Solar PV based Electric Vehicle

Nirmala. M, Malarvizhi.K, Thenmozhi. G

Abstract: The aspect of the locomotive trade is being restructured by concerns over oil deliveries, international guidelines and fuel rates. Consequently the vehicle technology should be adaptive to these concerns. The projected paper describes solar PV powered Electric Vehicle,that solves the key downside of fuel and pollution. It is an initiative in implementing eco-friendly transportation in the world to build a green environment. In general, an electric vehicle uses a battery that is charged from an external power supply, but solar PV modules are used to charge a battery by means of absorbing radiation from the sun and converting it into electrical power (Photovoltaic Effect) by proposed method. The electrical power to batteries obtained from solar PV modules which might be associated either in series or parallel and charge controllers. To traverse the ultimate power point in the solar panel, in addition Maximum Power Point Tracker (MPPT) controller is used. The Buck-Boost converter boost up the DC voltage generated from the solar PV panel and then its output fed to a voltage source inverter. Voltage source inverter convert to the AC power from a solar DC power and ultimately tracks the Brushless DC motor which controls the vehicle application. This planned model has Buck-Boost convertor which is used to control the battery from the prime possible power generation using a solar PV system fixed on the vehicle. An effectiveness of the proposed system have been modeled and its results, verified in MATLAB/SIMULINK.

Keywords:Maximum Power Point Tracker (MPPT), Electric Vehicle (EV), Permanent magnet Brushless DC motor(PMBLDC), Perturb & Observe (P&O)

I. INTRODUCTION

At present, energy crisis is a vital unsolvable problem. The consumption and extraction cost of fossil fuels such as gasolene and diesel are very high. The major reason of the surplus usage of these fossil fuel based vehicle is that have enhanced the excavating of these conventional resources in an untenable approach [1]. The most important downside is global warming caused by the burning of fossil fuels, where large amount of greenhouse gases is emitted that causes pollution. In prospect, there will be no fuel left for usage because of the rise in demand for gasolene and diesel. So, it is wise to adapt to electric vehicles rather than traditional IC engine vehicles. Solar power technology is an efficient and feasible alternative source of renewable energy [2][3]. Solar energy from the sun is stored in a battery and is employed torun a vehicle. These vehicles results as pollution free atmosphere and quiet operation. In 2030, all IC engine vehicles might be replaced by electric vehicles. In recent times, DC solar power based various electric vehicle has been fabricated and tested [3].

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Rendering to modern studies, the fossil fuels are depleting in a debauched amount where the whole fossil fuel in the universe could be entirely exhausted within 30 to 40 years. Thus novel investigation of natural resources of energy and power are necessary to fashion in the world. Solar PV energy is the most promising natural resource among the available resources. Solar power technology is an emerging technology in vehicles.

This solar powered electrical vehicle is unique with the design of the IGBT based Buck-boost convertor. It boosts the PV panel voltage to the specified output voltagerequired for the battery [4]. Clean solar vehicles to be quiet faraway from real-world feasibility due to several restrictions such asminor power density, energetic shortcomings, weight, the cost and saving of fuel even in the face of a substantial high-tech effort and some remarkable outcomes of solar energy[5].The MATLAB/SIMULINK is used to develop a self-driven simulation model for solar PV based vehicle, to endorse the faces of diverse components along with the competency of estimating its inclusive performance in a responsive simulation environment.

The main objective of this project is to simulate the performance of solar PV based electric vehicle using MATLAB/SIMULINK. The important components are PV panel, Battery and PMBLDC motor. The important components of the vehicle are modeled and its performance is analyzed. In this model, a Buck-Boost converter using IGBT have been designed such that the output voltage increases to the specified voltage in order to charge the battery [6]. Additionally, a Voltage source inverter designed to supply power the BLDC motor, under a closed loop operation with the help of Hall sensors [7]. Thus, simulation results of this model are analyzed.

II. PROPOSED SOLAR PV BASED ELECTRIC VEHICLE

In general, the suggested solar PV established Electric vehicle block diagram is shown in Fig.1.

A. Solar PV system

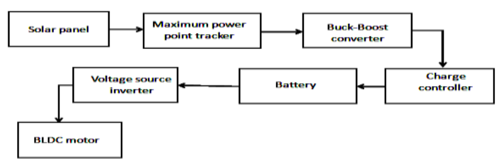

Fig. 1Solar PV Established Electric Vehicle Block Diagram

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A solar PV cell is a device that directly transforms solar energy to electrical energy by the photovoltaic effect, it defines an electrical characteristics such as current and voltage fluctuate when it exposed to light [8].

The solar cell equivalent circuit is shown in fig.2 and Equation (1) describes the current drawn from the solar cell.

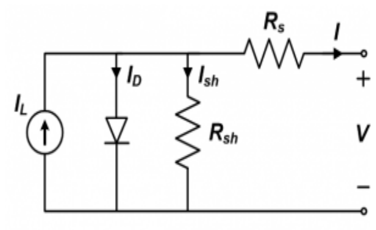

Fig. 2 Solar Cell Equivalent Circuit

$$I = I_{sh} - I_d = I_{sh} - I_0(e^{\frac{Q(V+IR_S)}{akTc}} - 1) \qquad (1)$$

a = Idealizing aspect
k= Boltzmann's constant
T_c= cell temperature in absolute
Q = charge of electron
V= voltage imposed across the cell
I_0= dark saturation current

The essential parameters of a solar cell are following: Short circuit current (I_{sc}) is the highest generated current under short circuit situations in which voltage across a cell is zero. Open circuit voltage is the voltage of cell at night, when generated current is zero and is given by the equation (2) mathematically[9],

$$V_{open\ circuit} = V_t\, ln(\frac{I_{sh}}{I_0}) \qquad (2)$$

Where, $V_t = \frac{\text{akTc}}{\text{Q}}$.

MPP is the point of current-voltage curve, where dissipated power is maximum. Maximum efficiency is the ratio between power at maximum and power at incident light.

$$\eta_{max} = \frac{P_{max}}{P_{min}} \qquad (3)$$

Fill Factor is the ratio between power at maximum and the product of short circuit current and open circuit voltage

$$FF = \frac{P_{max}}{(V_{oc}I_{sc})} \qquad (4)$$

B. Buck-Boost Converter

The converter is a switch mode DC to DC converter in which the DC output voltage can be altered to a lower or higher level than the DC input voltage. The magnitude of output voltage depends on the duty cycle of the switch in converter [10].

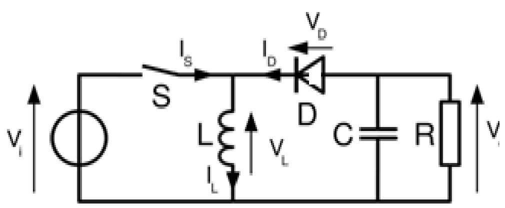

Fig. 3 Equivalent Circuit Of Buck-Boost Converter

This DC-DC converter can be actuated in two ways of operation, continuous and discontinuous conduction way. In former mode, afore the beginning of the switching cycle, the current flows through inductor moderately discharges, but never goes to zero. In the second mode, the current through inductor goes to zero. In this DC-DC converter [11], the duty cycle adjustment of the power switch controls the output voltage. When the power switch is triggered ON, the input source makes current to the inductor (L) and load. When the power switch is triggered OFF, the stored energy from inductor freewheels current continuously to the load through the diode.

C. Solar PV Panel with MPPT Charge Controller

The greatest govern feature of the entire vehicle is designed based on the solar PV panel intention. The power rating of a motor is 1000W. So, the solar PV is designed with 1050W with keeping 50W as tolerance. The total number of PV panel used in this vehicle is 4 and each having 250W.

The specification of solar PV is as follows: Maximum voltage from one cell is 0.666V, the available size of the 48V solar panel for all 4 panel is 49 Square feet, the maximum voltage from 72 cells of the solar panel at open circuit is 59.5V and maximum voltage output at average condition of the sunlight is 48.5V. The maximum current from 72 cells of the solar panel at open circuit is 8A, the maximum current output at average condition of sunlight a short circuit is 5.15A, the maximum power output from a solar panel in average condition of sunlight is 250W and the maximum power output from 4 solar panel output is 1000W.

The MPPT controller Simulink diagram is shown in Fig.4 which is a controller with buck -boost DC converter. It create enhancements in the counterpart between the solar PV output panels) and the battery voltage. It basically maintains DC output from the solar panels to the required voltage needed to charge the battery.

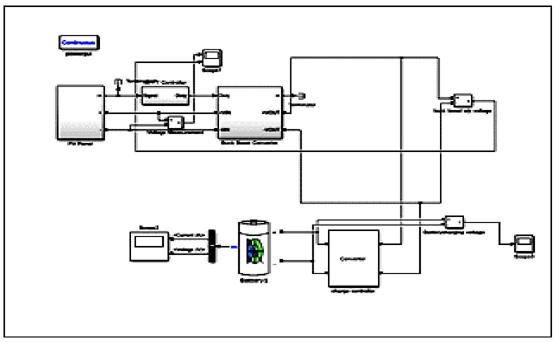

Fig. 4 DC-DC Converter And MPPT Charge Controller Simulink Model

The Buck-Boost Converter Simulink model is shown in Fig.5. To sustain the voltage in the battery, the main task of this converter is to excerpt the extreme power from the solar PV. By regulating operating voltage and current of the

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converter in such that, it achieves the Maximum Power Point (MPP). The MPPT controller works as follows: the PV array current and voltage are intuited at a certain sampling cycle using a current and voltage sensors respectively. These tracked values of voltage and current are fed into an MPPT block which computes MPP and provides the mention values for the current and voltage. These are converted to a power value that must be same as requirement of the converter. If there is a difference between the two duty cycles of the buck-boost converter is adjusted. The maximum power from the PV array is extracted, when the measured power equals to the reference value. Fig.6 shows the characteristics of PV panel. The converter is usually based on the typical non-isolated, boost type. The most crucial feature of the MPPT is its ability to track the MPP as rapidly and powerfully as possible. There are many types of MPPT controller such as Perturb and observe, incremental conductance and hill climbing. These controller are configured using static or adaptive step time. The incremental conductance method provides improved tracking efficiency, because it reduces steady state oscillation [12].

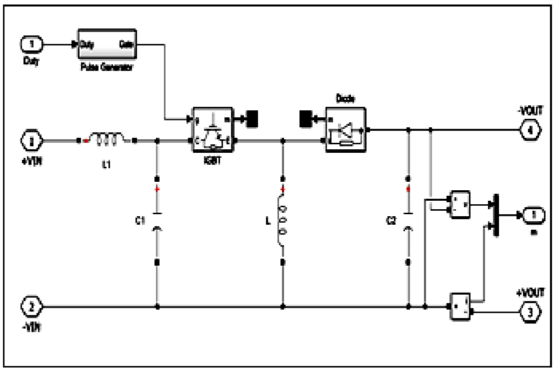

Fig. 5Simulink Model For Buck Boost Converter

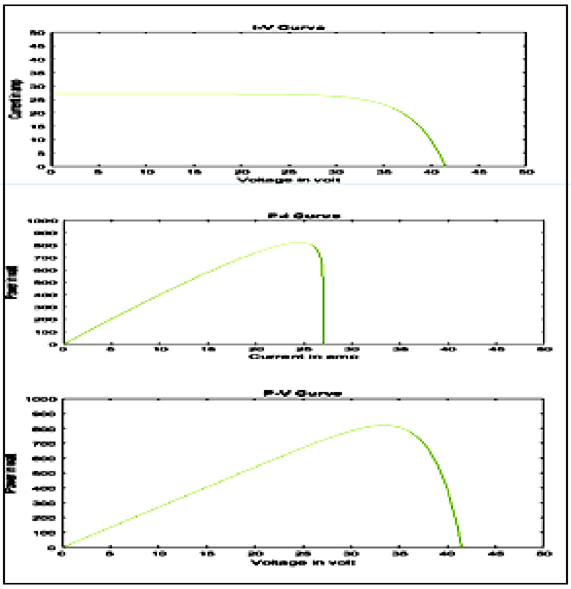

Fig. 6 The Characteristics Of PV Panel:A) I-V Characteristics B) P-I Characteristics C) P-V Characteristics

D. Battery

A battery is a 48 V deep cycle lead-acid re-chargeable battery. The lead–acid batteries are the oldest type of the rechargeable battery [13]. A lead-acid battery is deep-cycle discharged upon its capacity. The battery has an extremely small energy to weight ratio and a little energy-to-volume ratio, their facility to deliver high surge currents means that the cells maintain a relatively large power-to-weight ratio. The features of the PV cell, along with their low cost, make them attractive to provide the high current required by the motors used in the electric vehicle. The charging is carried out in three different stages rather than through a continuous fixed voltage/current supply to the battery. Due to the internal electro-chemical mechanism of a lead-acid battery, the quantity of voltage/current of each stage is diverted as per requirement of the battery. The charge controller controls charging voltage before battery [14]. Later monitoring the battery, the charge controller determines the period of charging.

E. BLDC motor

1000W synchronous type BLDC motor controls the electric vehicle. BLDC motor generates both stator and rotor magnetic fields with related frequency. The BLDC motor has a higher efficiency and extensive life without brushes and mechanical commutator. Also, it has a lower losses owing to high starting torque and increased in efficiency. Out of many configurations, three phase motors are the most popular and are widely used in e-bikes. The vehicle is selected a hub motor because the motor replaces the hub of the wheel. Coupling loss is reduced and mounting can be made easy without the use of chains or belts, and that reduces size and weight of the vehicle. Fig.7 illustrates that the BLDC motor simulink circuit

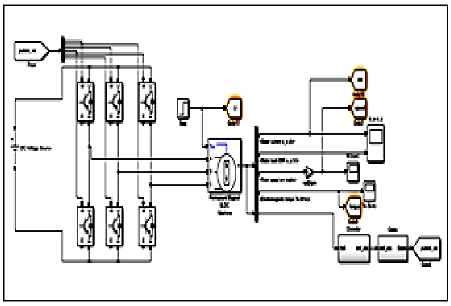

Fig 7BLDC Motor Simulink Circuit

III. SIMULATION RESULTS

The Solar irradianceand temperature are 1000 and 40 degree given as input to the PV module which produces a panel output voltage of about 36V which is not sufficient to charge the battery used. Thus by using a Buck-Boost converter required the voltage of 48V needed by the battery is provided. The Maximum power point tracker has been used to identify the maximum operating point of the PV module[15]. A charge controller is designed such that it controls the overcharging of the battery.

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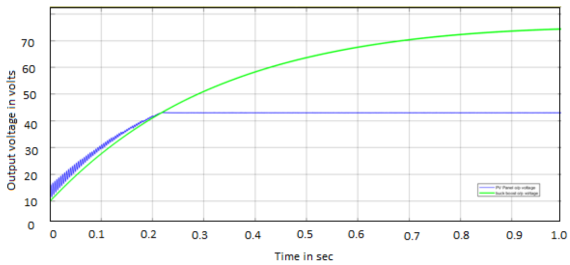

Fig.8 PV Panel Output Voltage, Boost Converter Output Voltage

Fig.8 shows simulation results of the output voltage at PV panel and at the Boost converter output voltage. This result shows that the PV module voltage is 36V and increased to about 60V, with help of the DC-DC converter.Fig.9 shows the voltage of the battery during charging.

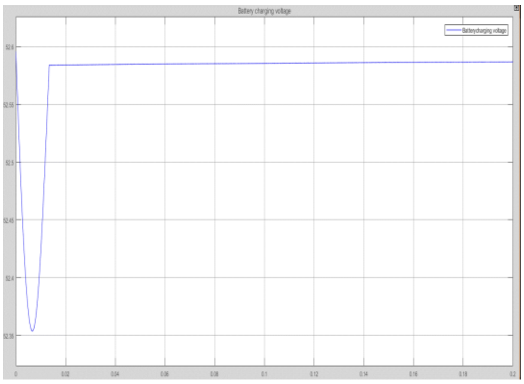

Fig.9The Battery Voltage During Charging

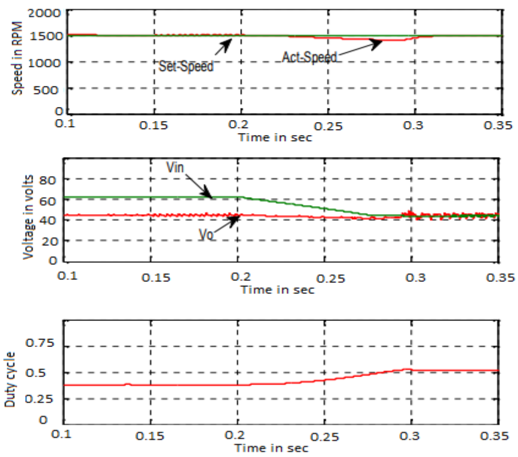

Fig. 10 Control Of Converter During The Reduction In Solar Irradiation

Fig.10 represents the change in a voltage of the PV panel due to decrease in irradiation at 0.2sec, from 60V to 45V. Then the output voltage of the photo voltaic array gets decreases up to 0.255 which makes speed gets decreases from 0.25 to 0.3s.At the same time, the duty cycle of buck-boost converter gets increases from 0.25 to 0.3 to improve the output voltage Vo, so as to maintain the rated speed as constant at 1500 rpm.

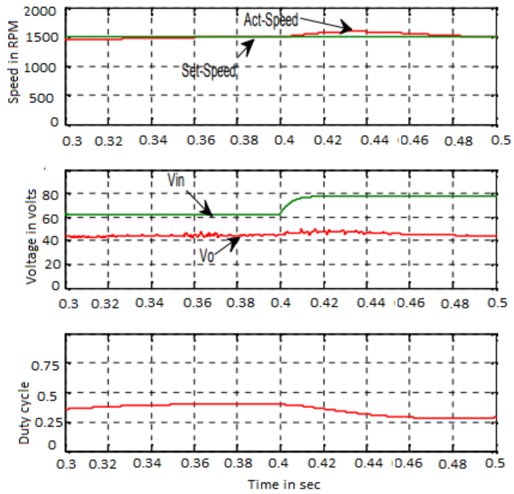

Fig. 11 Control Of Converter During The Increase In Solar Irradiation

Fig.11 shows that the increase in the voltage of the PV panel if the solar irradiation is very high, then the output voltage of the PV array increases from 60V to 80V. So the motor speed also increases thus increases the negative error. Since the controller reduces the duty cycle value from 0.4 to 0.3, the output voltage of the buck boost converter get reduces so as to maintain the rated speed as constant at 1500 rpm.

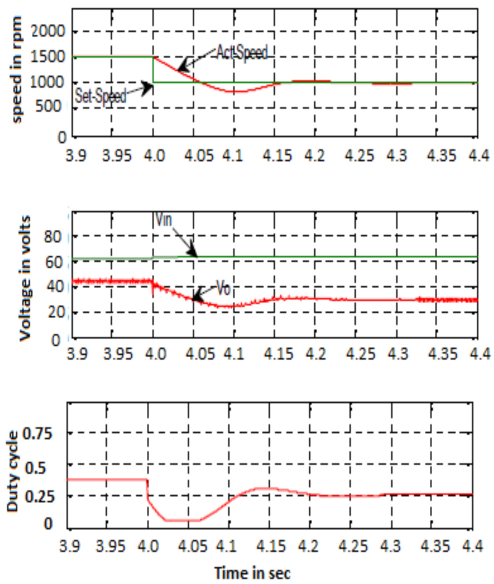

Fig.12 Control Of Converter During The Reduction Of The Set Speed

When the set speed is decreasing from 1500 rpm to 1000 rpmat 4 sec correspondingly, the duty cycle decreases from 0.4 to 0.25 in the time period of 4.2 sec. So the output voltage decreases from 45V to 30V. Hence the speeddecreases from 1500 rpm to 1000 rpm and settles in thetime of 4.2 sec, are shown in fig.12.

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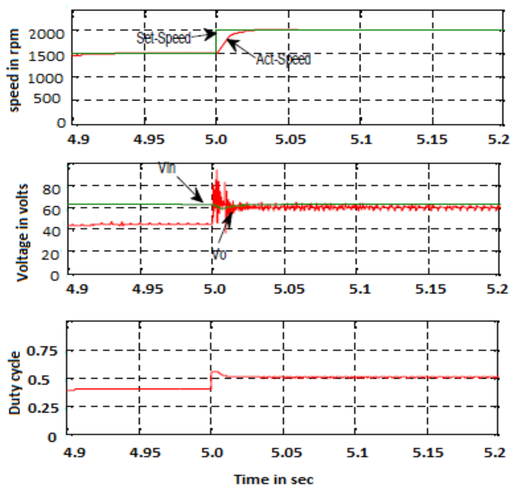

Fig.13 Control Of Converter During Increase Of The Set Speed.

The fig. 13 shows a response of the converter control. The set speed increases from 1500 rpm to 2000 rpm in the time of 5sec, a sudden voltage transient may occur, to achieve rated speed, the duty cycle of the converter increases from 0.4 to 0.5. So the converter output voltage increases from 45V to 60V to reach the decided speed of 1500rpm in the time of 5.05sec.Table 1 indicates the various value of simulation parameters used for the proposed work.

Description	**Type/ Rating of the system parameters**
PV panel	1000W
Battery	100Ah, 12 V (4 Lead –Acid Batteries connected in series)
Battery energy	4800wh
Converter	Buck –Boost converter
Duty cycle	0.25-0.7
Control of VSI	SPWM control
VehicleParameters	
BLDC motor	1KW. 48V,1500rpm
Wheel number	4
Powered axle	1 (rear)
Mass	300 kg
Average speed	25 km/hour

Table 1. Simulation Parameters Of The Solar Pv Based Vehicle

IV. CONCLUSION

The proposed solar powered electric vehicle has several merits such as fuel efficient, reduction in the pollution and provides noiseless operation. The paper deliberates about operation of the BLDC motor in closed loop control in accord with the change in solar irradiance condition and change in set speed of an electric vehicle. The advantages of BLDC motor is higher value of efficiency, power density and speed ranges, which makes selection of this motor, for various applications. The simulation result illustrates that, for various voltage level of PV array, controlling of duty cycle of the DC-DC converter, then the set speed gets maintained. The characteristics of proposed solar PV based BLDC motor driven electric vehicle and easiness create it efficiently beneficial in strategy of BLDC motor drives in numerous fields.The proposed procedure confirms the consistency of BLDC motor through non-conventional source by removing fossil fuel and also environmental responsive for life of the vehicle.

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