Design and Simulation of DC-DC Converter Used in Solar Charge Controllers

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Abstract:- With the increasing Energy demand Conservation and effective Utilisation of Energy are very essential. Solar Charge Controllers helps in increasing the efficiency of the solar power transferred to the Battery. It consists of mainly Dc-Dc Converters. These Converters are mostly Dc Choppers which converts fixed Dc voltage to a variable Dc source. These Regulators are used in case of Solar Charge Controllers to increase or decrease the PV panel voltage to as that required by Battery. The DC voltage from the PV panel varies with the light intensity which depends on time of day and temperature. Similarly on the Battery side the voltage varies depending on the load connections. Thus for optimal charging of battery it is important that the voltage of the PV panel and the current matches the battery charging state at any instant. There are various types of Dc-Dc Converter of which Buck Boost Converter is taken into consideration. This paper shows all the Design calculations and simulation results of a Buck-Boost converter as depending on the weather condition the Solar Charge Controller will take the voltage input from the Solar PV panel and convert it to that required for optimal charging of battery.

Keywords:- Controller, Buck-Boost, Regulators, MPP, PWM

I. INTRODUCTION

DC-to-DC regulators are also known as Switching Regulators which uses power switches like an inductor, a capacitor and a diode to transfer power from input to output. The switches are generally passive or Active type. Passive switches consists of a diode, where as the active switches are like MOSFET transistor. MOSFET transistors are an efficient and fast way to allow a pulse width modulation (PWM) signal to control the frequency and duty cycle of the ON and OFF time of the “switch”. More power is transferred from input to output when Duty cycle is high. One of the advantages of the PWM is that the signal remains digital from the source i.e. from the Microcontroller to the MOSFET’s so that any analog-to-digital signals conversion is no more needed. Digital signals are very rarely affected from outside noise, unless the noise is large to change the signal from one to zero or vice versa. There are many DC-to-DC converters so far studied. Some are like Buck, Boost, Buck-Boost, CUK, and Sepic. These regulators do not produce power. In fact some of the input power according to their efficiency is consumed by these Regulators. Therefore considering ideal case to maintain the same power level the adjusted voltage level affects the current level. Since current and voltage are both directly proportional to power therefore in buck mode the voltage is reduced as the current increases. While in boost mode the voltage is increased as the current decreases. The Solar Charge controller consists of various components like Dc-Dc Converter, Microcontroller, LCD, Temperature sensors, Voltage sensors, Current sensors, Irradiance Sensors. The Dc- Dc Converter is one among the major component of the controller which receives the input voltage from the PV panel and converts the voltage without use of transformer and gives the desired output as that required for various charging stages of Battery.

II. BUCK-BOOST CONVERTER

Buck-Boost Converter is a Dc Converter in which the output voltage can be increased or decreased than the input voltage. One of the striking features of this regulator is that it provides output voltage polarity reversal without the use of transformer. It is also called an Inverting Regulator. It has high efficiency and the output short circuit protection can be easily implemented. However it shows discontinues input current and high peak current flows through the switch. Buck Boost Converter consists of a switch which may be Mosfet or a Transistor, Inductor, Diode, Capacitor and Load may be resistive or any other.

Fig 1: Diagram of a Buck Boost Converter
The principle of operation of the buck–boost converter is simple (see figure 2):
- While in the On-state, the input voltage source is directly connected to the inductor (L) resulting in accumulating of energy in L. In this stage the output load is supplied with energy from the Capacitor.
- While in the Off-state, the output load and capacitor are connected with the Inductor, so energy is transferred from L to C and R via Diode D.

The characteristics of the buck–boost converter comparing to Buck and Boost are mainly:
- The output voltage polarity is opposite of the input voltage polarity.
- In case of an Ideal Converter the output voltage can vary continuously from 0 to \(-\infty\). The ranges for a buck and a boost converter are respectively 0 to \(V_1\) and \(V_2\) to \(\infty\).

### III. SOLAR CHARGE CONTROLLER

Solar Charge Controllers are the controllers which regulate the power output or the Dc output voltage of the solar panels to the batteries. Thus we can say these controllers take the Dc output voltage as the input voltage converts it into same Dc voltage but as that required for Battery charging. These are mostly used in off grid scenario and uses MPP i.e. Maximum Power Point Tracking scheme which maximizes the output efficiency of the Solar Panel. In Battery charging the output voltage Regulation plays an important factor as batteries require specific charging method with various voltage and current levels for specific stage. These charging processes enhance battery performance and battery life. Standard Charge controllers are used where the solar panel voltage used as input are higher than the output voltage. Thus keeping the current constant the voltage will be reduced by the controller. This results in loss of power. MPPT based solar charge controllers use smart technologies such as microcontrollers to compute highest possible power output at any given time i.e. voltage will be monitored and regulated without power loss. The Controller will lower the voltage simultaneously increase the current, thereby increasing the power transfer efficiency.

### IV. DESIGN PARAMETER CALCULATION OF BUCK-BOOST CONVERTER

In this paper Buck-Boost Converter is used for resistance matching to achieve the optimum output by maximum power point tracking. The PV panel used as a source of input for the DC-DC converter has the following characteristics: Maximum power \(P_{\text{max}} = 20\) watt, Maximum voltage \(V_{\text{max}} = 17\) volt, Maximum current \(I_{\text{max}} = 1.18\) Amp, Open circuit voltage \(V_{\text{OC}} = 21\)volt, Short circuit current \(I_{\text{sc}} = 1.30\)amp. The design of Buck-Boost Converter starts with the selection of one Inductor and one Capacitor with a resistive load.

Input voltage 12-16volt
Output voltage 12v, 1.2amp

By using the output equation \(V_o = - (D*V_s)/(1-D)\), where D is the Duty cycle D is calculated to be 0.48.

\[ D \geq 0.5 \quad \text{-----Boost mode} \]
\[ D < 0.5 \quad \text{-----Buck mode} \]

Is = source current, 1.3 Amp

Similarly by using this formula \(I_o = I_s*D/ (1-D)\), output current is calculated, \(I_o = -1.27\)Amp

The value of Inductance as calculated is given as \(L = (D*V_s)/ (F_s* \Delta I)\), \(L = 200\)μH

And the value of Capacitance is taken as \(C = D*I_s/ (\Delta V*F_s)\), \(C = 350\)μF

The switching frequency is chosen as \(F_s = 10\) KHz with Time period \(T = 0.1*10^{-3}\).

### V. SIMULATION DESIGN

![Image of Buck-Boost Converter](image-url)
Design and Simulation of DC-DC Converter Used in Solar Charge Controllers

VI. SIMULATION RESULTS

Fig 3: Shows the Simulation Design of Buck-Boost Converter performed using MATLAB

Fig 4: Shows the Converter output voltage, input voltage and Load current

Fig 5: Shows the Simulation Results of Voltage and Current of both Inductor and Capacitor
VII. CONCLUSION

In this paper the design analysis of Buck Boost converter is presented. The Proposed system has been simulated in MATLAB SIMULINK environment. From the simulation results the output of the Dc-Dc Converter is checked which can be used as an input to the Battery. The most important feature of this Design is that it is very simple and easy to implement as it requires very less number of components. Further in the future work the same design can be implemented in the hardware.

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