DEVELOPMENT OF ELECTRIC VEHICLE BATTERY CHARGING CONTROLLER USING BUCK CONVEERTER WITH MODIFIED PI CONTROL SYSTEM

[1]C P SUDHAKAR, [2]Dr. K VENKATA SUBBAIAH, [3]BHUMIREDDY RAVINDRAREDDY, [4]AMGOTH JAGAN, [5]KURAKULA HIMABINDHU, [6]N SURESH, [7]ADEPU RAJENDHAR

[1]Assistant Professor, Dept. Of EEE, DRK INSTITUTE OF SCIENCE & TECHNOLOGY, Hyderabad,

[2]Professor & Principal, Dept. Of CSE, DRK INSTITUTE OF SCIENCE & TECHNOLOGY, Hyderabad,

[3]Assistant Professor & HOD, Dept. Of MECH, DRK INSTITUTE OF SCIENCE & TECHNOLOGY, Hyderabad,

[4,5,6,7]BTech Student, Dept. Of EEE, DRK INSTITUTE OF SCIENCE & TECHNOLOGY, Hyderabad

***Abstract**: Research into automotive applications of battery charging systems powered by renewable energy sources for electric vehicles (EVs) has increased rapidly in recent years. This study investigates the feasibility of solar P-powered EVs in great detail. Battery storage for ground vehicles has various advantages, including the elimination of pollution, the ability to recover energy while braking, load leveling, and efficient transient functioning. To achieve these goals, a bidirectional DC-DC converter must be used to connect the dc-link of the PV to the dc-link of the battery. There are two modes of operation that a P-powered electric vehicle must support: charging and discharging. In this research, the Maximum Power Point Tracking (MPPT) method is used to extract the greatest energy possible from solar PV. In addition, a closed-loop control circuit is described in this study for DCDC converters with bidirectional output. The system's effectiveness is verified using MATLAB simulations.*

***Keywords**: Battery charging controller, Asynchronous Buck Converter, Electric vehicle,*

I. INTRODUCTION

Governments, corporations, and individuals alike are shifting their focus towards establishing industries in which renewable energy is viewed as one of its strongest foundations due to rising environmental concerns, energy conservation, and global warming. For example, EV has quickly become a hot topic among both the general public and academics [1]. Renewable energy sources include wind and solar power as well as hydel, ocean, and thermal sources. Boost converters and DC-DC bidirectional converters are two examples of power electronic converters that may be used to control the flow of renewable energy for various purposes. In order to use this energy, converters are required. All of these converters were formerly controlled by silicon-controlled rectifiers. Modern switches, such as MOSFETs and IGBTs, may now be operated throughout a wide frequency range. Increasing the operating frequency may lower the size and cost of instructors and capacitors. In order to compete with gas stations, rapid battery charging is also required. This study provides evidence that solar energy can be used to power electric vehicles in their entirety. With the price of photovoltaic modules continuing to drop, solar PV arrays are becoming an increasingly attractive renewable energy option. Therefore, many EV owners now opt to charge their batteries using PV arrays. Combining a PV array with an EV battery necessitates the use of an intermediate DC-DC converter as well as a bidirectional DC-DC converter.

Uninterruptible Power Supplies (UPS), fuel cell cars, and plug-in hybrid electric vehicles (PHEVs) all rely on bidirectional DC-DC converters. When moving from a low-voltage battery to a high-voltage source to charge electronics in the home, a DC-DC converter is essential. Bidirectional DC-DC converters may be either isolated or non-isolated. Due of its simpler construction, non-isolated is more effective. Recently proposed typologies employ a soft switching method to boost power transfer efficiency. For hysteresis current controller-based soft switching, it was necessary to implement bidirectional converters with coupled instructors [2]. In order to lessen the switching losses and boost the dependability of bidirectional converters, the ZVS and ZCS methods were developed.

The usage of a multi-phase bidirectional converter is advantageous in high-power applications. Many converters may be connected in parallel or series to get high voltage or current ratings when the switching frequency is low. A unified current controller was described for bidirectional converters with complementary switching between the top and bottom switches.

Using a bidirectional DC-DC converter in a photovoltaic-fed electric vehicle (PV-fed EV) system is the focus of this research. A closed-loop control strategy is described that allows the converter to operate in both the buck (charging) and boost (discharging) modes. A simplified diagram of a P-powered electric vehicle is shown in Fig.1. The system consists of a PV module connected to a boost converter.

Between the boost converter and the bidirectional converter, a further DC-link is generated for voltage transmission.

Connecting this bidirectional DC-DC converter to the EV's battery completes the setup. MATLAB/Simulation is used throughout to ensure accuracy and reliability of the setup.

II CIRCUIT DESCRIPTION

The DC-DC converter is shown conducting continuously in Fig. 2. In this setup, the boost mode diode is implemented as an anti-parallel diode, D1, which modulates switch S2 to control the boost converter. Switch S1 converts the topology to a buck converter by switching on the anti-parallel diode D2, which acts as a buck mode diode. The current through the induct-or in the two modes is flowing in opposite directions.

The gate drivers for switches S1 and S2 are shown in Fig. 3.

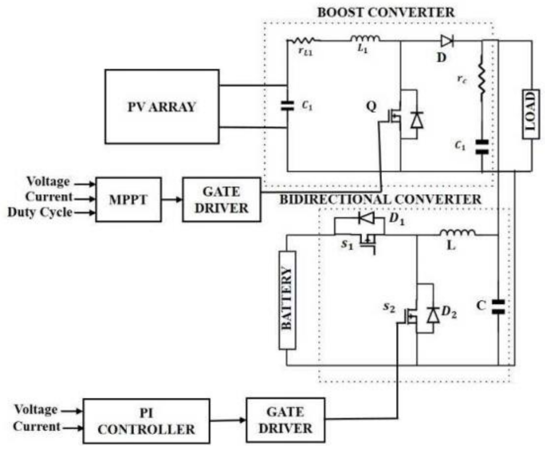


Fig. 1. Schematic diagram of solar PV fed EV.

When converter is operating in continuous conduction mode, state space representation is represented in (1),

$$A.\begin{bmatrix} I_L \\ V_1 \\ V_2 \end{bmatrix} + B.\begin{bmatrix} V_L \\ V_H \end{bmatrix} = 0 \qquad (1)$$

$$\text{Where } A = \begin{bmatrix} \frac{-r_l}{L} & \frac{D}{L} & \frac{-1}{L} \\ \frac{-D}{C} & \frac{-1}{R_1 C} & 0 \\ 1 & 0 & \frac{-1}{R_2} \end{bmatrix}$$

$$B = \begin{bmatrix} 0 & 0 \\ 0 & \frac{1}{R_1 C} \\ \frac{1}{R_2} & 0 \end{bmatrix}$$

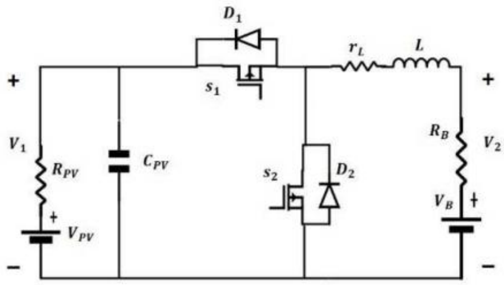


Fig. 2. Bidirectional DC-DC converter.

A. Comparison to Older Converting Methods

The results of the proposed converter's comparison with existing bidirectional DC-DC converters are shown in Table I. Count of switches, number of instructors, number of capacitors, connected inductor, and common ground are some of the fundamental components that play a dynamic role in building a converter circuit. The complexity of an electronic circuit is reduced as the number of its components decreases. It is clear from the table that the number of switches needed for the proposed converter is rather little.

Fig. 3. Power supplies for diodes and transistors.

relative to the range's converter need the same total number of switches. The greatest number of switches is needed for the converter.

The number of instructors is an additional variable. Both [3] and [4]'s proposed converter use two instructors. The induction is unnecessary for the converter. The greatest number of instructors is needed for the converter.

The proposed converter has a single capacitor, which eliminates complexity. Since the suggested converter is not an isolated kind, a linked induct-or is unnecessary. The linked induct-or is used in the circuit of the converter.

DESIGN OF PROPOSED SYSTEM

The block diagram of proposed buck converter controller using Modified Proportional Integral controller is depicted in Fig.1 The output voltage is sensed and compared with the processed reference value and the error goes to MPI controller and the PWM is generated based on that and thus the buck converter operates.

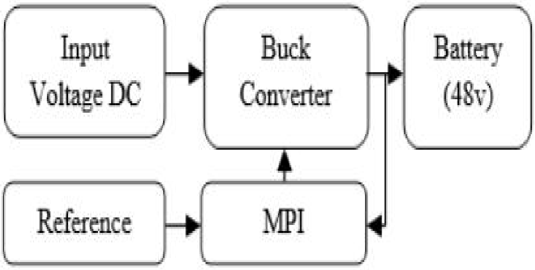


Fig.3 Block diagram of proposed system

Modified PI Controller

The modified proportional integral (MPI) controller is shown in Fig.2. To find the difference between desired voltage r′(t) and actual output voltage y′(t), the MPI is required. The desired output voltage is sampled and further processed according to predefined tuned value. The desired output voltage which is instantaneous defined as

$$r'(t) = nu(t) \qquad \text{e.q(1)}$$

In sample and process block the instantaneous desired voltage modified in the basis of equation (2)

$$r(t) = nr(t+0) - nr(t-m) \qquad \text{e.q(2)}$$

where n is the given desired output voltage value and m is the desired settling time. The desired output voltage is then compared with actual output voltage and the difference between them is fed to the PI block defined as

$$y(t) = k_P e(t) + k_i \int e(t)\,dt \qquad \text{e.q(3)}$$

where e(t) is the difference between desired and actual output voltage

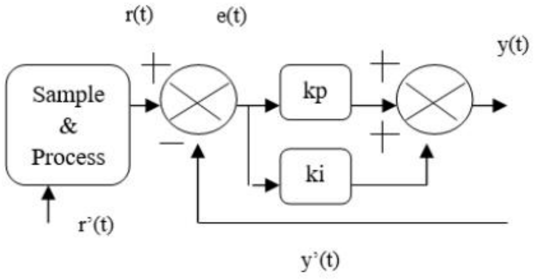


Fig.4 Block diagram of proposed MPI system.

III. MANAGEMENT METHOD

There were two kinds of controls used in this investigation. Maximum Power Point Tracking (MPPT) is one of the most popular solar PV algorithm choices. To ensure that maximum power is always extracted from a solar PV panel, the MPPT algorithm is crucial, even if certain modules may be impacted by shadowing. However, the remaining modules of the battery pack will be activated to ensure that the EV continues to operate normally. With MPPT, the value of solar PV power is regulated to meet the requirements of the load or battery charger. The converter circuit may be controlled using another technique.

As shown in Fig. 4, the control circuit for bidirectional DC-DC converters allows for operation in either the buck or boost converter modes. The block diagram of the closed-loop control circuit that responds to errors includes a PI controller and a pulse-width-modulation (PWM) generator. Both the inner current loop and the outer voltage loop are essential components of the control circuit. The outer voltage loop is where we do the math to get " (battery voltage) and compare it to #$.

The disparity between the two numbers is sent to the PI controller. The steady state error between the measured battery current and the reference battery current under monitoring may be minimized or eliminated with the use of a PI controller.

TABLE I.

COMPARISON WITH VARIOUS PARAMETERS OF CONVERTERS

Converters	**Proposed Converter**	**Converter [19]**	**Converter [20]**	**Converter [21]**	**Converter [22]**	**Converter [23]**
Inductor Count	1	1	1	0	0	2
Capacitor Count	1	3	3	4	3	4
Coupled-Inductor	0	0	0	0	2	0
Common Ground	Yes	Yes	Yes	Yes	Yes	No

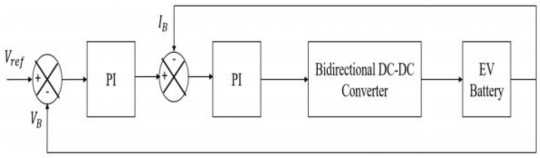


Fig. 4. Closed loop control circuit for bidirectional DC-DC converter.

PI controller's transfer function is specified by

$$G(s) = K_P + \frac{K_I}{s}$$

Proportional as well as integral gains are denoted by

notation *+ and *, , respectively. Then return to current

iteration of loop. Lastly, when compared to " (battery's current), difference is sent to PWM modulation via other PI

controller. Stable PV voltage as well as steady EV current

may be obtained via controller

IV SIMULATION RESULTS

The MATLAB Simulation platform is used to analyse a bidirectional DC-DC converter. The figures below depict a number of variables, such as the DC link voltage, the EV battery voltage, and the battery's State of Charge (SoC) as a function of the PV irradiance level. Neither the parasitic resistance of an induct-or nor the turn-on resistance of a MOSFET are taken into account. During the testing phase, we take into consideration the following converter parameter values to see whether the proposed topology is viable.

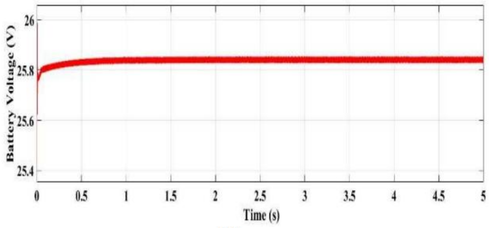
L = 500H, C = 1000F, and -./ = 5kHz are the primary parameters of the bidirectional converter.

Battery nominal voltage = 24 V; battery capacity = 50 Ah; initial state of charge = 45%.

Figures 5(a) and 5(b) show the battery voltage and battery current, respectively, as a function of the irradiation of the solar energy accessible to the PV module.

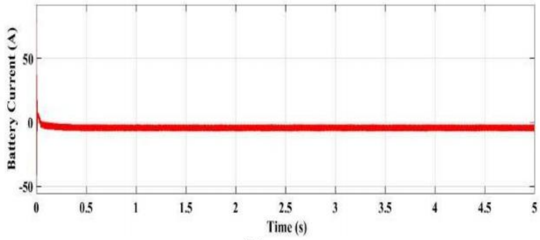
The charging mode of an EV battery is shown in Fig.5(a), where the voltage steadily rises with time; the same charging behaviour is depicted in Fig.5(b), where the current gradually decreases. The voltage, current, and power output of a PV module at 500 0/2 of irradiation and a cell temperature of 25°C are shown in Fig.6(a), 6(b), and 6(c), respectively. The irradiation level of 5000 2 is shown in Fig. 7. By connecting the PV module's output voltage to the battery side through a DC connection and then monitoring the battery's charging voltage and state of charge using a bidirectional direct current to direct current (DCDC) converter, as shown in Fig. 8 that depicts the rising nature, showing the charging mode

of the EV battery.



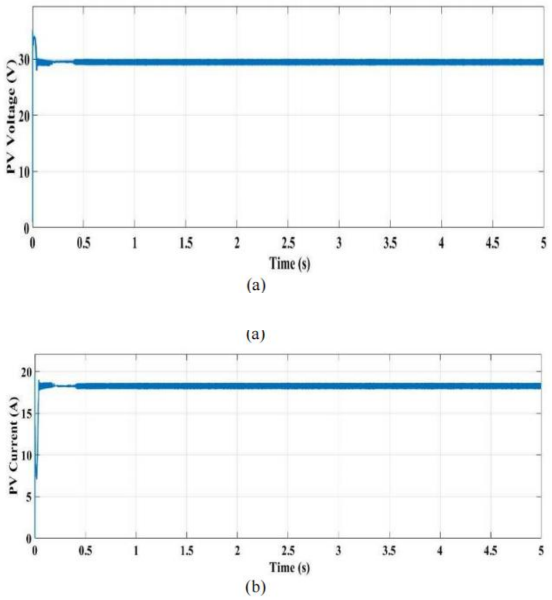
(a)

(a)



(b)

Fig. 5. Battery (a) Voltage (b) Current with respect to irradiation of solar energy.



(a)

(a)

(b)

Fig. 6. Solar PV (a) Voltage (b) Current

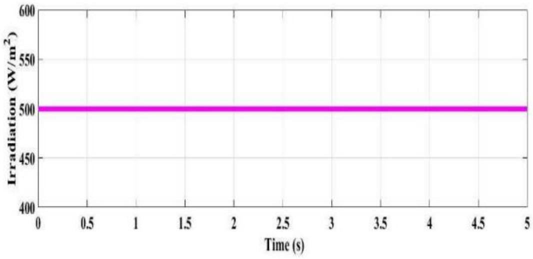


Fig. 7. Solar PV irradiation at 500 0/2

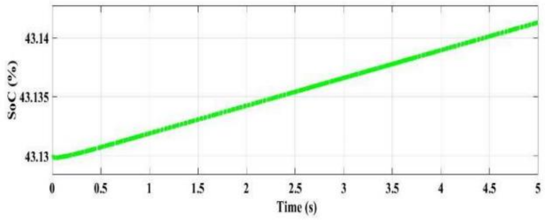


Fig. 8. Battery SoC showing its charging mode.

V Conclusion

Hybridized electric solar cars have become more popular in contemporary period because of their solar PV panels. An effective battery charging system and cost effective E Vs have resulted from recent technological

developments in this field. This paper proposes the integration of PV panel with EV battery charging system through a bidirectional DC-DC converter. The converter circuit is compared by various typologies. The converter used in this paper does not require coupled induct-or which makes the circuit more simplified. Also, the number of induct-or and capacitor used are very less compared to these topological. This converter operation is controlled through PI controller and switching of charging and discharging

modes can be done. This battery charging is well-suited to PI controller control strategy that has been suggested. Additionally, MPPT algorithm is employed to harvest optimum power by solar PV under all different irradiation

situations. EV's operation will not be disrupted in this way. DC-DC converter as well as control circuit have been shown to work as described in previous section.

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