IMPLEMENTATION OF DC-DC BOOST CONVERTER TOWARDS HIGH VOLTAGE CONTROL

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ABSTRACT

This research paper article work focussed on the development of an extra high gain boost dc-dc converter for high voltage dc application with simple closed loop control scheme is presented. Classical version of step-up voltage dc-dc conversion configurations are used in high power (voltage/current) applications, but they are limited due to the restricted voltage transfer gain ratio, less efficiency, and moreover require two sensors with complex control algorithm lead to non-economical utilization. Further, the effect of parasitic elements limits both output voltage and power transfer efficiency of dc-dc converters. But with the application of voltage lift techniques pay the way to overcome these limitation, opening reliable way to improve the performance characteristics. Complete model of the proposed high gain dc-dc converter along with simplified closed controller was implemented in numerical simulation software using Matlab/Simulink environment and hardware prototype was realized using DSPTMS320F2812 with resistive loads. The performances are investigated under both line and load perturbation conditions. Numerical simulation results along experimental verifications are provided with complete theoretical developments.

KEYWORDS: Boost converter, buck converter, dc-dc converter, PI controller, voltage lift, extra high voltage converter, HVDC converter, closed loop controller.

INTRODUCTION

Traditional dc-dc step-up (boost) converters are widely used in HV (high voltage) applications, but they are not perfectly suitable due to the limited output voltage transfer gain, less efficiency and further requires two sensors with complexity in control nature. Moreover, the effects of parasitic elements in converter configuration, the output voltage/transfer efficiency of dc-dc converters are further reduced [1]-[4]. In contrast, voltage lift technique is a popular method widely applied in electronic circuit design and successfully employed in dc-dc converter [1]-[5] applications in recent papers, and provides the open platform to design extra high output voltage gain converters from classical dc-dc step-down (buck) converter configurations. The output voltage increases in geometric progression with stage-bystage step-up ratio and to overcome the above limitations [6]- [8]. Extra high voltage (HV) dc-dc converter topology [1] which is derived from classical dc-dc step-down (boost) converter, by introducing voltage lift technique using additional passive (inductor/capacitor) components that implement the output voltage increase in a simple geometric progression. Hence, leads to enhance the increased voltage transfer gain as per power-law terms. The performance of this dc-dc extra high voltage converter posse advantageous in comparison to classical dc-dc version [1-2] as follows:

♣ High voltage transfer ratio gain (k).

♣Wide range of control with lower ripple at the output.

♣High power density and high efficiency.

♣ Closed-loop compensator requires only one sensor.

In proceeding to the research article [1], hardware prototype model implementation as been carried out for the extra HV dc-dc converter with simplified control technique using dsp tms320F2812 in this paper. Systematic procedure of operation modes, mathematical analysis as theoretical background of the complete system is presented. Further, a closed-loop control algorithm is developed to generate PWM pulses for the N-channel MOSFET of the proposed converter. Numerical simulation software model of the converter is developed in MATLAB/Simulink toolbox environment and the hardware prototype model was implemented with complete control algorithm developed with DSPTMS320F2812 processor. Detailed investigation is carried out to study the performance of the whole converter system under both line and load regulations. Simulation results are presented and they are closely matches with the hardware results in perfect agreement with the theoretical developments.

CONVERTER LOSS MODELING

Listings of DC/DC converter losses may be found in [5] and [6][10]. Boost converter losses considered in this work are given in Table 1, as itemized and developed analytically in the following subsections.

Table 1. Boost Converter Losses Considered

Synchronous	Asynchronous
M1:NMOS conductions	M1:NMOS conductions
M1:NMOS Switching	M1:NMOS Switching
M1:NMOS Gate Drive	M1:NMOS Gate Drive
M1:NMOS Body diode	Diode conduction
M2:NMOS conductions	Diode leakage
M2:NMOS Switching	Diode junction Capacitance
M2:NMOS Gate Drive	
M2:NMOS Body diode	
Dead Time	

1. NMOS Source Switch Conduction Loss

$$M1SL = \frac{1}{2} I_{M1S} \times V_{M1S} \times f_S \left(\frac{Q_{G(SW)}}{\frac{V_G + \frac{I_{M1S}}{G_m}}{R_{Driver(pull-up)} + R_G}} + \frac{Q_{G(SW)}}{\frac{V_{DD} - \left(V_G + \frac{I_{M1S}}{G_m}\right)}{R_{Driver(pull-up)} + R_G}} \right)$$

When the NMOS transistor is in forward conduction there is a resistive loss in accordance with eqn.(1),[8],[7]. NMOS conduction loss is associated with both asynchronous and synchronous converters.

$$\text{NMOS conduction Loss} \triangleq M1CL = I_{M1}^2 \times R_{DS} \times D \quad (1)$$

Where I_{M1} =NMOS current (Amp) RDS=NMOS forward conduction ON Resistance (Ohm), D=duty ratio [7],[8]

2. NMOS Source Switch Switching Loss

During the transition of voltage rising or falling between the maximum and minimum steady-state value across either switch, and similarly the rise or fall transition of current through the same switch, losses occur. Much work has been performed in an effort to correctly model this behavior [5][9], without a highly accurate model still as yet developed [9]. A combination of the work of [8] and [9] are presented here to develop the switch model beginning with eqn.(2), NMOS switching loss is associated with both converters.

$$M1SL = \frac{1}{2} I_{M1S} \times V_{M1S} \times f_S \left(t_{s(off)} + t_{s(on)}\right) \quad (2)$$

where M1SL=MOSFET switching loss power (Watt), =current through MOSFET (Amp), =drain to source voltage across MOSFET (Volt), fs=switching frequency (Hertz), ts(off)=MOSFET switching time transitioning off (second), ts(on)=MOSFET switching time transitioning on (second) [8],[9]All parameters of eqn.(2) are readily measurable in a physical circuit except the switching time terms and which are developed in [10].

3. NMOS Source Switch Gate Drive Loss

Gate drive loss accounts for the energy dissipated by the MOSFET to drive the gate for the switching operation. The loss equation is given in eqn. (3). NMOS gate drive loss is associated with both converters.

$$\text{NMOS Gate drive Loss} \triangleq \text{M1GDL} = Q_{G(SW)} \times V_G \times f_S \quad (3)$$

DC-DC BOOST CONVERTER WITH CONSTANT OUTPUT VOLTAGE

Nowadays, power generation using solar power had increased dramatically because it is pollution free as compare to power generation using fossil fuel. Besides, it needs low maintenance and no noise and wear due to the absence of moving parts which make solar power attractive to the people. Solar power uses solar panel to convert sun irradiation into electric energy using photovoltaic (PV) effect. The output voltage of a solar panel is varying depending on sun irradiation and temperature [1]. As the sun irradiation and temperature changes, output voltage changing as well. Since the voltage produced is fluctuating, a lot of electronic equipments are unable to be directly connected. Therefore, a DC-DC boost converter with constant output voltage is needed. The boost converter will step up the solar panel voltage to the suitable voltage required by electronic equipments. For AC electrical equipments, the system requires an additional AC-DC inverter which converts the constant DC voltage to AC voltage. This system is called dual power processing stage system. Figure 1 shows a grid connected PV application system using dual power processing system. From the block diagram, the system does not use any batteries to store energy produced by solar panel. Any power produced by solar panel is directly deliver to the grid. Batteries are excluded fromthe system because battery banks need high maintenance which had to be handled carefully in order to have a long lifetime and safe environment. Besides, batteries are the second major cost contributor for the system [2]. Therefore, the exclusion of batteries as the energy storage is economically advantageous [3].

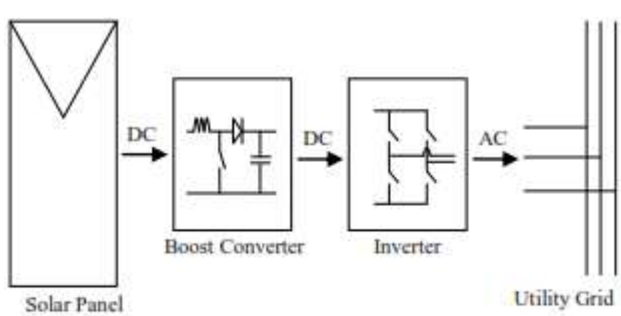

Figure 1. Block diagram of a grid connected PV application system

Basic Operation

The boost converter is a medium of power transmission to perform energy absorption and injection from solar panel to grid-tied inverter. The process of energy absorption and injection in boost converter is performed by a combination of four components which are inductor, electronic switch, diode and output capacitor. The connection of a boost converter is shown in Figure 2 [4]. The process of energy absorption and injection will constitute a switching cycle [5]. In other word, the average output voltage is controlled by the switching on and off time duration. At constant switching frequency, adjusting the on and off duration of the switch is called pulse-width-modulation (PWM) switching. The switching duty cycle, k is defined as the ratio of the on duration to the switching time period. The energy absorption and injection with the relative length of switching period will operate the converter in two different modes known as continuous conduction mode (CCM) and discontinuous conduction mode (DCM) [4][6].

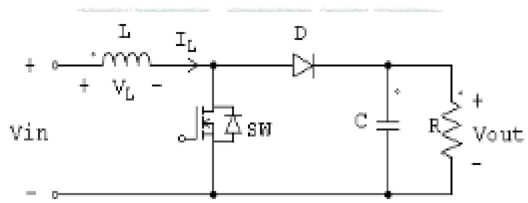

Figure 2. Schematic of boost converter

BOOST CONVERTER ANALYSIS

1. Continuous Conduction Mode

Under CCM, it is divided into two modes. Mode 1 begins when the switch SW is turned on at t = 0 as shown in Figure 3. The input current which rises flows through inductor L and switch SW. During this mode, energy is stored in the inductor and load is supplied by capacitor current. Mode 2 begins when the switch is turned off at t = kT. The current that was flowing through the switch would now flow through inductor L, diode D, output capacitor C, and load R as shown in Figure 4. The inductor current falls until the switch is turned on again in the next cycle. During this time, energy stored in the inductor is transferred to the load together with the input voltage. Therefore, the output voltage is greater than the input voltage and is expressed as

$$V_{out} = \frac{1}{1-k} V_{in} \quad (4)$$

whereVout is the output voltage, k is duty cycle, and Vin is input voltage [4].

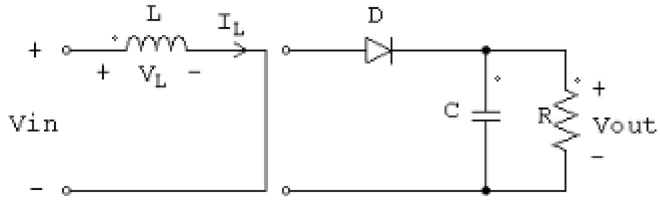

Figure 3. Circuit diagram of boost converter during Mode 1

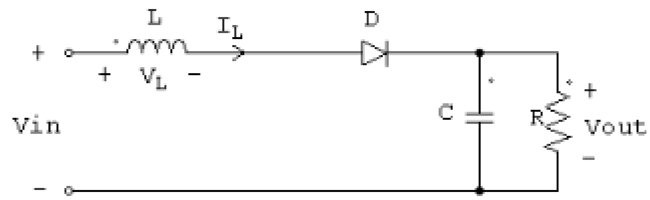

Figure 4. Circuit diagram of boost converter during Mode 2

CONCLUSION

Extra high voltage dc-dc converter hardware prototype was implemented using DSP TMS320F2812 process controller and compared with model developed in numerical simulation software in accordance with theoretical developments. The dc-dc conversion unit use the voltage lift technique to obtain higher output voltage than the classical dc-dc step-up (boost) converter for the same duty ratio and overcomes the effect of parasitic elements with minimized ripple at the output voltage/current. A simple controller with one sensor was developed to maintain the output voltage at the required level for the load/line perturbation testing environmental conditions. Both simulation and hardware results provided in this paper always perfectly matches with theoretical development and proves the effectives of converter configuration. Investigated extra HV dc-dc converter find suitable applications in computer peripheral circuits, medical equipment's and high voltage regulated power supply for industrial applications where requires high power.

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