

Development of power flow model of a STATCOM

A Dissertation Submitted

In Partial Fulfillment of the Requirements for the Award of the Degree Of

**MASTER OF ENGINEERING
IN
CONTROL AND INSTRUMENTATION**

Submitted By:

Ashok Kumar Bajia

University Roll No.: - 12231

Project Supervisor: **S. Bhowmick**



**DEPARTMENT OF ELECTRICAL ENGINEERING
DELHI COLLEGE OF ENGINEERING
DELHI-110042**

2009

DELHI COLLEGE OF ENGINEERING
DELHI

Department of Electrical Engineering



CERTIFICATE

This is to certify that **Mr. Ashok Kumar Bajia**, a student of final semester **M.E. (C&I), Electrical Engineering Department, Delhi College of Engineering**, during the session 2008-2009 has successfully completed the project work on **Development of Power flow Model of a STATCOM** and has submitted a satisfactory report in partial fulfillment for the award of the degree of **Master Of Engineering (Control and Instrumentation)** in **Electrical Engineering Department**.

Date:

Sh. S Bhowmick
Sr. Lecturer, EED
Delhi College of Engineering
Delhi - 110042

Acknowledgement

I would like to extend my sincere gratitude and thanks to my guide Sh.S Bhowmick, Sr. Lecturer, Electrical Engineering Department, Delhi College of Engineering, Delhi for his valuable guidance, constant encouragement and helpful discussions throughout the course of this work. He initiated the founding ideas behind this thesis and provided insight and valuable information into many of the problems that were encountered. His positive attitude throughout the duration of this thesis always put things into perspective whenever difficulties arose. This thesis would not have been possible without him.

I am extremely grateful to my parents for their encouragement, support and dedication which have helped me in great way to complete this work. Without their blessings, this work would not have been possible.

And lastly I express sincere gratitude to guide **Prof. Parmod Kumar**, Professor and Head of Electrical Engineering Department, Delhi College of Engineering, Delhi with whose blessing this project was completed. And finally, I thank Almighty GOD for his countless blessings.

Ashok Kumar Bajia
M.E(C&I)

Abstract

To enhance the power transmission capability over the existing transmission corridors, power electronics based flexible ac transmission system (FACTS) based controllers are now a days increasingly being used. The performance of voltage sourced converters (VSC) based FACTS controllers like STATCOMs, SSSC, UPFC and GUPFC is generally better than thyristor based ones like SVC, TCSC etc., and consequently evoke interest from both the industry and the academia. Amongst the VSC based controllers, the STATCOMs were the earliest devices and currently in installation in maximum numbers.

The first 100 Mvar STATCOM was installed in the Sullivan substation of the Tennessee valley authority in 1995. The project was jointly sponsored by the Electric Power Research Institute and TVA, and designed by the Westinghouse Electric Corporation.

For proper utilization of a STATCOM, power flow solution of the network containing STATCOM is a must, and hence, in this project, an attempt is made towards to developing a power flow model of a STATCOM.

At first, a program is developed for the power flow solution of a network using the Newton's method. Subsequently, STATCOM has been modeled for the Newton power flow solutions of the network containing them

Table of Contents

Certificate

Acknowledgement

Abstract

Contents

List of Figures

Chapter 1: Introduction 1 - 2

Chapter 2: FACTS controllers – an overview..... 3 - 25

2.1 Introduction

2.2 Types of Facts Controllers

2.3 Controllers Based on Conventional Thyristors

2.3.1 The Thyristor-controlled Reactor

2.3.2 The Static VAR Compensator

2.3.3 The Thyristor Controlled Series Capacitor (TCSC)

2.4 Power Electronic Controllers Based on Fully Controlled Semiconductor Devices

2.4.1 The Voltage Source Converter (VSC)

2.4.2 The Static Synchronous Compensator(STATCOM)

2.4.3 Principle of Operation

2.4.4 The V-I Characteristic

2.4.5 Static Synchronous Series Compensator(SSSC)

2.4.6 The Unified Power Flow Controller

Chapter 3: Load flow Studies26 - 45

3.1 Introduction

3.2 The Power flow Problem

3.2.1 Network Representation

3.2.2 Choice of Variables

3.2.3 Types of Buses

3.2.4 Variables for Balancing Real Power	
3.2.5 Variables for Balancing Reactive Power	
3.2.6 The Slack Bus	
3.2.7 Summary of Variables	
3.3 Power flow Equations and Solution Methods	
3.3.1 Derivation of Power flow Equations	
3.3.2 Solution Methods	
3.3.3 Steps of G-S Algorithm	
3.3.4 Newton-Raphson (N-R) Method for Power-Flow Solution	
3.3.5 The Newton-Raphson Method Applied to Power-Flow Equations	
3.3.6. Elements of Jacobian Matrix for N.R. method	
3.3.7 Algorithm of Newton-Raphson Method	
3.3.8 Characteristics of the Newton-Raphson Load Flow	
Chapter 4: Power flow analysis with STATCOM	46 - 51
4.1 Operation Principles of the STATCOM	
4.2 Power flow Constraints of the STATCOM	
4.3 Multi-control functions of the STATCOM	
4.4 Control function : bus voltage control	
4.5 Implementation of Voltage-Control Functional Model of STATCOM in Newton power flow	
4.6 Elements of Jacobian Matrix	
Chapter 5: Case Studies and Results	52 - 58
Chapter 6: Conclusions and Scope of Future work	59
References	60
Appendix.....	61 - 63

List of Figures

- Figure 2.1 Thyristor-based circuit (a) Basic thyristor-controlled reactor (TCR); (b) thyristor circuit symbol
- Figure 2.2 Current waveforms in the basic thyristor-controlled reactor
- Figure 2.3 Three-phase thyristor-controlled reactor
- Figure 2.4 Representation of a three-phase static VAR compensator
- Figure 2.5 The TCSC (a) structure formed by fixed capacitor and TCR ; (b) variable reactance presentation
- Figure 2.6 Circuit symbols for: (a) gate turn-off thyristor and (b) insulated gate bipolar transistor.
- Figure 2.7 Topology of a three-phase, two-level voltage source converter (VSC) using insulated gate bipolar transistors
- Figure 2.8 Operation of a pulse-width modulator (a) comparison of a sinusoidal fundamental frequency with a high-frequency triangular signal; (b) resulting train of square-wave signals; (c) harmonic voltage spectrum
- Figure 2.9 One leg' voltage source converter (VSC)
- Figure 2.10 Basic operation of a voltage source converter (VSC): (a) VSC connected to a system bus. Space vector representation for (b) lagging operation and (c) leading operation
- Figure 2.11 Static compensator (STATCOM) system: (a) voltage source converter (VSC) connected to the AC network via a shunt-connected transformer; (b) shunt solid-state voltage source
- Figure 2.12 The V - I characteristic of the STATCOM
- Figure 2.13 The power exchange between the STATCOM and the ac system
- Figure 2.14 Unified power flow controller (UPFC) system: (a) two back-to-back voltage source converters (VSCs; (b) equivalent circuit based on solid-state voltage sources

Figure 2.15 Figure 2.15 Solid state series compensator (SSSC) system: (a) voltage source converter (VSC) connected to the the AC network and (b) series solid state voltage source

Figure 3.1 One-line diagram for a power system