EFFECTIVE LOCATION OF THYRISTOR CONTROLLED SERIES CAPACITOR BY SENSITIVITY BASED METHOD FOR CONGESTION MANAGEMENT

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ABSTRACT

Increasing dependency of electrical energy has led to rapid growth of power system which results to few uncertainties. Instability problem in power systems have become one of the most important concerns in the power industry which lead to blackouts. Power disruption and individual power outage one of the major problem affect the economy of the country. If the exchanges were not controlled, some lines located on particular paths may become overloaded or congested. Plus, uncontrollable reactive power losses results to instability to maintain the voltage at all the buses around the nominal value lead to voltage collapse. It is important to have high efficiency, maximum reliability, and security in design and operation of power system. Recent development of power electronics introduces the use of Flexible AC Transmission System (FACTS) controllers in power systems. FACTS controllers are capable of controlling the network condition in a very fast manner and this feature of FACTS can be exploited to improve the stability of a power system. The aim of this project is to study the effect of Thyristor Controlled Series Capacitor (TCSC) to mitigate contingencies in transmission line by locating TCSC at the most sensitive line thru reactive power loss sensitivity indices approach. This project also focus on total reactive power loss reduction and transmission line loadability on tested small network (5 bus) and large network (modified IEEE 14 bus) system. Apart from that, the effect of degree of compensation of TCSC as well been studied. These studies and investigation was carried out using MATLAB/MATPOWER 5.0 and Power World Simulator GSO 18. This project concludes that the proposed approach is efficient for solving line contingencies, power losses reduction and line loadability in which meet the objectives of this research.

ABSTRAK

Peningkatan kebergantungan tenaga elektrik telah membawa kepada pertumbuhan pesat sistem kuasa yang mengakibatkan kepada beberapa ketidaktentuan. Masalah ketidakstabilan dalam sistem kuasa telah menjadi salah satu kebimbangan yang paling merisaukan dalam industri tenaga yang membawa kepada kelumpuhan. Gangguan kuasa dan gangguan kuasa individu salah satu masalah utama menjejaskan ekonomi negara. Jika bursa tidak terkawal, beberapa baris di laluan tertentu boleh menjadi terlebih beban atau kesesakan. Tidak terkawal kehilangan kuasa reaktif yang tidak terkawal telah menjurus keputusan untuk mengekalkan ketidakstabilan voltan pada semua bas di sekitar plumbum nilai nominal kepada keruntuhan voltan. Ia adalah penting untuk mencapai kecekapan tinggi, kebolehpercayaan yang maksimum, dan keselamatan dalam reka bentuk dan operasi sistem kuasa. Pembangunan baru-baru ini memperkenalkan kuasa elektronik menggunakan Sistem Penghantaran Fleksibel AC (FACTS) dalam sistem kuasa. FACTS mampu mengawal keadaan rangkaian dengan cara yang sangat cepat dan ciri ini boleh digunakan sepenuhnya untuk meningkatkan kestabilan sistem kuasa. Tujuan projek ini adalah untuk mengkaji kesan Tiristor Kawalan Siri Capacitor (TCSC) untuk mengurangkan tanggungan luar jangka dalam talian penghantaran dengan mencari TCSC di barisan paling sensitif melalui indeks sensitiviti kehilangan kuasa reaktif mendekati. Projek ini juga memberi tumpuan kepada pengurangan jumlah kehilangan kuasa reaktif dan talian penghantaran keupayaan beban di rangkaian kecil (5 bas) dan rangkaian besar (IEEE 14 bas) sistem. Selain itu, kesan tahap pampasan TCSC dan dikaji. Kajian-kajian dan siasatan telah dijalankan dengan menggunakan MATLAB/MATPOWER 5.0 dan Power World Simulator GSO 18. Projek ini menyimpulkan bahawa pendekatan yang dicadangkan adalah berkesan untuk menyelesaikan tanggungan luar jangka talian, kuasa dan kerugian pengurangan keupayaan beban talian yang memenuhi objektif kajian ini.

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FACTS	-	Flexible AC Transmission System
UPFC	-	Unified Power Flow Control
TCR	-	Thyristor Controlled Reactor
TCSR	-	Thyristor Controlled Switched Reactor
SVC	-	Static VAR Compensator
TCSC	-	Thyristor Controlled Series Capacitor
TSSR	–	Thyristor Controlled Switched Series Reactor
TCBR	–	Thyristor Controlled Brakening Reactor
TCVR	-	Thyristor Controlled Voltage Reactor
TCVL	-	Thyristor Controlled Voltage Limiter
TSSC	-	Thyristor Controlled Switched Series
TC-PAR	-	Thyristor Controlled Phase Angle Regulator
TC-PST	-	Thyristor Controlled Phase Shift Transformer
SSSC	-	Static Synchronous Series Compensator
STATCOM	-	Static Synchronous Compensator
UPFC	-	Unified Power Flow Controller
HPFC	-	Hybrid Power Flow Controller
HVDC	-	High Voltage Direct Current
PSS	-	Power System Stabilizers
AP	-	Active Power
RP	-	Reactive Power
VSC	-	Voltage Source Converter
VSI	-	Voltage Source Inverter
VS	-	Voltage Stability
VI	-	Voltage Instability
VC	-	Voltage Collapse
VP	-	Voltage Profile

VR	-	Voltage Regulation
SSVS	-	Steady State Voltage Stability
TS	-	Transient Stability
APTC	-	Available Power Transfer Capacity
PQ	-	Power Quality
SSR	-	Sub-synchronous Resonance
OPF	-	Optimal Power Flow
POD	-	Power Oscillation Damping
DGs	-	Distributed Generations
SS	-	Steady State
FCL	-	Fault Current Limiting

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CHAPTER 1

INTRODUCTION

1.1 Background

Over the coming years and decades, the power generation industry faces and intimidating challenge in the meeting of energy demands of the global need of electrical energy. Current scenarios of electric power industries had altered the operational strategy and management of utilities in many aspects. In years future, expected the electricity demand and usage will double globally or triple in developing countries. Financial and market forces are, and will continue to, demand a more optimal and profitable operation of the power system with respect to generation, transmission, and distribution [1]. Thus, ensuring continuous and reliable power generation have become crucial and one of the biggest barriers to reliable power generation is ability to maintain system security which is avoiding congestion in transmission lines as well have maintaining optimum line load ability and minimum system power losses.

The existing of network power system might not able to stand the entire new scenario for electricity trades. This is further endangered by relatively decline in transmission expansion due to requirement of huge investment couples with the problems in acquiring right of way for the new transmission facilities and concerns towards environment and cost [2]. Furthermore, due to security concerns, it will not be a good solution for the generation company to drop a certain load in order to maintain power system security which is actually may result them penalties. Plus with various environmental and regulatory concerns, expansion of the power facilities is restricted in some countries. Thus, it would be very beneficial to the world if we could tackle all the security issue which in results can delay the construction of new transmission line and also maintaining system security, stability and reliability in current emerging electricity market scenario. Because of all that, it becomes very important to improve line security and load ability along the transmission line to meet the requirement. With recent growth of power electronics devices, flexible AC transmission system known as FACTS is introduced in power system as a promising pattern for future growth of power system. These FACTS devices are capable to control power flow over the lines with optimum load ability and small power losses.

1.1.1 Control in Power System

Power system consists of three main components which are generation, transmission and distribution. Although power electronic based equipment is prevalent in each of these three areas, such as with static excitation systems for generators and custom power equipment in distribution systems [1, 3], we often observed the major power system constraints are accompanying in transmission system when transfer an amount of power from generator to where it is utilized. In today world, transmission systems are struggling to works as close as possible to their stability limits which at the same time maintaining quality of the power delivered. The transmission constraints may involve power deliver between a single area or more. Each of the transmission constraint may have one or more of system level complications such as congestion, high power system losses, minimum power transfer, voltage stability and quality and many others. The key to solve these problems is by controlling some of parameters of power system.

Figure 1.1 illustrates controllability of the power system in which will be impacted by controlling the power-angle curve. There are three main parameters that play a major role in power system control which are voltage, angle and impedance. The illustration demonstrates the point where this three main variables that in being controlled to influence its recital.

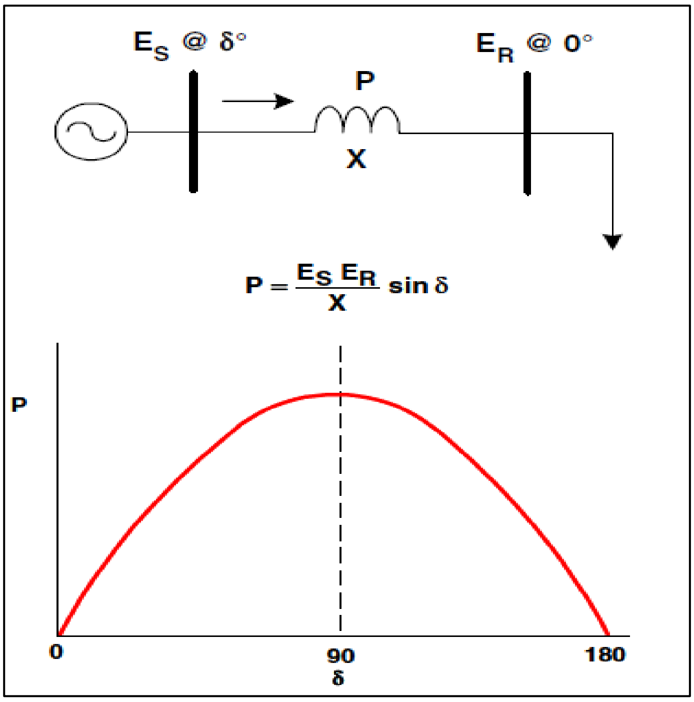

Figure 1.1: Illustration of Controllability Power System [1]

1.1.2 FACTS Technology

The concept of Flexible AC transmission system has been proposed in 1995, which best known as FACTS. The basic idea of FACTS is installing the power electronic devices at the high-voltage side of the power grid to make the whole system electronically controllable [9]. FACTS controller which are built from power electronic devices demonstrates capability control the voltage, power flow, stability a power system. There are few configurations to connect FACTS devices in transmission line which are in shunt, series or a combination of shunt and series. The definition and characterization of various FACTS devices are described in references [4, 5, 6]. FACTS devices are very effective and capable of increasing the power transfer capability of a line, insofar as thermal limits permit, while maintaining the same degree of stability [4, 7, 8].

1.1.3 FACTS Categories and Their Function

The FACTS devices have the capability to control real and reactive power to the power network in very fast manner. Basically, the FACTS can be best categories into two generations as describes in Figure 1.2 and have a four basic classification of their connection like series connected, shunt connected and combine both series and shunt connected.

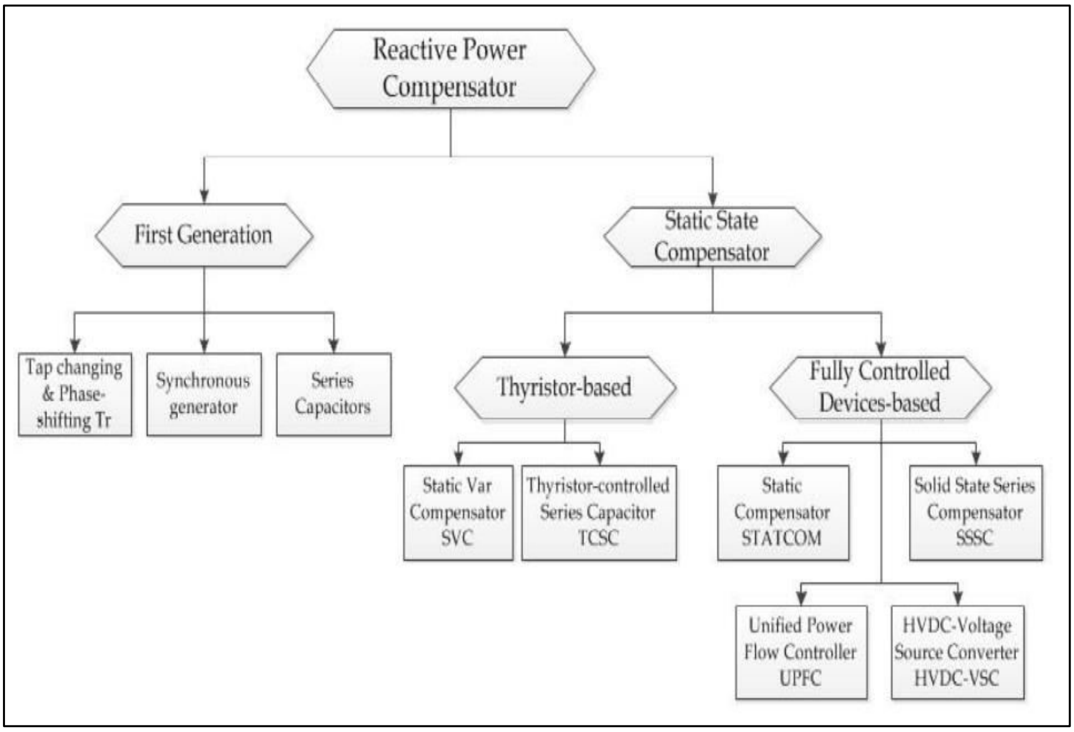

Figure 1.2: FACTS Categories [9]

1.1.3.1 Series Connected FACTS

Series FACTS devices as illustrated in Figure 1.3 could be variable impedance, such as capacitor, reactor, etc., or power electronics based variable source of main frequency, sub synchronous and harmonic frequencies (or a combination) to serve the desired need. In principle, all series FACTS devices inject voltage in series with the transmission line.

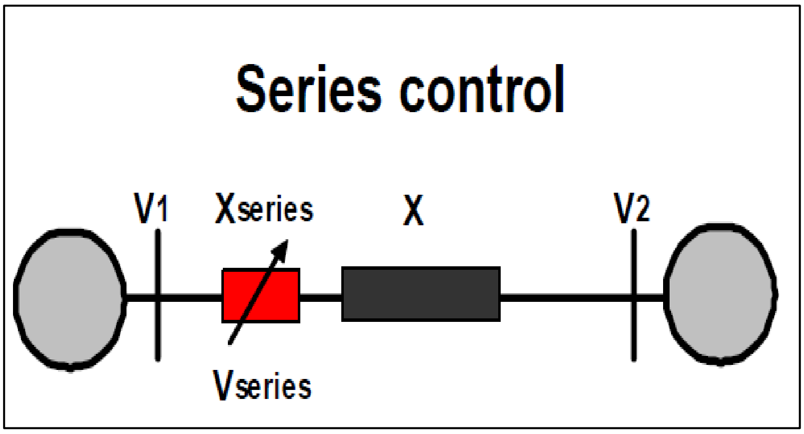

Figure 1.3: Series connected FACTS [10]

1.1.3.2 Shunt Connected FACTS

Shunt FACTS devices as in Figure 1.4 may be variable impedance, variable source, or a combination of these. They inject current into the system at the point of connection.

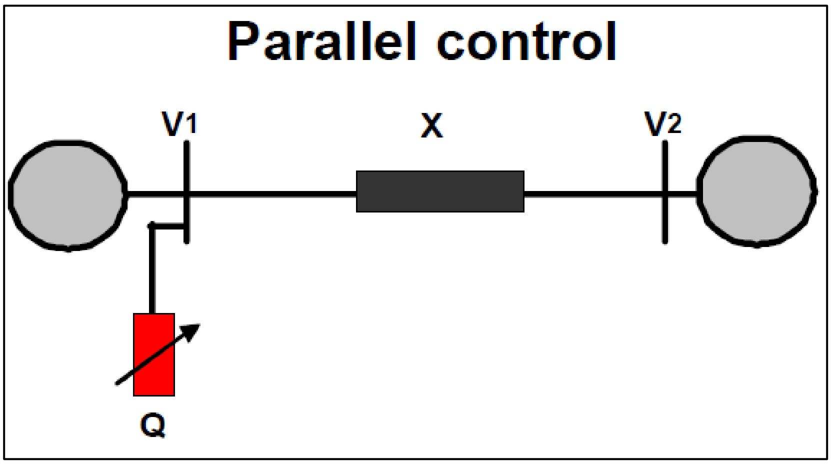

Figure 1.4: Shunt connected FACTS device [10]

1.1.3.3 Series-Shunt Connected FACTS

Series-shunt FACTS as in Figure 1.5 device is a combination of separate shunt and series devices, which are controlled in a coordinated manner or one device with series and shunt elements.

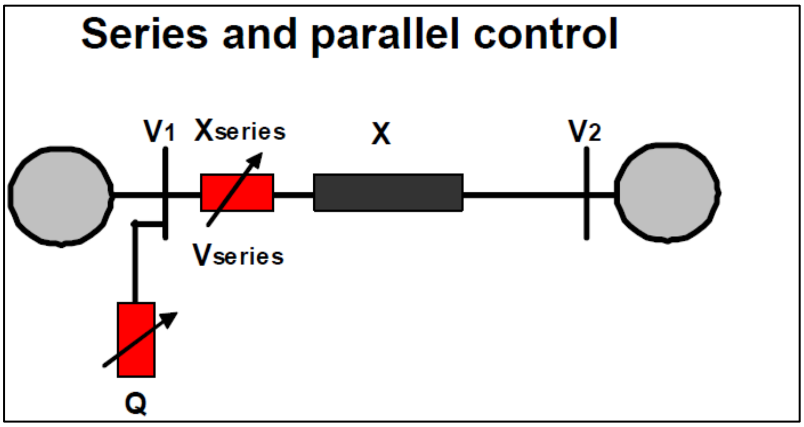

Figure 1.5: Series -Shunt connected FACTS device [10]

1.1.4 Control Attributes for Various FACTS

The Control Attributes for Various FACTS Controllers are shown in Table 1.1.

Table 1.1: Control Attributes for Various FACTS Controller

No	FACTS Controller	Control Attributes
1	SVC, TCR, TCS, TRS	Voltage control, VAR compensation, POD, VS, TS and DS
2	TCSC, TSSC	Current Control, POD, VS, TS, DS and FCL
3	TCSR, TSSR	Current Control, POD, VS, TS, DS and FCL
4	TC-PST or TC-PAR	AP control, POD, VS, TS and DS
5	TCBR	POD, TS and DS
6	TCVL	Transient and dynamic voltage limit
7	TCVR	RP control, voltage control, POD, VS, TS and DS
8	SSSC without storage	Current Control, POD, VS, TS, DS and FCL
9	SSSC with storage	Current Control, POD, VS, TS, DS and FCL
10	STATCOM without storage	Voltage control, VAR compensation, POD and VS
11	STATCOM with storage, BESS, SMES, large DC capacitor	Voltage control, VAR compensation, POD, VS, TS and DS, AGC
12	UPFC	AP and RP control, voltage control, VAR compensation, POD, VS, TS and DS, FCL
13	IPFC	RP control, voltage control, POD, VS, TS and DS

1.1.5 Advantages of FACTS

FACTS devices have become very popular in the recent power system world due to their following benefit benefits:

(i) Provide power flow control to meet the power system needs by ensuring optimum power flow, mitigate emergency conditions, or a combination of them;
(ii) Increase the loading capability of lines to their thermal capabilities, including short term and seasonal demands;
(iii) Enhance power system reliability and efficiency;
(iv) Eliminate construction of new transmission lines;
(v) Added flexibility in siting new generation;
(vi) Provide secure tie-line connections to neighboring utilities and regions thereby decreasing overall generation reserve requirements on both sides;
(vii) Upgrade of transmission lines;
(viii) Increased system security; and
(ix) Loop flow control.

1.2 Problem Statement

As stated in earlier section, increasing dependency of electrical energy has led to rapid growth of power system which results to few uncertainties. Power disruption and individual power outage one of the major problem affect the economy of the country. If the exchanges were not controlled, some lines located on particular paths may become overloaded or congested. And it even worse if uncontrollable reactive power losses results to instability to maintain the voltage at all the buses around the nominal value lead to voltage collapse.

1.2.1 Power System Congested and Overloaded

Transmission line overloaded or congested occurs when there is not enough transmission capacity to simultaneously accommodate all requests for transmission service within a region [11]. Restructuring and growth of energy industry has moved into competitive market which indirectly causing uncontrolled power delivery in transmission system. This difficulty and problem is exacerbating by the increase of the amount of congestion cause by increase of commercial transmission and the relative decline of total power delivery.

1.2.2 Power System Network Losses

In the energy system, the power generated at power stations is going through a large and complex network before reaching the end user. During power delivering and transmission process, some percentage of this power in the distribution network will be lost. Controlling the power flow in the network system either under normal or contingency conditions network can help to mitigate the heavily loaded and reduce system power loss, and so it will improve the stability and performance of the system without power interuption [12] [13].

1.3 Objectives

This master project was conducted with the objective to determine the effective location to install FACTS controller in the studied power system bus network. The effective location of TCSC is identifying to achieve the following target:

(i) To optimize location of TCSC using sensitivity based method;
(ii) To mitigate contingencies in transmission system;
(iii) To increase transmission line load ability; and
(iv) To reduce overall system power losses.

1.4 Scope of Work

Among available FACTS controller, this master project was scope down to Thyristor Control Series Capacitor (TCSC) only in which to study the effect of this FACTS controller in managing congestion, line loadability and reactive power losses in test case of 5 bus system(small network) and modified IEEE 14 bus network system (large network). This project is adopted reactive power losses indices method in determining the most sensitive transmission line for optimal placement of TCSC to the corresponding studied network system. The simulation was carried out with aid of Power World Simulator 18 GSO and MATLAB/MATPOWER 5.0. This paper as well investigated the approached method using difference degree of compensation of TCSC which is 20% compensation over 50% compensation.

1.5 Project Report Organization

This project report is organized in six chapters. Each chapter will discuss details on the particular topics. Chapter 1 basically outlines the main objectives and scopes of this research project and in brief addressing the issue of current world demand of energy and the challenges and opportunities that motivate FACTS controller's usage. It generally introduce FACTS devices as best approaches to attain current power reliability issue in such a way of power quality, transmission loadability, congestion management, lower losses reduction and voltage stability. This chapter in brief overviewing the introduction of FACTS technology in power system how it is important to establish an optimum power reliability, efficiency and quality in power system network. Provide an overview of various type of FACTS controller and demonstrates in details the differences in term of structure and functionality on each FACTS devices.

Chapter 2 illustrates the literature review and several case studies of related papers and articles by eminent authors in investigating and determining the optimum and reliable power transfer capability in transmission system. Discussing the propose techniques and approaches used by authors to control real and reactive power in transmission system.

Chapter 3 describes in details the basic working principle, characteristic and operation of selected FACTS devices (TCSC) studied in this research. This section will demonstrate mathematical modelling of TCSC to study the relationship between electrical transmission system and TCSC in steady state condition.

Chapter 4 highlights in details the methodologies used to model and simulate the system under study (5 bus system and modified IEEE 14 bus system) with existence of TCSC in the networks. Provide a general overview of software and frame works (Power World Simulator and MALLAB/MATPOWER 5.0) used is modeling corresponding networks system. This chapter illustrates the parameter setting of TCSC as well as the approach method to find the optimal placement based on several case studies develop in this research. The details such as flow chart and schematic diagram are shown in this chapter.

Chapter 5 presents the outcome of the project carried out by result and discussion obtained in Chapter 5. In this chapter, all the result gets will compare with among the cases evaluated. Any of gap and findings is highlighted in discussion part.

Chapter 6 presents the final conclusion of this project as well listed out the recommendation for future development and enhancement.

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