Buck Boost Converter for Small Wind Turbine

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***Abstract*- The Domestic Wind Machines are extensively used in both rural and urban areas to generate electric power from wind energy. In Domestic Wind Machines, if the wind speed is low, the output voltage of the Wind Machine after rectified into DC is less. The battery will not charge as it is lower than the rated charging voltage. This happens most of the time in a day, since the wind speed in domestic regions is in the range of 0 to 4 m/s. This limits the efficiency of a conventional domestic Wind Machine to 20%. Hence by implementing a controller based Buck Boost converter, the voltage produced at the lower wind speeds can also be utilized effectively by boosting it to the rated charging voltage of the battery. This paper deals with the design of cascaded buck boost converter for small wind turbine connected to the battery**.

Index Terms— maximum power point tracking, wind turbine

I. INTRODUCTION

Due to the exhaustion of fossil fuel and environmental problems caused by conventional power generation the focus has been shifted to the power generation by renewable energy, among them are the wind generator are most commonly used. Wind turbine are used in many applications such as battery charging, water pumping, home power supply, swimming pool heating system , satellite powering system etc..Wind generators have lower installation costs compared to the photovoltaic; hence the overall system cost can be reduced by using high efficiency power converter. They have advantage of being pollution free and free of cost. Though wind energy has many advantages the development is only in the preliminary stage. The wind energy is converted to electrical energy by exacting potential energy from wind to kinetic energy.

Even if there is abundant amount of energy available, there are many researches going on to extract maximum power by wind turbine. This paper deals with small wind turbine which is connected to a battery. Wind power depends purely on the wind speed, as the wind speed is not constant the wind power is always varying. For charging a battery the voltage has to be constant. In an existing system as shown in fig1, the rectified output is directly used to charge the battery. The battery will not charge even if there is a considerable amount of voltage available. At the most 30 % of output load is wasted due to this problem, due to which the overall efficiency of the system decreases to 20%

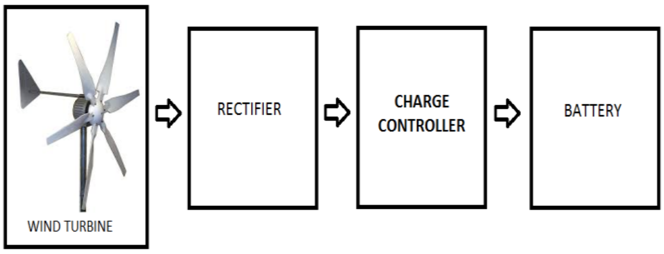

Fig1. Block of Existing wind energy system

There must be a control strategy to get the voltage of the turbine constant as shown in fig 2, hence an cascaded buck boost converter has been designed. When the wind energy is low the converter boost the output voltage and gets to constant voltage similarly when wind speed is high the converter operates in buck mode so as to reduce the voltage to keep the voltage constant and also to protect the system from damage.

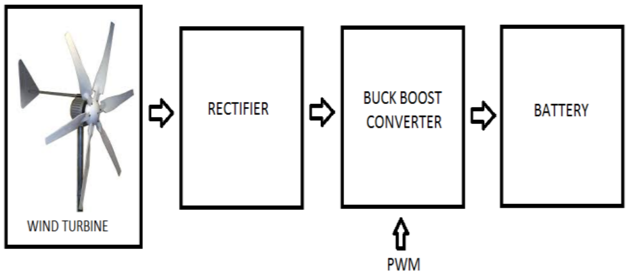

Fig 2: Block of proposed system

In this paper, a cascaded DC DC converter has been presented and studied for small scale wind energy system. The cascaded DC DC converter consists of Boost converter and a buck converter in series with each other to optimize the wind energy for all specified wind speed.

II PROPOSED SYSTEM

In this paper a based buck boost converter is designed to utilize the voltage produced by the wind turbine even at very low speed. According to the input of the buck boost converter the switches are controlled. Hence at lower speed the boost converter is activated and at higher speed the buck converter is activated, Hence charging the battery at very low speed and at very high speed and also protecting the battery from damage.

Cascaded buck boost converter: An buck boost converter is a DC DC regulator which provides output either higher than or lower than the input provided. The proposed system consists of an output boost converter and input buck converter. The boost converter is activated for duty cycle more than 0.5 and buck converter is activated for duty cycle more than 0.5. Among all the possible converters available buck boost converter is the most applicable one as it

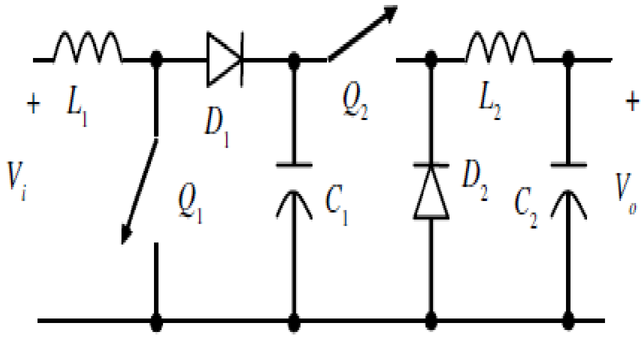

Fig 3: cascaded buck boost converter

provides a significant improvement in the performance of the system and also increases the efficiency of the overall system. In conventional buck boost converter the output is inverted and the output produced is too low. Hence an cascaded buck boost converter has been designed the operating modes of the system is similar to that of the conventional buck boost converter.

Operating Modes: the circuit operates in two modes

Mode1: When switch 1 is Provided with PWM signals and when switch 2 is closed it operates as an boost converter. Hence buck converter is in stand by mode.

Mode 2: When switch 2 is provided with PWM signal and switch 1 is open it operates as an buck converter. Hence the boost converter is stand by mode.

If the duty cycle of PWM is below 50%, the circuit bucks the output voltage as the amount of energy stored is less and if it is above 50%, the output voltage will be boosted to the nominal battery charging voltage operation of Buck Boost converter may be in Continuous Current Mode (CCM) or Discontinuous Current Mode (DCM) of operation depending on the Wind Machine output. The converter should be operated in CCM to charge the battery which depends on the value of the inductor and the load.

Conversion ratio: Conversion ratio is the ratio of input to output voltage of the converter.

$$M(D)=V_0/V_i$$

As the duty cycle is less than 0.5 the converter conversion ratio is less than 1 hence the system works in buck mode. As the duty cycle is more than 0.5 the conversion ratio is greater than one hence the system works in boost mode and for normal mode the duty cyle is to be in range of 0.58 to 0.68.

III DESIGN OF CASCADED BUCK BOOST CONVERTER

The most important part of the converter design is to choose proper inductor value and capacitor value as the output purely depends on the value of inductor and capacitor used. For getting an proper DC voltage filtering is important hence inductor and capacitor plays an important role in getting an stiff DC. The system has to work in continues current mode so as to charge the battery connected. For operating in continuous current mode the inductor value mist be chosen very high. If their values are low, then the high switching frequency is needed to obtain the same voltage level. This increases the cost of the switch involved. Therefore it is necessary to choose optimum values of L and C.

Inductor Selection: data sheets give a range for selection of inductor. usually an higher range of inductor has to be chosen. For buck mode the following equation is a good estimate for the right inductance:

$$L > \frac{V_{out} * (V_{inmax} * V_{out})}{K_{ind} * F_{sw} * V_{inmax} * I_{out}}$$

For boost mode the following equation is a good estimate for the right inductance

$$L > \frac{V_{inmin^2} * (V_{out} - V_{inmin})}{F_{sw} * K_{ind} * I_{out} * V_{out^2}}$$

Where:

Vinmax = maximum input voltage
Vinmin = minimum input voltage
Vout = desired output voltage
Iout = desired maximum output current
Fsw = switching frequency of the converter
Kind = estimated coefficient that represents the amount of inductor ripple current relative to the maximum output current

Capacitor selection: To select the capacitor the best practice is to use low-ESR capacitors to minimize the ripple on the output voltage. For buck mode, below equations are used to calculate the minimum output capacitor value for a desired output voltage ripple.

$$C_{outmin} = \frac{K_{ind} * V_{out}}{8 * F_{sw} * V_{out_{ripple}}}$$

For boost mode the following equations are used to adjust the output capacitor

$$C_{outmin} = \frac{I_{out} * D_{boost}}{F_{sw} * \Delta V_{out}}$$

Where:

Coutmin= minimum output capacitance required
Fsw = switching frequency of the converter

Voutripple = desired output voltage ripple
Iout = desired maximum output current
Kind = estimated coefficient that represents the amount of inductor ripple current relative to the maximum output current.
For boost mode the following equations are used to adjust the output capacitor
ΔVout = desired output voltage ripple

IV. SIMULATION RESULTS

The proposed system performance has been evaluated by simulation in tool called MATLAB simulink software. This software is used as it has the ability to simulate both dynamic system and electronic system such as switch mode power supplies. The simulation tool also helps in testing the validity of the design and save the cost by reducing the changes in error. Any defect in design can be easily identified and rectified well before the implementation thus saving cost and time.

The simulation parameter of the converter is calculated as given in previous chapter and is listed in table 1

Parameters	Values	Units
Inductor 1	5	mH
Capacitor 2	6	mF
Inductor 1	6	mH
Capacitor 2	33	µF

Table 1: simulation parameters

The cascaded buck boost converter simulink model is as shown in figure 4 .In this case, the switches are controlled according to the duty cycle as mentioned above. If duty cycle is more than 0.5, than boost mode is selected and if duty cycle is less than 0.5, buck mode is selected.
For generating gate pulse, a duty cycle reference signal is compared with a carrier signal of constant frequency to generate the PWM signal for the MOSFET. The output switching signal equals 1 if reference signal amplitude is greater than the carrier signal amplitude; else it equals 0.

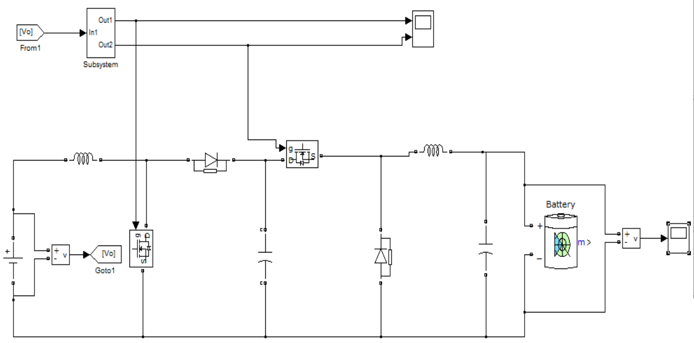

Fig 4: Simulation of cascaded buck boost converter

Figure 5 is the waveform of inductor currents, when above model was simulated
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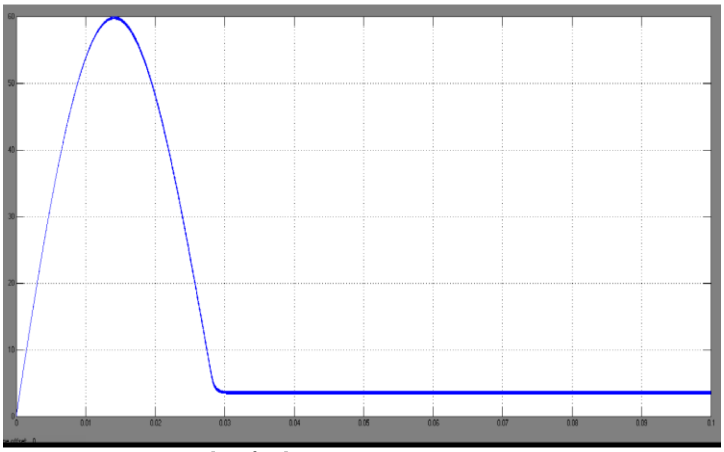

Fig 5: plot of induction current versus time

Figure 6 is the waveform of inductor currents, when above model was simulated

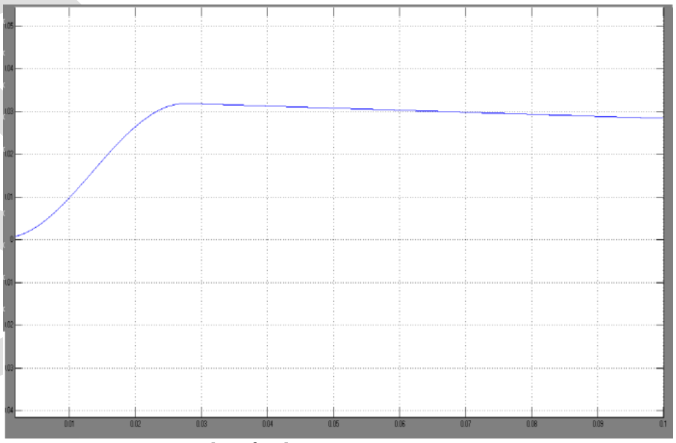

Fig 6: plot of induction current versus time

Figure 7 is the waveform of output voltage, when above model was simulated.

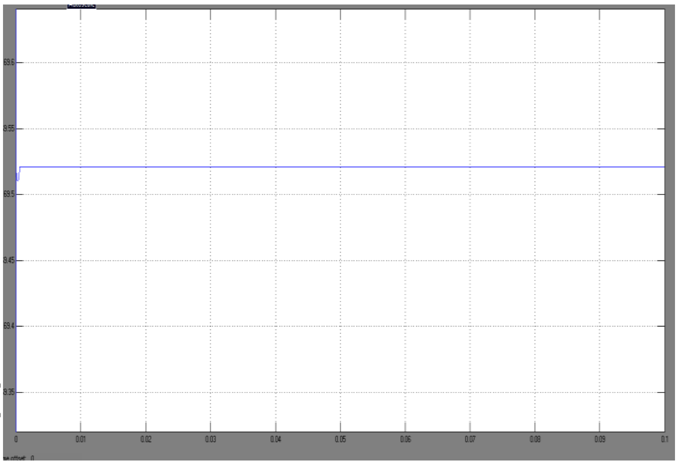

Fig 7: plot of output voltage versus time

The system was simulated for battery of 70 V, as observed in the plot the voltage is around 69 V at very low input voltage. The oscillation can be reduced by using PID controller.

CONCLUSION

In this article, a consistent modeling of a complete wind energy conversion chain has been presented. This, unfortunately, is not so easy and not so widespread. The proposed system of controller based cascaded Buck Boost converter is found to be more compact, user friendly and more efficient. Hence the voltage produced at lower wind speeds is also effectively utilized and the efficiency of the proposed system is 15% higher than the existing system.

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