

Abstract

Photovoltaic systems are widely used to convert solar energy to electricity. The output of the PV system is strongly affected by the weather. In order to maintain the stability of the power, rechargeable battery is necessary to store the electricity temporarily. The author object, in this poster, is to make the output voltage of PV (solar panel) constant to connect its rechargeable battery 12v DC.

Introduction

In this poster, the design of a feedback control compensator device to suit Buck- Boost converter is presented. The voltage output was required to remain constant 12v DC or return to steady state as fast as possible, whatever input voltage that comes from a solar panel, and when there is any changes in load. The designer will use a transfer function of the power stage (Buck- Boost converter) to find out the values of controller components such as (R and C). Also, the author works on PSPICE program to get on bode plot of Buck- Boost converter then can simulate all figures in order to prove the feedback control circuit works theoretically and practically. Furthermore, waves by oscilloscope will present to show the output and input of the Buck - Boost converter.

The voltage feedback controller circuit with a power pole board and solar panel will help in providing a constant DC voltage from a solar panel.

The Power Board and Buck-Boost converter

Both of the power Pole Board and Buck- Boost converter are important part for design and implement feedback controller.

The power pole board is an experimental power electronics laboratory kit. The main feature of board is a configurable power-pole which is made up of two MOSFETs and two diodes. Drive circuitry for the MOSFETs and also protection circuitry are included on the board. PWM signals for control of the MOSFETs may be generated from the board or supplied externally [2].

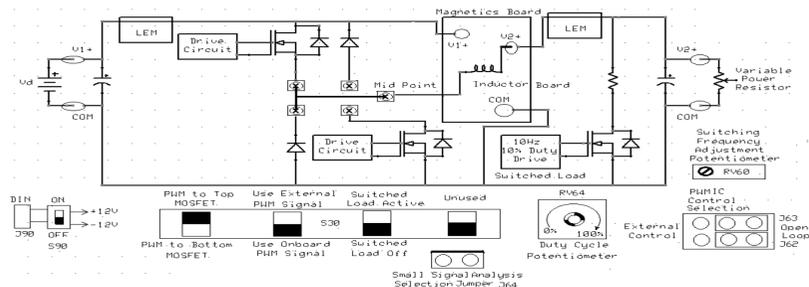


Figure 1 : Block Diagram of Power Pole Board

The Buck- Boost converter is step up/ down converter that allows the output voltage to be greater or lower than the input voltage by changing duty-ratio D. from equation below can find the transfer function of buck- boost converter .

$$\frac{V_o}{V_i} = \frac{V_{in}}{(1-D)^2} \frac{1+sRC}{LsC(S^2+s(\frac{1}{RC}+\frac{r}{Lc}))} \quad \text{Equation 1: the buck- boost transfer function}$$

Simulating the Buck- Boost Converter Dynamic Average Model

By using PSPICE program, Author has developed of the buck - boost converter. In the parameter listing to the right of the schematic, Parameters for the Power Pole Board Buck- Boost converter is inserted. The values can be altered to suit the values of any Buck- Boost converter that is modeled.

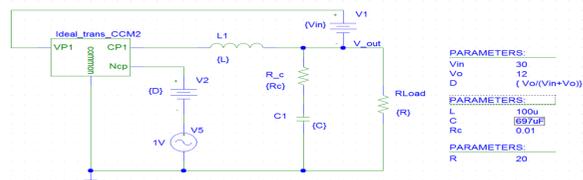


Figure 2 : Buck- Boost Converter Dynamic Average Model in PSPICE

In the figure 3, the frequency response of buck- boost converter is illustrated to determine the lowest point in phase angle that was 3khz for find out crossover frequency which is equal to 3KHz. This ensure that the phase angle of loop remain greater than -180 degrees.

. However, the original frequency of the circuit is 600Hz cause it is beyond to L-C response frequency = $\frac{1}{(2\pi\sqrt{LC})}$.

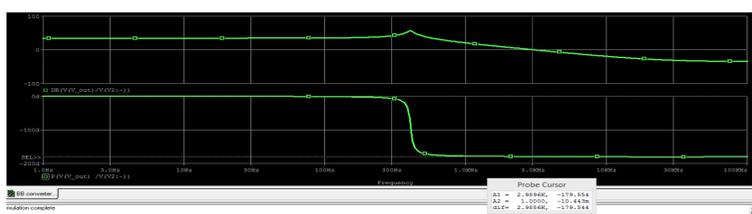


Figure 3 : The frequency response of buck boost converter

Also, by using PSPICE simulation software, Author can get on Bode plot of the gain of power stage $G_{ps}(s)$ of buck- boost converter where the gain was = -25db = 19 Amplitude and the phase angle of power stage $G_{ps}(s)$ of buck-boost converter by using probe cursor, Author get the phase angle = -89.

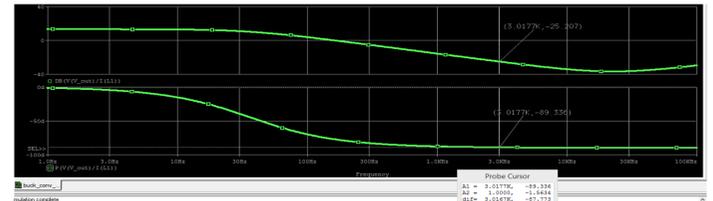


Figure 4: Bode Plot of Buck- Boost converter

Design of Feedback Control Compensator

The design of control feedback loop compensator in the figure (5) has made to befit the power stage transfer function $G_{ps}(s)$, PWM transfer function $G_{PWM}(s)$, and sensing equipment K_F .

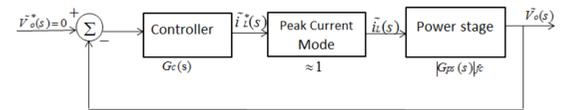


Figure 5: close loop feedback control

After author find the bode plot of power stage buck- boost converter, now the transfer function of controller should be determined for illustrating the components of controller such as resistor s R and capacitors C by using the equations below.

$$G_c(s) = \frac{K_c(1+s/\omega_z)}{s(1+s/\omega_p)} \quad \text{Equation 2: controller transfer function}$$

$$\phi_{boost} = -90^\circ + \phi_{PM} - \angle G_{PS}(S)|_{f_c} \quad \text{Equation 3: The require phase boost}$$

$$K_{boost} = \tan(45^\circ + \frac{\phi_{boost}}{2}) \quad \text{Equation 4: K factor according to Mohan [1]}$$

$$f_z = \frac{f_c}{K_{boost}} \quad \text{Equation 5: Frequency in Hertz at which transfer function zero occurs}$$

$$f_p = K_{boost} f_c \quad \text{Equation 6: Frequency in Hertz at which transfer function pole occurs}$$

$$k_c = \omega_z |G_{ps}(s)|_f \quad \text{Equation 7: gain of feedback amplifier}$$

From figure 3, and 4 , Both of crossover frequency, gain, phase angle has been found out. Therefore Author could find $\phi_{boost} = 59.56^\circ$, $K_{boost} = 3.67$, $f_z = 817.44Hz$, $f_p = 11.01kHz$, and $K_c = 97592.4$. Then, from equation 2, the controller implementation of $-G_c(s)$ has been developed, according of Mohan [1].

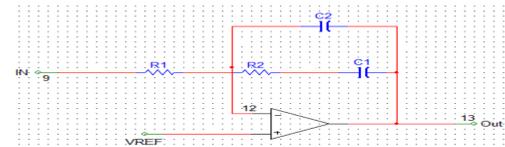


Figure 6: The controller implementation $-G_c(s)$

The transfer function of equation 2 can be comprehended by an op-amp circuit shown in the figure 6 that can be derived to get on the equation of R and C by obtaining the input-output relationship and comparing it with the transfer function. First assuming $R_1 = 10\Omega$ hence,

$$C_2 = \frac{\omega_z}{\omega_p R_1 K_c} = 78PF, \quad C_1 = C_2(\frac{\omega_p}{\omega_z} - 1) = 972.5PF, \quad \text{and} \quad R_2 = \frac{1}{(\omega_z C_1)} = 205K\Omega$$

After getting on the value of parameters, Author connects the practical circuit of controller figure 7- a into power pole board to test the controller circuit.

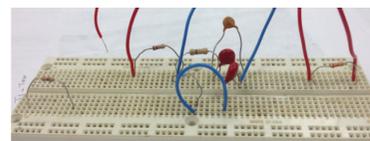


Figure 7- a : the practical controller Figure 7-b: the ports of power board

VREF (potentiometer) is used as a set point for the output voltage by controlling the duty ratio D. The output voltage, when VREF is minimized, can be set to 10 volts, but might approach the input voltage when VREF is maximized. All voltages in between are achievable. During test in the lab, Author set the VRFE at 16.5v and the input was varied from 5- 20v the out put was stable at 16.8v which is the set point.

Conclusion

The goal of this poster is to design feedback controller of buck- boost converter and test the practical control circuit by using the power pole board, then Author can use this project to control the output voltage from solar panel that is oscillating cause the weather condition to charge 12v rechargeable battery.

Future work

Although the general concert of the feedback control matches the purposes of the project, there are some points that could enhance the system future work.

- Getting the bode plot of the power stage (buck- boost converter) system by using MATLAB software that can be through applying transfer function equation 1.
- Operation of a controller using a discrete microcontroller with an external PWM.

References

- [1]- Mohan, N., *Power Electronics: A First Course*. 2012, Hoboken NJ: John Wiley & Sons, Inc. 270.
- [2]- Department of Electrical & Computer Engineering, *Power Electronics Laboratory User Manual*, U.o. Minnesota, Editor 2011.