FACTS devices stabilizer design by using Genetic Algorithms

Ali Zarei[1], Kayvan Karimi Tarazani[2], Negin Zarei[3], Yousef Katal[4]

[1, 2, 3, 4.] Department of Electrical Engineering, Islamshahr Branch, Islamic Azad University, Tehran, Iran
Ali_Zarei @yahoo.com

Abstract: Stability of power system is an important issue and should be considered and improved. Flexible AC Transmission Systems (FACTS) can be used to improve power system stability. Stability enhancement can be improved via damping of low frequency oscillations (LFO). Static Synchronous Series Compensator (SSSC) can be used for LFO damping. In this paper SSSC is used to damp out LFO and a supplementary stabilizer based on SSSC is designed. Genetic Algorithms (GA) is used to adjust the parameters of the proposed stabilizer.

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1. Introduction

With the practical applications of converter-based flexible AC transmission system (FACTS) controllers [1] such as the static synchronous compensator (STATCOM) [2], static synchronous series compensator (SSSC) [3] and unified power-flow controller (UPFC) [4], modeling and analysis of these FACTS controllers in power-system operation and control is of great interest. Power-flow calculations are fundamental to the operation, planning and control of power systems. In recent years, significant work has been done in the modeling of the FACTS controllers in power flow and optimal-power-flow studies [5–12].

SSSC is a voltage-sourced converter-based series compensator and was proposed within the concept of using converter-based technology uniformly for shunt and series compensation, as well as for transmission angle control. It has been successfully applied in power systems. In this paper, SSSC is used to increase power system stability. A supplementary stabilizer is equipped based on SSSC. The parameters of the proposed stabilizer are tuned by using PSO.

2. Static Synchronous Series Compensator (SSSC)

SSSC is one of the most important FACTS devices. It is installed in series with transmission line. This device has a voltage source converter serially connected to a transmission line through a transformer. It is necessary an energy source to provide a continuous voltage through a condenser and to compensate the losses of the VSC. A SSSC is able to exchange active and reactive power with the transmission system. But if our only aim is to balance the reactive power, the energy source could be quite small. The injected voltage can be controlled in phase and magnitude if we have an energy source that is big enough for the purpose. With reactive power compensation only the voltage is controllable, because the voltage vector forms 90º degrees with the line intensity. In this case the serial injected voltage can delay or advanced the line current. This means that the SSSC can be uniformly controlled in any value, in the VSC working slot.

The Static Synchronous Series Compensator (SSSC) uses a VSC interfaced in series to a transmission line, as shown in the Figure 1. Again, the active power exchanged with the line has to be maintained at zero hence, in steady state operation, SSSC is a functional equivalent of an infinitely variable series connected capacitor. The SSSC offers fast control and it is inherently neutral to sub-synchronous resonance.

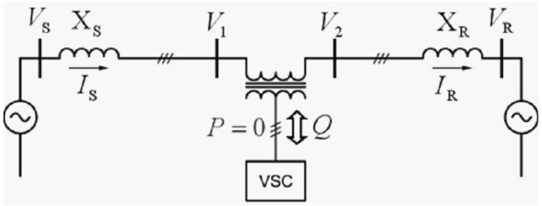

Figure 1: SSSC - A VSC interfaced in series to a transmission line

As mentioned, Static Synchronous Series Compensator (SSSC) is placed in the group of series connected FACTS devices. As shown in Figure 2, SSSC consists of a voltage source inverter connected in series through a coupling transformer to the transmission line. A source of energy is required for providing and maintaining the DC voltage across the DC capacitor and compensation of SSSC losses. Figure 3 shows the model of SSSC which consists of a series connected voltage source in series with impedance. This impedance represents the impedance of coupling transformer. The SSSC when operated with an appropriate DC supply (an energy source and/or sink, or suitable energy storage) can inject a component of voltage in anti-phase with the voltage developed across the line resistance, to counteract the effect of the resistive voltage drop on the power transmission.

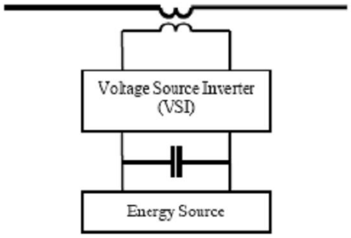

Figure 2: basic configuration of SSSC

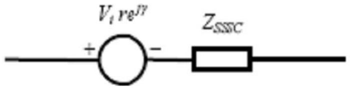

Figure 3: equivalent circuit of SSSC

3. Test system

A multi machine power system installed with SSSC is considered as case study. The proposed system is shown in figure 4. The SSSC is installed in line 4 and system data can be found in [13].

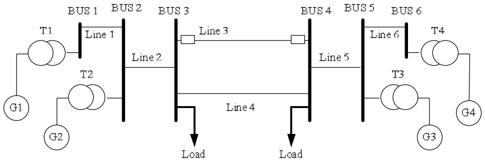

Figure 4: power system installed with SSSC in line 4

4. Power system stabilizer

An AVR (without supplementary control loops) can weaken the damping provided by the damper and field windings. This reduction in the damping torque is primarily due to the voltage regulation effects inducing additional currents in the rotor circuits that oppose the currents induced by the rotor speed deviation Δω. Adding supplementary control loops to the generator AVR or FACTS devices is one of the most common ways of enhancing both small-signal (steady-state) stability and large-signal (transient) stability. The Stabilizer can be used to add damping signal to the SSSC, where the output signal of the stabilizer is used as an additional input (v_{stab}) to the SSSC. The stabilizer input signal can be either the machine speed deviation, Δω, or its acceleration power. The stabilizer is modeled by the nonlinear system depicted in Figure 5.

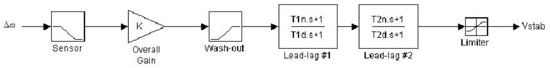

Figure 5: Conventional stabilizer

The model consists of a low-pass filter, a general gain, a washout high-pass filter, a phase-compensation system, and an output limiter. The general gain K determines the amount of damping produced by the stabilizer. The washout high-pass filter eliminates low frequencies that are present in the Δω signal and allows the stabilizer to respond only to speed changes. The phase-compensation system is represented by a cascade of two first-order lead-lag transfer functions used to compensate the phase lag between the excitation voltage and the electrical torque of the synchronous machine.

5. 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 [14].

6. Design methodology

The proposed supplementary stabilizer is designed based on the SSSC in the given test system. The performance index is considered as (3). In fact, the performance index is the Integral of the Time multiplied Absolute value of the Error (*ITAE*).

$$\mathrm{ITAE} = \int_0^t t|\Delta\omega|dt \qquad (3)$$

It is clear to understand that the controller with lower performance index is better than the other controllers. To compute the optimum parameters, different faults are assumed and then the best responses are chosen. It should be noted that GA algorithm is run several times and then optimal set of parameters is selected. The optimum values of the stabilizer parameters are obtained by using GA and summarized in the Table 1

Table 1: Obtained parameters of stabilizer

parameter	K	T_{1n}	T_{1d}	T_{2n}	T_{2d}
value	12.0	0.39	0.01	0.30	0.01

7. Simulation result

The proposed stabilizer is evaluated based on the test system. Large disturbance is considered to show ability of the proposed stabilizer. The simulation results are depicted in figures 6-8. Each figure contains two plots as: **Solid**: with stabilizer and **dashed**: without stabilizer. It is seen that the system without stabilizer contains insufficient damping and the responses are pendulous. But the stabilizer can greatly enhance power system stability and damp out the oscillations and the advantages of the proposed stabilizer are visibly seen.

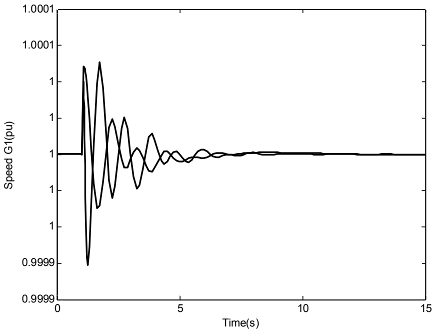

Figure 6: Speed G_1 following 10 cycle three phase short circuit in bus 1

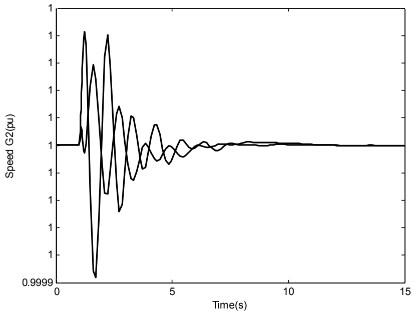

Figure 7: Speed G_2 following 10 cycle three phase short circuit in bus 1

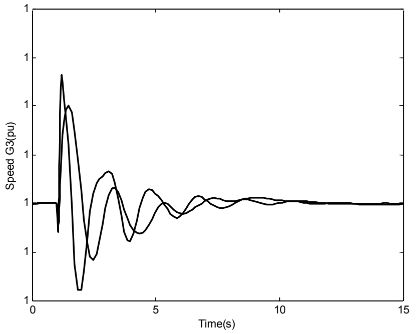

Figure 8: Speed G_3 following 10 cycle three phase short circuit in bus 1

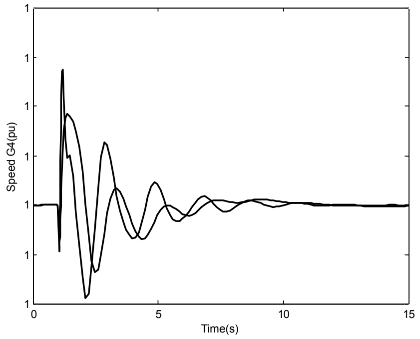

Figure 9: Speed G_4 following 10 cycle three phase short circuit in bus 1

8. Conclusion

A supplementary stabilizer based on SSSC presented here. A two area power system assumed to show the ability of the proposed method. Non linear simulation results demonstrated that the designed stabilizer capable to guarantee the robust stability and robust performance under disturbances. Also, simulation results show that the PSO is a suitable tool to design stabilizer parameters.

Corresponding Author:
Ali Zarei
Department of Electrical Engineering,
Islamshahr Branch, Islamic Azad University,
Tehran, Iran.

Email: Ali_Zarei @yahoo.com

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