A Novel Hybrid DC-DC Converter with High Voltage Gain for Electric Vehicle Charging Systems

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Abstract: The voltage gain of the traditional conventional converter is limited due to the rise in ripple current, elevated voltage stress across the diode and the active switch. The operation of large duty ratio associated with the low efficiency. In renewable energy power systems applications, high voltage gain is required with the low input voltage. A high voltage gain hybrid DC-DC converter for Electric Vehicle Charging Systems based on a new topology comprising of simple switching dual structures, formed by two capacitors and two diodes is proposed in this work. It provides fewer conduction losses and the low current stress leads to high efficiency in the switching elements. The converter is applicable in telecom standard equipment for providing internet services, battery charging in electric vehicle and the high-intensity discharge lamps for automobile headlamps. The simple dual structure is inserted in classical Boost converter to provide new power supplies with steep voltage conversion ratio.

Keywords: DC-DC hybrid converter, switched capacitor, Electric Vehicle, Charging Systems, Battery.

1. INTRODUCTION

In order to guard the natural environment on the earth, the clean energy is developed without pollution has the major representative role in the last decade. By accompanying the permission of Kyoto Protocol, clean energies, such as photovoltaic (PV) fuel cell (FC), wind energy, etc., have been quickly promoted. Due to the clean energy of electric characteristics, the generated power is significantly affected by slow transient responses or by the change in climate. The load variations easily influenced the output voltage. To ensure correct operation of clean energies the storage element is needed. For smoothing output power, different load conditions, and start-up transition, Super capacitor or batteries are usually used as a storage mechanism. The cost of power supply and system purchasing the installed capacity of the corresponding clean energies can be further reduced. For these reasons, hybrid power conversion systems (PCS) have become one of the interesting research topics for engineers and scientists at present. The high step-up DC-DC converter is a type of converters, which can increase a low voltage to a comparatively high voltage.

Normally, the output voltage of single PV module, battery sources, fuel cell stacks, or the supercapacitors is relatively low; it should be improved to a high voltage to feed the ac grid or other applications like new energy vehicles, uninterruptible power supplies, and so on. High step-up DC-DC power conversion has become one of the key technologies in these fields. As a matter of fact, it is essential to reduce the voltage stress, when the output voltage is high, on the output diode and active switch; otherwise, the cost will increase and it will cause high conduction loss. Due to the reality of parasitic parameters such as the equivalent series resistance (ESR) in inductors, conventional boost converters cannot supply a high voltage gain. The extremely narrow turn-off time will bring more peak current and considerable switching and conduction losses.

The switched-capacitor converters can provide any steep conversion ratio. However, they operate with a relatively low efficiency and put challenges in the charging path of the capacitors. Use of cascade of converters for getting the desired voltage ratio is a no-solution in the today's energy-saving conscious world, as this procedure implies an overall efficiency equal to the product of the efficiencies of each circuit. Quadratic converters can somehow alleviate the efficiency problem of cascade circuits by using a single driven transistor but they may present voltage or current overstresses. So, a novel switched-capacitor-based active-network converter (SC-ANC) for elevated step-up conversion, which has the following advantages: less voltage stress across diodes and switches, high voltage conversion ratio, and self-voltage balancing across the output capacitors. But in this system, insulated gate drive circuit is needed and additional two switches are utilized, which induces added cost. Also, the efficiency is low and conduction losses will be more.

A simple dual structure switching, formed by either 2-3 diodes and two inductors, or 2-3 diodes and two capacitors are defined. These circuit blocks can afford either a step-up or step-down input voltage of it. They are inserted in a traditional boost converter, buck converter, buck-boost, and cuk converters to provide new power supplies with a steep voltage conversion ratio. To attain an elevated step-up voltage-gain, switched capacitor technique is used in the hybrid DC-DC converter. The superiority of the latest, hybrid converters is mainly based on less current stresses in the switching elements, less magnetic field energy, leading to saving in the cost and size of the inductors, and, leading to smaller conduction losses.

2. OPERATING PRINCIPLE OF PROPOSED CONVERTER

Fig.1 shows the basic structure of step-up switching topology derived from a new concept comprising of two capacitors and two diodes. During turn-off period, C1 and C2 are charged in parallel, and during turn-on period C1 and C2 are discharged in series.

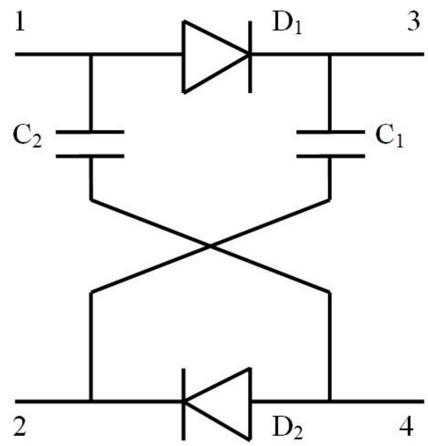


Fig.1.step-up switching topology

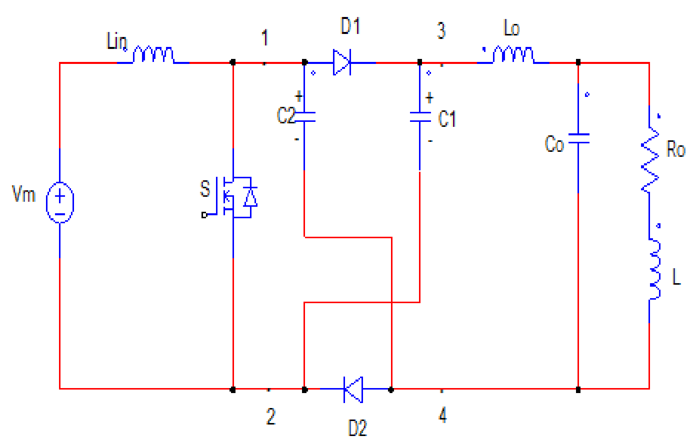


Fig.2. Proposed Hybrid DC-DC converter

The combined "step-up" *C*- or *L*-switching structures with the buck-boost converter boost converter, Cuk converter, Zeta, and Sepic converters, to get a step-up to enhance function. When the active switch of the hybrid DC-DC converter is ON, *L*-switching blocks in the inductor are charged in series and the *C*-switching blocks in the capacitor are discharged in parallel. When the active switch of the hybrid DC-DC converter is off, the *L*-switching blocks in the inductor are discharged in parallel and the *C*-switching blocks in the capacitor are charged in series.

3. PROPOSED MODEL

The simulation model for a proposed hybrid converter for Electric Vehicle Charging Systems is given as follows.

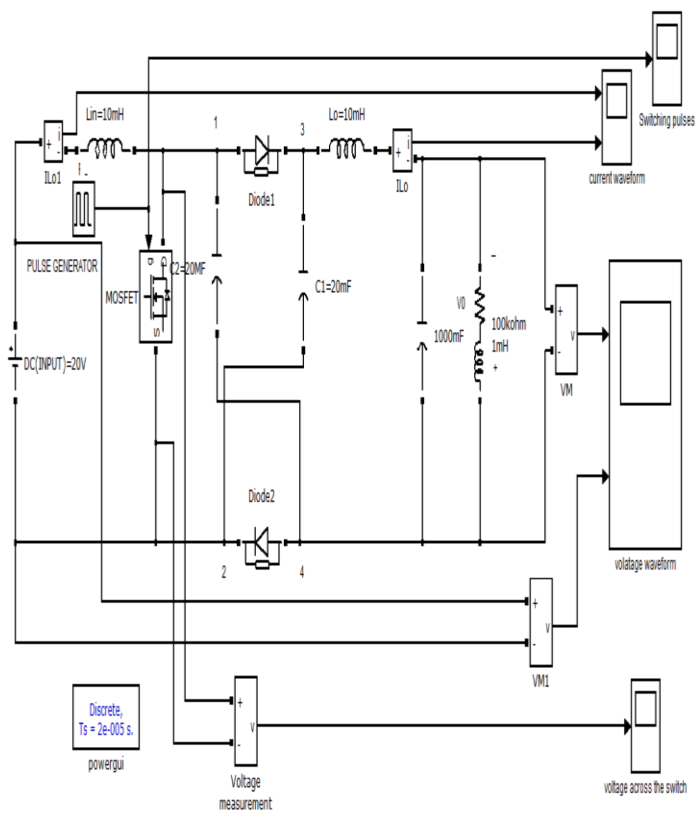


Fig.3 Simulation diagram

4. SIMULATION RESULTS

The simulation output for the hybrid DC-DC converter is given below.

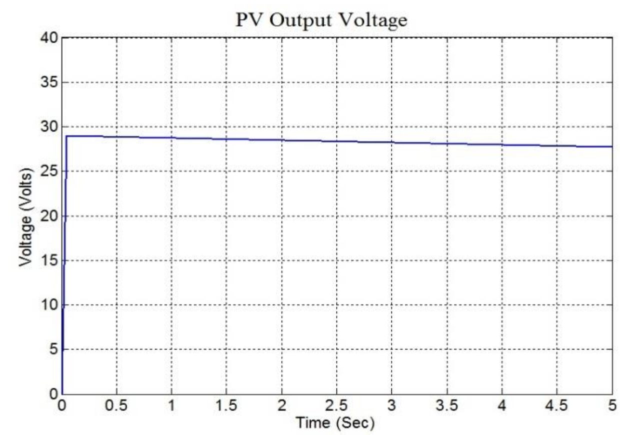


Fig.4 Experimental results when input voltage=20V

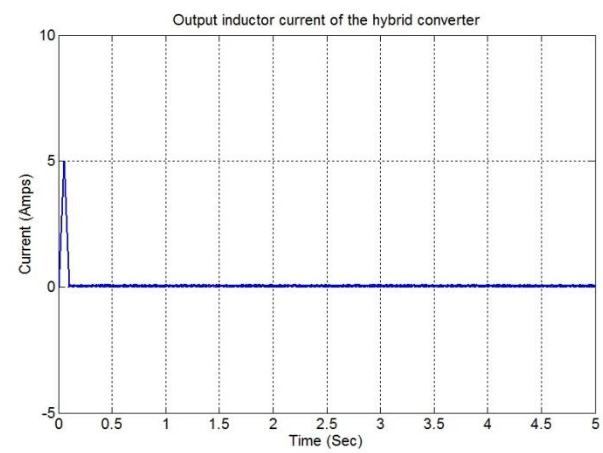


Fig.5 Output inductor current of the hybrid converter

The inductor current is reduced in the hybrid converter by the simple dual structure comprising of two diodes and two capacitors.

5. EXPERIMENTAL RESULTS

This section explains the proposed design of high voltage DC-DC converter for electric vehicle charging systems. In this experimental setup, we arranged the proposed system setup of electric vehicle charging systems. The motor used for an electric vehicle is 24V DC motor with speed of 1500RPM. The rating of the component is minimum, which is used in these systems.

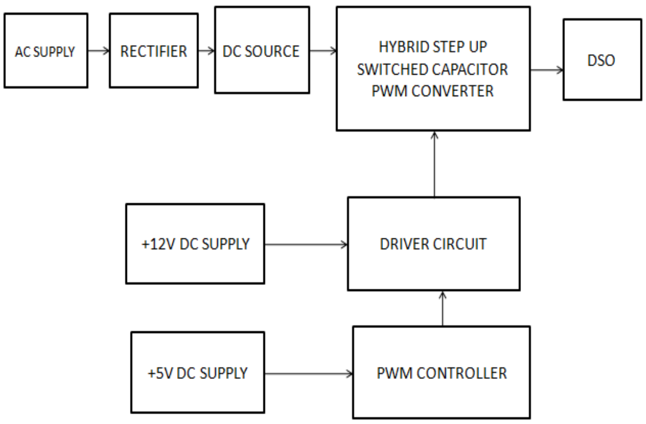


Fig.6 Block Diagram of the Hardware Setup

A 230V ac supply is given to the prototype. Two step -down transformers, each of 12V rating is used to step down the input given to the circuit. One of the transformers is connected to a regulated rectifier circuit and another one to an unregulated rectifier circuit. The 5V and 12V are the dc outputs of the regulated circuit, whereas 12V is the dc output of the unregulated circuit. LM317 regulator is used to regulate the unregulated output. The 5V dc is given as input to the LCD, PWM controller and the driver circuit, while 12V dc is input to the driver circuit for generating switching pulses from the microcontroller. The LCD displays the ON and OFF condition of the converter.

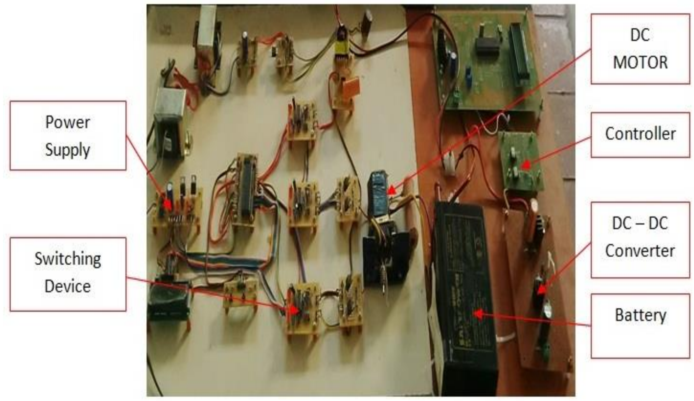


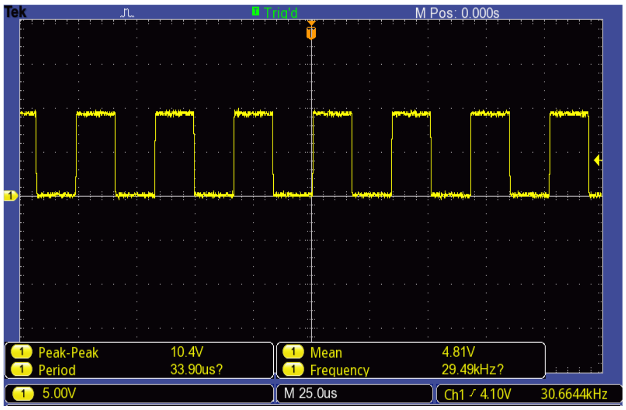
Fig.7 Experimental Setup of a proposed Model

SL. NO.	COMPONENT	TYPE
1.	MOSFET	IRF 840
2.	Driver IC	IRS 2110
3.	Resistors	47Ω , 33 Ω & 2K Ω
4.	Microcontroller	AT mega 16A
6.	Diodes	IN4002,UF4007
7.	Capacitors	22 µF, 63V;470µF,100V
8.	Inductors	1mH
9.	Voltage Regulators	LM317,LM7805,LM7812
10.	Transformers	12V,1.5A;12V,2A
11.	Battery	12 V
12.	DC Motor Voltage	24 V
13.	DC Motor Speed	1500 RPM

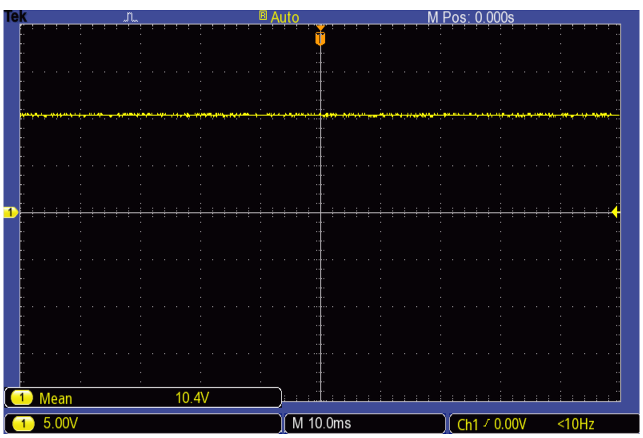
Table 1. System specification for the experimental result

The unregulated output is regulated by LM317 and one of the outputs is given to the MOSFET in the hybrid dc-dc converter circuit and the other is connected to a 12V potentiometer. The potentiometer is used to vary the input given to the converter depending on the applications. The load connected across the circuit is a resistive load of value 2kΩ, 30W. The output DC voltage is regulated at 30V with an input voltage of 10V DC without switching losses.

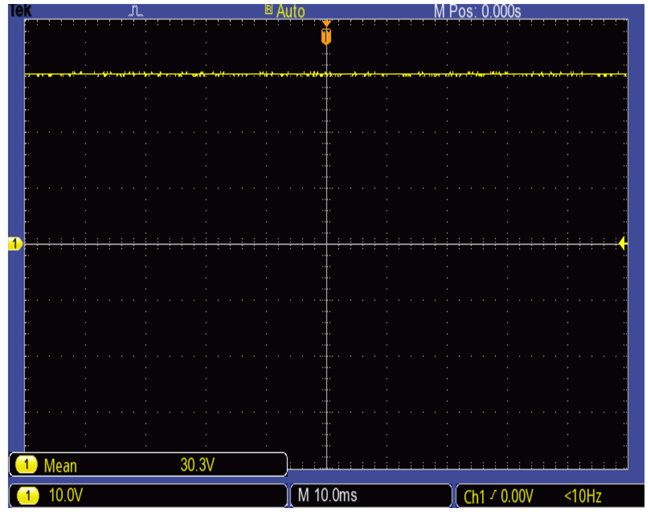
From the proposed Controller design, Each terminal point of the Scope result is described (a) Switching pulse of the Dc-Dc Converter (b) Input Dc Voltage (C) Output DC Voltage



(a) Switching pulse of the Dc-Dc Converter



(b) 10 V Input DC Voltage



(c) 30 V Output DC Voltage

6. CONCLUSION

This paper has proposed a high voltage gain hybrid DC-DC converter for electric Vehicle charging systems. The operating principle of the proposed DC-DC converter for electric vehicle charging systems has been discussed. The current stresses are low in the switching elements, which is beneficial to the high system regulation and low cost. The main advantages of the proposed hybrid DC-DC converter are: fewer losses due to being utilized of single switch, there is less energy in the magnetic elements, which leads to less weight, low cost, reduced in size and saving of the inductors, for the power supply, Increase in efficiency due to fewer conduction losses. In addition to all of these, the potential across the power device is less and the lower inductor current when compared to other quadratic converters. The superiority of the new, hybrid DC-DC converters for electric vehicle charging leads to saving in the size and cost of the inductor. It mainly based on low energy in the magnetic field. The low switching elements current stresses leads to the low conduction losses.

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