CHAPTER 1

INTRODUCTION

1.1 GENERAL

Nowadays, electric power systems have evolved through continual growth in interconnection, use of new technologies and controls. This formulates the power systems as one among the most complex systems to be planned and safely operated. Safe operation of electric power system is principally related to its stability. Even though power system stability can be broadly defined according to different operating conditions, an important problem that occurs frequently is that of transient stability. Transient stability is the dominant stability problem on most systems and it is the focus of utility industries concerning system stability evaluation. Transient stability assessment is concerned with the behaviour of the synchronous machines after they have been perturbed following a sudden large disturbance. The power system operates in a secure manner from the transient stability viewpoint, when the generators maintain synchronism after the system is subjected to severe disturbances.

According to IEEE/CIGRE task forces, power system stability is defined as the “Ability of an electric power system, for a given initial operating condition, to regain a state of operating equilibrium after being subjected to a physical disturbance, with most system variables bounded, so that practically the entire system remains intact.” The rotor angles of the synchronous generators in the systems are the variables to be bounded in the
transient stability phenomena. The duration of this stability is about a few hundreds of milliseconds after the final change in power network.

The electric power industry is a field enduring constant changes. The increase of power demand tends to make the power systems larger and more complicated and the dependence on electric power will be ever increasing. Thus, power outages will have more social and economic influences. So, it is very important to comprehend the state of the power systems and operate them in a stable manner. The implementation of open market environment and the restructuring of the electric power industry into separate generation, transmission and distribution entities have forced modern electric utilities to operate their systems under stressed operating conditions closer to their security limits. Under such fragile conditions, any breach of security can have far reaching impact. This justifies the continuous efforts to develop fast and accurate techniques for investigating the stability of power systems. Since, the stability phenomena limits the transfer capability of the systems, there is a need to ensure stability and reliability of the power system due to economic reasons.

The presence of new era regulators, controllers (Flexible AC Transmission Systems-FACTS) and other nonlinear components make the protection of power system very difficult. If the protection relay fails during a local fault, the neighbouring systems are also affected. Isolation of faulted transmission lines and redirection of power flow to other transmission lines may cause these transmission lines to be over loaded and they are tripped by relay operation. This cumulative action may lead to a terrible blackout. The economic loss in that kind of blackout is prohibitive and should be avoided by all means. Therefore, transient stability assessment and control for modern power systems is imperative and necessary.
1.2 SCOPE OF THE THESIS

The major objectives of this thesis are investigation and control the transient stability of electric power systems. The key objective of this thesis is to accomplish a detailed investigation of the transient stability of electric power systems, which includes both identification of stability status (Stable / Unstable) and estimation of the degree of stability or instability. To achieve a rapid and accurate transient stability assessment to guarantee the stability of the systems, Support vector classifier, a recently developed pattern recognition technique is used for identifying the status of electric power systems.

To initiate the necessary control actions to steer the system away from vulnerable situation, Support Vector Regression machine is employed to predict the critical clearing time, transient stability index and the energy margin of electric power systems subjected to severe disturbances. The degree of stability / instability of the power system can be obtained from the transient stability index and energy margin. Thus, they offer guidance for developing preventive or corrective control actions. Another important goal is to develop an event based preventive control action by rescheduling generators economically.

New England 39 bus test system and IEEE 17 generator 162 bus reduced Iowa system are considered as test systems to demonstrate the usefulness of the proposed algorithms. The IEEE 3 machine 9 bus system, IEEE 50 generator equivalent North American system and a practical South Indian grid are also added with the former two test systems for evaluating the algorithms considered in this work.
1.3 CONCLUSION

For the safe operation of power system, it is important that the transient stability of the system should be assessed in online. The conventional transient stability analysis methods require considerably long computing time to examine the during fault and post fault system behaviour, in order to obtain a correct critical clearing time or the degree of stability. Consequently, fast methods are required for assessing transient stability, preferably in real-time or even faster. Artificial Neural Network (ANN) has been proposed as an efficient alternative for Transient Stability Assessment (TSA) problem and the implementation of which requires extensive training process. In general, this is the major drawback of ANN applications to a power system that requires huge number of input variables to train an ANN. Increasing simulation speed to achieve real time and faster than real time performance is still a challenge. Support Vector Machine (SVM) is a new class of machine learning method for both regression and classification problems. They have firm grounding in Vapnik and Chervonenkis (VC) theory of statistical learning, and essentially implements Structural Risk Minimization (SRM). This made them feasible to devise fast training techniques even with huge training sets and high input dimension. SVMs are very well suited for TSA, because the learning focus is on the security border.

Despite its prominent properties, SVM is also not favoured for very large data set. In a real power system with good data recording, the data available are very large. In many real-world applications, the effects of the training points are different. But in SVM, all training points of a class are treated uniformly. The other difficulties in SVM are the identification of kernel functions which satisfy the Mercer’s conditions, the estimation of kernel parameters and error / margin trade-off parameter C.
For investigating the stability of power system precisely by overcoming the drawbacks of SVM, the following technically improved SVMs have been employed. The Clustering Based SVM (CB-SVM) is constructed to identify the stability status of power system which employs K-Means clustering algorithm and Fuzzy-C-Means clustering algorithms. To provide high priority to the crucial training points and to reduce the effects of noises outliers present in the training and testing data, thereby improve the performance of SVM, Fuzzy Support Vector Machines (FSVM) have been constructed and applied to TSA. Instead of relying on the decision of a single SVM classifier, three SVM classifiers are united using a fuzzy system and their combined decision is used to identify the operating status of a multi-machine system. Multi-class support vector machines have been employed to estimate the position of rotors of individual generators and hence the degree of stability of the system can be known.

Apart from the classification of power system as stable or unstable, if the degree of stability or instability is known, then the operator can take remedial actions to ensure the system stability. Interestingly, SVMs have also found applications in the domain of function approximation or regression. Performance of SVM can be enhanced by proper parameters setting. Genetic Algorithm (GA) has been employed to optimize the parameters of SVM such that the generalization error is minimized. In this work, both support vector classification and regression machines are used for fast transient stability investigation. Based on the output of regression machine, remedial control measures have been identified and deployed to control system dynamics so that the system security will not be jeopardized during abnormal operating states.

The thesis is organized as follows:

The chapter 2 presents the detailed literature survey made in the area of power system transient stability analysis. Earlier research work in the
field of TSA is categorized into conventional techniques and application of computational intelligence techniques. Apart from assessment, works done by earlier researchers in preventive control have also been studied and presented. An overview of SVM and other computational tools used are described in chapter 3.

To identify the stability status of power systems, Support vector Classifiers are trained and tested. The results are reported in chapter 4. This chapter consists of five sections. In the first section, CB-SVM has been developed and applied for transient stability classification. In the second section, to enhance the performance of SVM by including the fuzzy nature of training data, FSVMs are utilized and their performance is compared with standard SVM. In the third section, Fuzzy Combined Multiple SVM (FCSVM) classifiers have been built to provide a more accurate and robust power system stability classification. The fourth section employs Multi-Class SVM classifiers to predict the rotor angles of generators in a multi-machine system. A two-stage feature selection process, which selects the highly relevant data for SVM model development has been presented in the fifth section for classifying stability.

The Chapter 5 describes the estimation of Energy Margin (EM) and Transient Stability Index (TSI) of power systems subjected to symmetrical three-phase short circuit faults using Support Vector Regression (SVR) Machines with input dimensionality reduction and GA based parameter optimization. The combination of a multi-class SVM classifier and four SVR machines tuned using NSGA-II have been developed to estimate the CCT of varieties of contingencies which include symmetrical and unsymmetrical faults precisely within a short duration. Chapter 6 focuses on the transient stability preventive control based on modified economic rescheduling of generating units. Finally a conclusion is drawn in chapter 7.