

An Innovative Multi-input Boost Chopper for HEV



A. Ranganadh and M. Chiranjeevi

Abstract In this paper, for efficient functioning of hybrid electric vehicles, a DC–DC converter which has multiple inputs is used. The output gain can be increased considerably than that of existing methods. The main input sources for these converters are fuel cell (FC), solar panel and battery. In which FC is treated as the main power supply and a roof-top PV is used which helps in charging the battery increasing the efficiency and reducing the fuel consumption. By using this converter, demanded power can be produced continuously even in the disconnection of either one or two sources. Moreover, in this, the strategy of power management is described. In order to authenticate and validate the prototype, this multi-input boost HEV can be considered. Which is implemented and is tested. This paper presents design and implementation of a system which gives the information about multi-input DC–DC converter for hybrid vehicle by using MATLAB/Simulink.

Keywords Hybrid electric vehicle (HEV) • Multi-input DC–DC chopper • Fuel cell and pv and battery

1 Introduction

The main drawback of present-day vehicles which are powered by oil or diesel, etc., is that these fossil fuels are available in limited amount on the earth and is leading to environmental pollution. To eliminate the above-mentioned problems, most of the present-day innovators started showing interest in HEVs and PHEVs [1, 2]. As these are powered by renewable resources, EVs depend upon the energy which is maintained in the battery. The main problem which is faced by using this converter is that it consists of limited driving range, and large amount of time is required for charging. It can be overcome by using a bidirectional switch board charger.

A. Ranganadh (✉)

Department of EEE, Guru Nanak Institute of Technology, Hyderabad, India

M. Chiranjeevi

Department of EEE, PACE Institute of Technology & Sciences, Ongole, India

© Springer Nature Singapore Pte Ltd. 2020

H. S. Saini et al. (eds.), *Innovations in Electrical and Electronics Engineering*,

Lecture Notes in Electrical Engineering 626,

https://doi.org/10.1007/978-981-15-2256-7_15

Solar-based EVs can also be recycled as a conventional energy source in this system, which are not being implemented due to the size and location of PV panels [2]. As a result, fuel cells are used for powering the device. The main problems of FCs are high cost, great density output current capability and poor transient performance. Clean electricity generation, and high efficiency operation. The vehicles which are mechanized by fuel cells are mixed by ESSs [1]. Cost of per unit power can be reduced, and problems such as transients can be reduced by hybridization technique. Boost-dual-half bridge topology-based chopper is recycled for this purpose which consists of three half-bridges and a three-winding transformer. It is applied for high step-up applications. The converter size cost is going to high due to the managing components such as active switches, input inductors and filter capacitors [2].

The system was proposed by FC and a battery unit. V2G is main advantages of proposed converter. However, the great number of power switches could reduce the reliability and increase the cost. In a multi-input DC-DC step-up chopper for hybrid PV/FC/Battery is proposed. This converter can be charged and discharged only by using PV and FC leading to the improper functioning A two-input DC-DC converter is used to connect two power sources with a DC bus or load. Due to turn-on zero voltage switching (ZVS) of all switches, it attains high efficiency, and also, it does not consists of bidirectional port.

2 Solar Energy and Boost Converter

Silicon materials are used for building basic photovoltaic cell from its origin. Photovoltaic cells are made up of silicon material. In the process of photovoltaic cell structure, it consists of boron atoms from three valance electrons (p -donors) silicon to create a most affection to attract electrons (Fig. 1).

If any one of the array is shaded, then automatically output will educe, whose variation of reduction in magnitude depends upon electrical configuration of the array, and its output will be corresponding to the high amount of light intensity

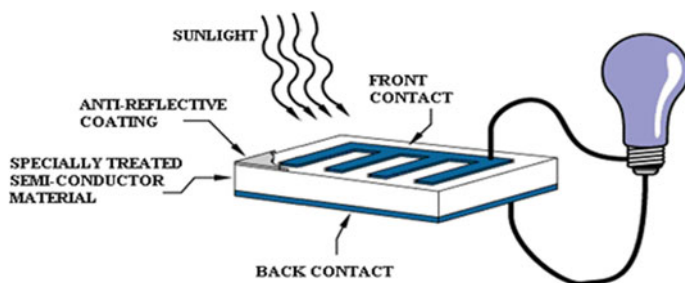


Fig. 1 Solar energy

which it is subjected to. If the shadowed cell or shadowed module is connected electrically to other cells and modules which are unshaded, then there will be a reduction in the performance characteristics.

2.1 Maximum Power Point Tracking (MPPT)

They follow the MPPT's maximum power cooperate photovoltaic (electronic) system module that allows power modules for everything. The main problem with this method is that it frequently, if it is necessary accordingly, finds the MPP V_{mpp} voltage or current or the maximum power given to it by the photoelectric and external temperature. In this segment, most useful MPPT techniques are described in any order [2].

A. Fractional Open-Circuit Voltage

In this approach, it shows the relationship between the maximum voltage and the V_{OC} is considered constant VMPP arrangement that made the observations. It was observed that K1 factor varies between 0.71 and 0.78. For this reason, the constant K1 is a measure of the V_{OC} and V_{MPP} with the help of periodic checking of those parameters. The implementation is simple and inexpensive to this effect, and the screening efficiency and its efficiency are low due to improper, which are in a constant K1 in the VMMP.

B. Fractional Short-Circuit Current

This method is based on the observation that the current at the maximum power point of the I_{MPP} is approximately linearly related to the short-circuit current of the I_{SC} . Here, it is not consistent with themselves and women, between 0.78 and 0.92. Circuit K2 is short, and accurate measurement of the current cycle of periodicals determines efficiency.

DC-DC Converter

DC-to-DC converter performs the operation of producing variable DC voltage under constant supply of DC voltage [3, 4]. Different ranges of output voltages can be achieved. They are used in power bus regulation, providing noise isolation, etc.

Boost Converter

The schematic in Fig. 2 depicts the basic boost converter. Boost converter increases the output voltage for the given input (Fig. 3).

Buck-Boost Converter

In order to required continuous current conduction operation Buck-Boost converter is preferred. the transistor will be on when $V_x = V_{in}$ and will be in off position when $V_x = V_0$. The duty cycle "D" range is from 0 to 1 for this convertor. As a result, the output voltage can vary the range of lesser or greater than input magnitude.

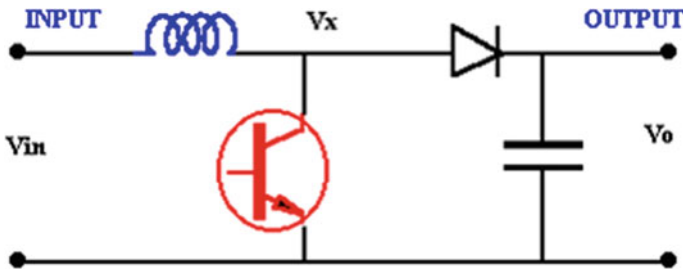


Fig. 2 Boost converter

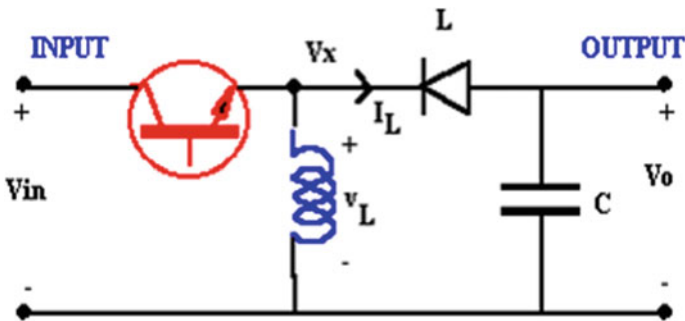


Fig. 3 Buck-boost converter

Among all the converters, only the buck converter exhibits linear graph between the duty ratio and output voltage. In order to get desired higher voltage, solar cells are assembled in series. In maximum cases this method of connecting cells in series. In such cases, boost converters are used which help in increasing voltage and decreasing of the cells [5, 6].

Battery

It is a device which provides electrical energy to electrical devices in which electrochemical cells are associated with cascaded or concurrent as per the requirement. In a battery, electrons flow from negative terminal to the device and reach one end of the cell that may be positive in order to transfer the energy from battery to device. When a device is linked to a battery, electrolytes exist in a battery move as ions which helps in completing the chemical reactions required in order to transfer the energy.

Lithium-Ion Battery

A battery of calcium ion and lithium-ion (LIB) batteries consists of charging and discharging of their energy levels. The lithium batteries inter calculated lithium compound is recycled as the electrode material and compared with a non-calcium



Fig. 4 Battery module for hybrid vehicle

metals are used in a rechargeable lithium battery. Electrolysis allows ionic movement, and two electrodes are a constituent component ion cell battery. Electrochemical reactions on electrolyte reagents and positive and negative lithium-ion electrolytes are providing a lithium-ion model into the conductive medium between the electrodes to move. The main important difference between a fuel cell and a battery is that fuel cell requires fuel and oxygen as a continuous source (Fig. 4).

Fuel Cell

An electrochemical cell which converts the electrical energy from chemical energy from a fuel by using an oxidizing agent by undergoing electro chemical reactions [7]. The main important difference between a fuel cell and a battery is that fuel cell requires of fuel and oxygen as a continuous source, whereas batteries do not require any such arrangement as it utilizes the chemicals that are previously exists in the battery. Hence, continuous supply of fuel is necessary for a fuel cell in order to produce electricity continuously.

2.2 Polymer Electrolyte Membrane Fuel Cells

Fuel cells with a polymer electrolyte membrane (PEM), also called proton membrane exchange fuel cells, are recycled to contribute high power density. It consists of advantages such as less mass and volume compared to other fuel cells [8]. In PEM fuel cells, a solid polymer is used as electrodes consisting of porous carbon containing a catalyst made of platinum or a platinum alloy. Work requires only hydrogen and oxygen from air and water.

2.3 Direct Methanol Fuel Cells

They supply hydrogen to the fuel cell system or by transferring hydrogen-rich fuels such as methanol, ethyl, and hydrocarbon fuels, by developing hydrogen in the fuel cell system [8]. Due to the high energy density property of methanol to handle hydrogen, this fuel supply and transportation become easier, as a result of which direct fuel cells with methanol are used in many modern applications such as mobile phones and laptops.

3 Proposed System and Control Strategies

For the performance verification of this converter, a 80 W prototype version of the circuit is built and tested in presented three states. Switching frequency is considered about 30 kHz. As mentioned earlier, the expected chopper had greatest capacity being used for different industrial and domestic applications such as HEV, DGs interface, smart homes. Power sources are mainly PV arrays, fuel cells and so on. Ignoring the transient time of the power sources, they could be replaced by DC power supplies to obtain experimental results. Li-ion type batteries are used widely due to their better performance in portable electronic gadgets. High reliability, high energy density, high temperature performance and being recyclable are main features of Li-ion batteries [6]. Due to high switching frequency, ferrite cores are chosen for the both inductors (Figs. 5 and 6) [9].

The structure of proposed multi-input step-up chopper is depicted. A conventional boost converters convert the voltage from lower level to higher level. Its characteristic converter is suitable for hybrid systems. In this work, the behavior of the source converter is in terms of objective managing to show the power of

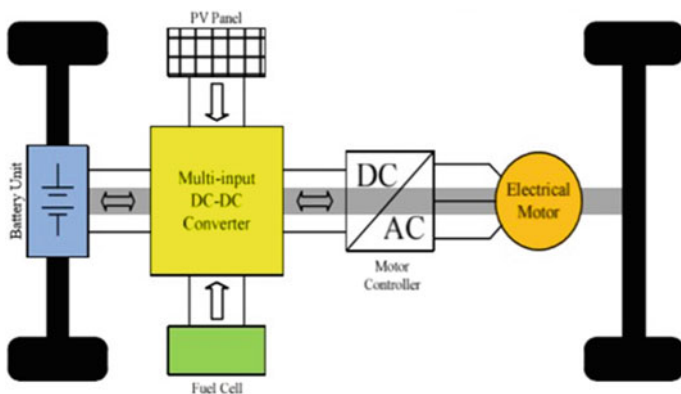


Fig. 5 General structure of multi-powered EHV

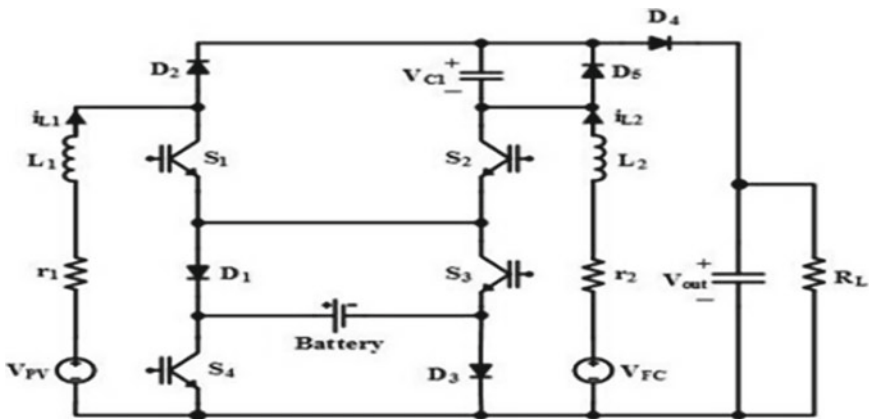


Fig. 6 Topology of the proposed convertor

management and control. The PV and FC are two independent power sources, and the output ratio is based on them. L_1 and L_2 are inductance grams from the input panel of fuel filters and the cell. And in a series began to use L_1 and L_2 to change the sources of current Sources of photovoltaic modules to the FC. r_1 and r_2 are V_{PV} 's and V_{FC} 's equivalent resistance, respectively. Earth is the equivalent resistance of R-600 connected to the bus loads. S_1, S_2, S_3 and S_4 are power switches. Diodes D_1, D_2, D_3 and D_4 are used to establish modes. The increase of the output to the capacitor C_1 to the capacitor C_o and the result is that the gain of the voltage output of filter. The behavior of the continuous operation system (CCM) to produce smooth operation with less amount of vibration can be performed [9, 10].

3.1 Principle of Operation

In this section, principles of the suggested converter are discussed. Operation of the converter is divided into three states: (1) The load is supplied by PV and FC, and battery is not used. (2) The load is supplied by PV, FC and battery; in this state, battery is in discharging mode. (3) The load is supplied by PV and FC, and battery is in charging mode.

3.1.1 Topological Modes and Analysis

A. *First operation state (The load is delivered by PV and FC, while battery is not used)*

In this state, there are three modes of operation. In this state, there is no operating system, the battery charge or discharge. Therefore, there are two paths for current to

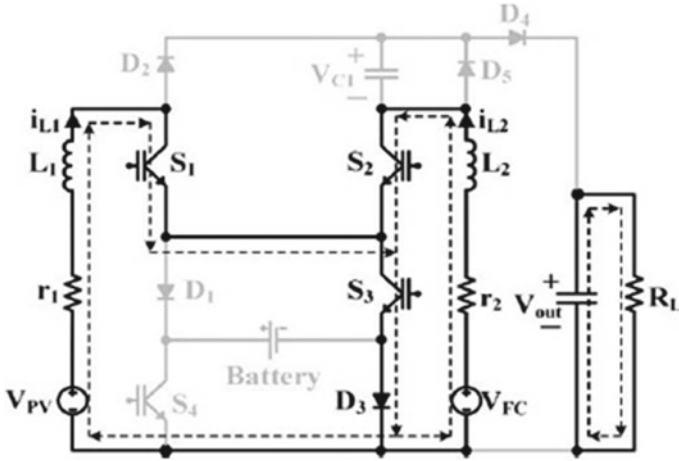


Fig. 7 Current flow path of operating modes in the first operating state

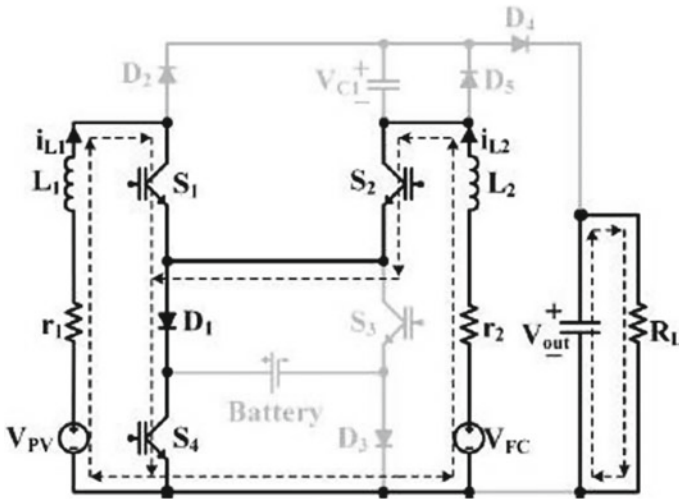


Fig. 8 Current flow path of operating modes in the third operating state

flow (through S_3 and D_3 or D_1 and S_4). In this paper, S_3 and D_3 are considered as a common path. However, D_1 and S_4 could be chosen as an alternative path. During this state, switch S_3 is permanently ON and switch S_4 is OFF (Figs. 7 and 8) [10].

B. Second operation state (The load is equipped by photo voltaic, FC and battery)

In this state, there are four modes of operation. During this state, the load is supplied by all input sources (PV, FC and battery). In the first mode, there is only one current path. However, in the other three modes, there are two current paths (through S3 and D3 or D1 and S4). In this state, current flows through D1 and S4. Switch S4 is permanently ON during this state.

C. Third operation state (The load is given by PV and FC, while battery is in charging mode)

This is illustrated in Fig. 10 four ways. In the state of FC, mass sends power to the battery. Both the first and second modes of operation, there are two S3 and S4 travels mainly D1 current or D3). D1 is selected to be in the S4 path, and the current flows in this state. During this state, switch S3 is permanently OFF and diode D1 conducts [9].

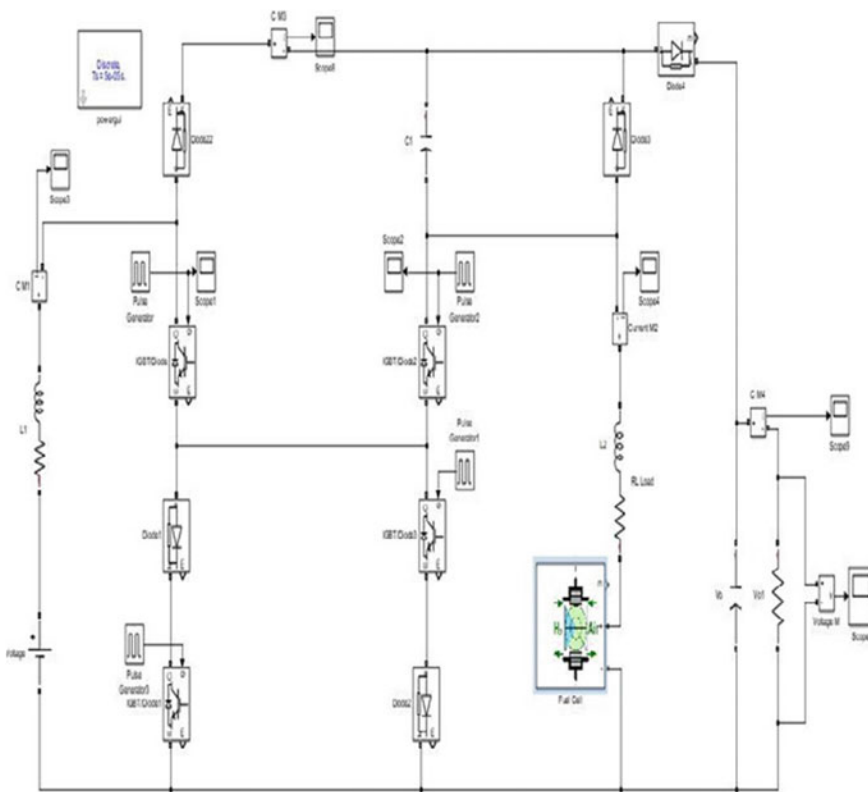


Fig. 9 Simulink for first mode operation

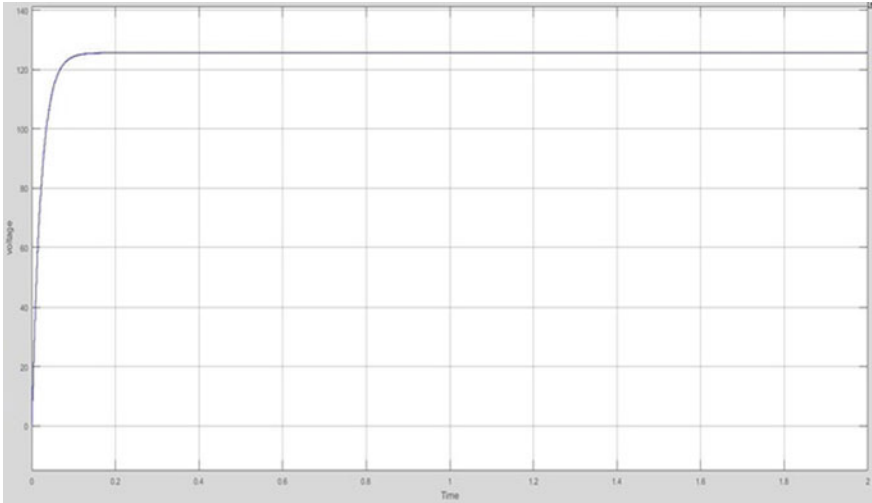


Fig. 10 Output voltage graph for the first case

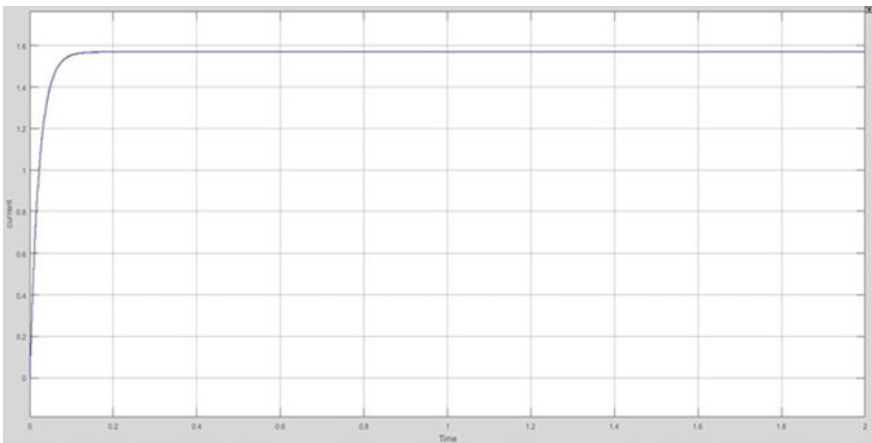


Fig. 11 Output current for the first case

4 Simulation Results

Figure 9. shows the Simulink circuit for the proposed system for first mode of operation.

Figures 10 and 11 show the output voltage and currents for the first mode of operation, respectively, output desired voltage is desired to be about 120 V, and output current is about 18A. As mentioned, in this state, battery's power is zero.

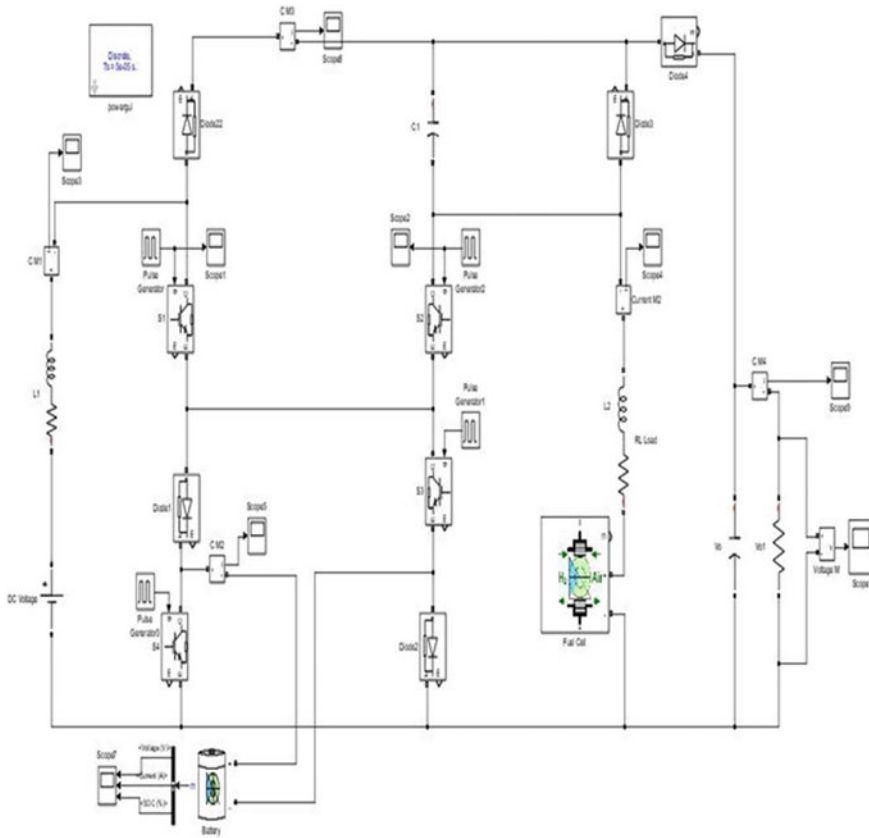


Fig. 12 Simulink model for the second mode of operation

4.1 For Second Mode of Operation (The Load is Supplied by PV, FC and Battery)

Figure 12 shows the Simulink circuit for the second mode of operation of the proposed system. During this state, the load is provided by all input sources (PV, FC and battery). The current paths are S_3 and D_3 or D_1 and S_4 .

Figures 13 and 14 show the graph of output current and voltages of the Simulink circuit for second mode of operation, respectively. The outputs of the system where the battery is in discharging mode are the voltage is around 125 V and output current is about 1.6A.

4.2 For Third Mode of Operation (The Load is Dispensed by PV and FC, While Battery is in Charging Mode)

Figure 15 shows the Simulink circuit for the third mode of operation of the proposed system. During this state, PV and FC charge the battery and supply the energy of load. The current paths are through S_3 and D_3 or D_1 and S_4 .

Figures 16 and 17 show the output voltage and output current graphs of the proposed system for the third state of operation, respectively. In this mode of operation, the battery is in charging mode. The output voltage and currents of the mode of operation are 120 V and 1.6A, respectively.

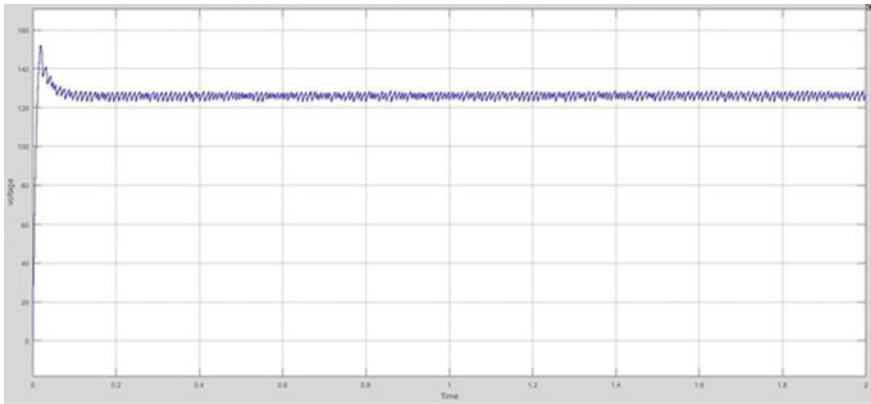


Fig. 13 Output voltage for the second mode

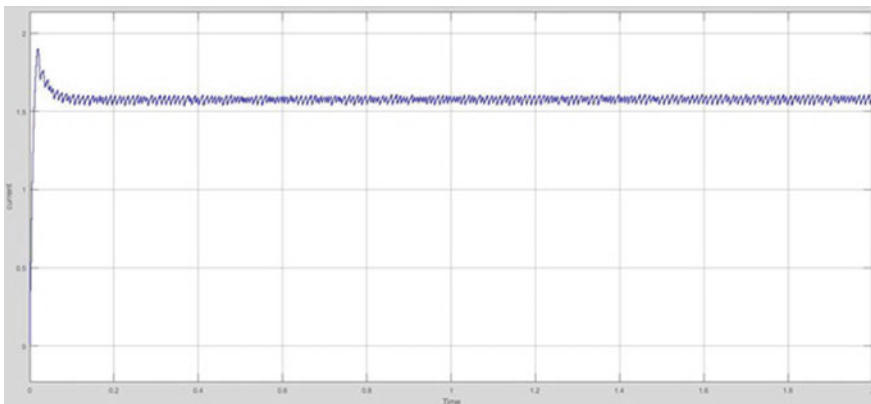


Fig. 14 Output current for the second mode

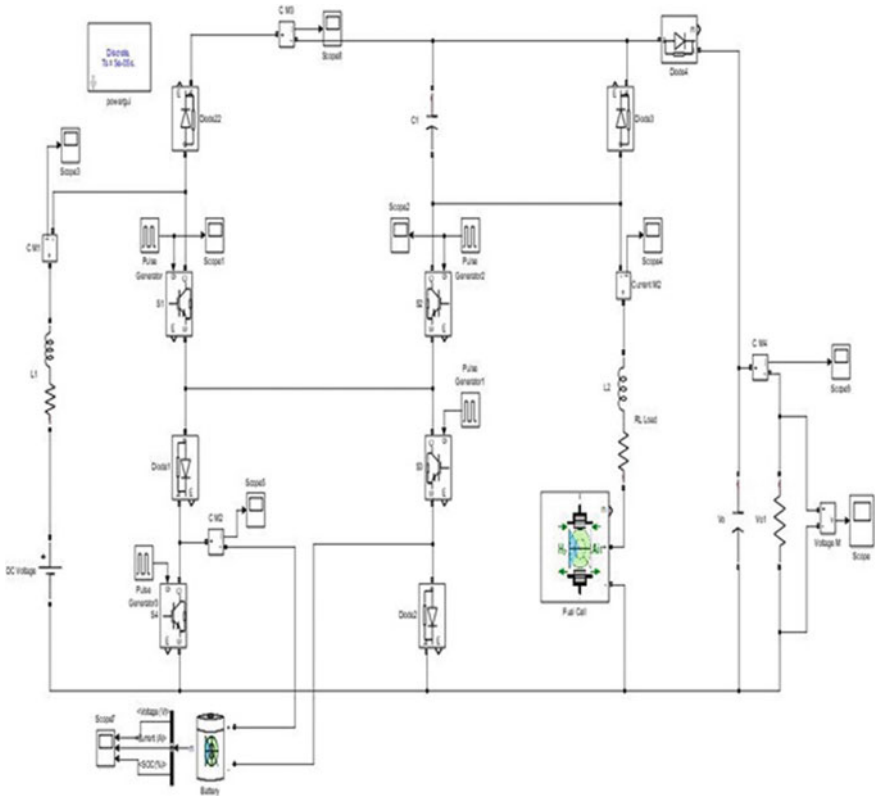


Fig. 15 Simulink model for the third mode

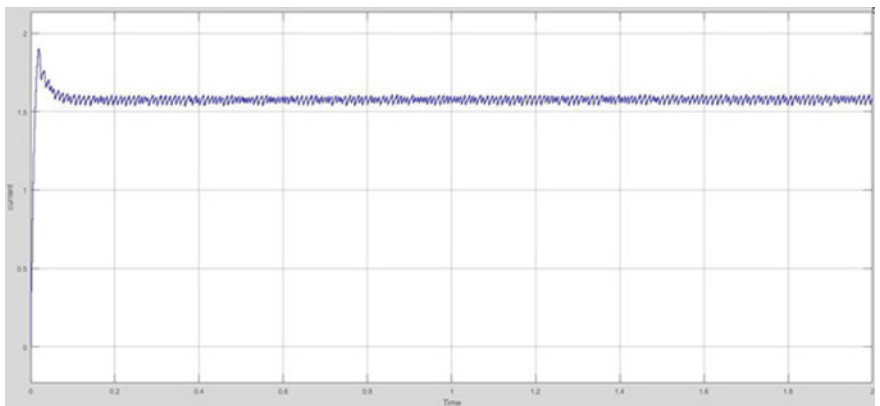


Fig. 16 Output voltage for the third case

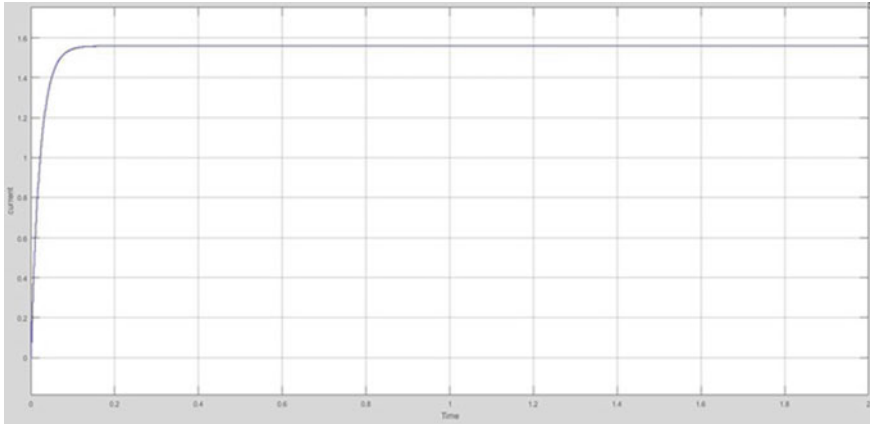


Fig. 17 Output current for the third case

5 Conclusion

In this paper, an emerging three-input DC/DC converter is proposed and analyzed thoroughly. The converter is able to supply the power load demanded in the search of one or two sources. Expectancy and performance patterns are also out of power of domestic and industrial processes with great reliability by stumbling the timer into the head and do an offering to use the converter. The converter is modeled for three different operational states and utilized to design a proper controller. MPPT algorithm is achieved and along power management is utilized to apply the commands of controller. Meanwhile, employing power management and MPPT procedure will enhance the performance of converter. Finally, a practical prototype of the presented converter is implemented, and results are taken and depicted. Results prove the analysis and performance of the converter.

References

1. O. Hegazy, R. Barrero, J. Van Mierlo, P. Lataire, N. Omar, T. Coosemans, An advanced power electronics interface for electric vehicles applications. *IEEE Trans. Power Electron.* **28**(12), 1–14 (2013)
2. R.B. Mohammad, H. Ardi, R. Alizadeh, A. Farakhor, Non-isolated multi-input–single-output DC/DC converter for photovoltaic power generation systems. *IET Power Electron.* **7**(11), 2806–2816 (2014)
3. L.W. Zhou, B.X. Zhu, Q.M. Luo, High step-up converter with capacity of multiple input. *IET Power Electron.* **5**(5), 524–531 (2012)
4. H. Ardi, R.R. Ahrabi, S.N. Ravandanegh, Non-isolated bidirectional DC–DC converter analysis and implementation. *IET Power Electron.* **7**(12), 3033–3044 (2014)

5. F.I.G. Maoosena, G-source inverter design, analysis and its applications, in *The prose fuel cell vehicles search campaign* (Michigan University, East Lansing, USA, 2007)
6. R.Y. Duan, J.D. Lee, High-efficiency bidirectional DC–DC converter with coupled inductor. *IET Power Electron.* **5**(1), 115–123 (2012)
7. T. Markel, M. Zolot, K.B. Wipke, A.A. Pesaran, Hybrid fuel cell energy storage requirements for vehicles, in *Battery advanced books miscarry* (2003)
8. H.J. Chiu, L.W. Lin, A two-directional chopper for fuel cell electric vehicle driving system. *IEEE Trans. Power Electron.* **21**(4), 950–958 (2006)
9. S. Danyali, S.H. Hosseini, G.B. Gharehpetian, New extendable single-stage multi- input DC–DC/AC boost converter. *IEEE Trans. Power Electron.* **29**(2), 775–788 (2014)
10. Y.M. Chen, A.Q. Huang, X. Yu, A high step-up three-port dc-dc converter for stand-alone pv/ battery power systems. *IEEE Trans. Power Electron.* **28**(11), 5049–5062 (2013)