# APPLICATION AND PERFORMANCE PARAMETRIC ANALYSIS OF STATCOM ON 500KV TRANSMISSION SYSTEM

***Adil Naseem**, ****Naveed Alam and Nasir Nauman**
Faculty of Electrical Engineering, Department of Technology, The University of Lahore, Lahore, Pakistan
**nalamkhan@hotmail.com
*Corresponding Author: adilnaseem.uol@gmail.com

*ABSTRACT-Shunt connected FACTS devices have been studied for voltage control and efficient power transfer. Different power systems in which shunt devices are connected are simulated and their ideal parameters and ratings are suggested to overcome voltage stability problem. In an interconnected system voltage control attains higher importance in view of dispatching of power and keeping the equipment loading within safe permissible limits. In this research, impact of shunt devices has been studied through computer simulation in MATLAB/Simulink software. The purpose of this research is to show through simulation how shunt connected FACTS devices are used for voltage stability and to transfer the power efficiently. In this research STATCOM is used as a shunt connected FACT device. In this paper simulation of shunt and stability analysis of STATCOM is done on 500kV transmission system for performance parameter analysis. MATLAB/Simulink is used for simulation results.*

**Keywords:** Microcontroller, Arduino, Distribution transformer, Potential Transformer, Current Transformer, Relay

## I. INTRODUCTION

In recent years numerous cumulative pressures have made it increasingly difficult to meet the high level of performance expected from the electricity supply industry. These pressures include environmental concern, the installation of new power plant or transmission lines, deregulation and development of fast electronic power flow control devices. Voltage stability and efficiently voltage transformation are major responsibilities of power system operators. It is concerned with the ability of power system to maintain acceptable voltage at all nodes in the system under normal and contingent conditions. Power system is said to have entered a state of voltage instability when cause a progressive and uncontrollable decline in voltage. Inadequate reactive power support from generators and transmission lines leads to voltage instability phenomena and designing mitigation schemes to prevent voltage instability is of great value to utilities[1].

FACTS devices provide the strategies to achieve a predetermined voltage profile and to relieve overload devices by switching controllable capacitors, reactors and by adjusting their reactive power at generation buses. In electrical power system operation, voltage control is the most important function for system stability, security and reliability [2]. This research is the study of performance of Series and Shunt connected FACTS devices. As in Pakistan not much work is done in this field. So this research is to explore the ideal rating, ideal parameters and ideal location of these devices and want to study their behavior under steady state and fault condition. In this research the impact of shunt connected FACTS devices (STATCOM) has been discussed using MATLAB simulation.

## II. PROBLEM STATEMENT

Voltage stability and transfer of electric power with efficiency is an issue. This problem can be rectifying using shunt connected FACT device to make system more stable. So, it is desired to check out the results of applying FACT device on power system.

This paper covers the stability analysis and sensitivity analysis of shunt connected FACT device (STATCOM) on 500kV transmission system.

Sensitivity analysis can be done by changing parameters of device like droop, proportional gain and integrated gain, location of device and rating of device.

Stability analysis compromises of steady state analysis and transient analysis.

## III. MODELING & IMPLEMENTATION OF STATCOM ON 500KV POWER SYSTEM

STATCOM is based on a voltage-sourced converter that regulates system voltage by absorbing or generating reactive power [4]. The power grid consists of four 500-kV equivalents (respectively 3000 MVA and 2500 MVA) connected by a 600-km transmission line. Without STATCOM, "natural" power flow on the transmission line is 1116 MW from bus B1 to B3.In the model shown in figure 1, the STATCOM is located at the midpoint of the line (bus B2) and has a rating of +/- 100MVA. This STATCOM is phasor model of a typical three-level PWM

STATCOM. Model represents a STATCOM having a DC link nominal voltage of 40 kV with an equivalent capacitance of 375uF. Total equivalent impedance is 0.22 pu on 100 MVA. Model is shown in figure 1 [3]. Value of active and reactive power of each line of model is shown in table 1 and figure 2. Reference Voltage ($V_{ref}$) is programmed to modify as follows:

From t=0 to t=0.2s $V_{ref}$ =1 pu; form t=0.2s to t=0.4s, $V_{ref}$ = 0.97 pu; then from t=0.4s to t=0.6s, $V_{ref}$=1.03 pu; and at t=0.6 s, $V_{ref}$ =1 pu.

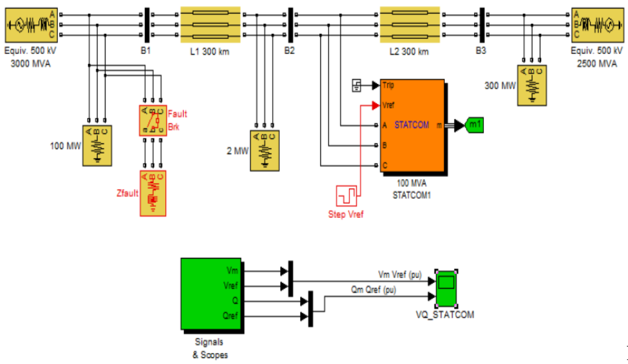


Fig . 1: Power Systems Model in MATLAB/Simulink

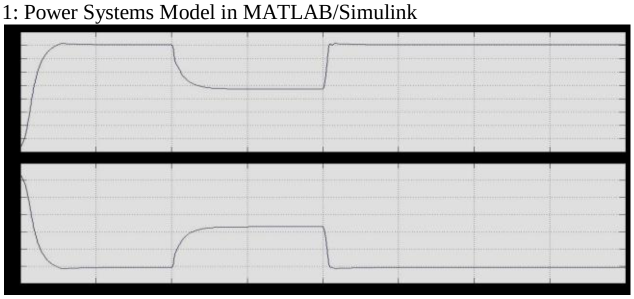

Fig. 2(a): Active and Reactive Power of Line1

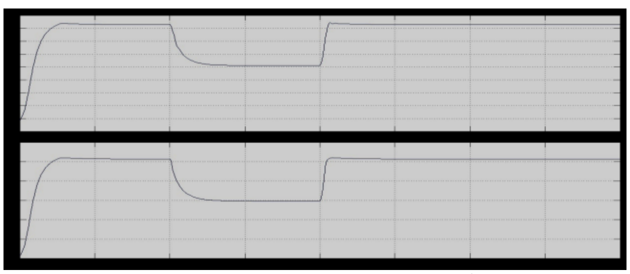

Fig. 2(b): Active and Reactive Power of Line2

Table 1: Active and reactive power of each line

| Line. No | P(MW) | Q(MW) |
|---|---|---|
| 1 | 1116 | -31 |
| 2 | 1087 | -119 |

Voltage and Phasor response of Bus1 and Bus2 is shown in figure 3 and table 2.

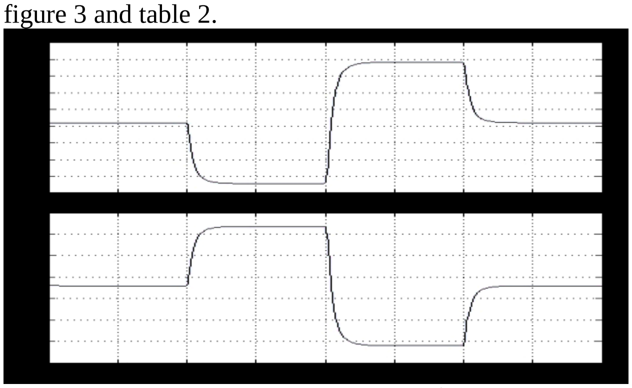

Fig. 3(a): Voltage and Phasor of Bus1

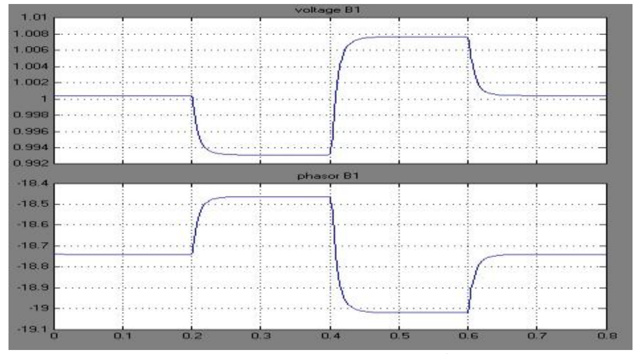


Fig. 3(b): Voltage and Phasor of Bus2

Table 2: Active and reactive power of each line

| Bus. No | Voltage (pu) | Phasor |
|---|---|---|
| 1 | 1.004 | -18.76 |
| 2 | 0.99 | -39.6 |

Table 3: Droop Analysis

| Droop | Difference b/w $V_m$ and $V_{ref}$ |
|---|---|
| 0.05 | 0.016 |
| 0.03 | 0.02 |
| 0.0 | 0.00 |

## IV. STATCOM PERFORMANCE PARAMETERS ANALYSIS

### IV.I SENSITIVITY ANALYSIS

a. **Droop** is the difference between the reference voltage of device and voltage of the bus to which device is connected For a given maximum capacitive/inductive range, droop is used to enhance the linear operating range of the STATCOM and also to ensure automatic load sharing with other voltage compensators [5].The effect of different values of droop is shown in figure 4 and table 3.

As table 3 and figure 4 shows that, by increasing the droop, the difference between $V_m$ and $V_{ref}$ increases. Ideally droop should be zero so that $V_m$ exactly follows the $V_{ref}$.

**b. Proportional and Integral Gains**

Kp and Ki are proportional and integral gains of STATCOM. There effect on performance of STATCOM is discussed in following table 4 and figure 5

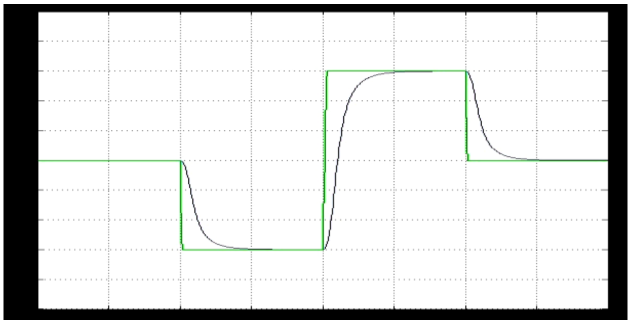

Fig. 4(a): When droop=0.0

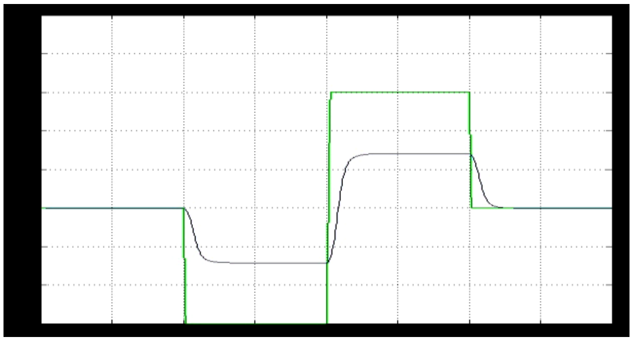

Fig. 4(b): When droop=0.05

.

Table 4: Effect of different Gains

| Sr. No | Kp | Ki | Steady State Response Time (sec) |
|---|---|---|---|
| 1 | 1 | 100 | ∞ |
| 2 | 5 | 1000 | 0.68 |
| 3 | 10 | 2000 | 0.64 |
| 4 | 20 | 4000 | 0.62 |

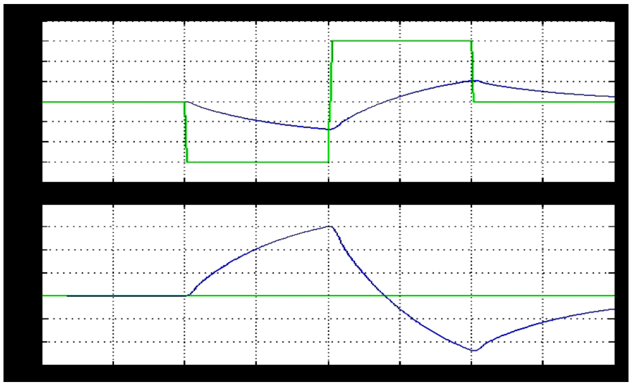

Fig. 5(a): When Kp=1 and Ki=100

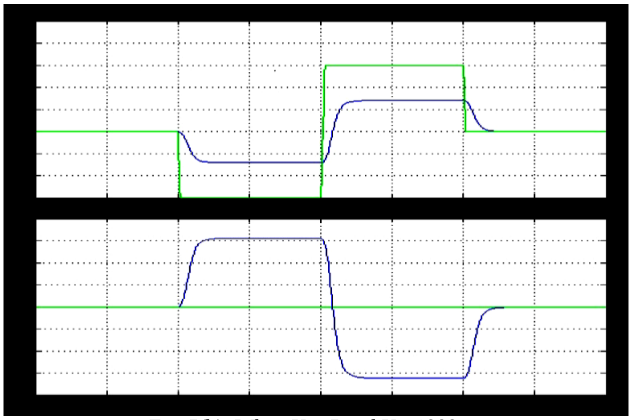

Fig. 5(b): When Kp=5 and Ki=1000

It has been shown in the table 4 and figure that with the increase in the gains response of STATCOM is faster, towards the disturbance, with smaller overshoot.

### c. Location of STATCOM

In this analysis, location of STATCOM is varied and applied on different buses. Observed values of reactive power absorbed and supplied at each bus are shown in table 5 and figure 7. As different loads is connected at different buses. So value of the voltage varies at buses as reactive power depends upon the value of voltage difference. Voltage difference changes at every bus as a result reactive power supplied and absorbed changes at every bus [6].

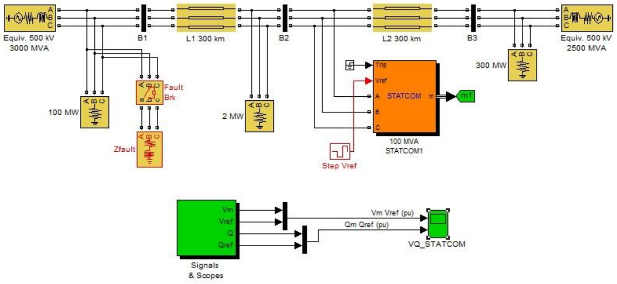


Fig. 6: Changing the Location of STATCOM

Table 5: Reactive Power Supplied and Absorbed

| Bus No. | Q(supplied in p.u) | Q(absorbed in p.u) |
|---|---|---|
| 1 | -0.5 | 0.5 |
| 2 | -0.4 | 0.4 |
| 3 | -0.79 | 0.18 |

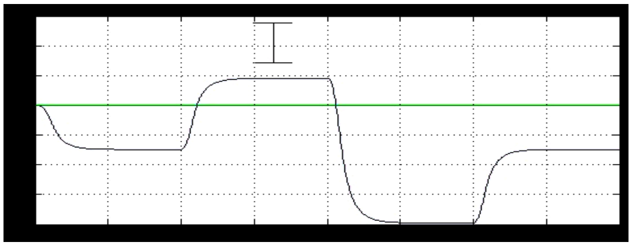

Fig. 7: Reactive power response when STATCOM at Bus 3

## IV.II STABILITY ANALYSIS

### a. Steady State Analysis

In this analysis load at different buses is varied for steady state analysis and performance of STATCOM is observed**.** Results are tabulated in table 6 and shown in figure 8.

According to the results, STATCOM supplies the reactive power according to load. If load increase for same MVA rating, then reactive power supplies by STATCOM increase to meet the demand. When load increases (500 MW) then $V_m$ always decreases from $V_{ref}$ as a result STATCOM supplies the maximum reactive power to meet the demand [7].

Table 7: For Different loads and STATCOM Rating=100MVA

| Load near B1(MW) | Load near B2(MW) | Load near B3 (MW) | Max. Q supplied by STATCOM |
|---|---|---|---|
| 200 | 4 | 600 | -0.6 |
| 400 | 8 | 1200 | -0.9 |
| 500 | 10 | 1300 | -0.93 |

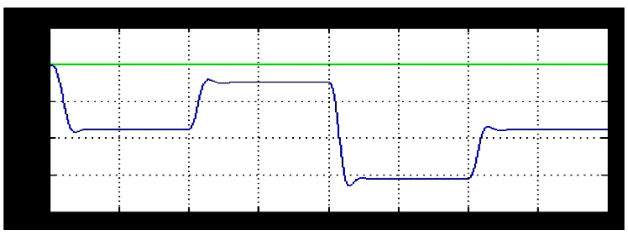

Figure 8(a): Reactive Power Response for First observation

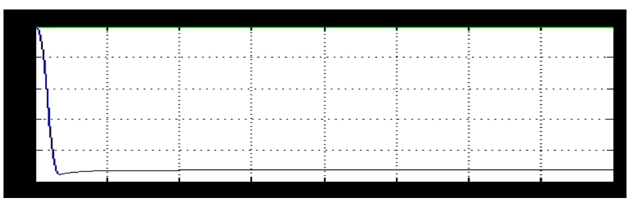

Figure 8(b): Reactive Power Response for Third observation

### b. Transient Analysis

Figure 9(a) depicts the general transient response when switching takes place of all three phases near bus 1 at time 0.23sec.

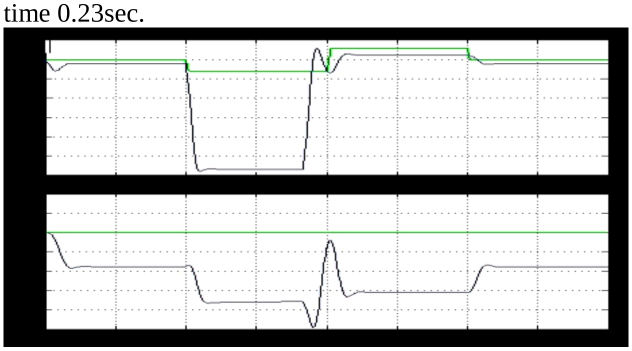

Figure 8(b): Fault at 0.23sec

Sudden decrease in voltage is measured when fault occurs. STATCOM supplies the maximum reactive power as shown in figure 9(a). Fault clears after 5 cycles, as a result, voltage again rises and reactive supplied by STATCOM decreases.

Table 8: P and Q under Fault

| Line No. | P(MW) | Q(MVAR) |
|---|---|---|
| 1 | 1151 | 148 |
| 2 | 1098 | -126 |

## V. CONCLUSION

Shunt control FACT device has been discussed for voltage control and for efficient power transformation. Two different power system networks have been simulated to which shunt connected FACT device have been connected and their impact is studied. Sensitivity analysis and stability analysis of shunt connected FACT device have been performed and important results about best rating and parameters have been concluded.

## REFERENCES


[1] R.C. Dugan, M.F. McGranaghan and H.W. Beaty, "Electrical Power Systems Quality", McGraw-Hill, New York, 1996.

[2] Sadeghazadeh S.M., Ehsan M., Hajsaid N., “Application of FACTS devices for the maximum laudability improvement in transmission line”, EPE’97, Trondheim, 8-10 sept, vol.3, pp.950-955.

[3] Enrique Acha, Claudia R and Hugo AmbrizPerz “Modeling and Simulation of Power networks (FACTS)”, Wiley,2003

[4] N.G. Hingorani, “Flexible AC transmission". IEEE Spectrum, v. 30, n. 4, 1993.

[5] A. Arulampalam, J.B. Ekanayake, N. Jenkins " Application study of a STATCOM with energy storage" IEE Proceedings - Generation, Transmission and Distribution, Volume 150, Issue 3, May 2003, p. 373 – 384

[6] K. R. Padiyar, "FACTS Controllers in Power Transmission and Distribution", New Age International (P), India, 2007

[7] Dai Wenjin, Chen Xiangjie, " Transient and steady-state analysis for STATCOM mathematical model" , IEEE, Power Electronics and Intelligent Transportation System (PEITS), 2009 2nd International Conference on (Volume:3 ),China, 19-20 Dec. 2009


.