CHAPTER-1

INTRODUCTION

1.1 POWER SYSTEM DYNAMICS

The power system behaves essentially as a set of coupled oscillators which are continuously perturbed due to load fluctuations and parameter changes. The amortisseur effects provide damping of the higher frequency oscillations and dynamic instabilities are associated with the lower frequency modes. Oscillations of small magnitude and low frequency in the range 0.5 Hz to 2.5 Hz often persist for longer period of time and cause limitation on power transfer capability [2], [23]. It is also assumed that the voltage regulator introduces negative damping at increased load [2], [22].. To offset this effect and to improve system damping, in general, artificial means of producing torques in phase with the speed are introduced. These are called SSSs. The network used to generate SSSs is called PSS [22].

A major concern of power engineers is to keep the power system under control at all times. In recent years the utilization of additional or supplementary control measures for improving the dynamic stability of power systems has received much attention [5], [6], [8]. The PSS design techniques continue to take advantage state-of-the-art control theories. PSS based on eigenvalue analysis methods, where the stabilizer loop parameters are chosen to counteract some critical system modes, have been applied to many power systems [2], [48], [49]. The application of LOC theory for the purpose of deriving a constant feedback gain matrix for the stabilizer loop has been extensively studied [2], [48], [49]. Considerable efforts have been made to develop adaptive control design for power systems. Unlike the conventional fixed parameter controller the adaptive control, which adapts itself to the change of system configurations and load levels has considerable potential for improving dynamic stability of power system performance over a wide range of operating conditions. Two main approaches to adaptive control have been employed in power system control: STAC and MRAC [8], [11].

In the STAC scheme, parameter identification techniques such as the RLS method is used to identify system parameters online and these parameter estimates are then incorporated in the control policy. If some or all of the parameters estimated are used to form the control action without the need of intermediate control design calculations, the STAC is called an implicit selftuner. On the other hand, if the estimated parameters are used online with control design calculations to form updated controller parameters, the STAC is called an explicit selftuner. In the MRAC scheme a reference model, exhibiting the desired system response is included in the control strategy. The error between the output of the reference model and that of the actual system is used to update the controller parameters with the objective of the system output converging to the model output [8], [31].

In STAC scheme, it is very difficult to design an online identifier [62], [31]. On the other hand, in the MRAC five possible types of instability mechanisms such as: parameter drift, linear instability, fast adaptation, high frequency instability and throughput instability were reported [68]. The parameter drift occurs due to the presence of bounded disturbances. Linear instability is due to high controller gains, which excite the parasitics and lead to instability. In this case, the feedback loop is unstable even with fixed gains that is, with adaptation switched off. The fast adaptation instability can arise when the speed of adaptation is high and parasitics are present. High frequency instability is due to the interaction of reference inputs with the parasitics. In contrast to linear instability, fast adaptation and high frequency instability disappear when the adaptation is switched off. The fifth type of instability is throughput instability, due to parasitics in the throughput that is, in the direct path from the input to the output. Although adaptive control based on STAC or MRAC have been reported to be effective, the inherent assumptions, different instabilities and nonlinearities associated with adaptive controllers raise a number of basic questions whose appropriate answers may complicate the control structure. The parameter estimator design in STAC and the appropriate selection of reference model in MRAC meet many difficulties [8].

It has long been the aspiration of the designers of adaptive control to have at their disposal a device that will automatically tune itself to the surrounding environment in order to maintain ideal closed loop behavior without instability problems and much complexity of computations. Thus the ultimate aim of the designer is to provide a device which will control the plant even with minimal engineering input onsite. MRAC systems have been the subject of investigation for a considerable time. The first MRAC scheme that attracted wide attention was the so-called MIT rule. This was based on sensitivity approach to design, which assumed that environmental changes were slow. However, the rule was subsequently shown to be unstable for specific input trajectories and for specific plants. A priority in the design of MRAC systems thus became one of absolute stability. But absolute stability deals with static cases whereas practical systems are generally dynamical in nature. The increasingly challenging dynamic problems however, are not hopelessly unmanageable.

If the plant model X(t) and the reference model $X_m(t)$ behaviors be given by the nth order state equations:

$$\dot{X}(t) = A\,X(t) + B\,U(t) \tag{1.1}$$

$$\dot{X}_m(t) = A_m\,X_m(t) + B_m\,r(t) \tag{1.2}$$

where, X is the state vector, U is the control input, A is the system matrix, B is the control matrix and the subscript m refers to model respectively. Then an error function can be formed by writing

$$X_e(t) = X_m(t) - X(t) \tag{1.3}$$

The aim of the control is to force this error function to zero. This can be done by choosing a Lyapunov function [31] or using Popov's hyperstability theory [31], [47].

The basis for many designs was the Lyapunov's second method [31]. An extension to Lyapunov's methods based on the SPR lemma was also used as a basis of adaptive control synthesis [31], [35] [40]. The main problem with the Lyapunov-based methods was the choice of a suitable Lyapunov function. Thus more general adaptive laws were developed by Landau [31] based upon hyperstability theory of Popov [47]. These laws have been tested in simulation and implementation studies and been shown to be robust in the face of external disturbances and plant parameter variations. Thus the hyperstability based MRAC approach has the definite advantage of stability assurance which is lacking in STAC and in others [68], [60]. However, the synthesis of those MRAC strategies still requires to satisfy Erzberger's model matching conditions, a plant system identification, linear controller synthesis and other minor tasks [31], [54].

In case of power system the application of LOC theory to the design of controllers encounters difficulties due to the complexity of modern power systems, with high transmission voltages and large ratings of individual units [72]. Another problem is the degree of uncertainty or vagueness concerning the values of plant parameters, which often vary according to the operating conditions. One way of dealing with the situation is the use of MRAC systems [32], [75].

The intention in this thesis is to present an extension of the hyperstability based MRAC that requires MCS. Thus the MCS algorithm is a significant extension of MRAC. Then MCS algorithm is applied to power systems for improving dynamic stability. The adaptive controllers in power system is often used as a supplementary controller in conjunction with a CFC [8]. While the CFC regulates the normal voltage and frequency adjustments, the supplementary controller is used to improve the dynamic stability, as restoring the system to normal operating condition after suffering a disturbance.

To avoid the burden of choosing a reference model, a NACS is also proposed in this thesis. This new adaptive scheme has been developed from the MCS algorithm. All these schemes have been applied to SMIB power system and MMPS.