STUDY OF SMALL-SIGNAL STABILITY OF A RENEWABLE INTEGRATED POWER SYSTEM USING A DYNAMIC PHASOR APPROACH

Wasala Appuhamilage Damsith Lakshan

208087L

Degree of Master of Science(Major Component of Research)

Department of Electrical Engineering
Faculty Of Engineering

University of Moratuwa
Sri Lanka

February 2024

STUDY OF SMALL-SIGNAL STABILITY OF A RENEWABLE INTEGRATED POWER SYSTEM USING A DYNAMIC PHASOR APPROACH

Wasala Appuhamilage Damsith Lakshan

208087L

Dissertation submitted in partial fulfillment of the requirements for the degree
Degree of Master of Science(Major Component of Research)

Department of Electrical Engineering
Faculty Of Engineering

University of Moratuwa
Sri Lanka

February 2024

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. I retain the right to use this content in whole or part in future works (such as articles or books).

Signature: Date: 18/03/2024

The supervisor should certify the Dissertation with the following declaration.

The above candidate has carried out research for the Degree of Master of Science(Major Component of Research) Dissertation under my supervision. I confirm that the declaration made above by the student is true and correct.

Name of Supervisor: Dr. WD Prasad

Signature of the Supervisor: Date: 18-0302024

DEDICATION

To my devoted parents, whose love, sacrifice, and teachings have been the beacon guiding me through life's journey. To my mother, for her nurturing spirit and unwavering belief in my abilities, and to my father, for his invaluable lessons on perseverance and integrity. And to my cherished wife, who has stood by me as a pillar of strength and understanding throughout this journey. Her love, patience, and encouragement have been the foundation upon which this work was built.

ACKNOWLEDGEMENT

First and foremost, my profound appreciation goes out to Dr. W.D. Prasad from the Department of Electrical Engineering at the University of Moratuwa. His exceptional knowledge, continuous guidance, and relentless support during the course of this research have been invaluable. His commitment to academic excellence and his role as a mentor has consistently motivated me to aim high and tackle challenges with determination and enthusiasm.

In addition, I'd like to express my heartfelt gratitude to the distinguished members of the Department of Electrical Engineering at UOM. Their collective wisdom and support have been pivotal in shaping this work. Moreover, a special acknowledgment is due to the faculty of Electrical and Information Engineering at the University of Ruhuna, where my foundational academic journey commenced. Their teachings and guidance during my undergraduate studies laid the groundwork for the researcher I am today.

ABSTRACT

The transition trend towards renewable energy in the modern world shows a rapid increment of renewable power sources in electrical power systems. Wind energy and solar energy can be considered as the leading energy sources nowadays. These renewable power plants have several power electronic interfaces, and they introduce more complex dynamics to the power system. A comprehensive evaluation is required to identify significant changes in the power system due to these changes. This study provides a detailed examination of the outcomes of introducing renewables to power systems with a significance on its effect on small signal stability and the complex dynamics arising from varying penetration levels of renewable energy sources are explored in-depth, providing a comprehensive understanding of their impact on the stability of the system. This research also revealed the significance of accounting for the network dynamics which are overshadowed in constant admittance network modeling to this study. This research deeply explores the complex mathematical representations of the power system with two types of network modeling techniques and to ensure the accuracy of the model this mathematical model is validated against a nonlinear response. Within this research, attention is drawn to five main scenarios and a real-world case study on wind power integration in Sri Lankan power system.

Keywords: In this research, various concepts and methodologies were explored, focusing on topics such as power system stability, eigenvalue analysis, participation factors, oscillatory modes, renewable energy integration, nonlinear responses, conventional energy sources, dynamic power system models, controller alterations, grid dynamics, power plant influences, wind energy penetration, solar energy penetration, system damping ratios, small signal stability, state matrix, mode shape analysis, complex plane eigenvalues,network interactions

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

Abbreviation	Description
AC	alternating current
DC	direct current
dq	direct quadrature
GSC	Grid side converter
MPPT	Maximum Power Point Tracking
PI	Proportional-Integral
PMSG	permanent magnet synchronous generator
PV	Photovoltaic
RSC	Rotor Side converter
SCIG	squirrel cage induction generators
TSR	Tip Speed Ratio
VSC	voltage source converters
VSI	Voltage Source Inverter
WRIG	wound rotor induction generators

LIST OF APPENDICES