TESTING OF STATCOM MODEL IN IEEE 0 BUS POWER SYSTEM NETWORK USING PSCAD AND MATLAB

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Date : 30 NOVEMBER 2010

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

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ABSTRACT

Power utilities have facing challenges due to increase load demands caused by rapid industries growth over years. One of the problems is the voltage instability in power system. Voltage stability is the ability of the system to maintain the voltage magnitude under normal condition and also under heavy stressed condition. Voltage instability is the power system that did not have the ability to meet reactive power demand. This will lead to a voltage collapse in the system. This project will present the performance of STATCOM installation in nine bus test system. A load flow analysis is conducted in order to obtain the power flow magnitudes, voltage levels and power losses in the distribution system. In addition, this project is to study the effectiveness of STATCOM by injecting at the critical location bus in the system. Thus, STATCOM that acts as a controller will regulate the terminal voltage and correcting the fault in transmission line of power system network.

ABSTRAK

Tenaga utiliti menghadapi cabaran akibat peningkatan tuntutan beban kerana pertumbuhan pesat industri selama bertahun-tahu. Salah satu sebab adalah ketidak stabilan voltan. Tegangan kestabilan adalah kemampuan sistem untuk mempertahankan besarnya tegangan pada keadaan biasa dan juga dalam keadaan stres berat. Punca ketidakstabilan voltan adalah sistem kuasa tidak memiliki kemampuan untuk memenuhi permintaan kuasa reaktif. Hal ini akan menyebabkan jatuhnya voltan dalam sistem. Tesis ini akan menyajikan keberkesanan pemasangan STATCOM di sembilan ujian sistem bas. Analisis aliran kuasa dilakukan dalam rangka untuk mendapatkan besaran aliran daya, tahap voltan dan kerugian daya dalam sistem pengedaran. Projek ini adalah untuk mengkaji keberkesanan STATCOM oleh suntikan di lokasi bas kritikal dalam sistem. Dengan demikian, STATCOM bertindak sebagai pengawal akan menetapkan voltan terminal dan perbaikan kesalahan dalam saluran penghantaran rangkaian sistem tenaga.

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LIST OF ABBREVIATIONS

AI	-	Artificial Intelligence
DM	-	Decision Maker
DC	-	Direct Current
FIS	-	Fuzzy Inference System
GA	-	Genetic Algorithms
L	-	Low Voltage
MV	-	Medium Voltage
SA	-	Simulated Annealing
TS	-	Tabu Search
TNB	-	Tenaga Nasional Berhad

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Overview of the project

Heavy industries and electrical utilizes facing a number of challenges and problems that is related to reactive power. These heavy industrial applications can cause phenomena and problem such as voltage unbalance, distortion or flicker on the electric grid. For electrical utilities, it may be confronted with phenomena of voltage sags, poor power factor or even voltage instability. Reactive power control can resolve these issues. The ultimate objective of the transmission system is to deliver electric power reliably and economically from generators to loads. Power systems are extremely complex, large beside has ever-changing structures that must respond continuously real-time. The electricity should be produced and should be delivered instantly when is demanded by a load. The system should carry out as economically as possible, with transactions and sales monitored accurately.

To overcome this problem, a new technology was develop to replace the mechanical control. The FACTS controllers have the ability of enhancing transmission system control, reliability, and operation, and also improve the distribution-system power quality. Static Synchronous Compensator (STATCOM) is one of the FACTSs' families. Over the last two decades, advancements in static reactive compensation technology based on VSC concepts have produced significant benefits. STATCOM systems offer rapid response to system events, improved voltage and power system stabilization and enhanced reliability.

1.2 Objective

The purpose of this project are:

i. to simulate STATCOM model IEEE 4 and IEEE 9 bus power system network using PSCAD software.
ii. to analyze the performance of the IEEE 4 and IEEE 9 bus power system network with and without STATCOM applied.
iii. to model STATCOM in IEEE 4 and IEEE 9 bus power system network.

1.3 Problem Statement

Nowadays, the increasing of power demand and loads especially non linear loads making the power system network become complex to operate. The system becomes insecure with large power flows without adequate control. To overcome these issues, STATCOM controllers is introduced to the power system. Ideally, these new controllers should be able to control voltage level and improve system's stability by applying at the critical location.

1.4 Scope of Project

The scope of this project is focusing on:

i. modeling STATCOM in IEEE 4 and IEEE 9 bus power system network
ii. simulation on the model using PSCAD.
iii. analyze and compare the performance of IEEE 4 and IEEE 9 bus system with and without STATCOM.

1.5 Thesis Outline

The thesis is organized into five chapters. The brief outline of each chapter is presented as below:

Chapter 1 contained about overviewed of overall of this project, objective of doing this project, scope of project description, and the problem statement regarding to this research.

Chapter 2 consist of literature review that been read. It contains of review of the technical paper written by expertise that have been taken from website and also books. Literature review is crucial for every thesis not only to support the proposed title but also for guidelines and references on the conducted thesis.

Chapter 3 represent about the analysis approach that involve in this research. It also included the procedures and the tools that used in the analysis which are PSCAD and MATLAB.

Chapter 4 states the result and the analysis made from the research and the discussion during the research done. Every result from the simulation are stated, analyzed and explained briefly.

Chapter 5 contains the conclusion of overall project by state the final result that gained from the project. Future recommendations also stated in order to improve this project in the future undertakings

1.6 Gantt Chart

Table 1: Gantt Chart for PSM 1

PROGRAM \ WEEK	PSM 1													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1)PSM 1 Briefing Session	■													
2)Find Supervisor and Project title	■	■												
3)Register Title and Submit Abstract			■											
4)Literature Review and research about STATCOM			■	■	■	■	■	■	■	■	■	■	■	■
5)Preparation for Seminar PSM 1			■	■	■	■	■	■	■	■	■	■	■	■
6)PSM 1 Seminar									■					

Table 2: Gantt Chart for PSM 2

PROGRAM \ WEEK	PSM 2																						
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1)Software and Simulation																							
7.1:PSCAD and MATLAB learning	■	■	■																				
7.2:Modeling Test System using PSCAD	■	■																					
7.2:Run Load Flow using MATLAB(MAT POWER)	■	■																					
7.2:Model test system using PSCAD			■	■																			
7.3:Run Load Flow using PSCAD			■	■																			
7.4:Compare result PSCAD versus MATLAB					■																		
7.5:Model IEEE 9 bus system with STATCOM			■	■	■	■	■																
7.6:Run Load Flow										■	■	■	■	■									
2) Documentation																							
2.1 Thesis Draft 1								■															
2.2 Thesis Draft 2								■															
2.4 Final Draft												■											
2.5 Thesis												■											
3)Preparation for PSM 2 Seminar & Demo																		■	■	■	■		
4) PSM 2 Seminar																						■	
5) PSM 2 Demo																							■

CHAPTER 2

LITERATURE REVIEWS

2.1 Power Flow

Load flow studies are performed using computer software that simulates actual steady-state power system operating conditions, enabling the evaluation of bus voltage profiles, real and reactive power flow and losses. Conducting a load flow study using multiple scenarios helps ensure that the power system is adequately designed to satisfy the performance criteria. A properly designed system helps contain initial capital investment and future operating costs [1]. Load flow studies are commonly used to investigate:

i. the component or circuit loading
ii. the bus voltage profiles
iii. the real and reactive power flow
iv. the power system losses
v. the proper transformer tap settings

The goal of a power flow study is to obtain complete voltage angle and magnitude information for each bus in a power system for specified load and generator real power and voltage conditions. Once of this information is known, real and reactive power flow on each branch as well as generator reactive power output can be analytically determined. Due to the nonlinear nature of this problem, numerical methods are employed to obtain a solution that is within an acceptable tolerance. The solution to the power flow problem begins with identifying the known and unknown variables in the system. The known and unknown variables are dependent on the type of bus. A bus without any generators connected to it is called a Load Bus. With one exception, a bus with at least one generator connected to it is called a Generator Bus. The exception is one arbitrarily-selected bus that has a generator. This bus is referred to as the Slack Bus [1].

For assessing the impact of the STATCOM in controlling the grid voltage, power flow study is necessary. Moreover, in the planning stage, to determine the ratings of the STATCOM, among others, repeated load flow studies are carried out. Also, in a stability study, load flow solution is required to establish the initial operating point. Thus, power flow studies are indeed one of the most fundamental studies necessary to be carried out before implementing any STATCOM in a power system [2].

2.2 FACTS

FACTS is stand for Flexible AC Transmission System. FACTS is an evolving technology based solution envisioned to help the utility industry to deal with changes in the power delivery business. FACTS is defined by the IEEE as “a power electronic based system and other static equipment that provide control of one or more AC transmission system parameters to enhance controllability and increase power transfer capability [3].

FACTS provide high speed and precise control of one or more AC system parameters within synchronous AC system, thereby greatly enhancing the value of AC transmission assets. These parameters include voltages, impedances, phase angle, currents, reactive power and active power [4].

There are three widely known FACTS controllers, namely as STATCOM, SSSC and UPFC. All of these controllers have a converter based which is Voltage-Source Converters (VSC). A basic building block of any VSC is the three phase converter bridge. One is commonly known configuration for a three phase bridge is shown in Figure 2.1. The bridge has two DC terminals indicated by “+” sign and “-” sign in the Figure 2.1 and three AC terminals “~” in the mid points of the converter legs. By controlling the states of switches in the legs we can produce arbitrary voltage waveforms at the AC terminals [5].

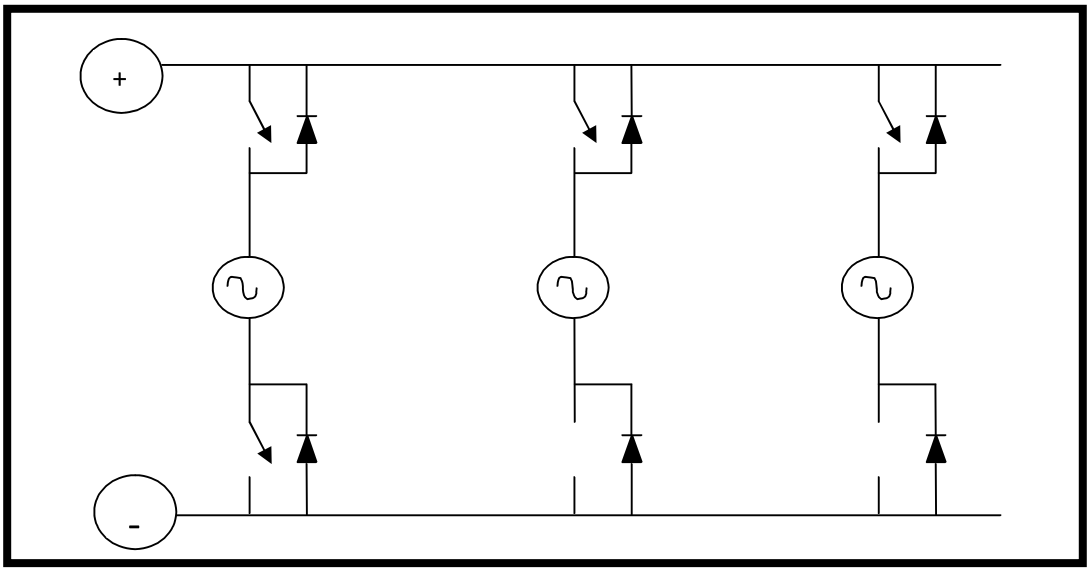

Figure 2.1: A three phase converter bridge-the basic building block of a Voltage Source Converters [5].

When a VSC is interfaced to a transmission system it has to operate at the line frequency and to produce a balanced set of sinusoidal voltages. Therefore, a VSC coupled to the transmission system has only two control degrees of freedom; it can vary the magnitude and the phase angle of its output voltage relative to the system voltage [5].

These two control degrees of freedom can be mapped to exchange active and reactive power with the transmission system. The amount of exchanged reactive power is limited only by the current capacity of the converter switches, while the active power coupled to (from) the line has to be supplied from (delivered to) the DC terminals, as shown symbolically in Figure 2.2 [5].

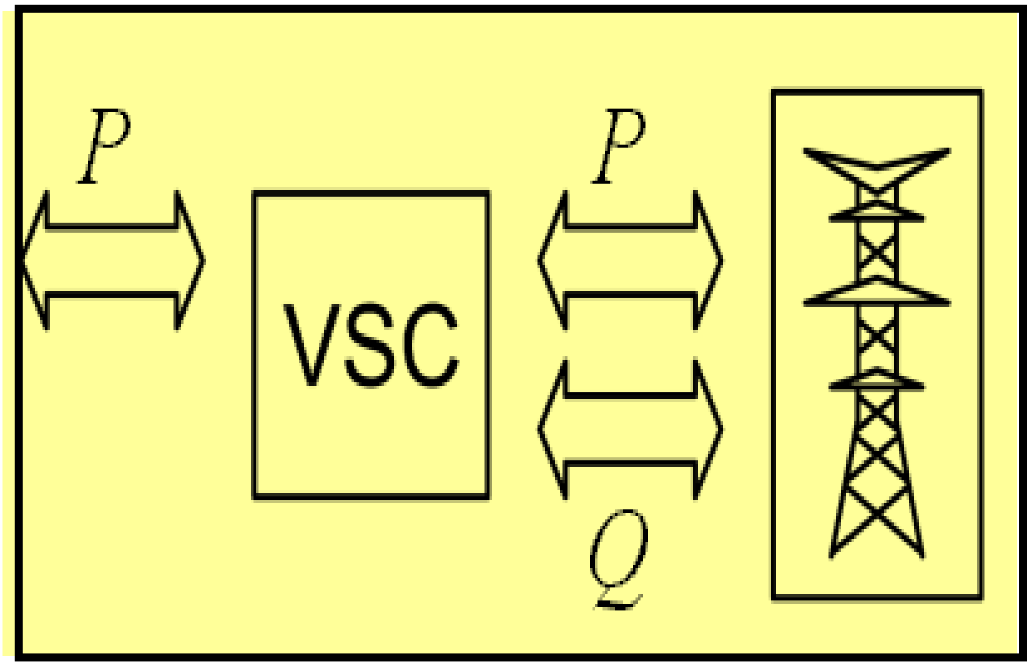

Figure 2.2: A VSC interfaced to a transmission line- P and Q exchange.

Among the main functions of FACTS devices that can enhance the flexibility and increase the security of a power system are [5]:

i. phase shifting: this is realized by injecting a voltage in series into the power system.
ii. voltage support by means of shunt device.
iii. line impedance adaption by means of series devices.

FACTS controllers can be connected to the system in the number of ways [5];

i. In shunt, the preferred way to meet equipment isolation requirements (one end of the device is referenced to ground) and from the stand point of protection from system short circuit currents.
ii. In series, which has the disadvantages mention above, but only requires relatively low voltage ratings; technological solutions have been develop to solve problems associated with insulating the equipment from ground and the full potential of series connections can now be exploited.
iii. With both shunt and series elements, such as in the UPFC.

2.2.1 Theory and control of STATCOM

The Static Synchronous Compensator (STATCOM) is based on the principal that a voltage source inverter generates a controllable AC voltage source behind a transformer reactance so that the voltage difference across the reactance produces active and reactive power exchange between the STATCOM and the transmission network [6]. The STATCOM is a shunt reactive power compensating electronic device that generates AC voltage, which intern causes a current of variable magnitude at the point of connection. This injected current is almost in quadrature with the line voltage, thereby emulating an inductive or a capacitive reactance at the point of connection with the transmission line. The functionality of the STATCOM model is verified by regulating the reactive current flow through it. This is useful to generate or absorb reactive power for regulating the line voltage of the bus where the STATCOM is connected [7].

A STATCOM installation plays an important role in power industries to improve the stability of the system. STATCOM in it basis is one DC-AC voltage source convertor having one storage unit energy, usually a DC capacitor. It operating as Synchronous Voltage Source (SVS) that connected to the line through a coupling transformer. STATCOM has a dynamic performance far exceeding the other Var Compensators [8].

Figure 2.3 demonstrates a simplified diagram of the STATCOM with an inverter voltage source, E and a tie reactance, Xtie connected to an ac system with voltage source, Vth and a Thevenin reactance, Xth. When the converter voltage is greater than the system voltage, the STATCOM “sees” an inductive reactance connected at its terminal. Hence, the system “sees” the STATCOM as a capacitive reactance and the STATCOM is operating in a capacitive mode [7]. The current flows from the STATCOM to the AC system, and the device generates reactive power. In this case, the system draws capacitive current that leads by and angle of 90° the system voltage, assuming that the converter losses are equal to zero [9].

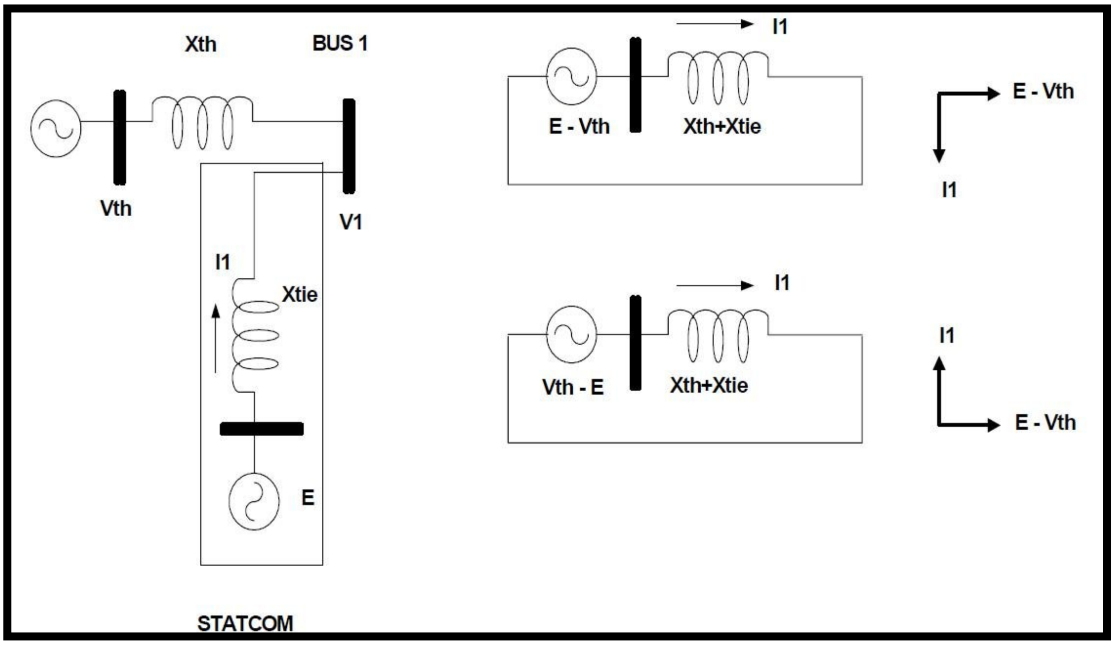

Figure 2.3: A static synchronous compensator operated in inductive and capacitive mode [10]

2.2.1.1 STATCOM Main Circuit Configurations

There are two types of STATCOM main circuit configuration which are multipulse converter and multilevel converter [8].

In the multipulse converter, the 3-phase bridges are connected in parallel on the DC side as shown in Figure 2.4. The bridges are magnetically coupled via a zigzag transformer. The transformer is usually arranged in order to make the bridges appear in series viewed from the AC sides. Each windings of the transformer is phase shifted. This is to eliminate selected harmonics and produce a multipulse output voltage. Pulse Width Modulation (PWM) is applied to improve the harmonics content, at the expense of higher switching and snubber loss, plus reduced the fundamental of var rating [8].

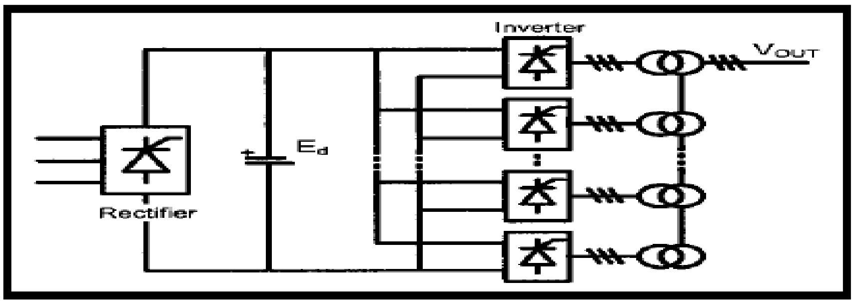

Figure 2.4: Multipulse Converter Diagram [8].

Figure 2.5 shows the multilevel converter configuration consists of three different configurations which are Diode-clamped converter, Flying Capacitor Converter and Cascade Converter. A cascade converter is constructed by standard H-bridges in series. Apart from other designs, cascade multilevel converter eliminates clamping diode, flying capacitors or zigzag transformer. Thus, its requires least 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 [8].

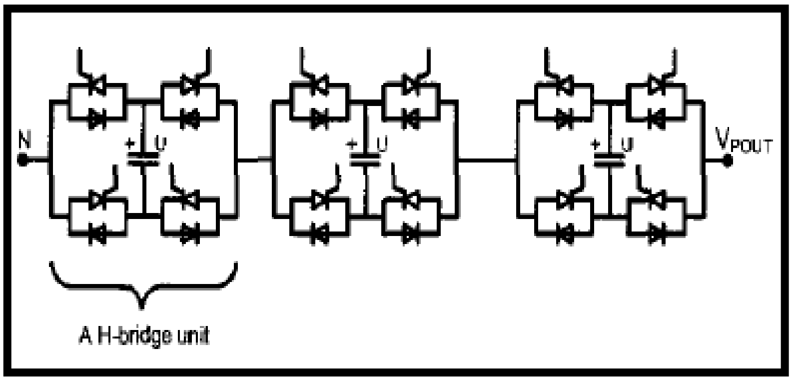

Figure 2.5: Cascade multilevel converter diagram [8]

2.2.1.2 Advantages of STATCOM

STATCOM has many advantages over the other compensators. The advantages of STATCOM can be summarized such as[10]:

i. it has short term overload capability of ~20%