Power System Oscillations suppression using Extended Automatic Voltage Regulator

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Abstract

This paper discusses and compares different control techniques for suppressing undesirable inter-area oscillation in power systems by means of Automatic Voltage Regulator (AVR) with Power System Stabilizers (PSS) and Fuzzy Logic Controllers. The performance parameters of synchronous generator, angular speed and angular position w.r.t time have been simulated for Automatic Voltage Regulator (AVR) with Power System Stabilizers (PSS) and Fuzzy Logic Controllers. Simulations have been carried on MATLAB/ Simulink software. The electromechanical oscillations suppression using E AVR (Extended Automatic Voltage Regulator) with Fuzzy Logic Controller is very robust technique.

Keywords: Fuzzy Logic Controller, PSS, EAVR, Simulink.

1. INTRODUCTION

In order to have a safe and continuous energy supply, it is necessary to provide a good performance for power system in terms of transient and steady state. With the development of extensive power systems, especially with the interconnection of these systems by weak tie-lines, electromechanical oscillations restrict the steady-state power transfer limits. Also, they may result in interruptions in energy supply due to loss of synchronism among the system generators and affect operational system economics and security. Therefore, they have become one of the major problems in the power system stability area and have received a great deal of attention.

Electromechanical oscillations have been observed in many power systems worldwide. The oscillations may be local to a single generator or generator plant (local oscillations), or they may involve a number of generators widely separated geographically (inter-area oscillations). Local oscillations often occur when a fast exciter is used on the generator, and to stabilize these oscillations, Power System Stabilizers (PSS) were developed. Inter-area oscillations may appear as the systems loading is increased across the weak transmission links in the system which characterize these oscillations. If not controlled, these oscillations may lead to total or partial power interruption.

In the past five decades the PSS have been used to provide the desired system performance under condition that requires stabilization. Stability of synchronous generator depends on a number of factors such as the setting of automatic voltage regulator (AVR). Many generators are designed with high gain, fast acting AVRs to enhance large scale stability to hold the generator in synchronism with the power system during large transient fault conditions. But with the high gain of excitation systems, it can decrease the damping torque of generator. A supplementary excitation controller referred to as PSS have been added to synchronous generators to counteract the effect of high gain AVRs and other sources of negative damping [2]. To provide damping, the stabilizers must produce a component of electrical torque on the rotor which is in phase with speed variations. The application of a PSS is to generate a supplementary stabilizing signal, which is applied to the excitation system or control loop of the generating unit to produce a positive damping. The most widely used conventional PSS is the lead-lag PSS, where the gain settings are fixed at certain value which are determined under particular operating conditions to result in optimal performance for that specific condition.

2. TYPES OF OSCILLATIONS

These oscillations are also called power swings and these must be effectively suppressed to maintain the system stability. Electromechanical oscillations can be classified in four main categories:

2.1. Local Oscillations: - Between a unit and rest of generating station and between the latter and rest of power system. Their frequency typically ranges from 0.2Hz to 2.5 Hz.

2.2. Interplant Oscillations: - Between two electrically close generating plants. Frequency can vary from 1 Hz to 2 Hz

2.3. Inter area Oscillations: - Between two major groups of generating plants. Frequencies are typically in the range of 0.2Hz to 0.8 Hz, generally called low frequency oscillations.

2.4. Global Oscillations: - Characterized by a common in phase oscillations of all generators as found on an isolated system. The frequency of such global mode is typically under 0.2 Hz.

3. VARIOUS CONTROLLERS FOR SUPPRESSION POWER SYSTEM OSCOLLATIONS

Electromechanical oscillations are generally studied by modal analysis of a linearized system model [2], [6]. However, given the characteristics of this problem, alternative analysis techniques can be developed by using bifurcation theory to effectively identify and control the state variables associated with the oscillatory problem [7], [8]. Among various types of bifurcations, saddle-node, limit-induced, and Hopf bifurcations have been identified as pertinent to instability in power systems [11]. In saddle-node bifurcations, a singularity of a system Jacobian and/or state matrix results in the disappearance of steady state solutions, whereas, in the case of certain limit induced bifurcations, the lack of steady state solutions may be associated with system controls reaching limits (for example, generator reactive power limits); these bifurcations typically induce voltage collapse. On the other hand, Hopf bifurcations describe the onset of an oscillatory problem associated with stable or unstable limit cycles in non linear systems (for example, interconnected power system). The availability of Flexible AC Transmission System (FACTS) controllers [12], such as Static Var Compensators (SVC), Thyristor Control Series Compensators (TCSC), Static Synchronous Compensators (STATCOM), and Unified Power Flow Controller (UPFC), has lead their use to suppress inter-area oscillations [13].

3.1 Power System Stabilizers:- A PSS can be viewed as an additional block of a generator excitation control or AVR, added to improve the overall power system dynamic performance, especially for the control of electromechanical oscillations. Thus, the PSS uses auxiliary stabilizing signals such as shaft speed, terminal frequency and/or power to change the input signal to the AVR. This is a very effective method of enhancing small-signal stability performance on a power system network. The block diagram of the PSS used is depicted in Figure. 1

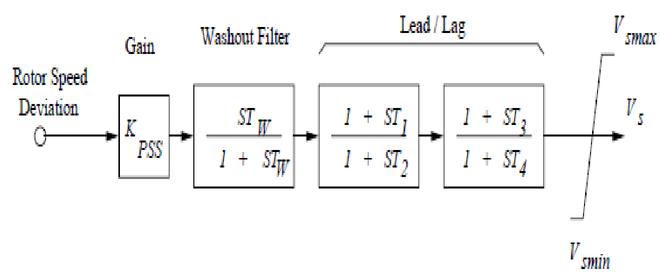

Figure 1 PSS model used for simulations, where Vs is an additional input signal for the AVR [2].

3.2 Static VAR Compensator (SVC)

SVC is basically a shunt connected static var generator/load whose output is adjusted to exchange capacitive or inductive current so as to maintain or control specific power system variables; typically, the controlled variable is the SVC bus voltage. One of the major reasons for installing a SVC is to improve dynamic voltage control and thus increase system loadability. An additional stabilizing signal, and supplementary control, superimposed on the voltage control loop of a SVC can provide suppression of system oscillation equivalent shunt susceptance of the controller. The SVC is basically represented by a variable reactance with maximum inductive and capacitive limits to control the SVC bus voltage, with an additional control block and signals to damp oscillations, as shown in Figure 1.2.

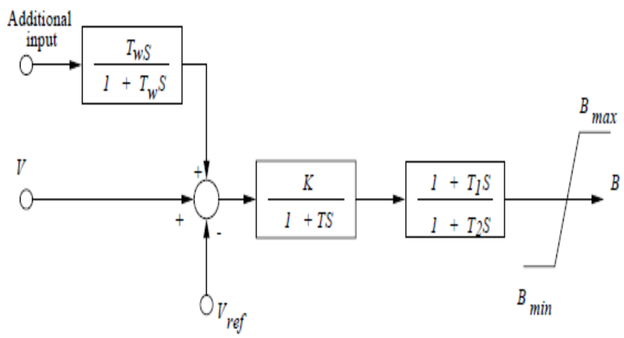

Figure. 2. Structure of SVC controller with oscillation suppression [2]

3.3 Thyristor-Controlled Series Capacitor (TCSC)

Many different techniques have been reported in the literature pertaining to investigating the effect of TCSC on power system stability. Several approaches based on modern control theory have been applied to TCSC controller design. However, the controller requires all system states which reduces its applicability. Thyristor-controlled series capacitor (TCSC) is a series FACTS device which allows rapid and continuous changes of the transmission line impedance It has great application potential in accurately regulating the power flow on a transmission line, suppression inter-area power oscillations, mitigating sub synchronous resonance (SSR) and improving transient stability.

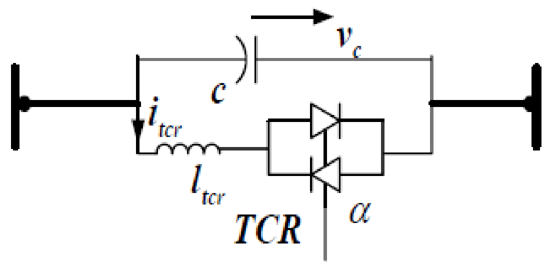

Figure 3 TCSC Model

The model to be adopted for any device in power systems analysis must be in accordance with the type of study involved and the tools used for simulation. Since this work is concerned with the application of the TCSC for stability improvement, the TCSC model used must rely in the assumptions that are typically adopted for transient stability analysis, i.e., voltages and currents are sinusoidal, balanced, and operate near fundamental frequency

3.4 Unified Power Flow Controller (UPFC)

A unified power flow controller (UPFC) is the most promising device in the FACTS concept. It has the ability to adjust the three control parameters, *i.e.* the bus voltage, transmission line reactance, and phase angle between two buses, either simultaneously or independently. A UPFC performs this through the control of the in-phase voltage, quadrature voltage, and shunt compensation.

To suppress the power system oscillations, Electricite de France developed two state feed back controllers aiming to effectively suppress electromechanical oscillations present in power system. These are Desensitized Four Loop Regulator (DFLR) and Extended Desensitized Four Loop Regulator(EDFLR) to suppress local and inter area electromechanical oscillations[1-2].

4 EXTENDED AUTOMATIC VOLTAGE REGULATOR WITH FUZZY LOGIC CONTROLLER

A Extended Automatic Voltage Regulator is developed using the concept of fuzzy basis functions. The FPSS is designed for cogeneration, but simulation studies are based on a one machine-infinite bus model. The method of Power System Stabilizer is designed for using linearized model in the specific operating point show a good control performance in the specific operating point. But these approaches are difficult to obtain a good control performance in case of change in various operating conditions. Therefore fuzzy logic control scheme is used in power system stabilizer to achieve the limitations of conventional power system stabilizer this new method is known as fuzzy logic based power system stabilizer. This approach to design power system stabilizer based on two input fuzzy logic controlled is used here for improving small signal stability of the system.

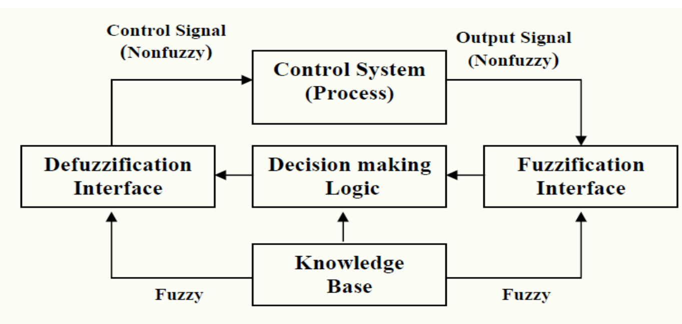

Figure.4 The principle of fuzzy logic Controller.

The fuzzy controller used in power system stabilizer is normally a two-input and a single-output component. It is usually a Multi Input Single Output (MIS0) system. The two inputs are change in angular speed and rate of change of angular speed whereas output of fuzzy logic controller is a voltage signal. The aim of fuzzy control systems is normally to replace a skilled human operator with a fuzzy rule-based system. The fuzzy logic controller provides an algorithm which can convert the linguistic control strategy based on expert knowledge into an automatic control strategy. Fig. 1 illustrates the basic configuration of a fuzzy logic controller which consists of a fuzzification interface, a knowledge base, decision making logic, and a de-fuzzification interface.

A fuzzy power system stabilizer (FPSS) is developed using the concept of fuzzy basis functions. The linguistic rules, regarding the dependence of the plant output on the controlling signal, are used to build the FPSS. The FPSS is designed for cogeneration, but simulation studies are based on a one machine-infinite bus model. The method of Power System Stabilizer is designed for using linearized model in the specific operating point show a good control performance in the specific operating point. But these approaches are difficult to obtain a good control performance in case of change in various operating conditions. Therefore fuzzy logic control scheme is used in power system stabilizer to achieve the limitations of previous discussed power system stabilizer this new method is known as fuzzy logic based power system stabilizer. This approach to design power system stabilizer based on two input fuzzy logic controlled is used here for improving small signal stability of the system.

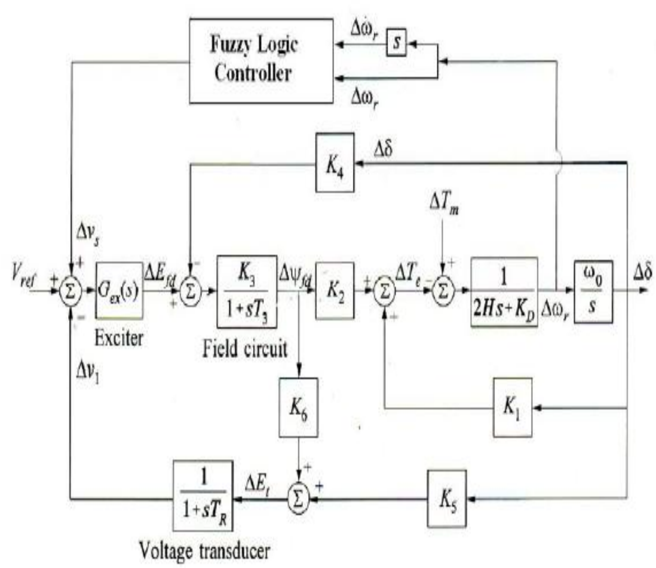

Figure 5 Conventional extended automatic voltage regulator with Fuzzy Logic Controller[5]

Initially set the value of K_{in2} and K_{out} equal to unity and study the effect of variation of third parameter on the response of the system and among them select the most suitable value then vary other variables keeping two parameter constant. Follow this procedure to investigate the effect of all three constants on the system. Then after studying the effect of these parameters on system, suitable selection can be made following the similar procedure until we get the desired response.

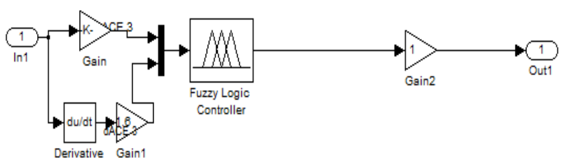

Fig.6 . Fuzzy Logic Controller used with Automatic Voltage Regulator

5. SIMULATION RESULTS

Simulink is a software package used extensively for modeling, simulating, and analyzing dynamic systems. It has the advantage of supporting linear and nonlinear systems, modeled in continuous time, sampled time, or a hybrid of the two. Systems can also be multirate, i.e., have different parts that are sampled or updated at different rates.

With the help of MATLAB and its Simulink feature, the power system model along with extended automatic voltage regulator has been developed and simulated.

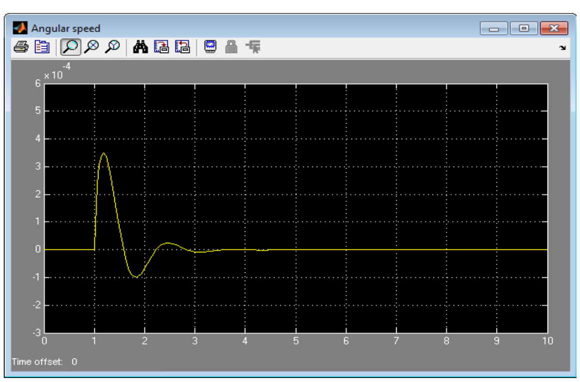

Fig.7 Angular speed variation w.r.t time.

The system performance parameters angular speed and angular position have been simulated w.r.t time. Fig.3 and Fig. 4 show variation in angular speed and angular position w.r.t. time respectively for Automatic voltage Regulator (AVR) with Power System Stablizer (PSS).

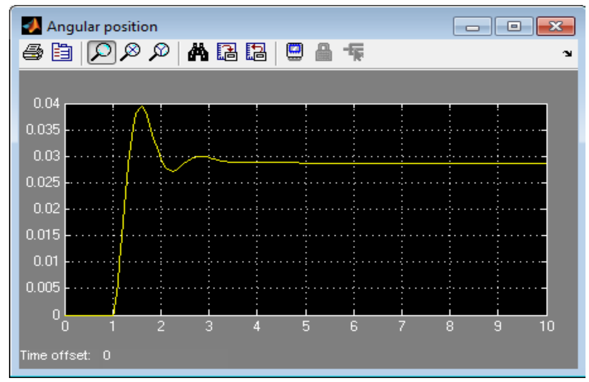

Fig.8 Angular position variation w.r.t time.

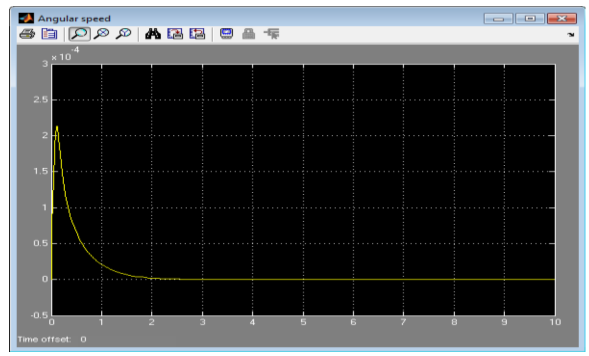

Fig.9 Angular speed variation w.r.t time.

Variations in angular speed and angular positions w.r.t time have been depicted in Fig.4 and Fig.6 respectively for extended Automatic Voltage Regulator with Fuzzy Logic Controller.

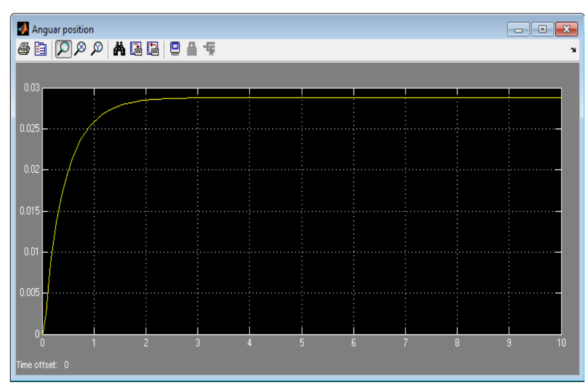

Fig.10 Angular position variation w.r.t time.

6. CONCLUSION

Simulations have been carried out by using MATLAB/Simulink software for angular speed and angular position. Angular speed and angular position for Automatic Voltage Regulator with Power System Stabilizer has more oscillations as compare to Extended Automatic Voltage Regulator with Fuzzy Logic Controller. Therefore, Extended Automatic Voltage Regulator is more robust to suppress power system oscillations as compare to conventional oscillation suppression techniques.

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