# PERFORMANCE ANALYSIS OF TRANSMISSION LINES BY 'FACTS' TECHNOLOGY AGAINST L-G FAULT

[1]Ankit Tandon, [2]Dr. P.C. Bapna, [3]Shruti Bhadviya

[1]Assistant Professor-EE [2] Professor & Head-EE [3] Assistant Professor-EE

[1]GITS, Udaipur,(Raj.), India; [2]GITS,Udaipur,(Raj.), India [3]GITS,Udaipur,(Raj.), India

*Abstract :* As population of the world is increasing day by day the energy requirements are also increasing continuously. Consistently increase requirements of electrical power transmission and lack of long term power transmission system planning causes less security and reduction in quality of the electrical power. EPRI (Electrical power research institute) introduced a new technology commonly known by FACTS (Flexible alternating current transmission system) to reduce or compensate some of these difficulties. Introduction of FACTS controllers in existing transmission network provide flexibility in the process of power transmission and control. FACTS controllers have the capability to compensate the system parameters like voltage, current, impedance (series and shunt) active and reactive power etc. This paper is a complete overview of existing FACTS devices. The main emphasis is to be placed on main four devices (SVC, SSSC, STATCOM, and UPFC); modeling and simulation of uncompensated and FACTS compensated system and their control actions will be analyzed and evaluated. The step of modeling with MATLAB and Simulink of different FACTS compensated system is presented and simulation results are discussed.

**Keywords-** FACTS controllers, SVC, SSSC, STATCOM, UPFC, Active and reactive power comparison.

## 1. INTRODUCTION

FACTS technology was introduced by EPRI (Electrical power research institute). According to IEEE definition of FACTS it is "alternating current transmission incorporating power electronics-based and other static controllers to enhance controllability and increase power transfer capability." Continuous and fast improvement of power electronics technology has made FACTS as a good concept. FACTS controllers are power electronics-based controllers which control the bus voltage and power flow through a transmission line more flexibly. These include various power semiconductor devices such as MOSFET, GTO IGBT, etc. [1]
Application of FACTS devices serves following advantages: -

- Increase the loading capacity of power transmission lines.
- Control the flow of bulk power so that it flows in a proper way.
- Increase the system stability.
- Reduce reactive power flows; allow the lines to transmit more active power.
- Increase the system security by the transient stability limit, limiting short circuit currents, overloads and managing the damping of system oscillations.
- Minimize the transmission losses and environmental impact thus improves the power quality.
- Provide separate tie line connections to other regions. It reduces overall generation reserve requirements on both sides. When this cannot be done, it follows that there is not enough cost-effective transmission capacity.

## 2. CLASSIFICATION OF FACTS CONTROLLERS

FACTS controllers are based on thyristor devices. Conventional thyristors are available with or without gate turn-off capabilities. Power electronics-based thyristors are used for dynamic and allowable change of transmission line parameters such as voltage, current, line impedance, phase angle etc. In existing transmission networks many conventional switches are replaced by different FACTS based devices for reliable operation of the large power system. These can be categorized into following four categories:

*Series controllers: -*

The series controllers may be variable impedance such as a power electronics based changeable source of supply frequency, sub synchronous and harmonic frequencies, a reactor or capacitor to fulfill the required load. Basically, all the series controllers inject voltage in series with the existing transmission line. As the voltage is in phase quadrature with the current flowing through the transmission line, the series controllers can donate or utilize variable reactive power. Examples of series controllers are SSSC, TCSC, TSSC, TCSR, and TSSR.

*Shunt controllers: -*

Similar to the series controllers, the shunt controllers may be variable impedance or source, or a combination of both these. Basically all the shunt controllers inject current into the system at the point of connection. As the injected current is in phase quadrature with the transmission line voltage, the shunt controller can donate or utilize variable reactive power. Examples of shunt controllers are STATCOM, TCR, TSR, TSC, and TCBR.

*Combined series-series controllers: -*

This type of controller is a combination of two separate series controllers, which are controlled in a coordinated manner, in a multiline transmission system. Sometimes it may be a unified controller in which series controllers provide not only independent series reactive power compensation line but also transfer the active or real power through the transmission lines via a suitable link. The capacity of transmission of active power of the unified series-series controller makes it possible to balance both the active and reactive power flow in the transmission lines. One example of combined series-series controller is IPFC.

*Combined series-shunt controllers: -*

This type of controller is a combination of series and shunt controllers, which are controlled in a coordinated manner, or a Unified power flow controller with one series and one shunt elements. Basically, combined shunt and series controllers inject current into the system with the shunt part of the controller and voltage in series in the line with the series part of the controller. However, when the shunt and series controllers are unified, there can be an active power exchange between the series and shunt controllers through a transmission link. Examples of such category controllers are UPFC and TCPAR.

## 3. SIMULATION MODELS OF FACTS COMPENSATED SYSTEMS

*Simulation of an uncompensated transmission line with line to ground fault:*

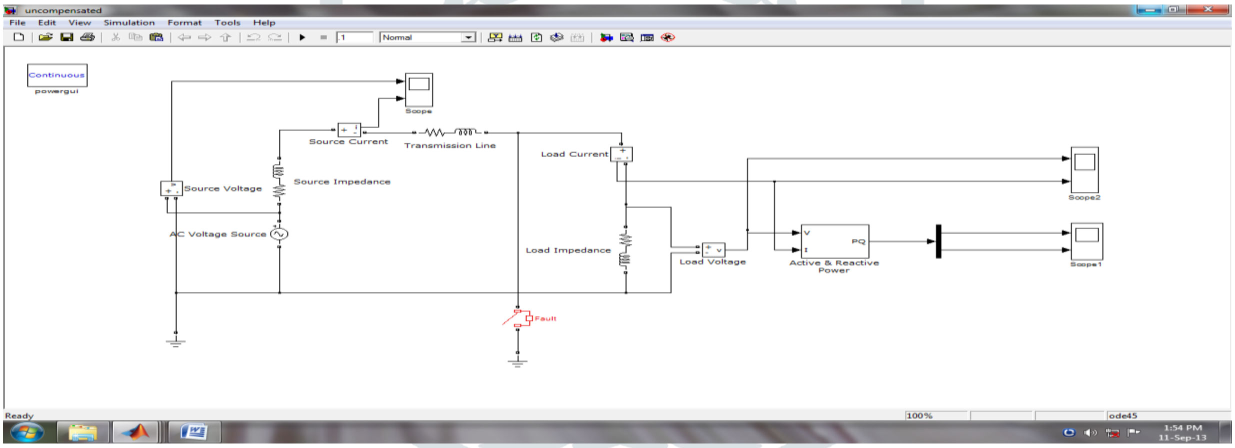



Fig.1 Uncompensated transmission system model

Figure 1 presents a simplified model of an uncompensated transmission line. The system is simulated in SIMULINK. Input voltage is supplied by an AC 11 KV voltage source. The line impedance is considered as (10 + j0.028) Ω and the load is kept fixed at 30 MW and 60 MVAR. Here, three scopes are used. Scope displays the source voltage and current, Scope2 displays the load voltage and current and scope1 displays the active and reactive powers.

*Simulation of SVC compensated transmission line with line to ground fault:*

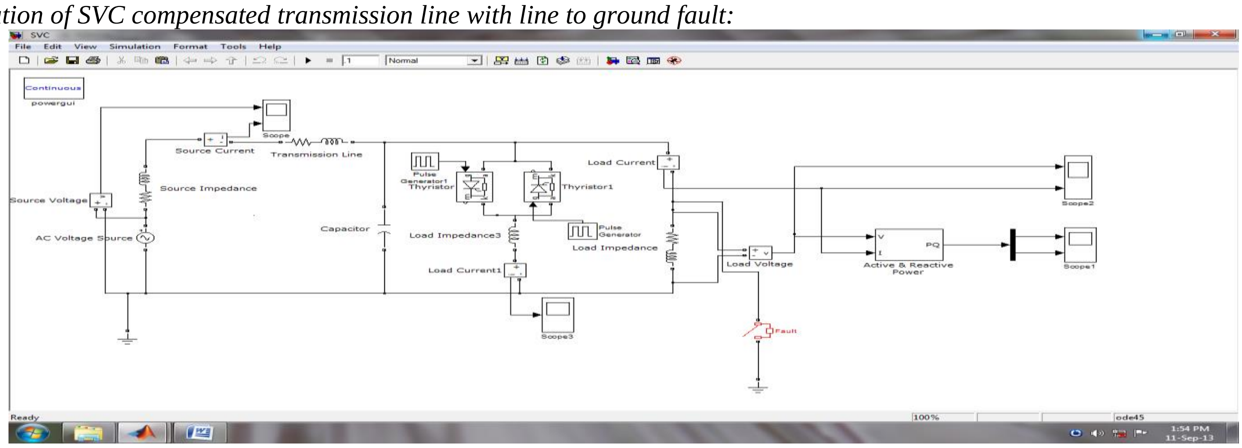



Fig.2 SVC compensated transmission system model

Figure 2 presents a static volt-ampere reactive compensated power transmission system, modeled in Fixed Capacitor- Thyristor control reactor configuration. Two thyristors with an inductive load are provided for system modification. The real and reactive powers are obtained for a fixed value of capacitance which is taken to be 100 µF and by changing the value of inductance of the device.

*Simulation of SSSC compensated transmission line with line to ground fault:*

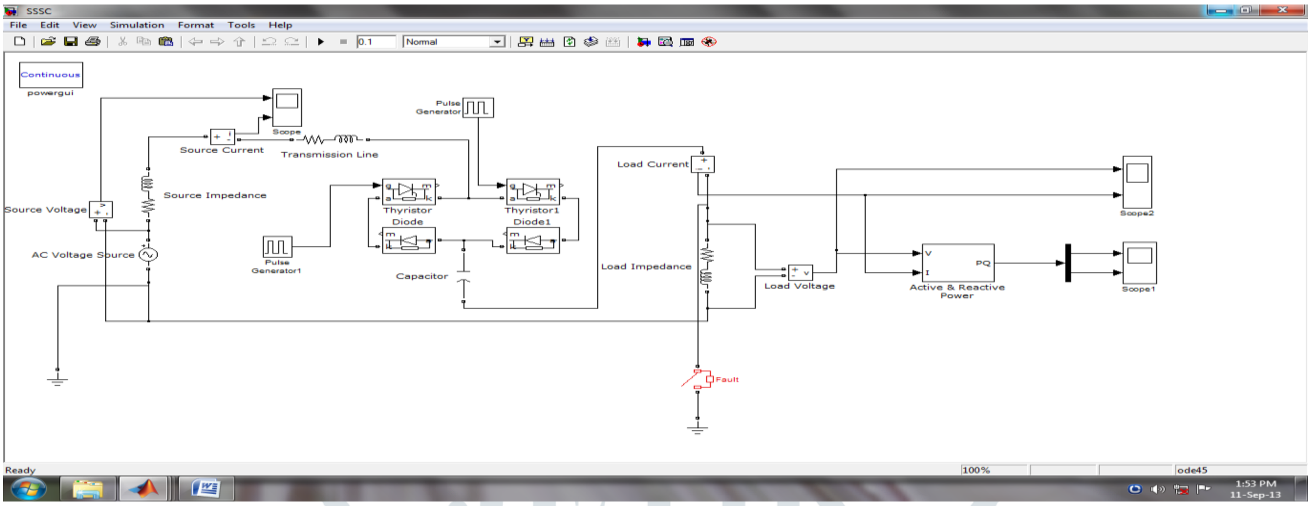



Fig.3 SSSC compensated transmission system model

*Simulation of STATCOM compensated transmission line with line to ground fault:*

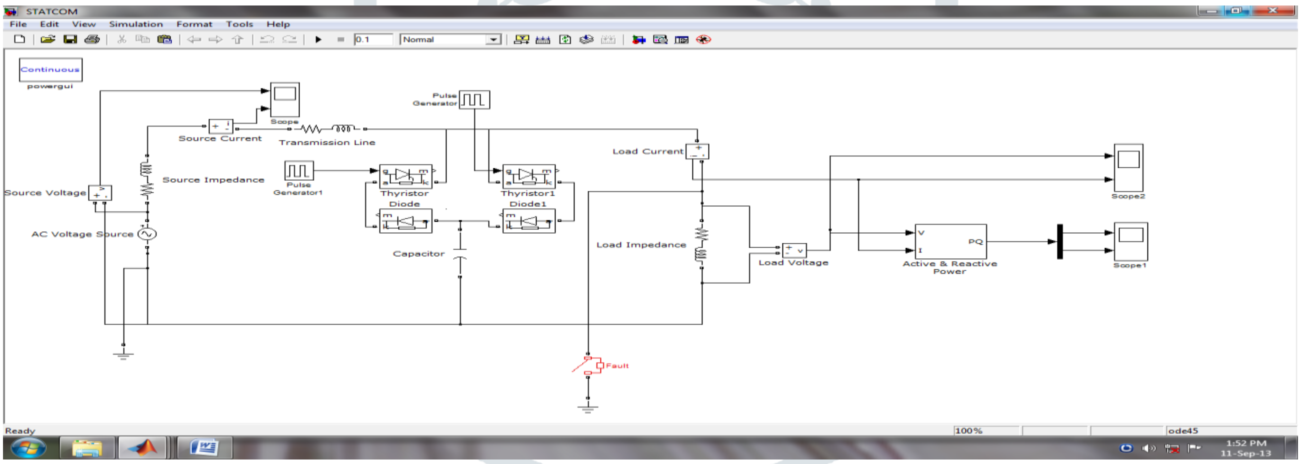



Fig.4 STATCOM compensated transmission system model

Figure 3 and 4 present a static synchronous series compensated power transmission system and static synchronous shunt compensated power transmission systems respectively. These models required application of two diodes along with two thyristors. Similar to the SVC model scopes give the voltage, current and power waveforms.

*Simulation of UPFC compensated transmission line with line to ground fault:*

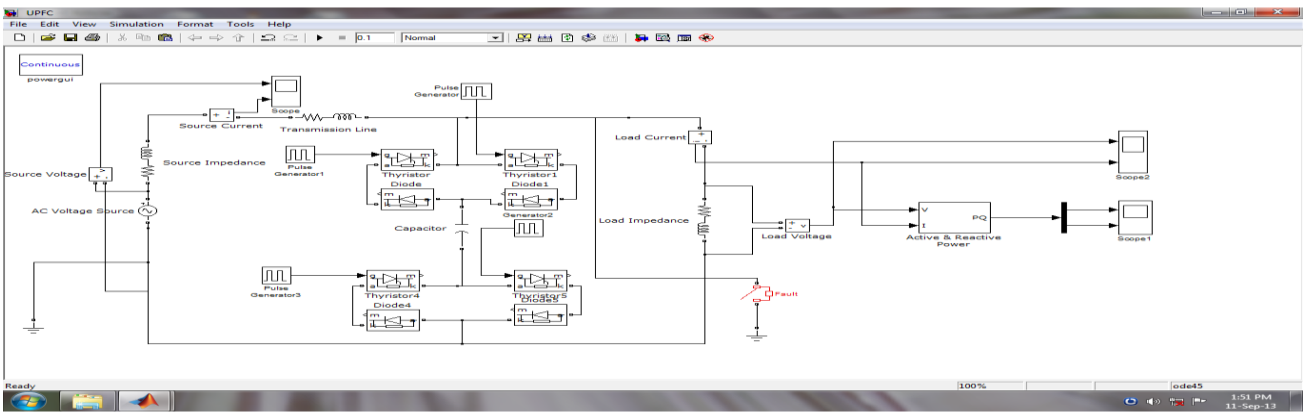


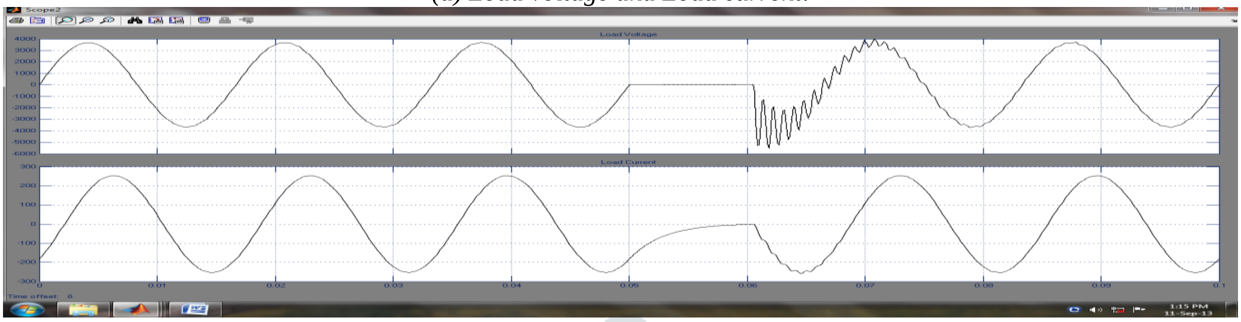

Fig.5 UPFC compensated transmission system model

Figure 5 presents a unified power flow controller compensated power transmission system model. This model is a combination of STATCOM and SSSC which are coupled via a common dc link to allow bidirectional flow of real power between the series output terminals of the SSSC and the shunt output terminals of the STATCOM.

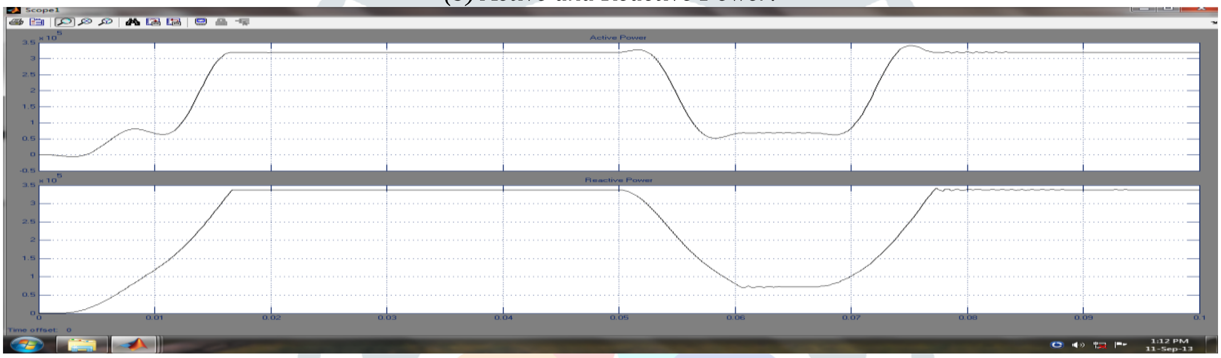
**4. SIMULATION RESULTS**

*Results of an uncompensated transmission line with line to ground fault:*

*(a) Load voltage and Load current:*

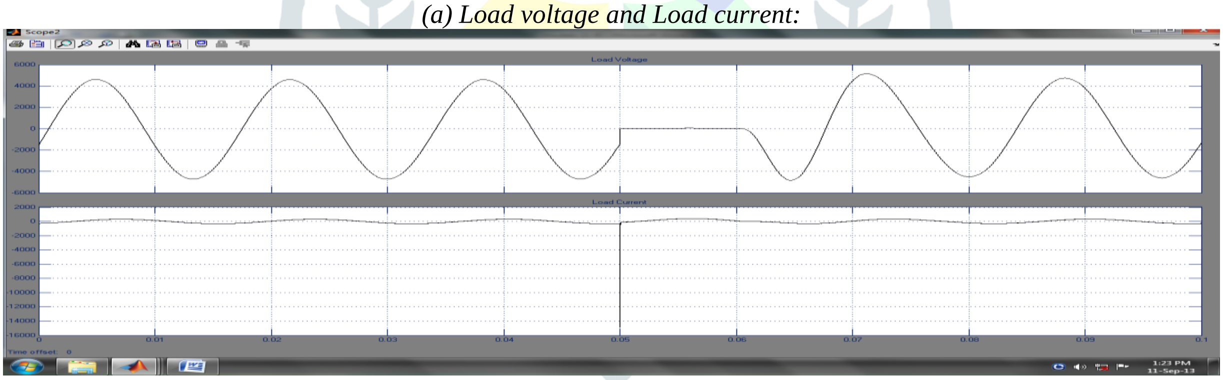



*(b) Active and Reactive Power:*

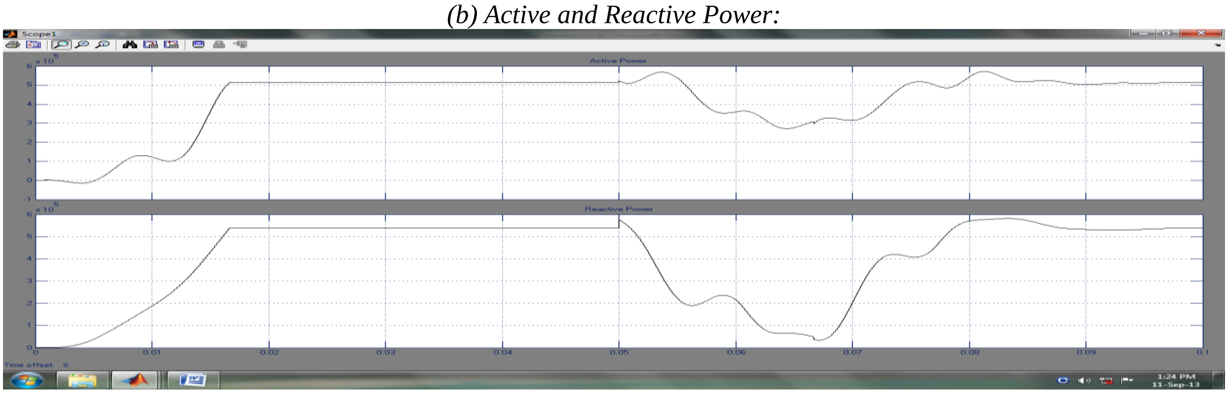



*Results of SVC compensated transmission line with line to ground fault:*

*(a) Load voltage and Load current:*

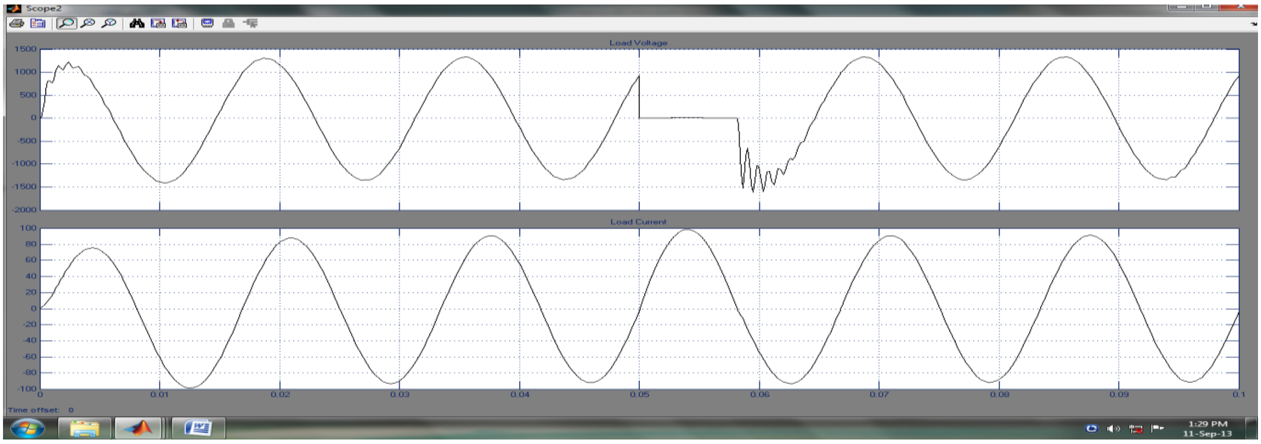



*(b) Active and Reactive Power:*

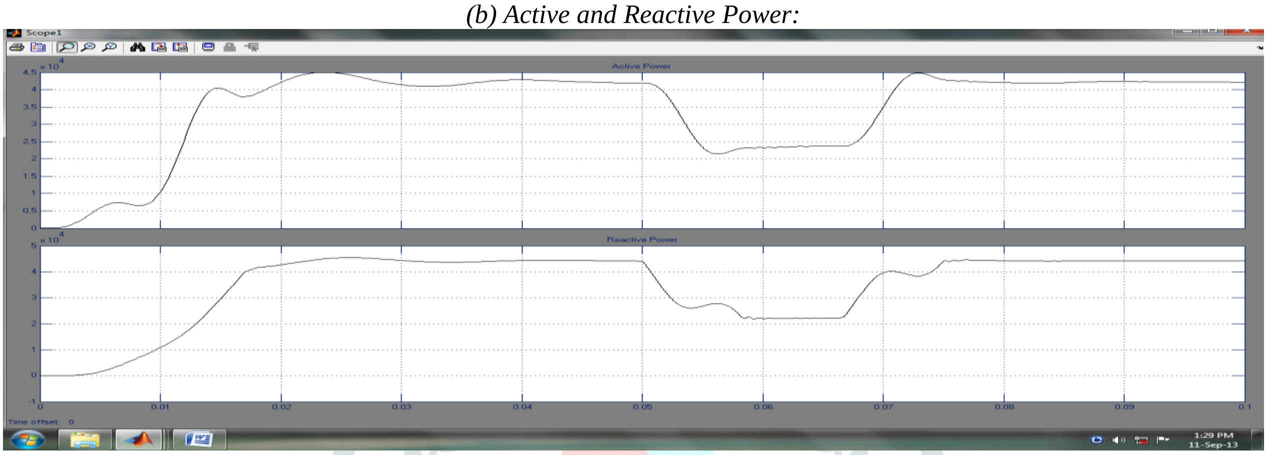



*Results of SSSC compensated transmission line with line to ground fault:*

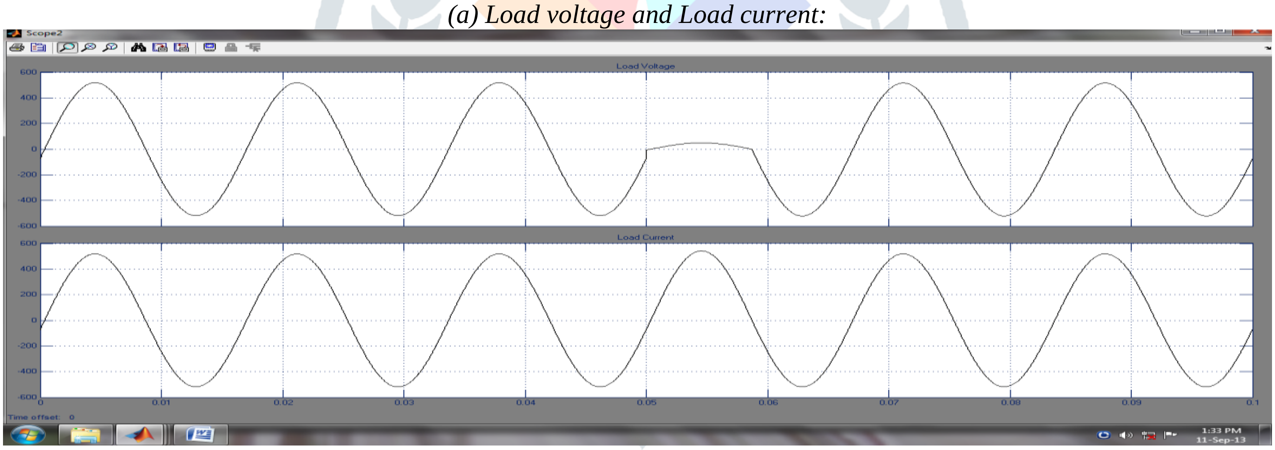
*(a) Load voltage and Load current:*



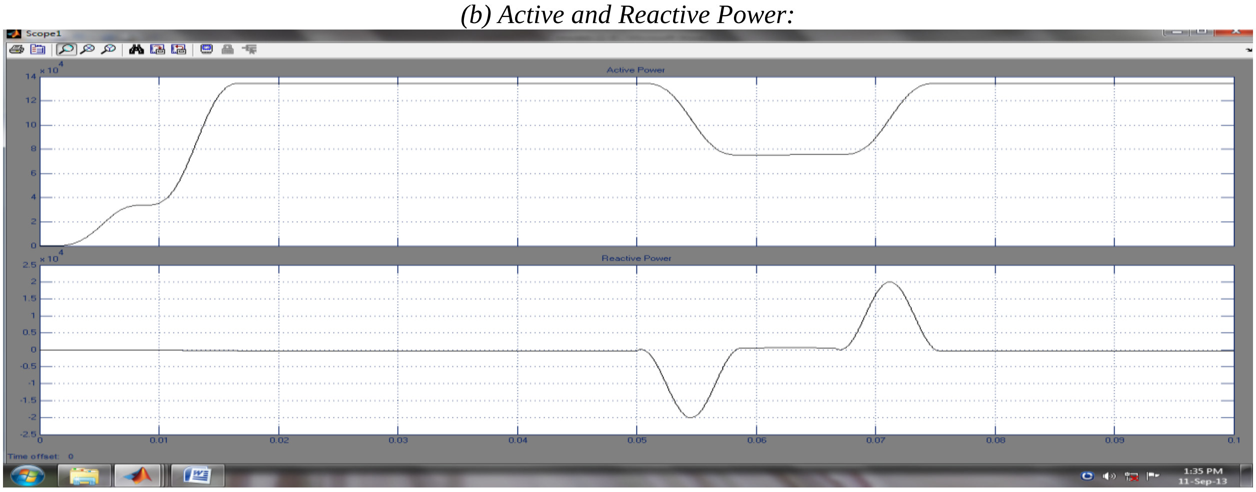

*(b) Active and Reactive Power:*




*Results of STATCOM compensated transmission line with line to ground fault:*
*(a) Load voltage and Load current:*

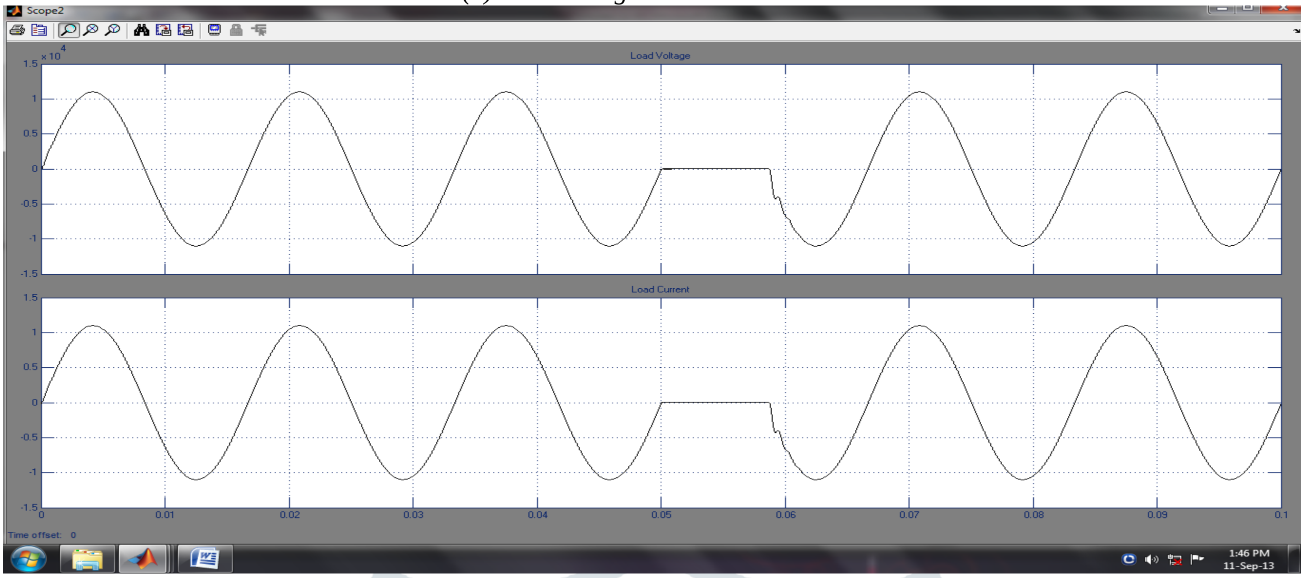



*(b) Active and Reactive Power:*

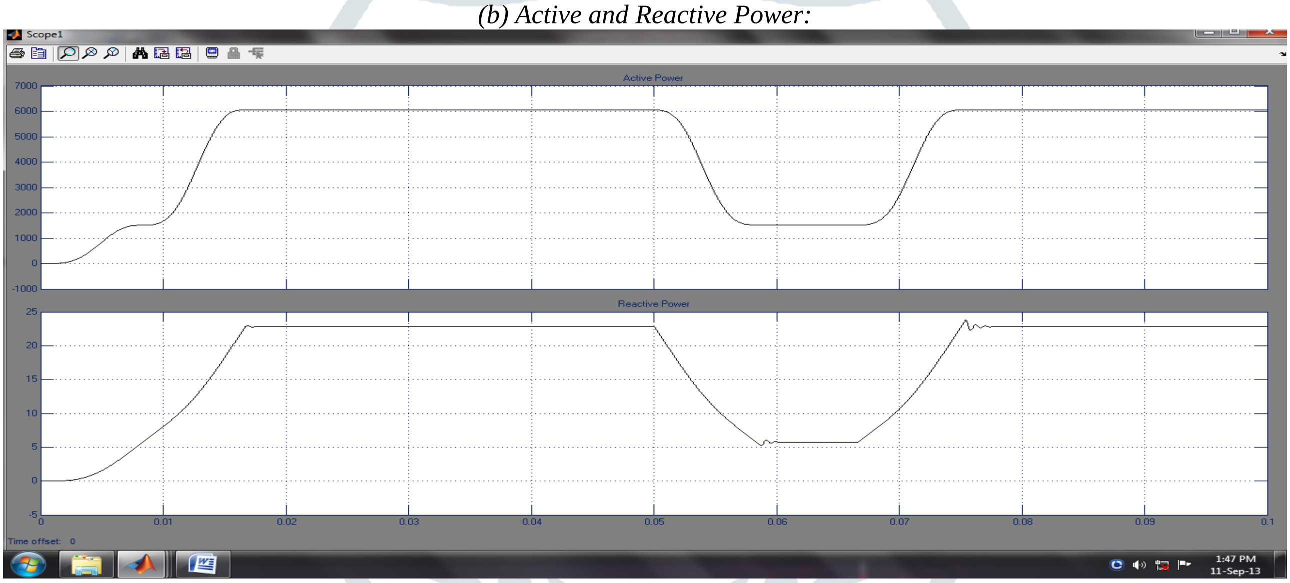



*Results of UPFC compensated transmission line with line to ground fault:*

*(a) Load voltage and Load current:*




*(b) Active and Reactive Power:*




## 5. RESULTS & DISCUSSION

For uncompensated transmission line model, the load voltage is found to be 0.95 KV, Which is somewhat lower than the required voltage level. The active and reactive power graphs are also shown. Therefore, in order to keep the system stable, we have to provide proper compensation to the power system. Voltage stability is dependent on the reactive power. So if we compensate the reactive power to meet the demand, then we can as well improve the voltage profile of the system to prevent it from becoming unstable.

In SVC compensated transmission system variation in the active and reactive powers obtained for different inductor values are tabulated below:

Table 1: Alteration in Active and Reactive Powers for Different Values of Capacitor (SVC)

| capacitance (μF) | Active power (MW) | Reactive power (MVAR) |
|---|---|---|
| 50 | 0.628 | 0.886 |
| 350 | 0.85 | 1.20 |
| 600 | 1.13 | 1.60 |
| 1000 | 1.82 | 2.55 |
| 1400 | 2.58 | 3.64 |

From the obtained results, it can be concluded that introduction of SVC causes some compensation in active as well as reactive power. Compensation in power transmission system causes the improvement in system voltage level and thus enhances the stability.

In SSSC compensated transmission system variation in the active and reactive powers obtained for different capacitor values are tabulated below

Table 2: Alteration in Active and Reactive Powers for Different Values of Capacitor (SSSC)

| Capacitance (µF) | Active power (MW) | Reactive power (MVAR) |
|---|---|---|
| 50 | 0.025 | 0.036 |
| 350 | 2.06 | 2.93 |
| 600 | 1.4 | 2.1 |
| 1000 | 1.02 | 1.5 |
| 1400 | 0.88 | 1.18 |

From above table 2 it is clear that if we increase the value of capacitance there is compensation in active and reactive powers without any deterioration. Voltage profile improves up to a desired level which depends on capacitance.

Table 3: Alteration in Active and Reactive Powers for Different Values of Capacitor (STATCOM)

| Capacitance (µF) | Active power (MW) | Reactive power (MVAR) |
|---|---|---|
| 50 | 0.66 | 0.89 |
| 350 | 0.85 | 1.18 |
| 600 | 1.13 | 1.56 |
| 1000 | 1.72 | 2.74 |
| 1400 | 2.61 | 3.66 |

For UPFC compensated system model, it can be observed that there is some improvement in the active and reactive power flows as well as the receiving end voltage. For a capacitor value of 50 µF, the active and reactive powers obtained are 0.028 MW and 0.055MVAR respectively. As capacitance changes active and reactive powers also changes.
The receiving end voltage is resulted to be 1.53 kv so the voltage profile improves. The alteration in the power flows is resulted for different values of capacitance tabulated as follows:

Table 4: Alteration in Active and Reactive Powers for Different Values of Capacitor (UPFC)

| Capacitance (µF) | Active power (MW) | Reactive power (MVAR) |
|---|---|---|
| 50 | 0.028 | 0.054 |
| 350 | 2.08 | 2.95 |
| 600 | 1.4 | 1.97 |
| 1000 | 1 | 1.4 |
| 1400 | 0.85 | 1.2 |

As presented in above table, it is clear that, both active and reactive powers are improved consistently up to a capacitor rating of around 350 µF. Increasing the capacitance value further improves the power profile.

Table 5: Comparison between SVC, SSSC, STATCOM and UPFC

| Device | Capacitance (350 µF) | | Capacitance (1400 µF) | |
|---|---|---|---|---|
| | Active Power (MW) | Reactive Power (MVAR) | Active Power (MW) | Reactive Power (MVAR) |
| SVC | 0.85 | 1.20 | 2.58 | 3.64 |
| SSSC | 2.06 | 2.93 | 0.88 | 1.18 |
| STATCOM | 0.85 | 1.18 | 2.61 | 3.66 |
| UPFC | 2.08 | 2.95 | 0.85 | 1.2 |

As indicated in table 5, at a capacitance value of 350 µf, STATCOM gives better performance while at a capacitance value of 1400 µF UPFC is superior as compared to others.

## 6. CONCLUSION

In this paper, modification of existing transmission system with different FACTS based devices has been developed. From the obtained results and study, following conclusions are made:

- Reactive power and system voltage profile compensation can be achieved in a suitable manner by different power electronics-based FACTS devices. Many FACTS devices are available to fulfill such requirements according to the system parameters.
- Four main devices SVC, SSSC, STATCOM and UPFC are simulated in Simulink. UPFC offers better performance in regulating the voltage stability of the system as compared to other three devices.

Different simulation results (P, Q, V and I) for various FACTS devices show that the system is able to deliver real and reactive power with reduced capacity during instability conditions while a power system is modified by FACTS based devices.

## 7. REFERENCES


[1] N.G. Hingorani & Laszlo Gyugyi, "Understanding FACTS: concepts and technology of flexible AC transmission systems", IEEE Press, New York (2000).

[2] Bindeshwar Singh, N.K. Sharma, A.N. Tiwari, K.S. Verma and Deependra Singh, "A Status review of Incorporation of FACTS Controllers in Multi-Machine Power Systems for Enhancement of Damping of Power System and Voltage Stability", *International Journal of Engineering Science and Technology* Vol. 2(6), *2010*, ISSN 1507-1525.

[3] G.Ramana and B.V.Sanker Ram, "power system stability improvement using facts with expert systems", *International Journal of Advances in Engineering & Technology*, Sept 2011. ISSN: 2231-1963.

[4] K.Vijayakumar, "Optimal Location of FACTS Devices for Congestion Management in Deregulated Power Systems", *International Journal of Computer Applications* (0975 – 8887) Volume 16– No.6, February 2011.

[5] Rahul Somalwar and Manish Khemariya, "A Review of Enhancement of Transient Stability by FACTS Devices", *International journal of emerging technologies in sciences and engineering*, vol.5, no.3, March 2012.

[6] Habibur Rahman, Md. Fayzur Rahman and Harun-Or-Rashid, "Voltage Level Improvement of Power System By Using SVC With PID Controller", *International Journal of Advanced Technology & Engineering Research*, Volume 2, Issue 4, July 2012, ISSN 2250-3536.

[7] Akhilesh A.Nimje, Chinmoy Kumar Panigrahi and Ajaya Kumar Mohanty, "Enhanced power transfer capability by using SSSC", *Journal of Mechanical Engineering Research* Vol. 3 (2), pp. 48-56, February 2011 ISSN 2141 – 2383.

[8] Bindeshwar Singh, N.K. Sharma and A.N. Tiwari, "Prevention of Voltage Instability by Using FACTS Controllers in Power Systems: A Literature Survey", *International Journal of Engineering Science and Technology* Vol. 2(5), 2010, 980-992.

[9] T.Bhaskaraiah and G.Umamaheswara Reddy, "Power System Stability Enhancement Using Static Synchronous Series Compensator", *International jouranal of electrical, electronic engineering and telecommunications* ISSN 2319 – 2518 Vol. 2, No. 1, January 2013.

[10] Wang, K. and Crow M.L. 2011, "Power System Voltage Regulation via STATCOM Internal Nonlinear Control". *IEEE Transactions on Power Systems* 26(3): (1252-1262)

[11] Bina, M.T., Bhat, A.K.S.2008.Averaging Technique for the Modeling of STATCOM and Active Filters *.IEEE Transactions On Power Electronics* 23(2) :(723-734)

[12] Sternberger, R.;Jovcic, D.2008.Analytical Modeling of a Square-Wave-Controlled Cascaded Multilevel STATCOM. *IEEE Transactions On Power Electronics* 23(2):(2261-2269)

[13] Akagi,H.; Fujita,H.;Yonetani,S.;Kondo,Y.2008.A 6.6-kV Transformer less STATCOM Based on a Five-Level Diode-Clamped PWM Converter: System Design and Experimentation of a 200-V 10-kVA Laboratory Model. *IEEE Transactions on Power Electronics* 23(2): (672-680)

[14] Jaen,A.V.;Acha,E.;Expósito,A.G.,.2008.Voltage Source Converter Modeling for Power System State Estimation: STATCOM and VSC-HVDC.*IEEE Transactions On Power Systems* 23(4) :(1552-1559)

[15] Nang sabai Hanin, Nandar Moung, Thinda Win. Voltage control and dynamic performance of power transmission system using Static VAR compensator, "*World academy of science, engineering and technology*"(18-2008)

[16] Habibur, Md. Fayzur Rahman, Harun "Modelling & Performance Comparison Of Different Types Of SSSC-Based Controllers" International *Journal of Engineering Research & Technology (IJERT)*Vol. 1 Issue 7, September – 2012 ISSN: 2278-0181.