Design, Simulation and Analysis of Microcontroller based DC-DC Boost Converter using Proteus Design Suite

S. Sheik Mohammed a, D.Devaraj b

a Faculty of Engineering, Dhofar University, PB No.2509, Salalah, Oman, PC-211.
Email : ssheikmd@yahoo.co.in

b Senior Professor, Kalasalingam University,Srivilliputhur,Tamilnadu, India

Abstract—Renewable energy sources and in particular Photovoltaic (PV) system are implemented in large scale in many countries for power generation. The characteristics of PV arrays are non-linear i.e., the change in temperature and irradiation levels results in change of power generated by the PV arrays. DC-DC converters are connected between the PV system and the load as power conditioning unit to regulate the output of the PV system. Simulation of DC-DC boost converter using Proteus Design Suite is presented and discussed in this paper. DC-DC boost converter is simulated with constant DC input and voltage variation at the input side. Boost converter controlled by microcontroller is simulated under open loop condition the results are obtained.

Index Terms—DC-DC Converter, Proteus design suite, Microbasic, Microcontroller

I. INTRODUCTION

Oil and gas are most commonly used fuels for power generation. Prices of such fuels are rocketing and the use of such fuels severely affects the environment. Global warming and green house effects are the main threat for the natural living system at the present situation and for the future generations. Usage of fossil fuels for power generation is also one of the main causes for the environmental pollution. Sources which are environmentally clean, low in cost and easily accessible can serve the global community in a better way to save the environment. Solar power generation received significant attention due to many advantages such as less maintenance, no wear and tear and absolutely no cost for fuel apart from the factors discussed above. PV modules are used to generate electricity from sun. Due to the non-linear characteristics of PV system the output power is not constant all the times through the day. DC-DC converters are used in PV systems to regulate the voltage of PV system. Modeling, design, simulation and implementation of different types of DC-DC converters are discussed in many literatures.

Simulation of electronic circuit is an important phase in design and implementation of any electronic circuits. Changing components in a hardware circuit is not an easy task after building the whole circuit. Circuit simulation is performed prior to hardware implementation. Based on the simulation results, the circuit can be modified at any stage until the expected performance and results are obtained. The results of simulation and hardware can be compared for analysis. Various software are used for circuit simulation such as Pspice, Multisim, Proteus design suite and
MATLAB/Simulink. The simulation of DC-DC converters are mostly carried out using MATLAB/Simulink. A detailed modeling and simulation of Buck, Boost, Buck-Boost and Cuk converters using MATLAB/Simulink is presented in [1]. The works carried out in [2-6] presents different topologies for PV based DC - DC Converters to obtain I-V and P-V curves under various conditions. Circuit simulation using Pspice and implementation of DC-DC converter for solar electric system is discussed in [7]. DC-DC Buck converter with MPPT control using Pspice is analyzed in [8]. The circuit simulation is easy and simple in MATLAB. But, using MATLAB/Simulink for electronic circuits has some limitations. Comparing to other software packages MATLAB toolbox has very limited electronic circuit components. For example, to simulate a DC-DC converter, it has only one electronic switch of each type in the toolbox such as MOSFET, IGBT and diode. For hardware implementation, the components are selected based on the requirement, power rating among the broad range of products available in the market whereas only one switch (for eg. MOSFET) is used for simulation of all type circuits irrespective of the power rating. In MATLAB, it is not possible to simulate and analyze the circuit with the components with the part number which are used for hardware implementation. Analysis and simulation of DC-DC boost converter using Proteus design suite is presented in this paper. An overview of Proteus software, its features is discussed. Simulation of DC-DC converter and results are presented.

II. DC-DC BOOST CONVERTER

DC-DC Converters are used to convert the unregulated DC voltage into regulated DC voltage. DC-DC converters are operated under continuous conduction mode (CCM) or discontinuous conduction mode (DCM). As the name implies, the output voltage of Boost converter is higher than the input voltage. The input and output power of DC-DC converters are same for ideal case. The DC-DC boost converters operate under two case, switch ON (SW_{on}) and switch OFF (SW_{off}). Circuit diagram for the boost converter is shown in fig 1.

![Fig 1. DC-DC Boost Converter](image)

A. Operation of DC-DC Converter

For the given circuit, the current flows through the inductor (L) and the energy is stored in inductor when the switch is ON. During SW_{off} mode, the sum of energy stored in the inductor during ON time and the supply current will flows through the load resistor (R_L) and the capacitor (C). The output voltage (V_o) appears across the load and the capacitor stores energy. During SW_{on} mode, the supply current flows through the inductor (L) and the energy is stored in the inductor. But, at the same time the energy stored in the capacitor during SW_{off} is discharged across the load. The diode D is reverse biased in SW_{off} and it blocks the reverse flow of current from load to source. Thus, the load current and voltage is continuous. The output of the converter is controlled by the duty cycle (D) of the switch. PWM technique is generally adapted to generate the triggering pulses to control the switch of the DC-DC converter. For the given input supply voltage (V_s), the output voltage (V_o) of the boost converter circuit can be obtained using

\[ V_o = V_s \frac{1}{(1-D)} \]

The capacitor and inductor values of boost converter are calculated using the formulas presented in [9].

600
B. Modeling of DC-DC Boost Converter

Mathematical model of DC-DC Converters are discussed in [1], [10-11]. The state space equation of the boost converter is described by assuming that the converter elements are ideal and the operating mode is continuous conduction mode (CCM). The equations are expressed for the duty cycle (D) over the total time period (T) for SW$_{on}$ mode and SW$_{off}$ mode. The equations are presented in [1] as follows. When the switch SW is ON,

\[
\begin{align*}
\frac{dI_L}{dt} &= \frac{1}{L} V_s, \quad ; 0 < t < dT, SW_{on} \\
\frac{dV_o}{dt} &= \frac{1}{C} \left( \frac{-V_o}{R_L} \right)
\end{align*}
\]

Similarly, when the switch SW is OFF,

\[
\begin{align*}
\frac{dI_L}{dt} &= \frac{1}{L} (V_s - V_o), \quad ; dT < t < T, SW_{off} \\
\frac{dV_o}{dt} &= \frac{1}{C} (I_L - V_o - \frac{V_o}{R_L})
\end{align*}
\]

III. PROTEUS DESIGN SUITE

Proteus software is developed by Labcenter Electronics. Proteus is software used for electronic circuits, microprocessor based circuits simulation and for designing printed circuit board (PCB). The main feature of Proteus design software is its multiple system components. Proteus is a package which has ISIS Schematic Capture which is a tool used for circuit design and simulations, Printed Circuit Board (PCB) design known as ARES PCB Layout, VSM (Virtual System Modeling) which is embedded software with popular microcontrollers and hardware design.

Hardware implementation of electronic circuits is not an easy task. To implement any hardware in real time, it is necessary to study the ratings of the circuit components. The rating of circuit components are depends on the application. For any circuits, the components for hardware can be selected after completing the mathematical calculations. The designed circuits are simulated for analyzing the performance and behavior of circuits prior to hardware implementation. Simulating the circuit with the same hardware components could give more accurate results than performing the simulation using generalized circuit components. In Proteus ISIS schematic capture, most commonly used components of many leading manufacturer are listed with their part number and the ratings. Hence, the user can simulate the circuit with same components which will be used for the implementation of hardware. Moreover, the PCB design of the designed circuits can also be generated by Proteus ARES PCB layout.

Another main feature of Proteus is that it can be integrated with mikroBasic software. mikroBasic is developed by mikroelectronika, and mikroBasic PIC is a compiler used to build PIC microcontroller based projects. This software allows users to write and compile the programs and the programs compiled in mikroBasic can be directly uploaded into the microcontroller chip used in Proteus design suite. So, the microcontroller based circuit analysis is easy and simple in Proteus.

IV. SIMULATION OF DC-DC BOOST CONVERTER

The design parameters and the components values of the DC-DC boost converter is presented in Table 1. The operating frequency of the switch ($f_s$) is considered as 10 kHz.
### TABLE I. Boost Converter Circuit Parameters

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply voltage ($V_s$)</td>
<td>18 Volts</td>
</tr>
<tr>
<td>Output voltage ($V_o$)</td>
<td>24Volts</td>
</tr>
<tr>
<td>Capacitor (C)</td>
<td>17.29 µF</td>
</tr>
<tr>
<td>Inductor (L)</td>
<td>1.80 mH</td>
</tr>
<tr>
<td>Resistor ($R_L$)</td>
<td>28.8 Ω</td>
</tr>
</tbody>
</table>

From the design parameters, the duty cycle of the converter is calculated as 25% , i.e., the ON time of the switch ($t_{on}$) is 25µs and the OFF time of the switch ($t_{off}$) is 75µs. The DC-DC Boost converter simulated using Proteus is shown in fig 2. The circuit performance is analyzed under open loop condition and the results are obtained.

![Simulation circuit of DC-DC Boost Converter](image)

**Fig 2. Simulation circuit of DC-DC Boost Converter**

![Input voltage waveform](image)

**Fig 3. Input voltage**

![Output voltage waveform](image)

**Fig 4. Output voltage**

The input voltage waveform for the supply voltage of 16V is shown in fig 3 and the waveform for output voltage where the voltage approaching 24V and the output current waveform are shown in fig 4 and fig 5 respectively. The switching pulse with dutycycle of 25% is shown in fig 6.
As mentioned earlier in this paper, simulation and analysis of microcontroller based circuit is easy and simple in Proteus. A microcontroller based DC-DC boost converter circuit simulated in Proteus is shown in fig 7.

The PIC16F887 microcontroller is used for firing pulse generation. PIC16F887 has inbuilt PWM and A/D converters in it. Microcontroller is programmed to generate the firing pulses with fixed duty cycle of 25% using PWM. PIC16F887 is 8 bit microcontroller so it receives the input as bits from 0 to 255. Hence, any input value should be converted into bits to obtain proper results. For example, to generate the PWM pulses for 25% duty cycle it should be converted as
\[ D = 25 \times \frac{255}{100} = 63.75 \approx 64 \]

The program code for PWM generation is as follows:

```c
program boostMCU18V

'Program to generate pulse with 25% duty cycle
main:
'   Main program
anselh=0
trisb=0
trisa=255
PWM1_Init(10000)
   'Initialise PWM 1; fs=10kHz
PWM1_Set_Duty(64)
   '(1%=2.55; 25%=25*2.55=63.75)
PWM1_Start()
while true
   PWM1_Set_Duty(64)
wend
end.
```

The DC-DC Boost converter controlled by microcontroller is analysed with disturbance at the input side. The supply voltage has increased from 18V to 22V after 25ms as shown in fig 8. For the fixed duty cycle the output voltage of the converter also has increased with the change of input voltage. The change of voltage at the output side is presented in fig 9.

Fig 8. Input voltage waveform with disturbance

Fig 9. Output voltage waveform for input with disturbance

The output current waveform with the disturbance is presented in fig 10.

604
V. CONCLUSION
Simulation of DC-DC boost converter using Proteus Design Suite is presented in this paper. The circuits are designed with the real time hardware components and the results are generated for constant DC input voltage and input with disturbances for fixed duty cycle. The circuit with direct control which uses pulse generator for control pulses is simulated for constant DC input, the output voltage and current waveforms are obtained. Further, the output voltage and current are obtained from the microcontroller driven circuit where the PWM pulses are generated for fixed duty cycle and the circuit is fed by input with disturbance. The circuit is analyzed under open loop condition for both cases.

REFERENCES
Bibliography

**S. Sheik Mohammed** is faculty of College of Engineering, Dhofar University, Salalah, Sultanate of Oman. He is having more than 7 years of experience in teaching. He received his M.E. in Power Electronics and Drives from Bannari Amman Inst. of Tech, Tamilnadu, India. He has published many papers in Int. Journals and Conferences. He is currently pursuing his PhD in the area of solar power converters.

**Dr. D. Devaraj** is Sr. Professor & Head of Computer Science and Engineering in Kalasalingam University, Sripilliputhur, India. He is having more than 18 years of teaching and research experience. He has received M.E. degree in Power System Engineering from Thiagarajar College of Engg., Madurai, India in 1994. He obtained PhD in Electrical Engineering from IIT Madras, Chennai, India in the year 2001. He has published more than 20 papers in National and Int. Journals, more than 60 papers in National and Int. conferences. His current research interest includes Power system security, Power System Optimization, Power Quality, Intelligent Control and Evolutionary Computing.