Wind Energy System

Functional Description and Complete System Block Diagram

Andy Brown, Basheer Qattum, Ali Gokal

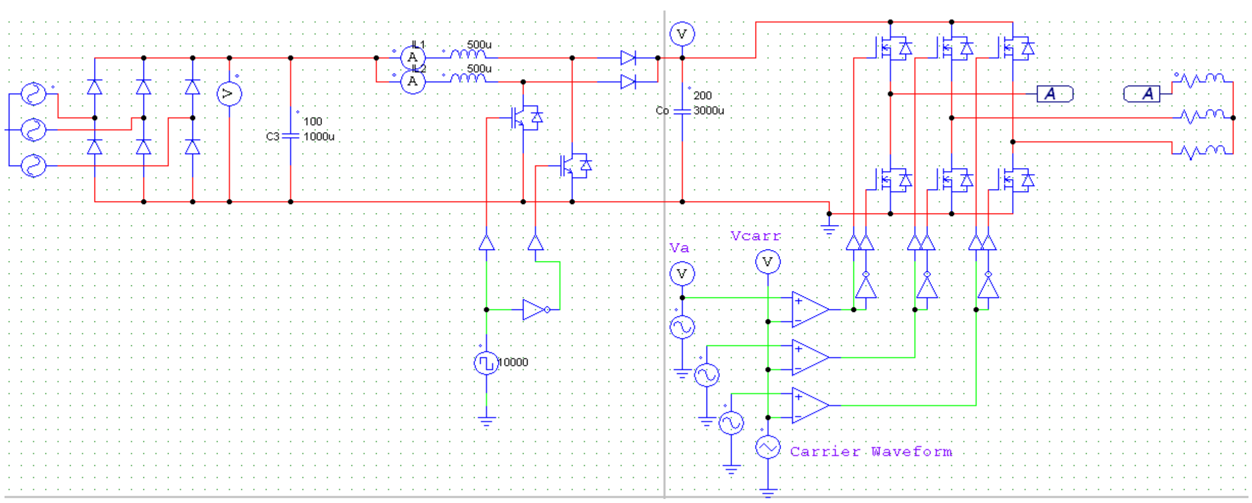
Dr. Na and Dr. Huggins

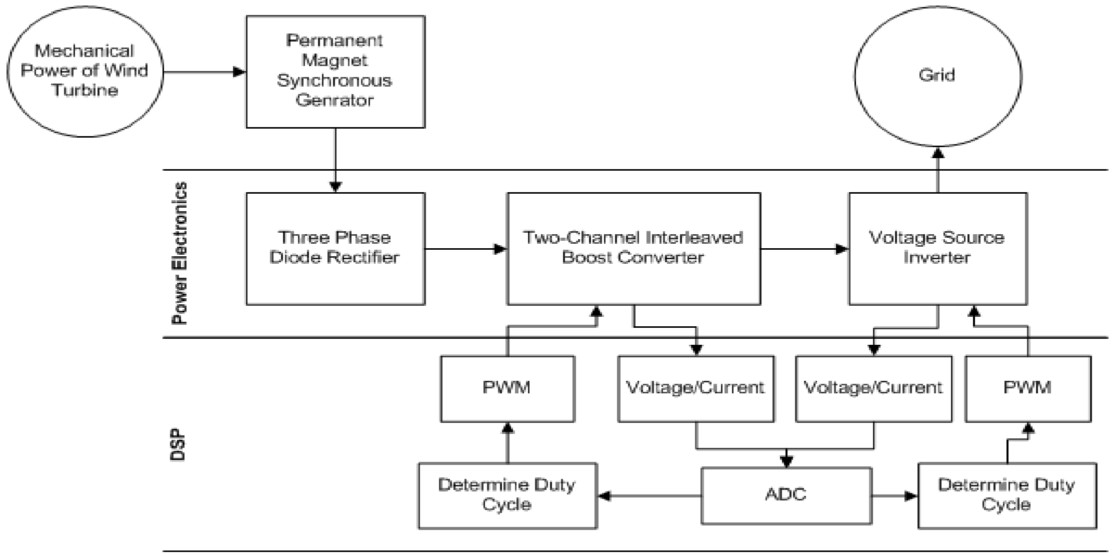
I. Introduction:

In a world where resources are becoming scarce, there is a high demand for renewable energy. Development has been made for more efficient and effective energy resources that are cheaper and more reliable than current methods of energy production. With new innovations arising in combination with current resources depleting, the world is turning its attention to wind energy in order to aid the sustainability of energy needs. Wind energy, as a rule of thumb, is a clean, renewable and environmentally friendly source due to the fact it is naturally generated. With that knowledge, our goal of this project is to design and implement a system that can harvest this energy source and convert it into AC power. Through a variety of power electronics, digital signal processing and controls we can utilize these tools to achieve this feasible goal.

II. Wind Energy Conversion Model

Complete System Description





(Figure 1 Top Level Diagram)

This particular system converts wind energy into electrical energy using components such as a permanent magnet synchronous generator, a diode rectifier, a two interleaved boost converter, and a voltage inverter as depicted in Figure 1. The system will begin by harnessing kinetic energy from wind that will rotate the blades of a permanent magnet synchronous generator creating mechanical power. The electrical energy produced from the permanent magnet generator will be output as three-phase AC. From this output, another conversion from AC to DC will take place through the use of a three-phase rectifier that will enable the use of a boost converter to boost our DC voltage. In order to boost the voltage that will be needed to supply the grid, we will use two interleaved boost converters. The DSP board will be responsible for handling the switching process of the boost converters. Moving from the boost converters we will perform yet another conversion from DC to AC by an inverter. Finally, this AC will be supplied to grid power.

Generator Identification Process

The main and primary component of the wind energy system is the generator. Basically, all of the following components in the system depend of the type of generator chosen. There are three different types of generators that are generally used in the wind industry: induction, permanent magnet, and brushed DC generators.

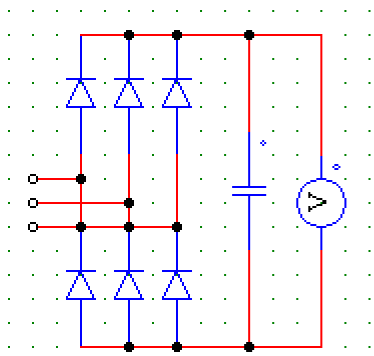
Induction generators require an external supply to produce a rotating magnetic flux. The external supply has to be supplied from either an electrical grid or a generator in order to produce power. The rotating magnetic flux from the stator induces currents in the rotor, which also produces a magnetic field. The rotor must turn at a high rate of speed to act like a generator in order to produce power at the synchronous frequency. Since we are located in the United States, the standard synchronous frequency is 60 Hz. The common down side of using an induction generator in a wind turbine is the need of additional gears. Typically one will need an induction generator to run 1500 RPM or higher to meet the synchronous needs, so gearing is very common.

For brushed DC generators, the electromagnets spin on the rotor with the power coming out of what is known as a commutator, which causes a rectifying effect when it is outputted, usually as a lumpy DC signal. Although this is not an efficient way to rectify the power from the windings, it is used because it's the only way to get the power out of the rotor. High-quality brushed motors can reach reasonable efficiencies, but are typically 70% efficient.

A permanent magnet generator has a set of electromagnets and a set of permanent magnets. Thus, the key difference between this particular generator and the rest is that the excitation field is provided by a permanent magnet instead of a coil. These permanent magnets are mounted on the rotor while the electromagnets are on the stator. Generally the coils of the generator are wired in a standard three phase wye or delta formation. This project will require the use of a permanent magnet generator because of the following reasons: They do not require an additional DC supply for the excitation circuit, they are generally simpler and maintenance free, it will be easier to rectify the power to be used with a grid tie, condensers are not required to maintain the power factor and operates at a higher efficiency over a wider range of power output.

Three-Phase Diode Rectifier

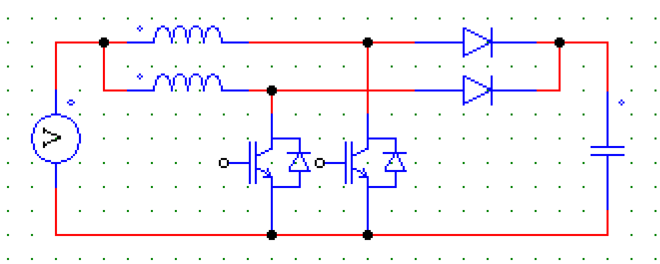
In short, a rectifier is an electrical device that converts AC into DC. In industry, rectifiers can take a variety of different forms. However, this project will require a diode rectifier. The reason being is that diodes allow an electric current to pass only in the forward direction, while at the same time blocking current in the reverse direction. This unidirectional behavior is called rectification which explains why this particular instrument is necessary. To go into further detail, the simple process of rectification produces a type of DC voltage that is characterized by a pulsating unidirectional voltage and current. Since the generator will output a pulsating voltage, and it will vary in both magnitude and frequency, there will be a need of a diode rectifier system shown in Figure 2 and a filter that will be able to extract the noise caused by the generator to generate a much smoother DC voltage. Once a permanent magnet generator that will meet industry and curricular standards is found, the goal is to attain the particular voltages and currents from the generator specifications that will be driven through the diodes of the rectifier. With this information in hand, choosing the diodes that will coordinate effectively with the output of the permanent magnet generator will be a simpler task. From there, the DC signal will move onto the boost converters.



(Figure 2 Three-Phase Rectifier System)

Two Interleaved Boost Converters

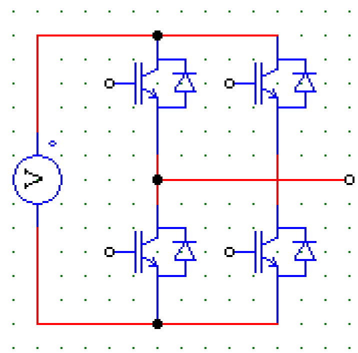
Most renewable energy sources, such as wind energy, have a low voltage output that requires a voltage boost converter in order to output a high enough voltage to be transmitted to distant locations. The boost converter takes in the varying DC voltage from the three-phase rectifier and outputs a constant voltage into the input terminals of the voltage inverter. The advantages of the boost converter are that it is a simple design and ripple output is very low. The disadvantages are that the duty cycle ratio is limited by the switches and the inductors, a large switch current occurs when the duty cycle is high, and power flow is unidirectional due the diodes. For this project, we are using two interleaved boost converters, composed of two elementary boost converters in parallel configuration. The two interleaved boost converters divide the current into the two switches, which reduces conduction losses and allows the use of lower rated silicon devices. This design minimizes the frequency noise at both the input and output terminals, increases the power conversion efficiency, and reduces the output ripple amplitude. The boost converters will be controlled by a DSP board which will handle the switching of the boost converters. From the boost converters we will use an inverter which will convert DC to AC to supply grid power.



(Figure 3 Two Channel Interleaved Boost Converter)

Single Phase Grid-Tie Inverter

An inverter is basically the opposite of a rectifier, as in it converts DC into AC. The type of the inverter that will be used is known as a grid-tie inverter. A single phase grid-tie inverter (GTI) is a unique type of inverter that converts DC into AC in which the output is fed into an existing electrical grid. These inverters are often used to convert DC produced by many renewable energy sources, such as solar panels or small wind turbines, into the AC used to power homes and businesses. However, in this case, the AC will be directed into a grid-tie.



(Figure 4, Voltage Inverter)

III. Summary

As mentioned before, the world's finite resources such as oil, coal and natural gas cannot be around forever. That is why a need for new technology like this wind system is in order to secure Earth's bright future. By creating and implementing a design, such as this project, conversion of the unlimited wind energy into usable AC power can be attained. By utilizing today's innovations in power electronics, there is an opportunity to combine these tools to truly attain something great. The steps toward this goal took the form of using raw energy "wind" and converting that mechanical power into electrical energy through the use of a permanent magnet synchronous generator. Once the electrical energy is obtained, several more conversions through a series of different power electronics would have taken place. The energy conversion will start as AC and move to DC through the rectifier, followed by the DC-DC conversion by the boost converters. After that conversion pursued the final conversion of DC-AC by the inverter. Successfully connecting all these tools and having the correct assumptions, the ability to achieve the predicted goal will be inevitable.

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