DESIGN OF CURRENT CONTROL MODE FOR WIND TURBINE APPLICATION

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Special for:

My late father and my mother …

Hussin b. Yusoff

&

Rahimah bt Hj.Ghazali

also to my brothers and sisters…

and not forgotten to my friends

Muhamad Amzar b. Ahmad

Nor Alhuda bt Mohammad Ishak

In thankful appreciation for support and encouragement to

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ABSTRACT

Stochastic nature of the wind speed is the main reason that leads to variability of output power of wind farm. Thus high penetration of the wind farm will cause power fluctuation and voltage variation in grid system. Current control method was designed to control power flow in the grid system hence the occurrence of fluctuant power can be eliminated in the network. A new technique using mathematical modeling was developed in designing the control system. The block diagram of this control system was built based on the dynamic analysis of the circuit by assuming the steady state condition. Some parameters for instance proportional and integral gain were determined based on the assumption of the values of line inductance, resistance and time constant . MATLAB/simulink tool was used to scrutinize the performance of the designed model. The performance of the designed control system is investigated by comparing the results between with and without control system and the results were also investigated in fault condition. The results show that the current control method has high potential in control power leveling in the grid system.

ABSTRAK

Sifat semulajadi kelajuan angin yang tidak menentu merupakan punca utama keluaran kuasa tenaga angin berubah dari semasa ke semasa. Penggunaan tenaga angin yang berleluasa akan menyebabkan kuasa dan voltan sistem grid juga turut berubah-ubah. Kaedah kawalan arus di reka khas untuk mengawal pengaliran kuasa dalam sistem grid seterusnya kepelbagaian kuasa dalam sistem rangkaian dapat dielakkan. Pendekatan baru telah diperkenalkan yang mana persamaan matematik dijadikan asas dalam pembinaan model tersebut. Blok diagram bagi model kawalan arus direka berdasarkan analisis dinamik terhadap litar dengan menganggap bahawa sistem tersebut dalam keadaan stabil dan beberapa parameter ditentukan berdasarkan nilai peraruh, rintangan, dan pemalar masa. Perisian MATLAB telah digunakan sebagai ukuran pencapaian bagi model tersebut. Pencapaian diukur dengan membandingkan keputusan ujian dalam dua keadaan iaitu tanpa dan dengan kawalan arus dan seterusnya ujian turut dijalankan dalam keadaan kerosakan. Keputusan mengesahkan bahawa sistem kawalan arus berpotensi tinggi dalam mengawal pengaliran kuasa dalam sistem grid.

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LIST OF ABBREVIATIONS

VSC	-	Voltage Source Converter
AC	-	Alternating Current
STATCOM	-	Static Var Compensator
SVS	-	Synchronous Voltage Source
SMES	-	Superconducting Magnetic Energy Storage System
ECS	-	Energy Capacitor Storage
PCC	-	Point of Common Connection
DFIG	-	Doubly-fed Induction Generator
IG	-	Induction Generator
SCC	-	short circuit capacity
GTO	-	gate turn-off
STATCON	-	static condenser
EDLC	-	electric double layer capacitor
PWM	-	Pulse Width Modulation
IGBT	-	isolated gate bipolar transistor
PFC	-	power factor correction
PSCAD	-	Power Systems Computer Aided Design
EMTDC	-	Electromagnetic Transients including DC
ETO	-	Emitter turn off
HAWT	-	Horizontal Axis Wind Turbines
VAWT	-	Vertical Axis Wind Turbines
TC	-	tap changers
MSC	-	mechanical switched cap

PV	-	Real Power vs Voltage
VQ	-	Voltage vs Reactive Power
KVL	-	Kirchhoff Voltage Law
PLL	-	Phase-Locked Loop
K_p	-	Proportional Gain
K_i	-	Integral Gain
PI	-	Proportional-Integral
ref	-	Reference
R	-	Resistor
L	-	Inductor
X	-	admittance
t	-	Time
Re	-	Real part
Im	-	Imaginary part

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LIST OF SYMBOLS

θ	-	Angle
f	-	Function
ω	-	Rad/s
α	-	Alpha
β	-	Beta
τ_i	-	Time Constant
j	-	Imaginary part
m	-	Mili
Gff	-	Feed forward Filter
Ω	-	Ohm
π	-	Pi
µ	-	Mikro
%	-	Percentage
s	-	Transfer function
Hz	-	Hertz
k	-	Kilo
A	-	Ampere
V	-	Volt
M	-	Mega
W	-	Watt

CHAPTER 1

INTRODUCTION

1.1 Context

Nowadays, electricity demand is increasing from year to year but at the same time the amount of fuel tends to be depleting over time. This phenomenon has become a big problem to the energy suppliers. Renewable and alternative energy is a few of the promising resources which have been introduced to overcome this problem. Wind energy, a form of a renewable energy is found to be the most popular source due to its free, clean and renewable character hence its integration into power system is important and rewarding task for the next decades [1]. There are four available types of wind turbine; Wind Turbine Squirrel Cage Induction Generator, Wind Turbine Asynchronous Generator, Doubly-Fed Induction Generator (DFIG) and Synchronous Generator Full Scale Converter. In this study, the latter type will be used in the simulation. In practical application, the wind turbine is designed either vertical or horizontal axis depending on the wind speed of the installed location. Horizontal Axis Wind Turbines (HAWTs) are more efficient in lower wind speed condition meanwhile; Horizontal Axis Wind Turbines (VAWTs) can withstand at higher wind speed which can be up to eight times more efficient than HAWTs [21].

The term of a wind farm is referred to a group of wind turbines which located at the same location in which it may consists of several hundred individual wind turbine. The main role of the wind turbine is to convert kinetic energy from the wind into mechanical energy that directs the blades to turn around. The blades of the wind turbine are connecting to the generator via the main shaft hence the rotation of the blades will cause the rotor to spin accordingly which further result in electricity generation. By understanding the fundamental work of the wind turbine, it reveals that its output power depends totally on the wind speed [22].

Due to stochastic nature of the wind, electricity generated from the wind turbine can be highly variable at several different timescales: from hour to hour, daily, and seasonally. Its variability cause the power in grid system fluctuates randomly, resulting in voltage and frequency variation. The integration of the wind farm into the grid system requires careful consideration in order to maintain a high degree of reliability and security of the system. To make sure the system is in secured condition, penetration of the wind turbine should not violate the limitation of transmission line capacity. Besides, its voltage fluctuation margin at the point of common connection (PCC) should be remains under limit which is ±2.5% and the nominal voltage of the power system should be maintained in between 0.95 to 1.03 per-units. The impact of wind turbine on system operation depends on the grid strength of the connection point for example, the location of the wind farms, the type of wind generator, and the correlation between wind power production and load consumption [23].

Control system has been introduced to solve the problem of grid connected wind turbine. Many methods of control system are available but in this research, a new technique using mathematical equation is used to design the control system where current is the main components that is going to control in this scheme [24].

1.2 Background of Study

Output power of the wind turbine fluctuates randomly depending on the stochastic nature of the wind speed. High wind speed will produce larger output power and vice versa. Penetration of the wind farm into the grid system will affect a normal operation of the power system in which will lead to power fluctuation and voltage variation in the system. Introducing a control system can help to fix this problem. Power electronic converter is one part of the control system in which it is mostly used for active filtering, compensation purpose and power conditioning. Good design of a control system is determined by the quality of the power system hence it became a big challenge for researchers nowadays.

In this research, the study focuses on the designing of the control system by using current control method. The main purpose of this work is to minimize power fluctuation caused by the wind turbine that utilized in distributed generation system [2]. In this study, the design is based on the mathematical analysis by assuming the system operates in steady state condition. MATLAB/Simulink software is a preferred tool in analyzing the performance of designed control system.

1.3 Problem Statement

Wind turbine always depends on wind speed characteristics to produce the output power. Thus, due to stochastic nature of the wind speed, output power of the wind turbine fluctuates randomly which contributes to power fluctuation in the grid system hence will affect the frequency of the system [3]. Frequency should be constant unless the system will be unstable. In the condition of lower frequency, the current in the system will suddenly increased thus, the system tend to blackout due to generator trip [4]. Moreover, the fluctuant power will induce voltage and current variation in the system. These types of problem can be solved accordingly by embedding control scheme in the grid system connected to the wind turbine. As a solution, current control scheme is designed in this study to damp power fluctuation that result in reducing the voltage and current variation in the system.

1.4 Objectives

The objectives of this research are:

1. To design the mathematical modeling of current control method and implement it in MATLAB/Simulink tool.
2. To study the performance of current control method in power leveling for grid connected wind turbine system.
3. To investigate the effect of using current control method in fault condition.

1.5 Scope of project

In this project, control system based on voltage source converter is designed for grid connected wind turbine. To control the voltage source converter, current mode control method is used instead of voltage mode since it has many advantages in which voltage source converter (VSC) is protected against over-current condition due to its robustness against variation parameters of the VSC and AC system. In addition, this method is superior in dynamic performance and has higher control precision. The control strategy is designed by using mathematical technique instead of using actual power electronic component. MATLAB/simulink is used to test the performance of the control system. The entire mechanical aspect of the wind turbine was not modeled since the project focus on the part of control system rather than obtaining precise values for wind turbine response.

1.6 Thesis Organization

This thesis is organized into six chapters:

Chapter I briefly describes the introduction of the thesis. It covers topics such as the context, problem statement, objectives and scope of the project.

Chapter II explains the literature review of the topics related to this research work. Two main topics have been highlighted which are the problems related to wind turbine connected to grid system and the concepts of various control methods.

Chapter III expresses the mathematical equations which contribute to the design of block diagram of the control system. In this chapter transformation process from abc-frame to dq-frame has been derived in detail.

Chapter IV explains the methodology of the project. This chapter will briefly explicate the design process of current control method using mathematical model and its implementation in MATLAB/Simulink.

Chapter V presents the results obtained from the simulation. These results are analyzed and discussed in detail. Here the results before and after implementation of current control will be compared accordingly.

Chapter VI presents the conclusion and recommendations or suggestions for future work.

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