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A STATCOM based Voltage Stabilization and Reactive Compensation for 220 KV Transmission System: A Case Study.

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Abstract

To study and analyze the dynamic performance of the Flexible AC Transmission System (FACTS) devices, modelling of the FACTS devices is needed. Reactive power compensation is an important issue in the control of electrical power system. Reactive power increases the transmission system losses and reduces the power transmission capability of the transmission lines. Moreover, reactive power transmitted through the transmission lines can cause large amplitude variations in the receiving-end voltage. This paper illustrates the effect of Static Compensator (STATCOM) in power system on reactive power control and voltage stabilization by proper modelling of simple power system and voltage source converter based STATCOM (Static compensator) using Simulink and Simpower system toolboxes in MATLAB.This paper presents the use of a new full 48 pulse GTO model of voltage source converter FACTS-STATCOM (Static Synchronous Compensator) for reactive power compensation and voltage stabilization of 220 KV Karad-Wathar-Mudshingi transmission line located in Karad zone of Maharashtra State Electricity Transmission Company Ltd. India. (M.S.E.T.C.L).

The STATCOM is capable of providing reactive power compensation for fundamental and harmonics; power factor correction under balanced and unbalanced loading conditions. The Power System Block set (PSB) in MATLAB/Simulink is a graphic tool that allows building schematics and simulation of power systems in the Simulink environment. The analysis and complete digital simulation of the STATCOM is performed in the MATLAB/Simulink environment using the Power System Block set (PSB), considering the actual data of the proposed system. The system is simulated considering various locations for STATCOM and the performance of system is evaluated.

Keywords: FACTS, STATCOM, 220 KV System, Voltage stabilization, Reactive power compensation.

Introduction

The Electric supply industry is undergoing a profound transformation worldwide. Market forces, scare natural resources and an ever increasing demand for electricity are some of the drivers responsible for such an unprecedented change. Particularly in the case of transmission systems, it requires non-discriminatory open access to transmission resources. Therefore sufficient transmission capacity for supporting transmission services is a great demand to transmission network's requirement. Further to meet the demand for a substantial increase in power transfers among utilities, as a major consequence of electricity market, a much more intensive utilization of existing transmission resource is needed[1]-[3].

Voltage stability is increasingly becoming a limiting factor in the planning and operation of many power systems. With increasing system loading and open transmission access, power systems are more vulnerable to voltage instability. Together with ever-present disturbances, this may result in a serious consequence of a voltage collapse as shown by number of major incidences throughout the world. Voltage collapse tends to occur from lack of reactive power support in heavily stressed conditions, which are usually triggered by system faults. Voltage collapse can be initiated due to small changes of system condition (e.g. Load increasing) as well as large disturbances (e.g. line outage or generation unit outage). Under these conditions, shunt FACTS devices such as SVC and STATCOM can improve the system security with fast and controlled injection of reactive power to the system. However, when the voltage collapse is due to excessive load increasing, FACTS devices cannot prevent the voltage collapse and only postpone it until they reach to their maximum limits. Under this situations, the only way to preventing the voltage collapse is load curtailment or load shedding. So, reactive power control using FACTS devices is more effective in large disturbances, and contingencies should be considered in voltage stability analysis.

The advent of Flexible AC transmission systems (FACTS) technology has coincided with the major restructuring of the electrical power industry. FACTS can provide benefits in increasing system transmission capacity and power flow control flexibility and rapidity. As deregulation picks up speed, making the demand for sufficient services is becoming more critical, it is imperative to investigate the capabilities and potential applications of FACTS on power networks.

FACTS devices are solid state converters that have the capability to control various electrical parameters in transmission circuits. FACTS devices include Thyristor controlled series compensator (TCSC), Static VAR Compensator (SVC), Thyristor controlled phase angle regulator (TCPST), Static compensator (STATCOM), Unified power flow controller (UPFC) etc.

The STATCOM was proposed by several researchers to compensate the reactive current from or to the power system. This function is identical to the synchronous condenser with rotating mass, but its response time is extremely faster than of the synchronous condenser. This rapidity is very effective to increase transient stability, to enhance voltage support, and to damp low frequency oscillation for the transmission system.

In this paper Karad-Mudshingi 220 KV transmission line looped at Wathar is simulated using MATLAB/Simulink. The performance of the system is studied for normal and transient condition for both cases that is with and without STATCOM. Transient condition is created by applying a heavy load, suddenly. The purpose of this work is to investigate the placement of STATCOM for enhancing the voltage stability and improvement of voltage profile of the proposed system.

Static Synchronous Compensator (STATCOM)

The Static Synchronous Compensator (STATCOM) is shunt connected reactive compensation equipment, which is capable of generating and/or absorbing reactive power whose output can be varied so as to maintain control of specific parameters of the electric power system. The STATCOM provides operating characteristics similar to a rotating synchronous compensator without the mechanical inertia, due to the STATCOM employ solid state power switching devices it provides rapid controllability of the three phase voltages, both in magnitude and phase angle. The STATCOM basically consists of a step-down transformer with a leakage-reactance, a three-phase GTO/IGBT voltage source inverter (VSI), and a DC capacitor. The AC voltage difference across the leakage reactance produces reactive power exchange between the STATCOM and the power system, such that the AC voltage at the bus bar can be regulated to improve the voltage profile of the power system, which is the primary duty of the STATCOM. However, a secondary damping function can be added into the STATCOM for enhancing power system oscillation stability [4]

The principle of STATCOM operation is as follows. The VSI generates a controllable AC voltage source behind the leakage reactance. This voltage is compared with the AC bus voltage system; when the AC bus voltage magnitude is above that of the VSI voltage magnitude, the AC system sees the STATCOM as an inductance connected to its terminals. Otherwise, if the VSI voltage magnitude is above that of the AC bus voltage magnitude, the AC system sees the STATCOM as a capacitance connected to its terminals. If the voltage magnitudes are equal, the reactive power exchange is zero. If the STATCOM has a DC source or energy storage device on its DC side, it can supply real power to the power system. This can be achieved adjusting the phase angle of the STATCOM terminals and the phase angle of the AC power system. When the phase angle of the AC power system leads the VSI phase angle, the STATCOM absorbs real power from the AC system; if the phase angle of the AC power system lags the VSI phase angle, the STATCOM supplies real power to AC system [5-7].

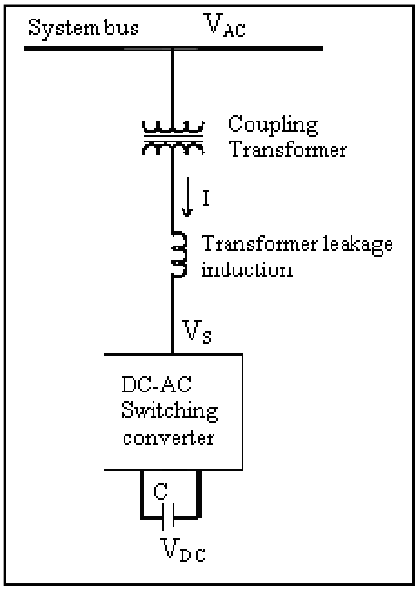

Figure 1: Single-line diagram of a STATCOM.

The voltage source-converter or inverter (VSC or VSI) is the building block of a STATCOM and other FACTS devices. A very simple inverter produces a square voltage waveform as it switches the direct voltage source on and off. The basic objective of a VSI is to produce a sinusoidal AC voltage with minimal harmonic distortion from a DC voltage. In the last decade commercial availability of Gate Turn-Off Thyristor (GTO) devices with high power handling capability, and the advancement of other types of power-semiconductor devices such as IGBT's have led to the development of controllable reactive power sources utilizing electronic switching converter technology [8]. These technologies additionally offer considerable advantages over the existing ones in terms of space reductions and performance. The GTO Thyristor enables the design of solid-state shunt reactive compensation equipment based upon switching converter technology. This concept was used to create a flexible shunt reactive compensation device named Static Synchronous Compensator (STATCOM) due to similar operating characteristics to that of a synchronous compensator but without the mechanical inertia.

Simulated Case Study

The Simulated case study is 220 KV Transmission line located in Karad zone of Maharashtra State India. Map of the simulated network is shown in Fig 2. This network is double circuit network, in which one line is connected between 400 KV Karad substation and 220 KV Mudshingi substation, while other line feeds another substation at Wathar region. System at Wathar is Loop in Loop out (LILO), which allows Wathar to take power from both the ends. Wathar substation is the only substation on Karad-Mudshingi 220KV line having a load of nearly 150MW. This network is a large industrial zone in Maharashtra state in India. In this region there are largest sugar factories, irrigation scheme, textile mills. Hence power network of this region is very important. It is very essential to maintain very good quality of power supply. It can be understood by the fact that, a slight drop in supplied voltage can cause a quality reduction in industries, which can ultimately cause a million of rupees loss to industrial consumers of this region. So taking all this facts into consideration it is very essential to maintain the voltage level at Wathar substation which can be achieved by placing the FACT device that is STATCOM at desired location.

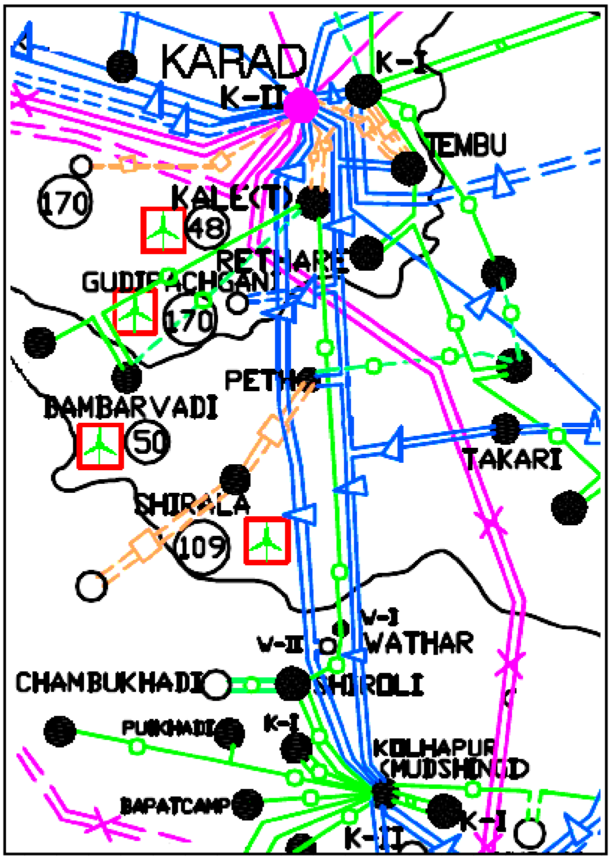

Figure 2: Map of Karad-Mudshingi Transmission Network.

The details of the system proposed in this paper are presented as:
All the constructional details and spacing are as per The Indian Electricity Rules and standards of Maharashtra state Electricity Transmission Company Limited (M.S.E.T.C.L). For proposed 220KV transmission systems the length of the line is as follows;

- Karad s/s to Mudshingi s/s - 93 KM
- Karad s/s to Wathar s/s -67 KM
- Wathar s/s to Mudshingi s/s- 26 KM

Simulation Tools

The modeling of STATCOM with proposed 220 KV transmission system is done by using the SimPower systems toolboxes in MATLAB /Simulink. The modeling is done by connecting a three phase source of 1200 MVA and RL loads through a transmission line. The source is representing a bus feeding Karad s/s and the RL loads are representing the different s/s. The power flow in the system without STATCOM is first studied. The AC voltage at source is maintained at 220 KV (1.p.u) and the frequency is 50Hz. The load is varied and the real and reactive power flows in the bus are observed. Using the active and the reactive power blocks available in SimPower System, the reactive power flow through the line is plotted against time. In each case the simulation results for both the system with and without STATCOM are compared.

Fig.3 (a) shows the simulink diagram of proposed 220 KV System without STATCOM having AC source, load, transmission line and measurement blocks. The source is a 3 phase synchronous generator having a capacity of 1200MVA at13.8 KV and 50Hz.The required voltage level of 220 KV is achieved with the help of a power transformer. The synchronous generator is also assisted by Power System Stabilizer, Exciter and Hydraulic Turbine and Governor System. The load at different buses is RL load, having real and reactive power ratings according to the original s/s load. The Transmission lines are of mentioned length and having 0.4 ACSR ZEBRA conductors.

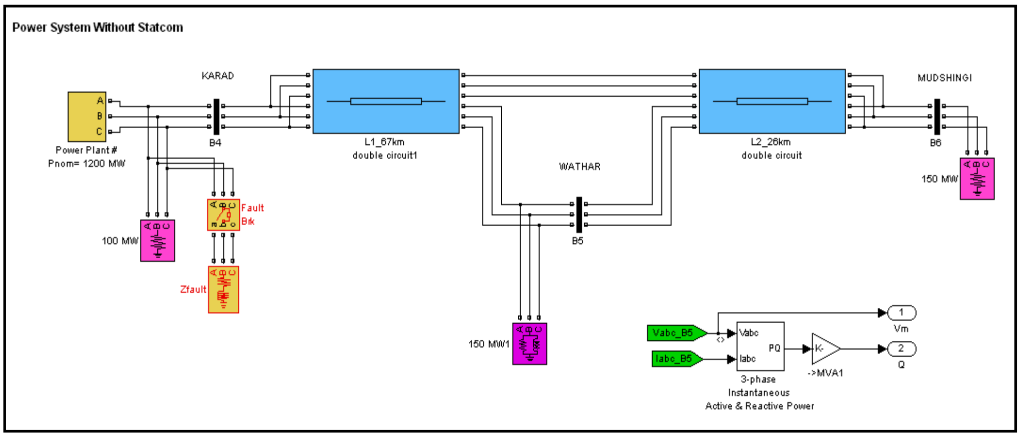

Figure 3 (a): Proposed System without STATCOM.

Fig.3 (b) shows the simulink diagram of proposed 220 KV System with STATCOM located at Wathar Bus (bus B1) and has a rating of +/- 100MVA. This STATCOM is a phasor model of a typical three-level PWM STATCOM. All the other elements are same as that of system without STATCOM. A remote fault will be simulated on both systems using a fault breaker in series with a fault impedance connected at Karad bus. The value of the fault impedance has been programmed to produce 25 percent voltage sag at Wathar bus B1for approximate10 cycles. The other buses are bus B2- Mudshingi and bus B3- Karad.

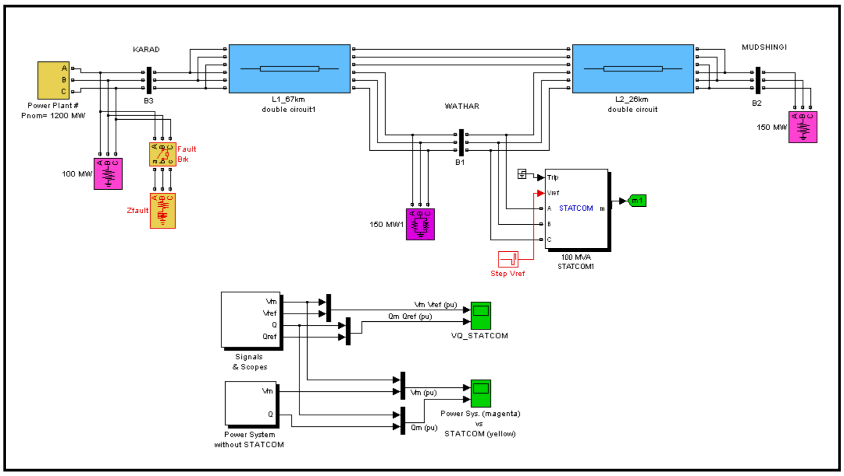

Figure 3(b): Proposed System with STATCOM.

Results and Discussions

The solutions for optimal possible location of STATCOM in the proposed system to get the optimal voltage stabilization and reactive power compensation for the proposed systems were obtained and discussed below. The simulation studies were carried out in MATLAB/Simulink environment for following possible conditions.

Dynamic Response of STATCOM

For observing the dynamic response of the STATCOM its reference voltage is controlled externally. Fig.3 displays the Vref signal (magenta trace) along with the measured positive-sequence voltage Vm at the STATCOM bus (blue trace). The second graph displays the reactive power Qm absorbed (positive value) or generated by the STATCOM. The signal Qref (magenta trace) shows the ref reactive power in the system.

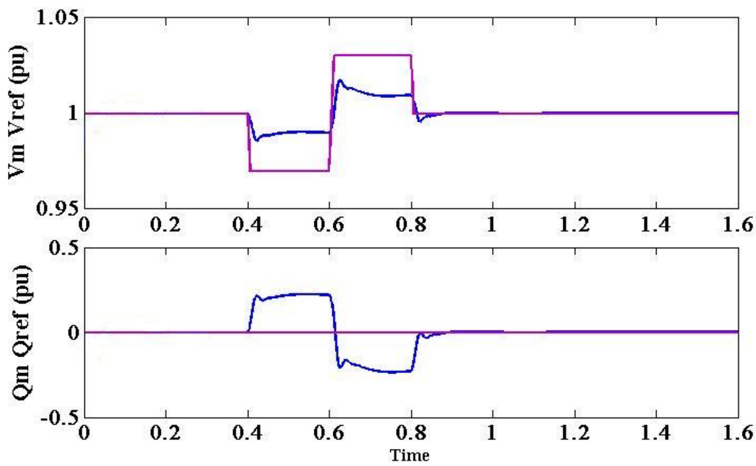

Figure 4: Dynamic response of STATCOM.

Case A

In this case the sudden change in load is applied at the generator bus 3- at Karad and the position of the STATCOM is varied, for all the 3 possible locations. The simulation is carried out for each case and results are obtained and plotted against time. These are shown in Fig.4, the numbers 1-3 are used to indicate the STATCOM positions at respective buses. Vm (pu) 1shows the voltage profile for the system having STATCOM at Wathar bus B1 similarly Vm (pu) 2 and Vm(pu) 3 are the voltage profiles for the systems having STATCOM at Mudshingi bus B2 and at Karad bus B3. It can be easily observed from the graph that there are large variations in voltage profile in System without STATCOM than the system with STATCOM and also change in STATCOM position does not produce a large variation in the voltage profiles. The other graph in each case is for reactive power compensation done by STATCOM. It is also clear from the graph that the STATCOM regulates voltage at its terminal by controlling the amount of reactive power injected into or absorbed from the power system. When system voltage is low, the STATCOM generates reactive power (STATCOM capacitive). When system voltage is high, it absorbs reactive power (STATCOM inductive).

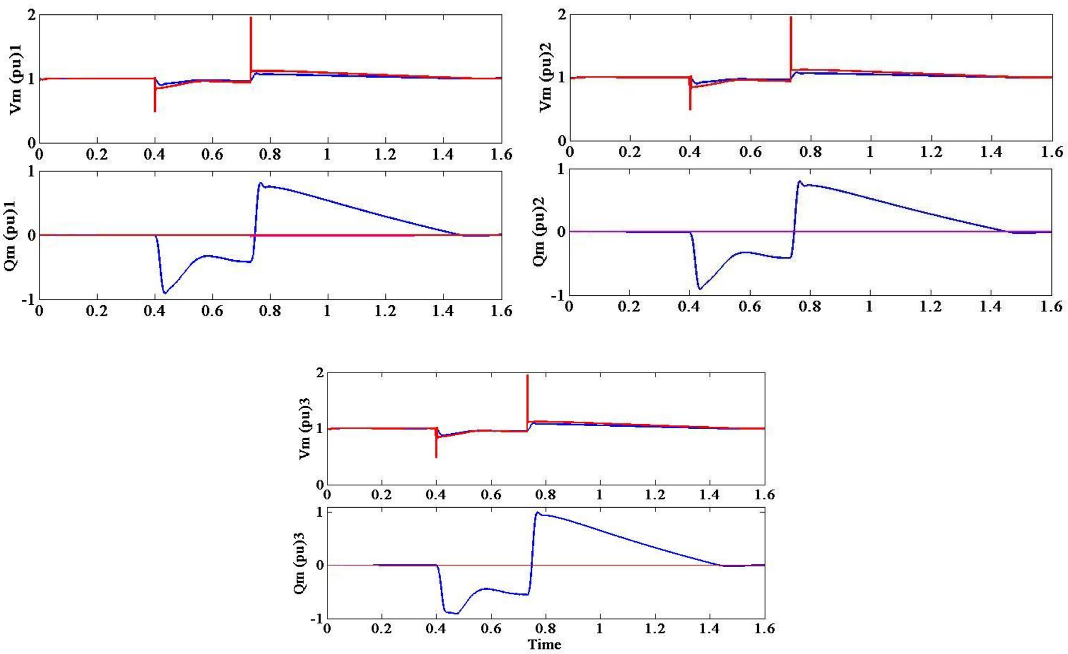

Figure 5: Voltage profiles and reactive power flow for the system with and without STATCOM.

Table 1 show the values of voltage in per unit for different STATCOM positions, when the sudden load is applied and removed from the generator bus. When the sudden load is applied at Wathar bus B1 the voltage drops to value 0.48 pu without STATCOM and it drops to value 0.9 pu with STATCOM. When it is removed the voltage rises to 1.95 pu without STATCOM and it is observed that after installation of the STATCOM the value raises only up to 1.08 pu

Table 1

STATCOM Location.	Vm (pu) Without STATCOM		Vm (pu) With STATCOM	
	Load Applied	Load Relieved	Load Applied	Load Relieved
Bus 1 - Wathar	0.48	1.95	0.9	1.08
Bus 2 – Mudshingi	0.48	1.95	0.9	1.08
Bus 3 – Karad	0.48	1.96	0.87	1.09

Case B

In this case the sudden change in load is applied at different buses and the position of the STATCOM is also varied, for all the 3 possible locations. The simulation is carried out for each case and results were obtained and plotted against time. These are shown in Fig.5 (a) and Fig 5 (b). The case A is repeated by changing the location of the application of load and all the results are tabulated so as to get a clear view.

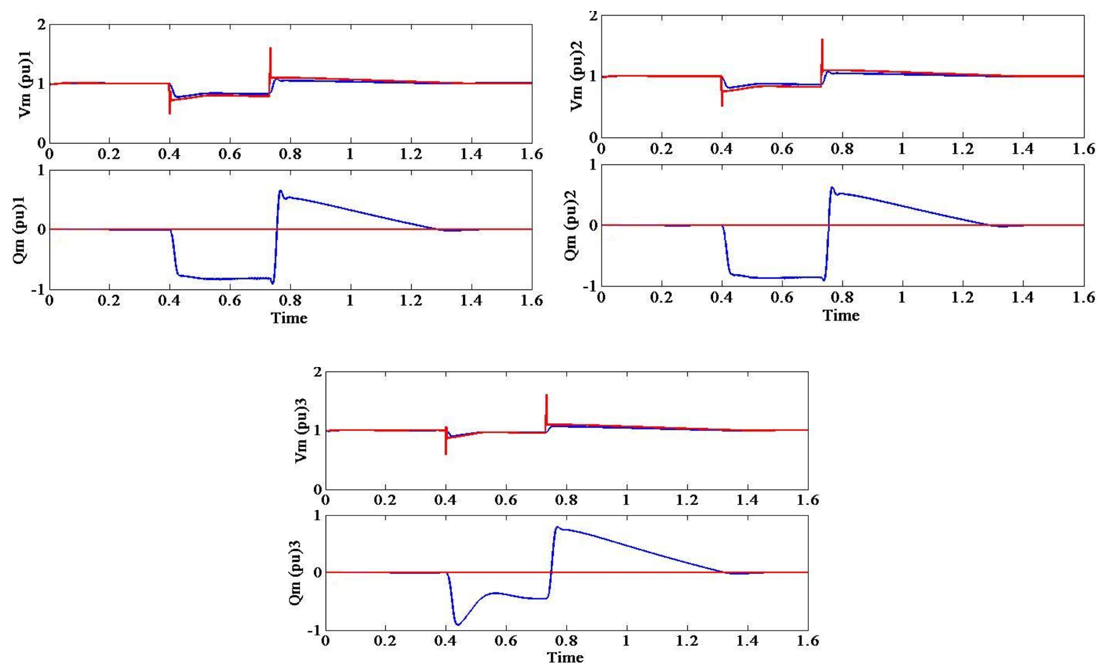

Figure 6 (a): Load at Wathar bus and STATCOM at various locations.

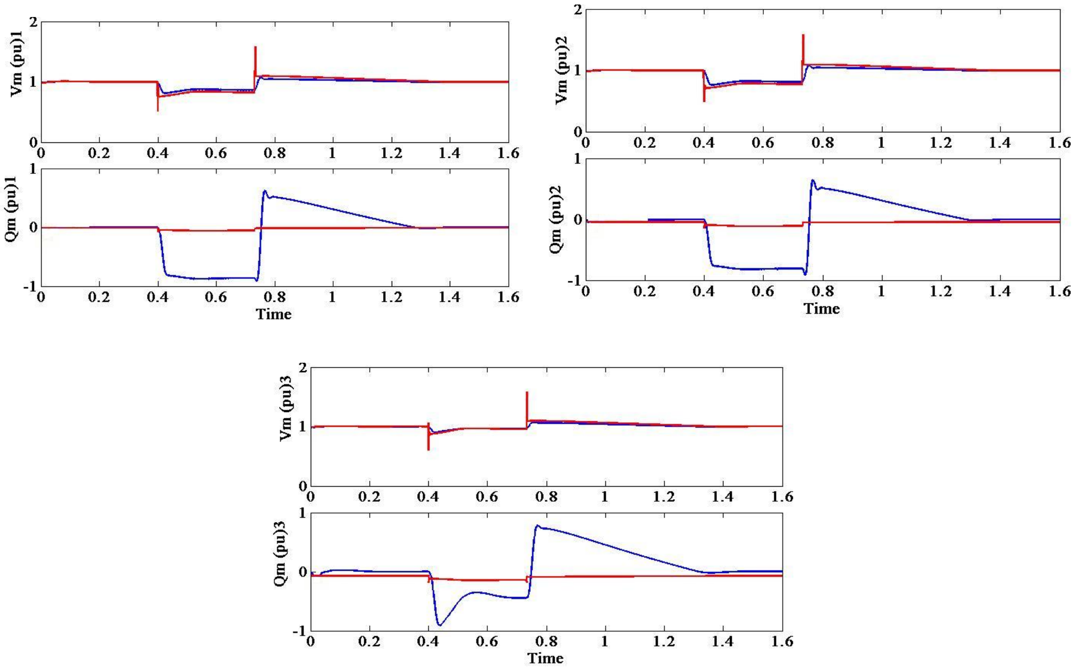

Figure 6(b): Load at Mudshingi bus and STATCOM at various locations.

Table 2 shows the values of voltage in per unit for different STATCOM positions and different load positions, when the sudden load is applied and removed from the system. This values results in better understanding of the system and helps in finding the optimal location for installation of the STATCOM.

Table 2

STATCOM Location.	Load at Bus 1- Wathar				Load at Bus 2- Mudshingi				Load at bus 3 - Karad			
	Vm (pu) W/O STATCOM		Vm (pu) With STATCOM		Vm (pu) W/O STATCOM		Vm (pu) With STATCOM		Vm (pu) W/O STATCOM		Vm (pu) With STATCOM	
Bus 1 - Wathar	0.48	1.6	0.76	1.07	0.52	1.55	0.81	1.07	0.48	1.95	0.9	1.08
Bus 2 – Mudshingi	0.5	1.6	0.8	1.07	0.49	1.58	0.76	1.08	0.48	1.95	0.9	1.07
Bus 3 – Karad	0.59	1.6	0.89	1.07	0.61	1.58	0.9	1.07	0.48	1.96	0.87	1.09

From the table it is clear that the system with STATCOM faces lesser voltage fluctuations on transients as compared to the system without STATCOM. This is achieved with the help of reactive power compensation of the STATCOM.

Conclusion

In this paper, brief information about STATCOM and its effect at different places on proposed power system have been considered. This study is very useful especially in investigating the effectiveness of the different methods in optimizing the optimum STATCOM location in the proposed system, by analysis the effects of power system contingency on static voltage stability, we specified optimal location for installing STATCOM in proposed power system to improve stability in network voltages.

In this research, the placement is determined conventionally based on the result obtained using MATLAB/simulink software. General idea of this work is to demonstrate the importance of STATCOM allocation for describing the effect of STATCOM and its placement on the proposed 220 KV Karad-Wathar-Mudshingi electrical power system. The simulated results indicated that, improper selection of STATCOM and its capacity, as well as its placement may result in not achieving the objectives accordingly. Considering the high cost of these elements, it is very important to have a better judgment and analysis, prior to purchasing and installation process.

References

[1] N.G. Hingorani and L. Gyugyi, Understanding FACTS Concepts and Technology of Flexible AC Transmission Systems, IEEE Press, 2000, ISBN 0-7803-3455-8.
[2] R.M. Mathur and R.K. Varma, Thyristor based FACTS controllers for Electrical transmission systems, John Wiley & Sons Inc., 2002.
[3] Y.H. Song and X.F. Wang, Operation of market oriented power system, Springer-Verlag Ltd, 2003, ISBN: 1-85233-670-6.
[4] Y. Liang and C.O. Nwankpa, "A new type of STATCOM based on cascading voltage-source inverter with phase-shifted unipolar SPWM," IEEE Trans. Ind. Appl., vol. 35, no. 5, pp. 1118–1123, Sep./Oct. 1999.
[5] P. Giroux, G. Sybille, and H. Le-Huy, "Modeling and simulation of a distribution STATCOM using simulink's power system blockset," in Proc. Annu. Conf. IEEE Industrial Electronics Society, pp. 990–994.
[6] Q. Yu, P. Li, and Wenhua, "Overview of STATCOM technologies," in Proc. IEEE Int. Conf. Electric Utility Deregulation, Restructing, Power Technologies, Hong Kong, Apr. 2004, pp. 647–652.
[7] M.R. Iravani, P.L. Dandeo, K.H. Nguyen, D. Zhu, d. Maratukulam,"Applications of static phase shifters in power systems," IEEE Trans on Power Delivery, Vol 9, No. 3, July 1994, pp. 1600-1608.
[8] "Static Synchronous Compensator," CIGRE, Working group 14.19,1998.P. Giroux, G. Sybille, and H. Le-Huy, "Modeling and simulation of a distribution STATCOM using simulink's power system blockset," in Proc. Annu. Conf. IEEE Industrial Electronics Society, pp. 990–994.

[9] Q. Yu, P. Li, and Wenhua, “Overview of STATCOM technologies,” in Proc. IEEE Int. Conf. Electric Utility Deregulation, Restructing, Power Technologies, Hong Kong, Apr. 2004, pp. 647–652.

[10] A. Krämer, J. Ruff, ”Transformers for phase angle regulation considering the selection of On-load tap-changers,” IEEE Trans on Power Delivery, Vol. 13, No.2, April 1998, pp. 518-523.

[11] Yong Hua Song, Allan T. Johns, Flexible AC transmition systems FACTS, IEE Power and Energy Series 30, 1999.