

# AN ADAPTIVE DUAL INPUT-DUAL OUTPUT CONVERTER WITH NON-ISOLATED FEATURES FOR USE IN ELECTRIC VEHICLE

<sup>1</sup>Lavudi Sindhu Rani <sup>2</sup>Dr. D. Kiran Kumar

Department of Electrical and Electronics Engineering, JNTUHUCEST, Hyderabad, India

Email: 1:sindhu.sindhurani345@gmail.com, 2 kirannkumar9@jntuh.ac.in

**ABSTRACT** 

A variety of power electronics applications have recently made use of dc/dc converters with high voltage conversion. Electric car and DC microgrid solutions are centred on multi-port converter topologies. This article primarily focusses on the new non-isolated four-port (two input and two output) power electronic interface structure that can be utilised in electric vehicle (EV) applications. Mainly, this converter can deal with power sources that have different characteristics in terms of voltage and current.

During its operation, the suggested architecture is capable of producing both buck and boost outputs simultaneously. Increased reliability and efficiency are achieved by implementing the proposed four-port converter (FPC) with fewer components and a more straightforward control method. The converter's bidirectional power flow capability also makes it a good fit for regenerative braking electric vehicle battery recharge. We analyse the converter's steady-state and dynamic behaviour and present a control approach to govern the power flow between the several energy sources. An extracted small-signal model is used to create the converter that is suggested. The modelling and testing results in MATLAB, along with the results from various operating modes, validate the converter design and establish its performance behaviour.

**Keywords:** Bidirectional dc/dc converter, electric car, multi-port converter, battery storage, and regenerative charging

Modeling with MATLAB/Simulink.

#### I. INTRODUCTION

These days' cars are to blame for a lot of problems, like rising petrol prices, more pollution, higher temperatures, and the eventual exhaustion of fossil fuels. Environmentally friendly electric and hybrid vehicles (HEVs) have so been produced by the automotive industry. This vehicle's motor drive system is a crucial part. An effective power electronic converter powers the motor drive system. For electric vehicles to function, this power electronic converter has to communicate with the vehicle's battery and motor control systems. Electric vehicle systems' power electronic interfaces have been the subject of substantial study and published reports. A number of nonisolated three-port converter topologies are covered, including DIC/DOC and SISO converter topologies.

A step-up converter that combines buck-boost and KY converters is known as a voltage conversion ratio-rich converter. Isolated bidirectional converters are known as multiport dc/dc converters. The converter is enlarged by a multi-winding transformer, which serves to simplify the transfer of electricity. By integrating dc-link, many multiport bidirectional dc/dc converter topologies can be achieved.

together with magnetic coupling. The operation of a SISO converter is identical to that of a full-direction universal dc-dc converter. The hybrid electric vehicle is designed to work with converters that have two inputs and two outputs. The lack of an improvement in battery power caused by the load is the primary drawback.

A fuzzy logic control—based energy management approach has been suggested to improve power management between the battery and the ultracapacitor, thereby avoiding problems like high battery current during peak power and overcharging the ultracapacitor. A fourport (FPC) three-switch, single-stage, transformer-less, bidirectional buck boost converter is the primary output of this research. The suggested converter may combine many sources with varying input voltage and current characteristics, and its modular construction makes it easier to manufacture with fewer parts.



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Along with the previously mentioned characteristics, the converter that has been presented can also provide an output that is either higher than or lower than the maximum input voltage (boost) or lower than the minimum input voltage (buck).

The efficiency of the suggested converter is enhanced by the decrease in switching losses.

document's organisational is the Part I: Introduction. Part II: The structure. Concept Behind **FPC Fundamental** Development. The third section covers the operational modes. Section Section IV: Controller and Integration Implementation

The Suggested Four-Port Converter's Control Strategy In Section V, we see some examples of how the features of the proposed converter were tested using experimental data and a power budgeting control technique. Final thoughts in Section VII. Works Cited.

# **II. Analysis of Multiport Buck-Boost Convertor Performance**

#### 2.1 The FPC topological framework

An electric vehicle system's fluctuating input power and dynamic load make it impossible to meet load requirements with a single energy source. Therefore, it is necessary to hybridise all energy resources.

The main goal is to create a converter architecture that can link different energy sources to the powertrain of a vehicle.

The function of the power electronic interface in an electric vehicle's power system is shown in Figure 1.1(a) and (b).

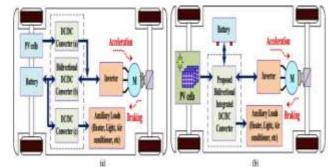


Figure 2.1 shows the proposed FPC interface for electric car systems in block diagram form, which combines classic converter (a) with integrated four-port (b)..

 Oversight of the independent power flow between generators A straightforward process for design, control, and execution

If you have a DC input voltage and want to convert it to DC voltage, you need a DC-to-DC converter. The levels of the input and output voltages are typically different. Among the many other uses for DC-to-DC converters are noise isolation and power bus regulation. Several common DC-to-DC converter topologies are detailed in this article.

#### 2.2 BUCK CONVERTER

With the transistor activated, voltage Vin is applied to one end of the inductor in this circuit.

Although the transistor is turned off, the current will still flow through the inductor and now go through the diode since the inductor current tends to climb with this voltage.

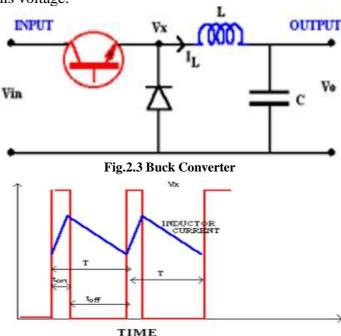


Fig:2.4. Voltage and current changes

Examining the inductor current's evolution through a single cycle will provide light on the circuit's voltages. When thinking about the connection

$$V_x - V_0 = L \frac{di}{dt}$$

$$d_i = \int (V_x - V_0) dt + \int (V_x - V_0)t$$

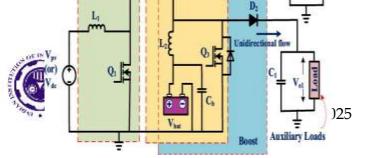


Figure 2.2 shows the suggested setup for a four-port converter (FPC).

The notable features of the recommended converter are:

• The capability of bidirectional electrical transfer

ON OFF

There is a satisfactory change in current.

#### 2.3 BOOST CONVERTER

A simplified diagram of the boost converter is shown in Figure 2.5. When the output voltage needs to be higher than the input voltage, this circuit is utilised.



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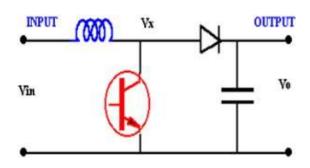


Fig.2.5: Boost Converter Circuit III. OPERATION STATE AND MODES OF OPERATION

#### SIDO (SINGLE INPUT DUAL OUTPUT) STATE 1 CONVERTER STATE (POWER TRANSFER FROM PV (Vdc) TO LOAD)

In this configuration, PV delivers power to the load independently. Between the timestamps 0 and d1Ts, the switches Q2 is in the off state while Q1 and Q3 are in the on state. Figure 5(a) and (b) show that the inductor current increases with a positive slope when Vpv>Vbat, since the voltage Vpv occurs across the inductor L1. During the time span d1Ts to Ts, switches Q2 are turned on while switches Q1 and Q3 are toggled off. The energy accumulated in inductor L1 during the previous time interval d1Ts is transferred to the current through diode D1. released to the output capacitor. When operating in a steady condition, the output voltage is determined by

$$V_0 = \frac{1}{1 - d_1} V_{pv}$$

$$V_{01} = \frac{1}{1 - d_1} V_{pv}$$
(1)
$$(2)$$

$$V_{01} = \frac{1}{1 - d} V_{pv} \tag{2}$$

#### 2) SITO (SINGLE INPUT THREE OUTPUT) STATE 2.

#### POWER TRANSFER FROM PV TO BATTERY AND LOAD STATUS OF THE CONVERTER

Q2 works with d2 < 05 to charge the battery when it has to be charged from PV (see Figure 5(c) and (d)). With d1 > 05, Q3 functions similarly to Q1 to generate increased output across the load. The relationship between the voltages Vbat, Vpv, and Vo, Vo1 is

$$V_0 = \frac{1}{1 - d_1} V_{pv} \tag{3}$$

$$V_{01} = d_2 V_{pv} \tag{4}$$

discharging action between 0 and d3Ts. The present iL2 declines with a negative slope between the intervals d3Ts to Ts. The switch's ON/OFF status The drive train's overall output is increased by Q3. Q1 is maintained in OFF mode during operation since it does not participate in the process of transferring energy from the battery to the load (see Figure 5(e) and (f)). When the battery is discharged, the output voltage across the load is provided as

$$V_0 = \frac{1}{1 - d_3} V_{bat} \tag{6}$$

$$V_{01} = \frac{1}{1 - d_3} V_{bat} \tag{7}$$

#### 4) THE CONVERTER'S STATE 4 DIDO (DUAL INPUT DUAL OUTPUT) STATE (POWER TRANSFER FROM PV AND BATTERY)

Figure 5(g) and (h) show that when the electric vehicle's power consumption is large, the power is supplied by the battery and PV. In order to charge the inductor, the currents iL1 and iL2 rise linearly between 0 and d1Ts, caused by gated switches Q1 and Q3. Here, Q2 receives the corresponding gate signal. In contrast, when switches Q1 and Q3 are not in use, the inductor currents iL1 and iL2 fall in a negative slope.

$$V_0 = \frac{1}{1 - d_1} V_{pv}$$
 (or)  $V_0 = \frac{1}{1 - d_3} V_{bat}$  (8)

$$V_{0} = \frac{1}{1 - d_{1}} V_{pv} \quad \text{(or)} \qquad V_{0} = \frac{1}{1 - d_{3}} V_{bat} \qquad (8)$$

$$V_{01} = \frac{1}{1 - d_{1}} V_{pv} \qquad (or) \quad V_{01} = \frac{1}{1 - d_{3}} \qquad (9)$$

#### STATE 5-POWER TRANSFER FROM LOAD TO BATTERY: SIDO STATE **CONVERTER**

The drive train's stored kinetic energy is transferred back to the battery during regenerative braking (see Figure5(i) and

The following is the state's switching sequence: While Q2 and Q3 are turned ON and OFF, respectively, Q1 remains permanently in the off state. The battery is charged by Q2 and Q3 in their ON-OFF states.

$$V_{bat} = d_2 V_0 \tag{10}$$

In the same condition, the second output uses regenerative braking power to replace the battery. The control relationship can be obtained as

$$V_{01} = d_3 V_0 \tag{11}$$



ISSN: 0970-2555

Volume: 54, Issue 10, October: 2025

 $V_{bat} = d_2 V_{pv} \tag{5}$ 

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

In this condition, the load receives the energy that the battery has stored. The inductor current iL2 increases linearly as a result of the battery's



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Volume: 54, Issue 10, October: 2025

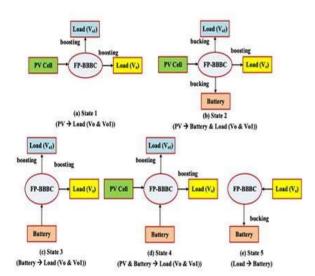


Fig.3.1: a) State 1(boost), b) State 2 (buck & boost), c) State 3 (boost), d) State 4 (boost), e) State 5 (buck).

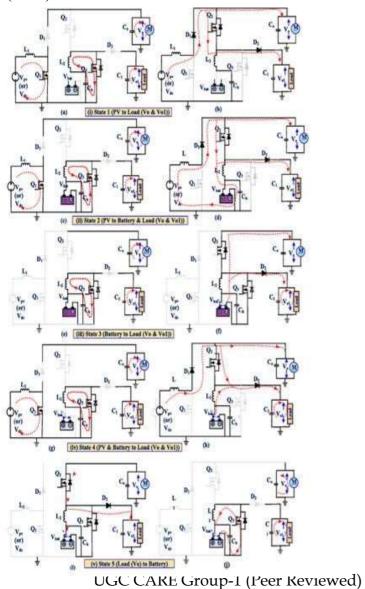


Fig.3.2: Typical diagram of all the states (i)State1, (ii)State2, (iii)State3, (iv)State4, &(v)State5



ISSN: 0970-2555

Volume: 54, Issue 10, October: 2025

#### **Operational conditions**

#### Table. 1

### IV.CONTROL STRATEGY

#### 4.1 PI CONTROLLER

A proportional integral derivative (PID) control can also be implemented using just the proportional and integral terms. When it comes to controller types, the PI controller is even more popular than full PID controllers. The value of the controller's output, u(t), is the altered variable input that the system receives.

e(t)=SP-PV

 $\mathbf{u}(t) = \mathbf{ubias} + \mathbf{Kce}(t) + \mathbf{Kc} \tau I \int t \mathbf{0} e(t) dt$ 

#### 4.2 DISCRETE PI CONTROLLER

Since digital controllers use discrete sample periods, the integral of the error must be estimated using a discrete variant of the PI equation. Here, nth represents the number of samples and  $\Delta t$  is the interval between each sample. The integral's continuous form is replaced by a sum of the mistake.

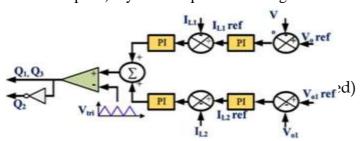
#### ADVANTAGES AND DISADVANTAGES

A PI controller's steady-state error is zero because of the integral term, which is not the case with proportional-only control in general. Without derivative action, the system may be more stable in steady state when dealing with noisy data. For one thing, derivative behaviour is more affected by input variables with higher frequencies.

#### 4.3 INTEGRAL ACTION AND PI CONTROL.

CE E	NB	NM	NS	Z	PS	PM	PB
NB	NB	NB	NB	NB	NM	NS	Z
NM	NB	NB	NB	NM	NS	Z	PS
NS	NB	NB	NM	NS	Z	PS	PM
Z	NB	NM	NS	Z	PS	PM	PB
PS	NM	NS	Z	PS	PM	PB	PB
PM	NS	Z	PS	PM	PB	PB	PB
PB	Z	PS	PM	PB	PB	PB	PB

A controller output (CO) signal is calculated and sent to the ultimate control device (such a valve or variable speed) by the Proportional-Integral



(PI) algorithm.

No.of States	Input Sources	MOSFET Switches		Inductors		Diodes		Battery	Capacitors		Outputs		
		Qi	Q:	Q.	L	L	Di	$\mathbb{D}_2$	V <sub>bu</sub> (or) C <sub>k</sub>	ζ,	Ci	(V,)	(Vol.)
State I (V <sub>p</sub> >V <sub>ba</sub> ) (V <sub>pc</sub> ) or (V <sub>b</sub> )	a	ON	OFF	ON	1	1	OFF	OFF		11	Boost B	Boost	
	OFF	ON	OFF	ļ	ļ	ON	ON		†	1			
State 2 (V <sub>p</sub> >V <sub>bel</sub> ) (V <sub>p</sub> ) or (V <sub>k</sub> )	ON	OFF	ON	t	1	OFF	OFF	1	1 1	1	Boost Boo	Boost	
	OFF	ON	OFF	ļ	1	ON	ON		1	1			
State 3 (V <sub>pv</sub> <v<sub>bil) (V<sub>bil</sub>)</v<sub>		OFF	ON		1		OFF	ı	ļ	Ţ	Boost	Boost	
		ON	OFF		1		ON		†	1			
State 4 (V <sub>py</sub> =V <sub>bel</sub> ) (V <sub>p</sub> ) and		(r) and (V <sub>bd</sub> ) OFF	OFF	ON	1	1	OFF	OFF		1	1	Boost	Boost
	(V <sub>pv</sub> ) and (V <sub>bit</sub> )		ON	OFF	ļ	ļ	ON	ON		1	1		
State 5 (V <sub>pr</sub> =0, V <sub>int</sub> <v<sub>load)</v<sub>	Regenerative braking power		ON	OFF		1	• 5	ON		ļ	ļ	Buck	Buck
			OFF	ON	×	1		OFF		1	1		

Table regresentation: ON- Switch close, OFF- Switch open, 1- charging of inductor and capacitor, and 1- discharge of inductor and capacitor.

pump), just as the P-Only controller does at each sample time T. In the PI method, the controller error, denoted as e(t), and the

u(t)=ubias+Kce(t)+KcτInt∑i=1ei(t)Δt

parameters used for tuning the controller have an impact on the calculated output.

#### 4.4 FUZZY LOGIC CONTROLLER

FLC takes in two signals and outputs one. The three components are the control signal, the error change (de), and the error (e). Linguistic variables, which represent inputs and outputs, can be grouped into the following kinds: NB, NM, NS, Z, PS, PM, and PB. The normalisation range for all inputs and outputs is 10, as can be observed. The fuzzy sets were described using the following terms: "Negative Big" (NB), "Negative Medium" (NM), "Negative Small" (NS), "Zero" (Z), "Positive Small" (PS), "Positive Medium" (PM), and "Positive Big" (PB). Decision rules can be assigned according to the ones shown in Table IV.

Human intuition and prior knowledge of the process form the basis of the fuzzy rules. These rules comprise the input/output links that define the control strategy. Since there are seven fuzzy sets in each control input, the maximum number of fuzzy rules is 49.

**Table 2: Table of FUZZY Rules** 



ISSN: 0970-2555

Volume: 54, Issue 10, October: 2025

### Fig:4.1 Proposed FPC PWM generator with PI control

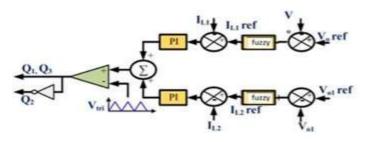


Fig.4.2 Proposed FPC PWM generator with Fuzzy

#### logic control

# V. SIMULATION CIRCUITS AND RESULTS

Complete model implementation and MATLAB/Simulink simulation were conducted to assess the efficacy of the suggested Dual Input Dual Output Four Port Converter.

The construction of the four-port converter requires only three MOSFET switches, namely Q1, Q2, and Q3. A direct current (DC) power source or a battery can power the input. From the converter, you can choose between a main and an auxiliary output, depending on your needs.

The converter can also buck and raise the voltage at the output. During regenerative braking, the drive train's stored kinetic energy is transferred back to the battery, enabling regenerative operation.

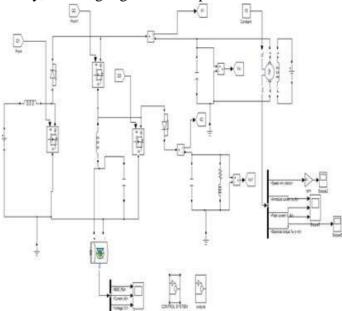
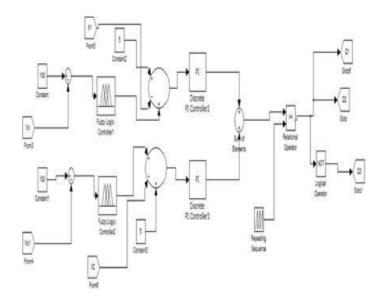


Fig: 5.1. Simulink Model of a Multifunctional Non-Isolated Dual Input- Dual Output Converter



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Volume: 54, Issue 10, October: 2025





ISSN: 0970-2555

Volume: 54, Issue 10, October: 2025

Fig:5.2. Simulink Model of a Control Circuit

To keep errors to a minimum, the control circuit compares the current voltage to a 100V reference using a fuzzy logic controller. With PI Controller, the research state error can be minimised. In order to acquire a digital signal, one must first acquire a sawtooth or triangle signal with carrier reference.

Parameters	Volts
Dc Voltage source	100V
Inductor (L1)	1mH
Inductor (L2)	120μΗ
Capacitor (C1)	1µF
Capacitor (C2)	1000μF
Load Resistance	1Ω
Load inductance	1mH

**Table 3: Model Specifications.** 

Parameters	Value	
Nominal Voltage	12V	
Number of batteries	1	
SOC	99.5%	ed)
Rated capacity	7Amp/hr	

**Table 3: Battery Specifications** 

10



ISSN: 0970-2555

Volume: 54, Issue 10, October: 2025

# 5.1 SIMULATION RESULTS SIMULATION RESULTS WITH FUZZY LOGIC CONTROLLER

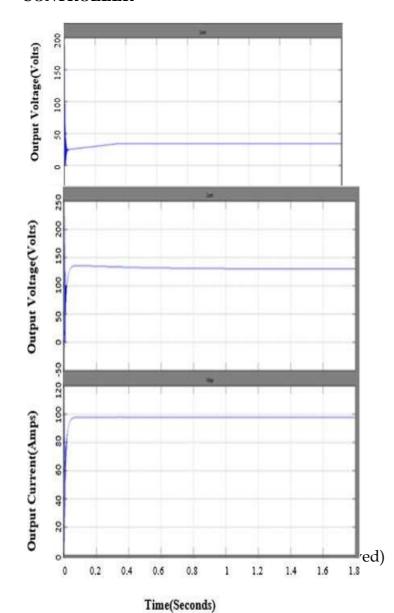
Output waveforms of a voltage and current across Main load with Fuzzy Logic Controller.

Output waveforms of a voltage and current across Auxiliary Load with Fuzzy Logic Controller.

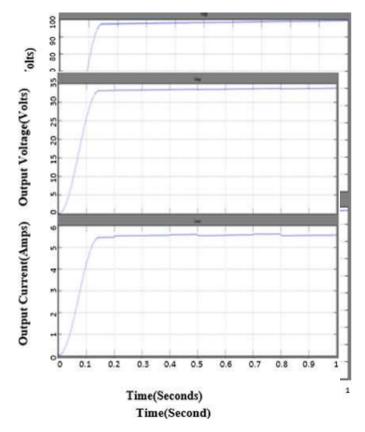
The input voltage of 21 volts is brought down to 35 volts by means of a buck operation after being increased to 100 volts. The fuzzy logic creates an output voltage that is ripple-free.

computer programmer.

## SIMULATION RESULTS WITH PI CONTROLLER



Output waveforms of a voltage and current across Main load with PI Controller.



Output waveforms of a voltage and current

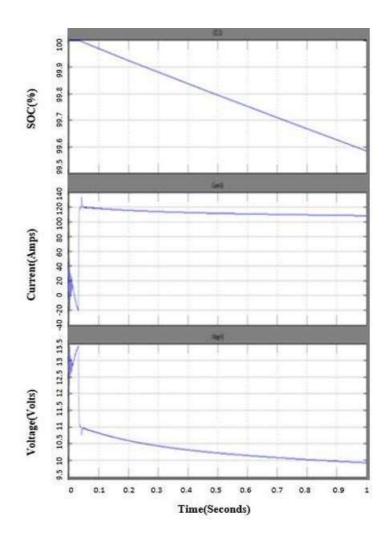


ISSN: 0970-2555

Volume: 54, Issue 10, October: 2025

#### across Auxiliary load with PI Controller.

The output voltage is boosted and buck-boosted by the PI Controller during first transients. This early transient can be mitigated by incorporating a fuzzy logic controller into the control circuit design.



## State of charge (SOC), Voltage & Current of the battery

The battery will enter a 99.5 state of charge when it stops conducting, which happens when the continuous DC source is conduction. Over the battery, the current is 110A and the voltage is 10V.

## 5.2 A comparison between the suggested fuzzy controller and the conventional pi controller.

Topology	Rise time	Settling time
Conventional pi controller	0.005sec	0.31sce
Proposed fuzzy controller	0.056sec	0.14sec

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#### VI. CONCLUSION

One possible component of an electric vehicle hybridisation technique is a single-stage four-port (FPC) buck-boost converter, according to this research. This converter has several advantages over other buck-boost converter topologies that have been discussed in the literature: A) it can manage many resources with varying voltage and current capabilities; b) it can provide buck, boost, or buck-boost output without an additional transformer; and c) it can have bidirectional power flow capabilities with fewer elements.

Analytical mathematics has shown the suggested converter's functionality. A simple control approach has been settled upon for the purpose of allocating input power budgets. Now we can use the Simulink model to confirm that the converter works as expected. Using simulation findings, we can confirm that the four-port buck-boost architecture is feasible.

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