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OVERVIEW ON DESIGN TECHNIQUES OF POWER SYSTEM STABILIZER FOR SYSTEM STABILITY

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ABSTRACT: The major problem in power system operation is related to small signal instability caused by insufficient damping in the system. The most effective way of countering this instability is to use auxiliary controllers called power system stabilizers, to produce additional damping during low frequency oscillations in the system. The use of power system stabilizers (PSS) to damp power system swing mode oscillations is of practical importance. This paper discusses the experience in assigning PSS projects in an undergraduate control design course to provide students with a challenging design problem using three different techniques and to expose them to power system engineering. The details of the PSS design projects using root-locus, frequency domain, and state-space methods are provided.

I. INTRODUCTION

Power system stability has received a great deal of attention over the year. Stability is now a major concern in planning and operating electric power System. A large interconnected power system is exposed to many disturbances, which make the system unstable and thus are a threat to its security. In recent days, the effects of these disturbances are more serious considering the intensive use available electric power and its wide transmission. These disturbances result in electromechanical oscillations being set up in the interconnected system. The capability of the system to achieve an operating equilibrium after disturbances are caused in it depends on its inherent strength and on the nature and intensity of the disturbance .Increasing attention has-been focused on the effect of excitation control on the damping of oscillations, which characterize the phenomena of stability. In particular it has been found useful and practical to incorporate transient stabilizing signal derived from speed, terminal frequency or accelerating power superimposed on the normal voltage error signal to provide for additional damping of this oscillation. Such device is known as Power System Stabilizer (PSS). The PSS extend the system stability limits by modulating generator excitation to provide damping to the oscillation of synchronous machine rotors relative to one another. The PSS produces a component of torque, which is in phase with the rotor speed deviations, in order to enhance system damping. Damping due to low frequency oscillation problems are very difficult to solve because power system are very large, complex. Therefore it is very necessary to utilize efficient techniques for implementation. From this perspective many successful methods and algorithms have been developed .This paper presents a survey of literature on the various methods, algorithms and optimization methods applied to solve the PSS problems. The effect of power system stabilizers on the oscillatory modes of a generating plant, which consists of a number of equal, identical generators, is discussed. It is shown that the power system stabilizer design and the type of power system stabilizer input may alter the damping produced by the stabilizer on the exciter mode and the intra-plant electromechanical modes. A power system stabilizer which is designed to match the ideal phase lead over a wide frequency range is shown to add damping to plant, inter area and intra-plant electromechanical modes. Up to now, generally speaking, power oscillations could be divided into three kinds of types, that is, local mode, inter-area mode, and global mode. Local oscillations lie in the upper part of that range and consist of the oscillation of a single generator or a group of generators against the rest of the system. In contrast, inter-area oscillations and global oscillations are in the lower part of the frequency range and comprise the oscillations among groups of generators. As a classic oscillation mode, there are relative mature technologies and devices such as kinds of power system stabilizers equipped as a part of the additional excitation system of machine unit to provide the efficient damping ratio to suppress the local oscillation. Never the less, as for the inter-area and the global oscillation mode, the classic stabilizer cannot play an important role to damp such oscillation very well. The leaded result is that the line power transmitted from one area to another will form the instable oscillation with the unease attenuation characteristic. Power System Stability, its classification, and problems associated with it have been addressed by many CIGRE and IEEE publications. The CIGRE study committee and IEEE power systems dynamic performance committee defines power system stability as: "Power system stability is the ability of an electrical power system, for given operating conditions, to regain its state of operating equilibrium after being subjected to a physical disturbance, with the system variables bounded, so that the entire system remains intact and the service remains uninterrupted".

II. POWER SYSTEM STABILIZER (PSS)

Power System stabilizer (PSS) has board application throughout the world. Power system stabilizer (PSS) applied to generate exciter to limit the excitation system phase lag in the frequency range corresponding to the natural frequency of the interconnected system. With interconnection of large electric power system, low frequency oscillations have become the main problem for power system small single stability. They restrict the steady state power transfer limits, which therefore affects operational system economics and security. Considerable efforts has been placed on the application of PSS's to damp low frequency oscillation and thereby improve the small signal stability of power system. [8].The introduction of the supplementary controller for the power system not only improves the dynamic performance but also increase the stability margin. Power systems stabilizers have been developed, using liner control theory to damp the oscillation of synchronous machine following any disturbance. Power system stabilizer design and characteristics have been discussed and dynamic model of PSS with excitation control system and generator for small perturbation has been analysed.

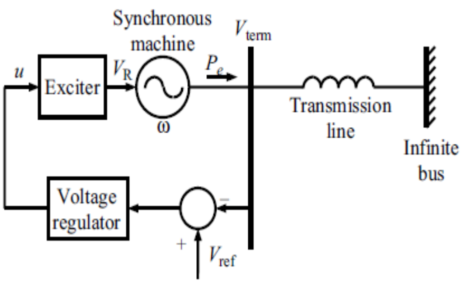


Fig. 1. Single-machine infinite-bus system.

Note that the conventional PSS path comes into the summing junction with a positive sign. Here, we use a negative sign, balanced by a sign inversion in the feedback path, because the MATLAB root-locus function assumes negative feedback. The open- and closed-loop transfer functions required in various design stages are generated from the Simulink diagram by opening appropriate connections.

The schematic below represents different methods of PSS design:-

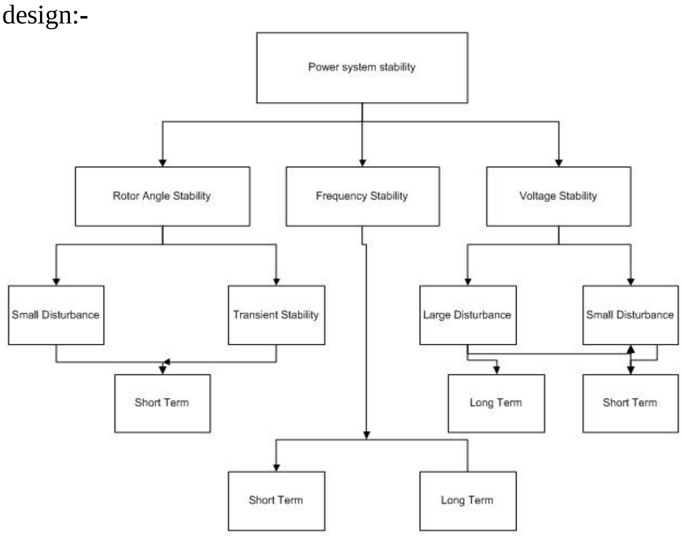


Fig.2 Different methods of PSS

III. POWER SYSTEM STABILITY ENHANCEMENT

Flexible AC Transmission System (FACTS) devices are example of enhancing power systems stability by controlling power flow at transmission end. They are divided into series, shunt and series-shunt categories according to the manner of device connection with the system. The concept behind enhancing power system stability by series FACTS devices such as Static Series Synchronous Compensator (SSSC) is to increase active power flow during faulty condition consequently decreasing area A1 and increasing area A2 [21]. On the other hand, shunt devices as Static Synchronous Compensator (STATCOM) boost power system transient stability by injecting reactive power into system to support the system voltage during disturbance and ultimately leading to decrease of area A1 and increasing area A2 [22]. The most commonly used FACTS controller is Unified Power Flow Controller (UPFC). It consists of two branches; one is connected in series and the other is in shunt with the system. UPFC controller uses notion of both series and shunt FACTS controllers for increasing power system stability effectively than any other FACTS controllers [19,23].Controlled Islanding is a technique in which whole power system is divided into sections, without having any interconnection, to avert major blackouts [15]. Controlled islanding is the last line of defence in strategy to keep power system stable. Additionally, it is not proposed as the answer to all instability problems in the system [20]. High Voltage DC (HVDC) transmission system is potentially a shield against synchronism loss. Nonetheless, it poses problem of voltage instability following disturbance, if the system depletes reactive power reserves [24].The control actions at generator end to thwart the system instability are either in terms of excitation system or power system stabilizers or at mechanical end of power plants. The main cause of transient instability of generator is inability of mechanical torque to quickly balance out changes in electrical torque [15] and also generator rotor inertia plays major role. After disturbance the electrical torque can be resolved into two components, one is synchronizing torque and other is called damping torque given by,

$$\Delta T_E = K_S \Delta\delta + K_D \Delta\omega \qquad \text{........ (2)}$$

Where ΔT_E is load angle also known as torque angle and K is constant. The first term of Equation (2) is synchronizing torque. This torque is dependent on air gap magnetic flux and magnetic coupling between rotor and armature of synchronous generator. This component of torque can be enhanced by high initial response Automatic Voltage Regulator (AVR) and negative field forcing capability of Exciter as well [3,24].Excitation system comprises of AVR and Exciter. The second component of Equation (2) is damping torque. It has very profound impact on small signal stability and generator dynamics during transient state following short circuit fault. Damping torque results from the phase lag or lead of excitation current [20,22]. The first swing transient instability is due to lack of sufficient synchronizing torque. Power system can diverge after convergence of first swing mainly because of insufficient damping torque [16].Currently, installed excitation systems are very fast responding systems and can immediately take corrective measures following very small oscillations. Nevertheless, from the time of recognition of desired excitation action to its real fulfilment, there is inevitable time delay owing to high time constant of field and armature windings. During this time period, position of oscillating system is bound to change and thus resulting in need of new excitation adjustment. The overall outcome of this time lag is induction of oscillations at the generator end. Power System Stabilizers (PSS) can effectively be used to damp out generator electromechanical oscillations by minimizing the phase lead and lag between synchronously rotating armature ux and rotor. AVR along with PSS are used to enhance power system stability [15,21].The focus of this research is transient stability enhancement by using efficient controlling at generator end, as it is a primary control.

IV. REVIEW OF DIFFERENT PSS TECHNIQUES

A. PID Control Approach

PID is used for stabilization in the system. The input is the change in speed from the generator. The aim is to control the angle between load and speed of generator. The PSS parameters are tuned from Open loop transfer function to close loop based on Fuzzy logic. Therefore, the open loop transfer function and maximum peak response parameter make the objective function which is used to adjust PID parameters.

B. LAG-LEAD Design

The washout block is used to reduce the over response of the damping during extreme events. Since the PSS produces a component of electrical torque in phase with speed deviation, phase lead blocks circuits can be used to compensate for the lag between the PSS output and the control action(hence lead-lag). It proves its value when the disturbance is multi natured.

C. Pole Placement Method

The pole placement method is applied to tune the decentralized output feedback of the PSS. The objective function is selected to ensure the location of real parts and damping ratios of all electro mechanical modes. At the end of the iterative process, all the electromechanical modes will be moved to the region if the objective function converges to zero [7][8].

D. Model predictive Control

It can handle non linarites and constraints in saturated way for any process model. In these techniques an explicit dynamic model of a plant is used to predict the effect of future actions of manipulated variables on the output.

E. Linear Matrix Inequalities:

The important feature is the possibility of combining design constraints into a single convex optimization problem. it is used in many engineering related problems. The condition that the pole of a system should lay within this region in the complex plane can be formulated as an LMI constraint.

F. Linear Quadratic Regulator

These are well known as compared to lag-lead stabilizers. This is used as a state feedback controller. A co-ordinated LQR design can be obtained with Heffron- Phillips Model and it can be implemented by using the information available within the power system. During the presence of faults even these methods prove to be stable [8].

G. Genetic Algorithm

Genetic algorithm is independent of complexity of performance parameters and to place the finite bounds on the optimized parameters [8]. As a result it is used to tune multiple controllers in different operating conditions or to enhance the power system stability via PSS and SVC based stabilizer when used independently and through different applications.

H. Fuzzy Logic Control

These are rule based controllers. The structure of this logic resembles that of a knowledge based controller; it uses principle of fuzzy set theory in its data interpretation and data logic. It has excellent response with small oscillations. The controller is robust and works effectively under all types of disturbance. It has very short computation time [9] [10].

I. Neural Network

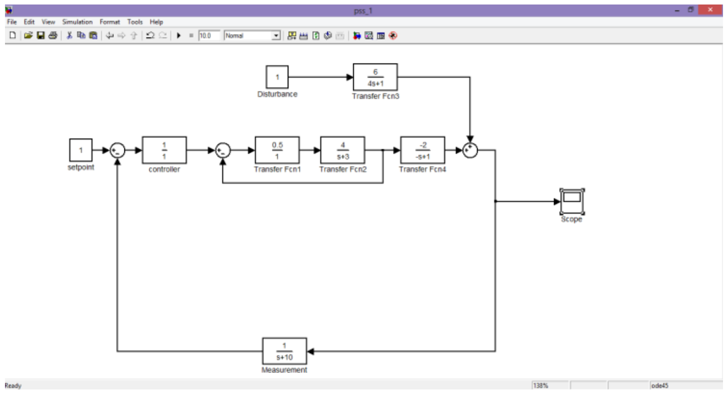
Neural Network is used to approximate the complex non-linear dynamics of power system. Magnitude constraint of the activators is modelled as saturated non-linearity and is used in Lyapnov’s stability analysis [9] [10]. The overshoot is nearly same as conventional PSS but settling time is drastically reduced.

J. Anfis PSS

The actual design method may be chosen based on real time application and dynamic performance characteristics. If the training data and algorithm are selected properly then good performance can be observed.

V. SIMULATION AND RESULTS

The simulation model for system stability issues are as given below:-



The stability problems regarding this system are given below in the results:-

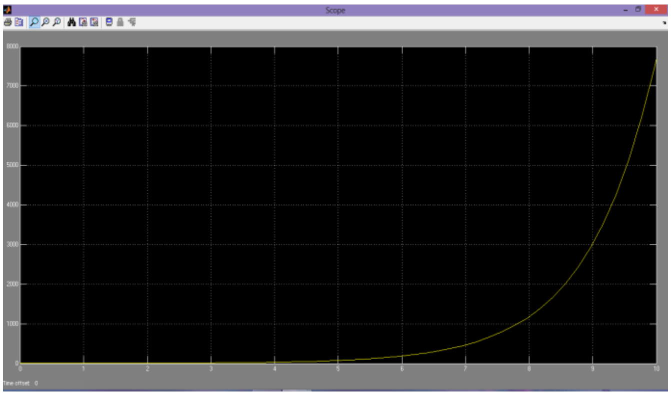


Fig 3. - Unstable system

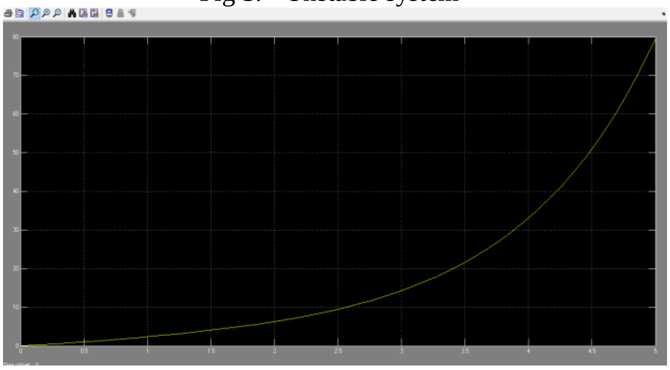


Fig 4. - Unstable system

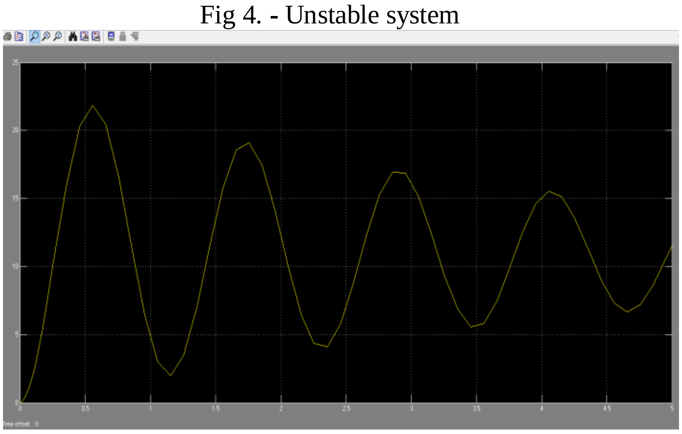


Fig 5. –Distorted waveforms

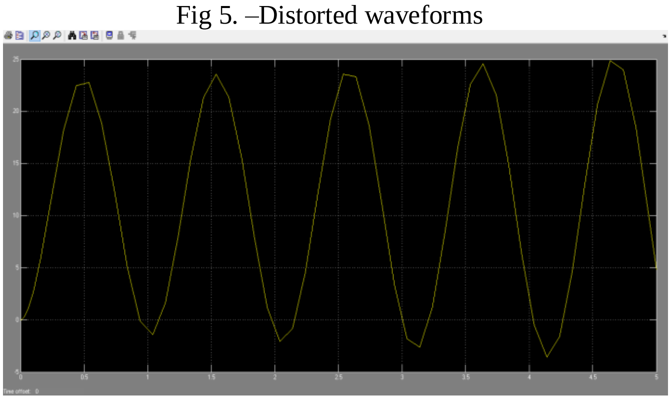


Fig 6. –Distorted waveforms

VI. CONCLUSION

Power system stabilizer design can have a considerable effect on the damping of the electrochemical modes associated with a generating plant consisting or identical generator unit. A power system stabilizer designed to match the ideal phase lead over a wide frequency range generally has a beneficial effect on the damping of both inter-area, local (or plant), and intra-plant modes. This paper has presented an overview of power system stabilizers design for power system stability improvement.

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