TESTING OF STATCOM MODEL IN IEEE POWER SYSTEM NETWORK USING PSCAD SOFTWARE

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"I hereby acknowledge that the scope and quality of this thesis is qualified for the award of the Bachelor of Electrical Engineering (Power System)"

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This thesis is submitted as partial fulfillment of the requirements for the award of the Bachelor of Electrical Engineering (Power System)

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To my beloved family and friends.

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In the name of Allah s.w.t., most gracious, most merciful.

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ABSTRACT

In any transmission system, the ultimate goals are to transmit power with high quality, economical and low risk of system failure. The ever increasing of power demands and loads especially non-linear loads making the power system network become complex to operate and the system becomes insecure with large power flows without adequate control. One way to introduce power system control is by applying controller known as FACTS (Flexible AC Transmission System) controllers. STATCOM (Static Synchronous Compensator) is one of the FACTS controllers and can be introduced to the power system to regulate terminal voltage and to improve system's stability. By using IEEE 4 bus power system network, the effectiveness of STATCOM is tested by applying the controller at the critical location of the power system. The critical location of a power system is determined by the voltage drop that falls below 0.95 or above 1.05. Using PSCAD/EMTDC simulation software, the simulations of STATCOM in IEEE 4 bus power system networks can be realized. To verify the PSCAD/EMTDC simulation results, load flow analysis are acquired using MATLAB software through Hadi Saadat's load flow analysis method. With these softwares, both systems' power flow can be compared to determine the effectiveness of STATCOM in the power transmission system.

ABSTRAK

Di dalam mana-mana sistem penghantaran, matlamat utama yang ingin dicapai adalah penghantaran kuasa yang berkualiti tinggi, murah dan kurangnya risiko untuk berlaku kegagalan sistem. Di dalam keadaan dimana permintaan terhadap kuasa elektrik yang semakin meningkat dan peningkatan beban terutama beban tidak terus menyebabkan rangkaian sistem kuasa menjadi semakin sukar untuk dikawal dan sistem menjadi kurang selamat dengan aliran kuasa yang tingi tanpa kawalan yang baik. Salah satu cara untuk mengawal sistem kuasa adalah dengan mengaplikasikan pengawal yang dikenali sebagai Sistem Penghantaran Arus Ulang-Alik Fleksibel (FACTS). STATCOM adalah salah satu pengawal FACTS dan boleh diaplikasikan di dalam sistem kuasa untuk mengawal voltan dan meningkatkan kestabilan sistem. Dengan menggunakan sistem 4-bas, keberkesanan STATCOM diuji dengan mengaplikasikan pengawal itu pada titik kritikal di dalam sistem kuasa. Titik kritikal itu ditentukan oleh kejatuhan voltan yang lebih daripada 1.05 dan kurang daripada 0.95 terhadap unit. Dengan menggunakan perisian simulasi PSCAD/EMTDC, simulasi STATCOM di dalam sistem 4-bas boleh dijalankan. Untuk mengesahkan keputusan simulasi PSCAD/EMTDC, analisis aliran beban diperolahi daripada simulasi MATLAB dengan menggunakan kaedah analisis aliran beban yang diperkenalkan oleh Hadi Saadat. Dengan bantuan kedua-dua perisian tersebut, perbandingan analisis aliran kuasa di dalam sistem dapat dijalankan dan keberkesanan STATCOM di dalam sistem penghantaran kuasa dapat dibuktikan.

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LIST OF ABBREVIATIONS

AC	Alternating Current
EMTDC	Electromagnetic Transient Direct Current
GTO	Gate Turn Off
IEEE	The Institute of Electrical and Electronics Engineers
IGBT	Insulated Gate Bipolar Transistor
MATLAB	Matrix Laboratory
PLL	Phase Locked Loop
PSCAD	Power System Computer Aided Design
p.u.	Per-unit
SPWM	Sinusoidal Pulse Width Modulation
STATCOM	Static Synchronous Compensator
VSC	Voltage-sourced Converter

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CHAPTER 1

INTRODUCTION

1.1 General Introduction

Wherever power is to be transported, the basic requirements are; the power transmission must be economical, the risk of power system failure must be low, and the quality of the power supply must be high. Reactive power compensation is increasingly becoming one of the most economic and effective solution to both traditional and new problems in power transmission systems. As power transfers grow, with the ever-increasing usage of non-linear loads, the power system network becomes increasingly complex to operate and the system becomes insecure with large power flows without adequate control [1].

To overcome these problems, STATCOM (Static Synchronous Compensator) is introduced to the power system to regulate voltage and to improve dynamic stability. Using IEEE 4 bus power system network along with STATCOM, this project's goals is to analyze the performance of the power system by introducing STATCOM into the system. Both models will be simulated using PSCAD software and the result of the performance will be analyzed and compared to determine the effectiveness of STATCOM's application in power system.

1.2 Objectives

The objective of this project is to;

i. To simulate STATCOM model in IEEE 4 bus power system network using PSCAD software.
ii. To analyze the steady-state analysis of the 4 bus power system network with and without STATCOM applied.
iii. To model STATCOM in IEEE 4 bus power system network sample.

1.3 Scope of Work

The scopes for this project are:

i. Modeling STATCOM in IEEE 4 bus power system network.
ii. Simulation on the model using PSCAD/EMTDC software.
iii. Analyze and compare the performance of 4 bus system with and without STATCOM.

1.4 Thesis Outline

For the thesis outline, the progress elements are divided into chapters and the details are as follows:

i. Chapter 1

This chapter consists of introduction, objectives, scope of work and thesis outline. In introduction, the problem statement is stated here along with the relevant solution. It’s to support the main objectives and the relevancy of the proposed title. In the objectives, the goal of the project is stated in here. It’s consists of the aim that must be achieved at the end of the project. In the scope of work, the detailed work flow stated in here. This step by step flow work is to keep the project’s progress on track and to meet the objective. Lastly in thesis outline, the overall elements needed in the thesis are stated.

ii. Chapter 2

Chapter 2 is about literature review. It is the study on the others papers, journal, website citation and other dependable sources that related to the project. Literature review is crucial for every thesis not only to support the proposed title but also for guidelines and references on the conducted thesis.

iii. Chapter 3

Chapter 3 explains the methodology of the project. It is to describe in details about the scope of project. In this part, every step on how to approach the solutions to overcome the stated problems is described in details. It shows how the work will be done. The details such as flow chart and schematic diagram are shown in here.

iv. Chapter 4

Chapter 4 is about result and discussions. In this chapter, all the finding related to the project is stated in here. Every output produce from the project are stated, analyzed and explained briefly.

v. Chapter 5

This chapter consists of conclusion and future recommendations section. In the conclusion, the project's objectives and achieved result are concluded. In future recommendations, the suggestions to improve the existed project are stated.

vi. References

CHAPTER 2

LITERATURE REVIEW

2.1 STATCOM

STATCOM (Static Synchronous Compensator) or known as ASVG (Advanced Static Var Generator) is a solid-state voltage source inverter that is coupled with a transformer and connected to a transmission line. A STATCOM injects an almost sinusoidal current, of variable magnitude, at the point of connection [2]. It is based on the principle that a voltage-source inverter generates a controllable AC voltage source behind a transformer-leakage reactance so that the voltage difference across the reactance produces active and reactive power exchange between the STATCOM and the transmission network [3]. The function of a STATCOM model is based on how it's regulating the reactive current flow through it. This property is useful for regulating the line voltage.

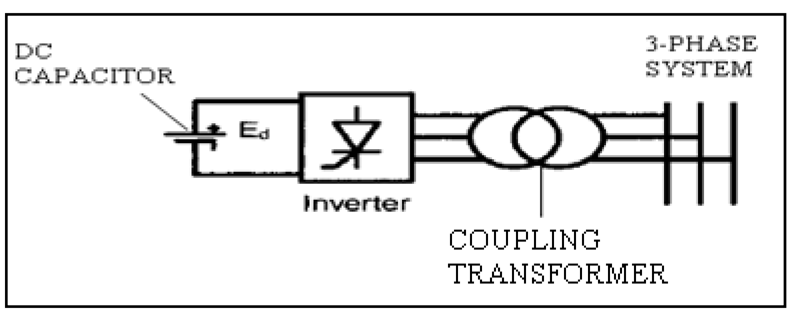

Figure 2.1 Schematic configuration of STATCOM diagram [3].

A STATCOM is basically a DC-AC voltage source inverter with an energy storage unit, usually a DC capacitor and operates as a controlled Synchronous Voltage Source (SVS) connected to the line through a coupling transformer as shown in Figure 2.1 [1]. The advantages of STATCOM are that its dynamic performance far exceeding other compensator with the response time is less than 10ms [1]. It also can improve transient stability by maintaining full capacitive output current at low voltage system.

The principle of control reactive power via STATCOM is well known that the amount of type (capacitive or inductive) of reactive power exchange between the STATCOM and the system can be adjusted by controlling the magnitude of STATCOM output voltage with respect to that of system voltage [8]. When Q is positive, the STATCOM supplies reactive power and when the Q is negative, the STATCOM absorbs reactive power from the system [8]. Reactive power generation was achieved by charging and discharging the energy storage capacitor [8]. The reactive power supplied by the STATCOM is given by this equation.

$$Q = \frac{V_{STATCOM} - V_S}{X} V_S \tag{2.1}$$

Where;

Q = reactive power.

$V_{STATCOM}$ = magnitude of STATCOM output voltage.

V_S = magnitude of system voltage.

X = equivalent impedance between STATCOM and the system.

There are two types of STATCOM main circuit configurations, and that is multi-pulse converter and multilevel converter. In the multi-pulse converter, the 3-phase bridges are connected in parallel on the DC side where the bridges are magnetically coupled through a zigzag transformer, and the transformer is usually arranged to make the bridges appear in series viewed from the AC sides [1].

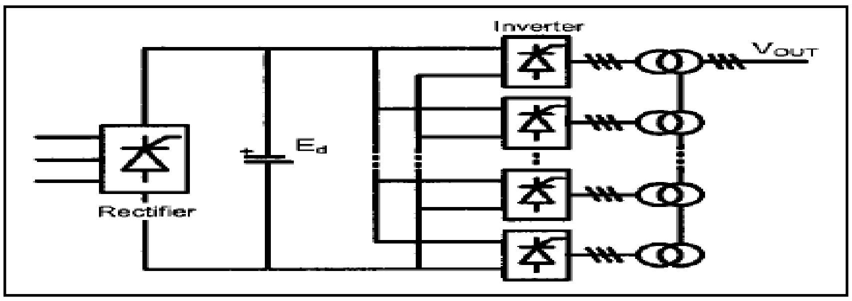

Figure 2.2 Multi-pulse converter diagram [1].

On the other hand, multilevel converter is consists of 3 different configurations, that is diode-clamped multi level inverter (DCMLI), flying-capacitor multi level inverter (FCMLI), and cascade cell multi level inverter (CCMLI). A cascade converter is constructed by standard H-bridges in series [1]. Apart from other designs, cascade multilevel converter didn't require clamping diode, flying capacitors or zigzag transformer. This means fewer components used and low cost are involved. Larger dc-side capacitors are required compared to the diode clamped and flying capacitor converter under balanced condition but it provides separate phase control to support significant voltage unbalance [1]. In ALSTOM's pioneering development, it is known as the "Chain Link Circuit": a series of links, which can be extended as required with each link, comprises a capacitor and four GTOs with inverse-parallel connected diodes [6].

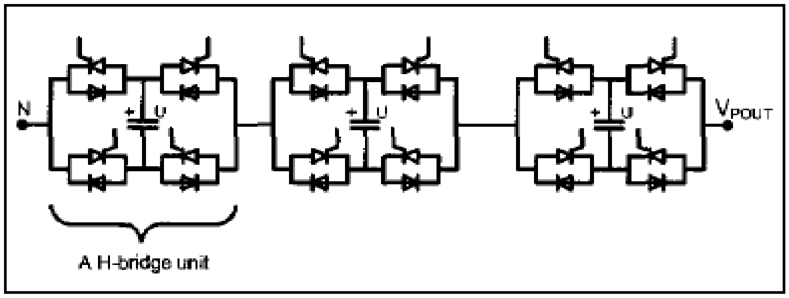

Figure 2.3 Cascade multilevel converter diagram [1].

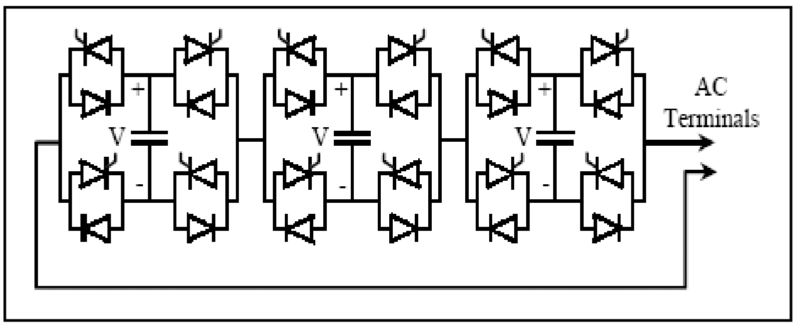

Figure 2.4 ALSTOM's Single phase three-link chain circuit [6].

In DCMLI, a first 3-level was called a neutral-point-clamped inverter. As the level increase more than 4 levels, several clamping diodes must block more than two times the voltages of the main device's collector-emitter voltage (V_{CE}) and become the reason for the diodes to be connected in series [7]. Still, this topology has severe problems with DC-link capacitor's voltage control. To equalize the voltage in each DC-link capacitor, an IGBT with anti-parallel diode is used instead of clamping diode [7]. The advantages of DCMLI are the DC-link capacitors are common to three phases, the switching frequency can be low and the reactive current and negative-phase-sequence current can be controlled [7]. The disadvantages are many diodes are used for clamping and many diodes will create physical layout such as an increase in stray inductance [7].