Ain Shams University
Faculty of Engineering
Electrical Power and Machines Department

Power Network Performance Enhancement Using FACTS Applications

A Thesis
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By

Ahmed Saad Kurdi

B. Sc., Electrical Engineering
(Power Engineering)
Cairo University, ١٩٩٦

Supervised By

Assoc.Prof.Dr. Abla Soliman Attia
Dr. Naggar Hassan Saad

Power & Machines Department
Faculty of Engineering
Ain Shams University

Cairo – ٢٠٠٧

بسم الله الرحمن الرحيم

STATEMENT

This dissertation is submitted to Ain Shams University for the degree of MASTER OF SCIENCE in Electrical Engineering.

The work included in this thesis is carried out by the author in the Department of Electrical Power and Machines, Faculty of Engineering, Ain Shams University, Egypt.

No part of this thesis has been submitted for the degree or a qualification at any other university or institution.

Thursday, October ٣١**,** ٢٠١٣
Signature:
Name: Ahmed Saad Kurdi

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Ahmed kurdi

ABSTRACT

The rapid development of power electronics technology provides opportunities to develop new power equipment to improve the performance of the actual power systems. During the last decade, a number of control devices called “Flexible AC Transmission Systems” (FACTS) technology have been proposed and implemented. FACTS devices can be used for power flow control, voltage regulation, and enhancement of transient stability and damping of power oscillations.

The possibility to improve the performance of the AC transmission system utilizing power electronic equipment has been discussed a lot since about ten years. Some new semiconductor based concepts have been developed. The Thyristor Controlled Series Capacitor (TCSC) is one of such concept. By varying the inserted reactance, an immediate and well-defined impact on the active power flow in the transmission line is obtained. Several potential applications, specifically power oscillation damping, benefit from this capability. The concept implied the requirement to design a semiconductor valve, which can be inserted directly in the high-voltage power circuit. This certainly presented a technical challenge but the straightforward approach appeared to be a cost-effective alternative with small losses.

This thesis presents a detailed model of TCSC to study its effect on the enhancement of the power network performance. This study covers the network performance under steady–state and transient conditions. The model with PID controller is used to control the power flow during steady state operation and with stability controller to improve system stability during transient conditions. The MATLAB-Simulink-Toolbox is used to check the validity of the proposed model by applying it to a simple power network. Results of the simulated network, on which both controllers were implemented, are presented and show its effectiveness, and capability in controlling system variables during steady state and transient operations.

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List of Acronyms

Acronyms	Description
FACTS	Flexible AC Systems
PLL	Phase-Locked-Loop
PWM	Pulse-Width Modulation
POD	Power Oscillation Damping
QFT	Quantitative Feedback Theory
Rms	Root Mean Square
RLS	Recursive Least Square
SSR	Subsynchronous Resonance
SSSC	Static Synchronous Series Compensator
STATCOM	Static Synchronous Compensator
SVC	Static Var Compensator
SVR	Synchronous Voltage Reversal
TI	Tensional Interaction (SSR)
TCR	Thyristor Controlled Reactor
TCSC	Thyristor Controller Series Capacitor
TSSC	Thyristor Switched Series Capacitor
UPFC	Unified Power Flow Controller
VSC	Voltage-Source Converter
P.U	per unit
TCPAR	thyristor controlled phase angle reactor
GTO’s	gate turn-off thyristor
FC-TCR	fixed capacitor with thyristor controlled reactor

SYMBOL INDEX

P	Active Power
P_{max}	Maximum Active Power
Q	Reactive Power
Q_{max}	Maximum Reactive Power
S	Complex, Active And Reactive Power
Pr	Receiving End Active Power
Qr	Receiving End Reactive Power
Ps	Sending End Active Power
X	Transmission Line Impended
Vr	Receiving End Voltage
Vs	Sending End Voltage
δ	Power Angle
P_{comp}	Transmitted Power In Compensated
mH	Milli Henry
km	Kilo Meter
Hz	Hertz

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CHAPTER (١)

INTRODUCTION

١,١ GENERAL

In today's highly complex and interconnected power systems, which is made of thousands of buses and hundreds of generators. So there is a great need to improve electric power utilization while still maintaining reliability and security.

Available power generation, usually not situated near a growing load center, is subject to regulatory policies and environmental issues. In order to meet the ever-growing power demand, utilities prefer to rely on already existing generation and power export/import arrangements instead of building new transmission lines that are subject to environmental and regulatory policies.

On the other hand, power flows in some of the transmission lines are well below their thermal limits, while certain lines are overloaded, which has an overall effect of deteriorating voltage profiles and decreasing system stability and security. In addition, existing traditional transmission facilities, in most cases, are not designed to handle the control requirements of complex, highly interconnected power systems.

This overall situation requires the review of traditional transmission methods and practices, and the creation of new concepts which would allow the use of existing generation and transmission lines up to their full capabilities without reduction in system stability and security. Another reason that is forcing the review of traditional transmission methods is the tendency of modern power systems to follow the changes in today's global economy that are leading to deregulation of electrical power markets in order to stimulate competition between utilities.

The desire to find solutions to these problems and limitations led to focused technological developments under the Flexible AC transmission system (FACTS) initiative of the Electric Power Research Institute (EPRI) in the United States with the ultimate objective to provide power electronics-based, real time control for transmission systems.

The benefits of utilizing FACTS devices in electrical transmission systems can be summarized as follows:

i) Better utilization of existing transmission