

LB/DON/53/09

# UNIFIED POWER FLOW CONTROLLER AS POWER SYSTEM STABILIZER

A dissertation submitted to the  
Department of Electrical Engineering, University of Moratuwa  
in partial fulfilment of the requirements for the  
degree of Master of Science

by

University of Moratuwa, Sri Lanka  
WARUSAPPERUMA KANKANAMALAGE MAHESH  
www.lib.mrt.ac.lk  
PRASANNA WARUSAPPERUMA

Supervised by: Prof. J.R.Lucas  
Dr. P.S.N. De Silva

LIBRARY  
UNIVERSITY OF MORATUWA, SRI LANKA  
MORATUWA

621.3 "09"  
621.3 (043)

Department of Electrical Engineering  
University of Moratuwa, Sri Lanka

TH



92969

January 2009

# DECLARATION

The work submitted in this dissertation is the result of my own investigation, except where otherwise stated.

It has not already been accepted for any degree, and is also not being concurrently submitted for any other degree.



University of Moratuwa, Sri Lanka.  
Electronic Theses & Dissertations  
[lib.mrt.ac.lk](http://lib.mrt.ac.lk)

***UOM Verified Signature***

.....

W.K.M.P. Warusapperuma

Date: 30<sup>th</sup> January 2009

We/I endorse the declaration by the candidate.

***UOM Verified Signature***

.....

Prof. J.R.Lucas

***UOM Verified Signature***

.....

Dr. P.S.N. De Silva

## Table of Contents

<b><u>ACKNOWLEDGEMENT .....</u></b>	<b><u>VI</u></b>
<b><u>LIST OF FIGURES .....</u></b>	<b><u>VII</u></b>
<b><u>LIST OF TABLES .....</u></b>	<b><u>VIII</u></b>
<b><u>CHAPTER 1 .....</u></b>	<b><u>1</u></b>
<b><u>INTRODUCTION.....</u></b>	<b><u>1</u></b>
1.0 SCOPE OF THE PROJECT .....	1
1.1 INTRODUCTION TO STABILITY.....	2
1.11 ROTOR ANGLE STABILITY .....	2
1.2 INTRODUCTION TO FLEXIBLE AC TRANSMISSION SYSTEMS .....	6
<b><u>CHAPTER 2 .....</u></b>	<b><u>12</u></b>
<b><u>THEORETICAL VERIFICATION .....</u></b>	<b><u>12</u></b>
2.0 UPFC AS A POWER SYSTEM STABILIZER .....	12
2.1 UPFC MODEL IN MATLAB/SIMULINK SIMULATOR.....	16
<b><u>CHAPTER 3 .....</u></b>	<b><u>21</u></b>
<b><u>CASE STUDY.....</u></b>	<b><u>21</u></b>
3.0 INTRODUCTION .....	21
3.1 KUKULE GANGA HYDRO POWER PLANT MODELLING .....	22
3.2 HORANA GENERATORS MODELLING .....	25
3.3 TRANSMISSION LINE MODELLING .....	28
3.4 TRANSMISSION LINE DATA.....	28
3.5 MODELLING OF PANNIPITIYA BUS.....	29
3.6 MODELLING OF PANADURA LOAD CENTER .....	29

3.7 UPFC MODELLING.....	30
<b>CHAPTER 4 .....</b>	<b>32</b>
<b>SIMULATION RESULTS AND ANALYSIS.....</b>	<b>32</b>
4.0 INTRODUCTION .....	32
4.1 ANALYSIS OF FAULTS.....	32
4.2 EFFECT OF INCREASE IN DAMPING COEFFICIENT OF THE UPFC .....	38
4.3 EFFECT OF INCREASE IN SHUNT CONVERTER POWER RATING.....	45
<b>CHAPTER 5 .....</b>	<b>47</b>
<b>CONCLUSION.....</b>	<b>47</b>
5.0 CONCLUSION AND RESULTS .....	47
5.1 RECOMMENDATIONS FOR FUTURE RESEARCH .....	49
<b>REFERENCES.....</b>	<b>51</b>
<b>APPENDIX – A: UNIFIED POWER FLOW CONTROLLER (PHASOR TYPE).....</b>	<b>53</b>
<b>APPENDIX – B: POWER GRID DATA .....</b>	<b>55</b>



## Abstract

The FACTS device - Unified Power Flow Controller (UPFC) and its performance is studied under transient condition in the usage as a power system stabilizer. This device creates an impact on power system stability with its unique capability to control real and reactive power flows simultaneously on a transmission line and regulate voltage at the bus connected. These features become significant as the UPFC can allow loading of the transmission lines up to their thermal limits by regulating the power flow through desired paths. This gives the power system operators the desired flexibility in satisfying the deregulated power system imposed requirements.

The new technology associated with the UPFC and its structure is studied. The theoretical analysis is done in verifying its capability for stability enhancement. A practical system is modelled to verify the theoretical analysis in MATLAB/SIMULINK platform.

Theoretical and practical verification reveals the function of UPFC in power system stabilisation. The parameters associated with the UPFC are studied for optimum stability criterion.



University of Moratuwa, Sri Lanka.

Electronic Theses & Dissertations

www.ho.mtu.ac.lk

## Acknowledgement

Thanks are due first to my supervisors, Professor J.R.Lucas and Dr. P.S.N.De Silva for their great insights, perspectives, guidance and sense of humour. My sincere thanks go to the officers in Post Graduate Office, faculty of Engineering, University of Moratuwa, Sri Lanka for helping in numerous ways to clarify the things related to my academic works in time with excellent cooperation and guidance. Sincere gratitude is also extended to the people who serve in the office of Department of Electrical Engineering.

I would also like to extend my sincere gratitude to M/s Maga Engineering (Pte) Ltd. for sponsoring me for the first year work of my MSc course and providing required duty leave.

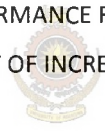
Lastly, I should thank my parents, many individuals, friends and colleagues who have not been mentioned here personally in making this educational process a success. May be I could not have made it without your support.

# List of Figures

<b>Figure</b>	<b>Page</b>
FIGURE 1.0: POWER – DELTA CURVE FOR SYNCHRONOUS MACHINE	3
FIGURE 1.1: PHASE-ANGLE COMPENSATION	8
FIGURE 1.2: COMPARISON OF FACTS DEVICES	9
FIGURE 1.3: UPFC BLOCK DIAGRAM	10
FIGURE 1.4: VSC SIMPLIFIED DIAGRAM	11
FIGURE: 2.0 (B): UPFC SIMPLIFIED MODEL	12
FIGURE 2.1 : PHASOR DIAGRAM	13
FIGURE 2.2: PROPOSED CONTROL LOOP FOR UPFC	15
FIGURE 2.3: UPFC BLOCK IN SIMULINK	17
FIGURE 2.4: CONTROLLER - SERIES COMPENSATOR	17
FIGURE 2.5 TRANSMISSION LINE WITH VOLTAGE SOURCES	18
FIGURE 2.6 : PHASOR DIAGRAM ILLUSTRATING P AND Q PROPOSTIONALITIES	19
FIGURE 2.7:CONTROLLER – SHUNT COMPENSATOR	20
FIGURE 3.0 : SUB NETWORK SELECTED FOR CASE STUDY	21
FIGURE 3.1: KUKULE GANGA HYDRA POWER PLANT	22
FIGURE 3.2 MODEL OF KUKULE GANGA POWER STATION IN SIMULINK	25
FIGURE 3.3 HORANA DIESEL POWER GENERATORS	27
FIGURE 3.4 MAIN SYSTEM CONSISTING MATUGAMA, HORANA, PANNIPITIYA & PANADURA BUS	29
FIGURE 3.8: MATUGAMA SUB SYSTEM WITH UPFC	30
FIGURE 4.0: ROTOR ANGLE RESPONSE TO FAULT ON HORANA BUS	33
FIGURE 4.1: ROTOR ANGLE RESPONSE TO FAULT ON PANNIPITIYA BUS F	34
FIGURE 4.2: ROTOR ANGLE RESPONSE TO FAULT ON PANADURA BUS	35
FIGURE 4.2: ROTOR ANGLE RESPONSE TO FAULT ON PANADURA BUS	36
FIGURE 4.3: ROTOR ANGLE RESPONSE TO FAULT ON MATUGAMA BUS	37
FIGURE 4.4: POWER VS. LOAD ANGLE CURE FOR A SYNCHRONOUS GENERATOR	38
FIGURE 4.5: SIMULATION RESULTS WITH $K = 1$	40
FIGURE 4.6: SIMULATION RESULTS WITH $K = 10$	42
FIGURE 4.7: SIMULATION RESULTS WITH $K = 30$	44
FIGURE 4.8: SIMULATION RESULTS DIFFERENT SHUNT CONVERTER RATINGS	46

# List of Tables

<b>Table</b>	<b>Page</b>
TABLE 3.0: KUKULE - GENERATOR PARAMETERS	23
TABLE 3.1: KUKULE - HYDRAULIC TURBINE PARAMETERS	23
TABLE 3.2: KUKULE - EXCITATION SYSTEM PARAMETERS	24
TABLE 3.3: KUKULE - UNIT TRANSFORMER PARAMETERS	24
TABLE 3.4: HORANA GENERATOR PARAMETERS	26
TABLE 3.5: HORANA GOVERNOR AND DIESEL ENGINE PARAMETERS	26
TABLE 3.6: HORANA EXCITATION SYSTEM PARAMETERS	27
TABLE 3.7: HORANA - UNIT TRANSFORMER PARAMETERS	27
TABLE 3.8: HORANA - UNIT TRANSFORMER PARAMETERS	28
TABLE 5.0: UPFC PARAMETERS	47
TABLE 5.1: PERFORMANCE RESULTS AFTER ADDING UPFC TO THE SYSTEM	48
TABLE 5.2: EFFECT OF INCREASE OF K VALUES	49

 Theses & Dissertations  
www.lib.mrt.ac.lk