ANALYZING POWER QUALITY ISSUES OF WIND POWER PLANTS IN PUTTALAM

D. M. Mahesha Thilini Dissanayake

(109207M)

Degree of Master of Science

Department of Electrical Engineering

University of Moratuwa

Sri Lanka

December 2014

ANALYZING POWER QUALITY ISSUES OF WIND POWER PLANTS IN PUTTALAM

D. M. Mahesha Thilini Dissanayake

(109207M)

Dissertation submitted in partial fulfillment of the requirements for the degree Master of Science

Department of Electrical Engineering

University of Moratuwa

Sri Lanka

December 2014

DECLARATION

I declare that this is my own work and this dissertation does not incorporate without acknowledgement any material previously submitted for a Degree or Diploma in any other University or institute of higher learning and to the best of my knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text.

Also, I hereby grant to University of Moratuwa the non-exclusive right to reproduce and distribute my dissertation, in whole or in part in print, electronic or other medium. I retain the right to use this content in whole or part in future works (such as articles or books).

UOM Verified Signature

Date: 18.12.2014

D.M.M.T. Dissanayake

The above candidate has carried out research for the Masters Dissertation under my supervision.

UOM Verified Signature

Date: 19/12/2014.

Dr. W.D.A.S. Rodrigo

UOM Verified Signature

Date: 19/12/2014

Dr. H.M. Wijekoon

ABSTRACT

Wind Power development has become a booming industry due to its advantages over conventional thermal power sources. However, wind is considered as an intermittent source in terms of power quality as wind turbines have an uneven power generation following natural variations of wind. Power quality (PQ) is an important issue for electricity consumers at all levels of usage, particularly industrial sector as PQ disturbances ultimately lead to huge economic losses and safety concerns.

The research objectives are; to study on major power quality issues associated with four wind plants in Puttalam, propose suitable PQ improving methods and to identify the most suitable wind technology in view of power quality. Project scope includes measurement of electrical parameters at each plant, analysis of parameters based on "IEC 61400-21" and "Grid Connection Requirement" published by Ceylon Electricity Board, study on mitigation techniques, computer modeling and simulation in MATLAB/SIMULINK environment to investigate harmonic mitigation. For each power quality aspect, a set of norms and marginal values were set to evaluate each wind plant's performance. There are four distinct wind technologies and three of them are available in Sri Lanka. Out of these technologies, Wind Turbine type "C" which employs a Doubly-Fed Induction Generator with a partial scale power converter shows the best power quality characteristics.

From Measurements and Data Analysis it was concluded that, none of the investigated plants adhere to power quality requirements of the grid code. Neither the utility (CEB) nor the Wind Power Producers pay adequate attention on these violations. It is recommended to pay more attention on PQ deviations. Systems must be developed to continuously monitor PQ parameters and take necessary actions to keep them within specified levels. Further, hybrid filters to reduce harmonic distortion and Dynamic Voltage Restorers to mitigate voltage sags are proposed for WPPs under study.

Keywords: Power Quality, Wind Power, Harmonics, Active Filter

ACKNOWLEDGEMENT

There are many individuals who deserve acknowledgement for their contribution towards successful completion of this research.

First, I would like to express my gratitude to my supervisors; Dr. W.D.A.S. Rodrigo and Dr. H.M. Wijekoon for their valuable advices, guidance and assistance throughout the entire period of study. I am much grateful for sharing their vast knowledge and expertise on the field of Power Quality.

Secondly, my sincere acknowledgement is towards my employer; Ceylon Electricity Board for providing me the necessary equipment for data recording and the authorities of Seguwantivu Wind Power (Pvt) Ltd, Vidathamunai Wind Power (Pvt) Ltd, Nirmalapura Wind Power (Pvt) Ltd and LTL Holdings for granting me permission to monitor and record parameters of my choice.

I am much grateful to the Head of the Department of Electrical Engineering, the Course Coordinator of Master of Electrical Engineering Course and to the staff of the Department of Electrical Engineering for their valuable guidance and corporation related to all academic works during the course.

My very special thanks go to my dear husband Nalaka for his continuous encouragement, assistance and patience during the entire period. My research would never be successful without his tremendous support.

Lastly, there are many friends and colleagues who have not been personally mentioned here that I am much indebted for their contribution at various stages of the research to make it successful.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

Abbreviation	Description
AC	Alternating Current
AF	Active Filter
CEB	Ceylon Electricity Board
CSC	Current Source Converter
CSI	Current Source Inverter
DC	Direct Current
DFIG	Doubly-Fed Induction Generator
DSP	Digital Signal Processor
DVR	Dynamic Voltage Restorer
GIS	Gas Insulated Substation
GSS	Grid Sub Station
HV	High Voltage
IEC	International Electromechanical Commission
IEEE	Institute of Electrical and Electronic Engineers
IPP	Independent Power Producers
IT	Information Technology
LV	Low Voltage
LVRT	Low Voltage Ride Through
NCRE	Non-conventional Renewable Energy
NE	North East
NEMA	National Electrical Manufacturers Association
NREL	National Renewable Energy Laboratory
OP-AMP	Operational Amplifier
OPEC	Organization of Petroleum Exporting Countries
PCC	Point of Common Coupling
PF	Passive Filter
PMG	Permanent Magnet Generator

PQ	Power Quality
PSS/E	Power System Simulation for Engineering
PWM	Pulse Width Modulation
RMS	Root Mean Square
SCIG	Squirrel-Cage Induction Generator
STATCOM	Static Synchronous Compensator
SVR	Static Voltage Regulator
SW	South West
THD	Total Harmonic Distortion
VSC	Voltage Source Converter
VSI	Voltage Source Inverter
WPP	Wind Power Plant
WRIG	Wound Rotor Induction Generator

Principal Symbols

A	Ampere
GW	Giga Watt
H	Harmonic number
Hz	Hertz
I	Current
IGBT	Insulated Gate Bipolar Transistor
km	kilometers
kV	Kilo Volt
kVA	kilo volt ampere
kW	Kilo Watt
m	Meters
m/s	Meters per second
MOSFET	Metal Oxide Semiconductor Field Effect Transistor
ms	Milliseconds
MVA	Mega volt ampere

MW	Mega Watt
MW	Mega Watts
P	Active Power
P_{LT}	Long Term Flicker Index
P_{ST}	Short Term Flicker Index
PU	per unit
Q	Reactive Power
R	Resistance
rpm	rounds per meter
s	Seconds
V	Volt

LIST OF APPENDICES