional dc-dc converter is the energy storage systems for Hybrid Vehicles, Storage systems Renewable energy, Uninterruptable power supplies and Fuel cell storage systems. The Bidirectional dc-dc converters block

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Volume 2: Issue 11: November 2016, pp 4-9. www.aetsjournal.com ISSN (Online) : 2394-6237

diagram is shown in Fig.1, which is used for when the dc bus voltage regulation has to be achieved in both the direction along with the exact power flow capability. The bidirectional dc-dc converter with energy storage has many power related systems, including hybrid vehicle, fuel cell vehicle, renewable energy system and so forth. The bidirectional dc-dc converter is not only reduces the cost, improves efficiency and also improves the performance of the system. One such example is the power generation by wind or solar power systems, which increase the more fluctuation in the generated power because of the large variation and uncertainty of the energy supply. In the electric vehicle applications, an energy storage battery absorbs the regenerated energy fed back by the electric machine.

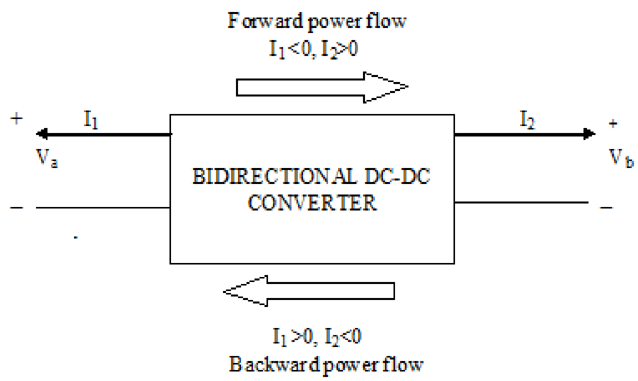

Fig.1.block diagram of bidirectional dc-dc converter

In addition, bidirectional dc-dc Converter is also required to regulate the draw power from the battery to boost the high voltage bus during vehicle starting, accelerate and hill climbing. The bidirectional dc-dc converters are being increasingly used to achieve power transfer in reverse direction when the vehicle goes the downstream and breaking time also. So the power transfer between two dc power sources in either direction is achieved in this method. These systems cannot serve as a standalone system for power supply because of these more fluctuations and therefore these systems are always backed up and supported by the sources which are rechargeable such as battery units or super capacitors.

The main source of supplements system at the time of energy to provide the power at regulated level and gets recharged through main system at the time of surplus power generation or at their lower threshold level of discharge. This can be avoided using bidirectional dc-dc converter is needed to be allow power flow in both the directions at the regulated level. Likewise in HEVs, bidirectional dc-dc converters are employed to link up the high voltage dc bus to the hybrid electrical storage system (usually a combination of the battery or a fuel cell with the super capacitor). Here they are needed to regulate the power supply to the motor drive power demand. The bidirectional dc-dc converter is often used to transfer the solar energy to the capacitive Energy source during the sunny days, while to deliver energy to the load when the dc bus Voltage is low. The bidirectional dc-dc converter is regulated by the solar array photovoltaic level, thus to maintain a stable load bus voltage and make fully usage of the solar array and the storage battery.

III. Proposed System

Today electric power is very essential for everywhere and it increase the economic growth rate of countries. One of the major concerns in the power sector is the day-to-day increasing power demand due to the unavailability of enough resources using the conventional energy sources. Solar energy is most widely used renewable resource, because of increasing power demand. Another advantage of using solar energy is clean source of energy, most effective and nonpolluting. Solar energy can be extracted through many ways including the photovoltaic effect that consists of a direct transformation of sunlight into electricity by means of solar panels. The solar system is the combination of switch mode system and control system i.e., boosts converter and MPPT system.

The block diagram of proposed system is shown in Fig.2, where the block of solar array used for generate electrical energy, MPPT algorithm used for extract maximum power, dc-dc boost converter used for step up the solar energy, battery used for stored solar energy and PMDC generator energy, PMDC motor used as either load generator. In this proposed bidirectional dc-dc converter switches are reduced compared to existing system and also other advantages are reduced complexity of circuit design, improve the efficiency and reduced cost.

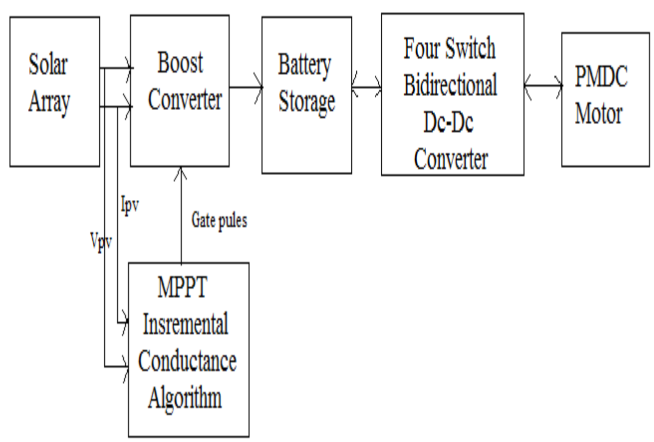

Fig.2. Block diagram of the proposed system

The MPPT algorithm is develop an efficient manner in which power has to be extracted from the incoming solar radiation .The use of the newest power control mechanisms of the Maximum Power Point Tracking (MPPT) algorithm method is incremental conductance has led to the increase in the efficiency of operation of the solar modules and thus is effective in the field of utilization of renewable sources of energy. A Maximum Power Point Tracking is normally operated with the use of a dc-dc converter is step up or step down. The dc-dc converter is responsible for transferring maximum power from the solar Photovoltaic module to the load. The output of MPPT algorithm is gate pulse, which is applied to the MOSFET of boost converter. Boost converter is used for step up and regulate the PV cell output voltage and stored in batter.

Soft switching technique are introduced in bidirectional dc-dc converter for Reduced switching losses, switch stress, possibly low EMI, easier thermal management. It must for very high frequency operation, medium frequency at high power levels also. Zero Voltage switching means the voltage across the device is reduced to zero before increasing the current when switch is turn on**.**

In load side PMDC motor act as a motor and generator, essentially simple in construction, this takes power form the battery through bidirectional dc-dc converter drive the vehicle. The vehicle goes down slope, now the PMDC motor act as a generator. That means convert's mechanical energy into electrical energy, which stored in battery through same bidirectional dc-dc converter. The generation of electrical energy is stored in battery through the bidirectional dc-dc converter. In this process provide the energy saving purpose also. The advantages of PMDC motor is very cheaper, use of permanent magnet excitation results in lower manufacturing cost, Motor selection is an important part of electric vehicle design since the motor and the motor drive configuration characteristics directly influences the performance of electric vehicle.

In the selection of the motor type, drive system, battery and power control system is based on the parameters used in the design specification of the vehicle like the start-up in maximum torque, maximum speed, average travel range, battery capacity, overall weight and size of the system. A PMDC motor is smaller size than a wound field dc motor of equal power rating, because field excitation current is not required, the efficiency of the PMDC motors is higher than the wound field motors and Low voltage PMDC motors is produce less air noise.

The Main advantages of this system are the cost, robustness, compactness due to possibility of reducing the motor size at high speed, reasonably high efficiency, should have the capability carrying the required load like weight of the bicycle, rider, battery, motor and other units fitted on the cycle under ideal driving conditions, while the bicycle is being driven up a slope, the motor should be in a position to meet it as far as possible.

A motor with a constant speed characteristic will provide a sense of comfort, while driving down steep slopes. Also, the incorporation of regeneration should be easy. This all factors of PMDC motor are the most appropriate in our case.

A. Maximum Power Point Tracking

The efficiency of a solar cell is increase using Maximum Power Point Tracking (MPPT) for match the source and load power. This is a technique used to obtain the maximum possible power from a varying source. This is done by using a boost converter whose duty cycle is varied by using a MPPT algorithm.

There are many types in maximum power point algorithms. The Perturb and Observe method, Incremental Conductance method are recently used to extract maximum power in MPPT algorithm from solar array with the help of boost converter. The incremental conductance method offers the main advantage of providing high efficiency under rapidly changing atmospheric conditions and more accuracy then Perturb and Observe. So it has been employed in the model.

The principle of Incremental Conductance algorithm is that the derivative of the power with respect to the voltage or current becomes zero at the MPP, the power increases with the voltage in the left side of the MPP and the power decreases with the voltage in the right side of the MPP. Thus the condition would be;

$$I+V*(dI/dV)=0$$

In eqn.........,

$dI/dV = -I/V$ at maximum power point
$dI/dV => -I/V$ move left of maximum power point
$dI/dV < -I/V$ move right of maximum power point

This condition based diagrammatic representation incremental conductance MPPT algorithm flowchart is shown in fig.3, regulates the PWM control signal of the dc – dc boost converter until the condition: $(dI/dV) + (I/V) = 0$ is satisfied. That condition repeated until reaching the maximum power or extract maximum power.

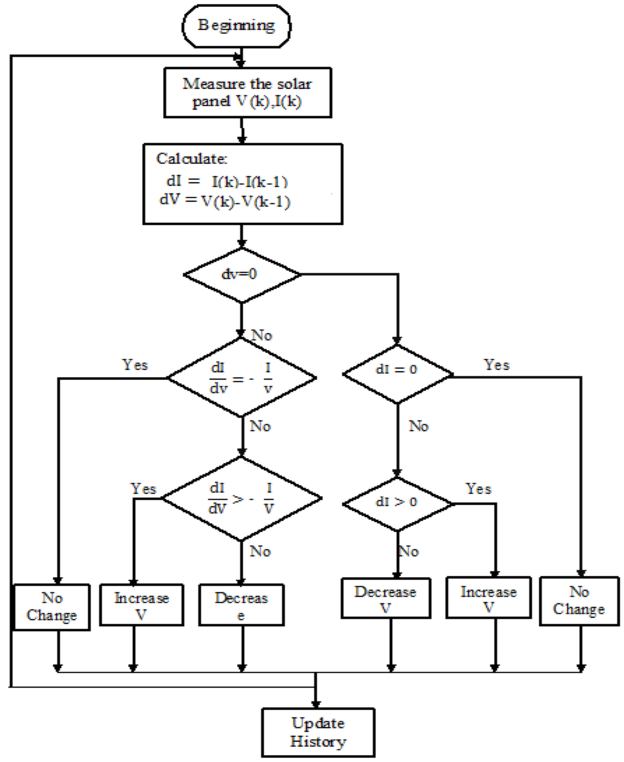

Fig.3. Flow Chart of Incremental Conductance Algorithm

a. Half Bridge Converter

Half bridge converter topology is an isolated dc-dc converter which is widely used in power electronics and drives application. This topology can be used for an output power capability up to 500W. One of the main features of half bridge converter is shown in fig.4, it reduces the OFF-stage voltage requirement of the primary side switches to Vi apart from maintaining the bi-directional flux swing in the core. Thus the voltage stress and cost of the power switches is significantly reduced as compared to the push-pull topology. The secondary side of the half bridge converter is exactly same as the push-pull converter. In addition to battery charging application half bridge converter can be used for many other applications like UPS etc due to the reduced complexity of the converter.

The operation of half bridge converter can be explained in two modes according to the switching ON of two switches T1 and T2 .

In Mode 1 starts when switch T1 is ON, when occurs during first DTs period. The input source voltage Vin is connected to one end of the primary winding through switch T1. The other end is at Vin/2. The voltage across the primary is Vin/2 with the dot end being positive with respect to the non dot end. The diode D1 is ON and D2 is OFF. The energy is supplied to charge up the inductor through the diode D1.

In This mode starts when the switch T2 is ON, occurs during the second *DTs* period. T1 and T2 will be ON during alternate DTs periods with *D* and *Ts* being defined with respect to the inductor current ripple. During this time, T2 is ON and the voltage across the primary winding is Vin/2., but the dot end is negative with respect to the non dot end. This will facilitate the core flux to swing in the negative direction. In secondary, D2 is ON and D1 is reverse biased. The inductor energy is flow through diode D2.

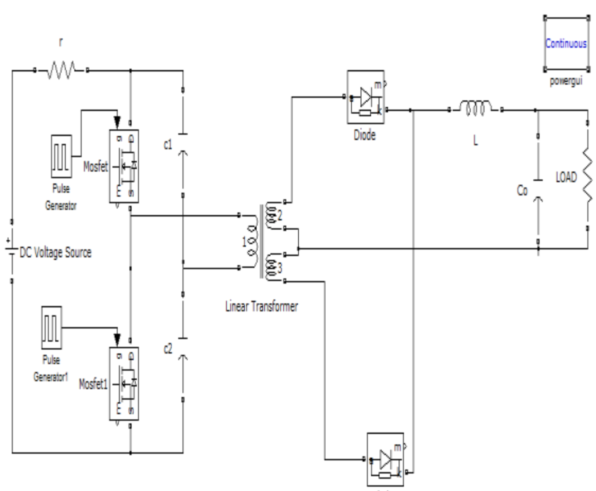

Fig.4. Half Bridge Isolated Bidirectional dc-dc Converter

When both T1 and T2 are OFF, the inductor current freewheels through both D1 and D2. The current flowing in the center tapped secondary is in directions that will cancel the flux in the core due to each other. This will leads to the voltage across the entire transformer being zero.

B. Zero Voltage switching

The zero voltage switching means the voltage across the switch is reduced to zero before increasing current at ZVS condition. In the switch can be controlled by the switch parasitic capacitance or by a resonant capacitor C_R is added in parallel across the semiconductor switch as shown in the Fig.5

When the switch is turn on, the voltage across the capacitor is equivalent to the forward voltage of the switch. During the time of transition the switch state capacitor voltage cannot change immediately, therefore the capacitor charging rate is decreased and hence the current almost falls to zero (off state current) till not the voltage across the switch starts increasing to that of the on state value. For the reason the switch is dissipated a very low power during turn off condition. The ZVS turn on is to get by the resonance operation of the CR with an external inductor is connected either in parallel or series with the switch depending up on the circuit topology.

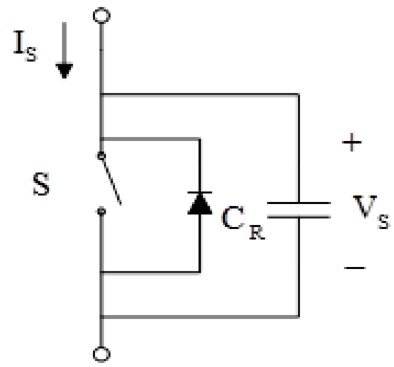

Fig.5. An Elementary resonant switch for achieving ZVS

The resonance transition, the current get increased after the voltage drops meet to zero and the hence ZVS is established. During resonance transition, because the current through the inductor cannot change initially, therefore the charging rate of the inductor is reduced and the voltage decreases appreciably before the current across the switch starts rising.

IV. MATLAB SIMULATION

The complete Simulation circuit diagram of this system is shown in Fig.6, the combination of solar panel with dc-dc boost converter of bidirectional dc-dc converter

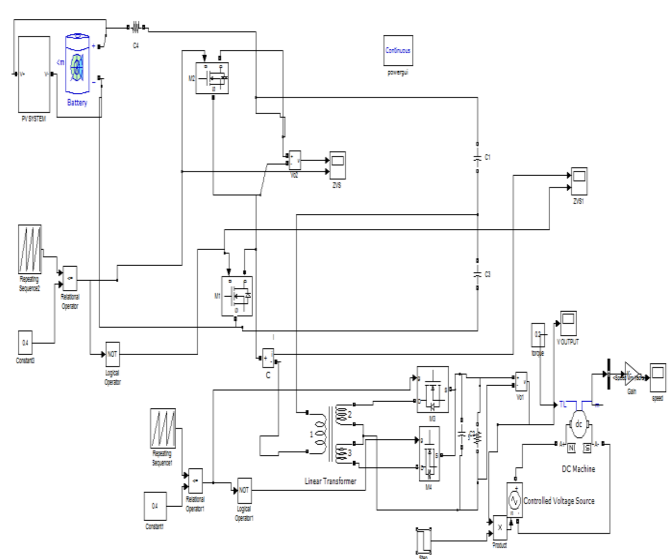

Fig.6.Simulation circuit diagram of overall system

The sub system of pv system with boost converter is shown in fig.7, which has incremental conductance algorithm of mppt subsystem. The output of mppt is given to the gate pulse for MOSFET of boost converter

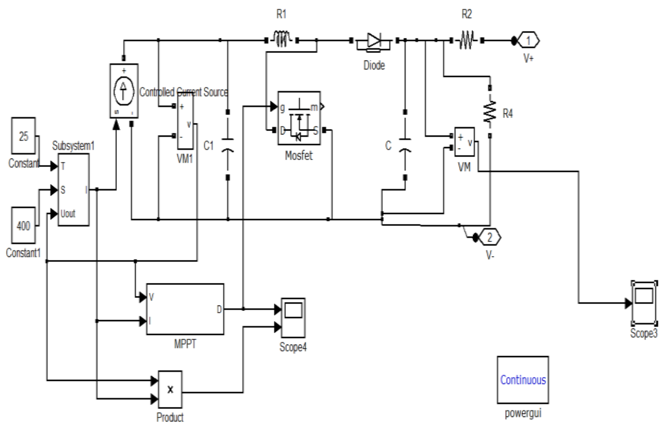

Fig.7 subsystem of MPPT algorithm with boost converter

The subsystem of incremental conductance algorithm model is shown in fig.8

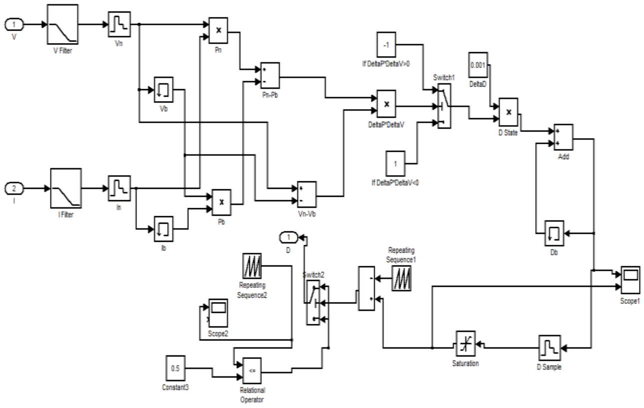

Fig.8.Subsystems for Simulink Model of Incremental Conductance Algorithm

V. Results And Discussion

Simulated solar system output voltage is shown in Fig.9, output of the solar system operate with MPPT is 48 voltage, which is stored in battery.

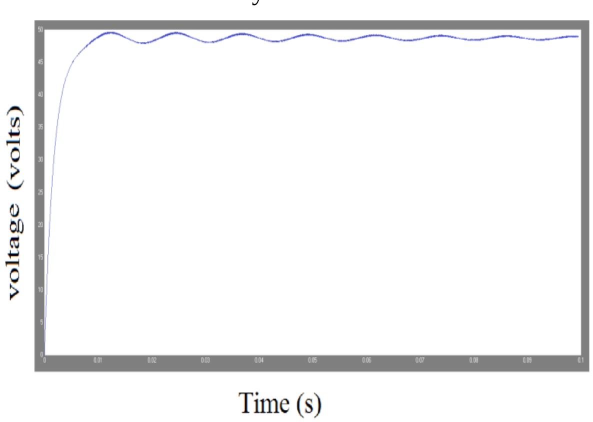

Fig.9.output voltage of boost converter waveform

The simulated Output voltage of bidirectional dc-dc converter is shown below Fig.10, connected to the PMDC motor.

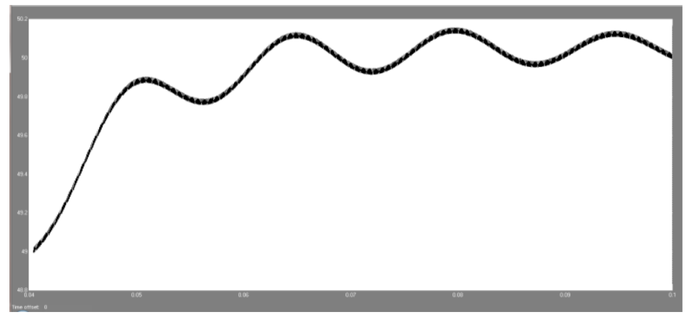

Fig.10. Load Side Output Voltage Waveform

The zero voltage switching of MOSFET is shown in below Fig.11, in bidirectional dc-dc converter each switch has ZVS. The voltage across the each switch is zero before going to turn on switch in this converter.

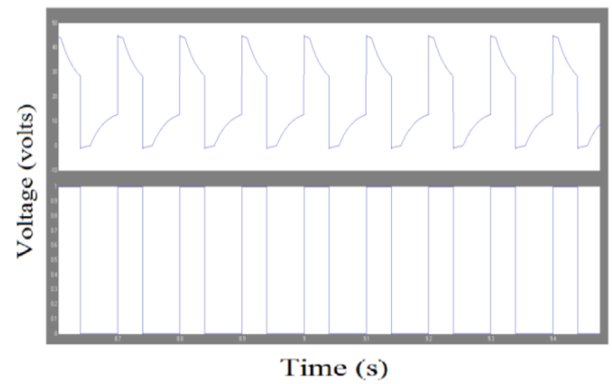

Fig.11. ZVS of MOSFET Waveform

The speed of PMDC motor is shown below Fig.12, the output of bidirectional dc-dc converter is supply to the armature winding of PMDC motor. After 0.05 sec the armature winding is zero, now the PMDC motor speed is reduced.

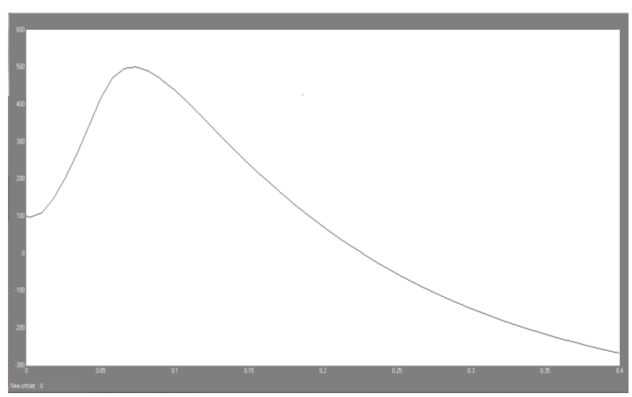

Fig.12. Speed of PMDC Motor Waveform

VI. Conclusion

The power flow in both directions is achieved from source side to load side of bidirectional dc-dc converter with the help of solar panel, ZVS of MOSFET, PMDC motor. Also the regenerative braking of the PMDC motor has been successfully realized thus achieving the design targets. The Incremental conductance Method is computes the maximum power and control directly the extracted power from the PV. In this method offers different good tracking efficiency, response is high and well control for the extracted power. The incremental conductance algorithm gives the optimum duty cycle as compare to Constant duty cycle control, to extract the maximum power from PV system. The model of bidirectional dc-dc converter with PV and MPPT algorithm has been successfully implemented, simulated in MATLAB/ SIMULINK 7(R2010a), carried out outputs and waveforms.

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