Wind Energy System

Project Proposal

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INTRODUCTION

With the increasing demand for renewable energy sources, wind power generation has become a popular option for electricity power generation, which is both environmentally friendly and economically competitive. A wind energy conversion system is a system that converts kinetic energy of the wind into electricity. A typical wind energy conversion system consists of a wind turbine, a generator, power electronics, and control systems. The primary focus of this project is to design and implement the power electronics and control systems of a wind energy conversion system.

PROJECT SUMMARY

The purpose of this project is to design and implement a wind system conversion system that interfaces a wind turbine with a single phase utility line. This system consists of a permanent magnet synchronous generator, a three phase diode rectifier, a two-channel interleaved boost converter, and a grid tie inverter. The IGBTs in the boost converter and inverter will be controlled by a TMS 320 F2812 Digital Signal Processor. Since a wind energy system can potentially generate hundreds of megawatts of power, the main goal of this project is to develop a system which shall output maximum power despite fluctuating wind conditions.

SYSTEM BLOCK DIAGRAM

This system, as shown in figure 1, uses an induction motor to simulate the rotation of a wind turbine. The motor will be powerful enough to turn the shaft of the permanent magnet synchronous generator in order to produce the desired voltage. The three phase diode rectifier bus will convert the varying frequency and magnitude sinusoidal voltage from the permanent magnet generator into a smooth but fluctuating DC voltage. Then the DSP-controlled two channel interleaved boost converter will increase the DC voltage, improve the power factor, decrease the total harmonic distortion, minimize the current and voltage ripples, and output maximum power by using a maximum power point tracking algorithm. Finally, the inverter will transform the DC voltage into a 120 V_{rms} AC voltage in order to integrate it into the grid.

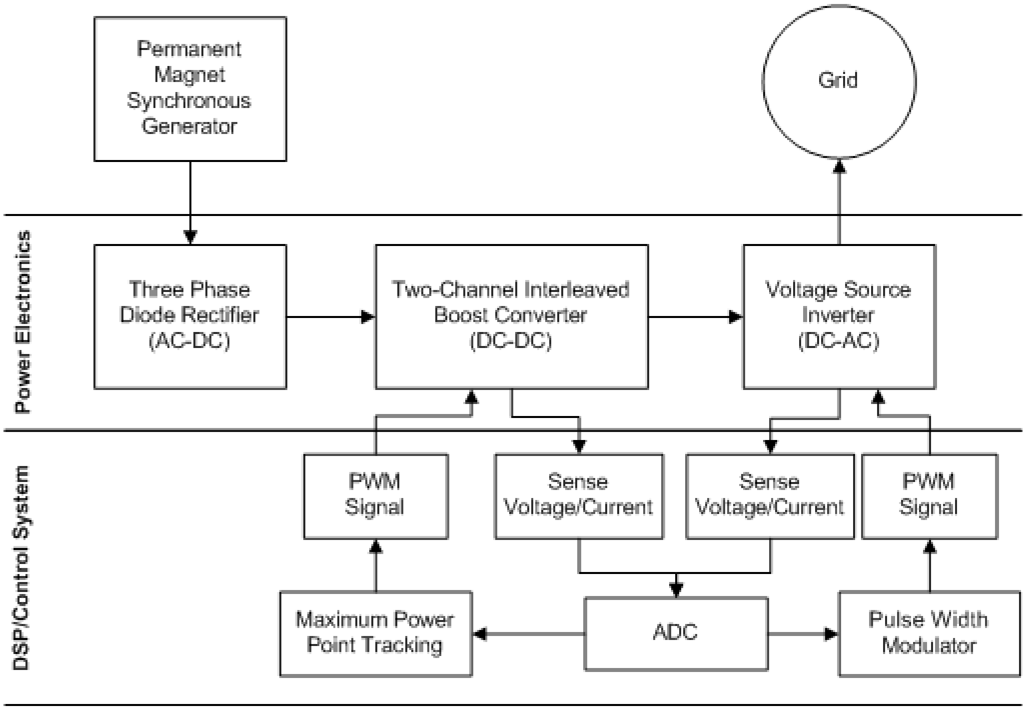

Figure 1 Top Level System Diagram

SUBSYSTEM DESCRIPTION

A description of the major subcomponents of this system is discussed below. The final design will depend on problems that occur during actual implementation and testing of the initial design. However, the overall topology of the system will be largely unaffected.

PERMANENT MAGNET SYNCHRONOUS GENERATOR

For this project, the permanent magnet synchronous generator will output power of about 1 kW. A permanent magnet synchronous generator allows the use of more power electronics converters than other types of generators such as induction generators. In addition, compared to other types of generators, a permanent magnet synchronous generator is easier and more cost-effective when implementing it to multiple phase and multiple pole power electronic circuitry. The power factor of the system can be improved independent of the generator by implementing a power factor correction control system.

THREE-PHASE DIODE RECTIFIER

The three-phase diode rectifier converts the variable AC voltage from the generator to DC voltage. The output of the diode rectifier has a low power factor. A power factor correction technique is necessary in order to improve the power factor. Some of the popular power factor correction techniques are a DC-DC Converter, PWM boost-type rectifier, tapped-transformer converter, and VIENNA rectifier. In this system, the DSP-driven boost converter will improve the power factor of the output of the diode rectifier.

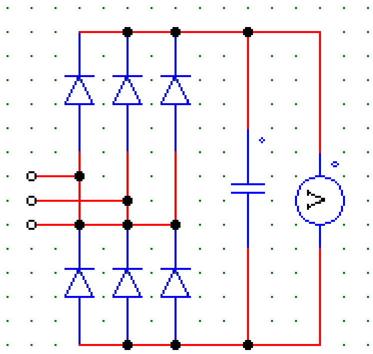

Figure 3 Three-Phase Rectifier

TWO-CHANNEL INTERLEAVED BOOST CONVERTER

The two-channel interleaved boost converter in this system is a DC-DC converter driven by a PWM signal generated on the DSP by using a maximum power point tracking algorithm. The rectified voltage from the three-phase diode rectifier passes through the two-channel interleaved boost converter in order to increase the DC voltage to about 200 V. The maximum power point tracking control system allows the system to output maximum power regardless of the wind speed. Also, the boost converter improves the power factor by decreasing the total harmonics distortion, and tracks the maximum power produced by the wind.

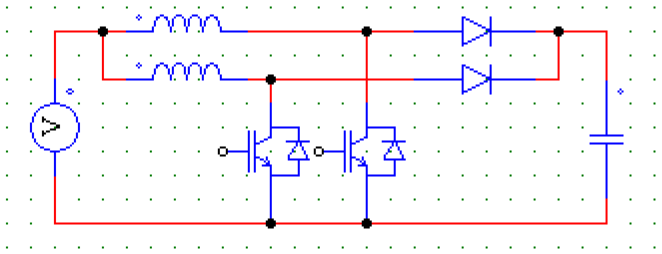

Figure 4 Two Channel Interleaved Boost Converter

MAXIMUM POWER POINT TRACKING

Maximum power point tracking (MPPT) algorithms are techniques to maintain maximum power output regardless of the wind conditions. Most MPPT algorithms are variations of perturbation and observation or hill climbing searching, wind speed measurement, or power signal feedback. A modified variation of the perturbation and observation method developed by Joanne Hui and Alireza Bakhshai will control the IGBTs in the boost converter [3]. This MPPT algorithm incorporates an adaptive memory algorithm in order to increase the speed of the search operation.

The perturbation and observation technique essentially perturbs the voltage in the boost converter by changing the duty cycle in small increments until maximum power is achieved. A flowchart of this technique is illustrated in figure 5. The MMPT algorithm will be created on MATLAB/SIMULINK, which will convert the SIMULINK diagram into C++ code, so it can be implemented on TMS 320 F2812 Digital Signal Processor using Code Composer v3.3.

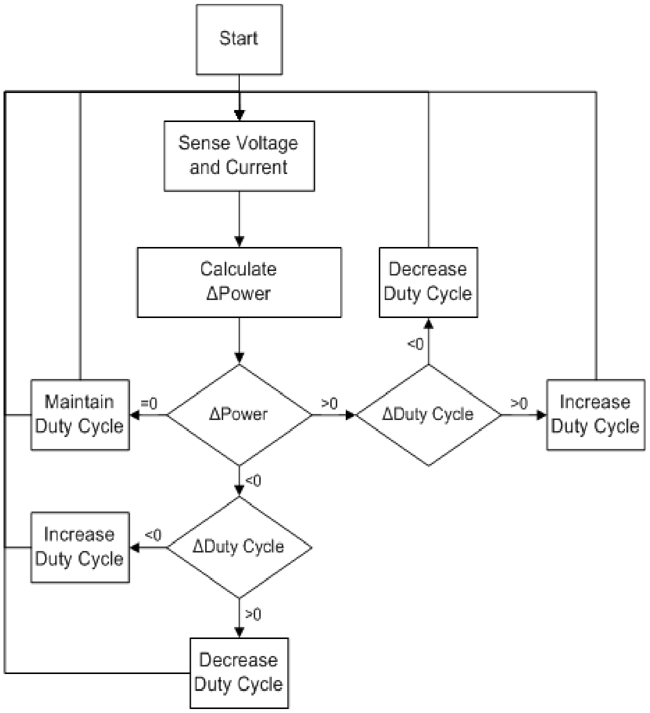

Figure 5 Perturbation and Observation Algorithm

SINGLE PHASE GRID-TIE INVERTER

The single phase grid-tie inverter, as shown in figure 6, converts DC voltage into 120 V_{rms} AC voltage and integrates the system into an existing electrical grid. The switching of the IGBTs is controlled by DSP in order to generate a sinusoidal voltage with frequency of 60 Hz. Also, the output of the inverter will pass through a low pass filter in order to reduce the high voltage harmonics.

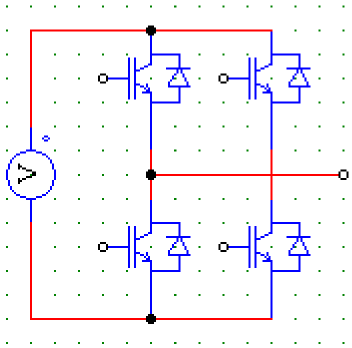

Figure 6 Voltage Inverter

SIMULATION RESULTS

SMALL THREE-PHASE DIODE RECTIFIER

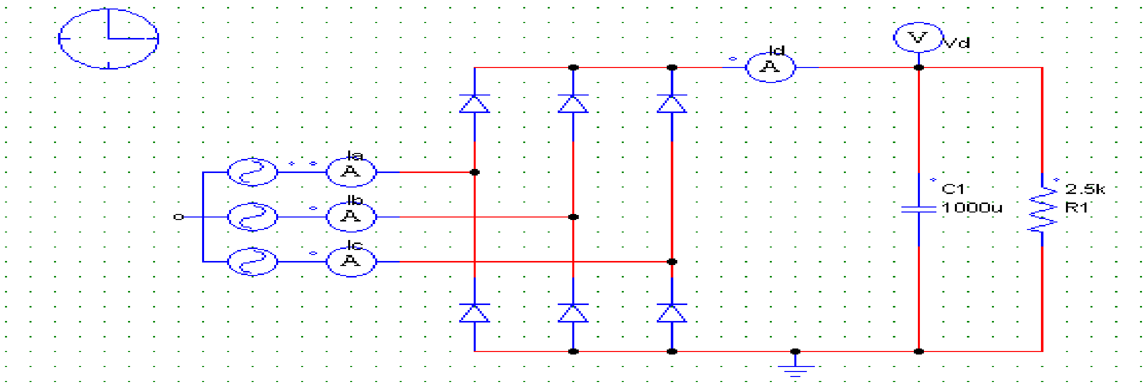

Figure 7 Three-Phase Diode Rectifier Circuit

The three-phase diode rectifier was simulated using PSIM. The circuit is modeled in PSIM as shown in figure 7. The theoretical voltage output from a three phase diode rectifier is found by $V_{out} = 1.35\ V_{IN,RMS.}$ The table below shows the results from the PSIM simulation and the theoretical voltage. Figure 8 illustrates the DC voltage output of the diode rectifier.

Table 1 Three-Phase Diode Rectifier Simulation Results

$V_{IN,RMS}$	V_{out} Simulation	V_{out} Theoretical	Percentage Error
10	14.1	13.5	4.44%
20	28.5	27	5.56%
40	56.5	54	4.63%
60	84.5	81	4.32%
80	113	108	4.63%
100	140.5	135	4.07%
120	169.5	162	4.63%

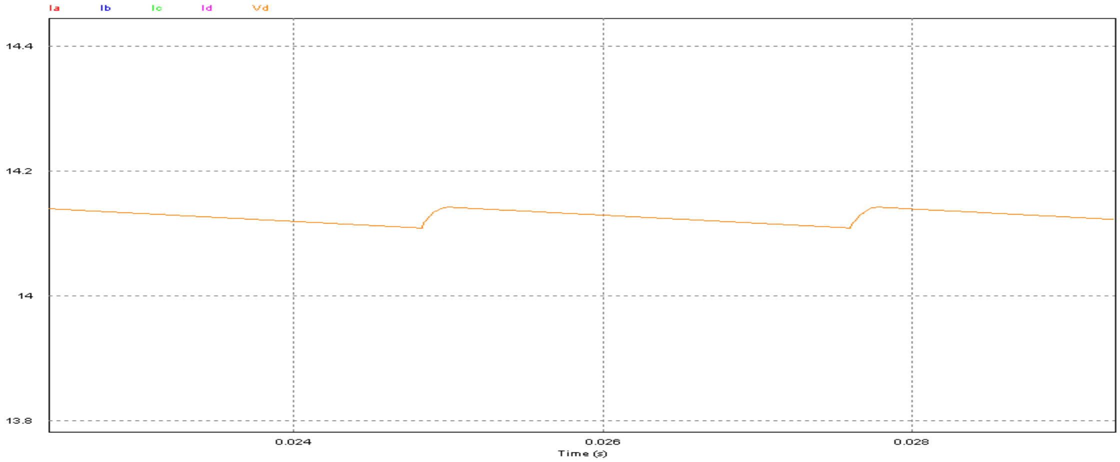

Figure 8 Three Phase Diode Rectifier Voltage Output

TWO-CHANNEL INTERLEAVED BOOST CONVERTER

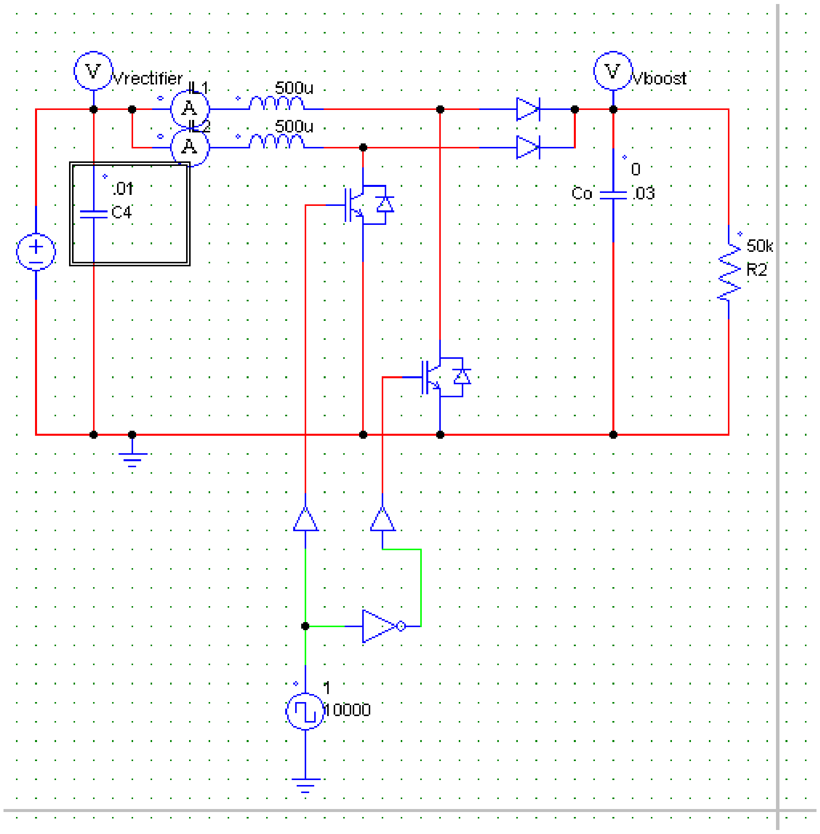

Figure 9 Two-Channel Interleaved Boost Converter Circuit

The three-phase diode rectifier was simulated using PSIM and the PSIM model of the circuit is shown in figure 9. The output of the simulation is shown in figure 10.

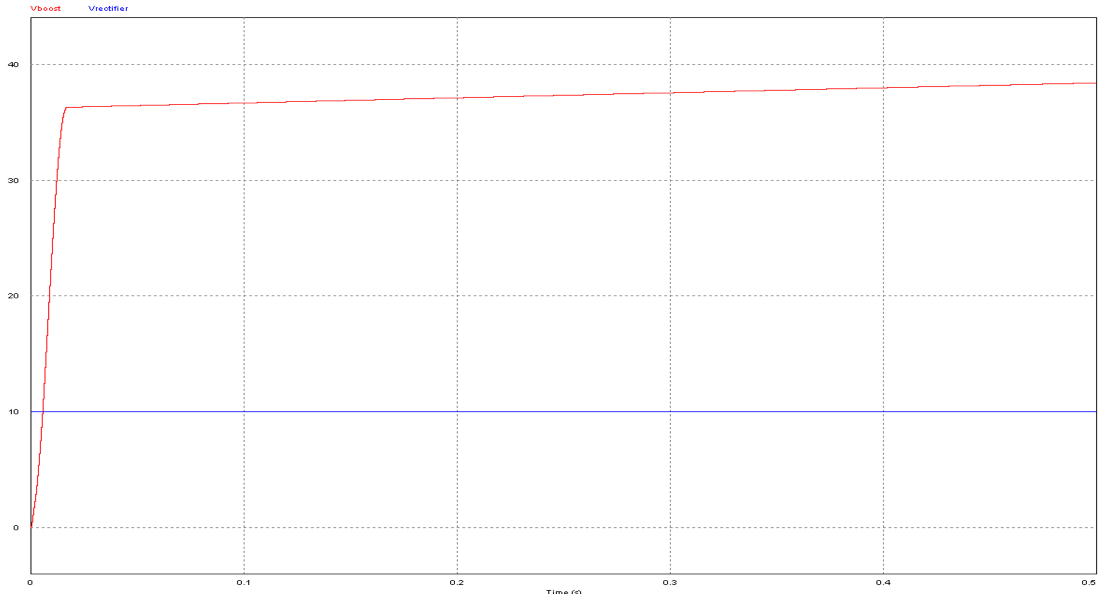

Figure 10 Two-Channel Interleaved Boost Converter Voltage Output

SCHEDULE

Week 1	Generator Set Up	
Week 2	Generator Set Up	DSP Programming
Week 3	Build Boost Converter	DSP Programming
Week 4		DSP Programming
Week 5	Build Inverter Converter	DSP Programming
Week 6		DSP Programming
Week 7	Build Rectifier Converter	DSP Programming
Week 8		DSP Programming
Week 9	Overall System Integration	
Week 10		
Week 11	Preparation of Senior Project Presentation	
Week 12	Preparation of Senior Project Report	
Week 13	Presentation Prep	
Week 14		

EQUIPMENT LIST

- Permanent Magnet Synchronous Generator
- Transformer
- Diodes
- Capacitors
- Heat Sink
- Inductor
- IGBT
- Fuse
- Fuse Holder
- Current Transducer
- Gate Driver
- Op Amp
- Voltage Regulator
- IGBT Heat Sink
- TMS 320 F2812 DSP

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