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A DIFFERENT APPROACH TO STEP-UP MULTI-INPUT DC-DC CONVERTER FOR HYBRID ELECTRIC VEHICLE USE

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Abstract— This research proposes and studies a multi-input DC-DC converter for hybrid electric vehicles (HEVs). In contrast to traditional works, there is an increase in output gain. The suggested converter uses fuel cells (FC), solar (PV) panels, and energy storage systems (ESS) as its input sources. Rooftop PV is used to reduce fuel economy, increase efficiency, and charge the battery; the FC is considered the primary power source. In the event that one or both resources are unavailable, the converter can still supply the load with the required power. Furthermore, the control approach describes and uses the power management strategy. To confirm the findings, a converter prototype is also put into use and put through testing.

Index Terms: power management, hybrid electric vehicle (HEV), multi-input converter.

1. INTRODUCTION

The two biggest disadvantages of automobiles running on oil or diesel are global warming and the depletion of fossil fuels. Automobile designers have expressed interest in plug-in hybrid electric vehicles (PHEVs) and hybrid electric vehicles (HEVs) as a means of addressing the aforementioned issues and realizing the promise of renewable energies in an electrical power capacity. Fig. 1 shows the general layout of a hybrid electric car that is fueled by renewable energy. EVs, or electric cars, have also been researched. Energy storage systems (ESS) are necessary for EV operation [1]. Their two biggest shortcomings are their short driving range and lengthy battery charging times. They might, however, be able to use a bidirectional on/off board charger to enable V2G. EVs using solar assistance have also been researched. Currently, PV panels are unfeasible due to their required placement and size [2]. The outcome of many years of HEV research and development is the use of fuel cells as the primary power source for HEVs. A fuel cell's sole emissions are heat and pure water. Moreover, FCs can generate clean power, operate with high efficiency, and have a high density output current capability [3]. However, the primary issues with FCs are their high cost and subpar performance in the short term. It is significant to remember that ESSs hybridize cars that are primarily powered by FCs. Enhancing fuel economy, offering a more adaptable operating strategy, resolving transient issues and fuel cell cold start, and lowering the cost per unit power are the primary benefits of hybridization [4]. There aren't many studies on the electronic interfaces between HEVs and EVs in the literature. Authors have examined using a Z-source inverter (ZCI) for electric vehicle (EV) applications in [5]. Its advantage is that it can increase input voltage in a single step; however, the main disadvantages of the converter that is being given are high voltage and current stress and a complex control mechanism. A different strategy was used in [6]. The system consisted of a battery unit and an FC-powered battery unit.

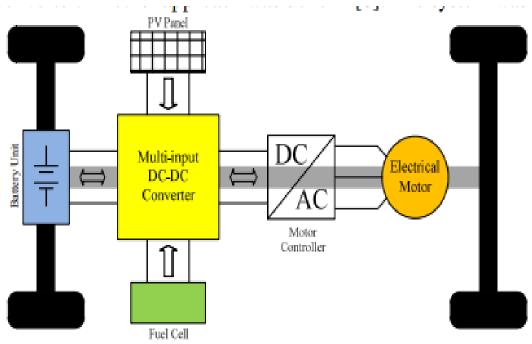

Fig.1. general structure of multi-powered HEV

One benefit of the suggested converter is V2G. On the other hand, an excessive number of power switches may make things less reliable and more expensive. A DC-DC boost converter with several inputs for hybrid PV/FC/Battery is suggested in [7]. Nevertheless, because the battery can only be charged by FC and discharged by PV, the suggested converter is unable to function as intended. It is suggested in [8] to use a two-input DC-DC converter to connect two power sources to a DC bus or load. Because all switches were able to achieve turn-on zero voltage switching (ZVS), the converter has a high efficiency. It does not, however, have a bidirectional port. Therefore, it cannot be used in applications that require ESS. In [9], a small two-input converter is suggested for independent photovoltaic systems. Additionally, the converter's high voltage gain qualifies it for low input voltage applications. Nevertheless, the efficiency is decreased by the large number of passive components and semiconductors. The power flow between renewable resources, the battery unit, and the electrical motor should be regulated by the control mechanism that is preset in the vehicle's controller. The primary responsibilities of the control system are to maximize the use of power resources, permanently supply demand power, and operate fuel cells and photovoltaic panels in their optimal regions. Recently, a few converters for PV systems have been presented [10–12]. However, the necessary converter for HEV applications ought to draw energy from FC and PV. Furthermore, a bidirectional port is required to charge and discharge the battery in accordance with the difference between generated power and demanded energy in order to supply backup power from the battery [13, 14]. Power from many energy sources can be applied to the load simultaneously or separately using a multi input converter (MIC). Numerous attempts have been made in literature to complete the task [15–19]. An attempt at introducing intelligent optimal power management was made in [20]. Three primary innovations in the method are the temperature fan control, fuzzy hydrogen control, and adaptive current-voltage fast-charging control. [21] describes a two-layer energy

Studies have been done on management. The aim of the study is to minimize the usage of hydrogen. Because photovoltaics (PVs) have a high starting cost, the MPPT algorithm must be used to maximize the power collected from the PV panels. A broad comparison of various MPPT methods is shown in [22] with regard to tracking factor, dynamic response, PV voltage ripple, and sensor utilization. Increasing the efficiency of the electric components is another strategy to increase efficiency [23]. This paper proposes a revolutionary three-input DC-DC converter that combines a fuel cell, a battery, and a photovoltaic system to link all three to the grid. Moreover, DC gain is improved over traditional converters. PV can obtain MPPT in the interim. Power management can be accomplished by charging and discharging the battery.

2 . MODELLING OF CASE STUDY

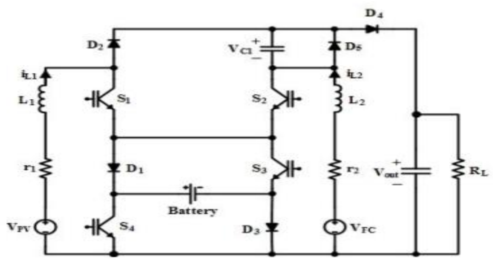

Fig. 2. Three-input DC-DC boost converter

Two traditional boost converters are combined with an additional capacitor in one of the converters, and the energy is stored in a battery to produce the converter. The converter's characteristic makes it appropriate for hybrid systems. This study examines the behaviour of the converter in the power management and control section with regard to source management. The output is thus reliant on the characteristics of the two separate power sources, vPV and vFC. The inductances of the fuel cell's and PV panel's input filters are L1 and L2. PV

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and FC modules are changed to current sources by connecting L1 and L2 in series with input sources. The analogous resistances of vPV and vFC are denoted by r1 and r2, respectively. The equal resistance of the loads attached to the DC bus is represented by RLoad. The power switches are S1, S2, S3, and S4. The modes that will be explained are established by diodes D1, D2, D3, and D4. Capacitor C1 is employed to enhance the output gain, while output capacitor Co serves as a voltage filter for the output. The system is producing smooth current with the least amount of current ripple by running in continuous conduct mode (CCM).

3. MODES OF OPERATION

The fundamentals of the suggested converter are covered in this section. The converter operates in three distinct states: 1. PV and FC supply the load; a battery is not used. 2. PV, FC, and the battery—which is currently in the discharging mode—supply the load. 3. The battery is charging and the load is being provided by PV and FC.

Initial operating state (Battery not used; PV and FC supply the load) There are three operation modes in this stage, as shown in Fig. 3. The system is neither charging or discharging the batteries while it is in this state. As a result, current can go through either D1 and S4 or S3 and D3. S3 and D3 are regarded as a shared path in this paper. D1 and S4, however, might be selected as a substitute route. Switch S3 is always ON in this state, while switch S4 is always off. Mode 1 (0< t < t < d2T): Switches S1 and D2 are turned ON and OFF respectively throughout this interval, while S2, S3, and D3 remain ON. As seen in Fig. 3(b), inductor L1 is being drained via vPV–vC1, but inductor L2 is still charged. Mode 3 (d2T < t < T): During this time, S1 and S2 are turned ON and OFF, respectively, while S3 and D3 remain ON. As shown in Fig. 3(c)], inductor L1 is charged with vPV, and inductor L2 is discharged by vPV+ vC1 – vo. It is possible to obtain the output voltage and voltage of capacitor C1 by applying the voltage–second balance low over the inductors L1 and L2.

$$L_1:\ d_1\left[V_{PV}-r_1 i_{L_1}\right]+(d_2-d_1)\left[V_{PV}-r_1 i_{L_1}-V_{C_1}\right]+(1-d_2)\left[V_{PV}-r_1 i_{L_1}\right]=0$$

$$V_{C_1}=\frac{V_{PV}-r_1 i_{L_1}}{d_2-d_1}$$

$$L_2:\ d_2\left[V_{FC}-r_2 i_{L_2}\right]+(1-d_2)\left[V_{FC}+V_{C_1}-r_2 i_{L_2}-V_o\right]=0$$

$$V_o=\frac{(d_2-d_1)(V_{FC}-r_2 i_{L_2})+(1-d_2)(V_{FC}-r_1 i_{L_1})}{(1-d_2)(d_2-d_1)}$$

Also, by applying the current–second balance low over the capacitors C1 and Co, voltage of capacitor C1, we have:

$$C_1:\ (d_2-d_1)i_{L_1}-(1-d_2)i_{L_2}=0$$

4. POWER MANAGEMENT AND MPPT ALGORITHM

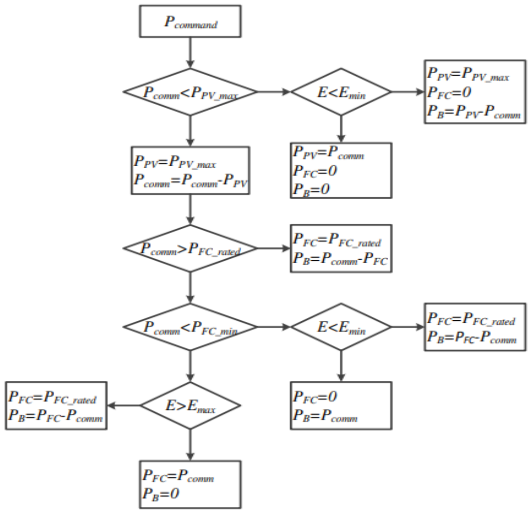
The building of the multi-powered hybrid electric vehicle is shown in Fig. 1. The FC serves as the primary power source for the drive system. To cut down on fuel usage and charge the battery, rooftop photovoltaic panels are used. The battery serves as a means of storage. An external power source won't be required to charge the battery if the design is sound [26]. PV and FC are two ways to charge the battery. To ensure that the system operates in its optimal zone, the following requirements must be met: 1. Power is always supplied on demand by electrical motors. 2. The optimal zone is where the FC and PV panel work. 3. The ideal range should always be reached by the battery's energy level. The strategy's flow chart is shown in Fig. 12, and the power management process is explained below. I. Control signals: brake and accelerate; pinpoint the command power. II. PV will operate at MPP and excess energy will be stored in the battery if command power is less than maximum PV power and battery energy level is less than minimum energy level. PV will generate the command power and the battery will remain off if the command power is less than the maximum PV power but the battery energy level is more than the minimum energy level. Under both circumstances, FC is off.

The PV panel will function in MPP mode if the command power exceeds the maximum PV power. The new command power will be defined as follows: new P P P command command = − PV (48). IV. The rated power of FC is contrasted with the new command power. The FC will operate at its rated power since the new command power exceeds the FC's rated power, with the battery supplying the remaining needed power.

The FC will operate at its rated power and any excess energy will be stored in the battery in the following phase if the new command power and battery energy level are both less than the FC's minimum power and energy level, respectively. The FC will be turned off and the battery will supply the required power if the new command power is less than the minimum power of the FC but the battery energy level is more than the minimum energy level.

The FC will supply the required power and turn off the battery if the new command power exceeds the FC minimum power and the battery's energy level exceeds the FC maximum energy level. The FC will operate at its rated power and any excess energy will be saved in the battery if the new command power exceeds the minimum power of the FC but the battery energy level exceeds the maximum energy level. Recent studies have examined and presented a variety of MPPT techniques, including as the perturb and observe (P&O) algorithm

[27], the incremental conductance algorithm , and slide control. Among other systems, the P&O method is a commonly used and useful scheme because of its simple programming and minimal computation.



5. SIMULATION RESULTS

An 80 W prototype simulation version of the circuit is constructed and tested in the three states that are offered in order to confirm the suggested converter's performance. The switching frequency is thought to be roughly 30 KHz. Power switches are managed by use of a pi controller. The aforementioned converter has the potential to be employed in various industrial and residential settings, including smart houses, DGs interface, and hybrid electric vehicles. Fuel cells, photovoltaic arrays, and other devices are the main power sources. To acquire experimental results, DC power supplies could be used in place of the power sources, disregarding their transient duration. The input sources are both configured for 20V. A 12-V, 7Ah Li-ion battery is employed as the energy storage component. Because Li-ion batteries work so well in portable electronic devices, they are used extensively. The primary characteristics of Li-ion batteries are their high energy density, high temperature performance, high reliability, and recyclable nature. One of its disadvantages is that they are quite expensive. For both inductors, ferrite cores are selected due to the high switching frequency. The inductor L2 has a value of 650 μH, while the inductor L1 has a value of 550 (μH).

470 μF capacitors are used in the converter. First states operation results are displayed in Fig. 13. The output and voltage of capacitor C1 Taking into account 20 V for every input-source voltage that is appropriately raised to roughly 110 V. the current flowing via inductors, whereas the current flowing through diodes and power switches. the voltage of power switches and diodes. The inductor currents in the first operation mode experimental results are around 2A. Diode D1 and switch S4 have zero currents, as seen in Figs. 13(c) and (d), while diode D3 and switch S3 are constantly on, resulting in a voltage across them that is nearly zero. A frequency of 30

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kHz is being used to swap the other components.

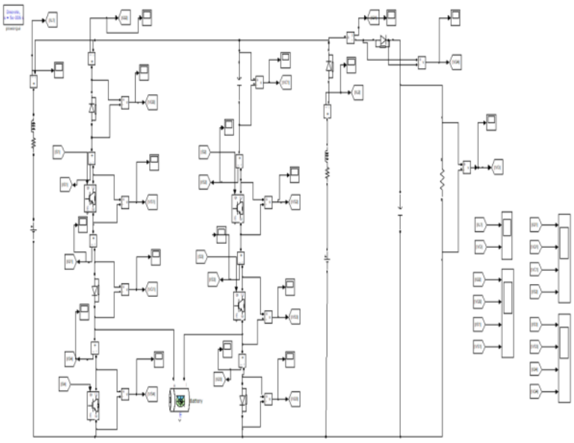

Fig 3. Simulink model

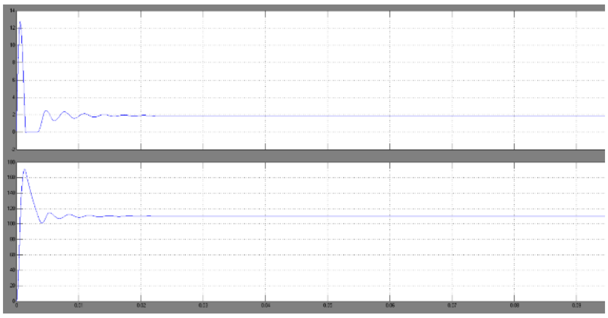

Fig 4. Output voltage and current

6. CONCLUSION

This work proposes and thoroughly analyzes a revolutionary three-input DC/DC converter. In the event that one or both resources are unavailable, the converter can still supply the load with the required power. The converter's control system and promising performance make it highly reliable for use in both industrial and household applications. To create an appropriate controller, the converter is modeled for three distinct operational states. The MPPT algorithm is implemented, and power management is used to carry out the controller's instructions. In the meanwhile, using MPPT and power management will improve the converter's efficiency. Ultimately, a lab version of the proposed conversion is used, and the outcomes are recorded and shown. Findings validate the analysis and the converter's functionality.

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