# DC-DC Converter With Multiple Inputs For Hybrid Electric Vehicles Application.

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**Abstract -** *A proposed DC to DC converter with multiple inputs for electric and hybrid vehicles (HEVs). The goal of the study is to increase production efficiency in comparison to earlier research. the converter's three sources of electricity are the battery, photovoltaic or PV panel, and the fuel cell. The roof-mounted PV panel fills the battery improves performance and reduces the consumption of fuel, while the FC serves as the primary power source. Regardless of whether certain resources are unavailable, the converter continues to power the load as required. The study also discusses and implements a power management technique in the control mechanism.*

***Key Words***: Multi input Converter, HEVs, Fuel cell, Photovoltaic cell

## 1. INTRODUCTION

The primary disadvantages of cars fueled by petroleum or diesel are an increase in global temperature and the unavailability of petroleum derivatives. To overcome the above-described challenges and to demonstrate the capacity of renewable energies to generate electricity, Parallel electric automobiles and modular electric cars have seen the appearance of automotive designers. Figure 1 depicts the overall framework of an electric hybrid car fueled by renewable energy. Their biggest drawbacks are limited driving range and lengthy battery recharge times. They might, however, have V2G capability by utilizing an in both directions on and off circuit charger. The primary outputs of power cells are pure water and warming. Nonetheless, the primary concerns with FCs are astronomical costs and inadequate transitory implementation. It should be noted that cars primarily fueled using FCs can hybridized using ESSs as well. Minimal volumes of research on an electric vehicle and hybrid electric vehicles circuitry are represented in the literature. It has an elevated output since it achieves turn-on switching to no voltage with all being identical. However, it falls short of an in two directions interface. As a result, it can't be used in applications that require ESS. Furthermore, the converter's large voltage rise makes it appropriate for small data voltage tasks. Regardless, the substantial number of transistors and active parts reduces efficiency. The flow of electricity among the natural resources, the energy storage unit, and the engine's motor must be controlled by the control approach established in the vehicle's processor. The major tasks of the control plot are to make the best use of power supplies, provide continuous interest power, and keep the power source and solar panels in their optimal location. In any scenario, the needed HEV converter ought to eliminate energy from Photovoltaic & FC. A multipurpose input converting device may provide voltage to a demand from numerous sources of energy simultaneously or independently.

As the fundamental price of photovoltaic panels is considerable, MPPT computation has to be utilized to generate separated electricity from the photovoltaic

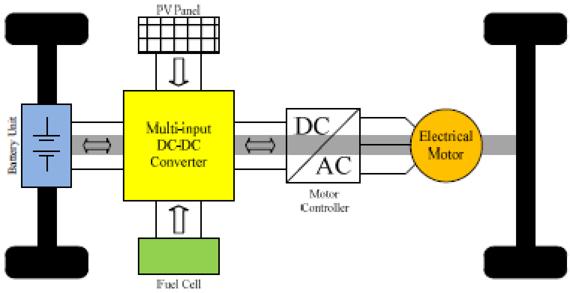



**Figure 1** depicts the overall construction of the Converting device

A unique DC to DC is presented for the photovoltaic electricity an electrical part, and a storage device to the network. Furthermore, DC output is enhanced over typical conversion devices. At this point, MPPT for photovoltaic cells may be obtained. The energy source may be loaded and discharged for powering the board. The suggested design is addressed in the next two parts, as are various operational types.

## 2. SUGGESTED TOPOLOGY FOR CONVERTERS

Figure 2 depicts the construction of the intended 3-input direct current to direct current step-up chopper. It is made up of 2 normal boost converters, with one of which has an additional capacitor. The converter's trait makes it appropriate for mixed systems. In the energy control and administration section of this study, the behavior of the chopper with regard to overseeing its energy sources is analyzed. The energy output of Vpv and Vfc is depending on their own characteristics, making them two distinct electrical sources. Both L1 as well as L2 are the data input masks for solar panels and fuel cells, respectively. Photovoltaic and fuel cell units can be converted to current supplies by connecting L1 and L2 in combination with the input sources. The equivalent resistances of Vpv & Vfc are r1 & r2, accordingly. The corresponding resistance of demand attached to the direct current bus is known as $R_{load}$. The power IGBT switches are S1, S2, S3, and S4. The types of operation that are established using diode D1, D2, D3, and D4 are discussed. Output capacitive device Co and capacitive element C1 is utilized for boost the resultant value. Continuous conduct mode is being used by the system to provide steady current via the lowest possible level of current fluctuation.

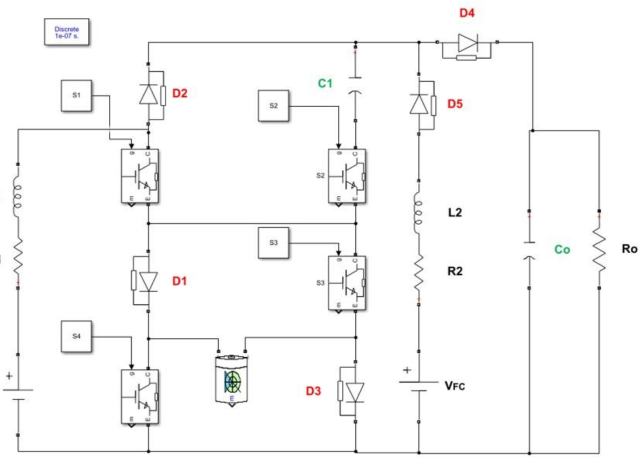



**Figure. 2.**Three-input step up chopper

## 3. OPERATION MODES:

The fundamental ideas behind the suggested design are covered in this section. The converter operates in 3 states: 1. There is no battery used; PV and FC supply the load. 2. The photovoltaic energy, Fuel Cell, and battery all contribute to supplying the load. 3- The storage device is in the electrical charging stage and the photovoltaic panel and fuel cell are supplying the demand.

### 3.1 First operation state (While the storage device is not being used, Photovoltaic and fuel cell supply the demand.)

There exist 3 operating modes in this condition, as shown in Figure 3. The system is working in this condition without any battery charging or discharging. As a result, current can move via D3 and S3 or S4 and D1 in one of two ways. D3 and S3 are regarded as a common route in this work. S4 and D1 may be selected as an option, though. Switch S3 is ON while switch S4 is always OFF under this condition.

**Mode 1** (0<t< $d_1$T): [in Figure. 3(a)]
The sources of electricity Vpv and Vfc, respectively charge inductors L1 as well as L2 Switches S1, S2, and S3 are switched ON during this time period, along with the diode D3.

**Mode 2** ($d_1$T<t<$d_2$T): [ Figure. 3(b)]
D2 is kept ON, Switch S1 is switched OFF and switches D3 and S2, S3 are all remaining ON. Inductor L1 is being depleted while inductor L2 is still being supplied.

**Mode 3** ($d_2$T<t<T) [ Figure. 3(c)]:
S2 is switched OFF, D3 and S3 were remained ON, S1 is switched ON during this time period. Inductor L2 is drained via Vpv+Vc1-Vo and inductor L1 is charged with Vpv .

The voltage on capacitor C1 and the output voltage can be measured by conducting the volt-

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

$$V_{C_1}=\frac{V_{PV}-r_1 i_{L_1}}{d_2-d_1} \tag{2}$$

$$L_2:\ d_2\left[V_{FC}-r_2 i_{L_2}\right]+\left(1-d_2\right)\left[V_{FC}+V_{C_1}-r_2 i_{L_2}-V_o\right]=0 \tag{3}$$

$$V_o=\frac{\left(d_2-d_1\right)\left(V_{FC}-r_2 i_{L_2}\right)+\left(1-d_2\right)\left(V_{FC}-r_1 i_{L_1}\right)}{\left(1-d_2\right)\left(d_2-d_1\right)} \tag{4}$$

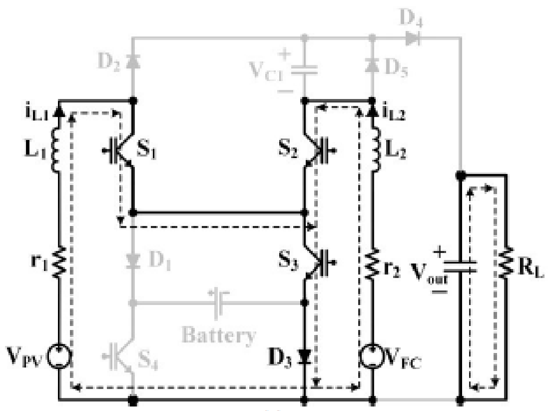
Additionally, we have the voltage of capacitor C1 by applying the amp-second balancing both capacitors C1 & Co.

$$C_1:\ \left(d_2-d_1\right)i_{L_1}-\left(1-d_2\right)i_{L_2}=0 \tag{5}$$

$$C_o:\ \left(1-d_2\right)i_{L_2}=\frac{V_o}{R_{Load}}$$

Battery isn't utilized in this scenario, thus we have the following values

$$i_{batt}=0;\ P_{batt}=0 \tag{7}$$




(a)

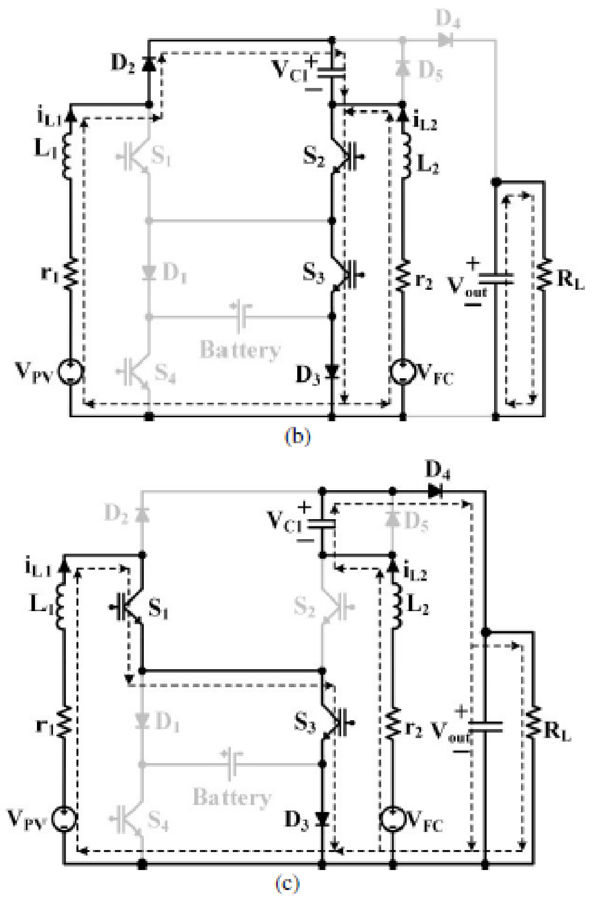



**Figure 3.** Operational mode path in (a) 1st Mode, (b) 2nd Mode, and (c) 3rd Mode.

### 3.2 Second operation state (While the storage device, Photovoltaic and fuel cell supply the demand.):

It has 4 operating modes in this state, as shown in Figure 4. The amount of power is provided by multiple input devices in this stage. There is just one current pathway in the first mode. However, there are two existing routes either D3 and S3 or D1 with S4 in the remaining categories. Current moves via S4 and D1 in this scenario. In this scenario, Switch S4 is always ON.

**Mode 1** (0< t<$d_1$T):
S1, S2, S3, and S4 have been switched ON during this time. According to Figure. 4(a), L1 is powered by Vpv +Vbatt and L2 is powered Vfc + Vbatt.

**Mode 2** ($d_1$T<t<$d_2$T):
D1 and S1, S2, S4 have been switched ON during this time. Charge is applied to L1 and L2 by Vpv and Vfc accordingly [ Figure. 4(b)].

**Mode 3** ($d_2$ T<t<$d_3$T):
D1, D2, S2, and S4 are switched ON during this time. L2 gets powered by Vfc while inductor L1 is drained to capacitor C1 [in Figure. 4(c)].

**Mode 4** ($d_3$T<t<$d_4$T): D1, D4, S1 and S4 have been switched ON during this time. Inductor L2 empties C1 to Co while inductor L1 is energized by Vpv. [in Figure 4(d)].
By doing volt-second balance low over the filters

$$L_1: d_1\left[V_{PV}+V_{bat}-r_1 i_{L_1}\right]+(d_2-d_1)\left[V_{PV}-r_1 i_{L_1}\right] +(d_3-d_2)\left[V_{PV}-r_1 i_{L_1}-V_{C_1}\right]+(1-d_3)\left[V_{PV}-r_1 i_{L_1}\right]=0 \quad (8)$$

And then:

$$V_{C_1}=\frac{V_{PV}+d_1 V_{bat}-r_1 i_{L_1}}{d_3-d_2} \quad (9)$$

$$L_2: d_1\left[V_{FC}+V_{bat}-r_2 i_{L_2}\right]+(d_3-d_1)\left[V_{FC}-r_2 i_{L_2}\right] +(1-d_3)\left[V_{FC}+V_{C_1}-r_2 i_{L_2}-V_o\right]=0 \quad (10)$$

And then:

$$V_o=\frac{(d_3-d_2)\left(V_{FC}+d_1 V_{bat}-r_2 i_{L_2}\right)+(1-d_3)\left(V_{PV}+d_1 V_{bat}-r_1 i_{L_1}\right)}{(1-d_3)(d_3-d_2)} \quad (11)$$

By putting amp-second balance to capacitors Co and C1, we get:

$$C_1:\ (d_3-d_2)i_{L_1}-(1-d_3)i_{L_2}=0 \quad (12)$$

$$C_o:\ (1-d_3)i_{L_2}=\frac{V_o}{R_{Load}} \quad (13)$$

$$i_{bat}=d_1\left(i_{L_2}+i_{L_1}\right) \quad (14)$$

$$P_{bat}=V_{bat}\left[d_1\left(i_{L_2}+i_{L_1}\right)\right] \quad (15)$$

### 3.3 Third operation state (While the storage device is being energized, Photovoltaic and fuel cell supply the demand.)

There are four possibilities in this stage, as shown in Figure 5. PV and FC charge the storage device while providing the load. It has two alternatives. either D3 and S3 or S4 and D1 in the first and second operational modes. In this situation, the current will flow along the line connecting S4 and D1. Switch S3 is always OFF in this condition, and diode D1 is conducting.

**Mode 1** (0<t<$d_1$T):

D1 and S1, S2, S4, have been switched ON during this time. Charge is applied to L1 and L2 by Vpv and Vfc accordingly [in Figure. 5(a)].

**Mode 2** ($d_1$T<t<$d_2$T):

D1, D2, S2, and S4 are switched ON during this time. L2 gets powered by Vfc while inductor L1 is drained to capacitor C1 [in Figure. 5(b)].

**Mode 3** ($d_2$T<t<$d_3$T):

S1, S2, D1 and D3 have been turned ON during this time. Loaded by Vpv-Vbatt & Vfc-Vbatt, respectively, are inductors L1 and L2. [in Figure. 5(c)].

**Mode 4** (d3T<t<d4T):

S1, S4, D1, and D4 have been switched ON during this time. L2 gets drained by Vfc-Vc1-Vo while inductor L1 is powered up by Vpv-Vbatt. [in Figure. 5(d)].

By doing volt-second balance low over the filters:

$$L_1: d_1\left[V_{PV} - r_1 i_{L_1}\right] + (d_2 - d_1)\left[V_{PV} - r_1 i_{L_1} - V_{C_1}\right] + (1-d_2)\left[V_{PV} - r_1 i_{L_1} - V_{batt}\right] = 0 \quad (16)$$

$$V_{C_1} = \frac{V_{PV} - (1-d_2)V_{batt} - r_1 i_{L_1}}{d_2 - d_1} \quad (17)$$

$$L_2: d_2\left[V_{FC} - r_2 i_{L_2}\right] + (d_3 - d_2)\left[V_{FC} - r_2 i_{L_2} - V_{batt}\right] + (1-d_3)\left[V_{FC} + V_{C_1} - r_2 i_{L_2} - V_o\right] = 0 \quad (18)$$

$$V_o = \frac{\left(V_{FC} - (d_3 - d_2)V_{batt} - r_2 i_{L_2}\right)}{(1-d_3)} + \frac{\left(V_{PV} - (1-d_2)V_{batt} - r_1 i_{L_1}\right)}{(d_2 - d_1)} \quad (19)$$

By putting amp-secnd balance to capacitors Co and C1, we get:

$$C_1: \ (d_2 - d_1) i_{L_1} - (1-d_3) i_{L_2} = 0 \quad (20)$$

$$C_o: \ (1-d_3) i_{L_2} = \frac{V_o}{R_{Load}} \quad (21)$$

the power by storage device and current may be acquired as:

$$i_{batt} = (d_3 - d_2)\left(i_{L_2} + i_{L_1}\right) + (1-d_3) i_{L_1} \quad (22)$$

$$P_{batt} = V_{batt}\left[(d_3 - d_2)\left(i_{L_2} + i_{L_1}\right) + (1-d_3) i_{L_1}\right] \quad (23)$$

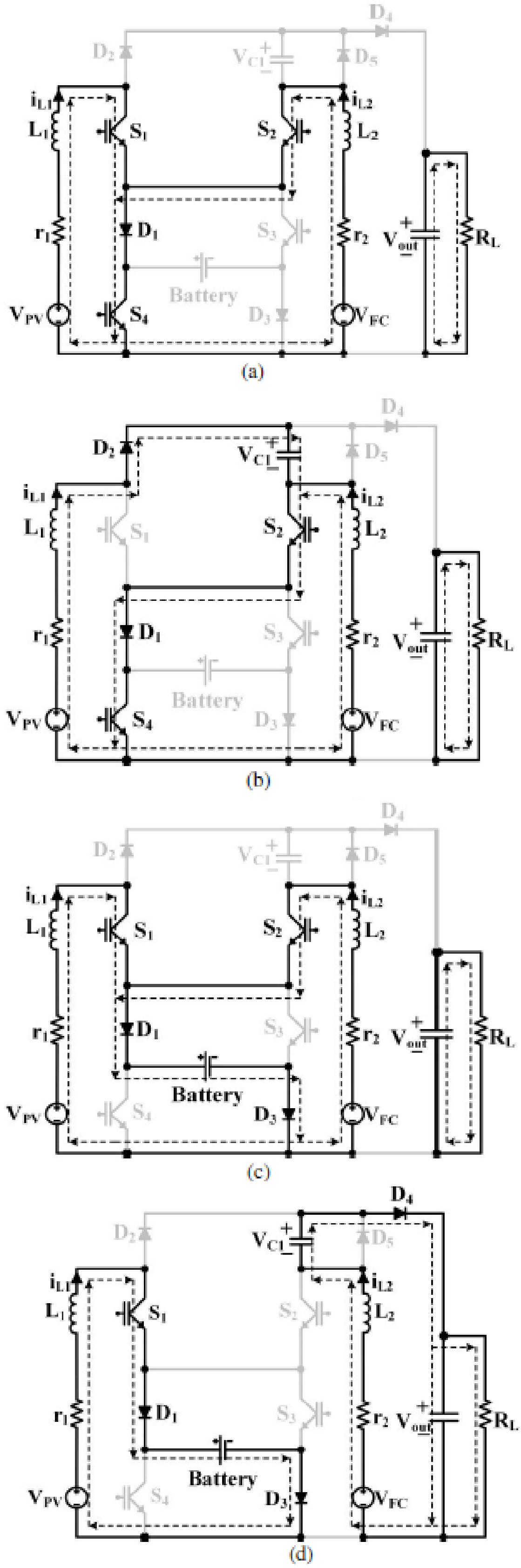



**Figure 4.** Operational mode path in (a) Mode 1, (b) Mode 2, (c) Mode 3 and (d)Mode 4.

The patterns for all conditions and all modes are shown in the figure 4.1. A saw-tooth waveform is contrasted with impulses d1, d2, d3, and d4 which can each individually controlled the state of the electricity to complete the switching process. 1 to 4 diode signals can be utilized for adjusting energy every source's the photovoltaic FC, and storage are producing with not considering the voltage of the output into account.

## 4. EXTRA BENEFITS OF THE DEVICE THAT MAKE IT RELIABLE:

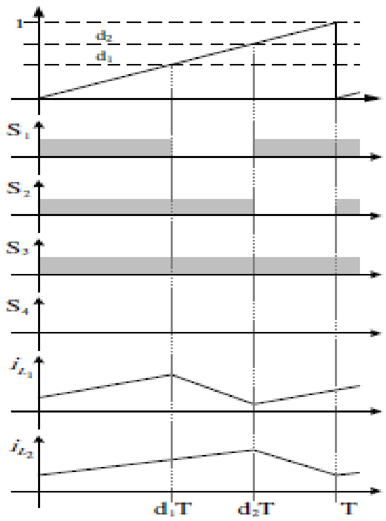
The recommended conversion device offers the advantage of just using a single source if either of the sources of electricity are unable to provide energy. The suggested converter's reliability and security are improved by this feature. These various potential states have been outlined:

• Only PV is active:

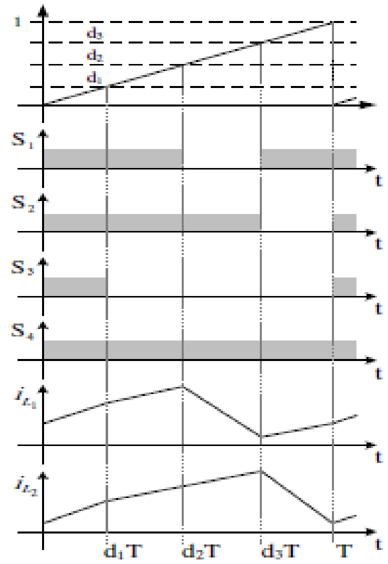
Because fuel cells take a while to start up, this condition typically occurs when an automobile starts nor when the fuel system is empty. In this condition, PV can charge or deplete the battery. Switch S2 is switched off to allow the PV to run independently, and power from the PV is then transmitted to the output capacitor Co rather than capacitor C1. In accordance with the architecture shown, a storage device can be supplied and depleted using solar power and switches S1, S3, and S4.

• Only FC is active:

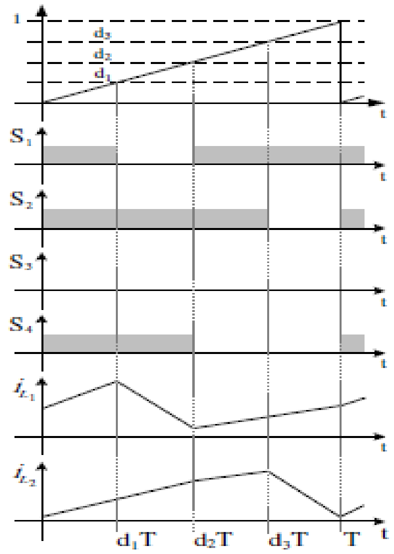
FC is the primary input for providing the demand by HEVs separately since Vpv is smaller than that of Vfc and is dependent on the climate. As a result, an additional diode (D5) pair with capacitor C1. Once capacitor gets filled up, diode D5 is turned off. When the FC is used alone, the capacitor C1 drains till the voltage across it reaches zero. As the value of the voltage over C1 becomes negative, diode D5 turns on and thus clips the voltage over C1.




(a)




(b)




(c)

**Figure 4.1.** The switching patterns for all states and all modes.

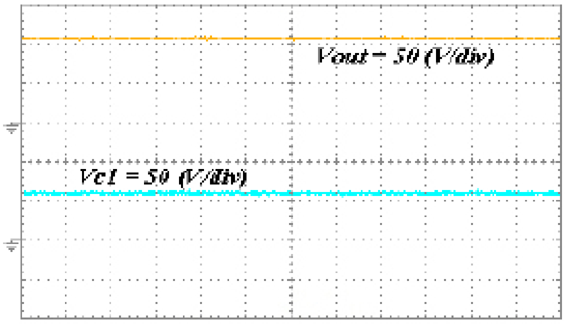
## 5. SIMULATION RESULTS:

The first inductive element L1 has an intrinsic value of 550 x $10^{-6}$ (H), while the second inductive component has a value of 650 x $10^{-6}$H. The capacitance of the capacitors used in the conversion device are 470 x $10^{-6}$ F. Figure 5 depicts the outcomes of the initial state operation. Figure 5(a) depicts the voltage of output and capacitor C1. Taking 20 V for every input voltage measurement correctly raised to around 110 V. Figure 5(b) depicts the inductors current, whereas Figures 5(c) depict the diode currents and 5(d) depicts power switch currents. Figures 5(e) illustrate the of diode voltage and Figure 5(f) depicts power switch voltages. The inductive electrical currents are around 2 Amps in the experimental findings of the first operational mode. As shown in Figure.

5(c) the diode current D1 and in Figure 5(d) diode D3 is forward biased, while switch S3 is on and switch S4 are zero which causes it to be open circuited. The remaining elements are swapped at a frequency of 30 kHz. As illustrated in Figures 5(c) shows the diode current of D1 and Figure 5(d) shows switch current S4 are zero, but the currents of switch S3 and diode D3 are constantly on, resulting in a volts is roughly zero. The remaining parts are swapped at an oscillation rate around 30 kilohertz.

Figure 6 depicts the operation outcomes of the second state. Figure 6(a) depicts the output and voltage of capacitor C1. Figure 6(b) shows the current via inductive elements Figure 6(c) illustrate the diode currents and 6(d) power switch currents. Figures 6(e) show the diode voltages and 6(f) power switch voltages. Figure 6(g) depicts the current of the batteries. In this scenario of operation, inductive currents is 1.99A having fluctuating with 0.9A. Furthermore, the energy storage device is depleted to a current of 4A flowing across device. Through the state of functioning, each of the switches are turned and only diode D3 remains inactive. As a result, the converter's efficiency in this mode was inferior to that of the remaining.

Figure 7 depicts the experimental findings for the third condition. Figure 7(a) depicts the capacitor voltage C1 and the intended voltage of the converting device. Figure 7(b) shows inductor currents. Figures 7(c) illustrate the diode currents and 7(d) illustrate the power switches, respectively.

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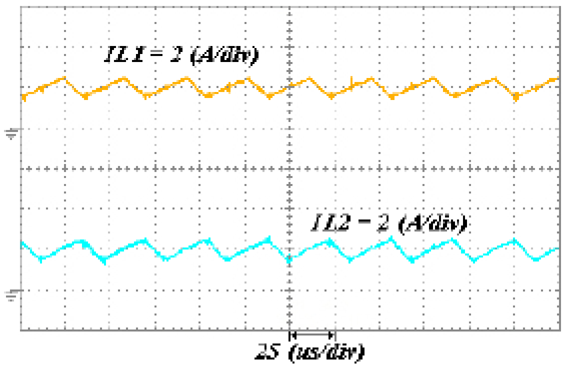


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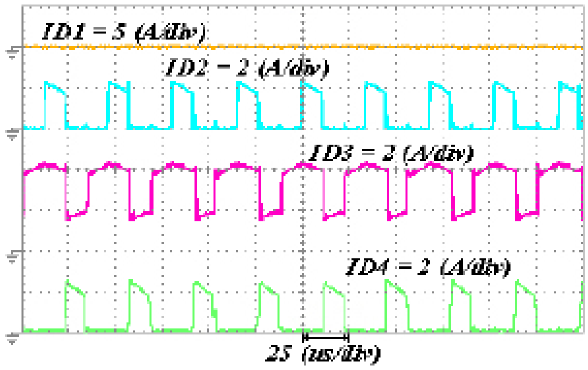
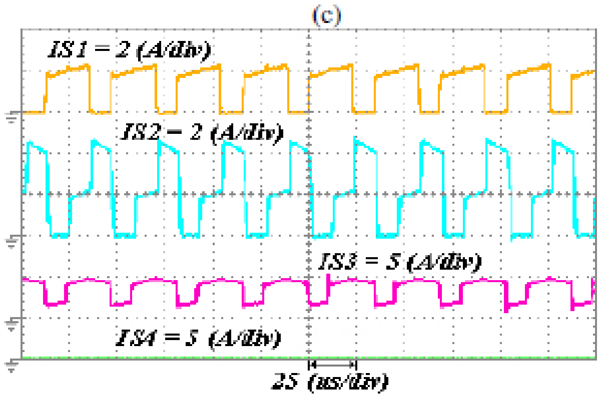



(c)

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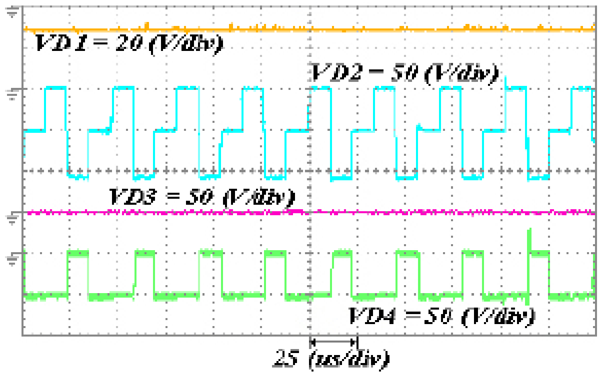


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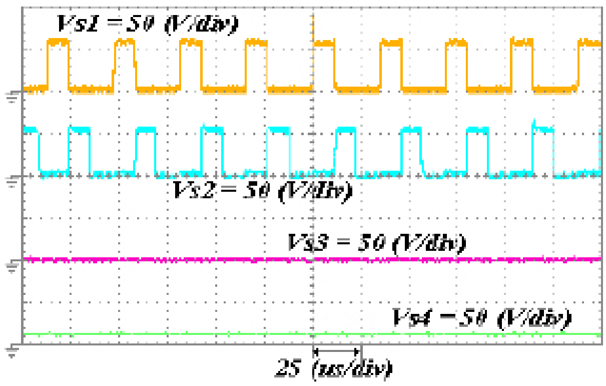
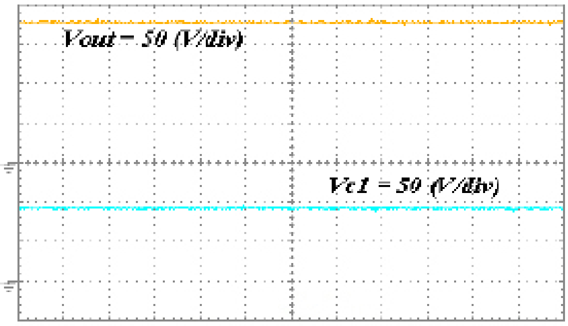
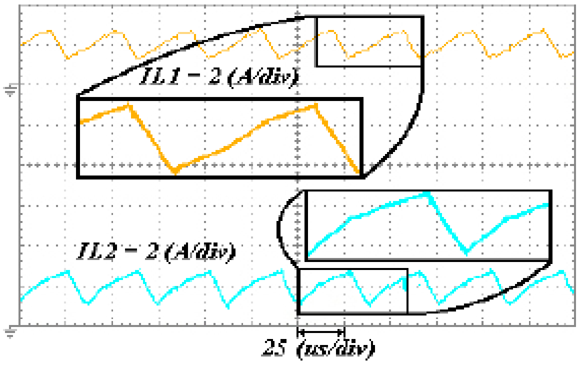



(f)

**Figure 5.** Results of Simulation1 operating state




(a)

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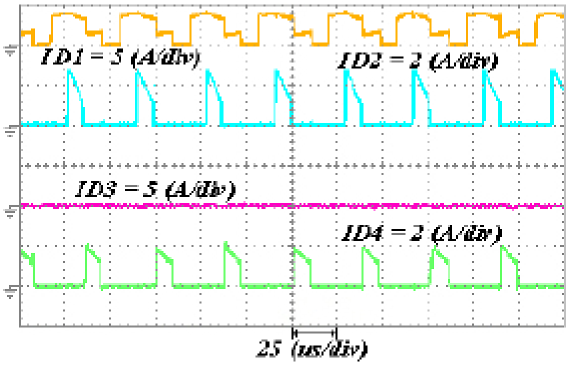


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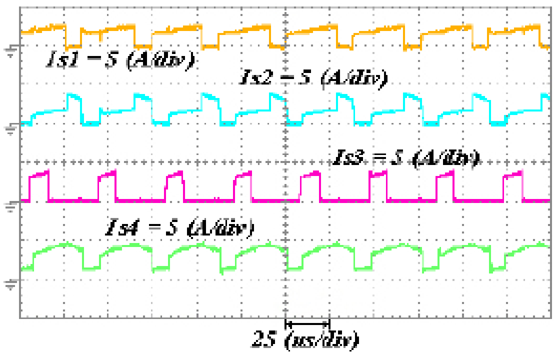


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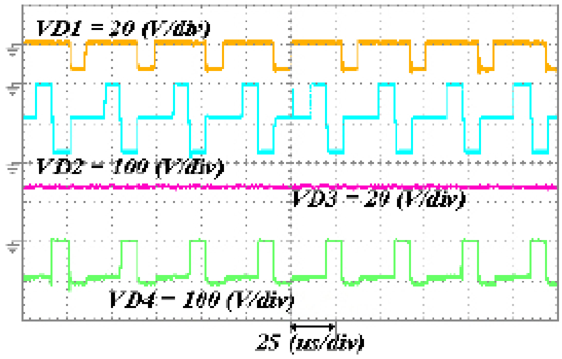


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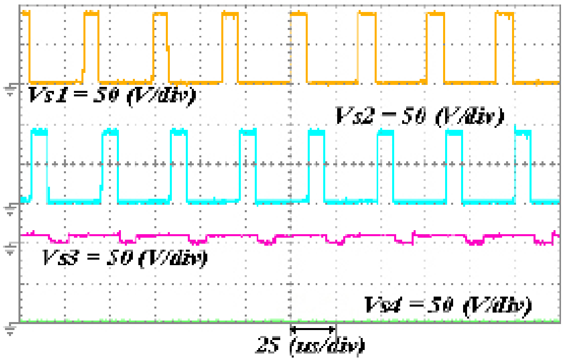


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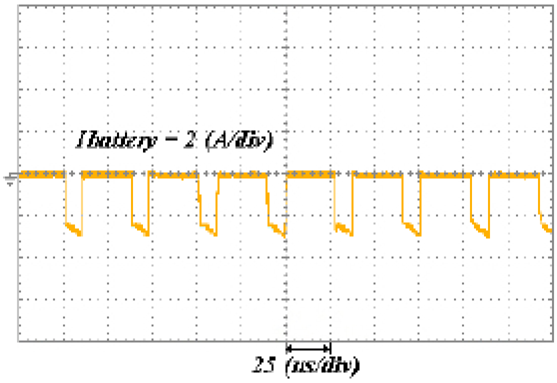
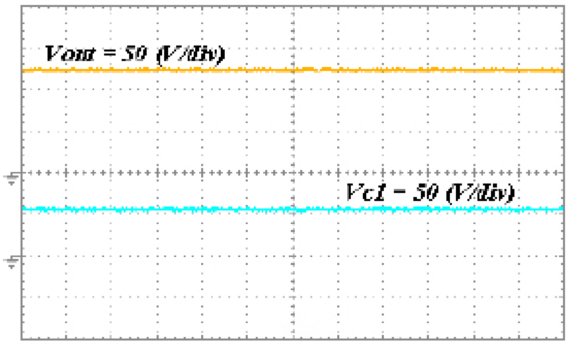



(g)

Figure 6.Results of Simulation2 operating state

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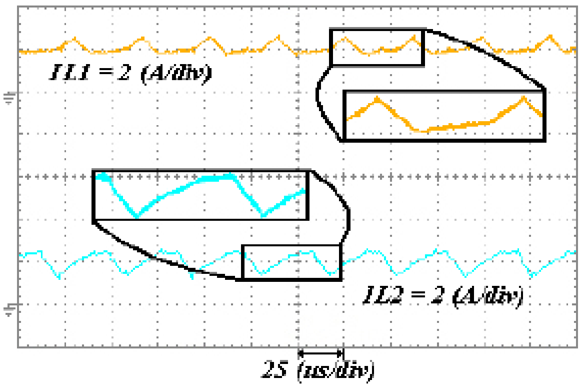

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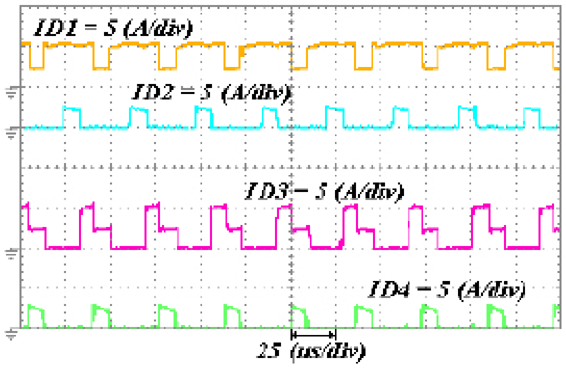

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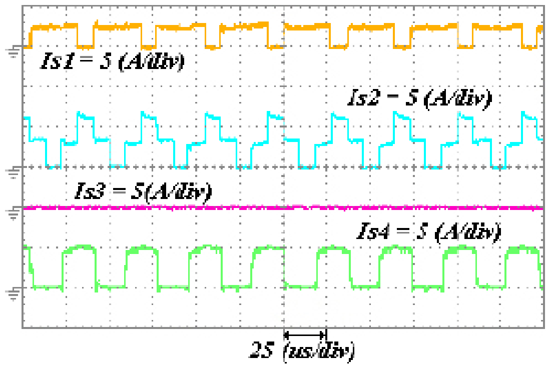

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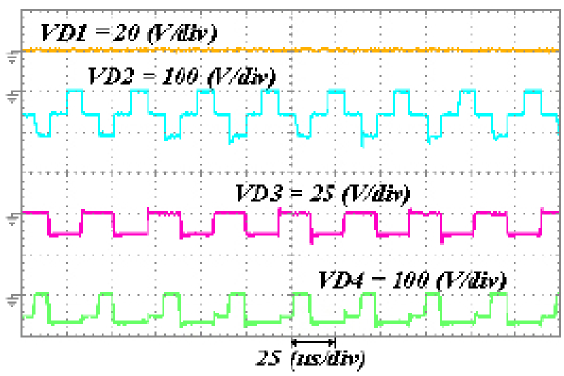

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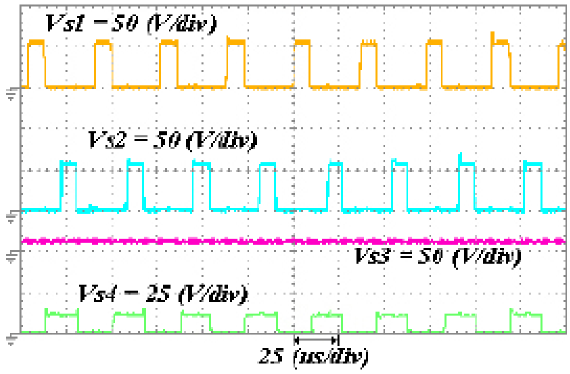

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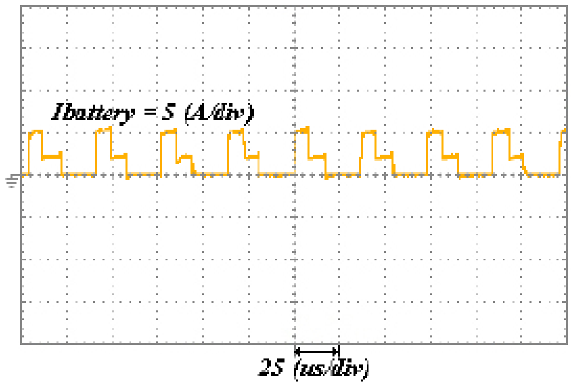

(g)

**Figure 7.** Results of Simulation3 operating state.

The outcomes verify the converter's optimistic effectiveness in every state of operation. The suggested converter performance is greater than the remaining ones in the initial operating state. The suggested converter's lowest performance is around 85 in draining mode. Because there are more switches in this state than in others. As a result, the loss of switching in this state is greater than in other states. In this endeavor, the output intended voltage is around 120V and the photovoltaic required current is approximately 2A in the first stage. As previously stated, the voltage of the battery is 0 in this situation. In the subsequent portion of the study, the photovoltaic guide current is increased to 4A, the fuel cells guide current is reduced to 2A, and the voltage needed for output is 120V. A current surge of inductive device is acceptable. and the second inductive element's current is somewhat lower as it was previously. The battery's flow of current is around 6A. Because of the cited standards, the system operates in battery charging mode near to 39.9 W. The output voltage fluctuates during these three steps, although it is unimportant. The converter's response to transients is satisfactory and may be used in HEV applications.

## 6. CONCLUSION:

This investigation proposes and deconstructs a revolutionary 3-input DC to DC conversion device. The conversion device is capable of providing the needed energy by demand without the use of an assortment of supplies. The converter's optimistic performance and used control approach provide great reliability for usage in commercial and residential applications. The converter's output is presented for three distinct operating modes that is utilized.

## 7. REFERENCES:

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