

Performance analysis of Buck Converter Controlled Synchronous Generator in Wind Energy Conversion System

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Abstract— Wind energy is clean and easily available source of renewable energy. But the output of wind turbines are variable and this affects the output voltage. Variable speed wind energy turbines are advantageous than fixed speed wind turbines for its good performance and high efficiency. But due to variable speed the efficiency could be affected and this can be overcome by maintaining constant speed at the output of wind generator by using buck converter. It helps to maintain the constant speed, Voltage stability & improve the efficiency of the system. This paper presents the performance analysis of buck converter controlled synchronous generator in wind energy generation system. The control strategy is to provide maximum possible wind energy and feed it to the load with high stability electricity. The design and performance analysis of buck converter is simulated in MATLAB/simulink. The design parameters are theoretical values taken by calculations.

Keywords— MATLAB, Wind energy conversion system, voltage stability, constant speed, buck converter, three phase alternator.

I. INTRODUCTION

Non-renewable energy sources may extinguish after few decades which can lead to the shortage of energy in the world. The increasing use of energy consumption makes renewable energy sources like solar energy, wind energy, geothermal energy as a future solution of energy generation. Wind energy is gaining attention in several years. Wind energy can be a standalone station used to charge a bank of batteries and other is grid connected system. Wind energy is a type of renewable energy and hence it is used to generate electricity. The kinetic energy of wind is converted into mechanical energy using wind turbines. Further this energy is converted into electrical energy by using generator.

The wind energy received by the wind turbines is variable in nature, due to this intermittent nature of wind the output voltage has to be maintained constant. This can be done by using converters like buck converter, boost converter, buck-boost converter, buck converter and SEPIC. At low

speed buck converter decrease the output voltage and helps to regulate it and maintain constant. To achieve the voltage stability and maintain constant voltage buck converter plays important role. To achieve good performance and increase efficiency buck converter simulation is done in MATLAB/simulink.

This project provides control strategy for maintaining and tracking a constant voltage and frequency across load through stand alone. Extracting as much as wind energy as possible and feeding the load with high quality stability electricity is to maintain the targets. Bucking dc link voltage is enough level to realize these targets. After bucking link rectifier output which is made constant. This project describes stability properties of energy generated by wind turbine connected to power system.

II. LITERATURE SURVEY

In this research we studied 3- phase diode bridge rectifier, its construction, working and output formula values to calculate V_{dc} by the provided V_{rms} value at the supply side.

The buck converter is dc-dc converter which converts high voltage dc to low voltage dc which is used for low voltage power electronic applications. The waveforms of buck converter and three phase rectifier with their output calculations.

It helps in designing and simulation of synchronous buck converter which can be used in low power generation system. This DC-DC buck converter topology suffers from low efficiency at light load due to dissipation that does not relate with the load current. In this proposed method of improving efficiency in buck converter by reducing gate drive losses. This paper uses the permanent magnet wind-turbine generator as the input.

Dc-Dc converter topology A closed loop model of switch mode buck converter provides a regulated output voltage. The switching frequency of converter is set at such values that it can perform with faster switching operation, also PID controller has been used to convert input DC voltage values to specified constant DC output voltage values. The simulation has been does not done using MATLAB/SIMULINK to verify the behavior of controlled model.

The widely used techniques are applied to the buck converter or step-down DC-DC converter to obtain simple equations which may then be used for control design and simulation. There are many common control methods which are described in this project. Their principal characteristics are explained clearly using MATLAB system i.e. in simulation diagram along with simulated results. The analyzed procedures may be applied to other DC-DC converters.

III. METHODOLOGY

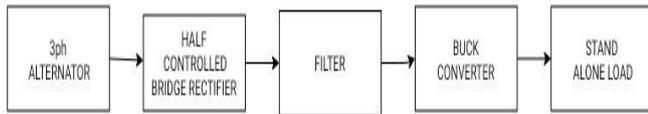


Fig 1. Block Diagram

Block Diagram:

In this block diagram, three phase alternator of source is used as AC power supply which works as a prime mover to the system. In this we can vary the prime mover from which we can vary the speed of generator which generates voltage. Thus from this we can also vary the generated voltage. Then this three phase varying voltage is further given to input side of the rectifier circuit block.

We are using 3phase half controlled rectifier, this is used to convert the ac supply to dc supply, this is because input to buck converter has to be DC. In this, it converts variable 3 phase AC voltage into variable DC voltage. Practically it is difficult to have 400 V DC voltage hence we use half controlled rectifier. In this half controlled rectifier it consist of three diodes and 3 IGBT's i.e. Insulated-Gate Bipolar Transistor, one of them in each phase as shown in fig. 2. below. This IGBT is a transistor which is an electronic device which has three terminal i.e. emitter, collector and gate. The symbol and collector current verses emitter-collector voltage characteristics of IGBT are shown in fig. 3. below.

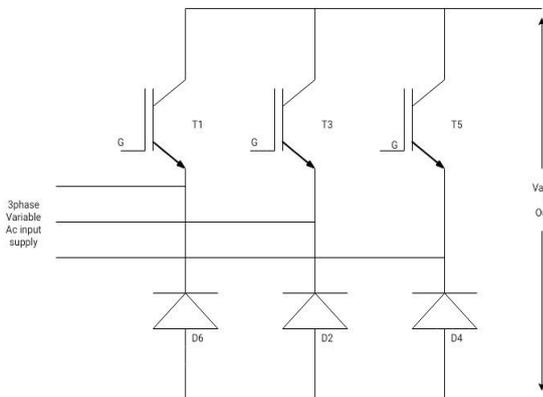


Fig. 2. Basic Circuit Diagram Of 3 Phase Half Controlled Rectifier.

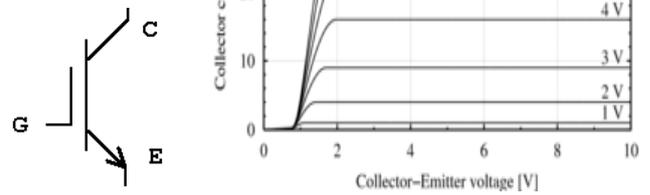


Fig. 3. IGBT Symbol And Characteristics

The diodes does not need any firing because it does not have gate terminal and it commutated at firing instant 0 but the IGBT/s conduct at 120degrees and are fired at intervals of 120degrees output of all the 3phases are added to get the net voltage at the output of rectifier. The 3 phases are 120 degrees out of phase with each other and has a phase sequence of 360degrees/3= 120 degrees as shown in fig. 4.

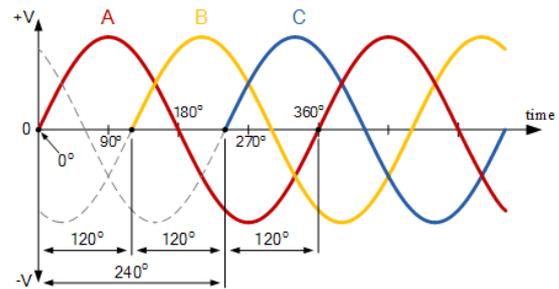


Fig. 4. Three Phase AC Waveform.

Also the performance of three phase half controlled bridge rectifier is given in fig. 5.

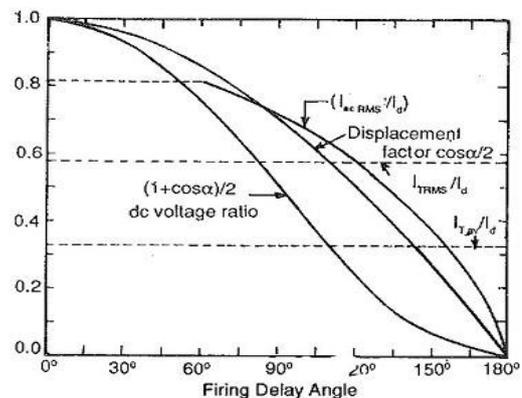


Fig. 5. Performance Of Half Controlled Bridge Rectifier.

The resultant waveform is observed in scope of simulink in shown in fig. 6.below.

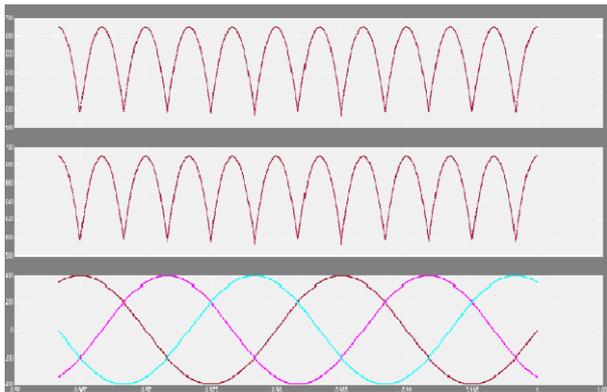


Fig. 6. Resultant Waveform Of Output Of Three Phase Bridge Rectifier.

The output of rectifier block is given to filter in which filtering of undesirable frequencies takes place by using capacitors. Signal processing can also done by filters. The output of rectifier which is rectified in previous block is not in pure dc form. It may contain ripples in it. So we have to use filters to filter out this ripple component by connecting capacitor in parallel across output of the rectifier. Capacitors work as filter and gives ripple free output. The filter value used in this is of 20 microfarad.

The filtered output is given to the buck converter which is DC to DC power converter and also it steps down the voltages to smaller values which can be used as input to electronics devices which work on low voltages. Buck converter is one of the class of switch mode power supply. High DC voltage gained from previous block or rectifier output which acts as input to buck converter is converted into low DC voltage. The output is not only of low value but also constant.

Basic circuit of Buck converter :

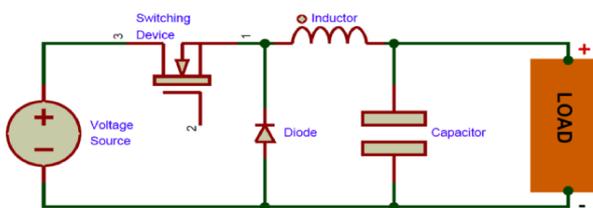


FIG 7. Buck Converter Circuit

A buck converter is DC to DC power converter which steps down voltage from its input to its output. It consists of a Transistor, diode, inductor, capacitor and a switching device which can be IGBT, MOSFET or BJT. The switching can be done by using PWM signals. The duty cycle of converter is given as,

$$\text{Duty cycle} = V_o/V_{in}$$

The above equation is valid for continuous conduction mode of operation of Buck converter.

Finally all the outputs of blocks are given to stand alone load in which we get stable voltage at output side.

In MATLAB we designed this system in both open loop as well as closed loop. Hence for simulation part we used rectifier circuit, we simply convert three phase AC supply into the constant DC supply. The rectifier is Half controlled bridge rectifier hence we use diodes and IGBT. Due to IGBT this becomes a controlled rectifier. Therefore in simulation we need to use pulse generation block to gate terminal of each IGBT. This provides a pulse to the gate terminal which is used to make the IGBT in on condition.

For designing buck converter parameters for 500 W, and we want to maintain 220V constant at the output of the Buck converter. According to this we design our standalone load, Inductor and capacitor values.

For designing the parameter, first we assume some data:

- Wattage:-500W
- Constant Voltage:-220V
- Switching Frequency:- 10KHZ

Calculations:

$$I_o = P_o/V_o$$

$$I_o = 2.27A$$

$$R_{load} = V_o/I_o$$

$$R_{load} = 100\Omega$$

$$D = V_o/V_s$$

$$D = 0.68$$

$$L_c = ((1-D)*R)/(2*\pi F)$$

Or

$$L_c = (V_s - V_o)*T_{on}/(2*I_o)$$

$$L_c = 2mH$$

$$C_c = (1-D)/(16*L*\pi^2 F^2)$$

$$C_c = 20e-6$$

In place of alternator here we used a 3 phase ac source which is same in magnitude and voltage in all its three phases. The phase angle in all three phases is also same. The input given by this source to rectifier is of variable nature.

Basic operation of buck converter

Buck converter is dc- to - dc converter. Buck means down so it steps down voltage from its input to output according to firing of switches. (MOSFET, IGBT etc.) But power at input and output terminal is remains constant. It is type of switched mode power supply (SMPS) which consists of two switches MOSFET and diode. Buck converter also consists of inductor and capacitor.

When switch is in on state, current flowing in inductor is goes on increasing and diode blocks the current. Inductor stores energy in the form of magnetic field when

switch is in on state. When rate of change of current decreases then voltage across the inductor also decreases.

When switch is in OFF state, then inductor itself acts as current source. Inductor's stored energy supports the current to flow through load. When switch is fired according to the duty cycle, there will be voltage drop across the inductor, therefore average voltage across the load will always less than input voltage.

According to output voltage, we simulate buck converter in MATLAB simulation.

1. Buck converter with Open loop.
2. Buck converter with Closed loop.

1. Buck converter with Open loop:

We know that, output of the wind energy conversion system is not constant. Therefore, output of the half controlled rectifier is also variable. Hence the output of the buck converter is also variable for fixed duty ratio.

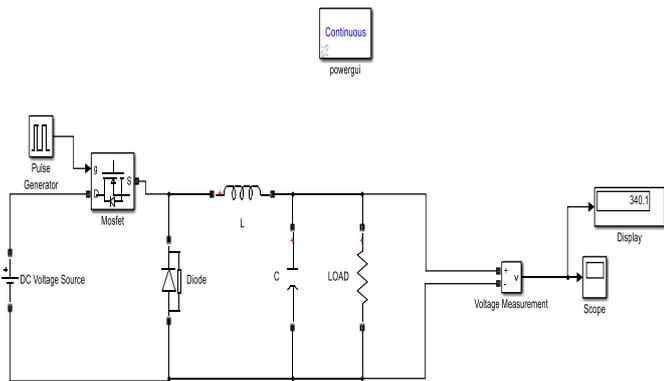


Fig. 8. Simulation Of Open Loop System Of Buck Converter.

2. Buck converter with Closed loop:

In many applications or to maintain voltage stability we require constant voltage. Hence we simulate buck converter with closed loop system.

In closed loop system, firing or switching of the switch in buck converter is done by comparing output voltage with the set constant voltage. So that duty cycle of the switch is also varied. Switching of the switch is done by using PWM method.

In simulation, output voltage is compared with already set constant voltage. Then this difference is compared with repeating sequence having frequency 50Hz using relational operator. Then this generated pulses is given to the gate terminal of the MOSFET.

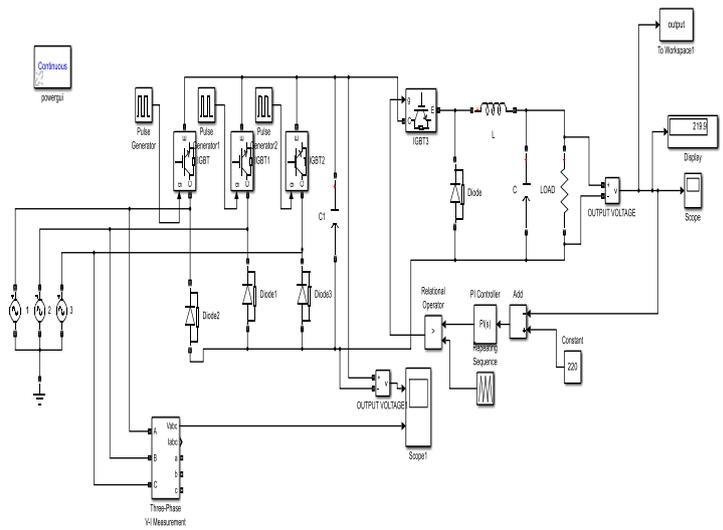


Fig. 9. Simulation Of Closed Loop System Of Buck Converter With Rectifier Circuit.

IV. RESULTS

In order to observe the performance of buck converter we did the study by using MATLAB/Simulation. The results of the open loop and closed loop systems are as shown in below figures.

Sr.No.	Buck converter Input (in volts)	Buck converter output(in volts)
1.	391.9	181.4
2.	529.2	245.2
3.	665.9	308

Table 1: Results Obtained From Buck Converter Open Loop Circuit Without Rectifier.

Sr.No.	Buck converter input(in volts)	Buck converter output(in volts)
1.	391.9	218.1
2.	529.2	220.5
3.	665.9	219.6

Table 2. Results Obtained From Buck Converter Closed Loop Circuit Without Rectifier.

Sr.No.	AC Input Voltage(in volts)	Rectifier output(in volts)	Buck O/P(in volts)
1.	300	391.9	219.9
2.	400	529.2	221.8
3.	500	665.9	221.8

Table 3. Results Obtained From Buck Converter Closed Loop With Rectifier Circuit.

In open loop system as we apply variable input voltage to buck converter the output also varies with respect to input proportionally as shown in table 1. In closed loop without rectifier system as input applied is varied output is also varied but the results observed are not accurately constant to 220 volts it contains some ripples in its output as shown in table 2. In closed loop with rectifier system as input applied is varied the output is also varied and this output is nearly constant to 220 volts as shown in table 3. This is due to the rectifier, it removes the ripples in the output values to give constant output voltage.

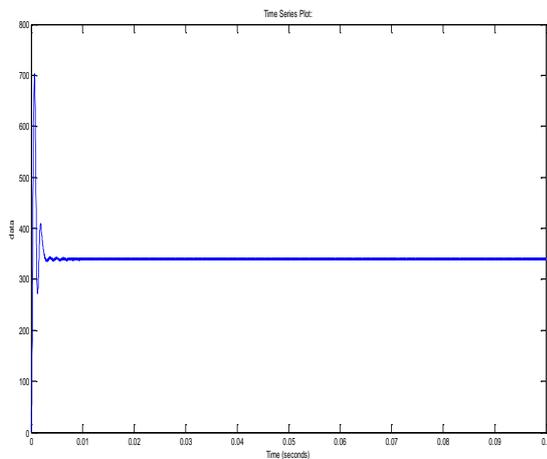


Fig. 10: Waveform Of Output Of Buck Converter Open Loop Circuit.

In open loop as shown in fig 10., output voltage of the buck converter changes with respect to the input voltage by keeping duty ratio constant.

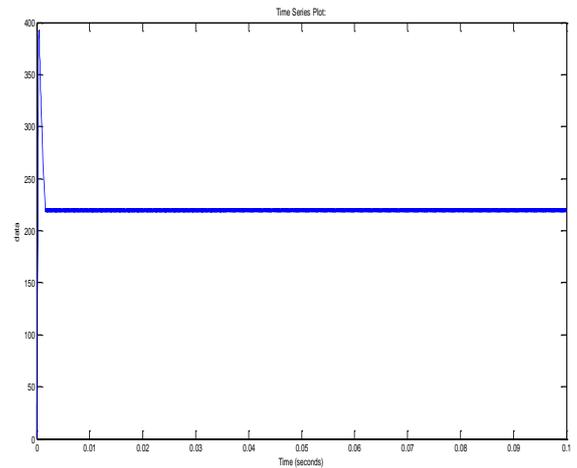


Fig. 11. Waveform Of Output Of Buck Converter Closed Loop Circuit.

In closed loop as shown in fig 11., output voltage is maintained constant for the any value of the input voltage which is above the voltage maintained to be constant. By comparing output voltage and constant voltage we generate pulses for switching IGBT.

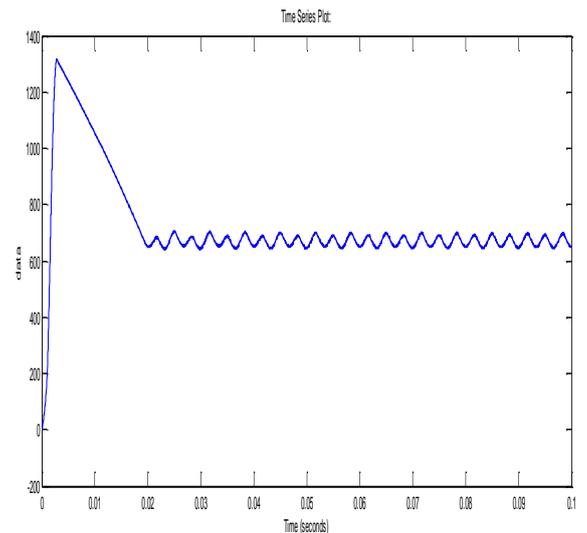


Fig. 12. Waveform Of Output Of Buck Converter Closed Loop Circuit Without Rectifier Circuit.

Fig 12 and fig. 13 shows the output waveforms of closed loop buck converter without and with rectifier respectively. The resultant waveform in fig 13 remains constant at 220 volts output voltage.

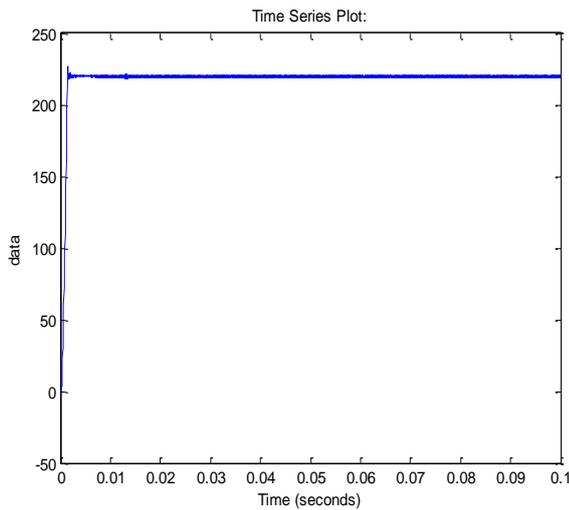


Fig. 13. Waveform Of Output Of Buck Converter Closed Loop Circuit With Rectifier Circuit.

V. CONCLUSION

This paper is to study and understand the new technologies and updates in electronic areas and for various electronic applications. This review paper can be useful and beneficial to many upcoming future researches and control voltage system. This paper has presented simulation of buck converter controlled synchronous generator in wind energy conversion system. By which we can analyze performance of buck converter and voltage stability. And also we can make model of wind power converter stability system.

By designing parameters appropriately with open loop as well as closed loop system we did the simulation for each block such as buck converter with open loop, closed loop and rectifier circuit. And obtain accurate results of those simulations respectively. This converter reduce amplitude of output voltage to the required and set values of voltage. Due to close loop system we can achieve stable operation at output of wind energy generation. This will be useful in future technologies.

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