

SVC SUPPLEMENTARY CONTROLLER FOR DAMPING OSCILLATIONS IN
POWER SYSTEM

NURLIDA BINTI ISMAIL

A project report submitted in fulfilment of the
requirements for the award of degree of
Master of Engineering (Electrical – Power)

Faculty of Electrical Engineering
Universiti Teknologi Malaysia

NOVEMBER 2009

To my beloved mother, father, brothers and friends

...

ACKNOWLEDGEMENT

Alhamdulillah, all praise and glory be to Almighty Allah S.W.T who gave me the courage and patience to carry out this work, and peace is upon his last prophet Muhammad S.A.W.

I would like to express my sincere gratitude and appreciation to my supervisor, Assoc. Prof. Dr. Mohd Wazir bin Mustafa and my co-supervisor Nuraddeen Magaji for their guidance, patience and encouragement throughout this project report. Their advices, critics and assistance in completion of this project report are thankfully appreciated.

A special thank also goes to my beloved family for their tireless support, encouragement and prayers in all my endeavors. Last but not least, I extend my thanks and appreciation to my friends, colleagues and everyone who helped to get this work done directly or indirectly.

ABSTRACT

Power system oscillations occur due to the lack of damping torque at the generators rotors. The oscillation of the generators rotors cause the oscillation of other power system variables such as bus voltage, bus frequency and transmission lines active and reactive power. Power system oscillations are usually in the range between 0.1 to 2 Hz depending on the number of generators involved in. They can be local or interarea oscillations. However, this project will focus on interarea oscillations only with the frequency range between 0.1 until 0.9 Hz. Flexible AC Transmission Systems (FACTS) got in the recent years a well-known term for higher controllability in power systems by means of power electronic devices. Several FACTS devices have been introduced for various applications worldwide. One of them is Static Var Compensator (SVC), which is a shunt device, provides dynamically variable shunt impedance to regulate the voltage at a bus where it is connected. Simulation of the case studies using SVC to show damping oscillations in the power system were done in Power System Analysis Toolbox. Moreover, location of SVC plays an important part to give effectively damped the oscillations. This project will discuss residue method to find the best placement of SVC for the case studies. Besides, the supplementary controller of SVC can be applied to improve the performance of damping oscillations in the power system. In this project, the supplementary controller for SVC is referred as proportional plus integral plus derivative controller. Lastly, a designing of SVC and supplementary controller to improve 10% of damping oscillations in the power systems is successfully designed.

ABSTRAK

Ayunan dalam sistem kuasa terjadi kerana kekurangan daya kilas redaman pada rotor di penjana. Ayunan pada rotor penjana boleh menyebabkan ayunan pada pembolehubah- pembolehubah sistem kuasa lain seperti voltan bas, frekuensi bas dan kuasa aktif dan reaktif talian penghantaran. Ayunan-ayunan dalam sistem kuasa kebiasaannya dalam julat antara 0.1 dan 2 Hz bergantung kepada jumlah penjana yang terlibat. Ayunan ini boleh terjadi samada ayunan tempatan ataupun ayunan antara dua kawasan. Walaubagaimanapun, projek ini akan memfokuskan kepada ayunan antara dua kawasan dengan julat frekuensi di antara 0.1 hingga 0.9 Hz. Sejak kebelakangan ini Sistem Penghantaran A.U Bolehlentur (SPAB) menjadi terkenal kerana kebolehkawalannya yang tinggi dalam sistem kuasa melalui peranti kuasa elektronik. Beberapa peranti SPAB telah diperkenalkan untuk pelbagai kegunaan di seluruh dunia. Salah satunya adalah Pemampas Var Statik (PVS) yang merupakan peranti selari di mana ianya menyediakan pembolehubah galangan selari untuk mengawal voltan pada bas yang disambungkannya. Simulasi kajian kes dengan menggunakan PVS bagi menunjukkan ayunan redaman dalam sistem kuasa telah dilakukan dalam *Power System Analysis Toolbox* . Tambahan pula, lokasi PVS memainkan peranan penting untuk memberikan ayunan redaman yang lebih berkesan. Projek ini akan membincangkan kaedah residue untuk mencari lokasi PVS yang terbaik dalam kajian kes. Selain itu, pengawal tambahan untuk PVS boleh digunakan bagi meningkatkan prestasi ayunan redaman dalam sistem kuasa. Pengawal tambahan untuk PVS dalam projek ini adalah merujuk kepada pengawal perkadaran dan pengkamiran dan pembezaan. Akhir sekali, kejayaan simulasi dengan menggunakan PVS dan pengawal tambahan untuk meningkatkan ayunan redaman sebanyak 10 peratus berjaya direka.

TABLE OF CONTENTS

CHAPTER	TITLE	PAGE
	DECLARATION	ii
	DEDICATION	iii
	ACKNOWLEDGEMENT	iv
	ABSTRACT	v
	ABSTRAK	vi
	TABLE OF CONTENTS	vii
	LIST OF TABLES	x
	LIST OF FIGURES	xi
	LIST OF SYMBOLS	xiii
	LIST OF APPENDICES	xiv
1	INTRODUCTION	1
	1.1 Introduction	1
	1.2 Problem Statement	2
	1.3 Objectives	3
	1.4 Scope of the Project	3
	1.5 Thesis Outline	4
2	POWER SYSTEM STABILITY AND FACTS	5
	2.1 Introduction	5
	2.2 Power System Stability	6
	2.2.1 Classification of Power System Stability	7
	2.3 Small Signal Stability Analysis	9
	2.4 Power System Oscillations	10

	2.4.1	Criteria for Damping Oscillations	11
2.5		Flexible AC Transmission Systems	12
	2.5.1	Basic Types of FACTS Controllers	13
	2.5.2	First Generation of FACTS Devices	15
	2.5.3	Second Generation of FACTS Devices	16
2.6		Static Var Compensator	17
	2.6.1	Operating Principle	17
	2.6.2	Advantages of SVC	19
	2.6.3	Disadvantages of SVC	19
	2.6.4	Applications of SVC	19
2.7		SVC for Damping of Power System Oscillations	21
2.8		Power System Analysis Toolbox	23
2.9		Summary	24
3		PLACEMENT OF SVC DEVICES	25
	3.1	Introduction	25
	3.2	Placement of SVC Devices for Damping Enhancement	25
	3.3	Method of SVC Placement	26
	3.4	Residue Method	28
	3.5	Procedures of SVC Placement in PSAT	29
	3.5.1	Steps of SVC Placement for Case Studies	35
	3.6	Summary	39
4		DESIGN OF SVC SUPPLEMENTARY CONTROLLER	41
	4.1	Introduction	41
	4.2	SVC Supplementary Controller	41
	4.3	Design of SVC Supplementary Controller	44
	4.4	Summary	46
5		RESULTS AND DISCUSSION	47
	5.1	Introduction	47

5.2	9 Bus Test System	47
	5.2.1 Best Placement of SVC	48
5.3	11 Bus Test System	51
	5.3.1 Best Placement of SVC	52
	5.3.2 Voltage Response	56
	5.3.3 Angle Deviation	57
	5.3.4 Speed Deviation	59
5.4	Summary	61
6	CONCLUSIONS AND RECOMMENDATIONS	62
	6.1 Introduction	62
	6.2 Conclusions	62
	6.3 Recommendation for Future Work	63
	REFERENCES	64
	Appendices	66-79

LIST OF TABLES

TABLE NO.	TITLE	PAGE
5.1	Rotor angle modes without SVC	48
5.2	Result of residue method due to corresponding SVC location	49
5.3	Rotor angle modes without SVC	52
5.4	Result of residue method due to corresponding SVC location	53

LIST OF FIGURES

FIGURE NO.	TITLE	PAGE
2.1	Classification of power system stability	8
2.2	General symbol of FACTS controller	12
2.3	Series controller	13
2.4	Shunt controller	14
2.5	Unified series-series controller	14
2.6	Unified series-shunt controller	15
2.7	SVC configuration	18
2.8	V-I characteristic of SVC	18
2.9	Static Var Compensator	20
2.10	SVC installation	21
2.11	A one-machine system with an SVC	22
2.12	SVC effects on system P- δ curve	23
2.13	PSAT initializing simulink library	24
3.1	First procedure to start with PSAT	30
3.2	Step to load a file	31
3.3	Step to choose case study	32
3.4	9 bus test system	33
3.5	Two area four machines system	34
3.6	Step to change SVC location	35
3.7	Save the file when change the location of SVC	36
3.8	Run power flow and eigenvalue analysis	37
3.9	Report of eigenvalue analysis	38
3.10	Run residue method in M-File	39
4.1	Closed loop system with POD controller	42

4.2	POD controller structure	42
4.3	Blocks of Power Oscillation Damper in PSAT	44
4.4	Blocks of Power System Stabilizer in PSAT	44
4.5	Closed-loop system with PID controller	44
5.1	Eigenvalues of 9 bus test system without SVC	49
5.2	9 bus test system with SVC at bus 7	50
5.3	Eigenvalues of 9 bus test system with SVC	51
5.4	Eigenvalues of two area 11 bus system without SVC	53
5.5	Eigenvalues of two area 11 bus system with SVC	54
5.6	Two area four machines with SVC at bus 7	55
5.7	Graph of voltage response at bus 7	56
5.8	Graph of angle deviation between generators G1 and G3	57
5.9	Graph of angle deviation between generators G1 and G3 without SVC	58
5.10	Graph of speed deviation between generators G1 and G3	59
5.11	Graph of speed deviation between generators G1 and G3 without SVC	60

LIST OF SYMBOLS

ac	-	alternative current
dc	-	direct current
kV	-	kiloVolts
MVA	-	Mega Volt Ampere
p.u.	-	per unit
Q _{max}	-	maximum reactive power
Q _{min}	-	minimum reactive power
S _n	-	power rating
V _{max}	-	maximum voltage
V _{min}	-	minimum voltage
V _n	-	voltage rating
V ₀	-	voltage magnitude
x _l	-	leakage reactance

LIST OF APPENDICES

APPENDIX	TITLE	PAGE
A	Power System Analysis Toolbox	66
B	Data for 9 bus test system	68
C	Data for 11 bus test system	70
D	Residue method to find the best placement of SVC	73
E	Programming to get voltage response for 11 bus test system	74
F	Programming to get angle deviation for 11 bus test system	76
G	Programming to get speed deviation for 11 bus test system	78

CHAPTER 1

INTRODUCTION

1.1 Introduction

Modern power system consists of four main parts. These are known as generation, transmission, distribution and loads part. The generation, transmission and distribution parts works together in order to supply power to the loads or consumers.

Power system stability has been recognized as an important problem for secure system operation since 1920s. Many major blackouts caused by power system instability have illustrated the importance of this phenomenon. Historically, transient instability has been dominant stability problem on most systems, and has been the focus of much of industry's attention concerning system stability.

Damping electromechanical oscillations between interconnected synchronous generators is necessary for a secure system operation. This is because if this problem is not overcome, it will cause voltage instability that will be leading to voltage collapse.

Flexible AC Transmission Systems (FACTS) got in the recent years a well-known term for higher controllability in power system by means of power electronic devices. Several FACTS devices have been introduced for various applications worldwide.

Static Var Compensator (SVC) is one of FACTS device that is recognized to damp oscillations in the power system. Recently, many papers have been investigated on the application of SVC to damp oscillations in the power systems.

1.2 Problem Statement

A good power system should possess the ability to regain its normal operating condition after a disturbance. Since ability to supply uninterrupted electricity determines the quality of electric power supplied to the load, stability is regarded as one of the important topics in power system researches.

Power system stability can be defined by the ability of synchronous machines to remain in synchronism with each other. The capability of power system to remain in synchronism in the event of possible disturbances such as line faults, generator and line outages and load switching, is characterized by its stability.

Following unbalances in the system, a power system may experience sustained oscillations. These oscillations may be local or interarea depending on the numbers of generators involved in. Damping the oscillations is not only important in increasing the transmission capability but also for stabilization of power system conditions after critical faults. If the net damping of the system is negative, then the system may lose synchronism. Extra damping has to be provided to the system in order to avoid this.

The availability and successfully of FACTS devices such as SVC to damp these oscillations have been reported by many researchers. Therefore, this project will illustrate the effective ways of SVC to damp oscillations in the power system.

1.3 Objectives

The objectives of the project are:

- i. To study on damping oscillations in power system.
- ii. To determine the critical eigenvalue of case studies with SVC.
- iii. To find the best location of SVC for damping oscillations.
- iv. To design the SVC supplementary controller for damping oscillations.

1.4 Scope of the Project

This project focuses on damping oscillations in power system with Static Var Compensator (SVC). Below described the scope of the project:

- i. Power system oscillations which are a part of power system stability. And SVC is one of device used to damp oscillations in the power system. The performance of SVC to damp oscillations in the power system will be illustrated by using MATLAB.
- ii. This project will covered residue method to find best placement of SVC for two case studies; 9 bus test system and 11 bus test system. In order to get the result of eigenvalue analysis, the case studies will be run in Power System

Analysis Toolbox (PSAT), and then based on the result obtained, programming of residue method is run in M-file in MATLAB.

- iii. In order to improve the damping of oscillations in the power system, supplementary control laws can be applied to SVC. In this project, these supplementary actions are referred to as proportional plus integral plus derivative (PID) controller.

1.5 Thesis Outline

This thesis is organized into six chapters. After this chapter, Chapter 2 will discuss on power system stability especially on power system oscillations and small signal stability. Besides that, a Flexible AC Transmission Systems (FACTS) device which is Static Var Compensator (SVC) also was discussed.

Chapter 3 concentrated on the placement of SVC device because the placement of this device plays an important rule to effectively damp oscillations in the power system. The method used to find the best placement of SVC also was discussed in this chapter. While Chapter 4 presents the design of SVC supplementary controller that can be applied to existing device to improve the damping oscillations in power system

Successful passing the previous chapter, we will analyze the result of SVC in order to dampen oscillation in case study in Chapter 5. Besides, the performance of SVC with supplementary also was discussed in this chapter. Finally, conclusions and recommendations of the report project to improve future work are documented in Chapter 6.