International Journal of Scientific & Engineering Research, Volume 4, Issue 6, June-2013
ISSN 2229-5518

Improvement in Voltage Profile using FACT Device

Chetan E. Morkhade, Bhushan S. Rakhonde

Abstract: The management of power system has become more difficult than earlier because power system are operated closer to the security limit, environmental constraints restrict the expansion of transmission network, the need for long distance power transfer has increased and fewer operator are engaged in the supervision and operation of power system. Voltage instability has become major concern in many power systems. The voltage levels of the system changes when there is change in load and the drop in the load voltage leads to an increased demand for the reactive power that, if not provided by the power system leads to a further decline in the bus voltage. This decline eventually leads to a progressive rapid decline of voltage at that location, which may have a cascading effect on neighboring regions that causes voltage collapse. In this paper, a FACTS controller such as Static synchronous compensator (STATCOM) is used to maintain the voltage within the limits. STATCOM will either supply the reactive power or extract the reactive power.

Index Terms: FACTS, STATCOM, Voltage Stability.

1 INTRODUCTION

DURING the past two decades, the increase in electrical energy demand has presented higher requirements from the power industry. More power plants, substations, and transmission lines need to be constructed. However, the most commonly used devices in present power grid are the mechanically-controlled circuit breakers. The long switching periods and discrete operation make them difficult to handle the frequently changed loads smoothly and damp out the transient oscillations quickly. In order to compensate these drawbacks, large operational margins and redundancies are maintained to protect the system from dynamic variation and recover from faults. This not only increases the cost and lowers the efficiency, but also increases the complexity of the system and augments the difficulty of operation and control. Severe black-outs happened recently in power grids worldwide and these have revealed that conventional transmission systems are unable to manage the control requirements of the complicated interconnections and variable power flow.

Therefore, investment is necessary for the studies into the security and stability of the power grid, as well as the improved control schemes of the transmission system. Different approaches such as reactive power compensation and phase shifting have been applied to increase the stability and the security of the power systems. The demands of lower power losses, faster response to system parameter change, and higher stability of system has stimulated the development of the Flexible AC Transmission systems (FACTS).

Based on the success of research in power electronics switching devices and advanced control technology, FACTS has become the technology of choice in voltage control, reactive/active power flow control, transient and steady-state stabilization that improves the operation and functionality of existing power transmission and distribution system. The achievement of these studies enlarge the efficiency of the existing generator units, reduce the overall generation capacity and fuel consumption, and minimize the operation cost.

- *Mr.Chetan E.Morkhade is currently pursuing masters degree program in electrical power system in Amravati University, India, PH-9689350698. E-mail: morkhadechetan7@gmail.com*
- *Mr.Bhushan S.Rakhonde is currently working in DES's COET, Dhamangaon (Rly), India, PH-9545956114. E-mail:Bhushan_rakhonde@gmail.com*

2 VOLTAGE STABILITY

Voltage stability is problem in power system which is heavily loaded, faulted, or has shortage of reactive power. The nature of voltage stability can be analyzed by examining the production, transmission and consumption of reactive power. The problem of voltage stability concerns the whole power system although it usually has large involvement in one critical area of the power system.

2.1 Definition and Classification of voltage stability

Power system stability is defined as characteristics for a power system to remain in state of equilibrium at normal operating condition and to restore an acceptable state of equilibrium after disturbance. Traditionally, the stability problem has been the rotor angle stability, i.e. maintaining synchronous operation. Instability may also occur without loss of synchronism, in which case concern is the control and stability of voltage. Define voltage stability as follows: "The voltage stability is the ability of power system maintain steady acceptable voltages at all buses in the system at normal operating conditions and after being subjected to disturbances".

Power system voltage is stable if voltages after a disturbance are close to voltages at normal operating condition. A power system become unstable when voltages uncontrollably decrease due to outage of equipment (generator, line, transformer, bus bar, etc.), increment of load, decrement of production and/or weakening of voltage control. According to reference the definition of voltage instability is: "Voltage instability stems from the attempt of load dynamics to restore power consumption beyond the capability of combined transmission and generation system." Voltage control and instability are local problem. However, the consequence of voltage instability may have widespread impact.Voltage collapse is the catastrophic result of a sequence of events leading to low voltage profile suddenly in major part of the power system.

The voltage stability can also called as "Load stability". A power system lacks of capability to transfer an infinite amount of electrical power to the loads. The main factor causing voltage instability is inability to meet the demand for reactive power in heavily stressed systems to keep desired voltages. Other factor contributing to voltage stability are the generator reactive power limit, the load characteristics, the characteristics of reactive power compensation devices and the action of the voltage control devices. The reactive characteristic of AC transmission lines, transformer and load restricts the maximum of power transfer. The power system lacks the capability to transfer power over long distances or through high reactance due to the requirement of a large amount of reactive power at some critical value of power or distance. Transfer of reactive power is difficult due to high reactive power losses, which is why the reactive power required for voltage control is produced and consumed at the control area.

3 NEED OF REACTIVE POWER COMPENSATION

Except in a very few special situations, electrical energy is generated, transmitted, distributed, and utilized as alternating current (AC). However, alternating current has several distinct disadvantages. One of these is the necessity of reactive power that needs to be supplied along with active power. Reactive power can be leading or lagging. While it is the active power that contributes to the energy consumed, or transmitted, reactive power does not contribute to the energy. Reactive power is an inherent part of the ''total power.''

Reactive power is either generated or consumed in almost every component of the system, generation, transmission, and distribution and eventually by the loads. The impedance of a branch of a circuit in an AC system consists of two components, resistance and reactance. Reactance can be either inductive or capacitive, which contribute to reactive power in the circuit. Most of the loads are inductive, and must be supplied with lagging reactive power. It is economical to supply this reactive power closer to the load in the distribution system.

Hence it is necessary to compensate reactive power in transmission line.

3.1 Ferranti Effect

The Ferranti Effect is a rise in voltage occurring at the receiving end of a long transmission line, relative to the voltage at the sending end, which occurs when the line is charged but there is a very light load or the load is disconnected. This effect is due to the voltage drop across the line inductance (due to charging current) being in phase with the sending end voltages. Therefore both capacitance and inductance are responsible for producing this phenomenon. The Ferranti Effect will be more pronounced the longer the line and the higher the voltage applied. The relative voltage rise is proportional to the square of the line length. This effect is also overcome by this reactive power compensation technique.

3.2 Need of Reactive Power

Reactive power (var) is required to maintain the voltage to deliver active power (watts) through transmission lines. Motor loads and other loads require reactive power to convert the flow of electrons into useful work. When there is not enough reactive power, the voltage sags down and it is not possible to push the power demanded by loads through the lines.

The reactive power is essential for creating the needed coupling fields for energy devices. It constitutes voltage and current loading of circuits but does not result in average (active) power consumption and is, in fact, an important component in all ac power networks. Electromagnetic devices store energy in their magnetic fields. These devices draw lagging currents, thereby resulting in positive values of Q; therefore, they are frequently referred to as the absorbers of reactive power. Electrostatic devices, on the other hand, store electric energy in fields. These devices draw leading currents and result in a negative value of Q; thus they are seen to be suppliers of reactive power. The convention for assigning signs to reactive power is different for sources and loads, for which reason readers are urged to use a consistent notation of voltage and current, to rely on the resulting sign of Q, and to not be confused by absorbers or suppliers of reactive power.

4 FACTS CONTROLLERS

The FACTS is a concept based on power-electronic controllers, which enhance the value of transmission networks by increasing the use of their capacity. As these controllers operate very fast, they enlarge the safe operating limits of a transmission system without risking stability. Needless to say, the era of the FACTS was triggered by the development of new solid-state electrical switching devices. Gradually, the use of the FACTS has given rise to new controllable systems.

According to IEEE FACTS are defined as follows:

- **Flexible AC Transmission System (FACTS):** Alternating current transmission systems incorporating power electronic-based and other static controllers to enhance controllability and increase power transfer capability.
- **FACTS Controller**: A power electronic-based system and other static equipment that provide control of one or more AC transmission system parameters.

4.1 Types of FACTS Controllers

- Series Controllers.
- Shunt Controllers.
- Combined series-series controllers.
- Combined series-shunt controllers.

4.2 Shunt Connected Controllers

1. Static Synchronous Compensator (STATCOM).
2. Static Synchronous Generator (SSG).
3. Battery Energy Storage System (BESS).
4. Superconducting Magnetic Energy Storage (SMES).
5. Static Var Compensator (SVC).
6. Thyristor Controlled Reactor (TCR).
7. Thyristor Switched Reactor (TSR).
8. Thyristor Switched Capacitor (TSC).
9. Static Var Generator or Absorber (SVG).
10. Thyristor Controlled Braking Resistor (TCBR).

4.3 Series Connected Controllers

1. Static Synchronous Series Compensator (SSSC).
2. Interline Power Flow Controller (IPFC).
3. Thyristor Controlled Series Capacitor (TCSC).
4. Thyristor-Switched Series Capacitor (TSSC).
5. Thyristor-Controlled Series Reactor (TCSR).
6. Thyristor-Switched Series Reactor (TSSR).

4.4 Combined Shunt and Series connected Controllers

1. Unified Power Flow Controller (UPFC).
2. Thyristor-Controlled Phase Shifting Transformer TCPST).
3. Interphase Power Controllable (IPC).

5 STATCOM

5.1 Operating Principles of STATCOM operation

$$P = \frac{V1\,V2\,\sin\delta}{X}$$

$$Q = \frac{V1\,(V1 - V2\,\cos\delta)}{x}$$

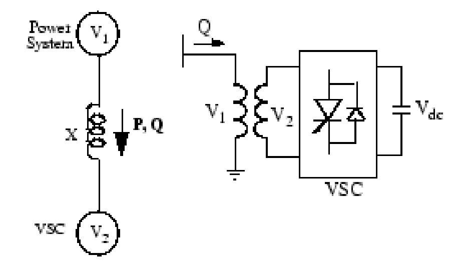

Fig. 5.1 Operating Principles of STATCOM operation

Where,
V1:- line to line voltage of source v1
V2:- line to line voltage v2
X: - reactance of interconnection transformer & filters
δ: - angle of V1 with respect to V2

- In steady state operation, the voltage V2 generated by the VSC is in phase with V1 (δ=0) , so that only reactive power is flowing (P=0) .
- If V2 is lower than V1, Q is flowing from V1 to V2 (STATCOM is absorbing reactive power).
- On the reverse, if V2 is higher than V1, Q is flowing from V2 to V1 (STATCOM is generating reactive power).

The amount of reactive power is given by

$$Q = \frac{V1\,(V1 - V2)}{x}$$

5.2 Working of STATCOM

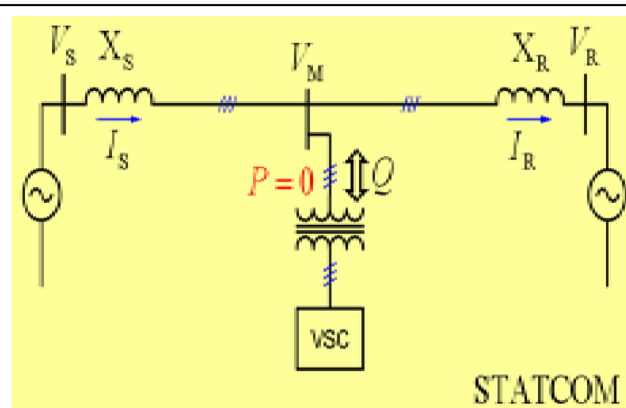

Fig.5.2 Working of STATCOM

ISSN 2229-5518

- An invertor takes current from DC source & converts into a near sinusoidal AC wave.
- Its injects this sinusoidal current into the network, under the control condition.
- STATCOM forms a co-ordinated AC output by controlling firing angle of triggering gates of inventor.
- It maintains a sequence between the 3 phases & establishes a sine waveform appropriately.
- It synchronizes the frequency of this generated signal, correctly with frequency of network.
- It ensures that the phase sequence coincides.
- It places the injected voltage sine wave at pre-determined point on the voltage wave on network with reference to voltage zero of latter.
- STATCOM injects reactive power into network.
- It injects current at right angles to voltage waveform.
- It then delivers inductive KVAR or capacitive KVAR into system.
- If induced voltage at STATOM network connection is higher than that of network it sends in capacitive current in network. When this is lower, it pumps in inductive current.
- Since reactive power has no active component, it requires very little active power.
- It may appear that it can deliver as much power as the current & voltage rating of the invertors permit, subject to short time overloads.
- The control system of invertor compares incoming voltage signal from network with reference point & adjust the KVAR output of STATCOM accordingly.
- The control can be base on other parameters of the network also such as its KVAR situation, power factor position, etc.

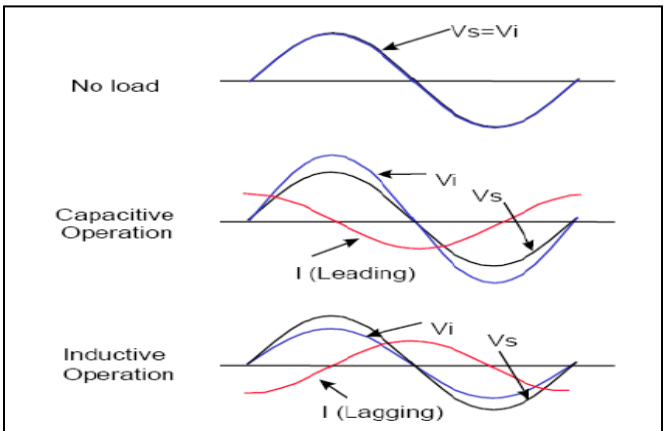

Fig. 5.3 Output waveforms of STATCOM

There can be a little active power exchange between the STATCOM and the EPS. The exchange between the inverter and the AC system can be controlled adjusting the output voltage angle from the inverter to the voltage angle of the AC system. This means that the inverter cannot provide active power to the AC system from the DC accumulated energy if the output voltage of the inverter goes before the voltage of the AC system. On the other hand, the inverter can absorb the active power of the AC system if its voltage is delayed in respect to the AC system voltage

6 MATLAB MODEL

6.1 Without STATCOM

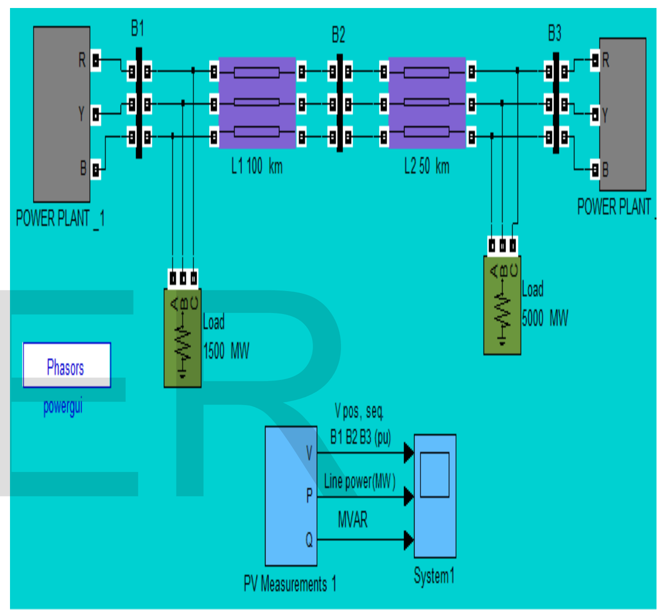

Fig.6.1 MATLAB model without STATCOM

6.2 With STATCOM

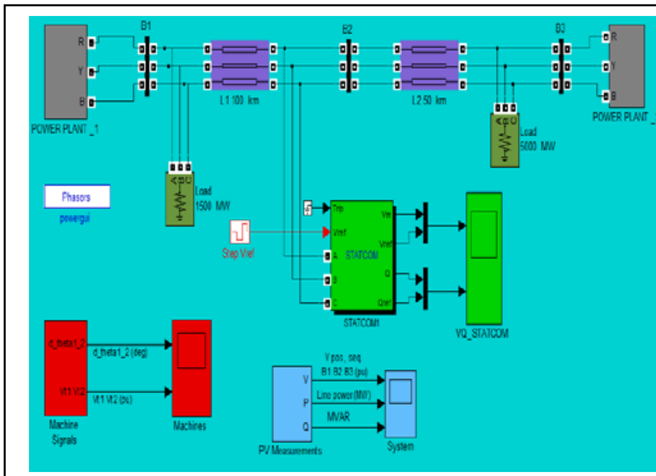

Fig 6.2 MATLAB model with STATCOM

ISSN 2229-5518

7 WAVEFORMS

7.1 Without STATCOM

7.1.1 Voltage at Bus B1, B2& B3

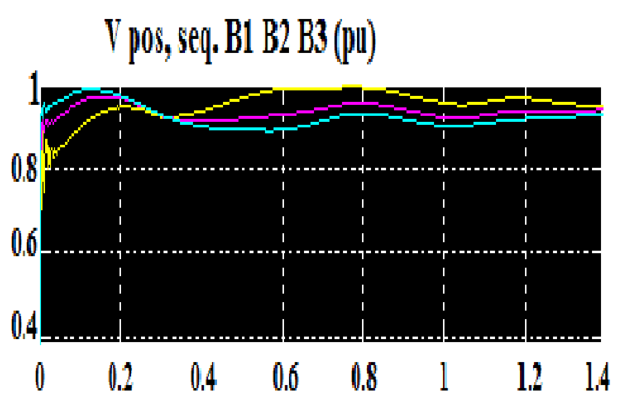

Fig. 7.1.1 Voltage at bus B1, B2, B3 (without STATCOM)

7.1.2 Reactive power

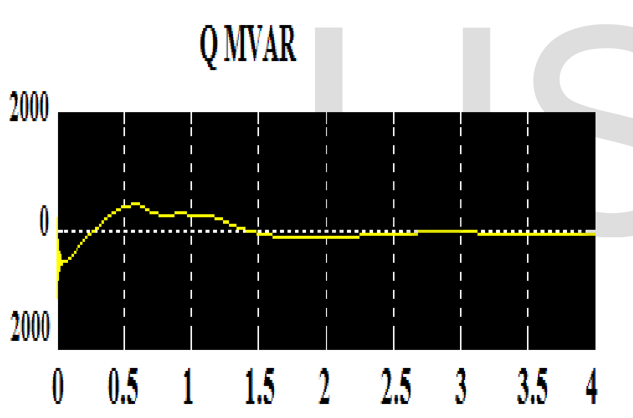

Fig. 7.1.2 Reactive Power (without STATCOM)

7.2 With STATCOM

7.2.1 Voltage at Bus B1, B2, B3

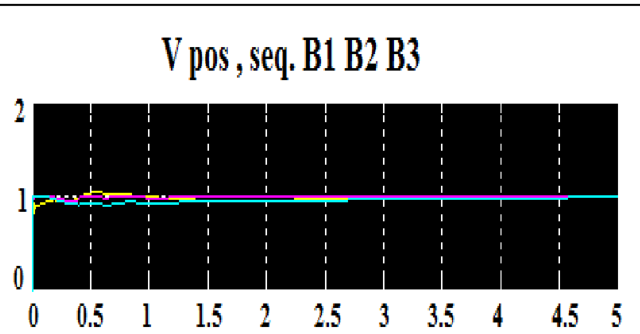

Fig. 7.2.1 voltage at bus B1, B2, B3 (with STATCOM)

7.2.2 Reactive Power

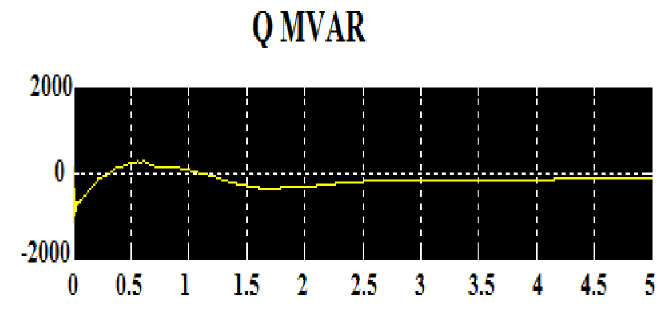

Fig. 7.1.2 Reactive Power (with STATCOM)

7.2.2 Voltage at buses B1, B2&B3

	Voltage at bus 1		Voltage at bus 2		Voltage at bus 3	
TIME (SEC)	without STATCOM	With STATCOM	Without STATCOM	With STATCOM	Without STATCOM	With STATCOM
0.5	**0.967**	**1.020**	**0.920**	**0.990**	**0.891**	**0.910**
1.0	**0.956**	**0.985**	**0.923**	**0.974**	**0.902**	**0.915**
1.5	**0.935**	**0.940**	**0.937**	**0.977**	**0.933**	**0.940**
2.0	**0.925**	**0.942**	**0.936**	**0.978**	**0.940**	**0.947**
2.5	**0.942**	**0.960**	**0.947**	**0.982**	**0.944**	**0.948**
3.0	**0.952**	**0.963**	**0.953**	**0.985**	**0.948**	**0.956**
3.5	**0.957**	**0.966**	**0.959**	**0.987**	**0.956**	**0.962**
4.0	**0.963**	**0.975**	**0.966**	**0.933**	**0.963**	**0.968**

8 CONCLUSION

Thus reactive power management at receiving end can be obtained using STATCOM. Voltage profile variation within specified fewer limits can be obtained using STATCOM. It was also shown that a STATCOM can improve system voltage performance both for heavy load conditions and light load conditions.

In future STATCOM placed at location where the maximum voltage is improve , which play an important role in controlling the reactive power flow to the power network and hence both the system voltage fluctuations and transient stability. Also improve the voltage at the time of faults like LG, LL, LLG, LLL faults.

9 REFERENCES

[1] N. Yorino, E. E. El-Araby, H. Sasaki, and H. Sugihara, "A new formulation for FACTS allocation for security enhancement against voltage collapse, " IEEE Trans. on Power Syst., vol. 18, no. 1, pp. 3-10, Feb. 2003

[2] Optimal Location of STATCOM and SVC Based on Contingency Voltage Stability by Using Continuation Power Flow: Case Studies of Khouzestan Power Networks in Iran.

[3] Hingorani, N.G."Flexible AC Transmission", IEEE Spectrum, Vol.30, pp.40-45, April 1993

[4] D M TAGARE, "Reactive power management".

[5] Lof P: A et al, Voltage dependent reactive power limit for voltage stability studies, IEEE Transactions on power system. Vol .10, No. 1, Feb 1995, pp. 220-226

[6] Study of a statcom application for voltage stability evaluated by dynamic PV Curves abd time simulations: By Hiroshi Yonezawa, Michiharu Taukada, John j. Paserba: Pg 1471-1476 IEEE-2000.