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Micro Wind Power Generation Based on SEPIC Converter

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Abstract

Sustainable energy sources are those that derive from the environment and are renewable. As an alternative to fossil fuels, it is clean. Power outages rise in tandem with rising energy demand. Therefore, constant loads can be supplied by renewable energy sources. This article suggested a system which uses wind energy because it is a very clean source of energy and produces no pollution when in use. The proposed micro wind energy battery storage uses batteries to store energy after it is produced at a cheap cost and maintain power quality. The regulated active and reactive power in the grid is exchanged, and the power quality is maintained, using the suggested micro wind energy conversion system with battery energy storage. The generated micro-wind energy can be harvested in conditions of changing wind speed and stored in the batteries during periods of low energy demand. By injecting or absorbing reactive power, the battery storage system and micro-wind energy generating system (μWEGS) will synthesis the output waveform and enable the true power flow required by the load. In the event of a grid breakdown, the system can also be used as a stand-alone system with an uninterrupted power source. In order to show the findings, this study deals with the simulation and implementation of DC to DC converters, such as SEPIC converters, in micro wind power generating systems.

Keywords: μWEGS, SEPIC converters.

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1. Introduction

In the upcoming years, traditional fossil fuels that pollute throughout the generating process, such coal, natural gas, and oil, will run out. People use renewable energy due to a lack of energy resources, wind is one among them. An expensive investment in coal plants, new gas generators, or thermal units is avoided when kinetic energy from wind is converted to electricity by a wind turbine. A by-product of solar energy is the wind. Wind energy is produced from about 2% of the solar energy that reaches the earth. Uneven surface warming and cooling causes atmospheric pressure zones, which cause air to move from high- to low-pressure regions. Supporting the crucial load without an uninterrupted power supply is particularly challenging in the microgrid network. At the point of common coupling, the suggested micro-wind energy conversion system with battery energy storage is employed to interchange the controllable real and reactive power in the grid and to maintain the power quality standards as per the International Electro-Technical Commission IEC-61400-21. When there is a low demand for electricity, the batteries can be used to store the created micro wind power, which can be harvested under different wind conditions. To facilitate a quicker dynamic switchover for the support of a critical load, this system uses hysteresis current control mode for inverter control. Combining battery storage with a micro-wind energy generating system (μWEGS), which will synthesize the output waveform by injecting or absorbing reactive power and enable the true power flow required by the load. Under severe load constraints, the system uses μWEGS and battery storage power to lessen its reliance on the conventional source. The system responds quickly to support critical loads. In the event of a grid breakdown, the system can also be used as a stand-alone system with an uninterrupted power source[1-8].

Small-scale turbines, like bigger ones, will generate the necessary electricity when they are located where there is the most wind. However, the wind must be stable or "clean". Strong winds that are turbulent frequently shift their speed and direction. A wind turbine must align itself with the wind; if the wind is turbulent, it must constantly reposition itself and generates significantly less electricity. In total, renewable energy sources account for around 16% of the world's final energy consumption. Traditional biomass, which is primarily used for heating, accounts for 10% of all energy, and hydroelectricity for 3.4%. Another 3% of energy came from new, fast expanding renewable sources such as small hydro, contemporary biomass, wind, sun, geothermal, and biofuel [9-12].

Energy is in extremely high demand as a result of urbanization and population growth. Alternative fossil fuels, including thermal power, diesel, oil, or coal, are expensive and hazardous to the environment. Wind energy is therefore regarded as the renewable, clean, and practical method to produce the energy when compared to all other power sources. The output power of the generator will, however, fluctuate due to variations in the wind. When a load is extremely sensitive and demands that there be no voltage sag or swell, this performance can have an impact on low power applications[13-15].

The standards for power quality of micro-wind generating systems are outlined in IEC-61400-21 by the International Electro-Technical Commission. Due to its short-term power supply, battery storage is employed for critical load applications. The distributed power system can produce an efficient, dependable, and long-lasting power system by combining battery energy storage and a micro-wind generating technology. Within the distribution network, the system also offers energy-efficient and uninterruptible power [3].

To reduce variability in the output of wind farms and stabilize the short-term fluctuations in output power, battery energy storage was deployed in highly developed countries. The distributed network's power flow will be improved by the parallel processing of wind energy generation and battery storage. The battery is charged using the micro wind energy generating systems when wind energy is abundant. The battery storage offers an instant response for either charging or discharging the battery and serves as a steady voltage supply for the crucial load in the distributed network. Lead-acid battery cells are used in the battery storage system to store energy. Numerous cells are linked in series to generate the necessary operating voltage for electrical energy storage applications. The current control method of the voltage source inverter is presented to interface the battery storage with the micro-wind energy generation into the distributed network in order to determine the efficacy of the proposed system.

2. Proposed Topology

The most prevalent topology for micro wind turbine systems consists of the wind turbine connected directly to an AC/DC/AC converter, which is then followed by a Permanent Magnet Synchronous Generator (PMSG).

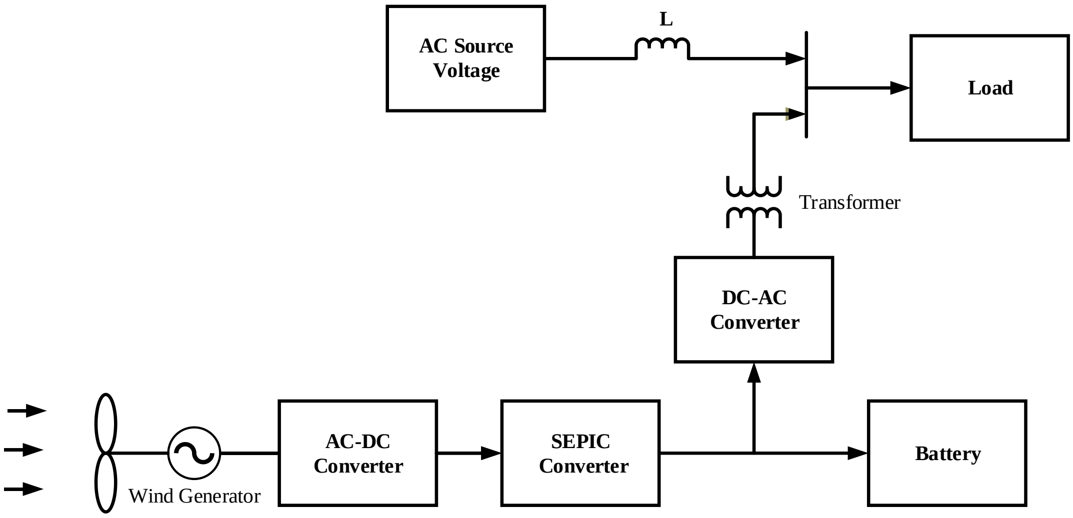

Figure.1. Block diagram of proposed system

The converter is realized with a AC/DC passive rectifier, a SEPIC converter and a DC/AC full-bridge inverter that injects the electric power into the grid. The micro-wind generating system (μWEGS) is connected to a generator, transformer, transformer, and ac-dc converter to obtain dc bus voltage. Dc bus current for constant dc bus voltage is used to depict the power flow in an inverter.

2.1 SEPIC Converter

This digest introduces a novel three-phase controlled converter for low power PMSG. It is a SEPIC converter that operates at DCM. The generator currents are practically harmonic-free since the topology uses the PMSG inductance as its input inductor. Results from simulations for both high and low wind speeds demonstrate that this topology has a strong potential in the suggested application, and design equations are also included. In Single-Ended Primary Inductor Converter (SEPIC), the voltage at the output can be greater, lower, or equal to the voltage at the input. It has buck-boost converter similarities. In relation to its common terminal, the converter's output polarity is positive.

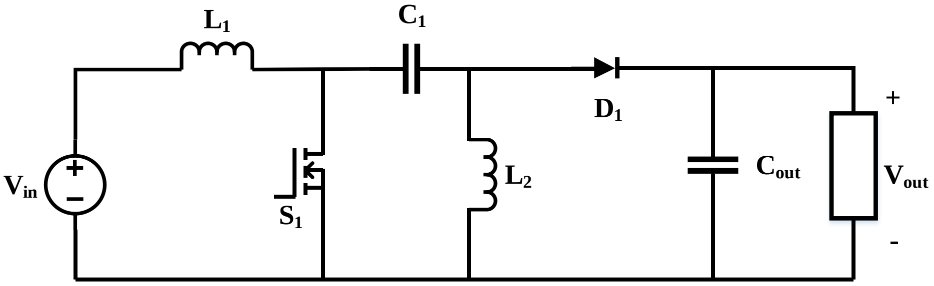

Figure. 2. SEPIC converter

The capacitor C_1 blocks any DC current path between the input and the output. The anode of the diode D_1 is connected to a defined potential. When the switch S_1 is turned ON, the input voltage, V_{in} appears across the inductor L_1 and the current I starts to increase. Energy is also stored in the inductor L_2 as soon as the voltage across the capacitor C_1 appears across L_2. The diode D_1 is reverse biased during this period. But when S_1 turns off, D_1 conducts. The energy stored in L_1 and L_2 is delivered to the output, and C_1 is recharged by L_1 for the period.

2.2 Duty Cycle

The duty cycle, D, for a SEPIC converter working at 100% efficiency is

$$D = \frac{V_{out}+V_D}{V_{in}+V_D+V_{out}} \qquad (1)$$

Where,

V_D = Forward voltage drop of the diode.

V_{in} = Input voltage of the converter.

V_{out} = output voltage of the converter.

2.3 Inductor Selection

When choosing an inductance, it's recommended to enable peak-to-peak ripple current to range from 20% to 40% of the maximum input current at the lowest input voltage.

Ripple current flowing through inductors L_1 and L_2 are same.

$$\Delta I_{L=}\ I_{IN} * 40\% \qquad (2)$$

$$\Delta I_{L=}\ \frac{I_{OUT} * V_{OUT}}{V_{IN(MIN)}} * 40\% \qquad (3)$$

$$L_1 = L_2 = \frac{V_{IN(MIN)}}{\Delta I_L * f_{SW} * D_{max}} \qquad (4)$$

f_{SW} = Switching frequency.

2.4. SEPIC Coupling Capacitor Selection

The capacitor C_s selection of SEPIC depends on the RMS current, which is given by,

$$I_{c1(rms)} = I_{out} * \sqrt{\frac{V_{out} + V_D}{V_{in(\min)}}} \qquad (5)$$

In relation to the output power, the SEPIC capacitor must be rated for a significant RMS current. Due to this characteristic, SEPIC is much well-suited to lower power applications. The SEPIC capacitor's voltage rating must to be higher than its maximum input voltage.

2.5 Output Capacitor Selection

When Q1 is turned on in a SEPIC converter, the output capacitor will be supplying the output current while the inductor is charging. Large ripple currents are thus observed in the output capacitor. The output capacitor must therefore have the capacity to handle the maximum RMS current.

$$C_{out} \geq \frac{I_{out} * D_{max}}{V_{ripple} * 0.5 * f_{sw}} \qquad (6)$$

3. Simulation Results

Figure 3 depicts a Simulink model of a wind turbine coupled to a permanent magnet synchronous generator. An angle exists between the blade's chord and the plane of rotation. There is a precise pitch angle for each wind speed that will maximize power output. Commercial wind turbines may incorporate a pitch control system since they need to produce nearly consistent power output throughout the day despite varying wind speeds.

Therefore, with a wind speed of 10 m/sec, the pitch angle is fixed at 25 degrees. The generator's input is set as the wind turbines output in radian/sec, which can be changed into RPM using the equation,

$$\frac{2\pi N}{60} = \omega \text{rad/sec} \qquad (7)$$

Where,

$$N=\frac{\omega*60}{2\pi} \quad \text{R.P.M} \qquad (8)$$

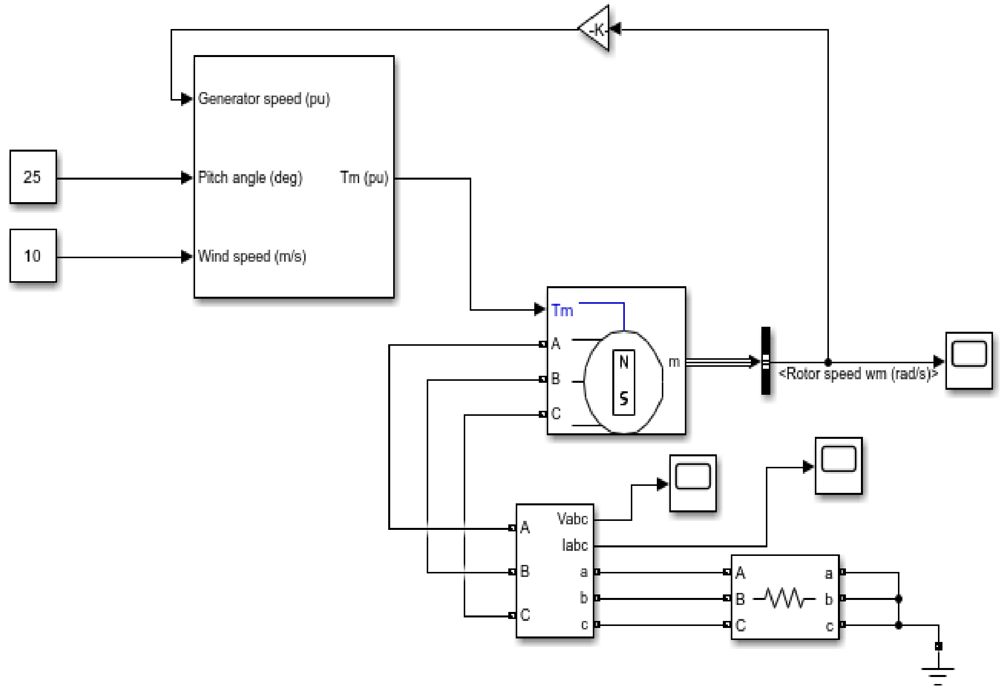

Figure.3.Wind turbine connected to a Permanent Magnet Synchronous generator

An uncontrolled rectifier is used to convert generated AC voltage to dc. Controlling the firing angle is not vital to this type of rectification. In order to change variable dc voltage into fixed dc voltage by adjusting the firing pulse, respective dc voltage is linked to the SEPIC converter. The PWM inverter is then provided the DC voltage from the SEPIC converter to power the load.

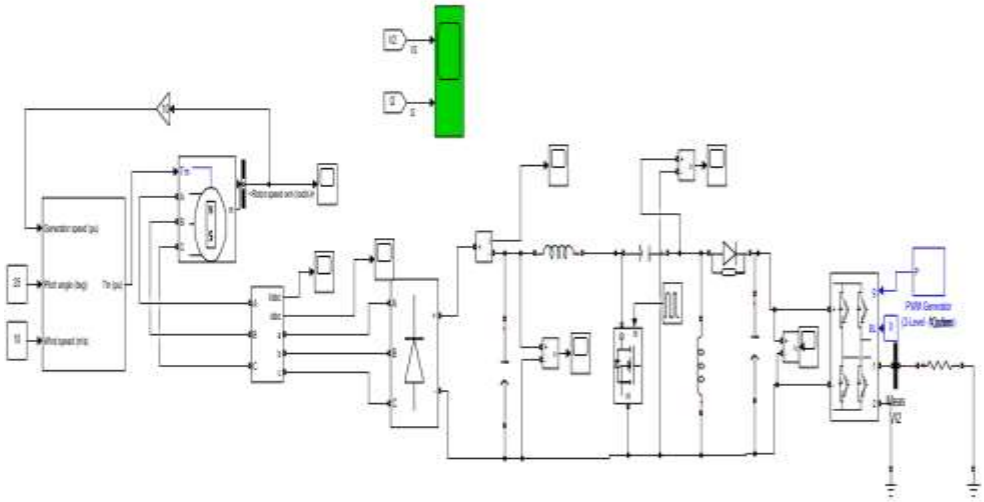

Figure.4. SEPIC converter connected in the wind power generation system

Simulink model of SEPIC converter connected in the wind power generation system is exhibits in Fig.4. The output voltage waveforms of the inverter and the SEPIC converter are illustrated in Figures 5 and 6 respectively.

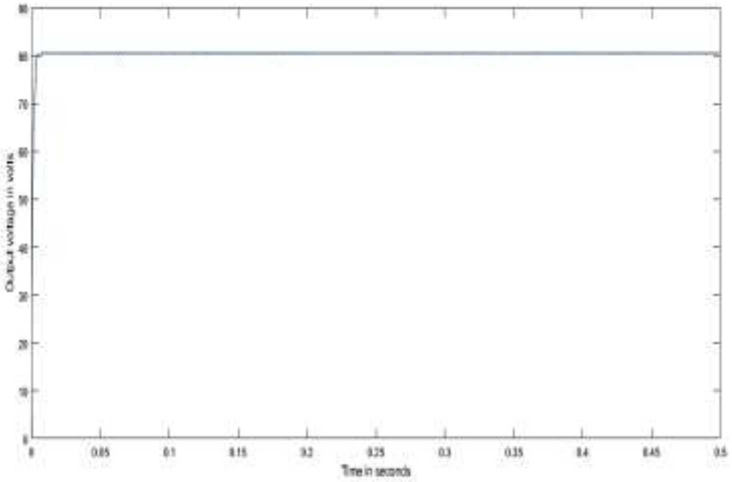

Figure.5.Output voltage waveform of the SEPIC converter

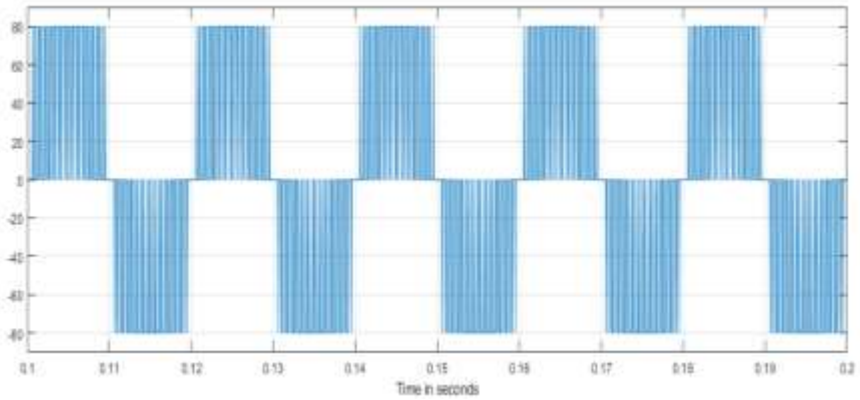

Figure.6.Output voltage waveform of the inverter

4. Conclusion

The suggested SEPIC converter-based micro-wind energy conversion system was examined, and it was coupled to a PWM inverter in current-controlled mode to interchange real and reactive power to support the essential load. Under steady state conditions, the transmission of wind energy is controlled across a dc bus with energy storage. This enables real power to flow when the load is instantly in demand. Moreover, a simulation of the micro wind power generation station with open loop control and pitch angle disturbance is performed. In addition, a simulation of a micro wind power generating system with open loop control and pitch angle disturbance is done.

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