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A Coordinated Control Scheme of PSS and SVC Devices for Improving Power System Oscillations

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Abstract: ***The use of wide area measurements for power system stabilization is recently given a lot of attention by researchers and the power industry to avoid cascading failures and blackouts such as the 2012 black out in India. This paper presents the design of a damping controller based on wide area measurements as inputs to a SVC based controller. The usage of remote signals obtained from a Wide-Area Measurement System (WAMS) to a wide-area lead-lag (PSS) based SVC, which would degrade system damping and even cause instability. The parameters of lead-lag based SVC is optimized by Genetic Algorithm based on integral of time error of speed deviation for G-2 and G-4. Some simulation results are carried out to verify the effectiveness of proposed controller under small disturbance and large disturbance. From the simulation results, it reveals that the proposed controller damps out the inter-area oscillations effectively under different conditions.***

Keywords: Inter-area oscillations, Power System Stabilizer, Static VAR Compensator, Integral of time error.

1. Introduction

In this modern era, large power system have many interconnection and bulk power transmission over long distance, which will increase the possibility of inert-area oscillations (0.1-1 Hz) between the different control area and as a result whole system breakup or moves towards the instability [1]. The traditional approaches to damp out such type of inter-area oscillations along with local mode, installation of Power System Stabilizer (PSS) at each generator with local signal as a control input signal. However, these controllers cannot always damp inter-area oscillations effectively because they usually employ local signals as input signals and inter-area modes are not always observable from the local signals [2].

In many cases it is seen that the utilization of PSS cannot always provide enough damping for inter-area oscillations. Flexible AC Transmission Systems based (FACTS) damping controllers are alternative efficient resolutions. FACTS are designed to overcome the limitations of the present mechanically controlled power systems and enhance power system stability by applying reliable and high-speed electronic devices.

The FACTS devices are generally utilized in power system to supply fast continuous control of power flow in the transmission system by controlling the voltages at critical buses, by changing the impedance of transmission lines or by controlling the phase angles between the ends of transmission lines.

One of the promising devices from the FACTS family is the Static VAR Compensators (SVC) which is a shunt compensation component and it can rapidly regulate its susceptance to supply dynamic reactive compensation and maintain the bus voltage in power system. SVC with damping controller is effective to increase damping of electro-mechanical modes (inter-area). However, the SVC controllers will likely to react differently with other damping controllers (e.g. PSS) in a power system. The interaction among stabilizers may increase or degrade the damping of the particular modes of rotor oscillation. This problem may happen especially after the clearance of a critical fault, with FACTS devices used in the same area. Interactions between damping controllers can adversely influence the rotor damping of generators and under weakly interconnected system conditions; it can even cause dynamic instability and restrict the operating power range of the generators. To improve overall system performance, many researches focus on the coordination between PSSs and FACTS controllers [2–5].

Due to the technology advancements in power electronics, the trend of using FACTS devices in power systems both transmission and distribution levels is increasing. If FACTS and wide-area power system monitoring and control system (WAMS) technologies are used together, they can help improve the stability performance of power systems. In this study, the SVC which is a shunt connected FACTS controller based on variable impedence is used to control the tie-line power flow between two areas of a study power system.

Normally, the input control signal of SVC is speed deviation of local generator. However, in order to obtain better performance, two Phasor Measurement Units (PMUs) are installed in different areas so as to detect the inter-area oscillation more obviously. The control signal obtained by PMUs is used as the control input of SVC damping controller. Moreover, in this paper, a simple SVC based controller designed based on change in tie-line active power as a input signal. Then the other parameters of controller are optimized by Genetic Algorithm (GA) based on Integral of Time Error (ITE).

This paper is divided into five sections. The first section is the introduction mentioning about the problem of power oscillations and the adoption of a SVC to solve the power oscillation issues. Section II describes the configuration of the study power system with SVC. Section III presents the design of the proposed controller for a SVC. Furthermore, the parameters of the PSS optimization method to obtain better performance and robustness based on GA. Section IV shows the simulation results of the proposed controller and the comparison results. Finally, it ends with the conclusions in section V.

2. Study Power System

Figure 1 shows the configuration of the study power system [1]. The system consists of two symmetrical areas linked by two parallel tie-line of length 220 Km and 230 kV. Each area is equipped with two identical round rotor generators rated 20 kV/900 MVA. All four generators have identical parameters, except inertia coefficient (H), which are H=6.5s for Gen-1 and Gen-2 in area-1 and H=6.175s for Gen-3 and Gen-4 in area-2.

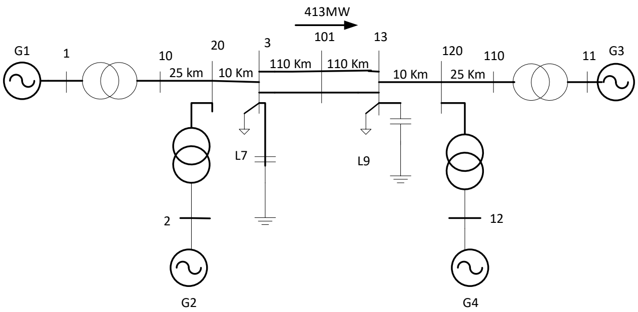

Figure 1: Kundur two-area four-machine system

3. The Proposed Control Method

3.1 Structure of PSS and SSSC

Figure 2 shows a damping controller structure which is basically used to control the susceptance to supply dynamic reactive compensation and maintain the bus voltage in power system. The change in tie-line active power of main trasmission line corridore is considered to be the input of the controllers. The damping structure considered here consists of three blocks [6], namely gain block with gain K, determines the amount of damping introduced by the PSS. A washout high-pass filter with time constant T_W, which eliminates the low frequencies that are present in the tie-line active power deviation and allows the PSS to respond only to tie-line active power changes and two-stage phase compensation block as shown in Figure 2. The signal washout block will serve as a high-pass filter and the appropriate phase-lead characteristics will be provided by the phase compensation block, with time constants T_1, T_2, T_3 and T_4.

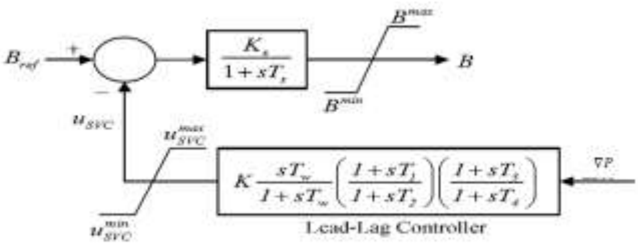

Figure 2: SVC with lead–lag controller

3.2 Optimization Method - Genetic Algorithm (GA)

The GA is basically a search algorithm in which the laws of genetics and the law of natural selection are applied. For the solution of any optimization problem (using GA), an initial population is evaluated which comprises a group of chromosomes. Initially, a random population is generated, then from this population fitness value of each chromosome is calculated. This can be found out by calculating the objective function by the process of encoding. Then a set of chromosomes termed as parents are evaluated which are known as offspring generation, which are generated from the initial population. The current population is replaced by their updated offspring that can be obtained by considering some replacement strategy. Figure 3 shows the flow chart for the Genetic algorithm [7].

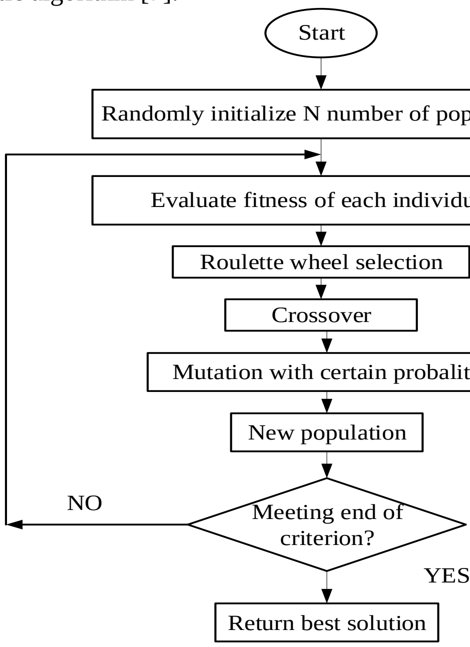

Figure 3: Flow Chat for GA

The genetic algorithm begins with a set of solutions (represented by chromosomes) called the population. Solutions from one population are taken and used to form a new population. This is motivated by the possibility that the new population will be better than the old one. Solutions are selected according to their fitness to form new solutions (offspring); more suitable they are, more chances they have to reproduce. This is repeated until some condition (e.g. number of populations or improvement of the best solution) is satisfied.

The oscillaions of a system can be seen through the tie-line active power deviation or speed deviation of rotor. To minimize the oscillation of any deviation is research objective. For kundur's two area four machines system, integral of time error of speed deviation for G-2 and G-4 taken as a objective function (J).

$$j = \int_{t=0}^{t=tsim} |\Delta\omega| \cdot t \cdot dt$$

where

t_{sim} = simulation time range.

For a stipulated period of time, the time domain simulation of the above power system is worked out and from the simulation the calculation for the objective function is calculated. The prescribed range of the PSS and damping controller are limited in a boundary. Thus the following optimization problem is formulated from the above design approach.

Minimize J

Subject to:

$$0.01 \leq T_1, T2, T3, T4 \leq 1$$
$$0.01 \leq K \leq 100$$

Where, '0.01' and '1' are the lower and upper bound of time constant and '0.01' and '100' are lower and upper bound for gain in the controllers.

4. Simulation Results of Proposed Controller

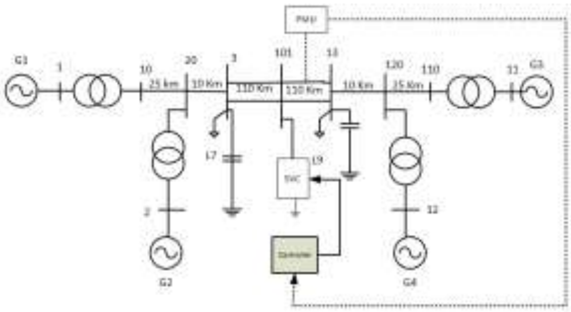

Figure 4: Two-area four-machine interconnected power system with a SSSC installed in series with the transmission line

The structure of study power system with proposed controller as shown in figure 4. The SVC is installed in shunt with the transmission line between B-101 and B-13. For wide-area control, a Phasor Measurement Units (PMUs) are installed to measure the tie line active power representing the inter-area oscillation mode. For this reserch work the value of controller gain taken as 'K' and other parameters of proposed controller after GA optimization based on ITE criterion tabulated in Table – I

Table 1: Optimized Controller Parameters Using GA

	K_T	T_1 (S)	T_2 (S)	T_3 (S)	T_4 (S)
Damping Controller	93.1426	0.7707	0.1088	0.1536	0.1380

5. Signal Stability Assessment

To perform the dynamic analysis of the closed loop test system for Kundur two area four machine system as shown in figure 4, a small pulse with magnitude of 5% as a disturbance was applied to the generator G1 for 12 cycles and in another case 3-phase fault was applied between bus B1 and bus B2. The simulation time was of 20 seconds. Then the response of tie-line active power flow from area-1 to area-2 and rotor speed deviation are examined by considering the test system with proposed controller.

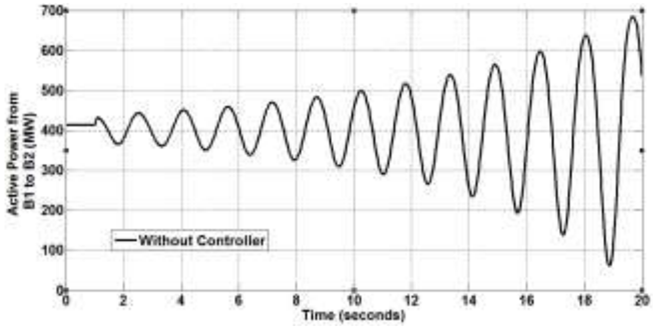

Figure 5: Tie-line active power flow without any controller

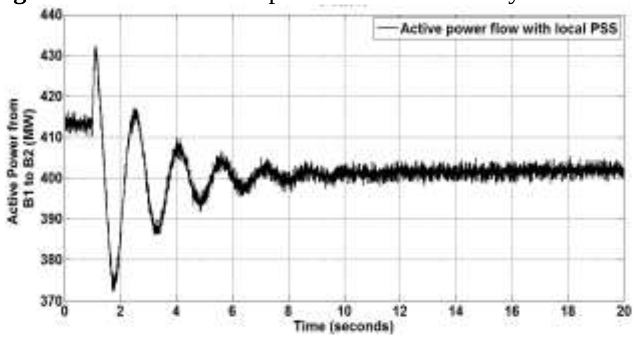

Figure 6: Tie-line active power flow with local PSS

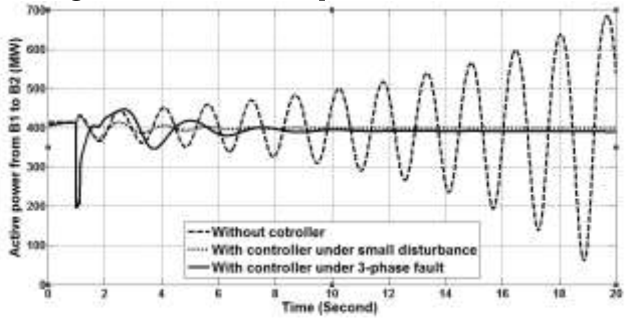

Figure 7: Tie-line active power flow with SVC and local PSS

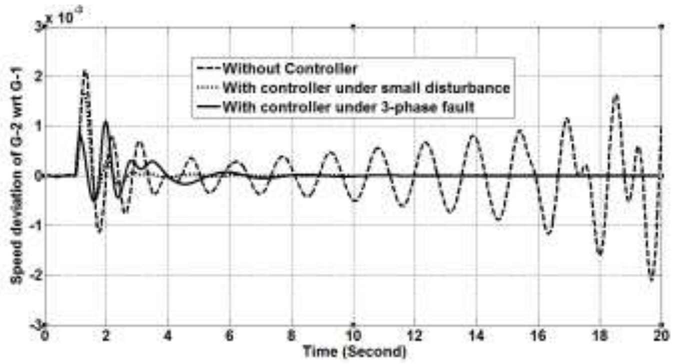

Figure 8: Speed deviation of G-2 w.r.t. G-1 with SVC and local PSS

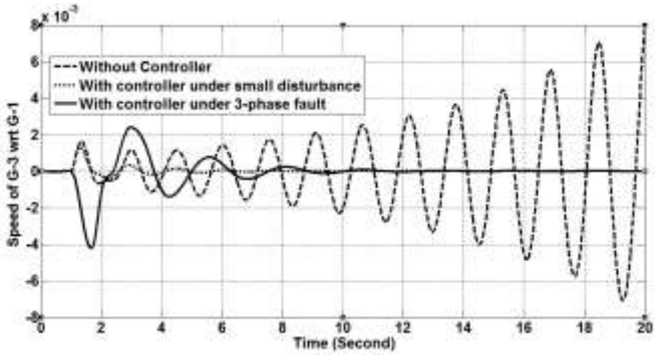

Figure 9: Speed deviation of G-3 w.r.t. G-1 with SVC and local PSS

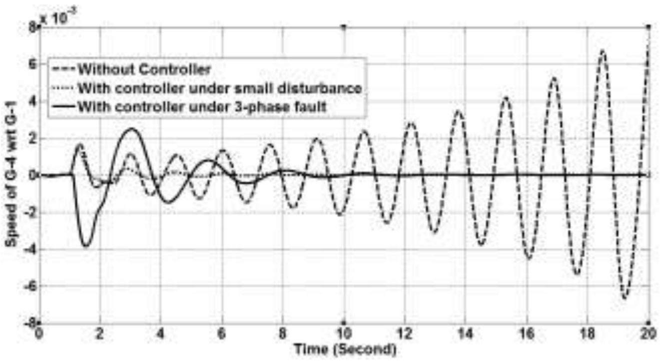

Figure 10: Speed deviation of G-4 w.r.t. G-1 with SVC and local PSS

6. Conclusion

In this paper researcher designed a wide-area damping controller to damp out the inter-area oscillations in a large scale power system using SVC for small disturbance and 3-phase fault. A time domain simulation based on minimization of an objective function for the controllers is carried out by using GA. Some simulation results are carried out to verify the effectiveness of proposed controller under small disturbance as well as 3-phase fault. From the simulation results, it reveals that the proposed controller damps out the inter-area oscillations effectively

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