# Voltage Control by using STATCOM

Amin Imanian [1], Ramtin Sadeghi [2], Payam Ghaebi Panah [3], Iman Saadi Nezhad [4]

[1,2,3,4] Department of Electrical Engineering, Majlesi Branch, Islamic Azad University, Isfahan, Iran
sadeghi@iaumajlesi.ac.ir

**Abstract:** Static synchronous compensator (STATCOM) is one the parallel FACTS devices which is mainly used to control of voltage in power systems. STATCOM is usually installed in a bus which suffer voltage drop. The researches have shown that STATCOM can successfully control the system voltage by injecting a relevant signal to the proposed bus where the STATCOM is installed. In this paper the ability of STATCOM in voltage control is investigated at a multi machine power system. An optimization technique is used to tune the proposed STATCOM controllers. The results are compared with the system without STATCOM. Simulation results visibly show the ability of STATCOM in voltage support.

[Amin Imanian, Ramtin Sadeghi, Payam Ghaebi Panah, Iman Saadi Nezhad. **Voltage Control by using STATCOM.** *Life Sci J* 2012;9(4):5497-5500] (ISSN:1097-8135). http://www.lifesciencesite.com. 814

**Keywords:** Static Synchronous Compensator, Voltage Support, Multi-machine Power System, Genetic Algorithm.

## 1. Introduction

It has long been recognized that the steady-state transmittable power can be increased and the voltage profile along the line also can be controlled by appropriate reactive shunt compensation. The purpose of this reactive compensation is to change the natural electrical characteristics of the transmission line to make it more compatible with the prevailing load demand. Thus, shunt connected, fixed or mechanically switched reactors are applied to minimize line overvoltage under light load conditions, and shunt connected, fixed or mechanically switched capacitors are applied to maintain voltage levels under heavy load condition [1].

The ultimate objective of applying reactive shunt compensation such as STATCOM in a transmission system is to increase the transmittable power. This may be required to improve the steady-state transmission characteristics as well as the stability of the system. Var compensation is thus used for voltage regulation at the midpoint (or some intermediate) to segment the transmission line and at the end of the (radial) line to prevent voltage instability, as well as for dynamic voltage control to increase transient stability and damp power oscillations.

The static synchronous compensator (STATCOM) is one of the most important FACTS devices and it is based on the principle that a voltage-source inverter generates a controllable AC voltage source behind a transformer-leakage reactance so that the voltage difference across the reactance produces active and reactive power exchange between the STATCOM and the transmission network. The STATCOM can be used for dynamic compensation of power systems to provide voltage support [2, 3]. Also it can be used for transient stability improvement by damping low frequency power system oscillations [4-7].

The objective of this paper is to investigate the ability of STATCOM for voltage support. Genetic algorithm (GA) method as a meta-heuristic optimization method is considered for tuning the parameters of STATCOM. A multi-machine power system installed with STATCOM is considered as case study. Simulation results show the validity of STATCOM in voltage support at bulk electric power systems.

## 2. Test system

A multi machine power system installed with STATCOM is considered as case study. The proposed test system is depicted in Figure 1. The system data can be found in [8]. In this paper, turbine-governor system is also modeled to eliminate steady state error of responses.

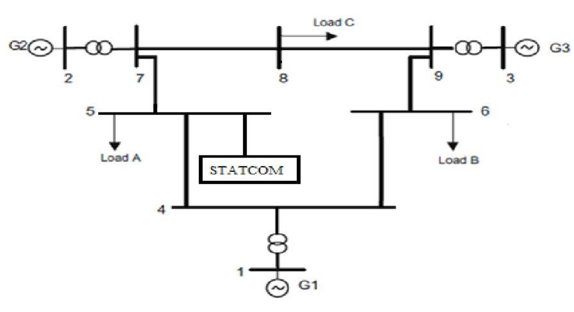


Figure 1. Multi-machine electric power system installed with STATCOM

### 2.1. Dynamic model of the system with STATCOM

The nonlinear dynamic model of the system installed with STATCOM is given as (1). The dynamic model of the system installed with STATCOM is completely presented in [1].

$$\begin{cases} \dot{\omega}=(P_m-P_e-D\omega)/M \\ \dot{\delta}=\omega_0(\omega-1) \\ \dot{E}'_q=\left(-E_q+E_{fd}\right)/T'_{do} \\ \dot{E}_{fd}=\left(-E_{fd}+K_a(V_{ref}-V_t)\right)/T_a \\ \dot{V}_{dc}=\left(K_r(V_{ref}-V)-b_{STAT}\right)/T_r \end{cases} \quad (1)$$

Where, δ: Rotor angle; ω: Rotor speed (pu); Pm: Mechanical input power; Pe: Electrical output power (pu); M: System inertia (Mj/MVA); E´q: Internal voltage behind x´d (pu); Efd: Equivalent excitation voltage (pu); T´do: Time constant of excitation circuit (s); Ka: Regulator gain; Ta: Regulator time constant (s); Vref: Reference voltage (pu); Vt: Terminal voltage (pu).

By controlling $m_E$, the output voltage of the shunt converter is controlled. By controlling $\delta_E$, exchanging active power between the STATCOM and the power system is controlled.

## 2.2. STATCOM Controllers

In this paper two control strategies are considered for STATCOM:

DC-voltage regulator
Bus-voltage regulator

STATCOM has two internal controllers which are bus voltage controller and DC voltage regulator. A DC capacitor is installed behind the STATCOM; this capacitor is used to provide the reference voltage for PWM performance. In order to maintaining the voltage of this capacitor, a DC-voltage regulator is incorporated. DC-voltage is regulated by modulating the phase angle of the shunt converter voltage. This controller is commonly a PI type controller. A bus voltage controller is also incorporated based on STATCOM. The bus voltage controller regulates the voltage of bus where the STATCOM is installed.

The most important subject is to tuning the STATCOM controller parameters. The system stability and suitable performance is guaranteed by appropriate adjustment of these parameters. Many different methods have been reported for tuning STATCOM parameters so far. In this paper, an optimization method named is considered for tuning STATCOM parameters. In the next section an introduction about the proposed optimization method is presented.

## 3. Genetic Algorithms

Genetic Algorithms (GA) are global search techniques, based on the operations observed in natural selection and genetics. They operate on a population of current approximations-the individuals-initially drawn at random, from which improvement is sought. Individuals are encoded as strings (Chromosomes) constructed over some particular alphabet, e.g., the binary alphabet {0.1}, so that chromosomes values are uniquely mapped onto the decision variable domain. Once the decision variable domain representation of the current population is calculated, individual performance is assumed according to the objective function which characterizes the problem to be solved. It is also possible to use the variable parameters directly to represent the chromosomes in the GA solution. At the reproduction stage, a fitness value is derived from the raw individual performance measure given by the objective function and used to bias the selection process. Highly fit individuals will have increasing opportunities to pass on genetically important material to successive generations. In this way, the genetic algorithms search from many points in the search space at once and yet continually narrow the focus of the search to the areas of the observed best performance. The selected individuals are then modified through the application of genetic operators. In order to obtain the next generation Genetic operators manipulate the characters (genes) that constitute the chromosomes directly, following the assumption that certain genes code, on average, for fitter individuals than other genes. Genetic operators can be divided into three main categories: Reproduction, crossover and mutation [9].

## 4. STATCOM tuning based on GA

In this section the parameters of the STATCOM controllers are tuned by using GA. The optimum values of controllers which minimize different performance indices are accurately computed using GA. The performance index is considered as (2). In fact, the performance index is the Integral of the Time multiplied Absolute value of the Error (ITAE).

$$ITAE=\int_0^t t\sum_{i=1}^{3}|\Delta\omega_i|dt+\int_0^t t\sum_{i=1}^{9}|\Delta v_i|dt \quad (2)$$

Where, Δω shows the frequency deviations and Δv shows the voltage of buses. To compute the optimum parameter values, different faults are assumed in all buses and then the minimum solution is chosen as final solution. The results are listed in Table 1.

Table 1. Optimal parameters of STATCOM

| | gain | value |
|---|---|---|
| PI controller of voltage | Proportional gain | 1.35 |
| | Integrator gain | 0.55 |
| PI controller of DC link | Proportional gain | 24.8 |
| | Integrator gain | 0.30 |

**5. Simulation results**

The proposed STATCOM is evaluated on the test system given in section 2. The disturbance is provided by a 10 cycles three phase short circuit in bus 7. This disturbance shows a large signal disturbance in power systems. The simulation results are presented in Figures 2-6. Where, solid line indicates the system installed with STATCOM and dashed line shows the system without STATCOM.

The STATCOM is installed in bus 5 and it is expected that voltage of bus 5 be controlled. In this regard, the voltage of bus 5 and bus 1 are depicted in Figures 2-3. It is clearly seen that the STATCOM can successfully control the voltage of bus 5. It is also seen that STATCOM has a positive effect on the voltage of rest buses. Where, the voltage profile in bus 1 is better than the system without STATCOM.

The STATCOM is installed to control of voltage, bus is has an effect on the system dynamic performance. Figures 4-6 show the speed of generators following disturbance. It is seen that the system with STATCOM is more stable than system without STATCOM. STATCOM affects the system damping and the oscillations are rapidly damped out with being of STATCOM.

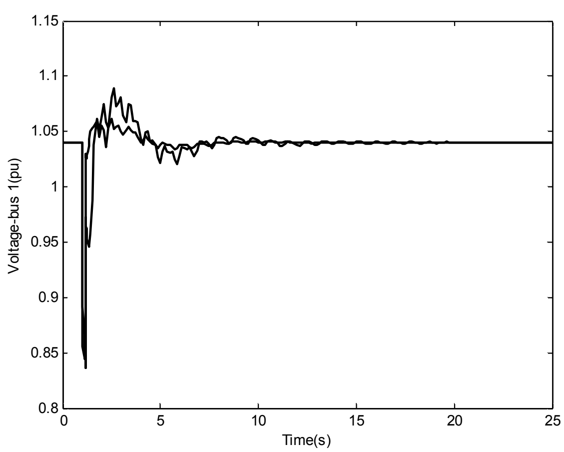


Figure 2. Voltage bus 1 following disturbance

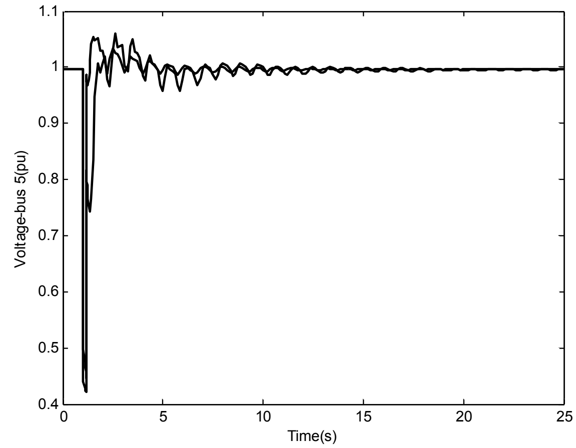


Figure 3. Voltage bus 5 following disturbance

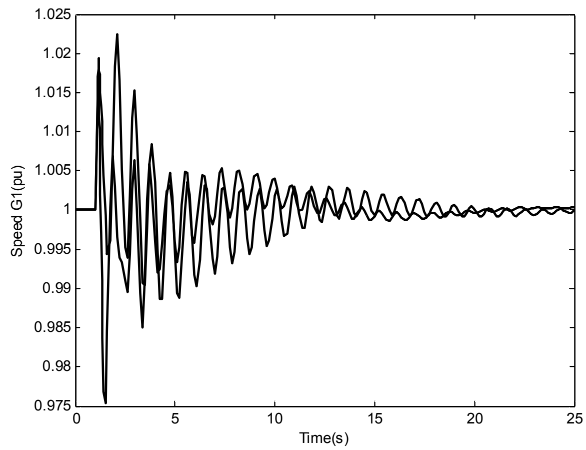


Figure 4. Speed $G_1$ following disturbance

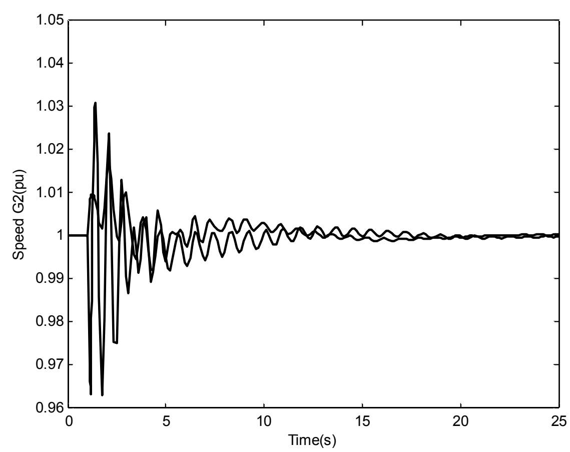


Figure 5. Speed $G_2$ following disturbance

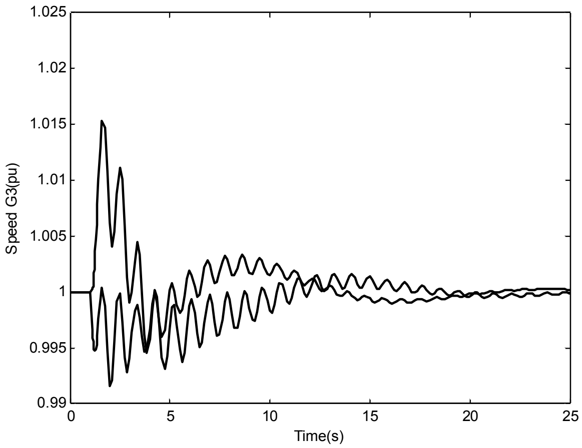

Figure 6. Speed $G_3$ following disturbance

## 6. Conclusions

The application of STATCOM in voltage support was investigated in this paper. A multi-machine electric power system installed with STATCOM was assumed to demonstrate the ability of STATCOM in voltage support. The parameters of the proposed STATCOM were tuned by using a Meta-heuristic optimization method. The proposed optimization procedure guaranteed the solution to reach a suitable and optimal response. Three phase short circuit was considered as disturbance, this is the worst case fault in power system which was assumed to evaluate the dynamic performance of system. Simulation results demonstrated that the designed STATCOM can guarantee the robust stability and robust performance under large signal disturbances.

**Corresponding Author:**
Ramtin Sadeghi
Department of Electrical Engineering,
Majlesi Branch, Islamic Azad University,
Isfahan, Iran.
E-mail: sadeghi@iauln.ac.ir

12/21/2012

## References

[1] N.G. Hingorani, L. Gyugyi, M. El-Hawary. Understanding FACTS: concepts and technology of flexible AC transmission systems: IEEE press New York; 2000.
[2] A.H.M.A. Rahim, M.F. Kandlawala. Robust STATCOM voltage controller design using loop-shaping technique. Electric Power Systems Research. 68 (2004) 61-74.
[3] C.A. Cañizares, C. Cavallo, M. Pozzi, S. Corsi. Comparing secondary voltage regulation and shunt compensation for improving voltage stability and transfer capability in the Italian power system. Electric Power Systems Research. 73 (2005) 67-76.
[4] M.A. Abido. Analysis and assessment of STATCOM-based damping stabilizers for power system stability enhancement. Electric Power Systems Research. 73 (2005) 177-85.
[5] S.A. Al-Baiyat. Power system transient stability enhancement by STATCOM with nonlinear H∞ stabilizer. Electric Power Systems Research. 73 (2005) 45-52.
[6] W. Du, X. Wu, H.F. Wang, R. Dunn. Feasibility study to damp power system multi-mode oscillations by using a single FACTS device. International Journal of Electrical Power & Energy Systems. 32 (2010) 645-55.
[7] M.A. Furini, A.L.S. Pereira, P.B. Araujo. Pole placement by coordinated tuning of Power System Stabilizers and FACTS-POD stabilizers. International Journal of Electrical Power & Energy Systems. 33 (2011) 615-22.
[8] P.W. Sauer, M. Pai. Power system dynamics and stability: Prentice Hall New Jersey; 1998.
[9] R.L. Haupt, S.E. Haupt. Practical genetic algorithms: Wiley-Interscience; 2004.