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A Novel Step-up Multi-Input DC-DC Converter for Hybrid Electric Vehicles Application

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ABSTRACT- In this paper, a multi-input DC-DC converter is proposed and studied for hybrid electric vehicles (HEVs). Compared to conventional works, the output gain is enhanced. Fuel cell (FC), photovoltaic (PV) panel and energy storage system (ESS) are the input sources for proposed converter. The FC is considered as the main power supply and roof-top PV is employed to charge the battery, increase the efficiency and reduce fuel economy. The converter has the capability of providing the demanded power by load in absence of one or two resources. Moreover, power management strategy is described and applied in control method. A prototype of the converter is also implemented and tested to verify the analysis.

I. INTRODUCTION

Global warming and lack of fossil fuels are the main drawbacks of vehicles powered by oil or diesel. In order to overcome the aforementioned problems and regarding the potential of clean energies in producing electricity, car designers have shown interest in hybrid electric vehicles (HEVs) and plug-in hybrid electric vehicles (PHEVs). The overall structure of hybrid electric vehicle powered by renewable resources is depicted in Fig.1. Electric vehicles (EVs) have also been studied. EVs rely on energy stored in energy storage system (ESS) [1]. Limited driving range and long battery charging time are their main drawbacks. However, by using a bidirectional on/off board charger, they could have the V2G capability. Solar-assisted EVs have also been studied. Required location and size of PV panels have made them impractical at present [2]. Employing fuel cell as the main power source of HEVs is the result of many years of research and development on HEVs. Pure water and heat are the only emissions of fuel cells. Furthermore, FCs have other advantages like high density output current ability, clean electricity generation, and high efficiency operation [3]. However, high cost and poor transient performance are the main problems of FCs. It is important to note that vehicles mainly powered by FCs, are hybridized by ESSs. The main advantages of hybridizing are enhancing fuel economy, providing a more flexible operating strategy, overcoming fuel cell cold-start and transient problems and reducing the cost per unit power [4].

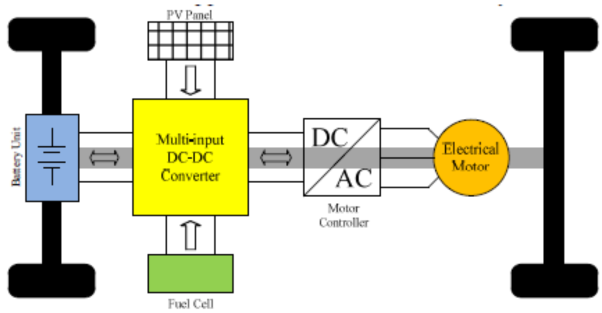


Figure 1: general structure feaof multi-powered HEV

In the literature, few numbers of researches have been reported on EVs' and HEVs' electronic interfaces. In [5], authors have studied employing a Z-source inverter (ZCI) for EV vehicles. Boosting input voltage in one stage is its advantage, while high voltage and current stress and complex powered by FC and a battery unit. V2G is one of the advantages of proposed converter. However, the great number of power switches could reduce the reliability and increase the cost. In [7], a multi-input DC-DC boost converter for hybrid PV/FC/Battery is proposed. But the proposed converter cannot work properly because the battery can be only discharged by PV and only charged by FC. In [8], a two-input DC-DC converter is proposed to interface two power sources with a DC bus or load. The converter has high efficiency due to achieving turn-on zero voltage switching (ZVS) of all switches.

However, it lacks a bidirectional port. Hence, in applications in need of ESS, it can't be used. A compact twoinput converter is proposed for standalone PV systems in [9]. Moreover, high voltage gain of the converter makes the converter suitable for low input voltage applications. However, the high number of semiconductors and passive elements reduce the efficiency. Control method preset in the vehicle's controller should control the power flow between renewable resources, battery unit and electrical motor. Optimal utilization of power resources, providing demand power permanently, operating fuel cell and PV panel in their optimum region are the main duties of control scheme. Some converters have been proposed recently for PVs systems [10- 12]. But, the required converter for HEV applications should extract power from PV and FC.

Besides, in order to supply Back-up power from the battery, a bidirectional port is needed to charge and discharge the battery according to discrepancy between generated power and demanded energy [13, 14]. A multi input converter (MIC) can provide power to the load from different energy sources simultaneously or individually.

II. PROPOSED SYSTEM

The structure of proposed three-input DC-DC boost converter is depicted in Fig. 2. The converter is formed of two conventional boost converters, substituting extra capacitor in one of the converters, and a battery to store the energy. Characteristic of the converter is suitable for hybrid systems.

In this paper, behavior of the converter in terms of managing the sources is analyzed in power management and control part. Then *vPV* and *vFC* are two independent power sources, that output is based on characteristic of them. *L1*and *L2* are the inductances of input filters of PV panel and fuel cell. Using *L1* and *L2* as in series with input sources change PV and FC

modules to current sources. *r1* and *r2* are *vPV*'s and *vFC*'s equivalent resistance, respectively. *RLoad* is the equivalent resistance of loads connected to the DC bus. *S1*, *S2*, *S3* and *S4* are power switches. Diodes *D1*, *D2*, *D3* and *D4* are used to establish modes, which will be described. Capacitor *C1* is used to increase output gain and output capacitor *Co* is performed as output voltage filter. System is operating in continuous conduct mode (CCM) to produce smooth current with least po Figure depicts the proposed three-input DC-DC boost converter's structure. 2. The converter consists of a battery for energy storage and two conventional boost converters that each have an additional capacitor in one of them. The converter's characteristic is suitable for hybrid systems.

In the power management and control section of this paper, the converter's behavior in managing sources is examined. Therefore, vPV and vFC are two distinct power sources whose output is determined by their characteristics. The fuel cell and PV panel input filters' inductances are L1 and L2. PV and FC modules become current sources by connecting L1 and L2 in series with input sources. The equivalent resistances of vPV and vFC are r1 and r2, respectively. The equivalent resistance of loads connected to the DC bus is referred to as RLoad. The power switches are S1, S2, S3, and S4. The modes that are established by diodes D1, D2, D3, and D4 will be discussed. Capacitor C1 is utilized to increment yield gain and result capacitor Co is proceeded as result voltage channel. Framework is working in ceaseless lead mode (CCM) to create smooth current with least conceivable measure of current wave.

III. OPERATION MODES

The principles of the proposed converter are discussed in this section. The converter can be used in three different states: 1- The load comes from PV and FC, and no battery is used. 2- The battery is in the discharging mode when the load is supplied by PV, FC, and the battery. 3-The heap is provided by PV and FC and battery is in charging mode.

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

In this condition, as shown in Fig. 3, there are three modes of operation. The system is in this state and does not charge or discharge the battery. As a result, current can travel either through S3 and D3 or through D1 and S4. S3 and D3 are regarded as a common path in this paper.

However, as an alternative route, D1 and S4 could be chosen. Switch S3 is always on and switch S4 is off in this state.

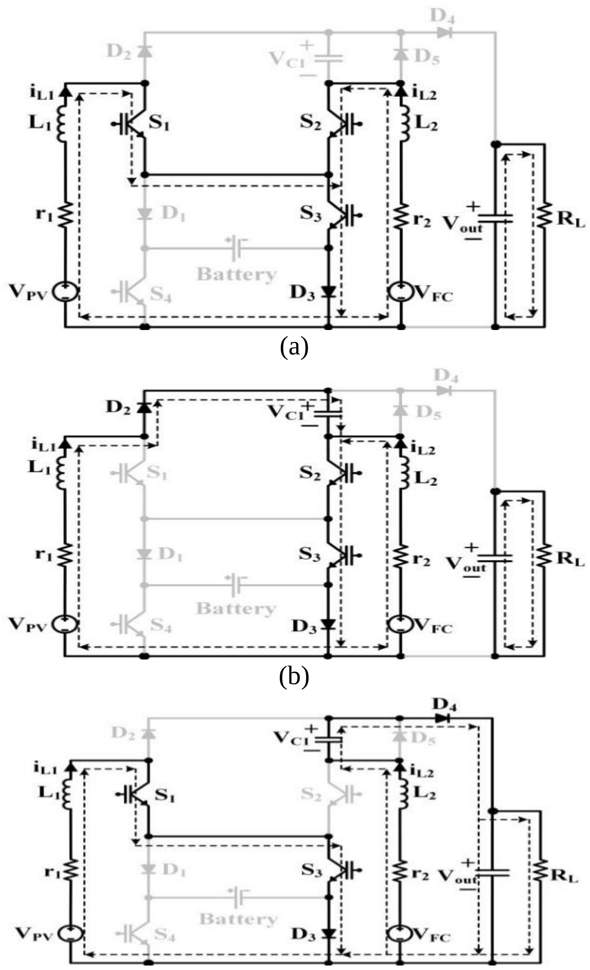
Mode 1 (td1T): Switches S1, S2, S3, and diode D3 are activated during this time period. Power sources vPV and vFC are used to charge inductors L1 and L2 [see Fig.]. 3(a)].

Mode 2 (d1T < t < d2T): During this time, switch S1 is off, switch D2 is on, and switches S2, S3, and D3 are still on. Inductor L1 is being discharged via vPV–vC1 while inductor L2 remains charged [see Fig. 3(b)].

Mode 3: d2T t T: In this span, S1 is turned ON and S2 is switched OFF and S3 and D3 are still ON. vPV is applied to inductor L1, and vPV+ vC1 – vo is used to discharge inductor L2 [see Fig. 3(c)].

The voltage of the capacitor C1 and the voltage of the output can be obtained as follows by applying the voltage–second balance low over the inductors L1 and L2.

Additionally, by applying the current–second balance low to the voltage of capacitor C1 and the capacitors C1 and Co, we obtain:



(a)

(b)

(c)

Figure. 3. Current-flow path of operating modes in first operating state. (a) Mode 1. (b) Mode 2. (c) Mode 3.

In this case, battery is not used and so we have:

IV. CONCLUSION

A novel three-input DC/DC converter is proposed and thoroughly examined in this research. The converter has the capacity of giving the requested power by load innonattendance of a couple of assets. The converter's promising performance and utilized control method provide a high level of dependability for use in both domestic and industrial settings. The converter is displayed for three unique functional states and used to plan a legitimate regulator. The MPPT algorithm is implemented, and power management is used to implement the controller's commands. In the meantime, using power management and the MPPT procedure will make the converter work better. Lastly, a working prototype in the lab of the presented converted is implemented and results are taken and depicted. Results prove the analysis and performance of the converter.

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