

An Integrated Multiport Dc – Dc Converter for Renewable Energy Applications

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Abstract As conventional energy sources are steadily depleting in nature due to human activities, renewable energy sources are the need of the hour. Renewable energy source delivers environmental friendly, sustainable power. Due to the intermittent nature of these sources, the power produced cannot be used directly by the consumers. So the output power is conditional to meet the grid requirements by using semiconductor devices. In the present system, wind energy output is coupled with back to back power converter and solar energy output with dc to ac converter. The output from the two systems are separately interfaced with the power grid. This has the disadvantages of higher components count, increased cost and inefficient power flow management. The proposed system consists of four ports among which one port is for solar point input, one port is for wind energy input, one bi-directional battery port and an isolated load port. Zero voltage switching is adopted for all main switches in the converter. The integrated four port converter has the advantages of interfacing two sources and controlling them with low cost, compact structure that allow and intelligent power flow management between the household users, the electric distribution grid and the distributed generation units. This converter provides the facilities to combine two or more generation sources. Solar power and wind power are given as input to the two input ports of the converter. The converters use four main switches for this conversion. The output voltage will be a DC voltage. This voltage can be used to derive any DC load or can be converted to AC voltage using inverter to drive an AC load.

Key words: solar energy, wind energy, PIC controller, dc-dc converter.

I. INTRODUCTION

Renewable energy source is a naturally available source which can replace with the opening of time, either through natural reproduction or other certainly recurrent procedures. Renewable energy is energy as of natural sources such as radiation from sunlight, wind energy, rain, tidal wave and geothermal energy. The share of renewable energy in electricity generation is nearly 19% with 16% of electric energy coming from hydroelectric power and 3% from solar and wind. The need for alternative energy sources is getting urgent due to the depleting conventional sources. Hence, the development of renewable energy is moving faster at present. Sunlight and strong wind sources are abundant and free to use. Photovoltaic power generation is becoming added promising then the introduction of the thin film PV technology. Airflows can be used to run wind turbines. Wind energy is one of the top energy alternative solutions which can be widely used in all places.

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Utilization of wind energy is increasing at a yearly rate of 20%, through a wide range installed capacity of 238000 megawatts. The two wind energy and PV energy are haphazard in nature, they can be collective together to reimburse the lack of each other and supply the required energy to the electrical systems. When battery is added to the combined wind and PV system, the energy can be efficiently controlled to deliver to the loads.

The world-wide growth of wind and PV energy during the past 5 years is shown in figure 1.1. From the below chart, it can be inferred that usage of solar and wind energy is on the increase compared to the other available renewable energy sources. So, the demand for these two energy sources is high among people all over the world which is the main reason for selecting solar and wind as the input sources for the proposed system.

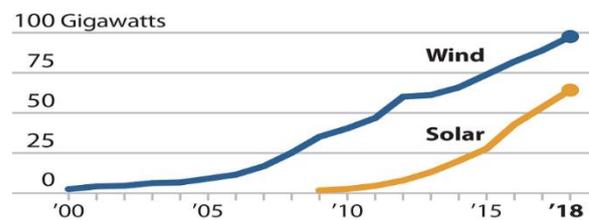


Fig 1.1 world-wide Growth of wind and solar energy

Object of the proposed system is to develop a multiport DC-DC converter to integrate energy storing elements with alternative energy sources such as solar and wind energy.

II. EXISTING SYSTEM

A comprehensive comparative study of two and three output ports DC-DC converter with zero voltage switching (ZVS) as main switches are discussed [1]. The ZVS can be attained using with joined inductor, which also regulates supply current through the load disturbances. The control strategy and energy management for an integrated three-port converter. There are different modes of operation, so it is challenging to describe different methods and to more tool autonomous mode transition based on the energy state of the three power ports [1]. A modest way is used to grasp smooth and seamless mode conversion. The converter technology that lines four power ports. The four-port DC-DC converter is resulting by only adding two switches and two diodes to the old half bridge technology. Zero – voltage switching is realised for all pairs of main switches [2]. A fixed frequency topology for the renewable energy has been introduced. And the detailed power diversification and optimization has been investigated. In contiguous mode of conduction, the flowing current is not a ripple free one. [3]. In the present system, wind energy output is coupled with back to back power converter and solar energy output with dc to ac converter [4].

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The outputs from the two systems are separately interfaced with the power grid to meet the energy demands or to supply and specific load. [5]

This disadvantages of this system are discontinuity of power supply, higher components count, and high cost and less energy flow management. And closed loop control without proper decoupling is difficult to implement [6].

Three of the four ports can be regulated and the fourth port is difficult to interfacing with the main power circuit, because of the return supply of the other three are opposing the fourth port [7].

III. PROPOSED SYSTEM

The propose converter has four ports in which two are for the input consisting of the solar and the wind sources, a bidirectional battery storage port and an isolated load port. The system employs four main switches for which zero voltage switching is realized. A PIC microcontroller is used for generating switching pulses which controls the operation of the switches.

2.1 Advantages of proposed system

- Improved reliability and efficiency.
- Efficient utilization of solar and wind energy.
- Facility of combining multiple generation sources.
- Provides alternative feeding sources for loads whenever the power supplied by domestic generators is not enough to satisfy the user's load.

IV. BLOCK DIAGRAM

The availability of both solar and wind is unpredictable and random in nature. So, both the sources are integrated such that either of them can compensate the shortage of the other and supply the required energy. The proposed interfaces the above two sources along with a bidirectional battery source. The following fig1.2 shows the functional block diagram of proposed system

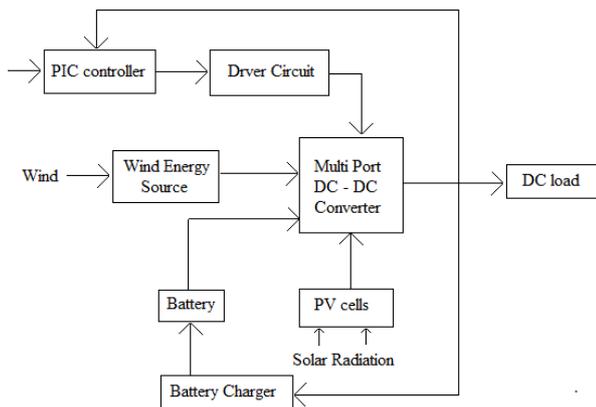


Fig 2.1 block diagram of propose system

These input voltages from the PV module, wind mill the battery are together given to the multiport converter which is obtained by with two switches and two diodes to the traditional half bridge technology. The converter is made up of four main primary MOSFET switches – S1, S2, S3 and S4. Zero voltage switching is grasped for four main switches.

The converter has twelve stages of operation where the switching signals are generated by the PIC microcontroller and driven by the driver circuit. The output is fed back to the PIC microcontroller. The output can be used drive any DC load. When seeing the semiconductor tensions, this

adapted half bridge technology shows striking like to its traditional half bridge counterpart. The major difference is that the transformer design of this four port converter required to permit for a DC current flow, and becomes similar to an inductor or a fly back transformer design.

Other than the transformer, the circuit design and optimization technique used for the traditional half bridge topology can be used here for this four port topology, which provides great convenience for the practicing engineers to implement the power stage design.

Solar power and wind power are given as input to the two input ports of the DC converter converts the variable input voltage to a constant voltage. The DC – DCconverter converts the variable input voltage to a constant voltage. The converter uses four main switches for the conversion. The integrated constant voltage is converter into a AC voltage by the single phase inverterthrough the isolating transformer. The capacitor C near the isolating transformer is used for filtering purpose. The output voltage is taken across C_o

Designed data

Input voltage $V_{in} = 12V$

Output volate $V_o = 24V$

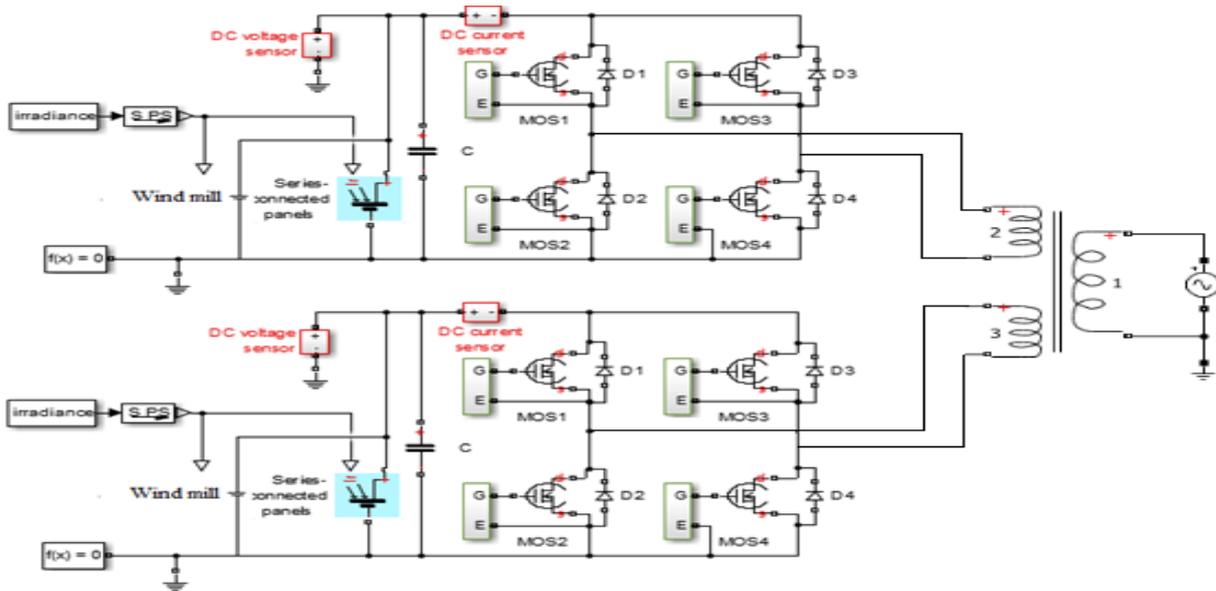
Switching frequency = 100kHz

Load current $I_L = 1.5A$

$\Delta I_L = 1.2A$ $L_m = 50 \mu H$

Duty cycle $D = 0.69$

$V_{ripple} = 0.018V$; $C = 330 \mu F$



The Fig 2.2 shows the MATLAB Simulink diagram.

2.3 Stages of operation

The Fig 2.2 shows the MATLAB Simulink model. And the fig 2.3 shows the various stages of operation of the converter. The main operation stages are described below.

Stage 1 (t₀ – t₁)

At begin stage, the diode of switch S₁ is compulsory on the reuse the stored energy from transformer, the leakage inductor, and the result is fly wheeled. At starting time t₀, S₁ is triggered to turn ON with ZVS, and then the leakage inductor is return to zero and inverse – energised.

Stage 2 (t₁ – t₂)

At the time t₁, the primary of the transformer current increases to repeat current of i_{L0}, the diode of SR₂ will be blocked. And the converter has to start to deliver the output power.

Stage 3 (t₂ – t₃)

Through the time t₂, S₁ is turned OFF, making the leakage current i_p, to charge the S₁ parasitic capacitor and discharge S₂, S₃ and S₄ parasitic capacitors.

Stage 4 (t₃ – t₄)

At time t₃, the voltage through the S₂ parasitic capacitor is discharged to zero, and the S₂ feedback diode conducts to transmit the current, and it provides the ZVS condition for S₂. During this time period, the result is freewheeled through SR₁ and SR₂ feedback diodes.

Stage 5 (t₄ – t₅)

At time t₄, S₂ is triggered ON with ZVS, and then, the leakage inductor is rearrange to zero and charged inversely. The resultant inductor current drip from t₂ to t₅ is due to the leakage inductor charge or discharge.

Stage 6 (t₅ – t₆)

At time t₅, the transformer primary current rises to the reproduced current of i_{L0}, freewheel diode of SR₁ is blocked, and the converter starts to provide power as output.

Stage 7 (t₆ – t₇)

At time t₆, S₂ is gated OFF, thus producing the leakage current i_p to charge the S₂ parasitic capacitor and discharge the S₁ and D₃ parasitic capacitor.

Stage 8 (t₇ – t₈)

At level t₇, the voltage across D₃, is reduced to zero, and then, D₃ start to conduct. S₃ is getting turn ON before this time; therefore, S₃, has natural ZVS. The resultant inductor current freewheels across SR₂ during this level.

Stage 9 (t₈ – t₉)

At time t₈, S₃ is turned OFF, thus producing the leakage current i_p, to control S₂ and S₃ parasitic capacitors and discharge S₁ and D₄ parasitic capacitors.

Stage 10 (t₉ – t₁₀)

At level t₉, the voltage across D₄ is reduced to zero and diode D₄ start to conducts. Hence S₄ is gated ON before this time, the leakage current freewheels through D₄ and S₄ so that the leakage current is trapped. On the secondary side, resultant inductor current freewheels through SR₁ and SR₂.

Stage 11 (t₁₀ – t₁₁)

At level t₁₀, S₄ is gated OFF, producing the trapped leakage current to discharge the S₁ parasitic capacitor and charge the S₂, S₃ and S₄ parasitic capacitors.

Stage 12 (t₁₁ – t₁₂)

At time t₁₁, the voltage across S₁ is discharged to zero, and the S₁ freewheel diode start to conduct to carry the current, which provides ZVS condition for S₁. During this time period the resultant current is freewheeled. This is the end of the switching cycle. The switching pattern for MOSFET switches is shown in table 1.

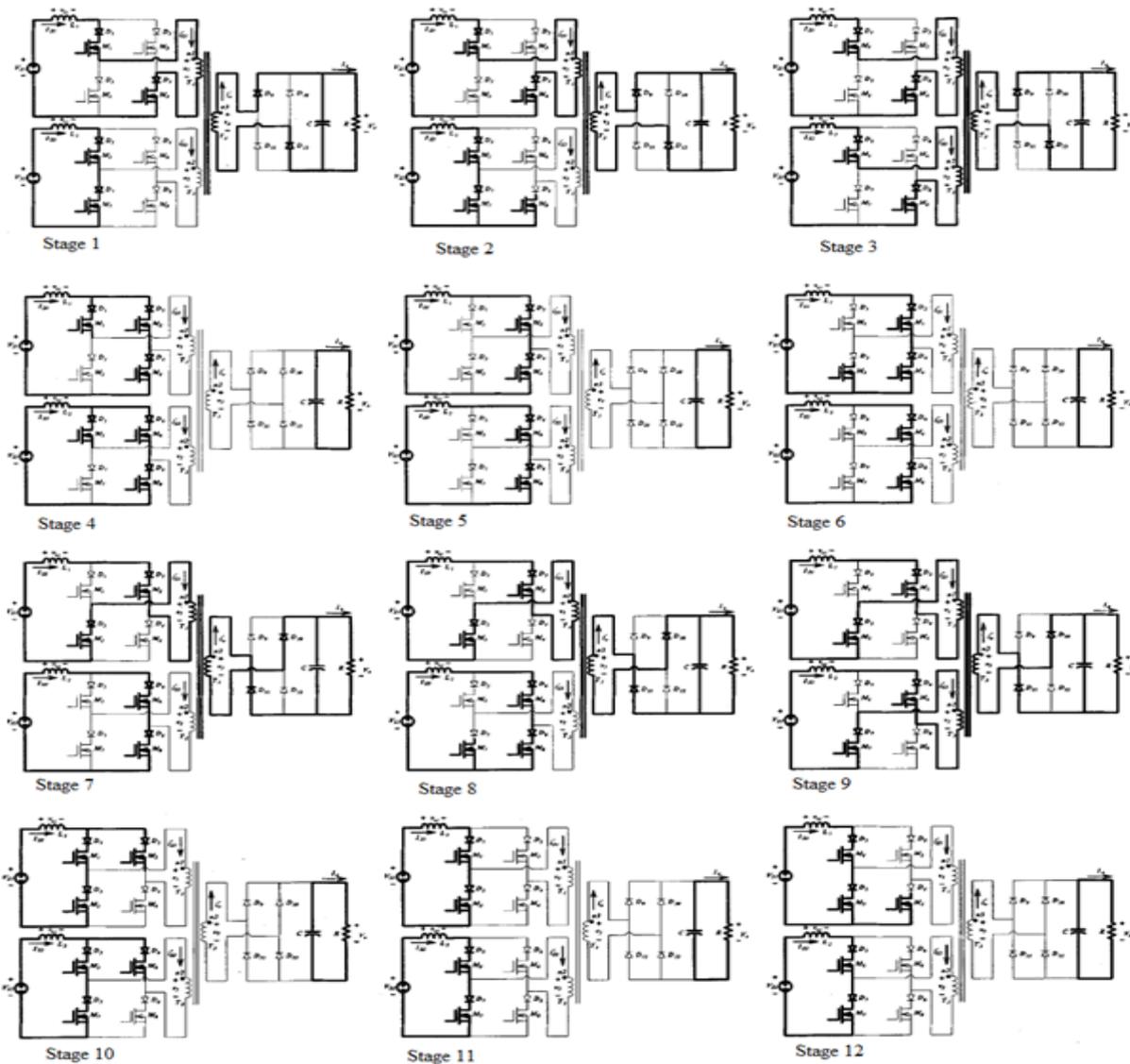


Fig 2.3 Equivalent circuits of every switching stages

Table 1.

MOS FET 1	MOS FET 2	MOS FET 3	MOS FET 4	MOS FET 5	MOS FET 6	MOS FET 7	MOS FET 8
ON	ON	ON	ON	OFF	OFF	OFF	OFF
OFF	ON	ON	ON	ON	OFF	OFF	OFF
OFF	OFF	ON	ON	ON	ON	OFF	OFF
OFF	OFF	OFF	ON	ON	ON	ON	OFF
ON	OFF	OFF	OFF	OFF	ON	ON	ON
ON	ON	OFF	OFF	OFF	OFF	ON	ON
ON	ON	ON	OFF	OFF	OFF	OFF	ON
ON	ON	ON	ON	OFF	OFF	OFF	OFF

Output voltage of multiport DC – DC converter

The output voltage of the four port DC - DC converter is shown in Fig.2.4. The circuit was simulated with the input voltages to three ports as 12V, 9V, 9.4V respectively and the output voltage was obtained at the fourth port as 25V DC. The circuit has been simulated for different levels of input voltages.

The input voltage of two ports have been varied and simulated that signify the varying voltages from the solar

and the wind while the voltage of one port is kept constant to indicate battery source. It has been observed that for variable DC inputs, the output has been a constant DC voltage.

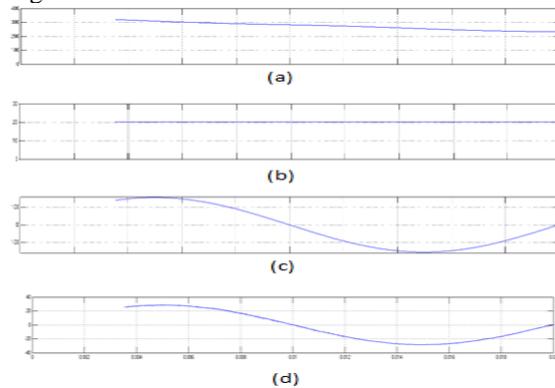


Fig 2.4 output waveform (a)Capacitor voltage (b) solar panel voltage (c) output current (d) load current

2.4 Generation of control pulses using PIC micro controller

The program for generation of switching pulses to derive the MOSFET switches is fed to the PIC microcontroller. By setting and resetting the PIC controller, two different loops run alternatively and the square pulses are generated with an on time of 500microseconds. In between the switching of each MOSFET switch a delay function is called.

The hard ware consists of four input ports DC – DC converter, driver circuit for each switch in the converter, the PIC microcontroller to generate the pulses and the power supply unit for the driver circuit and the controller. There are four MOSFET switches in the converter to which three sources namely the solar, wind and battery are given. The output is obtained from the isolated load port where the isolation transformer provides the necessary isolation. The switching pattern of the MOSFET switches is controlled by the PIC controller. When the input voltage are given, the converter gives a constant output voltage whose operation is divided into twelve stage.

There are six driver circuits, four for the main switches and two for the output switches. The driver circuit delivers the generating pulses in the PIC controller to the MOSFET switches since the MOSFET gate triggers with the actual operating voltage to the gate terminal, the driver circuit provides the necessary voltage with the switching pattern decided by the controller. The driver circuit of each leg consists of a buffer for impedance matching, opto coupler for isolation and Darlington pair for amplification.

Since the voltage levels of the PIC controller and the MOSFET switch does not match, it is necessary to an opto coupler in the driver circuit which provides an optical connection between the controller and the Darlington pair. The driver circuit is given a 12V supply which is obtained after rectification, filtering and regulation of the regular operating AC supply.

The PIC controller controls the turn on and turn off time of the MOSFET switches. The switching pattern of the switches is fed to the controller through software program C language. The input supply of 5V DC is given to the V_{ss} pin of the controller and the output is obtained from port. The switching frequency and the delay time are specified in the program according to which the pulses are generated. The output obtained from the converter can be directly used to drive any DC load or can be changed in to AC using an inverter to supply any AC load. Since the two renewable sources utilize a single converter, efficient component sharing is achieved. The load is supplied continuously as there a source available at the input.

2.5 Algorithm for switching pulses generation

- Step 1 : start the program
- Step 2 : Include the required header files and configure the oscillator
- Step 3 : Declare the control variable
- Step 4 : Clear the register and initialise port C
- Step 5 : Check if register RB 7 = 0; if yes, go to next step, else go to step 7
- Step 6 : Set the gate pulse as 2millisecond and 1 millisecond for switches 1 and 2 respectively. And set the turn ON time as 500microseconds for switch S1 and 500microseconds for switch s2
- Step 7 : Check if register RB6 = 0. If yes, go to next step, else, go to step 9

Step 8 : Set the gate pulse as 2 milliseconds for switches 3 and 4 respectively. And Set the turn ON time as 500 microseconds for switches S3 and 500microseconds for switch s4.

Step 9 : STOP the programme.

V. RESULT AND DISCUSSION

The circuit diagram is tested with the inputs to the three input ports. The battery input is given to port 1, solar input to port 2 and wind input to port 3. The input voltages were varied and corresponding output voltage was recorded the output voltages obtained from simulation and the hardware has been tabulated in Table 2.

Table 2.

Sl. No	Input Voltage (V)			Output Voltage (V)	
	BATTERY	PV PANEL	WIND MILL	SIMULAT ION RESULT	HARDWA RE RESULT
1.	12	9	9.4	24	21.5
2.	12	6.2	7.6	20	18.2
3.	12	4.5	5.2	18	16.3
4.	12	3	3.5	16	14.4

In the absence of renewable energy, the load gets input from the battery source. Hence a continuous input supply to the load is ensured. It is observed that the output voltage level remains constant even when the input voltage changes.

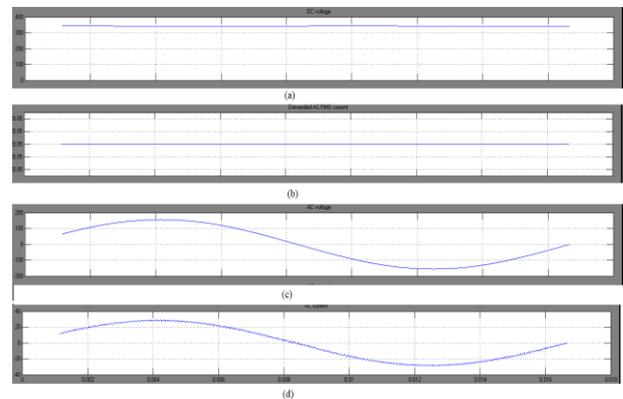


Fig 2.5 output waveform of (a) Capacitor voltage (b) solar panel voltage (c) output current (d) load current

The Fig 2.5 (a) shows the output waveforms of capacitor voltage. Which is improved to s constant voltage. (b) Shows the output voltage of solar panel. It is improved to 12 voltage coupled with capacitor. (c) and (d) shows the output current to the load. The output voltage is constant one and pure sinusoidal voltage.

VI. CONCLUSION

The proposed system consists of four ports out of which two ports are for solar and wind source respectively, one port is a bi-directional battery port and another is an isolated load port.



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The system has been tested with simulation, hardware and zero voltage switching had been adopted for all main switches. The converter has been shown to achieve a constant output voltage for variable input voltage. The simulation and hardware results have been shown to variable the feasibility of the proposed system. It can be inferred that the proposed system provides continuous and constant output with better power flow management.

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