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Research Paper

VOLTAGE VARIATION CONTROL OF WIND ENERGY USING BUCK BOOST CONVERTER

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***Abstract*—This project explores the application of a Buck-Boost Converter for managing wind energy, specifically aimed at addressing the issue of voltage variations in the output from wind turbines. The objective is to ensure a consistent output voltage during electricity generation, thereby improving the reliability of wind power supply. While there have been notable advancements in wind technology, further enhancements are necessary to optimize power control under diverse loading conditions. The use of a single power MOSFET with a low on-resistance (RDS-ON) is shown to significantly enhance the efficiency of the proposed converter design. This study includes a detailed technical overview, mathematical analysis, and a comparative review of similar systems found in existing literature. A laboratory setup was conducted with a load power rating of 100W at a switching frequency of 50 kHz to validate the performance of the converter. By integrating the Buck-Boost Converter across the DC link, we can maintain a stable voltage supply, which is crucial for consistent electricity distribution under varying environmental conditions. Simulation results were conducted using MATLAB/SIMULINK.**

key words: Wind Energy, Buck Converter, Boost Converter

I.INTRODUCTION

The Wind energy is a renewable and sustainable power source, but its main challenge is the variability of wind speed, which leads to fluctuations in output voltage. These voltage variations make it difficult to maintain a stable power supply, essential for efficient energy conversion and use. To address this, a Buck-Boost Converter is used to stabilize the output voltage from wind turbines. The converter operates by boosting voltage during low wind speeds and reducing it during high wind speeds, ensuring a constant voltage for optimal energy storage and usage. The system's performance can be monitored remotely through GSM technology, which tracks parameters like voltage, current, and wind control. Utilizing wind energy reduces dependence on imported fossil fuels and boosts local economies by creating jobs, especially in rural communities. Although wind energy is considered environmentally friendly and pollution-free, concerns about its impact on local climates, such as causing droughts, still exist. Nonetheless, wind energy continues to grow as a viable alternative to conventional energy sources, with ongoing research aimed at improving system efficiency and stability.Energy production from wind is becoming more popular nowadays as it is abundant, in-exhaustive, environmentally friendly, and pollution free. Wind energy generation has increased much with the development of power electronic converters. Power electronics plays a vital role in achieving high efficiency and good performance in variable speed wind energy conversion systems. Variable speed wind turbines have many advantages over fixed speed wind turbines like increased energy capture, operation at maximum power point, higher efficiency, and improved power quality. With wind energy being intermittent in nature, it is important to increase the voltage output of the wind generator during low wind speeds. This is achieved by using a buck-boost converter. The output voltage of permanent magnet synchronous generator (PMSG) driven by wind turbine is stepped up for low wind speeds and stepped down for high wind speeds and is maintained constant with a PI controller. Design of Buck-Boost Converter for Wind Energy Conversion System 398 The paper is arranged as follows. Section 2 describes the wind turbine modelling and section 3 presents the modelling of PMSG. The design of buck-boost converter is brought in section 4 while section 5 describes the design of PI controller for the converter. In section 6 the Cascaded H-Bridge (CHB) multilevel inverter is designed to increase the voltage output. Simulation results are presented in section 7 and conclusion.

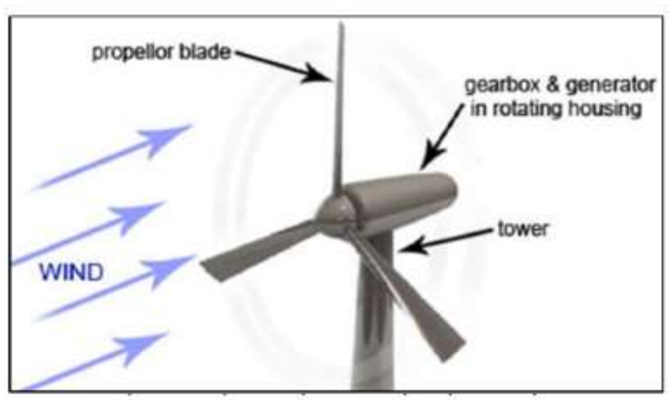


Fig.1.1: Typical horizontal Axis wind turbine

The mentioned converter isa quadratic buck-boost converter with low ripple content through output current. Although Such Structures arevery capable of working in high voltage applications because of using quadratic voltage gain, their control systems are complicated and the system cost is high.The converters in are single switch to buck-boost converter that they have more advantages such as better efficiency, simple structure with simple control and higher power density. However, the fundamental issue related to these topologies is the high peak voltage of switches and also, the input voltage variations cannot be made over a wide range. There is another buck-boost converter based on switching capacitor technique, which has been proposed in recent past years. This buck-boost converterscan get relevant voltage gain with low current ripple content which leads to decreasing the EMI noise. However, this converter is operating ina hard switching condition that leads to increase the losses of the power converter and also it has large peek voltage throughout the switch. The buck-boost converter operates using a switch, typically a transistor, and a diode, which control current flow through an inductor and a capacitor. During the switch's ON state, energy is stored in the inductor, and during the OFF state, the energy is transferred to the output through the diode. The duty cycle of the switch, or the ratio of ON time to the total period of the switching cycle, determines the converter's output voltage. Adjusting the duty cycle allows the output voltage to be controlled and maintained at the desired level. A Buck-Boost Regulator produces an output voltage which may be less than or greater than the input voltage. The polarity of output voltage is opposite to that of input voltage. So, this regulator is also known as inverting or flyback regulator.

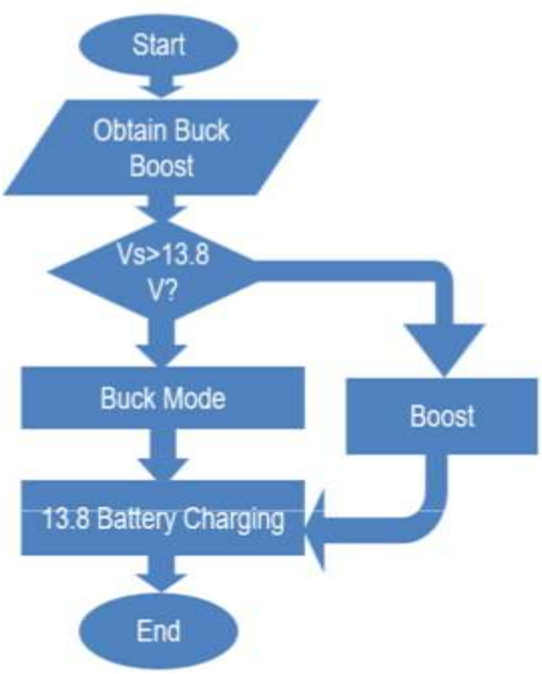


Fig:1.2. Flow Chart

The mentioned converter in a quadratic buck-boost converter with low ripple content through output current. Although such structures are capable of working in high voltage applications because of using quadratic voltage gain, their control systems are complicated and the system cost is high. The converters in are single switch buck-boost converter that they have advantages such as better efficiency, simple structure with simple control and higher power density. However, the fundamental issue related to these topologies is the high peak voltage of switches and also, the input voltage variations cannot be made over a wide range. There is another buck-boost converter based on switching capacitor technique, which has been proposed in recent past years. This buck-boost converter can get relevant voltage gain with low current ripple content which leads to decreasing the EMI noise. However, this converter is operating in hard switching condition that leads to increase the losses of the power converter and also it has large peek voltage throughout the switch.

1.1 Objectives of the project

Wind energy is play vital role in day to day life. The buck boost converter is useful for control voltage variation. For extension we can interface solar power with same system so the output voltage remains constant with the help of buck-boost converter. In addition we can use artificial intelligence control instead of PWM technique so that the output voltage becomes more constant and stable. We can use GSM technology to monitor the system output over mobile or computer.The main objective of a buck-boost converter is to receive an input DC voltage and output a different level of DC voltage, either lowering or boosting the voltage as required by the application.

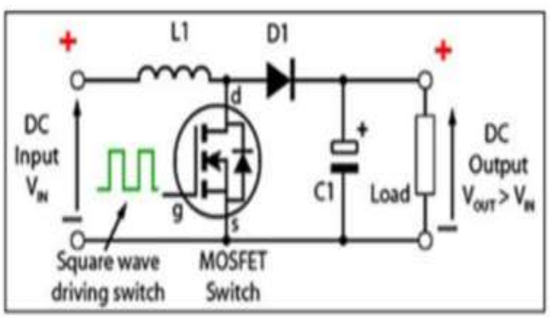
II.METHODOLOGY

In this study, a horizontal axis wind turbine (HAWT) is employed for domestic-scale power generation. A buck-boost converter is used to regulate the output voltage of the wind turbine, ensuring stable power delivery despite the variability in wind speed. A five-blade small-scale wind turbine, coupled with a DC generator, is utilized to generate electrical power. The annual energy production and efficiency of the system are affected by power losses such as friction and ohmic losses, which are modeled in the wind turbine system. The wind speed vvv is defined as an average value over a 10-minute interval, neglecting sudden changes. The simulation uses a wind speed ramp as the input for the turbine model, capturing the wind's fluctuating nature.

The wind turbine's rotor is designed to convert the wind's kinetic energy into mechanical power. The power coefficient CPC_PCP, which relates wind speed to actual power output, is defined through a lookup table. The turbine's gearbox and generator are connected to the rotor, and their associated torque and speed are modelled, with losses in the gearbox taken into account.Wind turbines typically operate in the range of 3-15 m/s wind speed to maximize efficiency. At higher wind speeds (15-25 m/s), aerodynamic power control is implemented to avoid turbine damage. Buck-boost converters are used in this system to control the charging voltage of the battery. Under low wind conditions, the converter operates in boost mode, increasing the output voltage; conversely, during high wind speeds, the converter operates in buck mode to lower the voltage and protect the system from overvoltage conditions. Without this control, up to 30% of the energy is lost, decreasing the system's overall efficiency to about 20%.

2.1 Control Strategy: Buck-Boost Converter

The primary goal of the buck-boost converter is to regulate the voltage from the wind turbine to match the battery's charging requirements. In low-wind conditions, the converter boosts the voltage to the required level, whereas, in high-wind conditions, it reduces the voltage to prevent battery damage. The converter operates based on pulse-width modulation (PWM), where the duty cycle adjusts the output voltage. fluctuations in wind speed, ensuring the stability of



the inverter's DC output.Wind energy is play vital role in day to day life. The buck boost converter is useful for control voltage variation. For extension we can interface solar power with same system so the output voltage remains constant with the help of buck-boost converter. In addition we can use artificial intelligence control instead of PWM technique so that the output voltage becomes more constant and stable. We can use GSM technology to monitor the system output over mobile or computer.

A schematic diagram of the converter's operation is shown in Figure 3.1, highlighting the PWM control mechanism that adjusts the duty cycle for efficient energy conversion. The advantage of using a buck-boost converter lies in its ability to both step-up and step-down the voltage, which is crucial in applications like wind energy where the input voltage is highly variable.

Fig.2.1: Buck Boost Converter

2.2 Operation of Buck and Boost Converters

The buck converter is a DC-DC converter designed to step down the voltage. During its operation, the switch turns on and current flows through an inductor, storing energy in its magnetic field. When the switch is turned off, the energy stored in the inductor is released to the load through a diode. The output voltage is regulated by adjusting the duty cycle of the switch. This configuration ensures that the voltage is reduced to the desired level.

Conversely, the boost converter operates by stepping up the input voltage. The switch is periodically turned on, allowing current to flow through the inductor and store energy. When the switch is turned off, the inductor's magnetic field collapses, forcing the current to flow through a diode and increase the output voltage. The boost converter is designed to operate at a constant frequency, and its output voltage is always higher than the input voltage.The operational characteristics of both the buckand boost converters are essential for stabilizing the voltage output in a system powered by wind energy, where the input voltage can fluctuate significantly due to changing wind conditions.

III. MODELLING AND SIMULATION

A detailed simulation model of the buck-boost converter was developed using Simulink, where both buck and boost modes of operation were tested. Figure 3.2 shows the Simulink model of the buck converter operation, while Figure 3.3 illustrates the boost converter operation. The simulation results demonstrate that the converter successfully maintains a stable output voltage, ensuring efficient charging of the battery and protecting the system from damage under varying wind conditions.

The simulation model utilizes PWM control, adjusting the duty cycle to maintain the output voltage in a controlled range. The stability of the converter under varying load and input voltage conditions was verified through extensive testing. The results showed that the converter operates efficiently, with minimal losses and a high voltage conversion ratio, making it suitable for integration into wind energy systems.

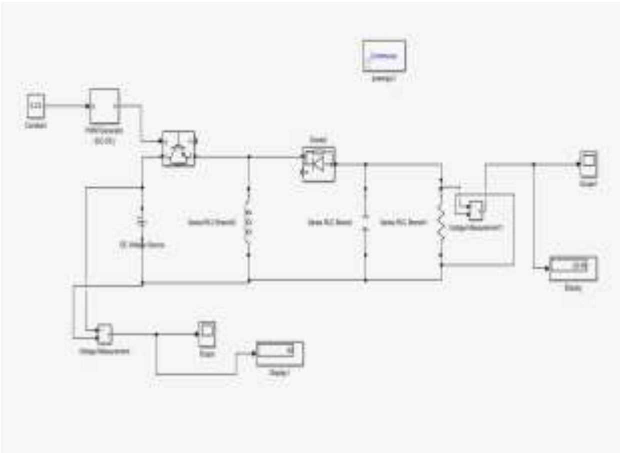


Fig.3.1: Simulink model of Buck Operation

A buck converter, also known as a step-down converter, operates by transferring energy from an input to an output through a capacitor, inductor, and switches. The operation of a buck converter can be explained in two modes: when the switch is on and when the switch is off.The primary advantage of the buck converter is its simplicity, which enables efficient voltage conversion using a relatively small number of components.

Capital letters are generally given to variable names to indicate a steady-state quantity. By adjusting the duty cycle of the high-side switch, the average output voltage can be regulated proportionally to the input voltage. This stored energy is then transferred to the output, charging the output capacitor and powering the load. When the high-side switch is turned off and the low-side switch is turned on, the inductor's magnetic field collapses, releasing the stored energy and maintaining the current flow to the load. The buck converter is designed to operate within a closed-loop control system, where a feedback mechanism continuously compares the output voltage to a reference voltage to ensure that the output voltage remains stable and regulated, regardless of changes in input voltage or load conditions. The individual application requirements, desired performance traits, and design limitations will determine whether CCM or DCM should be used. A converter might occasionally work in both modes, switching between them when the load current fluctuates. The stability and performance of the system must be maintained in what is known as the border conduction mode (BCM) or critical conduction mode, which calls for more complicated control techniques.

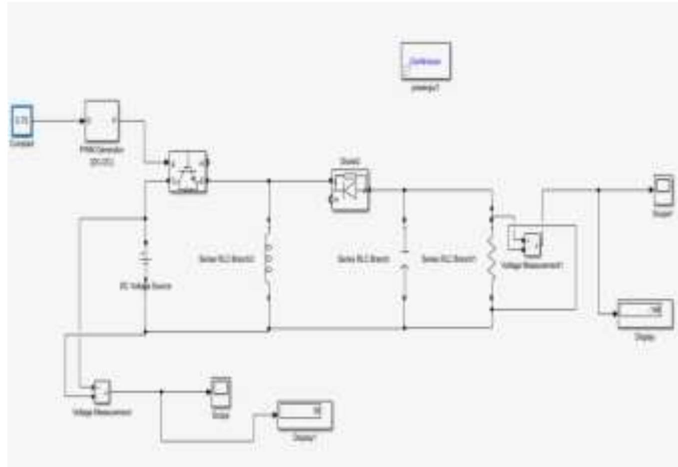


Fig.3.2: Simulink model of Boost Operation

When the high-side switch of a buck converter is switched on, it allows current to flow through the inductor, which stores energy in its magnetic field. The operating principle of the buck converter involves controlled energy transfer from the input to the output through switches, an inductor, and a capacitor.The main goal of this section is to provide a derivation of the voltage conversion relationship for the continuous conduction mode buck-boost power stage. This is important because it shows how the output voltage depends on duty cycle and input voltage or conversely, how the duty cycle can be calculated based on input voltage and output voltage. Steady-state implies that the input voltage, output voltage, output load current, and duty-cycle are fixed and not varying.

The boost converter is a DC-to-DC converter designed to perform the step-up conversion of applied DC input. In the Boost converter, the supplied fixed DC input is boosted (or increased) to adjustable DC output voltage i.e. output voltage of the boost converter is always greater than the input voltage. So, a Boost converter is also called a step-up converter or step-up chopper. It is given the name “boost” because the obtained output voltage is higher than the supplied input voltage. It performs the reverse operation of the buck converter which converts higher DC input into lower DC output.

The boost converter is used to step up an input voltage to some higher level as per the requirement of the load. This step-up conversion in the boost converter is achieved by storing energy in the inductor and releasing it to the load at a higher voltage. Boost converters are widely used in battery-powered devices where perhaps a pair of batteries deliver 3V but need to supply a 5V circuit.

3.1 Efficiency and Power Losses

The efficiency of the buck-boost converter is influenced by several factors, including switching losses, inductor losses, and the efficiency of the power semiconductor switches. The high efficiency of the converter is critical to improving the overall performance of the wind energy system. By maintaining a constant voltage output, the converter minimizes power loss during energy transfer and ensures efficient charging of the battery. The system's design takes into account the power losses associated with each component, ensuring optimal performance across the operating range of the wind turbine.

IV. SIMULINK RESULTS

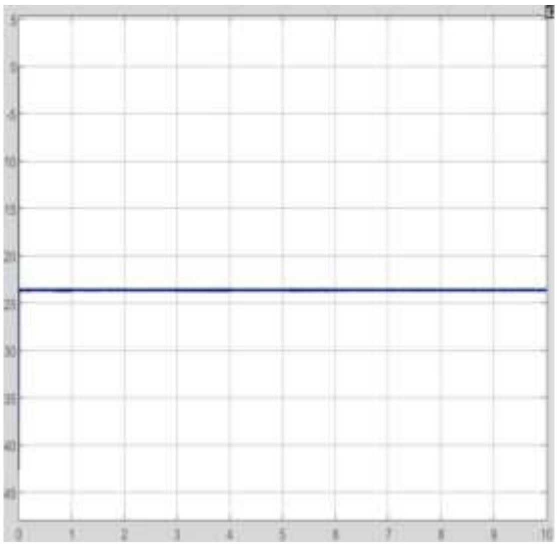


Fig.4,1: Buck Output Voltage Waveform

Here in the figure 5.3 we can observe the waveform of the DC Buck Output voltage 23V.As duty ratio D decreases, the output voltage of the buck converter also decreases. Ideally if D has a value of 0.33 then an input of 50 volts generates an output of about 23.5 volts. If D is 0.66 then the output would be about 45.6 volts. As we adjust the duty ratio the output varied in reference to the input voltage. We can Observe these waveforms in matlab Simulink.

Fig.4.2: Boost Output Voltage Waveform

Here in the figure 5.2 we can observe the waveform of the DC boost Output voltage 145V.As duty ratio D increases, the output voltage of the boost converter also increases. Ideally if D has a value of 0.75 then an input of 50 volts generates an output of about 145 volts. If D is 1.4 then the output would be about 210 volts. As we adjust the duty ratio the output varied in reference to the input voltage. We can Observe these waveforms in matlab Simulink.

V.CONCLUSION AND FUTURE SCOPE

The Wind Energy System utilizes a Buck-Boost Converter with PWM control to regulate the output DC voltage, adapting to changes in wind speed. By adjusting the duty cycle (D), the system can either step up or step down the voltage: in boost mode (D increases), the output voltage rises (e.g., D = 0.75 → 145V, D = 1.4 → 210V), while in buck mode (D decreases), the output voltage drops (e.g., D = 0.33 → 23.5V, D = 0.66 → 45.6V). Maximum Power Point Tracking (MPPT) technology optimizes power extraction from the turbine, enhancing energy efficiency. Wind energy is becoming cost-competitive with traditional thermal power and is a clean, pollution-free energy.

FUTURE SCOPE

The buck boost converter is useful for control voltage variation. For extension we can interface solar power with same system so the output voltage remains constant with the help of buck-boost converter. In addition we can use artificial intelligence control instead of PWM technique so that the output voltage becomes more constant and stable. We can use GSM technology to monitor the system output over mobile or computer. Buck-Boost Converters are also used in renewable energy systems, aerospace applications, and LED lighting fixtures for efficient power conversion. The fastest-growing application segment for Buck-Boost Converters in terms of revenue is expected to be Electric Vehicles.

REFERENCES

1. Anshul Mittal, Khushboo Arora Control of Wind Energy by Using Buck-Boost Converter "International Journal of Emerging Technology and Advanced Engineering Vol 5, April 2015, ISSN 2250-2459.

2. Deepak Uniyal & Vaskar Raychoudhury., "Energy resources and use: the present situation and possible paths to the future," Energy, vol. 33, no. 6, pp. 842–857, 2016.

3. S. Pourjafar, F Sedaghati, H. Shayeghi, and M. Maalandish, "High step-up DC–DC converter with coupled inductor suitable for renewable applications," IET Power Electronics, Vol. 12, No. 1, pp. 92–101, Oct. 2018.

4. Alejandro Rolan, Alvaro Luna, Gerardo Vazquez, Daniel Aguilar, Gustavo Azevedo, 2009. "Modeling of a Variable Speed Wind Turbine

with a Permanent Magnet Synchronous Generator", IEEE International Symposium on Industrial Electronics, pp. 734-739.

5. N Praksah, D.Ranithottungal and M. Sundaram on "An Effective Wind Energy system Based on Buck-boost Controller" Research Journal of Applied Sciences, Engineering and Technology, ISSN: 2040-7459; e-ISSN: 2040-7467, Volume 6, June 2013, pp. 825- 834.

6. Mr. Najmuddin Moulaali Jamadar, Mr. A. Ram Reddy Load Frequency Control for Two Area Deregulated Power System Using ANN Control International Research Journal of Engineering and Technology (IRJET)

7. M. Veerachary and V. Khubchandani, "Analysis, design, and control of switching capacitor based buck-boost converter," IEEE Transactions on Industry Applications, Vol. 55, No. 3, pp. 2845– 2857, Dec. 2018.