Smart Power Transmission System Using FACTS Device

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ABSTRACT

Making of smart grids puts mounting pressure on the nation's aging electric power transmission system. Just planting additional towers and stringing more line won't practice the nation's electric power transmission infrastructure to meet up the energy challenges ahead. Smart grids stand geared up to play a much larger role in the energy equation for reduction of transmission line losses with the range of technologies and methodologies now on hand. The FACTS controllers come out with the capability of enhancing transmission system control, reliability, and operation. Shunt Flexible AC Transmission Systems (FACTS) devices have been used in power systems since the 1970s for the improvement of its dynamic performance. This paper will discuss and express how Static Synchronous Compensator (STATCOM) has effectively been applied to power system for efficiently regulating system voltage and thus increase system load ability. This paper investigates the effects of (STATCOM) on voltage stability of a power system at different positions. STATCOM plays an important role in controlling the reactive power flow to the power network, when it is placed in a long transmission line. The simulation analysis of this paper can be used as guideline for power industry. The study is thereby simulated using the MATLAB/SIMULINK software and simulation results show that STATCOM is effective in midpoint voltage regulation on transmission line. In this paper comparison is also performed between STATCOM and SVC under fault condition and it is proved that STATCOM have the capacity to provide more capacitive power for the period of a fault than SVC. It is also displayed that STATCOM shows faster response than SVC.

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1. INTRODUCTION

It is expected that authors will submit carefully written and proofread material. Nowadays changing electric power systems generate a growing need for reliability, flexibility, fast response and accuracy in the fields of electric power generation, transmission, distribution and consumption. The transmission system is the high-voltage part of the electric power infrastructure responsible for the bulk transfer of electricity from power plants to substations located near population centres. Transmission and Distribution (T&D) losses between 6% and 8% are considered normal [1]. An efficient, reliable transmission system will persist to have a vital role in satisfying the nation's growing thirst for electricity._The transmission system of the future (Smart Transmission) is the logical extension of today's electric grid. Transmission has a long history of installing new technologies that always improve performance in reply to the varying needs of society. This approach of innovation is required today, more than ever before. A transmission system that is both bigger and smarter than today's system is wanted to meet the nation's goal of a sustainable future for electric energy.

Transmission expansion is obviously a significant aspect of grid modernization, but this path consists of obstacles that have been not easy to overcome. Hence, pertaining advanced technology to improve the existing grid is the suitable parallel path, one that implements the concepts of a smart grid. A smart grid is an umbrella term that envelops modernization of both the transmission and distribution grids. Transmission is the unsung song of the smart grid and Utility of the Future. After years of neglect, it is understandable that we require more than Band-Aids and piecemeal patches to enable a smarter and modern transmission grid. The time has arrived to increase the smart grid's focus on transmission.

As utilities shift forward with smart grid uses, there has never been a better time to think about the use of advanced power electronics as a workable transmission planning choice. With the use of *FACTS Devices* known as flexible AC transmission systems, the future of electric transmission systems can be smart. FACTS can raise transmission to a new level of performance and can provide a variety of benefits for increasing transmission efficiency. The most urgent is their capacity to let the existing AC lines to be loaded more heavily without mounting the risk of disturbances on the system. The use of FACTS device [STATCOM] can also result in lower system losses.

Actual results vary with the characteristics of each installation, but industry experience has shown FACTS devices to enhance transmission capacity by 20-40% [2]. STATCOMs stabilize voltage which can remove some of the operational safety constraints that prevent operators from loading a given line more heavily. In addition to the efficiency gains, these devices also deliver a clear reliability benefit.

2. PROBLEM STATEMENT

A commonly occurring situation in a power system is the requirement to transmit more power over the system than it was originally designed for. In cases where there is a need to transmit more power, simply building of new transmission lines is an often a safe way out. This, however, may not at all be the best solution. Adding new lines may be too costly and time-consuming. Concessions for right-of-ways may be hard or impossible to overcome. And last but not least, environmental aspects are much more important now and require to be properly addressed in conjunction with transmission development. We have to build away bottlenecks in existing transmission systems.

The voltage will sag if there is not enough reactive power. If there is too much of it, the voltage will be too high. Unfortunately, the grid is extremely sensitive to small variations in voltages. Since blackouts in the majority of cases are caused by a deficit of reactive power.

"Self-healing" capability of smart grids to detect and respond to system disturbances using FACTS [STATCOM] come into the picture as a remedy in a natural way. So, to have the reactive power in the right amounts at all times, and in the right places of the grid, that is the task to be performed by means of Reactive Power Compensation. Another important point is that a reactive power compensator needs to be fast, i.e. fast response is a key characteristic of the device.

Maintaining proper balance of reactive power in the transmission grid is important also from another point of view, i.e. too much reactive power flowing in the grid also gives rise to losses, and losses cost money which is always, at the end, charged to the customer. Among the FACTS controllers, STATCOM propose rapid acting dynamic reactive compensation for voltage support for the period of contingency events or else it would depress the voltage for a considerable length of time. FACTS devices can normalize the active and reactive power control with adaptive to voltage magnitude control simultaneously for the reason of their flexibility. Yet, due to high capital investment, it is needed to place these controllers optimally in the power system. In this paper V-I Characteristics of STATCOM is described. STATCOM is modeled in MATLAB/ Simulink and simulation results are shown and discussed. Simulation results attest that shunt FACTS devices provide maximum advantage from their stabilized voltage support when positioned at the mid-point of the transmission line. This paper confers about dynamic response of STATCOM and put side by sides STATCOM and SVC under fault condition.

A. SVC

Static var compensator is shown in Fig. 1 schematic diagram. The compensator in general includes thyristor-switched capacitors (TSCs), harmonic filters and thyristor controlled reactor (TCR).Mechanically switched shunt capacitors (MSCs) may also be included and then the term static var system is used. At fundamental frequency the harmonic filters are capacitive. It is used for the harmonics generated by TCR. The TSC block is typically smaller than TCR so that continuous control is grasped. Other possibilities are thyristor switched reactors (TSRs) and fixed capacitors (FCs). Typically at medium voltage, a dedicated transformer is used with the compensator equipment.

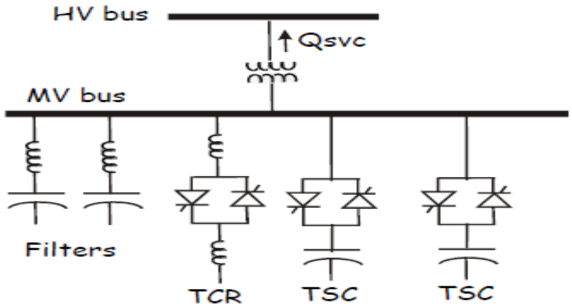

Figure 1: Schematic diagram of an SVC

The SVC rating can be optimized to meet up the required demand. With respect to inductive and capacitive reactive power the rating can be symmetric or asymmetric. For example, the rating can be 200 Mvar capacitive and 200 Mvar inductive or 200 Mvar capacitive and 100 Mvar inductive. SVCs are well known to improve power system properties such as steady state stability limits, voltage regulation and var compensation, dynamic over voltage and under voltage control, counteracting sub synchronous resonance, and damp power oscillations [3].

B. STATCOM

It is a voltage source converter, VSC that converts a dc voltage at its input terminals into three-phase ac voltages at fundamental frequency of controlled magnitude and phase angle. Fig. 2 shows the simplest implementation of a STATCOM.

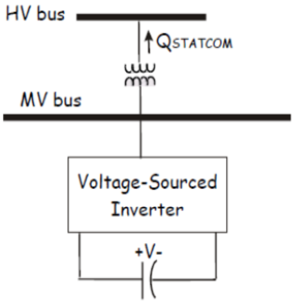

Figure 2: Schematic diagram of a basic STATCOM

C. Basics of STATCOM

The Static Synchronous Compensator (STATCOM) is one of the Flexible AC Transmission Systems (FACTS) devices with promising prospect of applications. There are two basic controls which can be applied in the STATCOM. One is the control of the DC voltage across the DC capacitor inside the STATCOM and another is the AC voltage regulation of the power system at the bus bar where the STATCOM is installed. AC voltage regulation is comprehended by controlling the reactive power exchange between the STATCOM and a power system. Pulse width modulation (PWM) is used for loss consideration in converters. The DC voltage across the DC capacitor must be constant if the STATCOM converter works on Pulse Width Modulation (PWM) algorithm. The idea of assigning two separate controllers to these two STATCOM functions is suggested. However, from the point of view of control system design, when both STATCOM AC and DC voltage controls are implemented , a power system installed with the dual functional STATCOM is a two-input two-output multivariable system.

Hence closed-loop system stability can be pledged when AC and DC voltage regulators are designed together or in co-ordination. STATCOMs have a symmetrical rating with respect to capacitive and inductive reactive power. For example, the rating can be 100 Mvar capacitive and 100 Mvar inductive. For asymmetric rating, it needs a complementary reactive power source. This can be understood for example with MSCs.

VSCs use pulse width modulation, PWM, technology, which makes it capable of providing high quality ac output voltage to the grid or even to a passive load [4]. STATCOM provides shunt compensation in a similar way as SVC but utilizes a voltage source converter rather shunt capacitors and reactors (Machowski, 1997). The basic principle of operation of a STATCOM is the generation of a controllable AC voltage source behind a transformer leakage reactance by a voltage source converter connected to a DC capacitor. The voltage difference across the reactance produces active and reactive power exchanges between the STATCOM and the power system [5].

3. OBJECTIVES

The main objective of this research paper is implementing FACTS device [STATCOM] for dynamic reactive power support to ensure satisfactory voltage profiles to effectively increase line capacity. Without the need to reinforce the grid by means of additional lines, using FACTS [STATCOM] objectives are:

To use SVC and STATCOM on propose power system to increase power transmission capability and to use STATCOM at different position in the proposed power system and hence find the suitable position of installation for Improving power quality in transmission lines .To examine the provision of installing STATCOM for providing dynamic reactive power support and voltage control which will help to decrease overall system transmission losses and also to compare the analytic results of both the STATCOM and SVC for making a better choice in VAR compensation of transmission lines.

4. METHODOLOGY

Following methodology will be adopted to achieve the above objectives:

a. To study in depth about the literature of High voltage Transmission Lines, Smart grids, Flexible AC transmission line [FACTS].
b. To study the shunt connected FACTS devices STATCOM & SVC.
c. Power system simulator MATLAB SIMULINK will be used to analyze the transmission model.
d. The 3-bus system will be employed in Matlab/Simulink program to study about the STATCOM in detail.
e. By implementing the proposed power system through Matlab Simulink, Simulation and results of STATCOM at different positions will be shown.

The impact of STATCOMs and SVCs on the studied power system will be shown and compared on the basis of simulation and analytical results.

5. DESCRIPTION OF THE SYSTEM

A 3-bus system has been employed in Matlab/Simulink program to study about the STATCOM in detail. This system has been initiated in [7], which is modified to serve up the purpose of this paper. To validate the operation of the STATCOM, a single line diagram of the sample power transmission system shown in Figure 3. It has two load units (1300 MW and 1500 MW) and two source units (700 MVA and 1400 MVA) with a 500 km long transmission line. The appropriate location of STATCOM is chosen by referring to the critical bus where the voltage magnitude is fewer than 5% of the rated voltage [6].

Under steady state condition for the proposed power transmission system in the Figure 3, four cases are studied via time simulation. The four cases are:
Case 1, without any controllers in the system;
Case 2, with STATCOM at the near busB2 (Mid-point Connection);
Case 3, with STATCOM at the near busB1 (Left side connection);
Case 4, with STATCOM at the near busB3 (Right side connection).

6. ANALYSIS OF SIMULATION RESULTS

To validate the implementation of the STATCOM model working under steady state condition, the test system in Fig.3 is used. By using Power System Blockset (PSB) The STATCOM operation in Fig.3 is simulated in Matlab/Simulink. A typical +/-100 MVAR STATCOM, three-level PWM and 500 KV connected at the center (mid-point) of the power system as shown in fig 3. Fundamentally, the Static Synchronous Compensator (STATCOM) is one of the key FACTS devices. The STATCOM controls system voltage by absorbing or generating reactive power based on a voltage-sourced converter. STATCOM output current (inductive or capacitive) can be controlled freely of the AC system voltage contrary to a thyristor-based Static Var Compensator (SVC). In this Paper the proposed power transmission system in Fig.3 has been simulated with the STATCOM controlled to boost up the voltage at the mid-point of the transmission line. In this analysis three installation positions have been chosen for the STATCOM (Left side connection, Mid-point Connection, Right side connection).

Tabel I. shows that the magnitude voltage of bus 1, 2, 3 is comprehensively increased when STATCOM is connected to the system. The reactive power is in fact increased at the affected line and as an outcome the STATCOM is providing vars to the system. It is monitored that the reactive power flows from the converter to the system hence the STATCOM is in capacitive mode of operation.

TABLE I. Simulation Result for the Proposed Power Transmission System

Parameter	Without STATCOM	With STATCOM Left Connection	With STATCOM Mid connection	With STATCOM Right connection
Voltage at Bus B1(KV)	497.6	509.3	492.4	473.4
Voltage at Bus B2(KV)	460.5	485.3	489.2	464.6
Voltage at Bus B3(KV)	470.8	491.5	495.1	490.3
Max.Active Power flow at Bus B2(MW)	585.5	640.6	631.4	609.6

The simulation results from Matlab/Simulink program for the proposed power transmission system are illustrated in Figure 4, 5& 6.

7. STATCOM COMPARED TO SVC UNDER FAULT CONDITION

We will now compare our STATCOM model with a SVC model having the same rating (+/- 100 MVA). We will see a SVC connected to a power grid alike to the power grid on which our STATCOM is connected as we double-click on the "SVC Power System" (the magenta block). On both systems a remote fault will be simulated with a fault breaker in series through fault impedance. The value of the fault impedance is programmed so as to create 30% voltage sag at bus B2. We will initially disable the "Step Vref" block by multiplying the time vector by 100, before running the simulation. By selecting the parameters "Switching of phase A, B and C" , We will program the fault breaker and confirm that the breaker is programmed (looking at the “Transition times" parameter) to activate at t=0.2 s for a duration of 10 cycles. We also check that the fault breaker within the "SVC Power System" has the same parameters. Finally, set the STATCOM droop back to its original value (0.03 pu). Run the simulation and look at results.

Fig. 7 and Fig. 8 show active and reactive power changes. Fig. 9 shows three phase current changes. Fig. 10 shows the measured voltage Vm on both systems (magenta trace for the SVC). The Fig. 11 displays the measured reactive power Qm generated by the SVC (magenta trace) and the STATCOM. A key difference between the SVC and the STATCOM can be observed during the 10-cycle fault.
The reactive power generated by the STATCOM is -0.71 pu and the reactive power generated by the SVC is -0.48 pu .

We can then observe that the maximum capacitive power generated by a STATCOM decreases linearly with voltage decrease (constant current) while the maximum capacitive power generated by a SVC is proportional to the square of the system voltage. One important advantage of the STATCOM over the SVC is its ability to provide more capacitive power during a fault.

The STATCOM has no delay linked with the thyristor firing (in the order of 4 ms for a SVC) for the reason that of the voltage-sourced converter hence the STATCOM will normally exhibit a faster response than the SVC.

8. CONCLUSIONS

In recent years, alongside with the fast increasing electric power necessity, the reconstruction of power network is becoming more vital. Stability of AC transmission systems during transmission upgrade process and for the improvement of efficiency there will be huge demand for reactive power compensation. Static Synchronous Compensator (STATCOM) is a device proficient of solving the power quality problems at the power system.

This paper demonstrates in detail the principle characteristics of STATCOM. The steady state performance of the STATCOM is analyzed by using computer simulations with Matlab/Simulink program. The simulation of STATCOM in this paper has verified that it can be efficiently applied in power transmission systems to solve the problems of poor dynamic performance and voltage regulation in the power transmission system of Fig.3. It is revealed that STATCOM present better performance in the enhancement of voltage regulation in a power system and it is most useful when connected at the mid-point of a transmission system.

STATCOM system can be used under distorted mains voltage conditions and for reactive power compensation in the industrial network grid. It is more reliable than shunt capacitor reactive power compensator. We have observed the performance of STATCOMs and SVCs in electric power systems too. On the basis of simulation and analytical studies, the impact of STATCOMs and SVCs on the studied power system is shown. It was presented that both devices appreciably improve the transient voltage behavior of power systems. Despite the fact that working principle of SVCs and STATCOMs is different, yet their impact on increasing power system transmission capacity can be comparable.

APPENDIX

The data for various components used in the MATLAB model of Fig. 3. (All data are in pu).

TWO SOURCES: Base voltage: 500 kV, Phase to phase rms voltage: 500 kV x 1.078, Frequency: 50 Hz, 3 phase short circuit level at base voltage (VA): 1400x106 and 700x106, X/R ratio: 8.

TWO LOADS: Nominal phase to phase voltage: 500 kV , Configuration: Y (grounded), Active power: 1300 MW and 1500 MW, Freq: 50 Hz

TRANSMISSION LINE: No. of phases: 3, Line length (km): 500, Resistance per unit length (ohms/km): [0.01755 0.2758], Inductance (H/km): [0.8737x10-3 3.220x10-3], Capacitance (F/km): [13.33x10-9 8.297x10-9].

STATCOM parameters: 500 kV, ±100 MVAR, R = 0.071, L = 0.22, Vdc = 40 kV, Cdc = 375 ± μ F, Vref = 1.0, Kp = 50, Ki = 1000.

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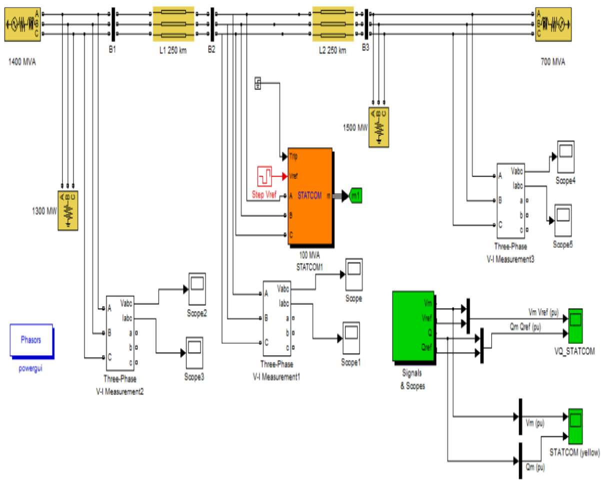

Figure 3: Single line diagram of the power transmission system with the STATCOM

Figure.4: Simulation result for the proposed power transmission system: Voltage at bus B1, B2, B3 without STATCOM

Figure.5: Simulation result for the proposed power transmission system: Voltage at bus B1, B2, B3 with STATCOM (Mid-point Connection)

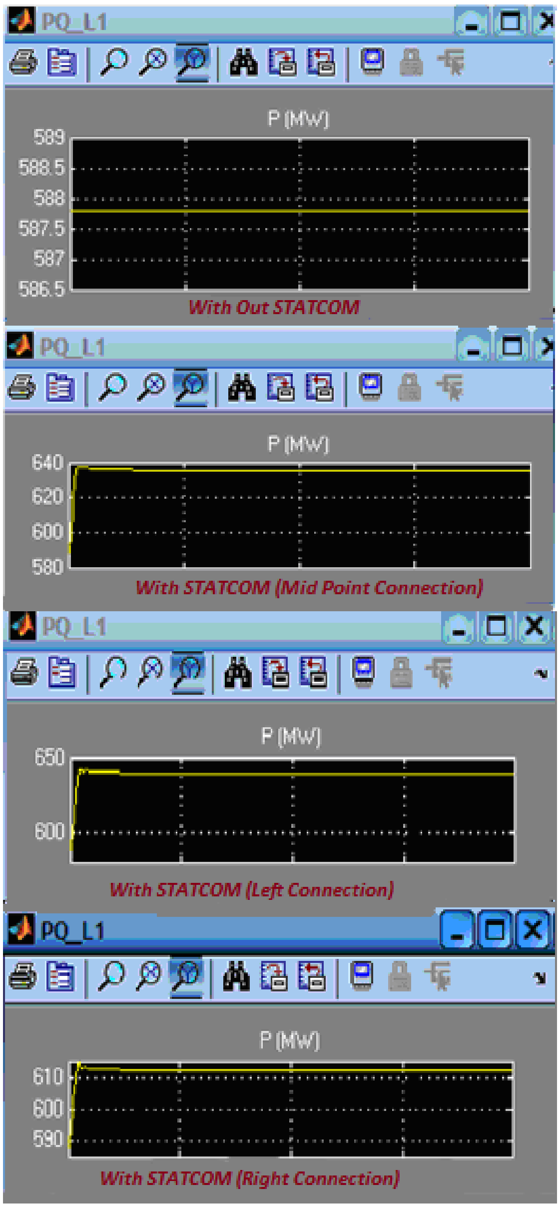

Figure 6: Simulation result showing the active power flow at Bus B2

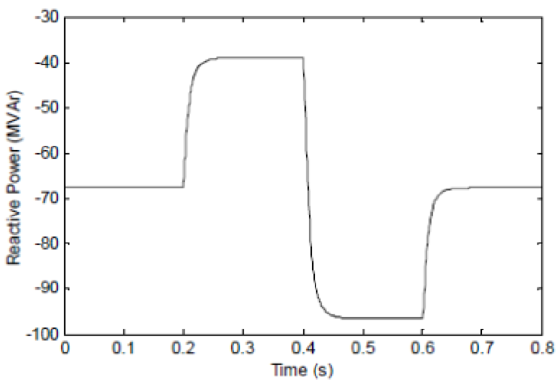

Figure 7**:** Changes of active power

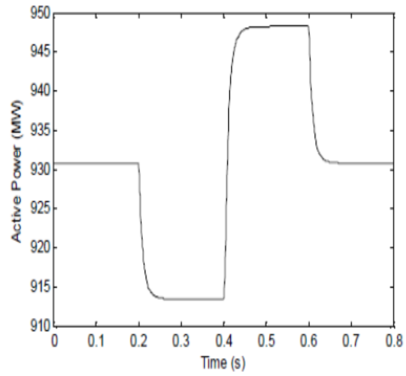

Figure 8: Changes of reactive power

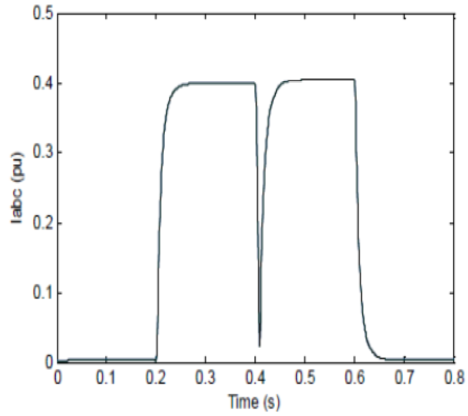

Figure 9: Three phase current changes

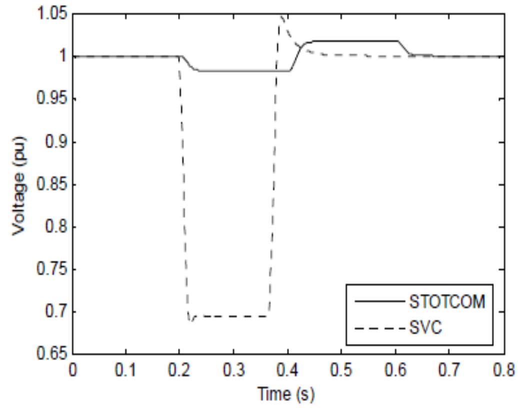

Figure 10**:** Measured voltage Vm on both systems

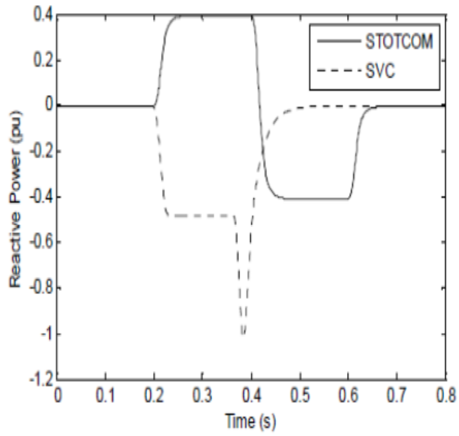

Figure 11**:** The measured reactive power Qm generated by the SVC and the STATCOM

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