An Integrated Multiport Dc – Dc Converter for Renewable Energy Applications

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Abstract As conventional energy sources are steadily depleting a 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 source, the power produced cannot be 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.

1. INTRODUCTION

Renewable energy source is a naturally available source which can replace with the opening of time, either through natural reproduction or other certain recurrence procedures. Renewable energy is energy as of自然界 solar 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. Utilization of wind energy is increasing at a yearly rate of 20%, thru a wide range installed capacity of 238000 megawatts.

Fig.1.1 world-wide Growth of wind and solar energy

Object of the proposed system is to develop a multipower 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 modestway 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]. 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].

Revised Manuscript Received on October 15, 2019

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DOI: 10.35940/ijeat.A1374109119/2019/V9I123

Retrieved Number: A1374109119©BEIESL

Published By:

Blue Eyes Intelligence Engineering & Sciences Publication

International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249 – 8958, Volume-9 Issue-1, October 2019
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.

Designed data

Input voltage $V_{in} = 12V$
Output voltage $V_o = 24V$
Switching frequency = 100kHz
Load current $I_L = 1.5A$
$\Delta I_L = 1.2A$ $L_m = 50 \mu H$
Duty cycle $D = 0.69$
$V_{ripple} = 0.018V; C = 330 \mu F$

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 – DC converter 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 inverter through the isolating transformer. The capacitor C near the isolating transformer is used for filtering purpose. The output voltage is taken across $C_o$.

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.

![Fig 2.1 block diagram of propose system](image-url)
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 \((t_0 \rightarrow t_1)\)
At begin stage, the diode of switch \(S_1\) is compulsory on the reuse the stored energy from transformer, the leakage inductor, and the result is fly wheeled. At starting time \(t_0\), \(S_1\) is triggered to turn ON with ZVS, and then the leakage inductor is return to zero and inverse – energised.

Stage 2 \((t_1 \rightarrow t_2)\)
At the time \(t_1\), the primary of the transformer current increases to repeat current of \(i_{\text{DL}}\), the diode of \(S_2\) will be blocked. And the converter has to start to deliver the output power.

Stage 3 \((t_2 \rightarrow t_3)\)
Through the time \(t_2\), \(S_1\) is turned OFF, making the leakage current \(i_p\) to charge the \(S_1\) parasitic capacitor and discharge \(S_2\), \(S_3\) and \(S_4\) parasitic capacitors.

Stage 4 \((t_3 \rightarrow t_4)\)
At time \(t_3\), the voltage through the \(S_2\) parasitic capacitor is discharged to zero, and the \(S_1\) feedback diode conducts to transmit the current, and it provides the ZVS condition for \(S_2\). During this time period, the result is freewheeled through \(S_1\) and \(S_2\) feedback diodes.

Stage 5 \((t_4 \rightarrow t_5)\)
At time \(t_4\), \(S_2\) is triggered ON with ZVS, and then, the leakage inductor is rearrange to zero and charged inversely. The resultant inductor current drip from \(t_2\) to \(t_3\) is due to the leakage inductor charge discharge.

Stage 6 \((t_5 \rightarrow t_6)\)
At time \(t_5\), the transformer primary current rises to the reproduced current of \(i_{\text{DL}}\), freewheel diode of \(S_1\) is blocked, and the converter starts to provide power as output.

Stage 7 \((t_6 \rightarrow t_7)\)
At time \(t_6\), \(S_2\) is gated OFF, thus producing the leakage current \(i_p\) to charge the \(S_2\) parasitic capacitor and discharge the \(S_1\) and \(D_2\) parasitic capacitor.

Stage 8 \((t_7 \rightarrow t_8)\)
At level \(t_7\), the voltage across \(D_3\) is reduced to zero, and then, \(D_4\) starts to conduct. \(S_3\) is getting turn ON before this time; therefore, \(S_2\) has natural ZVS. The resultant inductor current freewheels across \(S_2\) during this level.

Stage 9 \((t_8 \rightarrow t_9)\)
At time \(t_8\), \(S_3\) is turned OFF, thus producing the leakage current \(i_p\) to control \(S_2\) and \(S_1\) parasitic capacitors and discharge \(S_1\) and \(D_2\) parasitic capacitors.

Stage 10 \((t_9 \rightarrow t_{10})\)
At level \(t_9\), the voltage across \(D_4\) is reduced to zero and \(S_1\) parasitic capacitor and discharge \(S_1\) and \(D_2\) parasitic capacitors.

Stage 11 \((t_{10} \rightarrow t_{11})\)
At level \(t_{10}\), \(S_4\) is gated OFF, producing the trapped leakage current to discharge the \(S_1\) parasitic capacitor and charge the \(S_2\), \(S_3\) and \(S_4\) parasitic capacitors.

Stage 12 \((t_{11} \rightarrow t_{12})\)
At time \(t_{11}\), the voltage across \(S_1\) is discharged to zero, and the \(S_2\) freewheel diode start to conduct to carry the current, which provides ZVS condition for \(S_1\). During this time period therestulant current is freewheeled. This is the end of the switching cycle. The switching pattern for MOSFET switches is shown in table 1.

The Fig 2.2 shows the MATLAB Simulink diagram.
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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 2.3 Equivalent circuits of every switching stages

| 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        | OFF       | OFF       | OFF       | OFF       |
| OFF       | OFF       | ON        | ON        | ON        | OFF       | OFF       | OFF       |
| OFF       | OFF       | OFF       | ON        | ON        | ON        | OFF       | OFF       |
| OFF       | OFF       | OFF       | OFF       | ON        | ON        | ON        | ON        |
| ON        | OFF       | OFF       | OFF       | OFF       | ON        | ON        | ON        |
| ON        | ON        | ON        | ON        | OFF       | OFF       | OFF       | OFF       |
| ON        | ON        | ON        | ON        | OFF       | OFF       | OFF       | OFF       |

Table 1.

Output voltage of multiport DC – DC converter

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 microcontroller

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 are run alternatively and the square pulses are generated with an on time of 500 microseconds. 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 is 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 at 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 Vcc 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 2 milliseconds and 1 millisecond for switches 1 and 2 respectively. And set the turn ON time as 500 microseconds for switch S1 and 500 microseconds 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 500 microseconds 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.

| Sl. No | Input Voltage (V) | Output Voltage (V) |
|-------|-------------------|--------------------|
| BATTERY | PV PANEL | WIND MILL | SIMULATION RESULT | HARDWARE 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.
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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