DEVELOPMENT OF A DC-AC POWER CONDITIONER FOR WIND GENERATOR BY USING NEURAL NETWORK

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To my beloved parents, sisters, brother, brothers-in-law, friends and lecturers, without your fully support, guidance and advice I might not had this kind of achievement.

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ABSTRACT

This project present of development single phase DC-AC converter for wind generator application. The mathematical model of the wind generator and Artificial Neural Network control for DC-AC converter is derived. The controller is designed to stabilize the output voltage of DC-AC converter. To verify the effectiveness of the proposal controller, both simulation and experimental are developed. The simulation and experimental result show that the amplitude of output voltage of the DC-AC converter can be controlled.

ABSTRAK

Projek ini mempersembahkan fasa tunggal pembangunan penukar DC-AC untuk aplikasi penjana angin. Model matematik penjana angin dan kawalan Artificial Neural Network untuk penukar DC-AC diterbitkan. Pengawal direka bagi memantapkan voltan keluaran penukar DC-AC. Untuk mengesahkan keberkesanan pengawal cadangan, kedua-dua simulasi dan eksperimen telah dibangunkan. Simulasi dan keputusan eksperimen menunjukkan bahawa amplitud voltan keluaran penukar DC-AC boleh dikawal.

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LIST OF ABBREVIATIONS AND ACRONYMS

DC	-	Direct Current
AC	-	Alternate Current
SPWM	-	Sinusoidal Pulse Width Modulation
MATLAB	-	Matrix Laboratory
DSP	-	Digital signal Processes
WECS	-	Wind Energy Conversion Systems
PI	-	Proportional plus Integral
PMSG	-	Permanent Magnet Synchronous Generator
DFIG	-	Doubly Fed Induction Generator
PWM	-	Pulse Width Modulation
SIMULINK	-	Simulation and Link
IGBT	-	Insulated Gate Bipolar Transistor
MOSFET	-	Metal Oxide Semiconductor Field-Effect Transistor
S	-	Switch
VDC	-	Voltage Direct Current
Vr	-	Voltage Reference
Vo	-	Voltage output
Fr	-	Frequency Reference
Vc	-	Voltage Carrier
Fc	-	Frequency Carrier
MF	-	Modulation Frequency
MI	-	Modulation Index
MLP	-	Multilayer Perceptron
BPNN	-	Backpropagation Neural Network

PCB	-	Printed Circuit Board

CHAPTER 1

INTRODUCTION

1.1 introduction

The use of renewable energy sources, such as solar, wind and hydraulic energies, is very old; they have been used since many centuries before our time and their applications continued throughout history and until the "industrial revolution", at which time, due to the low price of petroleum, they were abandoned.

During recent years, due to the increase in fossil fuel prices and the environmental problems caused by the use of conventional fuels, we are reverting back to renewable energy sources. Renewable energies are inexhaustible, clean and they can be used in a decentralized way (they can be used in the same place as they are produced). Also, they have the additional advantage of being complimentary, the integration between them being favorable. For example, solar photovoltaic energy supplies electricity on sunny days (in general with low wind) while on cold and windy days, which are frequently cloudy, the wind generators are in position to supply more electric energy.

The wind energy supplied by the wind, therefore the device able to perform this conversion is called wind generator, this consists of a mechanical system of rotation which is powered by blades as in old windmills. This rotary system is connected to an electric generator whose axis joined to the driving system. In this way the wind, forcing the blades to turn, drives the electric generator which can be either a dynamo or an alternator (the alternator, in comparison to the dynamo, presents the advantage of a higher efficiency, supplying energy at a lower speed, and supplying more energy at higher speed).

1.2 Project's Background

Wind turbine technology is one of the fastest developing renewable technologies. In 1888 built the first automatically operating wind turbine for electricity generation (Charles F. Brush, 2003) Figure: 1.1. With a few tens of kilowatt power rating wind turbines to today's megawatt range wind turbines. In the earlier time wind power production did not have any serious impacts on the power system operation and control, but now it plays an active part in the grid since the wind power system is increasing rapidly.

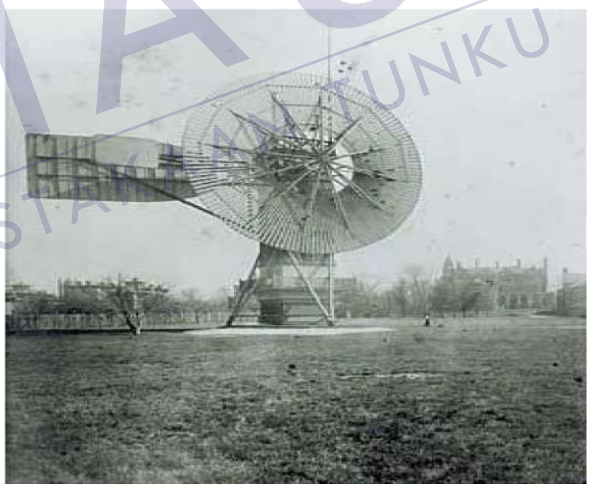

Figure: 1.1: The first automatically wind turbine built in 1888

The technology used in wind turbines was in the beginning based on squirrel-cage induction generators directly connected to the grid. By that, power pulsations in the wind are almost directly transferred to the grid. Furthermore, there is no active control of the active and reactive power that typically are the control parameters to the system frequency and voltage however, they necessitate power electronic converters to provide a fixed frequency and fixed voltage power to their loads (Slootweg, 2003).

Most modern turbine inverters are forced commutated PWM inverters to provide a fixed voltage and fixed frequency output with a high power quality. For certain high power wind turbines, effective power control can be achieved with PWM (pulse width modulation) converters which provide a bidirectional power flow between the turbine generator and the utility grid.

As the power range of the turbines increases these control parameters become more important. Also the introduction of power electronics has changed the basic characteristic of wind turbines from being an energy source to be an active power source. With the price of the power electronic devices falling, the solutions with power electronics become more and more attractive.

1.3 Problem Statements

Wind generator system depends on wind speed as kinetic source to rotate shaft (rotor) for generator. Variations of wind speed generate output voltage of wind generator system not constant. By this reason it is importance of develop converter for maintain the output voltage of the wind generator become constant.

1.4 Project's Objectives

The major objective of this project is development of DC-AC power conditioner for wind generator. Its measurable objectives are as follows:

i. To develop modeling system of DC-AC converter of DC wind generator.
ii. To develop modeling neural network controller that suitable for DC-AC of a converter of a wind generator.

iii. To develop performance of a neural network DC-AC converter for wind generator.

1.5 Project's Scopes

This project is primarily concerned with development of (DC-AC) power conditioner for wind generator. The scopes of this project are:-

i. Modeling of a DC wind generator, DC-AC converter and neural network are simulating using MATLAB.

ii. Sinusoidal Pulse Width Modulation (SPWM) technique is used to control the switching signals for the DC-AC power inverter

iii. Using neural network intelligent technique as controller to improve performance of power conditioner for system.

iv. The controller and (SPWM) develop in DSP Board.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter includes some of literature review on wind energy conversion system and wind turbine. Also, focus on main parts of wind turbine system and controller used in this project.

2.2 Wind Power Generate

The terms "wind energy" or "wind power" describe the process by which the wind is used to generate mechanical power or electricity. Wind turbines convert the kinetic energy in the wind into mechanical power. This mechanical power can be used for specific tasks (such as grinding grain or pumping water) or a generator can convert this mechanical power into electricity to power homes, businesses and schools.

2.3 Literature Review on Wind Energy Conversion System

Wind energy conversion systems (WECS) are the devices which are used to convert the wind energy to electrical energy. There exists a large collection of literature on the modelling of wind energy conversion systems more specifically on the modelling of individual system components of a wind energy conversion system. A wind energy conversion system is mainly comprised of two subsystems, namely a wind turbine part and an electric generator part. Detailed descriptions of these concepts can be found in text books on wind energy (Mukund., 1999) and (Tony Burton, *et al* 2001). A summary of the typical wind turbine models and their control strategies is presented in (Manwell, J.G. McGowan & A.L. Rogers, 2002).

2.4 Literature Review on Wind Turbines

In the literature, most of the models used to represent a wind turbine are based on a non linear relationship between rotor power coefficient and linear tip speed of the rotor blade (Mukund. 1999) and (Slootweg, *et al* 2003).

Muljadi and Butterfield mention the advantages of employing a variable speed wind turbine and present a model of it with pitch control. In this model, during low to medium wind speeds, the generator and the power converter control the wind turbine to maximize the energy capture by maintaining the rotor speed at a predetermined optimum value. For high wind speeds the wind turbine is controlled to maintain the aerodynamic power produced by the wind turbine either by pitch control or by generator load control. However, generator load control in the high wind regions, in some cases suffers from the disadvantage of exceeding the rated current values of the stator windings of the generator. Care should be taken not to exceed the rated values of the current (Eduard Muljadi & C. P. Butterfield, 2001).

References (Anderson & Anjan Bose, 1883) and (Wasynczuk, *et al,* 1981) propose a detailed model of the variable speed pitch controlled wind turbine suitable for studying the transient stability of multi- megawatt sized wind turbines. The simulated model is based on a set of non linear curves depicting the relation between the blade tip speed, rotor power coefficient and pitch angle of the wind turbine. The references also consider a detailed model for the wind input which includes the effects of gust, noise added to the base value of wind input.

(Anderson & Anjan Bose, 1883) uses transfer-functions to represent the dynamics of the electrical generator driven by the wind turbine, while (Wasynczuk, *et al* 1981) usesdq- axis representation for the synchronous machine acting as an electrical generator. A proportional integral (PI) controller is used to implement the pitch angle controller to limit the wind turbine output in the high wind speed regimes. Simulation results obtained for these models indicate a good approximation of the dynamic performance of a large wind turbine generator subjected to turbulent wind conditions.

As an extension to this work done in (Anderson & Anjan Bose, 1883) and (Wasynczuk *et al*, 1981) presented a general model that can be used to represent all types of variable speed wind turbines in power system dynamic simulations. The modelling of the wind turbine given by the authors retains the pitch angle controller, which reduces wind turbine rotor efficiency at high wind speeds, as given in (Anderson & Anjan Bose, 1883) and (Wasynczuk, *et al*, 1981). The wind turbine dynamics are approximated using nonlinear curves, which are numerical approximations, to estimate the value of wind turbine rotor efficiency for given values of rotor tip speed and pitch angle of the blade. The authors offer a comparison between the per-unit power curves of two commercial wind turbines and the one obtained theoretically by using the numerical approximation. The results indicate that a general numerical approximation can be used to simulate different types of wind turbines.

2.5 Literature Review on Generator

The conversion of mechanical power of the wind turbine into the electrical power can be accomplished by an electrical generator which can be a DC machine, a synchronous machine, or an Induction machine.

DC machine was used widely until 1980s, in smaller power installations below 100 kW, because of its extremely easy speed control (Mukund, 1999). The presence of commutators in DC machines has low reliability and high maintenance costs. The second kind of electric generators are synchronous generators, suitable for constant speed systems. Requirement of DC field current and reduced wind energy capture of constant speed systems, compared to variable speed systems, are discouraging factors in their use in wind systems (Mukund, 1999). Another choice for the electric generator in a WECS is a permanent magnet synchronous generator. Reference (Antonios *et al* 2004) presents a model of the variable speed wind turbine connected to a permanent magnet synchronous generator (PMSG). But PMSGs suffer from uncontrollable magnetic field decaying over a period of time, their generated voltage tends to fall steeply with load and is not ideal for isolated operation (Bimal, 2003). Induction generators, on the other hand, have many advantages over conventional synchronous generators due to their ruggedness; no need for DC filed current, low maintenance requirements and low cost (Mukund, 1999).

References (Anca, *et al*, 2004) and (Rajib Datta & Ranganathan, 2002) give a model of the WECS using doubly fed induction generator (DFIG). DFIGs allow one to produce power both from the stator and the rotor of a (wound rotor) induction generator. However increase in the power output comes with increased cost of power electronics, and their control, for the rotor circuit. One advantage of this configuration is its suitability for grid-connected operations where reactive power is supplied by the grid.

2.6 Wind turbine system

The following figure illustrates the most important parts of the wind turbine system. The wind turbine system is divided into two main types:

1 - Mechanical power (Blades and gearbox).

2- Electric power (generators, power converter, transformer and utility).

Figure: 2.1 shows the most important parts wind system Turbine.

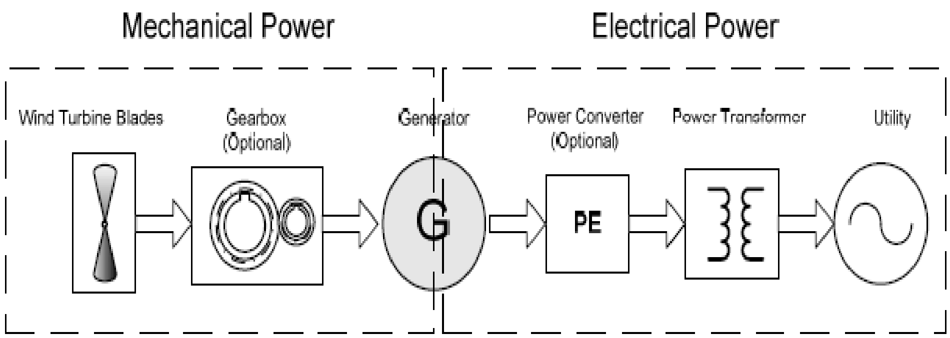

Figure: 2.1 : Wind turbine system.

2.7 DC Generator

An electric generator is a device used to convert mechanical energy into electrical energy. The generator is based on the principle of electromagnetic induction discovered in 1831 by Michael Faraday. Faraday discovered that if an electric conductor, like a copper wire, is moved through a magnetic field, electric current will flow in the conductor. So the mechanical energy of the moving wire is converted into the electric energy of the current that flows in the wire.

By the use of a generator, mechanical energy is then converted into electrical energy fed into a grid. In this stage, a power electronic converter and a transformer with circuit breakers and electricity meters are needed. Wind turbines can be connected to the grid at low, medium, high, and extra high voltage systems since an electricity power system's transmittable power is usually directly proportional to the voltage level. Turbines these days are mostly using a medium voltage system while large wind farms use high and extra high voltage settings.

2.8 Work of DC Generators

The commutator rotates with the loop of wire just as the slip rings do with the rotor of an AC generator. Each half of the commutator ring is called a commutator segment and is insulated from the other half. Each end of the rotating loop of wire is connected to a commutator segment. Two carbon brushes connected to the outside circuit rest against the rotating commutator. One brush conducts the current out of the generator, and the other brush feeds it in. The commutator is designed so that, no matter how the current in the loop alternates, the commutator segment containing the outward-going current is always against the "out" brush at the proper time. The armature in a large DC generator has many coils of wire and commutator segments. Because of the commutator, engineers have found it necessary to have the armature serve as the rotor (the rotating part of an apparatus) and the field structure as the stator (a stationary portion enclosing rotating parts). The following some advantages of the DC generator:

- Simple structure.
- Can be used for DC appliances.
- No health problems for people near transmission lines.

2.8 Power Electronics

Power electronics is defined as the application of solid state electronics for the conversion and control of electric power. Before discussing the electronic aspects of wind turbines, it is imperative that a discussion on how wind turbines convert mechanical energy to electric energy. Generally, it is composed of three major conversions or transfer. It starts with the rotor converting wind energy into mechanical energy, the generator converts that mechanical energy into electrical power, and then the transformer transfers the electric power to the grid.

2.10 Power electronic devices

Power electronic systems are used by many wind turbines as interfaces. Wind turbines function at variable rotational speed; thus the generator's electric frequency varies and needs to be decoupled from the grid's frequency. This action is possible if a power electronic converter system comes in handy.

The power converter is an interface found between the load/generator and the grid. Depending on the topology and the applications present in the system, power can flow into the direction of both the generator and the grid. In using converters, three important things must be considered: reliability, efficiency, and cost. Figure 2.2 shows a single-input single-output power converter system.

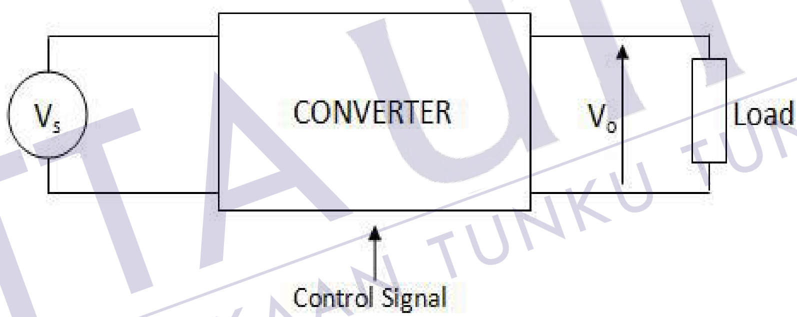

Figure 2.2: A simple power electronic converter system

Converters are made by power electronic devices, and circuits for driving, protection and control. Two different types of converter systems are currently in use: grid commutated and self commutated converters. Grid commutated converters are thyristor converters containing 6 or 12 pulse, or even more, that can produce integer harmonics. This kind of converter does not control the reactive power and consume inductive reactive power.

The other type of converter, self-commutated converter systems, are pulse width modulated (PWM) converters that mainly (IGBTs) or (MOSFETs) Transistors. In contrast to grid-commutated, self-commutated converters control both active and

REFERENCES

Anca D.Hansen, Florin Iov, Poul Sorensen, and Frede Blaabjerg, (2004): *Overall control strategy of variable speed doubly-fed induction generator wind turbine*. Nordic Wind Power Conference, Chalmers University of Technology, Sweden.

Anderson. P.M. and Anjan Bose (1983); *Stability simulation of wind turbine systems.*

IEEE Trans. on Power and Apparatus and Systems, vol. PAS-102, no. 12, pp. 3791-3795.

Antonios E. Haniotis; Konstantinos S. Soutis, Antonios G. Kladas, and John A. (2004): *Grid connected variable speed wind turbine modeling, dynamic performance and control*. IEEE PES Power Syst. Conf. Expos., vol. 2, pp. 759-764, New York, N NY, United States.

Bimal K.Bose (2003): *Modern Power Electronics and AC Drives*. Pearson Education.

Charles F. Brush (2003): *A Wind Energy Pioneer*. Danish Wind Industry , Association Copenhagen (Denmark).

Cheng- Yuan Liou and Yen-Ting Kuo (2007): *Data Flow Design for the B Backpropagation Algorithm*. Computer Science and Information Engineering, National Taiwan University.

Eduard Muljadi and Butterfield C. P (2001): *Pitch-controlled variable-speed wind t turbine generation*. IEEE Transactions on Industry Applications , vol. 37, no. 1, pp. 240-246.

Faeka Khater .M. H. (2002): *Power Electronic in wind energy conversion system.*

Hassaine. L (2001): *Asymmetric SPWM used in inverter grid connecte*. IEEE Transactions on Energy Conversion.

Jan Verveckken (2004): *Control Strategies for High Frequency Power Electronic C Converters*.

Manwell J.F, McGowan. J.G and. Rogers. A.L (2002): *Wind energy Explained – Theory, Design and application*. John Wiley& Sons.

Martin. T. Hagan (2006):*An Introduction to the use of Neural Networks in control System.*

Mukund. R. Patel (1999): *Wind Power Systems*. CRC Press, ch. 4-6.

Rajib Datta and V. T. Ranganathan (2002): *Variable-speed wind power generation using doubly fed wound rotor induction machine – A comparison with alternative schemes.* IEEE Transactions on Energy Conversion, vol. 17, no. 3, pp. 414-420.

Sanchis P. (2003): *A new control strategy for the Boost DC-AC Inverter. Lefeuvre in Proc. IEEE.*

Sebastian Seung (2006): *Multilayer perceptrons and backpropagation learning*.

Sharrif Z.A.M. (2004): *An Artificial Neural Network for Condition Monitoring and Fault Detection in Sinusoidal pulse width inverter drives*.

Slootweg J. G, De Haan S.W.H, Polinder. H and. Kling .W.L (2003): *General model for representing variable speed wind turbines in power system dynamics simulations*. IEEE Transactions on Power Systems, vol. 18, no. 1, pp. 144-151.

Slootweg .J.G, (2003): *Inside wind turbines - Fixed vs variable speed*. Renewable Energy World.

Texas Instruments (2007): *TMS320C28x™ DSP Workshop*. www.spectrumdigital.com

Tony Burton, David Sharpe, Nick Jenkins and Ervin Bossanyi (2001): *Wind Energy Handbook*. ch 4.

Wasynczuk. O, Man. D.T. and Sullivan J. P, (1981): *Dynamic behavior of a class of wind turbine generators during random wind fluctuations*. IEEE Transactions on Power and Apparatus and Systems, vol. PAS-100, no. 6, pp. 2837-2845.

Ying-W tzou (2004): *Full Control of a PWM DC-AC Converter for AC Voltage Regulation.* Member, IEEE SHIH-LUNG JUNG, Student, IEEE National Chiao Tung University Taiwan.