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Design and Simulation of Renewable Energy Based Multi-Port DC-DC Converter

Abstract

Hybrid power sources require the promising concepts of multiport converters. They are much beneficial as conversion can be done in single stage while even interfaced with multiple input power sources. The comparison between multiport converter and conventional converter is presented. The multiplexing of source is presented as an application of multiport converter. Multiport converter gives several advantages. Applications are electric vehicle, renewable energy sources for UPS without energy storage facility.

Keywords: Multiport, DC - DC converter, Hybrid Electric Vehicle, Pulse Width Modulation, Solar panel, System – On –Chip, Portable Power Supply.

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Introduction

Energy efficiency and environmental contamination has forced us to reduce the dependency on conventional sources. The energy efficiency is enhanced by utilisation of renewable energy in transportation instead of fossil fuel which affects the environment negatively. Electrical Vehicles (EV) is an innovative solution for reduction of carbon footprint. EV's have an exceptional power profile that has both energy utilisation and recovery at various moments of its operation. Power supply to load is carried out by interfacing DC-DC converter equipment. As per the load requirements, the adjustments of source parameters are carried out. The DC-DC converter is used for modification of the received power from the source before sending it to load. There are two ways for the integration of supply systems with the storage device and the load. 1) Common DC-DC bus (Conventional method) 2) Multiport DC-DC bus. This paper eliminates the drawback of conventional method. Unconventional energy source based generation systems are connected with their own DC-DC converter. For multiple input-multiple output ports a single controller is used.

Proposed System

A novel PWM control to synthesize a Multi-port converter was developed for medium power application and its principle of operation is summarized here. In this case, the idea is to keep the basic dynamic property of the converters intact and reduce the number of switches while realizing multiple outputs.To realize a Multi-port converter using this principle, the boost switch is replaced by a synchronous buck converter. In this case, the boost interval is realized by turning on S_1 and S_2 at the same time. This will allow the boost inductor to charge. During switches S_1 and S_2 are turned off, the inductor current flows through the capacitor C_1. If S_1 is turned ON keeping S_2 is turned OFF, the inductor current flows through capacitor C_1 and C_2. Thus, output voltage V_o it act as input voltage to the synchronous buck structure. In this interval, the power is routed to loads from the source, however the buck converter operates with an input of V_{C1}. The proposed system is simulated in MATLAB and results are presented.

Fig. 1 Proposed System

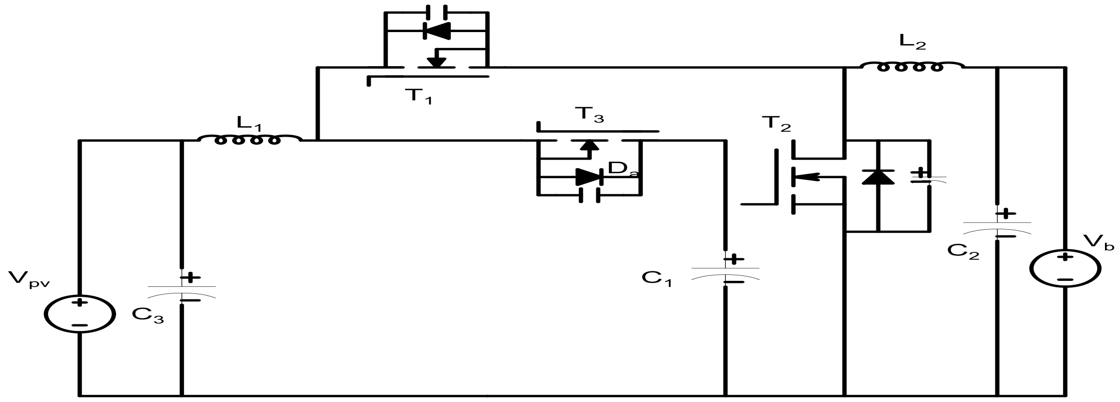
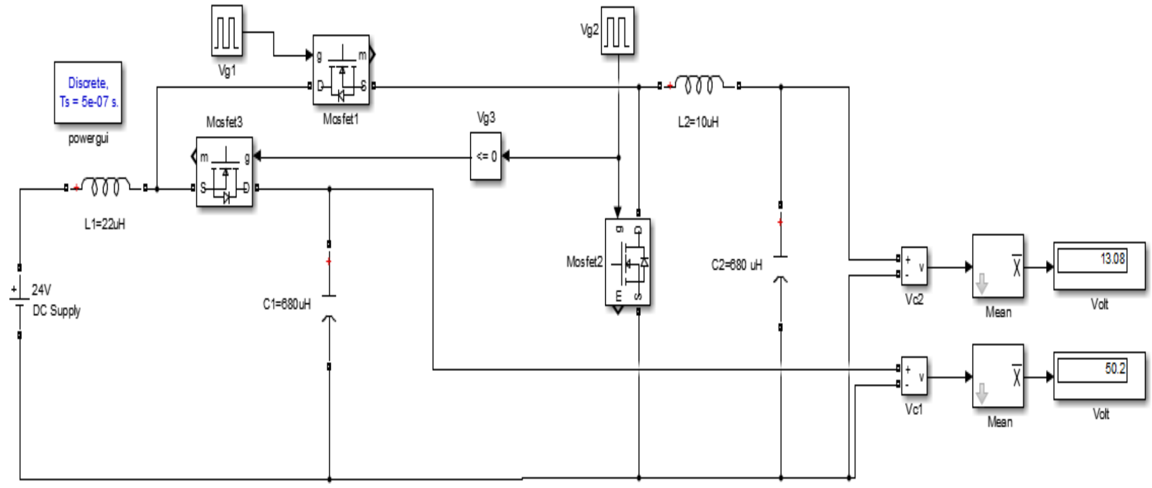


Fig. 2 simulation circuit of the proposed system



The proposed circuit has two modes of operation.

Phase 1 operation (Three switch conduction)

This mode has input voltage of 24 V is connected to the input port of the multi-port converter shown in Fig.2. The inductor L_1 is connected in series with the input 24 V. There are three MOSFET (S_1, S_2, S_3) switches are used in the circuit. The frequency of operation circuit is 20 kHz. The rating of inductor is 680 micro Henry. The duty cycle of switch S_3 is 0.65, switch S_2 is turned on after delay time of 5 micro seconds and duty cycle is 0.55 and switch S_1 is turned ON after 180 degree phase shift. Fig.3 shows the duty cycle of switches in this phase.

Mode 1

(S_1=1, S_2=1 and S_3=0)

During this mode, the proposed circuit works in boost mode. Switches S_1 and S_2 are turned on simultaneously. The current through inductor L_2 freewheels through S_2.

Mode 2

(S_1=0, S_2=1, S_3=0)

During this interval, only the switch S_2 is turned ON and the current in the Inductor L_2 freewheels through the switch S_2 and the capacitor C_2.

Mode 3

(S_1=0, S_2=0, S_3=1)

Switch S_1 is turned OFF and switch S_3 is turned ON. The current in the inductor flows through the body diode of switch S_2.

Mode 4

(S_1=1, S_2=0, S_3=1)

This mode represents buck mode operation. Switch S_2 is turned OFF and switch S_3 is turned ON, while the S_1 remains ON condition. The inductor L_1 discharges and inductor L_2 charges. The voltage across capacitor 1 is V_{C1} act as input voltage.

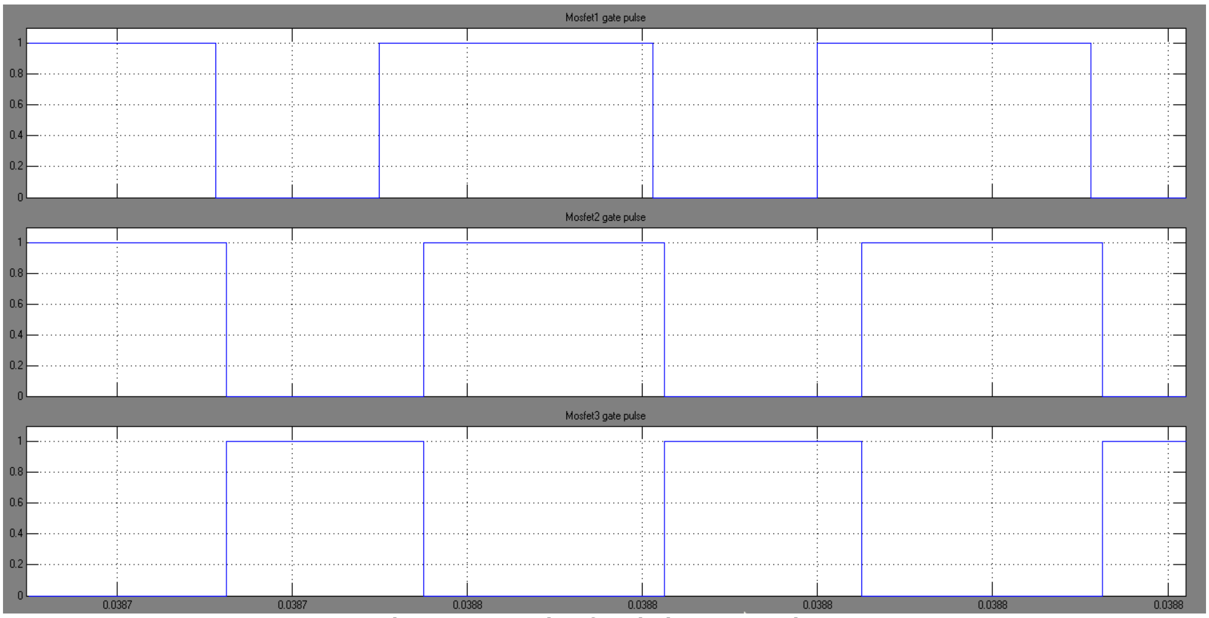


Fig. 3 Duty cycle of Switch S_3, S_2 and S_1

Phase 2 operations (Two switch conduction)

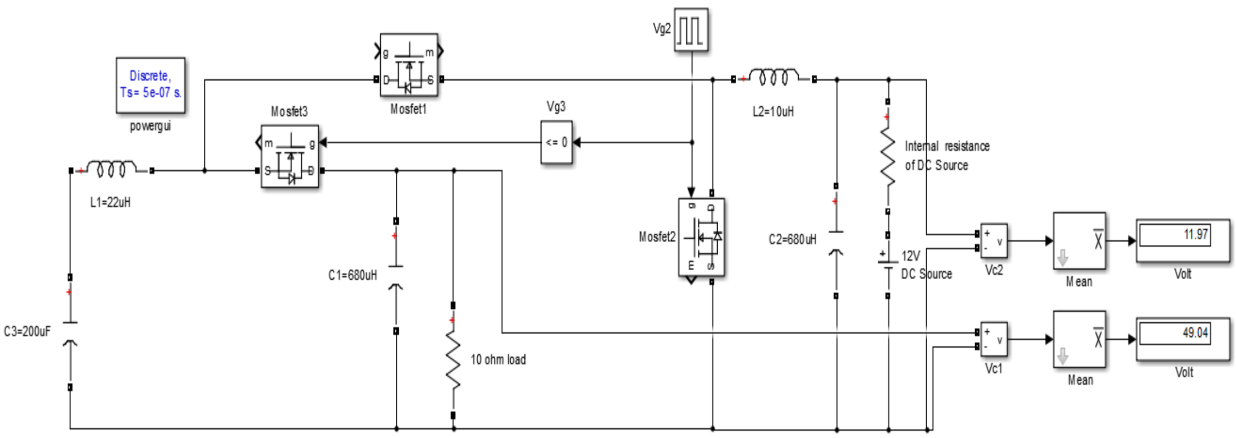


Fig. 4 Simulation circuit

Fig. 4 shows the simulation diagram of proposed system in phase 2. During night time there is no power generation from solar panel. Here the input is fed from 12 V battery connected to the multi-port converter. Converter in turn connected with 48 V bus. In this mode of operation switch S_1 is turned OFF. This phase has two modes in a switching cycle. The switching frequency remains same. The S_2 and S_3 are turned ON at 180 degree phase shift. The duty cycle of switch S_2 is 0.8. Fig. 5 shows the duty cycle given to switches S_2 and S_3 respectively.

Mode 1(S_2=1 and S_3=0)

In this mode, circuit works in boost mode. The inductor L_2 is charged to input voltage and output voltage is more than input voltage.

Mode 2 (S_2=0 and S_3=1)

In this mode inductor L_2 starts discharges and output is connected with 48V bus. At the same time the voltage across capacitor C_3 is V_{C3} and no current flows through inductor L_1.

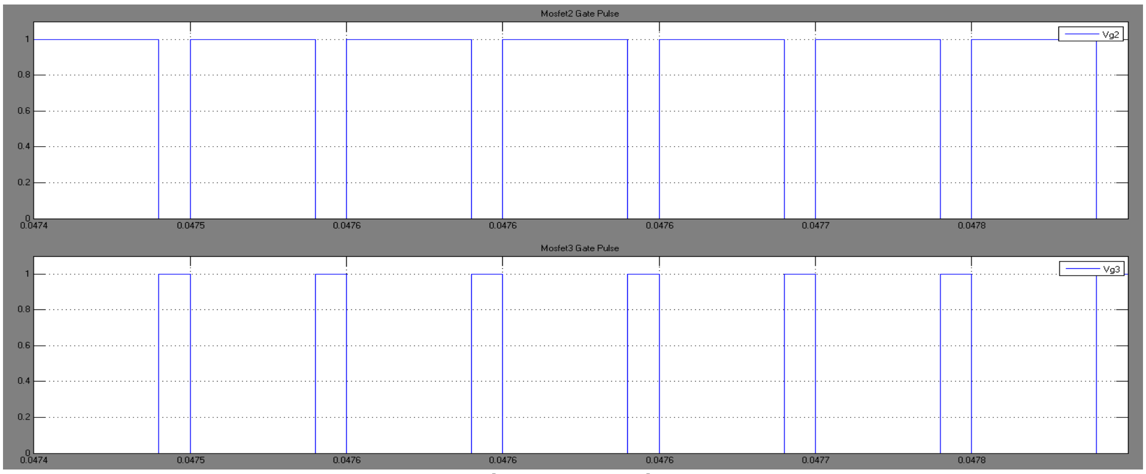


Fig. 5 Duty cycle

Fig. 6 shows the waveform of input voltage, voltage across capacitor C_1 is output voltage 50 V and voltage across the capacitor C_2 is 13 V.

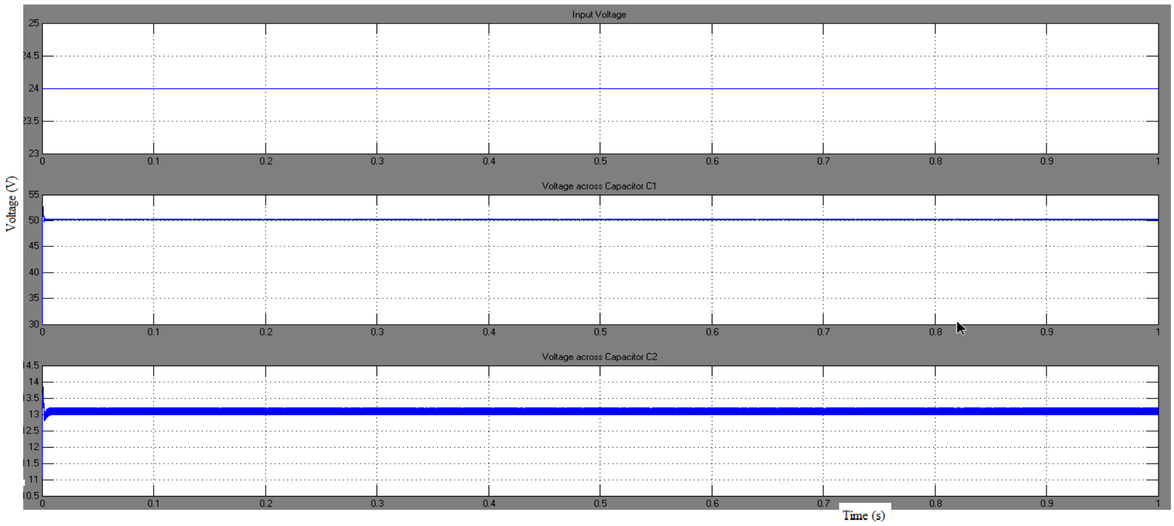


Fig. 6 Capacitor voltage in phase – 1 operation

Fig. 7 shows the waveform of voltage across capacitor C_1 is input voltage 49 V and voltage across the capacitor C_2 is 12 V.

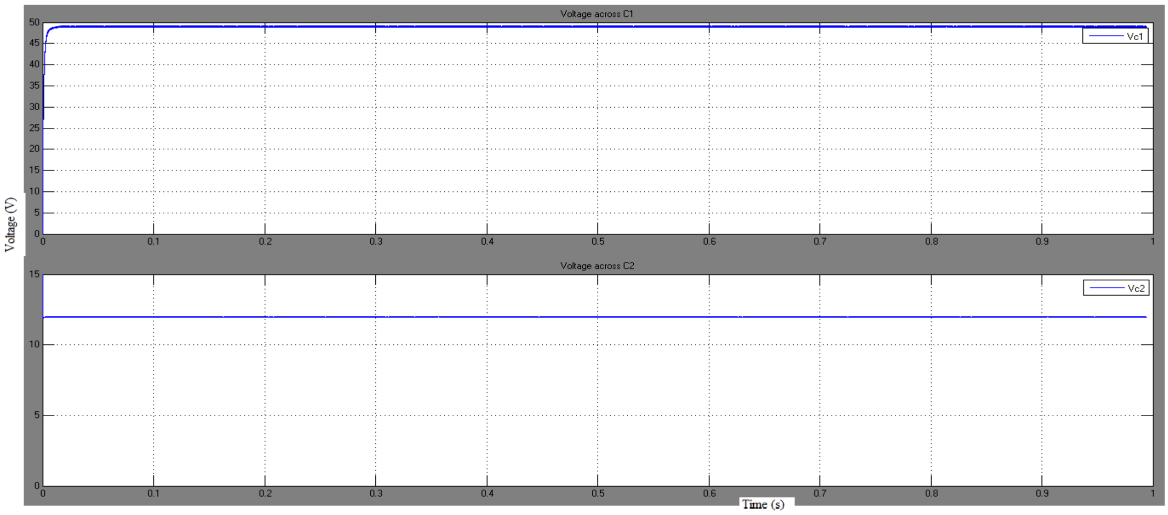


Fig. 7 Capacitor voltage in phase – 2 operation

Conclusion

A novel PWM switched multi-port converter was presented. Compared to existing designs, the converter requires fewer inductors, power devices, and simple control technique, which is suitable for portable applications and System-On-Chips (SOCs). System implementation issues also discussed. The Multi-port converter provides a cost-effective solution in designing on-chip power management systems and realizing voltage scheduling techniques. The Simulation results demonstrate the functionality and shows good voltage regulation.

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