DESIGNING AND SIMULATION THE STABLE COMPENSATION NETWORKS FOR BUCK BOOST CONVERTER FOR WIND ENERGY SYSTEM FOR LOW POWER APPLICATION

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ABSTRACT

Because of combustion of fossil fuels global warming caused by environmental problems, the raising prices of crude oils and natural gases. They promote continuous effort to improve energy system and its efficiency. There is a need to search for abundant and clean energy sources due to the depleted and increasing prices of oil. Wind energy acts as an alternative renewable energy source.

Wind energy is used as renewable energy system. Wind generator is used to generate ac voltages. This ac voltage is given to rectifier and then to Buck boost converter. The buck boost converter output is given to battery to inverter and load. Buck boost converter gives constant output which will control by PWM controller and feedback control system. Feedback control system has compensation network with different types and parameters. Depending upon parameters and controlling method, we have to decide stability analysis using Bode Plot. This analysis is carried out by using MATLAB software.

It will be used to design buck boost converter with different parameters which gives constant output. It is helpful for optimizing feedback-loop design for the best transient response while maintaining a comfortable margin for stability. Design for highest gain and bandwidth feedback loop. It is useful to study different controlling methods and comparison. It is used to select switching frequency, power inductor, selecting capacitors and verify the quality of the output voltage, harmonic content of the output voltage.

KEYWORDS: Buck Boost Converter, Compensation Network, Design Parameters, Stability, Wind Energy Conversion System

INTRODUCTION

Nowadays it is easy to see increasing role of renewable energy and its growing interest in whole produced energy, mainly because of ecological reasons. Demands for wind energy are increases significantly.

The state of art is that the wind farm market is widely known and widely explored. However it is focused mostly on high power (hundreds of kW) power stations. There is still gap in low power plant application. It is so-called small wind turbines which swept area is smaller than 200m^2, and generating power is in the range of 1-10kW. Moreover there is still need to set a low power self sufficient system.

The wind energy system extracts the wind energy and converts it to the electrical energy. The output of wind energy varies depends on the wind speed. Due to nonlinear characteristics of wind turbine, it is challenging task to maintain the maximum power output of the wind turbine for all wind speed condition. There is simple approach to track maximum power from wind turbine is buck boost converter.

In this system output of wind system is variable with respect to different operating condition. So as to get constant output from wind system we connect the output of wind generator to rectifier and then to buck boost converter to battery and battery to inverter and load. For making the constant output, we have to design system parameters and stability circuits. We developed the compensating circuit which gives stable output under different conditions.

WIND GENERATOR MODEL

Wind energy system converts the kinetic energy of the wind into the electrical energy. The mechanical power of the wind can be expressed as

$$P_{\text{wind}} = \frac{1}{2}\rho\pi R^2 V_w^3 \tag{1}$$

Where ρ is the air density,

R is the turbine radius,

V_w is the wind speed.

In this system

Model 1: Small wind turbine with low speed permanent magnet synchronous generator

Model 2: Rectifier which gives constant dc output

Model 3: BUCK BOOST converter which gives constant output voltage with maximum power with suitable feedback control system which charges the batteries.

DESIGNING OF BUCK BOOST CONVERTER TOPOLOGIES

Buck-Boost converter is combination of a buck and boost converter. It can be an inverting topology where the output voltage is of opposite polarity as the input. It can also act as a buck converter follow by the boost converter function.

When the switch is in the "on state", the inductor stored the energy in the magnetic field as it is connected with the source voltage where currents will flow through. The diode is reversed biased and hence no current can flow to the load through the diode. The capacitance will provide current in this "Ton" situation. When the switch is off, inductance is disconnected from the source and there will be no current drop which the inductance will reverse it EMF. A voltage is generated as the diode at this time is forward biased; current will flow in the load and charged up the capacitance.
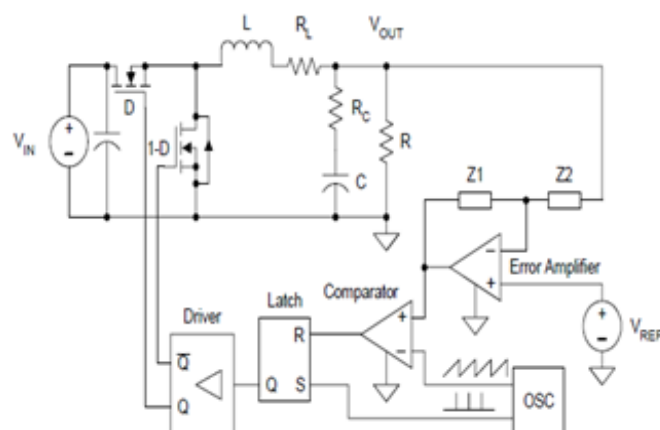

Figure 1: Buck Converter with Feedback System

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The converter is made up of an input source voltage, an inductor, a switch, capacitor and the output load. This type of configuration is use to boost up the output voltage with a lower input source. Most of the designs usually specified the require value of input voltage, output voltage and the load current whereas the inductor and ripple current are free parameters. To reduce a ripple, a larger value of inductor should be able to reduce it since it is inversely proportional to the ripple current. Likewise when choosing the inductor, it should ensure the saturation current is greater than the inductor peak current and able to cope with the rms current.

While designing the buck boost converters following main points are considered [3,4]

- Input voltage to converter

- Desired supply output voltage magnitude

- DC-DC converter efficiency (Pout / Pin)

- Output voltage ripple

- Output load transient response

- Output load transient response

- Duty cycle of PWM controller

For design of this buck boost converter, the output of the converter is designed for 24 V which is given to the Battery. Output voltage=24V

Design of Power Inductor

The power inductor is a very important component within the boost dc-dc design. The inductor value is closely linked with the input voltage, the output voltage, the forward voltage of the diode, the duty cycle, the load current as well as the switching frequency.

$$L = \frac{[V_{out} - V_{in} + V_D][1 - D]}{\min{(i_{load})}f}$$

Current rating of inductor is given by

$$I_{pk} = \frac{V_{input}}{2 * f * L}$$

The minimum inductor value can be found

$$L_{min} = (V_{out} - V_{in} + V_F)(1 - D) / \min(i_{load})f$$

Selecting Switching Frequency

For the different values of frequency the values of inductors are calculated.

Table 1

Switching Frequency	Inductor Value
50	158
100	79
200	40
400	20
500	16
1000	8
1500	5
2000	4

Design of Power MOSFET

Low power loss Mosfet is selected depending on rating.

PWM Controller

The basic idea is to control the duty cycle of a switch such that a load sees a controllable average voltage. To achieve this, the switching frequency is chosen high enough. With pulse-width modulation control, the regulation of output voltage is achieved by varying the duty cycle of the switch, keeping the frequency of operation constant.
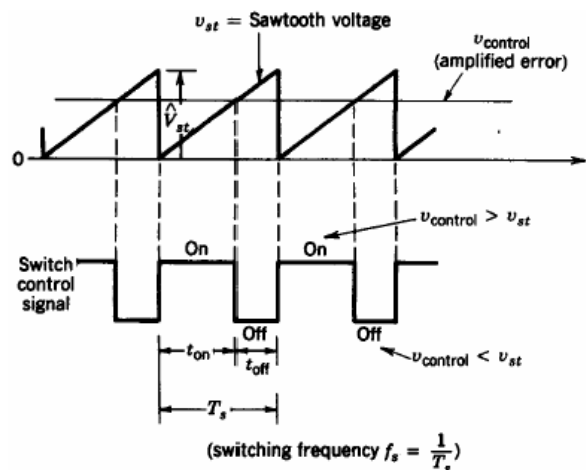
Duty ratio-D = ton/ (ton + toff)

Figure 2: Duty Cycle

Power Efficiency

Power Efficiency of a Buck Converter changes with a change in the load

CONTROLLING METHODS

Voltage Mode Control

This is a simple method in which there is only one feedback from the output voltage. The input voltage is a main parameter in the loop gain, any changes in the input voltage will alter the gain and will change the dynamics of the system. The voltage mode controller alone cannot correct any disturbances or changes until they are detected at the output. In the voltage based controllers the compensation loop is difficult to implement [8].
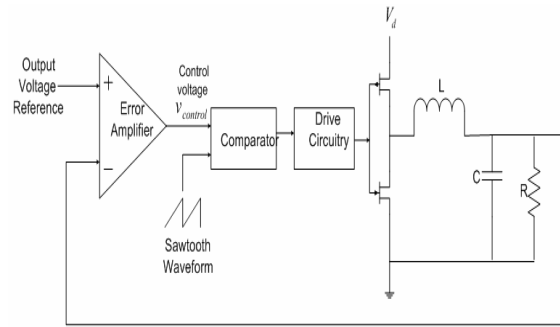
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Figure 3: Voltage Mode Control

Current Mode Control

In a current-mode control, an additional inner control loop is used. The control voltage directly controls the output inductor current that feeds the output stage and thus the output voltage. The control voltage should act to directly control the *average* value of the inductor for the faster response.
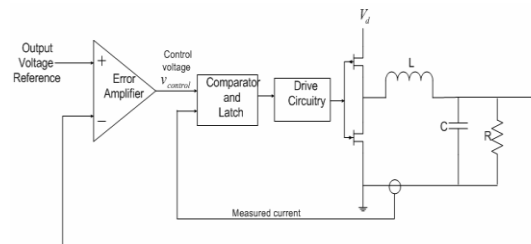

Figure 4: Current Mode Control

STABILITY CRITERIA

To accomplish regulation we need to add a feedback loop Also we need to introduce a high DC gain. But with high gain again comes the possibility of instability. These two issues determine the need to have stability criteria 1) feedback compensation design involves selection of a suitable compensation circuit configuration 2) positioning of its poles and zeros to yield an open loop transfer function. Following points to be considered for stability [5, 6]

- Variations in input voltage do not cause instability.

- Allow for variations in the peak-to-peak oscillator voltage.

- Error amplifier has sufficient attenuation at the switching frequency.

- Mid-frequency gain is greater than zero to prevent a large overshoot at turn-on and during transient conditions.

- Error amplifier has the drive capability to drive the feedback network properly.

- The phase margin determines the transient response of the output voltage in response to sudden changes in the load and the input voltage.

- Gain Margin is the difference between unity gain (zero dB) and the actual gain when the phase reaches 180°. The recommended value is -6dB to -12 dB.

Type III Compensation

The Type III compensation circuit has two poles, with two zeros and a pole at its origin providing an integration function for better DC accuracy.
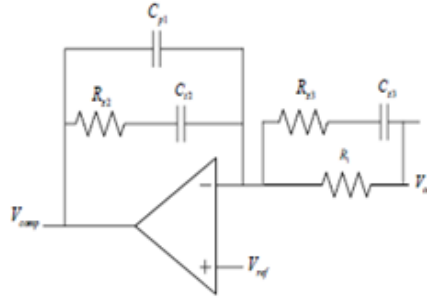
Figure 5: Type III Compensation Circuit

Optimal selection of the compensation circuit depends on the power-stage frequency response [6]. There are certain guidelines that can be used for positioning the poles and zeros and for calculating the component values.

- Choose a value of R1

- Select a gain (*R2 / R1*) that will shift the Open Loop Gain up to give the desired bandwidth. Following equation will calculate an 2 *R* , that will accomplish this given the system parameters and a chosen *R*1 .

$$R_2 = \frac{DBW}{F_{LC}} \cdot \frac{\Delta V_{OSC}}{V_{IN}} \cdot R_1$$

- Calculate C2 by placing the zero at 50% of the output filter double pole Frequency

$$C_2 = \frac{1}{\pi R_2 F_{LC}}$$

- Calculate 1 C by placing the first pole at the ESR zero frequency

$$C_1 = \frac{C_2}{(2\pi R_2 C_2 F_{ESR}) - 1}$$

- Set the second pole at half the switching frequency and also set the second zero at the output filter double pole This combination will yield the following component calculations

$$R_3 = \frac{R_1}{\left(\frac{f_{SW}}{2F_{LC}}\right) - 1}$$

$$C_3 = \frac{1}{\pi R_3 f_{SW}}$$

Transfer function for type III compensation is given by

$$GAIN_{TYPEIII} = \frac{R_1 + R_{z3}}{R_1 \cdot R_{z3} \cdot C_{p1}} \cdot \frac{\left(s + \frac{1}{R_{z2} \cdot C_{z2}}\right) \cdot \left(s + \frac{1}{(R_1 + R_{z3}) \cdot C_{z3}}\right)}{s\left(s + \frac{C_1 + C_2}{R_{z2} \cdot C_{p1} \cdot C_{z2}}\right)\left(s + \frac{1}{R_{z3} \cdot C_{z3}}\right)}$$

Type III compensator is used to compensate a second-order LC filter. A traditional type III compensator is sufficient to stabilize the synchronous buck converter for all three modes subsequently being voltage mode control, current mode control.

CALCULATIONS AND RESULTS

According to the above steps if we design buck boost converter for the output of 24 V for any input voltage to the

converter from the solar panel or system. We write a MATLAB programming for finding the different parameters for type III compensation. [5]

For this consider RL = 10Ω, ESR = DCR = 1, R1 = 50 kΩ. Switching frequency =10 Khz

From MATLAB programme results are as follows

Table 2

C	10 μF
L	68.11μH
R1	40 kΩ
Cz2	264 pF
Rz2	143 kΩ
Cp1	46 pF
Rz3	20 kΩ
Cz3	247 pF
Vripple	23.95 mV
Iripple	16.63 mA
Efficiency (%)	72.2

For the above values, we can calculate the transfer function for the Buck Boost converter, compensation network. From transfer function we plot BODE PLOT for Stability analysis and find out Gain Margin and phase Margin. We write programming for plotting the BODE PLOT and results are shown
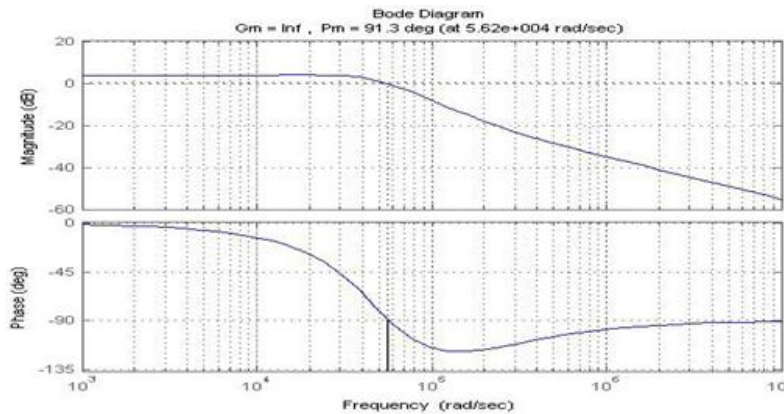
Bode Plot of Buck Converter

Figure 6: Bode Plot Buck Converter

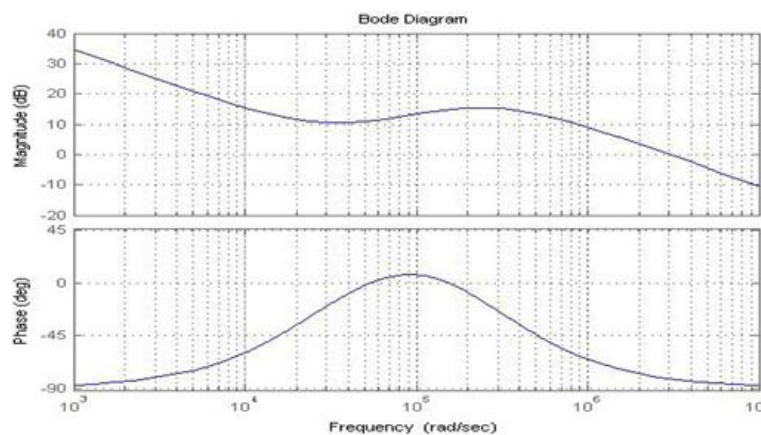**Bode Plot of Type III Compensation Network**

Figure 7: Bode Plot Type 3 Network

CONCLUSIONS

In this paper we develop renewable energy system using wind energy as the main source of energy. The output of wind is given to rectifier and then to buck boost converter. We have calculated different parameters of buck boost converter such as power inductor, duty cycle for PWM controller and capacitors. For stability analysis we designed feedback control system compensating network with type III and its transfer function gives detailed stability analysis by plotting bode plot. Design for highest gain and bandwidth feedback loop. It is helpful for optimizing feedback-loop design for the best transient response while maintaining a comfortable margin for stability. A phase margin ranging between 45°and 60° is recommended to avoid instability. The type 3 compensation circuit is used for voltage-mode control because of design flexibility.

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