CHAPTER 1

INTRODUCTION

In the modern energy management systems, network application functions are used as valuable tools to balance increasingly stringent operating conditions against economic efficiency. With the growing stress on today's power systems, many utilities increasingly face the threat of transient stability problems. There is a pressing need for inclusion of on-line dynamic security analysis capabilities in the energy management systems. Dynamic security analysis entails evaluation of the ability of the power system to withstand a set of severe but credible contingencies and to survive transition to an acceptable steady-state condition. Both transient stability and voltage stability are often of concern in these systems.

Various methods for off-line transient stability analysis are under research and development. They include efficient step-by-step integration of the differential equations, direct methods of stability analysis, pattern recognition techniques, expert systems, and neural networks. The step-by-step time simulation is a conventional method, but also the most reliable one we present. However, efficient computation of a stability margin is needed to rank different contingencies and indicate the remedial actions required to alleviate or reduce the threat of instability. Among different methods proposed in the literature, the standard "Energy Approach" has received a great deal of attention. It belongs to the class of direct methods for stability analysis. A direct method for transient stability analysis is defined in [1] as a method that is able to determine stability without explicitly integrating differential equations describing the post-fault system. For example, it offers the opportunity of assessing the transient stability of power systems more directly and effectively than the conventional approach based on simulation. More fundamentally and, in terms of potential applications, more significantly, it also provides a quantitative measure of how stable or unstable a particular case may be. However, direct methods have one disadvantage when compared to conventional step-by-step methods. The models used in direct methods are less detailed. For example, turbine governors, voltage regulators and static VAR compensator are not considered. One of the main idea of the Energy Approach as a direct method is that if the transient energy of a multimachine power system could be measured fast enough and system corrections could be made soon enough, the system could withstand a set of severe disturbance by injecting energy equal and opposite to the disturbance.

Due to major developments in the area of real-time phasor measurements (further explanations on phasor measurements are in appendix A [20],[21]), it is now possible to measure at a fast sampling rate the phase angles at the terminal buses of all the machines in a system.

Thanks to PMUs, a good and complete generator model is no longer needed. This overcome one of the major drawback of the direct methods. Because of these real-time synchronized measurement capabilities, a recent focus in power system research [1,6,12] has been on coming up with a real-time way to assess the transient stability margins of a system following a major disturbance in the system. To realize such task, a new computationally fast method is developed in this thesis to assess the system transient stability margins in a range of a hundred of milliseconds, such that proper control mechanisms can be activated in time to maintain stability.

This method is developed not only to overcome the transient stability assessment problems but also to deal with voltage regulators, static VAR compensator or dynamic braking as control tools [19]. However, this thesis will mainly focus on predicting the trajectory in the angle space and assessing the transient stability margin in real-time. The last chapter outlines how to integrate control tools. Those directions have to be considered as proposals, and that much more research will be necessary to implement them. Successfully tested on 3 and 4 machine system and also on the 10-machine New-England Power system, the developed algorithm is able to quickly enhance the stability margin of the system at the first swing and also at the second swing. To complete the prediction step, a second-order linear model and a second-order auto-regressive model are estimated using a least-squares estimator. The method proposed by Y.Ohura, extended to fit an iterative algorithm, is also computed. Then, these methods are compared with a time domain simulation method that consists in integrating the dynamic equations using a fourth order Runga-Kutta method. Also, the way to extend the prediction to subsequent swings is shown.

The prediction is stopped when the exit point is reached. This point is located at the intersection of the predicted path and the Potential Energy Boundary Surface (p.e.b.s.) and used as starting point to locate the c.u.e.p. The exit point is determined thanks to a combination of the so called " Ball-Drop" method [23] and the local maximum of the potential energy along a ray starting at the Stable Equilibrium Point (s.e.p.) and the last point of the prediction. The c.u.e.p is then computed using an improved version of the Shadowing method which makes use of the Ball-drop method [22]. The transient potential energy at the c.u.e.p is compared to the transient energy at the clearing time. The Energy Margin (EM) between these two values is used as index of stability. If the EM is negative, the system is unstable; otherwise it is stable.

This thesis has been divided into six chapters. In the second chapter, the basic multimachine stability theory, the different dynamic, state and transient energy equations are presented. All the formulations are based on a Center of Angle notation. The theory is first explained using one machine connected to an infinite-bus system and then extended to a multimachine system. To illustrate the latter case, Athay's 3-Machine System is used. In chapter 3, the different assumptions on which is based the proposed method are described. A detailed methodology is also proposed and compared to a method proposed by Y.Ohura et al [6], a method based on decision trees[5] and a method proposed by Bettiol et al [12]. Simulations have been carried out on the 10-machine New-England power system. In chapter 4, various prediction methods are described, their respective performances are compared and the computation of the location of the exit point is explained. Chapter 5 focuses mainly on the computation of the c.u.e.p

once the exit point has been found. The approach consists in integrating the differential equations of the reduced system as the BCU [3], [14] and the Shadowing methods [4] do. Chapter 6 gives some conclusions on the proposed method and includes directions for further research.