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Optimum design of boost converter for charging the battery by non-conventional energy source

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Abstract
The utilization of battery can be improved by designing an appropriate charger capable of fast charging. Photovoltaic panel is used as input source for converter. The objective of this paper is to investigate the converter topologies and control techniques for fast charging of a battery which are required for its optimum design. A charging monitoring system is implemented based on converter technologies. Experimental simulation work is carried out in MATLAB-7.7b. A PI-gain controller feedback is used with reference voltage of 15 V for the ripple free output voltage.

Keywords: Converter technology, fast charging, MATLAB based monitoring system.

Introduction
The paper concentrates on practically developing an optimal boost converter model. A photovoltaic panel is taken as a voltage source in this present model (Rai, 2008). The main factors affecting the converter are photovoltaic panel output parameters, design of converter, environment and operating states of PV-panel (Maksimovic *et al.,* 1996).
The following are the basic considerations for designing the converter:
i. Selection of battery type
ii. Design of charging method
iii. Design of fast charging.

Conventional charging methods include constant-current method, constant voltage method, and constant current-constant voltage method (two-step). This paper analyze the charging characteristics (viz. charging time, charging current, temperature, switching frequency & pulse period) of constant-current method (Chattopadhyay *et al.,* 2000).
The basic non-transformer-isolated topologies of converters are:
i. Buck (step-down)
ii. Boost (step-up)
iii. Buck-Boost (inverting).

The basic circuit diagram of a boost converter is shown in the Fig. 1 (Singh & Khanchandani, 2007).
The circuit is analyzed by using
$V_{in}D + (V_{in}-V_{out})(1-D) = 0$,
$V_{out} = V_{in}/(1-D)$
Here, it is observed that $V_{out} > V_{in}$ always. This is called boost or step-up converter.

The power output of the boost topology is limited to about 150 W due to the high peak currents which stress the power switch and diode (Robbins & Hawkins, 1994). The ability of the boost regulator to prevent the hazardous transients from reaching the load is also quite poor (Basu & Underland, 2005). The boost converter (step-up) is used to step-up the voltage from photovoltaic panel for charging the battery.

Simulation procedure
MATLAB-7.7b based monitoring system is used to record the input voltage, output voltage and output current of boost converter. The current and voltage input parameters which are given to boost converter are drawn from photovoltaic panel. Actually in simulation procedure, this photovoltaic parameters are represented as repetitive sequence source block. The simulation circuit diagram for the boost converter shown in Fig. 2.

Design procedure
Voltage divider
The values of resistors and the other parameters are taken as per requirement for boost converter. Output voltage of the converter is set by voltage divider R1, R2 and R3. A reasonable compromise for divider string overall impedance is a target of approx 1 MΩ. R1 and R2 are typically split equally in value, to create the upper resistor in the divider so as to keep the maximum voltage across each resistor within the voltage rating of these devices (250 V). The voltage feedback with PI- Gain controller technique with the reference voltage of 15 V is shown in Fig. 3.

PI-controller:
Output voltage for RC load when the reference output is set to 15 V is shown in fig. 4.
The following parameters are taken for the designing of boost converter:
R1 = 1433.33 K.Ohms
R2 = 100 K.Ohms
R3 = 300 K. Ohms
Total resistance can be R_s = 251 K Ohms.
Current sense calculations:
Resistance (total), R_s = 251 K Ohms
V_{in} (rms) = 74 Volts
Power dissipation in resistor is given by

$$P_{R_s} = I^2_{in(rms)} \cdot R_s$$

Therefore, Power can be calculated as

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Fig. 1. Basic circuit diagram of a boost converter

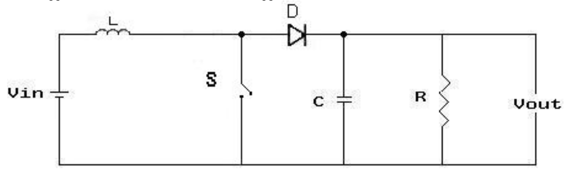


Fig. 3. Voltage feedback with PI-gain controller

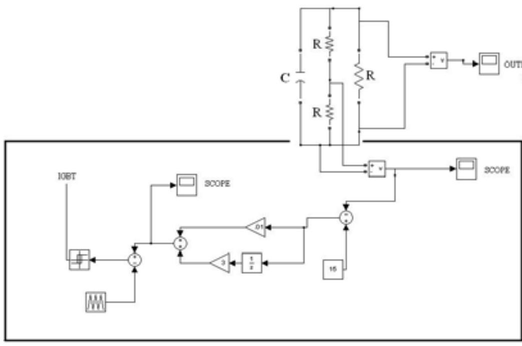


Fig .5. Block diagram of a boost converter in simulink

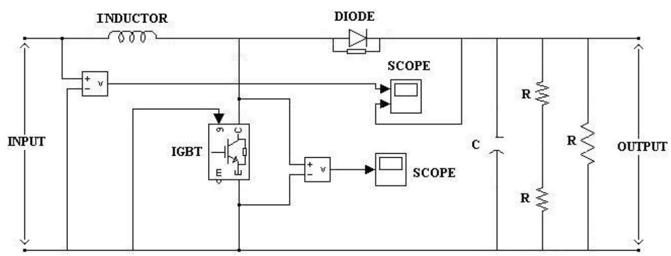


Fig. 7. Output current of 12 A

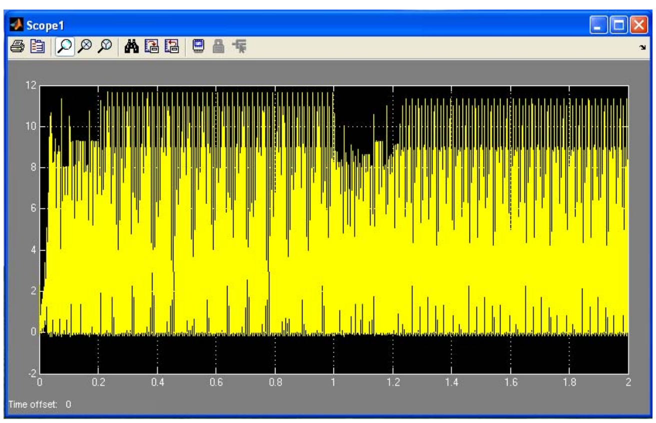


Fig. 2. Simulation diagram for the boost converter using the PI-gain controller

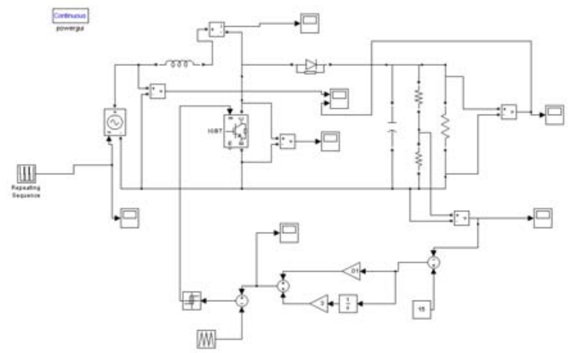


Fig. 4. PI-gain controller output

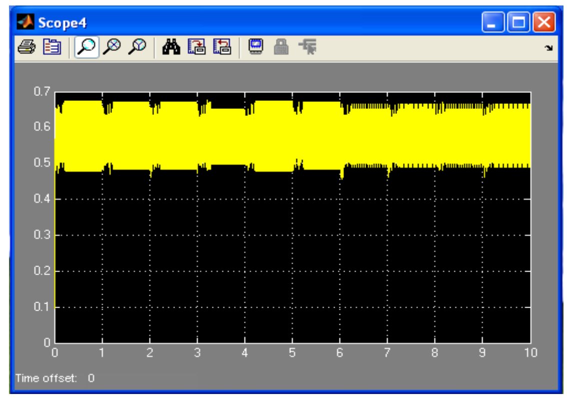
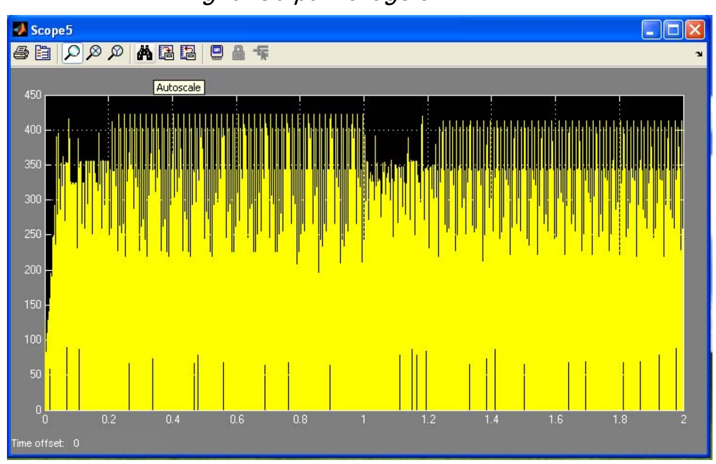


Fig. 6. Output voltage of 421.4 V



P_{in} = 12*12*251= 361.44KW.

The efficiency of input to PV panel is calculated as 0.83 by considering input voltage and current from source.

$P_{out} = P_{in}$ * efficiency =361.44*0.83 =300 KW.

Simulation results

In the experimental set up, the input voltage given to the boost converter is between 14 V-74 V.

Experimental results for an input voltage of 74 V are:

Output voltage : 422.4 V
Output current : 12 A
Switching frequency : 50 KHz
Current ripple : 10% (maximum)
Efficiency : 82.46%
Power Factor : 0.998 or greater.

Design example results:

The Simulink model of the boost converter is shown in the Fig. 5.

From the simulation process, the results are shown in Fig. 6.

Output voltage vout = 421.4 V

Voltage waveform: Scope: -5

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Fig. 8. V_s (of source) and V_{out} readings at the primary voltage

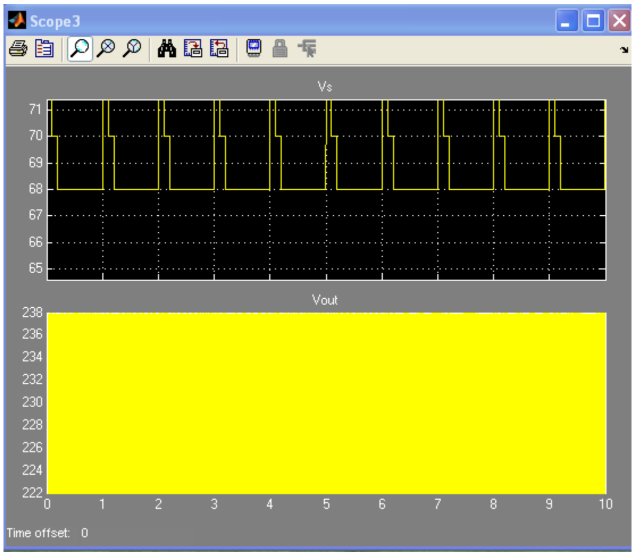

Fig. 9. The readings after auto scale

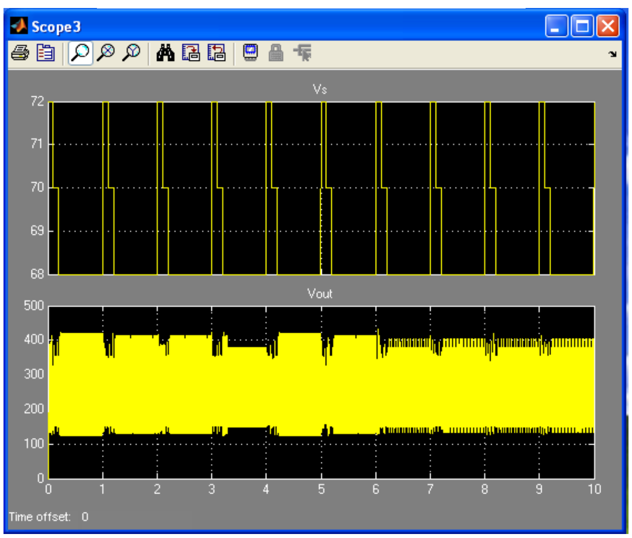

Fig. 10. At the IGBT switch voltage reading with ripple free

Reading shown: 0 to 422.4 V
From the simulation process, the output current is shown in Fig. 7.
I_{Out} = 11.65 A (12 A)
Current waveform: scope: -1
Reading shown: 0-12 A
Vs (of source) and V out readings at the primary voltage are shown in Fig. 8, scope 3.
Simulation time: 0 min
Simulation mode: Normal
After auto scale the reading is shown in Fig. 9, scope 4.
Simulation time: 10 min
Simulation mode: Normal
At the IGBT switch, voltage reading with ripple free is shown in Fig. 10, scope 5.

Majority of the converter design is based on low line current. That is the worst case condition for efficiency and input currents. Maximum input power can be calculated assuming a nominal efficiency at low line in boost converter. In some applications, such a high percent ripple may not be acceptable. Therefore, the value of the inductor is to be increased to decrease the ripple shown in Fig. 10. .

Conclusion

Input voltage is taken from photovoltaic panel for the boost converter. Proper constant voltage converting topology is very important because it provides continuous rated output to the charger. The constant current charging scheme followed in the present work is simple and takes less time to execute. The output of the boost converter varies according to the input voltage of the converter giving ripple free voltage. We presented the optimum design of boost converter, which combined the monitor system features of fast charging and adjustable control.

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