

PRACTICAL IMPLEMENTATION OF EMBEDDED CONTROLLED BOOST CONVERTER FOR SOLAR INSTALLATION SYSTEM

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Abstract: The solar photovoltaic power has received great attention and experienced impressive progress in the countries all over the world in recent years because of more and more serious energy crisis and environmental pollution. This paper proposes a Embedded controlled boost converter for solar installation system. Boost converter system is simulated using Matlab and it is implemented using embedded controller. The simulation and experimental results of this system are presented and compared. This converter has advantages like improved power factor, fast response and reduced hardware.

Keywords: Embedded controller, Boost converter, Solar cells, PV cells.

1. INTRODUCTION

With the rapid depletion of the conventional fossil fuels, energy crisis and environment pollution become more and more serious. In recent years, much effort has been made to find renewable clean energies, and solar energy has become a promising alternative source because it has many advantages such as abundance, pollution free and renew ability. The solar photovoltaic (PV) power will play an important role in alleviating the energy crisis and reducing the environmental pollution and has a bright prospect of applications. The output voltage generated by the photovoltaic arrays, the fuel stacks, the super capacitors or the battery sources is relatively low, it should be boosted to a high voltage. How to realize high step-up DC/DC converters with high performance is one of the main issues in the renewable energy applications. The limitations of the conventional boost converters are analyzed and the conceptual solution for high step-up conversion is proposed in this paper. Then the state-of-the-art topologies are covered and classified based on the circuit performance. The challenges in high step-up

renewable energy applications are summarized to generate the next generation high step-up DC/DC converters.

DC-DC converters are used in renewable energy systems to step up the low battery or electric storage devices voltage to high voltage levels required by the loads. Some of the main factors to look for while designing DC converters for solar energy systems are the gain, output power and the ease of design.

The conventional step up converters are not provide the required gains even with maximum duty cycles [6]. Other topologies such as flyback converters also suggested. However they cannot be used in energy systems as they have low power ratings below 100 watt [5] as a result, modified boost designs such as the half and full bridge converters can be used. By looking at the disadvantages of these converters, one can see that they lack the ease of design factor and have lower efficiencies due to the use of transformers [5].

As a result, new super-lift techniques are applied in the converters design. The advantage of these techniques is the increases in the stage-by-stage voltage transfer gain in geometric progression [3]. Modeling and control of a cascaded boost converter with a single switch is discussed [4].

The above literatures does not deal with the embedded implementation of boost converter system for solar installation. The limitations of the conventional boost converters are analyzed and the conceptual solution for high step-up conversion is proposed in this paper. This work makes an attempt to implement the boost converter using 89C2051 controller.

2. SOLAR CELL SYSTEM

The density of power radiated from the sun (referred to as the "solar energy constant") at the outer atmosphere is 1.373kw/m^2 . The final incident sun light on the earth surface has the peak density of 1kw/m^2 at noon in the tropics. The technology of photovoltaic (PV) is essentially concerned with the conversion of this energy into usable electric form. The basic element of the PV system is the solar cell. Solar cell can convert the energy of sunlight into electricity directly. A simplified equivalent circuit of a solar cell consists of a current source in parallel with a diode variable resistor connected to the solar cell generator as a load. The relationship between the current and voltage may be determined from the diode characteristics equation:

$$I = I_{ph} - I_o (e^{qv/kT} - 1) = I_{ph} - I_d \quad (1)$$

Where q is the electron charge, k is the Boltzmann constant, I_{ph} is the photocurrent, I_o is the reverse saturation current, I_d is the diode current and T is the solar cell operating temperature (K).

The stand-alone photo-voltaic energy system requires storage to meet the energy demand during period of low solar radiation and night time. The battery storage in a solar system should be properly controlled to avoid catastrophic operating condition like over charging or frequent deep discharging. Storage batteries account for the most PV system failures and contribute significantly to both initial and the eventual replacement cost. Charge controllers regulate the charge transfer and prevent the battery from being excessively charged and discharged. Switch Mode DC to DC converters are used to match the output of a PV generator to a variable load. The DC to DC converters allow the charge current to be reduced continuously in such a way that the resulting battery voltage is maintained at a specified value. A practical photovoltaic energy conversion system block diagram is shown in Fig.1. The equations of boost converter are as follows:

The average output voltage is given as,

$$V_{o(\text{avg})} = V_s / (1-D) \quad (2)$$

The ripple in output voltage is given as,

$$V_{o(\text{ripple})} = I_{o(\text{avg})} D / fC \quad (3)$$

and the ripple in output current is given as,

$$I_{o(\text{ripple})} = V_s D / fL \quad (4)$$

Where V_s is the input voltage, D is the duty cycle ratio L is the inductance and f is the frequency of the boost converter. Boost inductor and capacitor are calculated using the formula

$$L = V_o D / fI_o \quad (5)$$

$$C = D / 2fR \quad (6)$$

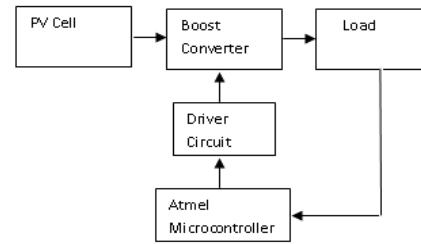


Fig. 1. Block Diagram of PV Installation system

3. SIMULATION RESULTS

Simulation is done using Matlab and the results are presented. Boost converter for solar installation system is shown in Fig 2a. PV array is represented as a DC source. The DC input voltage is shown in Fig 2b. The driving pulses of the MOSFET are shown in Fig 2c. The voltage across the MOSFET is shown in Fig 2d. The voltage across the MOSFET is complement of the input. The output current is shown in Fig 2e. The ripple can be reduced by using a large value capacitor. The DC output voltage is shown in Fig 2f. DC output takes long time to settle due to the presence of filter capacitor. The output voltage reaches 50V. The closed loop system is shown in Fig 3a. Output voltage is sensed and it is compared with a reference voltage. The error is processed by a PI controller. The output of PI controller adjusts the pulse width to maintain the output voltage constant. Input voltage and output voltage of closed loop system is shown in Fig 3b. The output voltage reduces and reaches the set value.

Data used for simulation studies are as follows:

Input Voltage	15 V
Output Voltage	50 V
L_F	1 μ H
C_F	10 μ F
R_L	200 Ω
T_{ON}	0.3 ms
T_{OFF}	0.1 ms

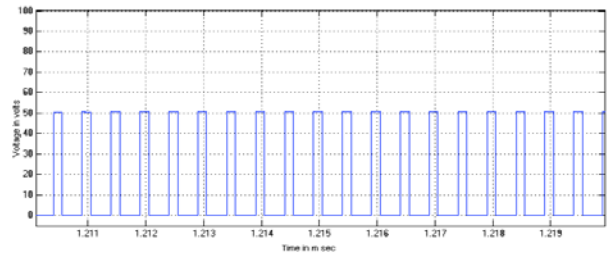


Fig. 2d. Voltage across the switch

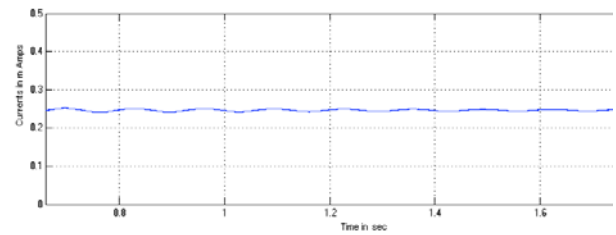


FIG. 2E. OUTPUT CURRENT

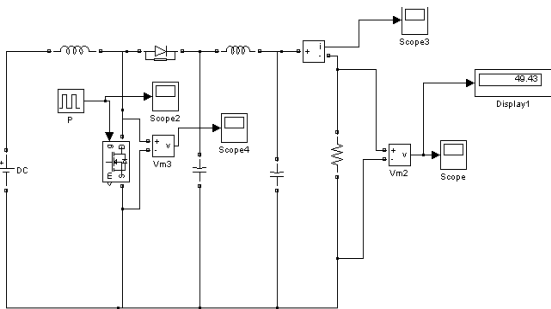


Fig. 2a. Simulink circuit of solar installation system

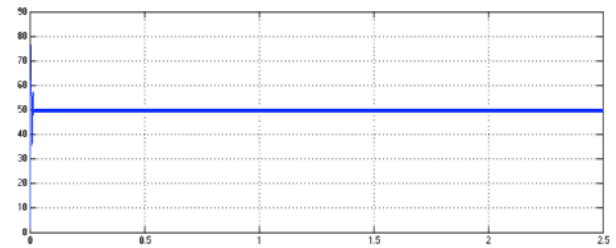


Fig. 2f. DC Output voltage

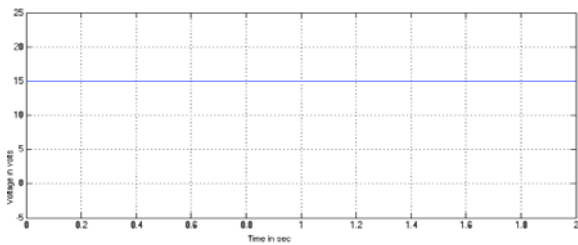


Fig. 2b. Input voltage

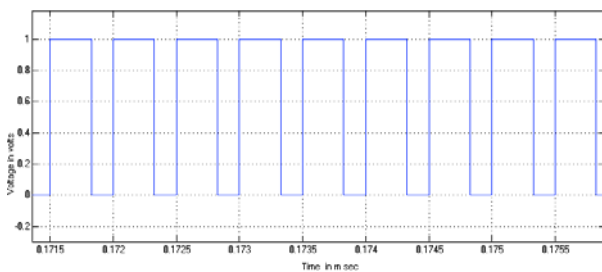


Fig. 2c. Driving pulses

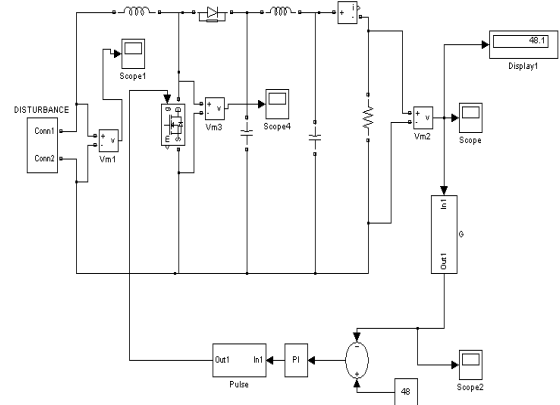


Fig. 3a. Simulink circuit of Closed loop solar installation system

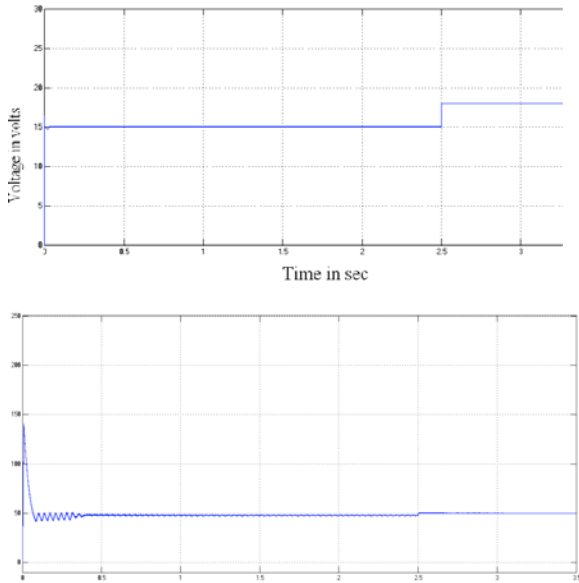


Fig. 3b. Input and output voltages

4. EXPERIMENTAL RESULTS

In order to verify the circuit operation and confirm the simulation results a prototype is built and lab tested. The Embedded controller based driver circuit is shown in fig 4b. The output pulse from the controller are amplified using the driver chip IR 2110. The hardware implementation is shown fig. 4a. The driving pulses applied to the MOSFET are shown in Fig 4c. The input voltage applied to the converter is shown in Fig 4d. The input voltage is 13.2V. The output voltage of the boost converter is 50.4V. The oscillogram of input voltage is shown in Fig 4e. Display of output voltage is shown in Fig 4f. The oscillogram of input voltage is shown in Fig 4g. The output is free from ripple. From the figures 2c and 4c, it can be seen that the experimental results are almost similar to the simulation results.

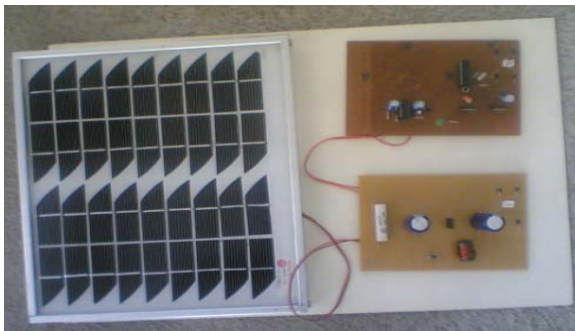


Fig. 4a. Hardware Circuit

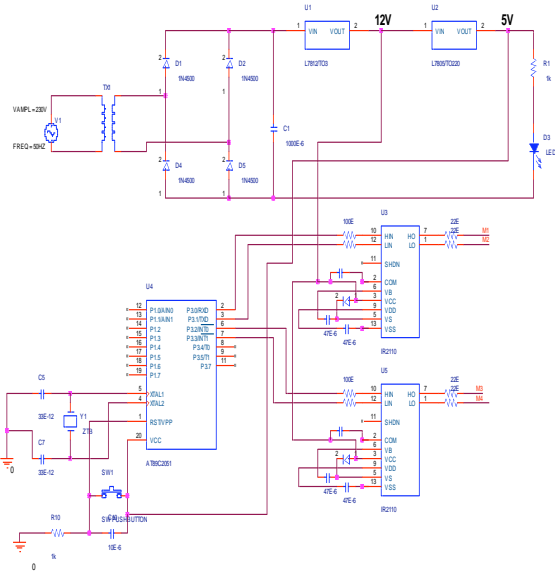


Fig. 4b. Control circuit



Fig. 4c. Driving pulses



Fig. 4d. Display of the input voltage

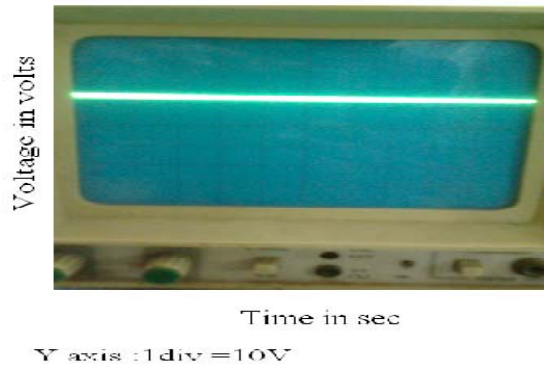


Fig. 4e. Input voltage



Fig. 4f. Display of the output voltage

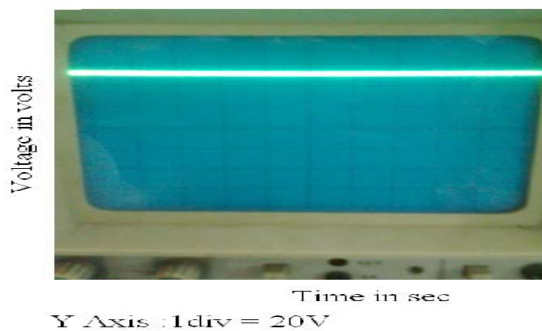


Fig. 4g. Output voltage

5. CONCLUSION

The limitations of the conventional boost converter in high step-up renewable energy applications are analyzed and a lot of topologies, which are published in previous papers, are summarized. From the above analysis, the major challenges in high step-up DC/DC converters are the following:

- 1:) How to extend the voltage gain and avoid the extreme duty cycle to reduce the current ripple and the conduction losses;
- 2:) How to reduce the switch voltage to make low voltage MOSFET's available;
- 3:) How to alleviate the output diode reverse-recovery problem;
- 4:) How to increase the power level easily and reduce the passive component size.

This paper presents simulation and experimentation of embedded controlled boost converter system for solar installation system. Matlab model for boost converter system is developed by using Matlab / Simulink. This converter has advantages like simple hardware and good output voltage regulation. The embedded controlled boost converter is capable of improving the voltage level from 15V to 50V. The experimental results closely agree with the simulation results

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