Enhancement of EV Rane Using Multiport Converter and Conversion of ICE engine to Hybrid or Pure EV

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ABSTRACT

High voltage conversion dc/dc converters have been perceived in various power electronics applications in recent times. In particular, the multi-port converter structures are the key solution in DC microgrid and electric vehicle applications. This thesis focuses on a modified structure of non-isolated four-port (two input and two output ports) power electronic interfaces that can be utilized in electric vehicle (EV) applications. The main feature of this converter is its ability to accommodate energy resources with different voltage and current characteristics. The suggested topology can provide a buck and boost output simultaneously during its course of operation. The proposed four-port converter (FPC) is realized with reduced component count and simplified control strategy which makes the converter more reliable and cost-effective. Besides, this converter exhibits bidirectional power flow functionality making it suitable for charging the battery during regenerative braking of an electric vehicle. The steady-state and dynamic behavior of the converter are analyzed, and a control scheme is presented to regulate the power flow between the diversified energy supplies. A small-signal model is extracted to design the proposed converter. The validity of the converter design and its performance behavior is verified using MATLAB simulation and experimental results under various operating states.

An electric vehicle is a sort of alternative fuel vehicle that runs on electricity rather than gasoline. Rather than using a carbon-based fuel, power is obtained from battery packs. This not only keeps costs down, but it also has a lower environmental impact. It also has numerous benefits over conventional internal combustion engines, including lower local pollution and better energy efficiency. The limitations of battery technology, high purchasing costs, and a lack of recharging facilities are all obstacles to the quick adoption of EVs. In our project, we will convert an ICEV into EV with a Li - ion battery and an in wheel brushless DC motor.

INTRODUCTION

Increasing environmental pollution, the rapid rise in fuel costs, global warming, and depletion of fossil fuels have led to the development of advanced vehicle technologies. Therefore, automobile industries have started manufacturing eco-friendly electric (EV) & hybrid electric vehicles (HEV). In such vehicles, the motor drive system is an important component. An efficient power electronic converter is required to propel the motor drive system. In the case of EV, this power electronic converter must possess the bidirectional capability to interface the energy resources with battery and motor drive systems. Numerous research work has been reported by the researchers in the literature on power electronic interfaces for EV systems. Different topologies of non-isolated three-port converter synthesized from dual input (DIC) or dual output (DOC) converter along with the single input single output (SISO) converter is dealt in [1]. A step-up converter combining the features of KY converter and buck-boost converter with a high voltage conversion ratio is presented in [2].

The method of improving the conversion efficiency using the interleaving concept in a double switch buck-boost converter is proposed [3]. A non-isolated boost converter with high voltage gain capable of balancing automatically under an unbalancing load condition is analyzed in [4]. Bang and Park [5] describe buck cascaded buck-boost power factor correction converter for wide input voltage variations. The above-mentioned converters are unidirectional with the SISO configuration. A non-isolated bidirectional dc/dc converter in [6] is a SISO model that uses four active switches. A comparison of two different bidirectional converters such as cascaded buck-boost capacitor in the middle and cascaded buck-boost inductor in the middle is carried out.

It has the basic disadvantage of battery power not being boosted across the load. A solar power aided EV with battery backup has been in [27]. To catalyze the energy between the battery and solar in the above EV a dc/dc converter structure has been presented. The number of switches in this converter varies based on the number of battery modules (Say if there exists ‘n’ no. of battery modules, then the system requires ‘2n’ numbers of switches for effective operation). For effective power management between the ultra-capacitor and battery and to suppress the issues such as overcharging of ultra-capacitor and high battery current during peak power, a fuzzy logic control-based energy management strategy has been proposed.

Prototype development to study the real time performance of battery, Motor, and controller has been carried out, where the charge and discharge performance of battery can be analyzed, during the development of it is considered the Motor to be BLDC (Brushless DC) Hub motor in reference to convenience in installing and availability of material at the earliest possibility. Although the functioning of both PMSM and BLDC motor is very much closer, and efficiency is also merely similar.

The developed prototype is compatible to work as Hybrid as well as only Electric.

Photovoltaic Energy System:

In order to meet demand, a PV panel is typically made up of several cells connected in series. The photon effect is converted to electrical energy by the solar panel. When light is absorbed at the junction, it generates the current. The solar electrical equivalent circuit was then used to convert it to electrical voltage. The circuit includes a PN junction diode to block the return currents. Figure 2 depicts the physical layout of an electrical circuit equivalent to a solar panel. Due to changing temperatures and irradiance, the fundamental issue with solar panels is that their output is not constant. An MPPT-based DC-DC converter is used to obtain continuous DC voltage from the panel; it is then supplied to the inverter for operational loads.

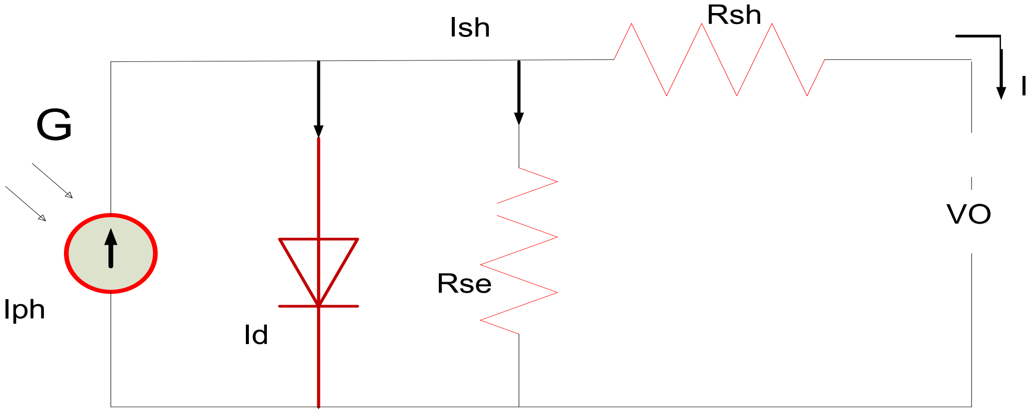


Figure 1: Electrical Circuit of PV System

The expression for PV current is expressed as

$$I = I_{ph1} - I_{o1}(exp(\frac{q(v + IR_{s1})}{NKT} - 1)) - \frac{(v + IR_{s1})}{R_{sh1}}$$

ELECTRIC VEHICLE STRUCTURE:

In present scenario the utilization of electric vehicle increases rapidly. The structure of electrical vehicle is shown in figure 2. It is operated by electricity provided to motor. Electric vehicle consists set of components namely Electric motor, Power converters, battery and control circuit for power converters. The energy required to motor is maintained properly by using power converters, it also helps to regulate the charging and discharging conditions of battery.

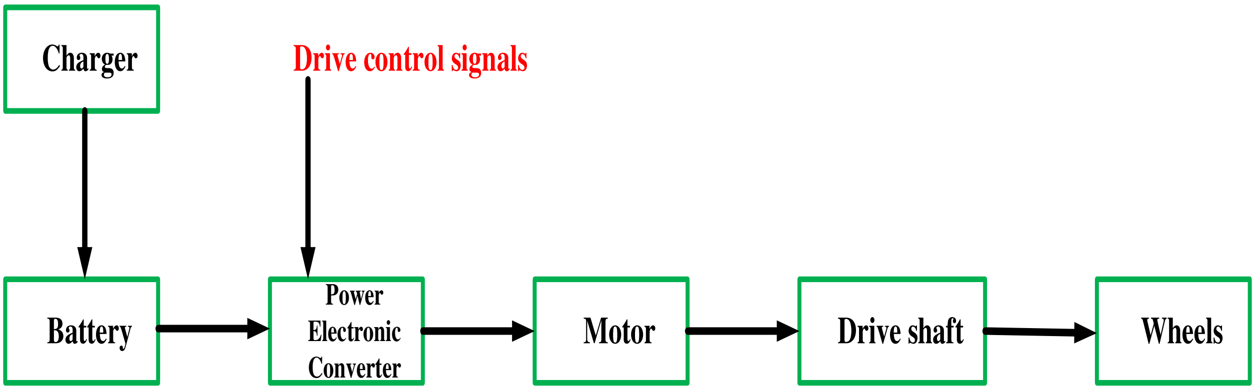


Figure 2: Block Diagram of EV

- As shown in figure 1, the electric vehicle is operated by motor. Also, it consists of two converters, i.e a) A dc-dc bidirectional converter used to control the SOC of battery system, b) the second one is PWM based converter which helps to control the motor conditions.

ICE Engine to Pure Electric Vehicle:

The majority of automobiles on the road are traditional gasoline automobiles with large emission levels; transportation is now contributing considerably to climatic changes and pollution-related health issues. Countries all over the world have teamed together to limit the harmful emissions in order to prevent global warming from reaching a point of no return. To reach this goal, automobile manufacturers have developed a wide range of electric automobiles. Because EVs do not emit any emissions or pollutants, they are seen as a good alternative to ICEVs. This widespread of EV adoption renders the conventional gasoline powered vehicles useless. Therefore, there is an absolute necessity for converting the combustion engine vehicle to electric vehicle.

BLDC (Brushless DC) MOTOR:

The BLDC motor is widely used in applications including appliances, automotive, aerospace, consumer, medical, automated industrial equipment, and instrumentation. The BLDC motor is electrically commutated by power switches instead of brushes. Compared with a brushed DC motor or an induction motor, the BLDC motor has many advantages:

- Higher efficiency and reliability
- Lower acoustic noise
- Smaller and lighter

- Greater dynamic response
- Better speed versus torque characteristics
- Higher speed range
- Longer life

BLDC (Brushless DC) motors are widely used in various applications ranging from consumer electronics to industrial machinery due to their efficiency, reliability, and controllability. Controlling a BLDC motor involves managing its speed, direction, and torque. Here are some common methods used for controlling BLDC motors:

1. **Trapezoidal Control:** This is one of the simplest methods for controlling BLDC motors. It involves energizing the motor windings in a predetermined sequence to generate a rotating magnetic field. This method is often used in low-cost and simple applications where precise control is not necessary.
2. **Sinusoidal Control:** Sinusoidal control provides smoother operation and better efficiency compared to trapezoidal control. It involves modulating the amplitude and phase of the current supplied to the motor windings to create a sinusoidal magnetic field. This method is suitable for applications requiring higher performance and efficiency, such as electric vehicles and industrial automation.
3. **Field Oriented Control (FOC)**: Also known as vector control, FOC decouples the control of the motor's magnetic flux and torque components, allowing independent control of speed and torque. It involves transforming the three-phase currents from stationary coordinates to rotating coordinates (d-q axis) and then controlling them in these coordinates. FOC provides precise control over motor performance and is commonly used in high-performance applications where accurate speed and torque control are required.
4. **Direct Torque Control:** DTC is a control method that directly regulates the motor torque and flux without requiring transformation to the d-q axis. It provides fast and robust torque control and is suitable for applications requiring quick dynamic response, such as electric vehicle traction control and robotics.
5. **Sensorless Control:** Traditionally, BLDC motors require position sensors (such as Hall effect sensors) for commutation. However, sensorless control methods have been developed to eliminate the need for position sensors, reducing cost and complexity. Sensorless control techniques use algorithms to estimate the rotor position based on the motor's back electromotive force (EMF) or other measurable parameters.
6. **PWM (Pulse Width Modulation) Control:** PWM control is used to regulate the amplitude of the voltage supplied to the motor windings. By adjusting the duty cycle of the PWM signal, the average voltage applied to the motor can be controlled, thereby controlling motor speed and torque.
7. **Closed Loop Control**: In closed-loop control systems, feedback from sensors (such as encoders or Hall effect sensors) is used to monitor the motor's actual performance and adjust the control signals accordingly to achieve the desired performance. Closed-loop control improves the accuracy and stability of motor control, especially in dynamic operating conditions.

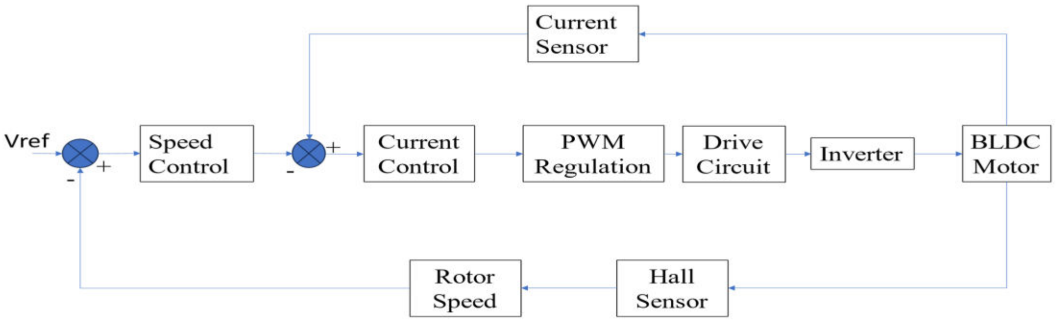


Figure 3: Block diagram showing digital PWM control operation for a BLDC motor drive system.

STRUCTURE OF FOUR PORT CONVERTER:

The use of a single energy resource cannot meet the load demand due to input power variations and dynamic load in the electric vehicular system. Therefore, the hybridization of arbitrary energy resources is required. This manuscript focuses on synthesizing a converter topology that could interface various energy resources with the drive train of a vehicle. Figure 1 (a) and (b) depict the role of power electronic interface in the power system of an electric vehicle system.

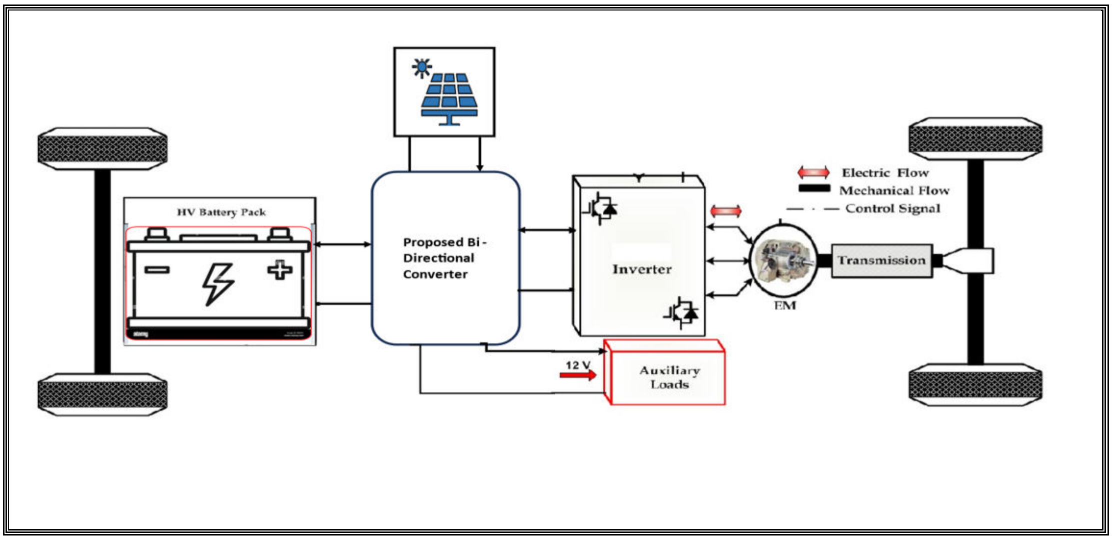


Figure 4: Block diagram of Proposed integrated four-port converter (FPC) interface in an electric vehicle system

Figure 4 shows the proposed topology of a four-port (FPC) converter. Prominent features of the proposed converter are: • Bidirectional power flow capability • Individual power flow control between the sources • Easy design, control, and implementation process As shown in Figure 5 the power flow between load and input sources is controlled by the controllable switches Q1, Q2, and Q3. As seen from Figures 2.3(a) to 2.3(e), five different states of operation can be considered for the proposed converter. State 1 is a (single input dual output) SIDO state.

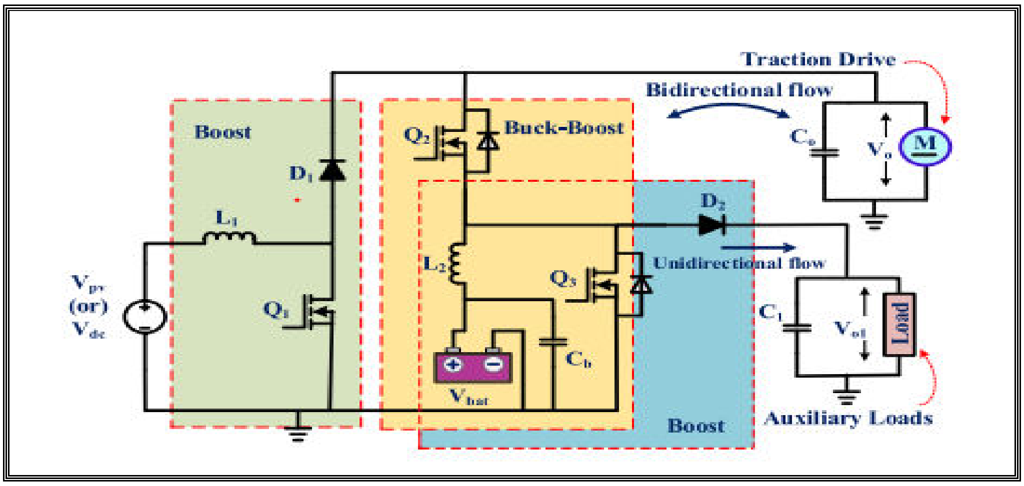


Figure 5: Topology diagram of four-port (FPC) converter

In this state (see Figure 5), the drive train of EV (load) is powered by the power generated from PV. The battery in the proposed topology can be charged either from the input PV power or from the load. In state 5, due to regenerative braking the energy returning from the load is stored in the battery. Due to low irradiation and if the PV is not able to generate the power, the battery discharges to meet the entire load requirement. During peak power demand, the battery unit and PV provide the necessary power to drive train. The converter then operates in the DIDO state. Switching schemes of the proposed converter and equivalent circuits under different operating states are depicted in Figures 5 respectively.

SIMULATION RESULTS & DISCUSSION:

In this project the performance of the A Multifunctional Non-Isolated Dual Input-Dual Output Converter is validated in four states of operation. In state1, the converter acts as the single input dual output) state of the converter (power transfer from PV (vdc) to load). In state 2, the converter acts as (single input three output) state of the converter (power transfer from PV to battery and load). In state 2, the converter acts as – single input Dual output state of the converter (power transfer from the battery). In state 4, (dual input dual output) state of the converter (power transfer from pv and battery). Finally In state 5, SIDO state of the converter (power transfer from load to battery) in this mode these systems working under regenerative breaking the fed back the supply to the loads and battery.

STATE_1 SIDO (SINGLE INPUT DUAL OUTPUT) STATE OF THE CONVERTER (POWER TRANSFER FROM PV (Vdc) TO LOAD)

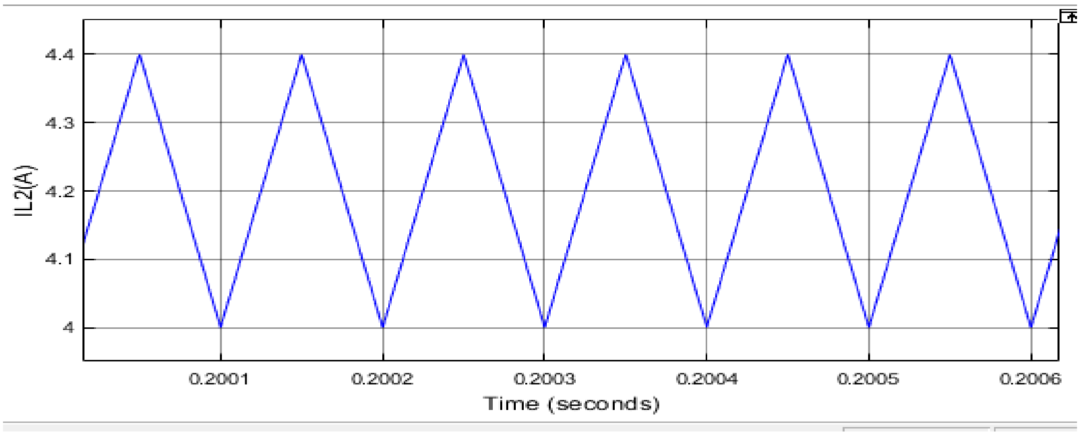


Figure 6: Simulation waveform for Q2- Inductor current

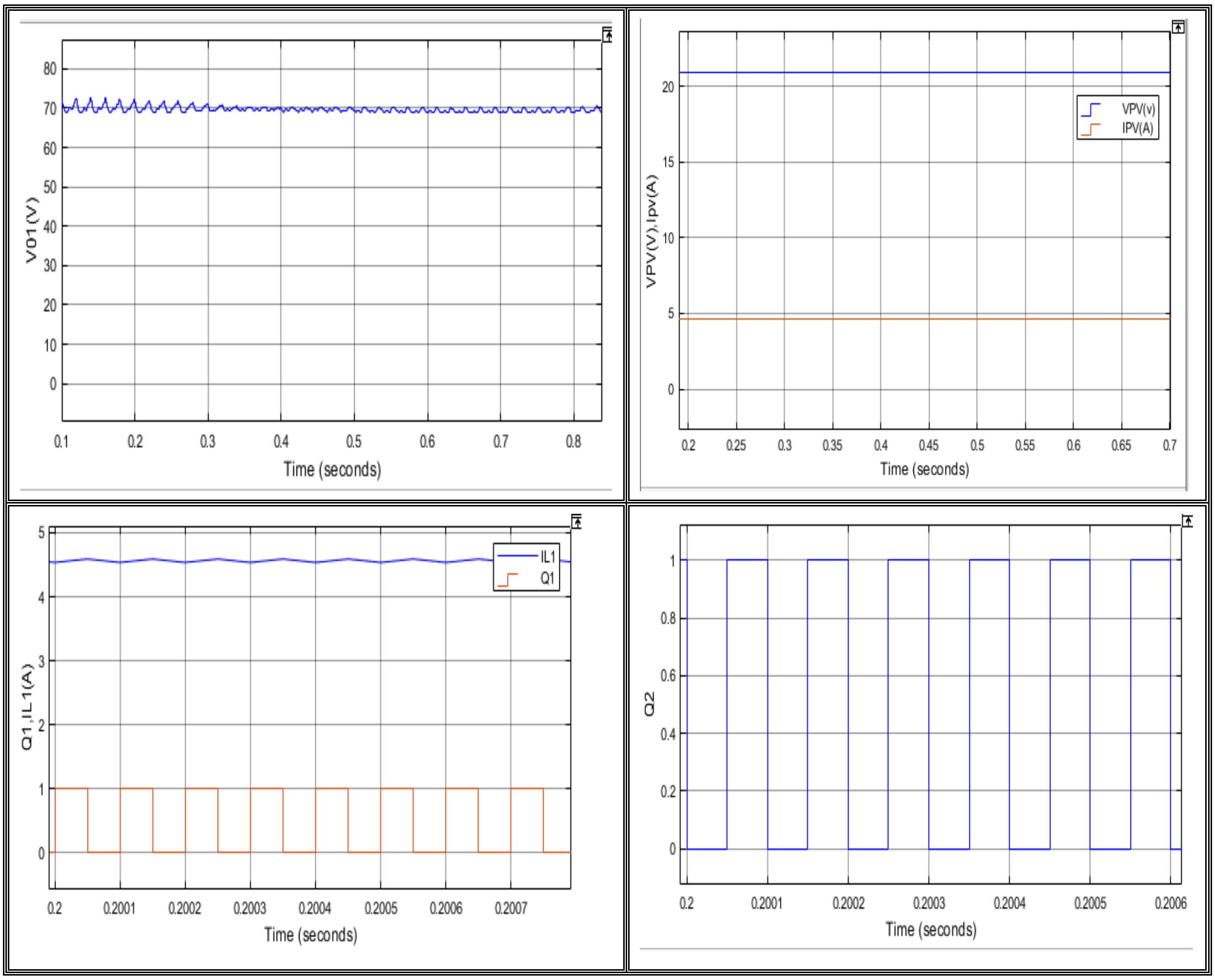
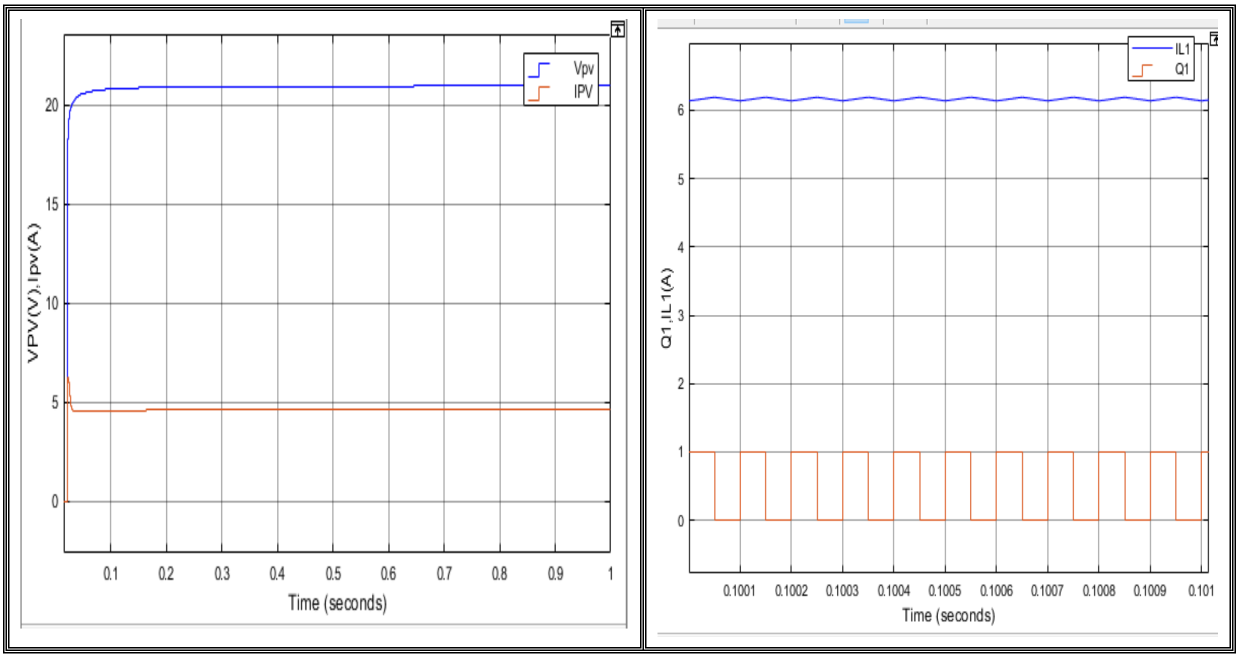


Figure 7: Simulation waveform for a) Output Voltage, b) PV voltage and current, c) Inductor current and d) Q2-Inductor current

STATE 2- SITO (SINGLE INPUT THREE OUTPUT) STATE OF THE CONVERTER (POWER TRANSFER FROM PV TO BATTERY AND LOAD)



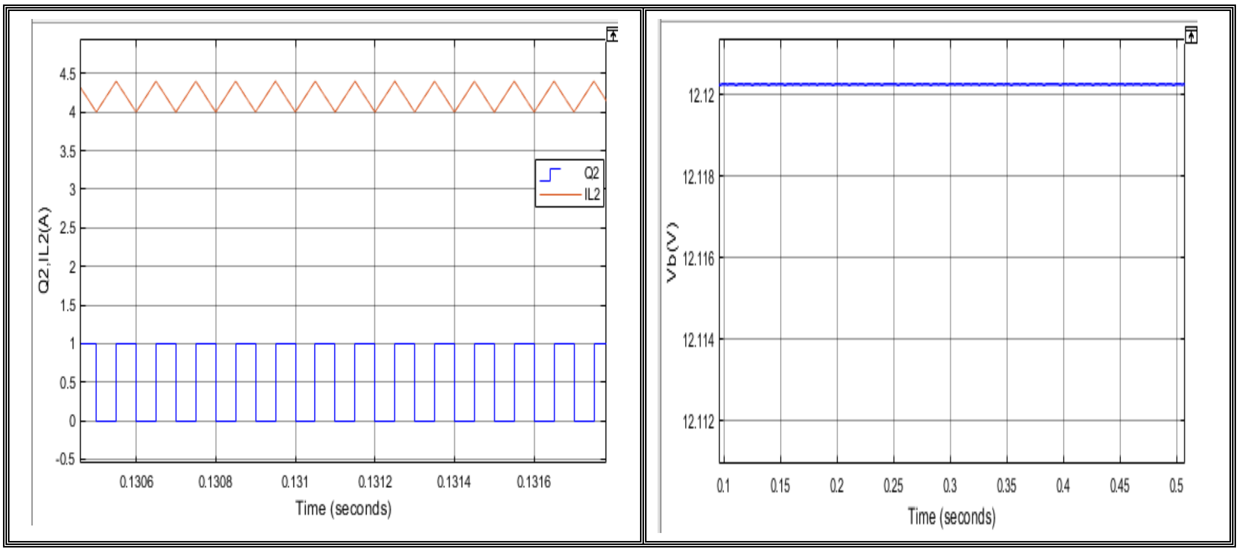


Figure 8: Simulation waveform for a) PV voltage and current, b) Inductor current, c) Q2- Inductor current and d) Battery Voltage

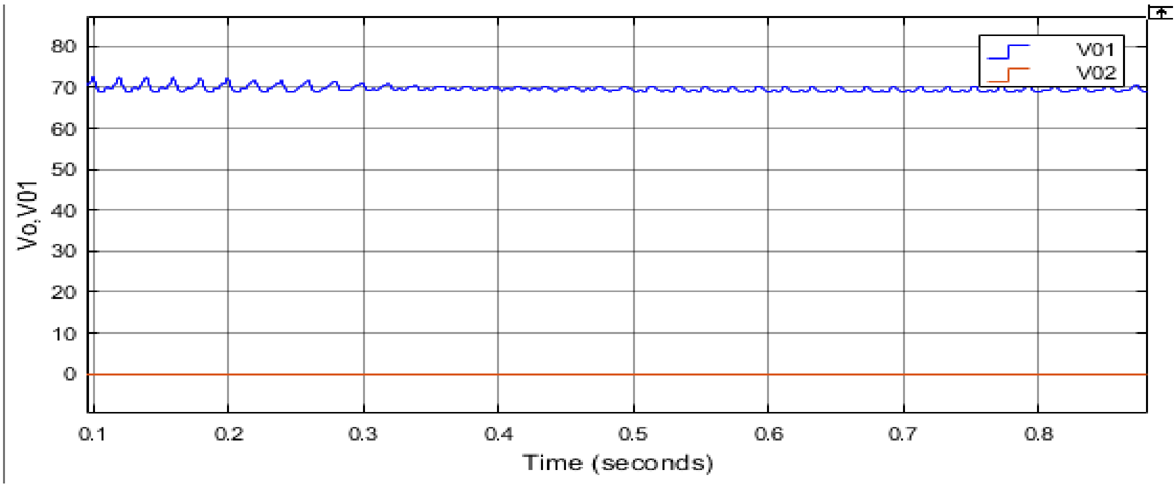


Figure 9: Simulation waveform for Output Voltage

STATE 3 - SIDO STATE OF THE CONVERTER (POWER TRANSFER FROM THE BATTERY)

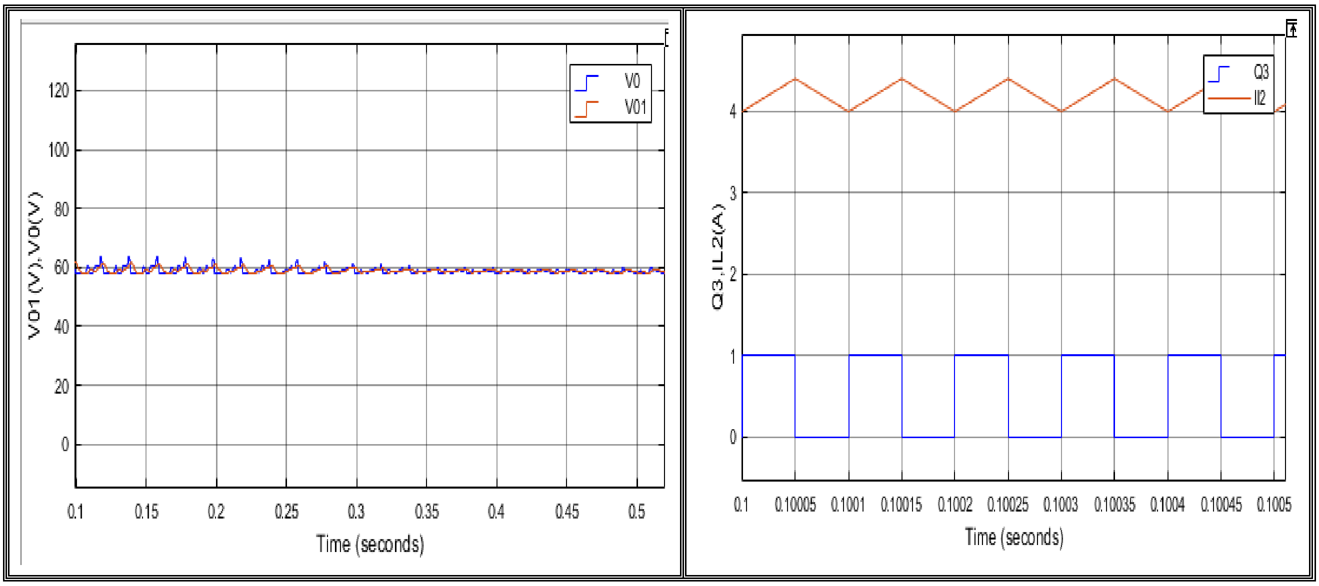


Figure 10: Simulation waveform for a) Output Voltage and b) Q2- Inductor current

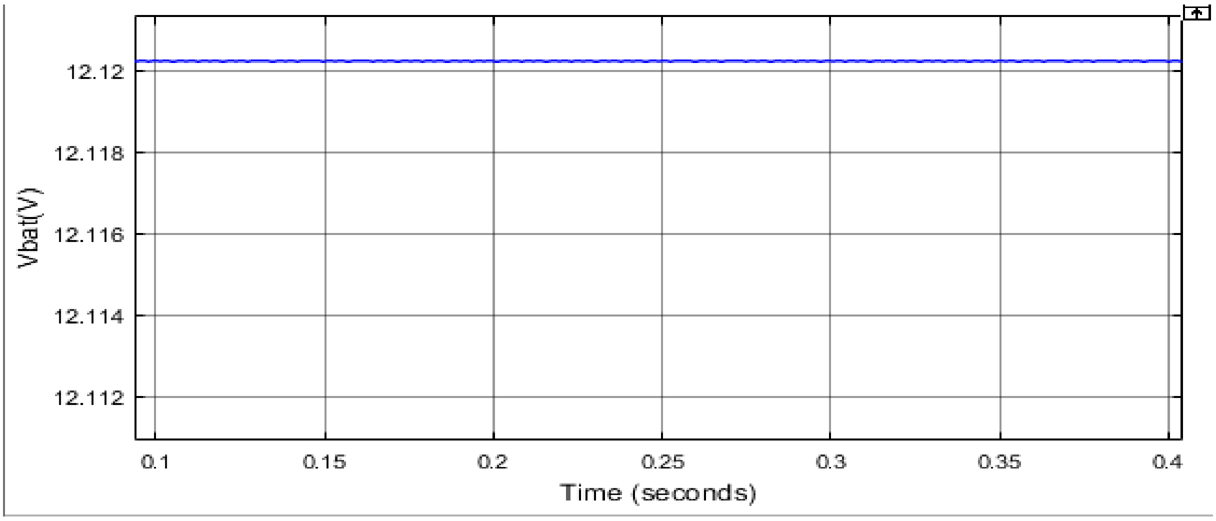


Figure 11: Simulation waveform for Battery voltage

STATE 4 – DIDO (DUAL INPUT DUAL OUTPUT) STATE OF THE CONVERTER (POWER TRANSFER FROM PV AND BATTERY)

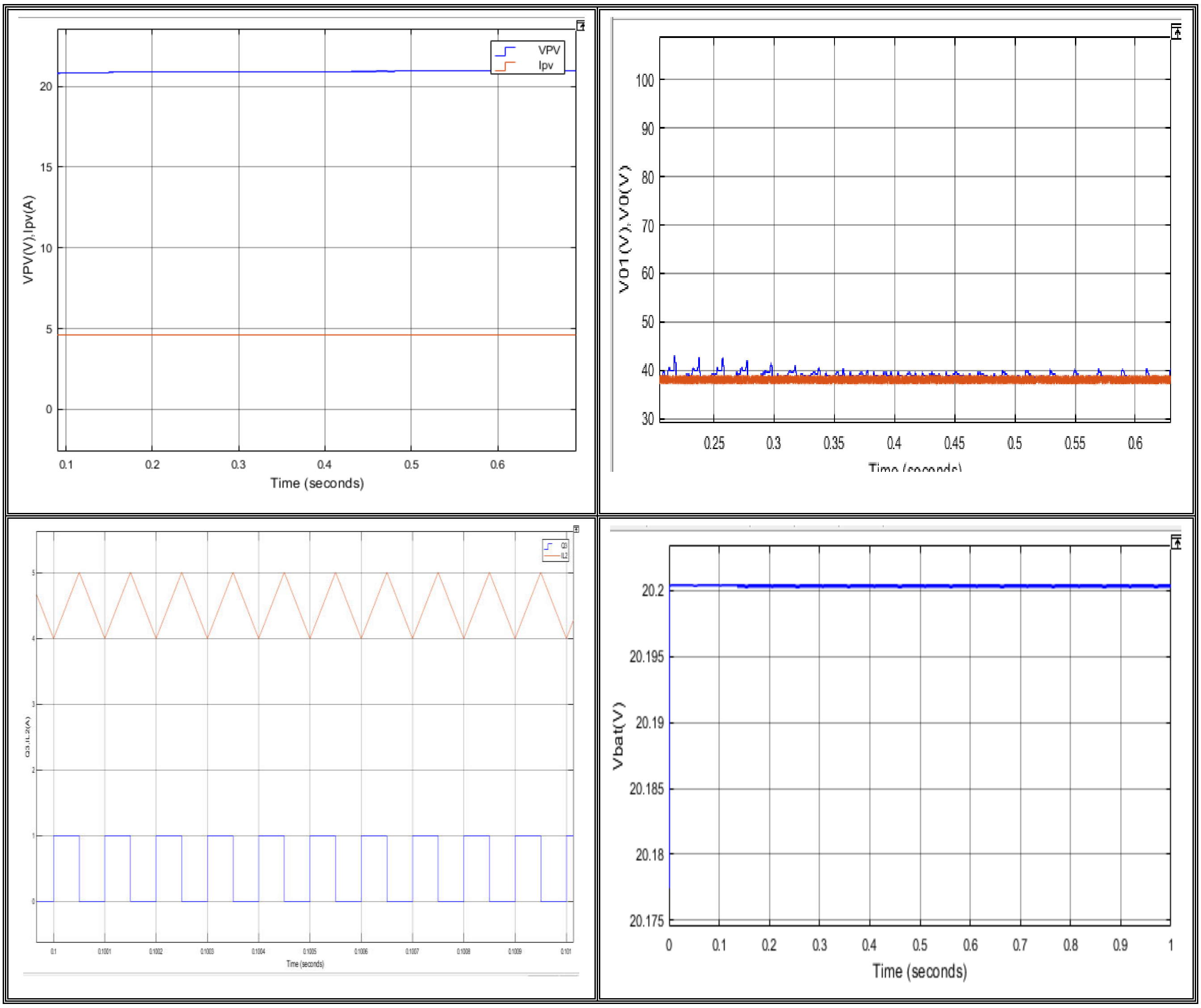


Figure 12: Simulation waveform for a) PV voltage and current, b) Output Voltage, c) Inductor current and d) Battery Voltage

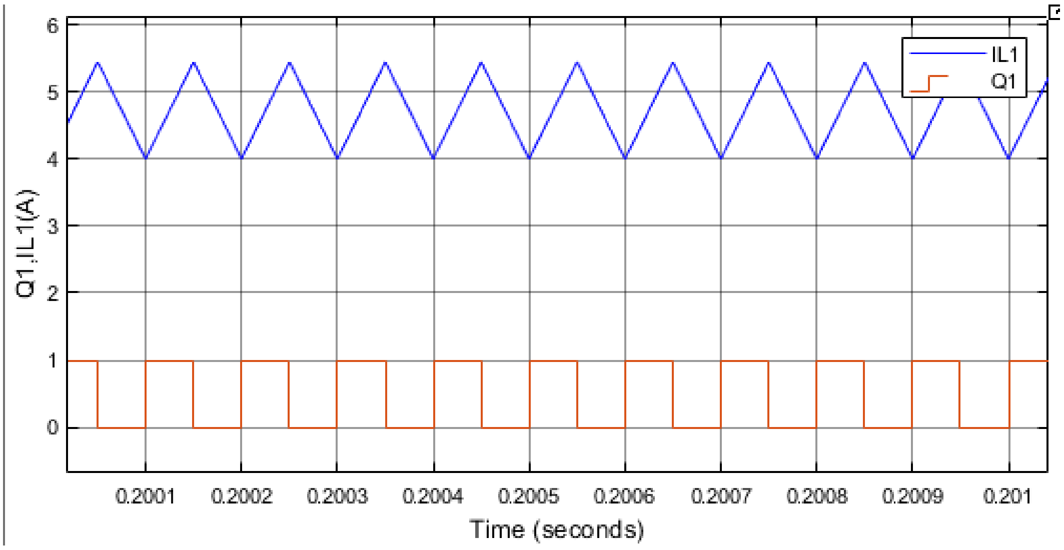


Figure 13: Simulation waveform for Inductor current

STATE 5 - SIDO STATE OF THE CONVERTER (POWER TRANSFER FROM LOAD TO BATTERY)

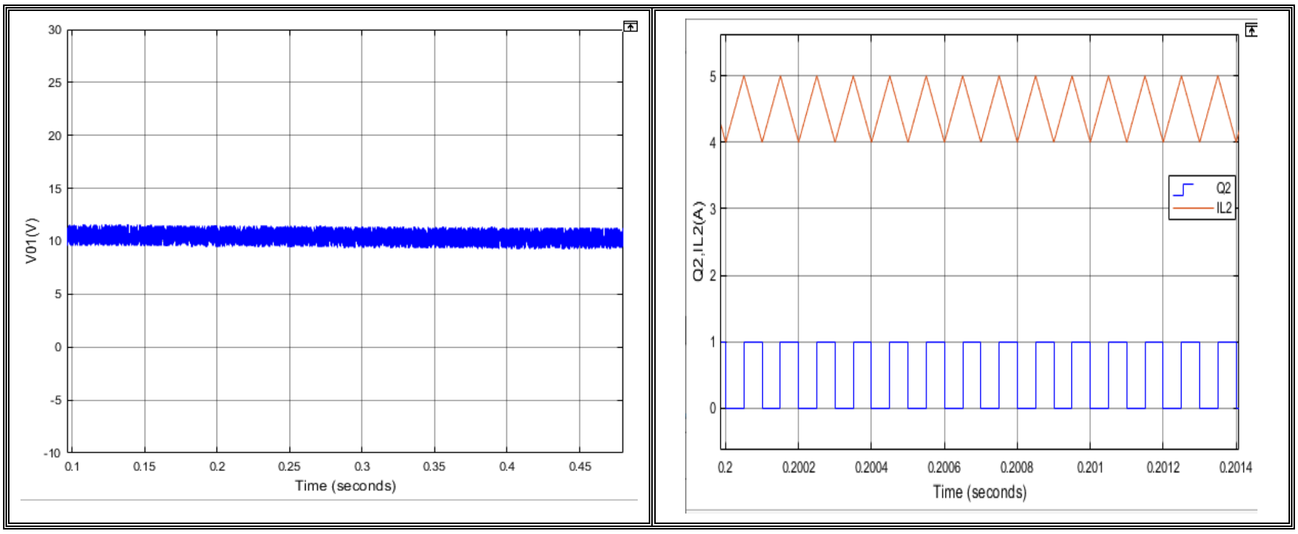


Figure 14: Simulation waveform for a) Output Voltage, b) Inductor current

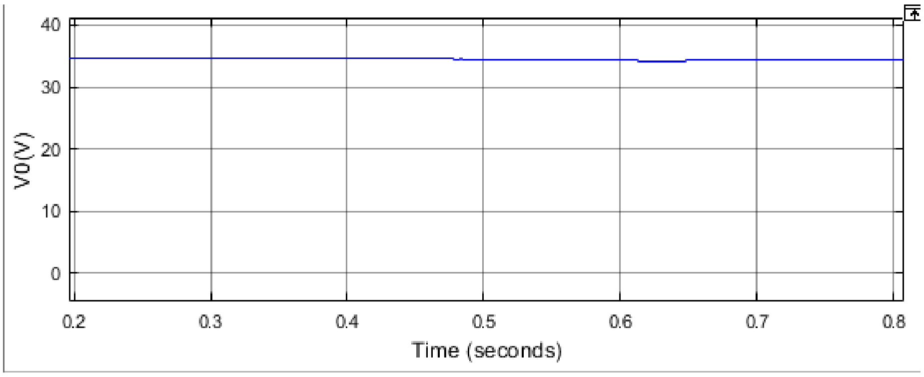


Figure 15: Simulation waveform for Output Voltage

CONCLUSION

A single-stage four-port (FPC) buck-boost converter for hybridizing diversified energy resources for EV has been proposed in this thesis. Compared to the existing buck-boost converter topologies in the literature, this converter has the advantages of a) producing buck, boost, buck-boost output even without the use of an additional transformer b) having bidirectional power flow capability with reduced component count c) handling multiple resources of different voltage and current capacity. Mathematical analysis has been carried out to illustrate the functionalities of the proposed converter. A simple control algorithm has been adopted to budget the power flow between the input sources. Finally, the operation of this converter has been verified through a low voltage prototype model. Experimental results validate the feasibility of the proposed four-port buck-boost topology.

Electric retrofits do have potential to assist in the transition to zero-emission vehicles, reducing the transportation sector's considerable contribution to GHG emissions. By embracing the re-use notion of a circular economy, transforming current vehicles could reduce the number of well-functioning vehicles going to scrap because of the purchase of new EVs. Furthermore, EV technology might be embraced at a moderate pace, eliminating the requirement to build and promote many EVs soon. Thus, there is an increasing need for converting existing combustion engine vehicles to electric vehicles. In this thesis, we have discussed the main components required, calculations for the selection of the ratings of the electrical components and the methodology.

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