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Experimental Verification of Variable Speed Wind Power Generation System Using Permanent Magnet Synchronous Generator by SEPIC Converter Circuit

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Abstract:
Nowadays, the extraction of power from wind at a large scale became a well recognized industry. This fast development of the wind power industry was possible due to several reasons, like: the increasing resistance regarding the use of coal, oil or uranium, the high price of oil and the climate change problem. Because of the rapid development of power electronic devices and thus decreasing equipment costs, the variable speed wind turbine concept with full-scale frequency converter has an increasing market share. The most common generators used in this topology, the doubly fed induction generators (DFIGs) and permanent magnet synchronous generators (PMSGs), allow the extraction of maximum power from a large wind speed interval. This project presents the experimental results of variable-speed wind power generation system using permanent magnet synchronous generator. The boost converters and inverter are utilized as converters for the variable speed wind power generation system. The wind turbine emulator are reproduced the behaviors of windmill by the servo motor drives. The variable frequency obtained from the PMSG is converted into the fixed frequency output irrespective of the variable wind speed and generator output. The level of harmonics in the inverter circuit is greater reduced with the implementation of Space Vector Modulation. For variable wind speed are changed two values have been chosed and result of SEPIC converter is compared. SEPIC converter operating at fixed frequency and duty ratio. It reduces the component count and eliminates the need of bulk inductor. Thus the simulation and prototype model is developed to demonstrate the effectiveness of the system.

Keywords: *doubly fed induction generators (DFIGs), permanent magnet synchronous generators (PMSGs).*

1. Introduction

At present, the practical application of variable-speed wind Power generation systems using the PWM converter. The cost is high because the PWM converter needs a large number of switching devices and its control is complicated.
However, the PWM converter is used for variable-speed large capacity wind generator systems which require the control of windmill speed, because it can apply the vector control, and realizes the high-speed and high-precise generator torque control. The wind power generator system does not need to supply the excitation energy from the converter side, when the permanent magnet synchronous generator (PMSG) is used as a generator. Therefore, the wind generator systems using PMSG and diode bridge rectifier for the purpose of charging battery are mainly driven at the rated wind velocity of which induced.
Voltage becomes high enough. The wind generator system using PMSG and diode bridge rectifier can constitute the low-cost converter. However, the windmill speed control is difficult, since the torque control of PMSG cannot be carried out by using the converter. And, the induced voltage necessary for the system interconnection is not obtained in low wind speed. At present, the system using PMSG and diode rectifier which realized the windmill speed control and system interconnection is not reported. This paper proposes the variable-speed wind power generation system using the boost converters. The whole system, including the wind turbine emulator, power system, main circuit and controllers are tested to verify the proposed system. In the experimental results, it is shown that the proposed system has the sufficient performances as variable speed wind power generation systems.

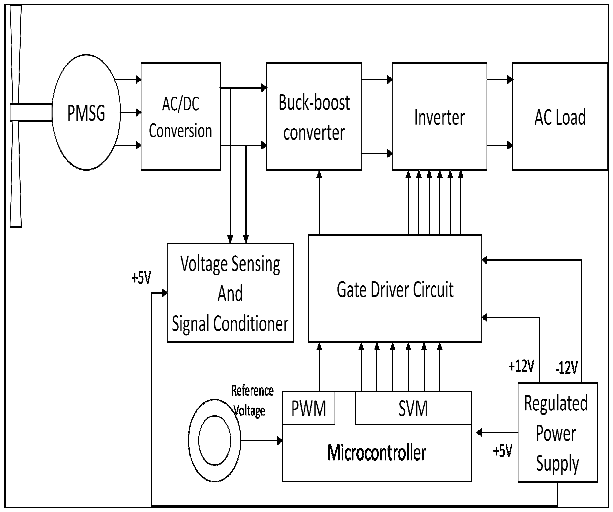

Figure 1: Block Diagram

2. System Description

2.1. Wind Power

Wind power is the conversion of wind energy into a useful form of energy, such as using wind turbines to produce electrical power. Wind power, as an alternative to fossil fuels, is plentiful, renewable, widely distributed, clean, produces no greenhouse gas emissions during operation and uses little land. The effects on the environment are generally less problematic than those from other power sources.

Figure 2: wind Power

2.2. Proposed Converter (SEPIC Converter)

SEPIC converters are mainly used for industrial applications such as power factor correction, photovoltaic system and LED lighting. Unlike conventional and multi resonant converters no bulk inductor is used in the new resonant SEPIC converter. This converter operates at fixed switching frequency and duty ratio. These characteristics improve response speed, reduce passive component size, and allow the use of low-loss sinusoidal resonant gating.

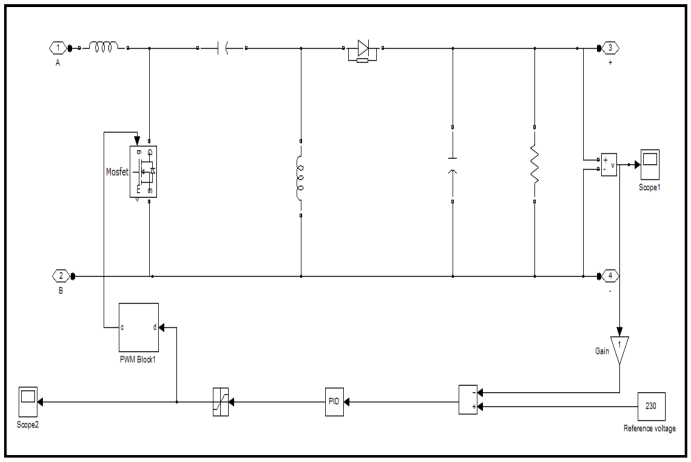

Figure 3: Proposed Converter

Figure 3 shows a simple circuit diagram of a SEPIC converter, consisting of an input capacitor, CIN; an output capacitor, COUT; coupled inductors L1a and L1b; an AC coupling capacitor, CP; a power FET, Q1; and a diode, D1. Figure 2 shows the SEPIC operating in continuous conduction mode (CCM). Q1 is on in the top circuit and off in the bottom circuit. To understand the voltages at the various circuit nodes, it is important to analyze the circuit at DC when Q1 is off and not switching. During steady-state CCM, pulse-width modulation (PWM) operation, and neglecting ripple voltage, capacitor CP is charged to the input voltage, VIN. Knowing this, we can easily determine the voltages as shown in Figure 3. When Q1 is off, the voltage across L1b must be VOUT. Since CIN is charged to VIN, the voltage across Q1 when Q1 is off is VIN + VOUT, so the voltage across L1a is VOUT. When Q1 is on, capacitor CP, charged to VIN, is connected in parallel with L1b, so the voltage across L1b is –VIN. The currents flowing through various circuit components are shown in Figure 4. When Q1 is on, energy is being stored in L1a from the input and in L1b from CP. When Q1 turns off, L1a's current continues to flow through CP and D1, and into COUT and the load. Both COUT and CP get recharged so that they can provide the load current and charge L1b, respectively, when Q1 turns back on.

2.3. Flow Chart

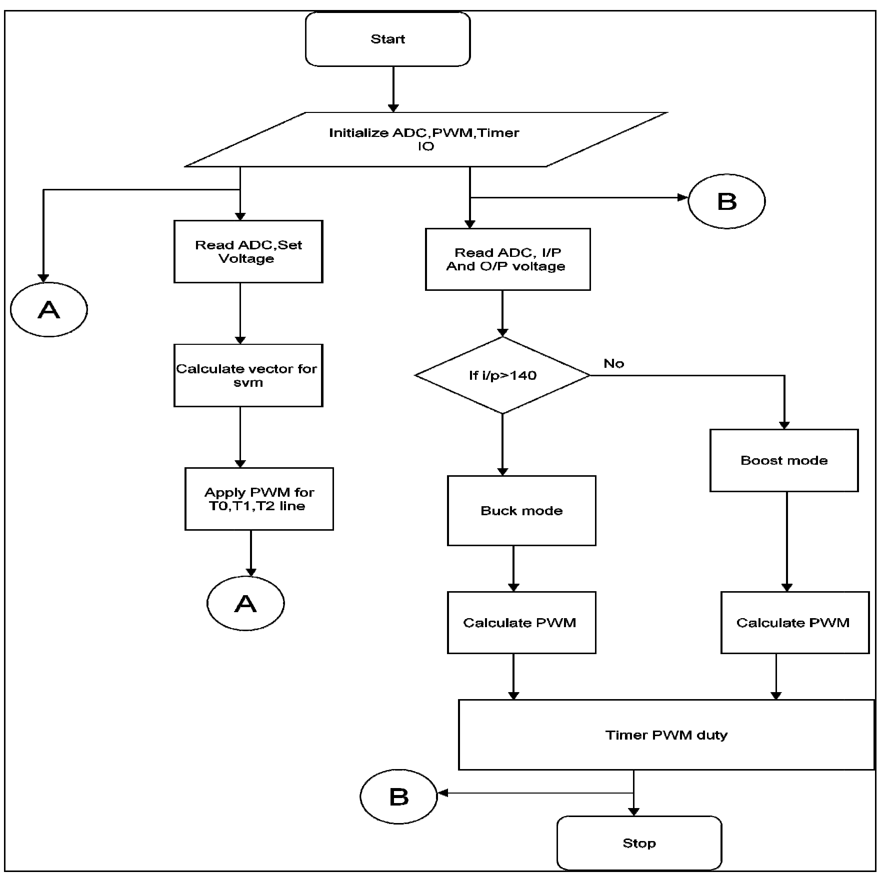

Figure 4: Flow Chart

2. Simulation Result

The simulation result for the proposed method is analyzed with the MATLAB software. Simulation is analyzed for existing and proposed method. Proposed converter is compared with conventional converter and the results are analyzed.

2.1. Existing Converter Simulation Diagram

The existing method is analysed with conventional converter with open loop condition. The buck–boost converter is a type of DC-to-DC converter that has an output voltage magnitude that is either greater than or less than the input voltage magnitude. It is equivalent to a fly back converter using a single inductor instead of a transformer. Two different topologies are called buck–boost converter. Both of them can produce a range of output voltages, from an output voltage much larger (in absolute magnitude) than the input voltage, down to almost zero. i.e. PWM concept is not implemented. Thus the output changes as the input changes from the wind system. So the output variation causes the load under different voltage conditions. The overall simulation diagram of the existing method is as shown in the following fig. 5.

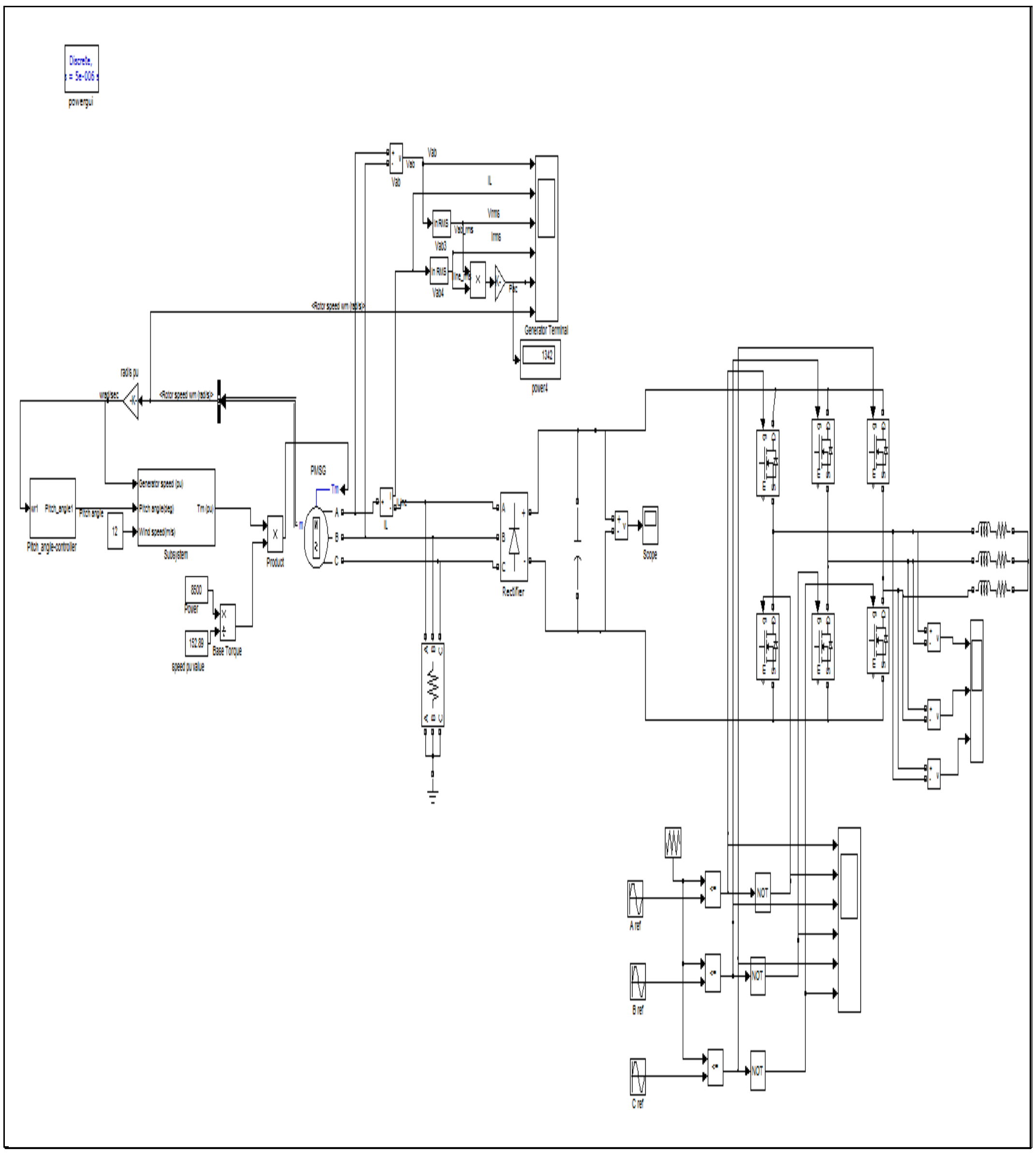

Figure 5: Existing Simulation Diagram

2.1.1. Generator Outputs

The generator output to the existing method is as shown in the fig.6. The various outputs are voltage, power and speed.

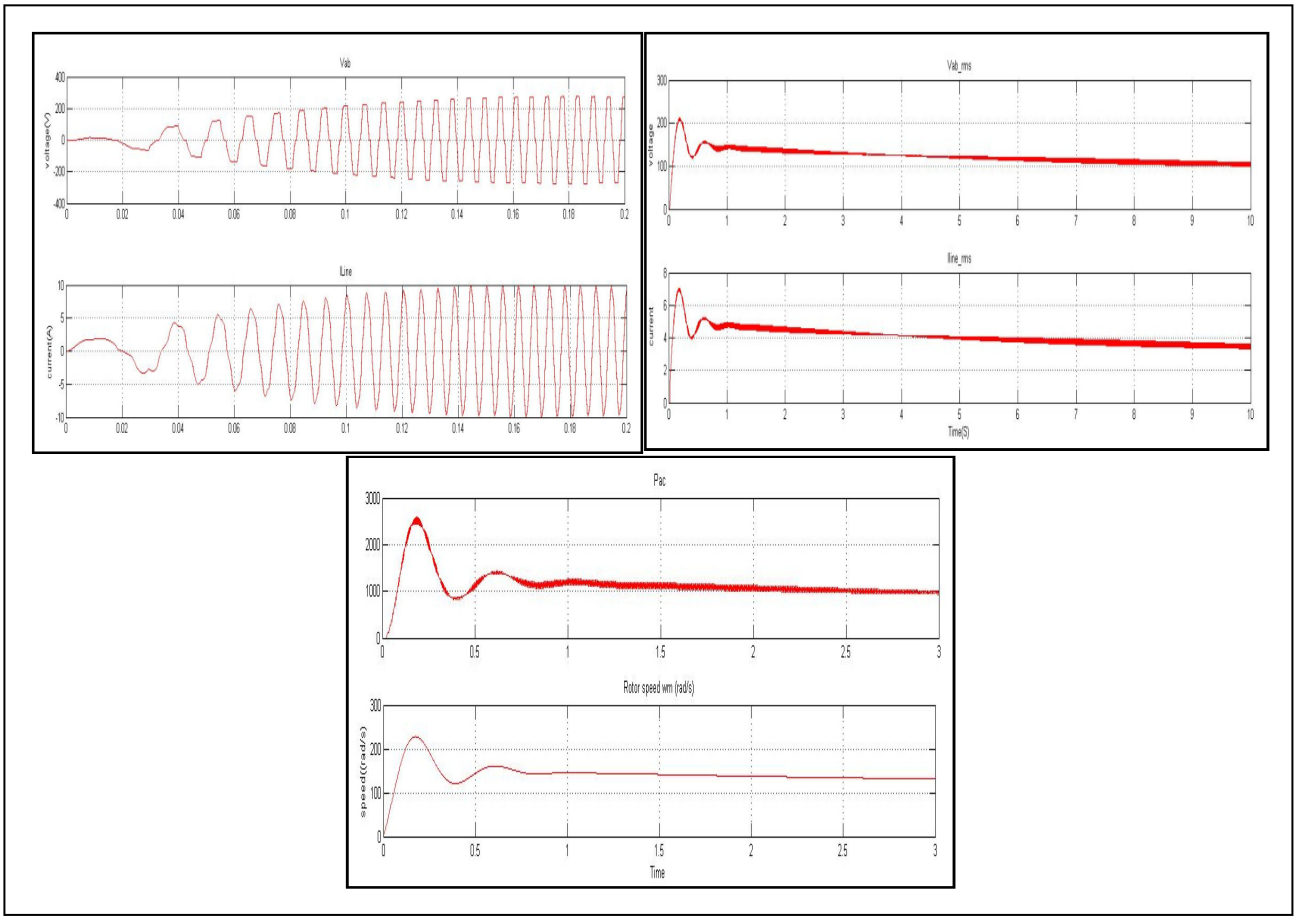

Figure 6: Generator Outputs

2.1.2. Inverter Switching Pulse

Inverter switching pulse in the existing method and the output power waveform is as shown in the below fig. 7.

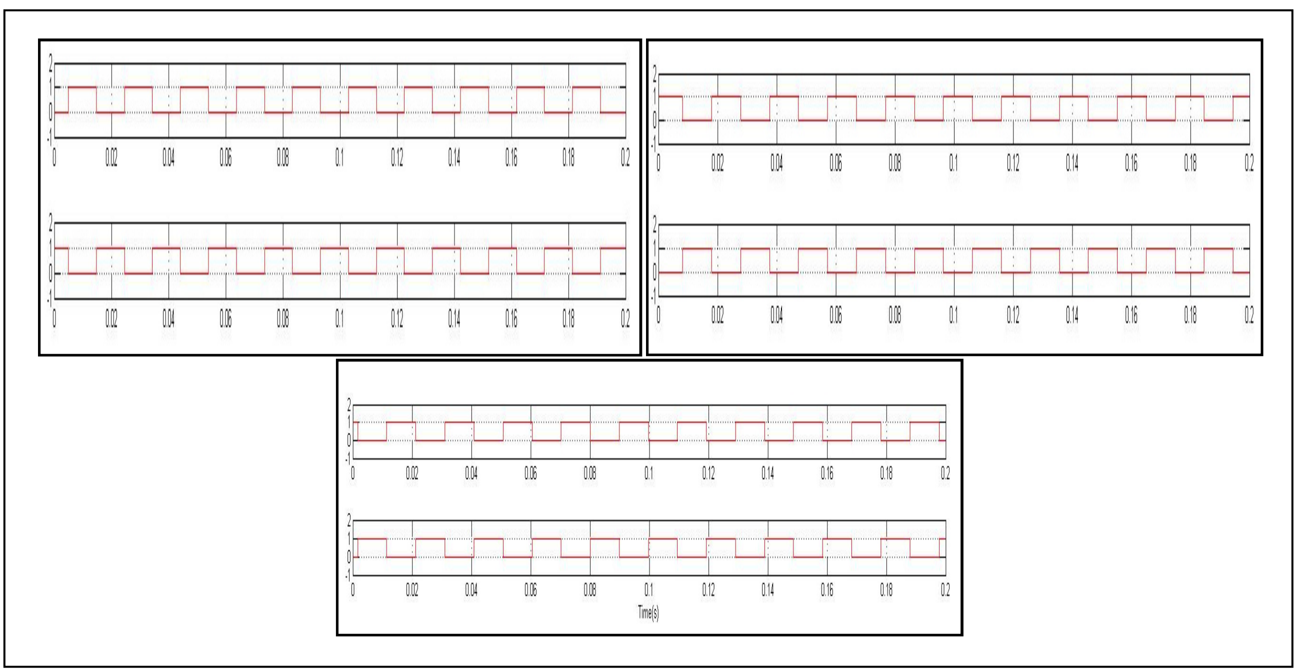

Figure 7: Inverter Switching Pulse

2.1.3. Generator DC Output Voltage @ wind speed = 7 m/s

In the below fig.8 generator DC output voltage of the existing method is produced. The wind speed is about 7 m/s.

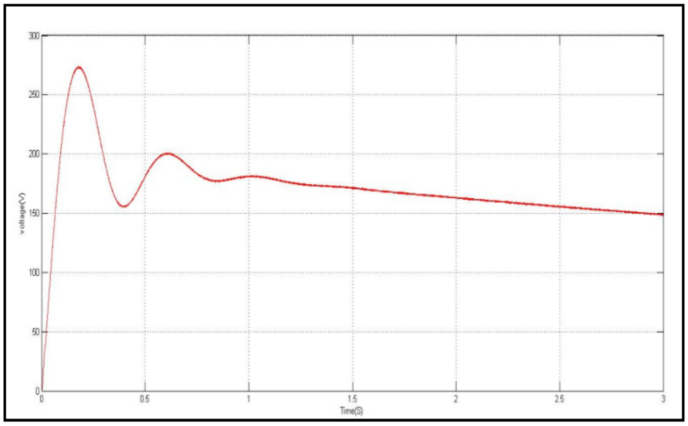

Figure 8: Generator DC Output Voltage @ wind speed = 7 m/s

2.1.4. Three Phase Output Voltage wind speed = 7 m/s
In the below fig.9 three phase output voltage waveform is analyzed. The wind speed is about 7 m/s.

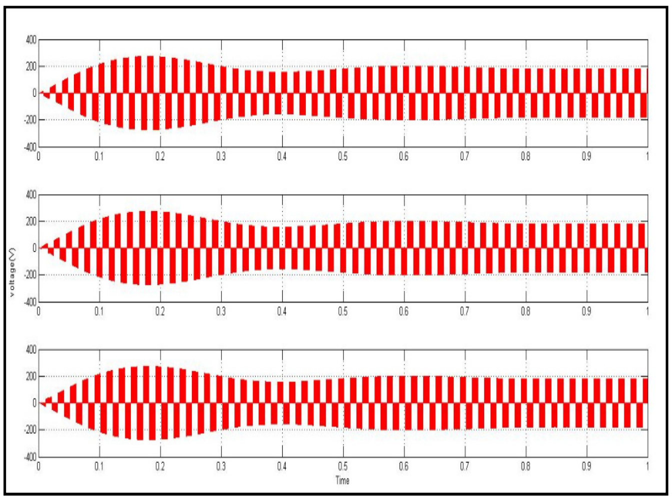

Figure 9: Three Phase Output Voltage wind speed = 7 m/s

2.1.5. Generator DC Output Voltage @ wind speed = 10 m/s
The Generator DC Output Voltage @ wind speed of the existing method is as shown in the following fig. 10.

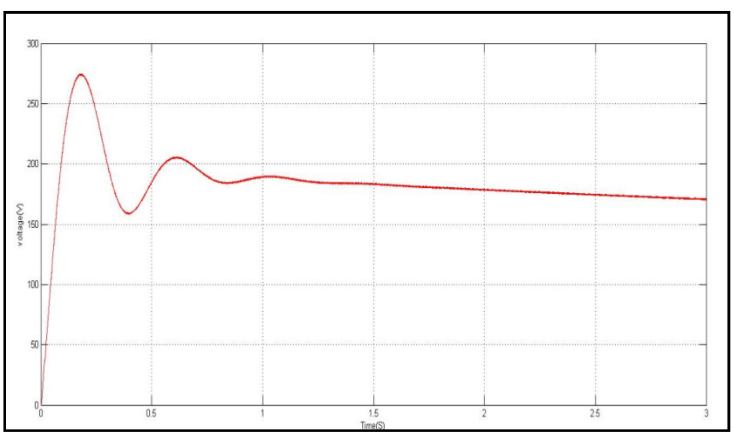

Figure 10: Generator DC Output Voltage @ wind speed = 10 m/s

6) Three Phase Output Voltage @ wind speed = 10 m/s
The output voltage at wind speed is 10 m/s is noted. The voltage waveform is as shown below fig.11.

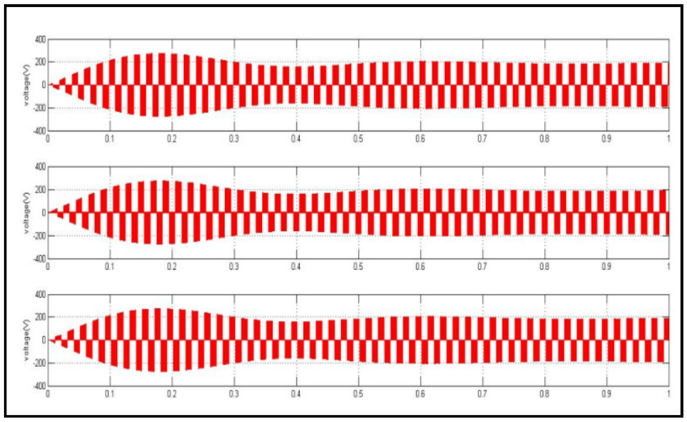

Figure11: Three Phase Output Voltage wind speed = 10 m/s

2.2. Proposed Converter Simulation Diagram

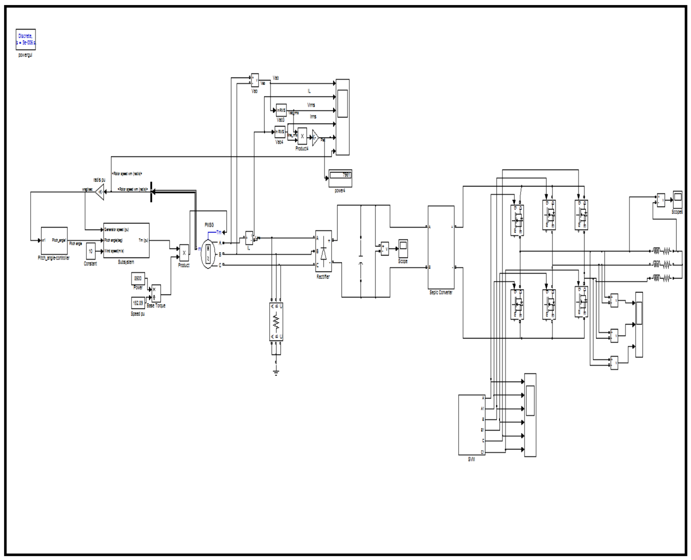

Figure 12: Proposed Simulation

1) Generator Outputs

Generator Outputs to the proposed converter in IC is about 12V.The MATLAB simulation waveform is as shown below in fig. 13.

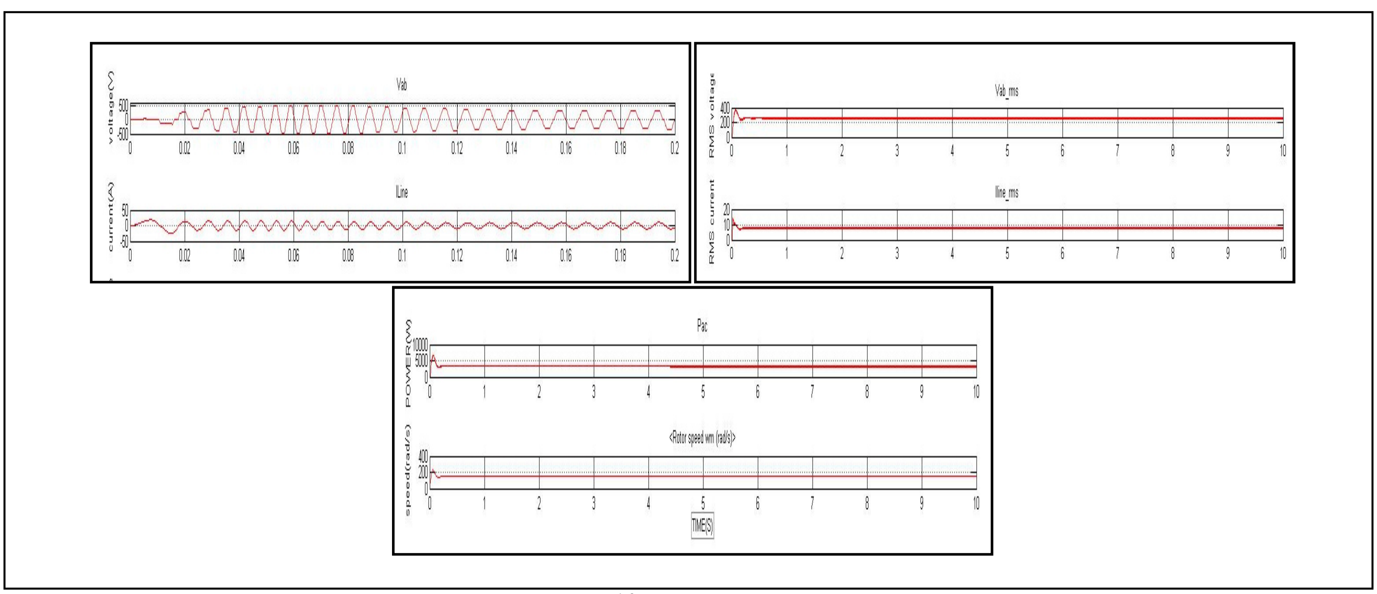

Figure 13: Generator Outputs

2) Inverter Switching Pulse
In the proposed simulation the inverter switching pulse is analyzed. The waveform for the switching pulse is as shown in the following fig. 14.

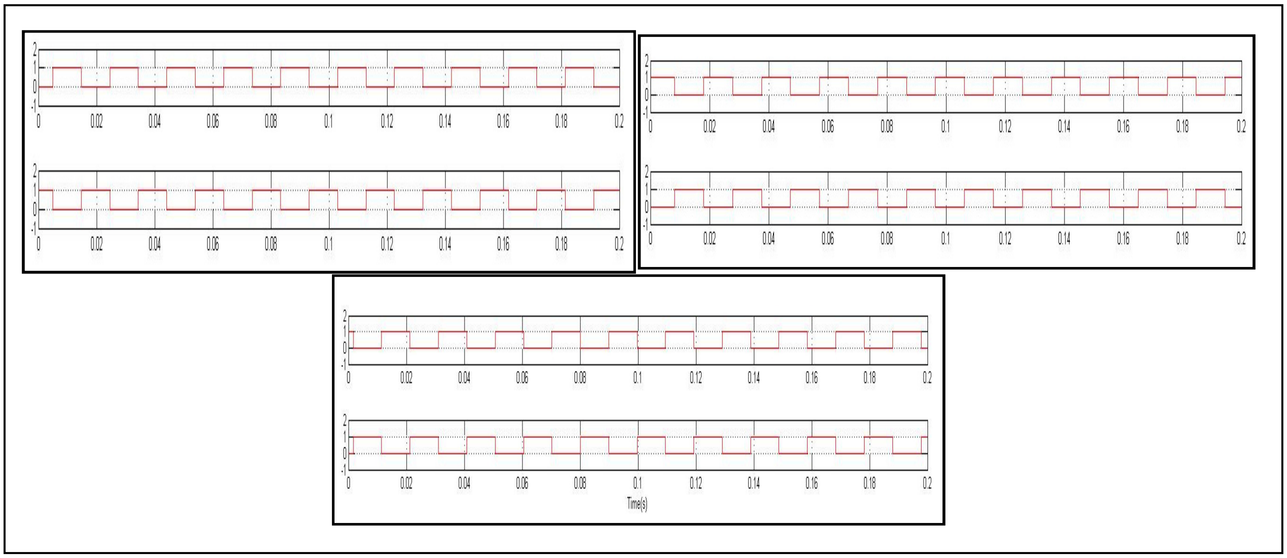

Figure 14: Inverter Switching Pulse

3) Generator DC Output Voltage @ wind speed = 7 m/s
The Generator DC output voltage from the proposed converter is as shown in the below fig. 15. The wind speed = 7 m/s.

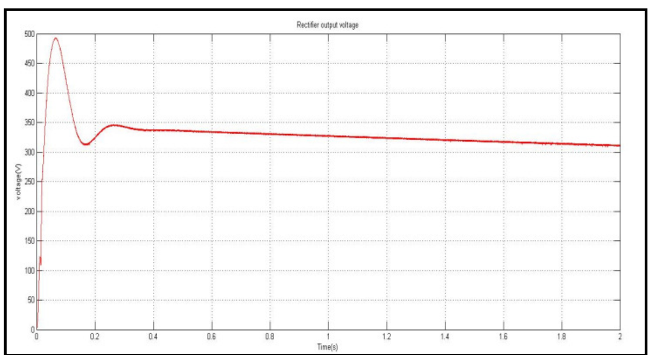

Figure 15: Generator DC Output Voltage @ wind speed = 7 m/s

4) SEPICCONVERTER Output Voltage @ wind speed = 7 m/s
The SEPIC CONVERTER Output Voltage for the proposed method to the load is as shown in the following fig. 16. The wind speed is 7 m/s

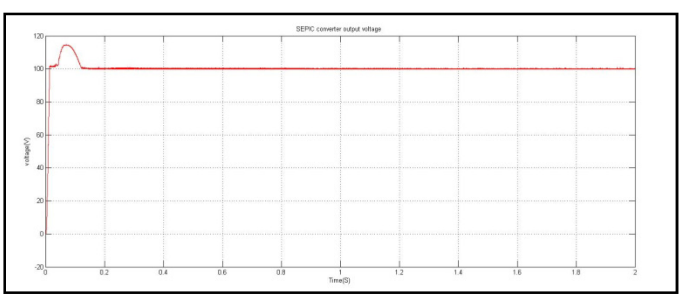

Figure 16: SEPIC CONVERTER Output Voltage @ wind speed = 7 m/s

5) Three Phase Output Voltage wind speed = 7 m/s
The Generator DC output voltage from the proposed converter is as shown in the below fig. 17. The wind speed is 7 m/s.

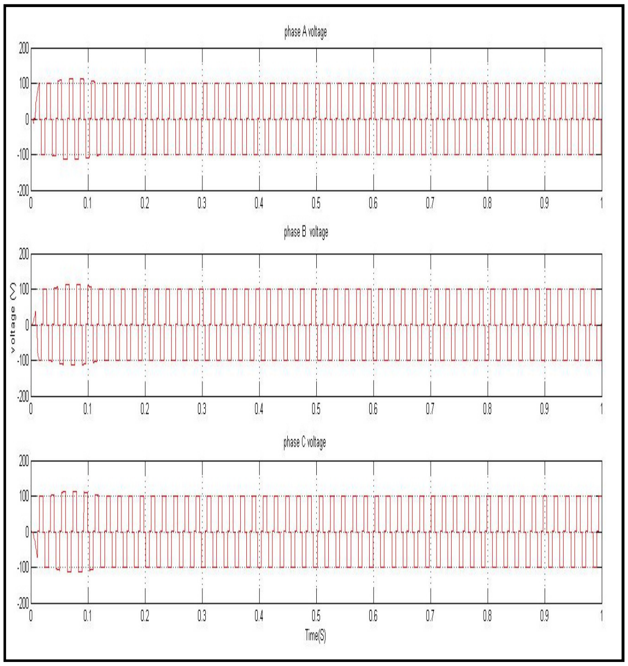

Figure 17: three phase output voltage

6) Generator DC Output Voltage @ wind speed = 10 m/s

The Generator DC output voltage from the proposed converter is as shown in the below fig. 18. The wind speed is 10 m/s.

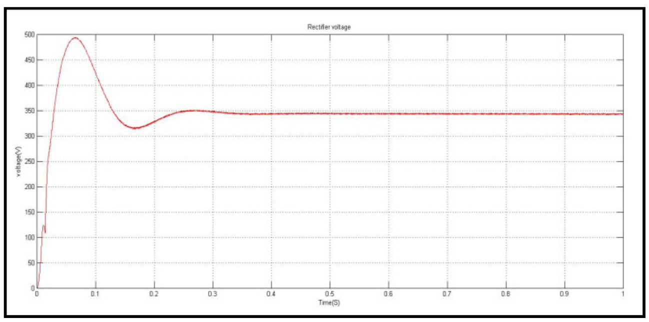

Figure 18: DC Output Voltage

7) SEPIC CONVERTER Output Voltage @ wind speed =10 m/s

The SEPIC CONVERTER Output Voltage for the proposed method to the load is as shown in the following fig. 19. The wind speed is 10 m/s.

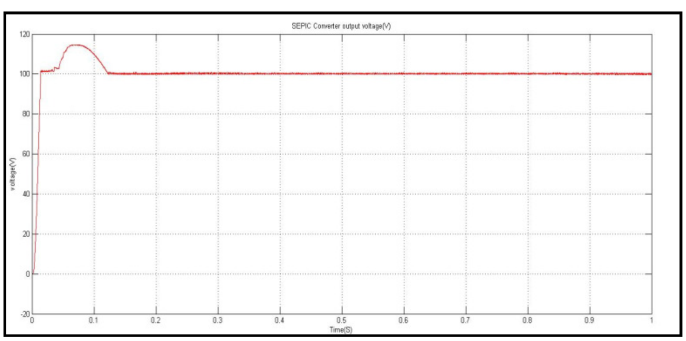

Figure 19: SEPIC CONVERTER Output voltage

8) Three Phase Output Voltage wind speed = 10 m/s

The output voltage to the proposed system is as shown in the following fig. 20. The wind speed = 10 m/s.

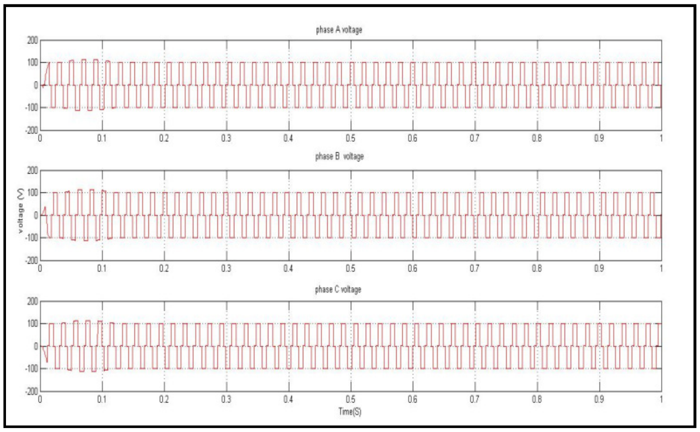

Figure 20: Three Phase Output Voltage wind speed = 10 m/s

3. Comparison of Conventional and Proposed System

The proposed converter with SEPIC converter is compared with existing converter and the results of the two methods are presented in the following table 1.

Description	Conventional System	Proposed System
Wind speed@7 m/s –Output Voltage	170V	100 V
Wind speed@10 m/s–Output Voltage	150V	100 V
Total Harmonics Distortion	136%	31.06%

Table 1: Comparison of conventional and proposed system

4. Conclusion

In the existing system, with the change in the wind speed the generator output also varies. Thus the output could not be maintained constant. The harmonics generated at the output is also high. In the proposed system, with the change in the wind speed, the generator output is maintained constant with the implementation of the SEPIC CONVERTER which is used for the voltage regulation or maintenances at the output and also the harmonics generated at the output is very low when compared to the existing method.

5. References

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