

**DEVELOPMENT OF STATCOM TO IMPROVE VOLTAGE SAG DUE TO
STARTING OF 5KILOWATT INDUCTION MOTOR**

By

ABDURRAHMAN FETURI S. HUWEG

**Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia in
Fulfillment of the Partial Requirements for the Degree of Master of Science**

March 2005

Dedicated to my parents, lovely brothers and sisters

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the partial requirements for the degree of Master of Science

DEVELOPMENT OF STATCOM TO IMPROVE VOLTAGE SAG DUE TO STARTING OF 5KILOWATT INDUCTION MOTOR

By

ABDURRAHMAN FETURI S. HUWEG

March 2005

Chairman: Associate Professor Senan Mahmud, Ph D

Faculty : Engineering

Voltage sags are the most frequent power quality problems for many industrial processes. Due to the wide usage of sensitive electronic equipment in many fields as, electronic controller, communication and computers, even voltage sags which last for only few tenths of a second may cause production stops with considerable associated costs; these costs include production losses, equipment restarting, damaged or lower-quality product and reduced customer satisfaction.

An advanced static var compensator “STATCOM” is a reactive power source applied for the dynamic compensation in power systems to provide voltage support, increase transient stability margin and improve damping of power systems. This thesis investigates the possibility to develop a STATCOM that improve the voltage sag due to starting of 5-kilowatt induction motor. The setup of this implementation consists of inverter with a capacitor in its dc side, coupling transformers, and a control system.

The self commutate thyristor inverter has been used in this implementation has a simple switching On/Off control operation. It operates at low frequencies (most often around ac line frequency), and in the conducting state. Thyristors feature have very low losses, making them attractive devices to efficiently control very high currents and energies.

A capacitor in the dc side is charging via a diode bridge rectifier which is supplied from the same power source.

The STATCOM compensator based line commutation voltage source inverter for correcting voltage sag in steady-state condition has been simulated using Matlab, and a good improvement on voltage sag has been obtained by injecting reactive power into the system during sag period.

In order to verify the results obtained by the experiments. These results have been compared with simulation results and a good agreement has been obtained.

Abstrak tesis yang dikemukakan kepada senat Universiti Putra Malaysia sebagai memenuhi sebahagian keperluan untuk ijazah Master Sains

**PEMBINAAN STATCOM UNTUK MEMPERBAIKI VOLTAN LENDUT
DISEBABKAN OLEH PERMULAAN 5KILOWATT MOTOR ARUHAN
BERKUASA TINGGI**

Oleh

ABDURRAHMAN FETURI S. HUWEG

March 2005

Pengerusi: Profesor Madya Senan Mahmud, Ph. D.

Fakulti : Kejuruteraan

Voltan lendut adalah masalah yang ketara di dalam kualiti kuasa untuk kegunaan industri. Ia disebabkan oleh kegunaan bahan elektronik yang sensitif di dalam pelbagai bidang seperti pengawal elektronik, perhubungan, perkomputeran walaupun voltan lendut ini berlaku dalam jangka masa satu persepuluh saat dan ia akan menyebabkan pengeluaran terhenti yang memberi implikasi kepada kos pengeluaran di mana ia akan menyebabkan kekurangan pengeluaran, hidup semula mesin, kerosakan atau kualiti barang yang rendah yang akan menyebabkan pelanggan tidak puas hati.

Pemampas Statik (STATCOM) merupakan pembekal kuasa aktif kepada pemampas dinamik di dalam sistem kuasa dengan membekalkan bekalan voltan, meningkatkan kestabilan dan memperbaiki damping pada sistem kuasa. Tesis ini menyelidik tentang kemungkinan merekabentuk STATCOM untuk memperbaiki voltan lendut akibat

daripada memulakan 5-kilowatt motor yang berkuasa tinggi. pelaksanaan ujikaji ini mengandungi penyongsang dengan pemuat pada sebelah dc, pengubah gandingan dan sistem kawalan.

Penyongsang tiristor penukartertiban sendiri telah digunakan dalam projek ini yang mana ia memiliki keupayaan untuk membuka atau menutup kawalan operasi. Ia beroperasi pada frekuensi yang rendah (dalam lingkungan frekuensi talian AC dalam) dan keadaan pengaliran. Sifat tiristor mempunyai kehilangan yang rendah di mana ia merupakan alat yang memberi kecekapan pengawal yang tinggi untuk arus dan tenaga. Pemuat dc dicas dari penerus jejambat diod yang mana dibekalkan pada punca yang sama.

Pemampas static STATCOM dengan berasaskan penukar sumber voltan penukarterbitan sendiri untuk mengatasi voltan lendut di dalam keadaan pegun telah disimulasi menggunakan Matlab dan hasil yang didapati adalah sangat baik iaitu dengan kuasa reaktif disuntik ke dalam sistem semasa voltan lendut berlaku.

Untuk mengesahkan keputusan yang diperolehi melalui ujikaji, keputusan ujikaji telah dibandingkan dengan keputusan simulasi. Simulasi dan hasil yang diperolehi didapati hampir sama.

ACKNOWLEDGEMENTS

First and foremost, I would like to express my gratitude to the Most Gracious and Most Merciful ALLAH S. W. T, for helping me to complete this thesis.

It has been an honor and a pleasure to have Assoc. Prof. Dr. Senan Mahmod Abdullah as supervisor. In addition to his huge knowledge and experience, I also enjoy his support and patience during the hardest moments of the research work and writing of the thesis. His broad technical skills, sense of humor, and constructive criticism have been very instrumental and will remain with me as a model for the future. In the end, I feel proud to have had a very positive and instructive cooperation not only with the Assoc. Prof. figure but also with the person Senan Mahmod.

I would like to express my deepest thanks and admiration to Assoc. Prof. Ir. Dr. Norman Mariun, lecturer and head of Electrical and Electronic Department, Universiti Putra Malaysia, and Puan Nashiren Farzilah bit Mallah for their valuable discussion and comments on this work, and for serving in graduate committee.

I am grateful to the members of the Electric and Electronic Engineering Department at University Putra Malaysia for their support and their comradeship. I would like to express special thanks to power system Lab Staff member for being helpful in preparation of the research project.

Thanks to all my friends, who provided me with all kinds of help either academically or morally. Especially, thanks to Mohammed Dhaidah, Ramadan Rajab, for giving me so much convenience during my graduate study and research.

Last but certainly not least, I would like to deeply acknowledge my parents, brothers and sisters for their continuous support, best wishes, love, and encouragement through my life.

I certify that an examination committee has met on 25th of March 2005 to conduct the final examination of Abdurrahman Feturi S. Huweg on his Master of Science thesis entitled “Development of STATCOM to Improve Voltage Sag Due to Starting of 5kilowatt Induction Motor” in accordance with Universiti Putra Malaysia (higher Degree) Act 1980 and Universiti Pertanian Malaysia (higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the relevant degree. The Committee Members for the candidate are as follows:

Chairman, Ph.D.

Professor
Name of faculty/institute
Universiti Putra Malaysia
(Chairman)

Examiner 1, Ph.D.

Professor
Name of faculty/institute
Universiti Putra Malaysia
(Member)

Examiner 2, Ph.D.

Professor
Name of faculty/institute
Universiti Putra Malaysia
(Member)

Independent Examiner, Ph.D.

Professor
Name of faculty/institute
Universiti Putra Malaysia
(Independent Examiner)

GULAM RUSUL RAHMAT ALI, Ph.D.

Professor/Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date :

This thesis submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfillment of the requirements for the degree of Master of Science. The members of the Supervisory Committee are as follows:

SENAN MAHMOD BASHA, PhD

Associate Professor
Faculty of Engineering
University Putra Malaysia
(Chairman)

NORMAN MARIUN, PhDP. Eng

Associate Professor
Faculty of Engineering
University Putra Malaysia
(Member)

NASHIREN FARZILAH MAILA, M.Eng

Lecture
Faculty of Engineering
University Putra Malaysia
(Member)

AINI IDERIS, PhD
Professor/Dean
School of Graduate
Studies
Universiti Putra Malaysia

Date :

DECLARATION

I hereby declare that the thesis is based on my original work except for equations and citations, which have been duly acknowledged. I also declare that it has not been previously or currently submitted for any other degree at UPM or other institutions.

.....
ABDURRAHMAN FETURI S. HUWEG

Date:

TABLE OF CONTENTS

	Page
DEDICATION	ii
ABSTRACT	iii
ABSTRAK	v
ACKNOWLEDGEMENTS	vii
APPROVAL	ix
DECLARATION FORM	xi
LIST OF TABLES	xv
LIST OF FIGURES	xvi
LIST OF ABBREVIATIONS	xix
CHAPTER	
I INTRODUCTION	1
1.1 Static Synchronous Compensators (STATCOM)	3
1.2 Trends of Power Electronic Switches	4
1.3 Objectives and Aims	5
1.4 System Description	6
1.5 Structure of Thesis	6
II LITERATURE REVIEW	
2.1 Introduction	8
2.2 Power Quality	8
2.2.1 Power Quality Definition	10
2.2.2 Power Quality Problems	12
2.2.3 Cause of Power Quality Problems	12
2.3 Voltage Sags Definition	12
2.3.1 Sources of Voltage Sags	14
2.3.2 Effect of Voltage Sags on Equipment	14
2.3.2.1 Electromechanical Relays and Motor Contactors	14
2.3.2.2 Programmable Logic Controllers (PLC)	15
2.3.2.3 Adjustable Speed Drives (ASD)	15
2.3.2.4 Effect of voltage Sags on Induction Motors	15
2.4 Voltage Sag Mitigation	17
2.4.1 Normally Used Measures Against Voltage Sags	17
2.4.1.1 Uninterruptible Power Supply (UPS)	18
	xii

2.4.1.2	Ferroresonant Transformer or Constant Voltage Transformer (CVT)	19
2.5	Reactive Power Compensators	20
2.5.1	Static Synchronous Compensator (STATCOM)	27
2.5.1.1	The Basic STATCOM	27
2.5.1.2	Effect of the STATCOM	29
2.6	Advantages of STATCOM Over the Conventional SVC	31
2.7	Summary	34
III	MATERIAL AND METHODS	
3.1	The STATCOM Experimental Setup	36
3.2	Three-Phase Six Pulse Uncontrolled Rectifier	37
3.3	Three-Phase Six Pulse Inverter Based Thyristor	39
3.4	Principle of Reactive Power Control	44
3.5	Design of the dc Side of the Compensator	45
3.5.1	Calculation of the dc Smoothing Inductance in the Voltage Source Inverter	45
3.5.2	Calculation of the Size of the dc Capacitor	48
3.5.3	The Control of dc Capacitor Voltages	49
3.6	Firing Control Circuit	50
3.7	Simulation Circuit	51
3.8	Induction Motor	54
IV	RESULTS AND DISCUSSION	
4.1	Simulation Results	58
4.1.1	Simulation Setup	58
4.1.2	Simulation Results with STATCOM	65
4.1.3	Effect of Triggering Angle	66
4.1.4	DC Link Capacitor voltage and Current	69
4.1.5	Active and Reactive Power Generated with STATCOM	71
4.2	Experimental Results	73
4.2.1	Experiments Hardware Setup	73
4.2.2	Experimental Results with STATCOM	73
4.2.3	Output of the Triggering Unit	77
4.3	Experimental and Simulation Results Analysis	79
4.3.1	Comparison between Simulation and Experimental Results	79

V	CONCLUSIONS AND RECOMMENDATIONS	
5.1	Conclusion	82
5.2	Future Work and Recommendations	83
	REFERENCES	R.1
	APPENDICES	A.1
	BIODATA OF THE AUTHOR	B.1