International Journal Of Scientific & Engineering Research, Volume 4, Issue 8, August 2013
ISSN 2229-5518

# Transient Stability Analysis of Wind Integrated Power Systems with Central Area Controller

Anju G Pillai, Thomas P C, Sreerenjini K, Sarin Baby, Sasidharan Sreedharan and Tibin Joseph

**Abstract**— It is widely accepted that transient stability is an important aspect in designing and upgrading electric power system. This paper covers the modeling and the transient stability analysis of the wind integrated IEEE 14 test bus system using Matlab Power System Analysis Toolbox (PSAT) package. A three-phase fault is applied in the test system and stability is analyzed. Later, area controller is implemented to analyze the system stability. The evaluation is illustrated by conducting two case studies, modified IEEE-14 bus system and southern Kerala grid. It was observed that addition of area controller improves the system stability and thereby the power system performance.

*Index Terms*— Power system modeling, Wind integrated model, Power system stability, Transient stability, Area controller, IEEE 14 bus system, Secondary voltage control scheme

◆

## 1. INTRODUCTION

***P****ower-system stability* is a term applied to alternating-current electric power systems, denoting a condition in which the various synchronous machines of the system remain in synchronism, or "in step," with each other. Conversely, *instability* denotes a condition involving loss of synchronism, or falling "*out of step*." Occurrence of a fault in a power system causes transients. To stabilize the system load flow analysis is done. Actually in practice the fault generally occurs in the load side. As we controlling load side which will lead to complex problem in order to avoid that we are controlling the generator side.

Transient stability of a transmission is a major area of research from several decades. Transient stability restores the system after fault clearance. Any unbalance between the generation and load initiates a transients that causes the rotors of the synchronous machines to “swing” because net accelerating torques are exerted on these rotors. If these net torques are sufficiently large to cause some of the rotors to swing far enough so that one or more machines “slip a pole” and synchronism is lost. So the calculation of transient stability should be needed. A system load flow analysis is required for it .The transient stability needs to be enhanced to optimize the load ability of a system, where the system can be loaded closer to its thermal limits.

Transient stability entails the evaluation of power systems ability to withstand large disturbances, and to survive transition to a normal operating condition. These disturbances can be faults such as: a short circuit on a transmission line, loss of a generator, loss of a load, gain of load or loss of a portion of transmission network [2]. Large number of simulations is carried out regularly during planning stages to gain knowledge of this system. Yet, even a well designed and normally operated system may face the threat of transient instability.

The aim of the investigation is to analyze the behaviour of the synchronous machine in particular the angular position of the rotor with respect to time after the fault occurs in the system. Section 2 describes the stability of power systems. The case study of wind integrated IEEE-14 bus system and the results from the case study are presented in section 3 and section 4 respectively. Section 5 concludes the paper.

Power System Analysis Toolbox (PSAT) is an open source Matlab and GNU/Octave-based software package for analysis and design of small to medium size electric power systems. PSAT includes power flow, continuation power flow, optimal power flow, small-signal stability analysis, and time-domain simulation, as well as several static and dynamic models, including nonconventional loads, synchronous and asynchronous machines, regulators, and FACTS. PSAT is also provided with a complete set of user-friendly graphical interfaces and a Simulink-based editor of one-line network diagrams [7].

The objective of this paper is to analyze the impact of central area controller on the transient stability analysis of a wind incorporated IEEE 14 bus system.

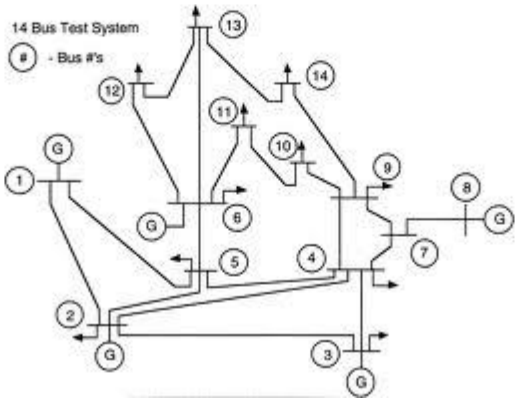

Figure1. IEEE 14 bus system

## 2. STABILITY OF POWER SYSTEMS

In this section, we provide a formal definition of power system stability. The intent is to provide a physically based definition which, while conforming to definitions from system theory, is easily understood and readily applied by power system engineering practitioners.

The proposed definitions of power system stability given in open literatures as follows:

*"Power system stability is 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".*

Power system stability is essentially a single problem; however, the various forms of instabilities that a power system may undergo cannot be properly understood and effectively dealt with by treating it as such. Because of high dimensionality and complexity of stability problems, it helps to make simplifying assumptions to analyze specific types of problems using an appropriate degree of detail of system representation and appropriate analytical techniques. Analysis of stability, including identifying key factors that contribute to instability and devising methods of improving stable operation, is greatly facilitated by classification of stability into appropriate categories [4].

Classification, therefore, is essential for meaningful practical analysis and resolution of power system stability problems.

The classification of power system stability proposed here is based on the following considerations [4]:

- The physical nature of the resulting mode of instability as indicated by the main system variable in which instability can be observed.
- The size of the disturbance considered which influences the method of calculation and prediction of stability.
- The devices, processes, and the time span that must be taken into consideration in order to assess stability.
- The appropriate method of calculation and prediction of stability.

### 2.1 Transient Stability of Power Systems

Among the large disturbances which could affect the transient stability of the system, short circuits and possibly subsequent tripping of the faulted transmission line are the most common. Instability which may a rises from these severe disturbances is often characterized by a constantly increasing angular separation without any periodicity. This kind of behavior is often referred to as first swing instability. As it is the case in small signal stability non oscillatory unstable behavior was largely eliminated by the widespread use of fast acting regulators. Most common instability behavior is therefore in the form of large oscillations with increasing amplitude among generators of different areas. In actual power system the classification based on the nature of the disturbance could result quite artificial. Some real occurrences of system instability, although caused by large disturbances, i.e. generator tripping, manifested as small signal stability problem, i.e. oscillations of growing amplitude.

### 2.2 Modeling of power system components

Modified IEEE 14-bus system with wind integration and central area controller has been used in this paper for the analysis. Later case study is conducted by modeling southern Kerala grid and incorporating central area controller. IEEE 14-bus system has been modeled and the power flow results are verified with the standard values.

### 2.3 Secondary Voltage Control

A Secondary Voltage Control is included in PSAT by means of a Central Area Controller (CAC) which controls the voltage at a pilot bus, and Cluster Controllers (CC), which compare the CAC signal with the reactive power generated by synchronous machines and/or SVCs and modify the reference voltages of AVRs and SVCs.

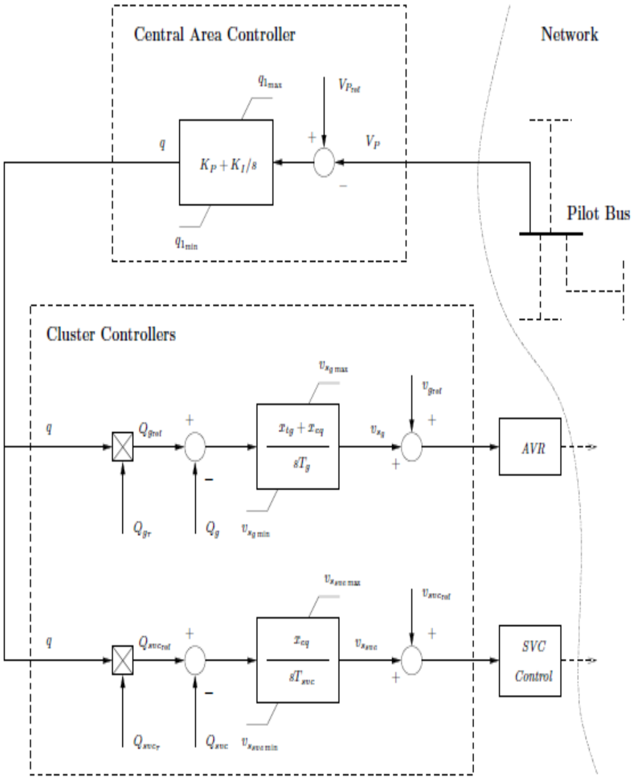

Figure2. Secondary voltage control scheme

## 3. TEST SYSTEM

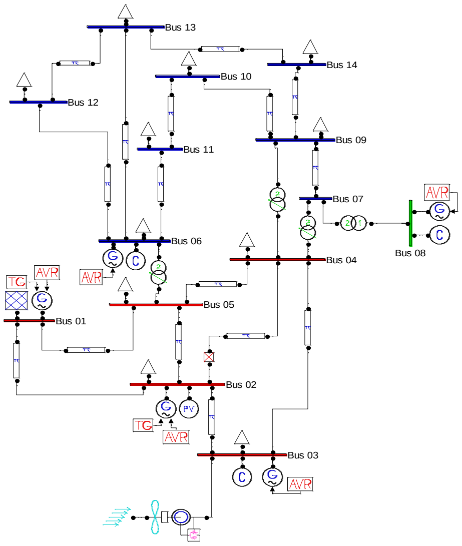

Figure3. Modified IEEE 14 bus test system

Modified IEEE14-bus system used is as shown in figure 3. Bus-2 is PV bus and 3, 6 and 8 are synchronous compensator buses. Loads were modeled as constant power loads (PQ load). A wind farm is integrated at bus 3. The system performance is assessed in terms of rotor angle deviation of the system. Time domain analysis has been considered. Other factors considered are, voltage settings of PV buses and synchronous compensators.

## 4. RESULTS AND DISCUSSIONS

The results consist of two steps. The first step is to analyze the effect of a three phase fault in line 1-2 on rotor angle deviation of the system and the second is the implementation of central area controller and analysis on the same. The proposed concept has been tested on wind incorporated IEEE14-bus system as shown in figure 3. Bus-2 is PV bus and 3, 6 and 8 are synchronous compensator buses. Loads were modeled as constant power loads (PQ load) and were solved by using Newton Raphson Power flow Routine. The time domain simulations were done in PSAT/MATLAB [7] integrated environment.

### 4.1 Modified IEEE 14-bus system

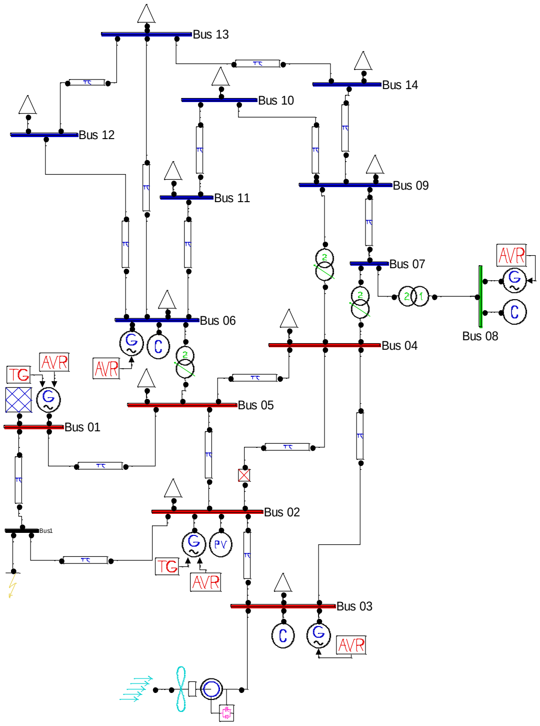

Figure4. Modified IEEE-14 bus system with fault in line 1-2

Three phase fault is applied in 0.6 sec and critical clearing time is obtained as 1.2 sec. Time domain simulations on the system in figure 4 are done and the rotor angle deviations obtained are shown below.

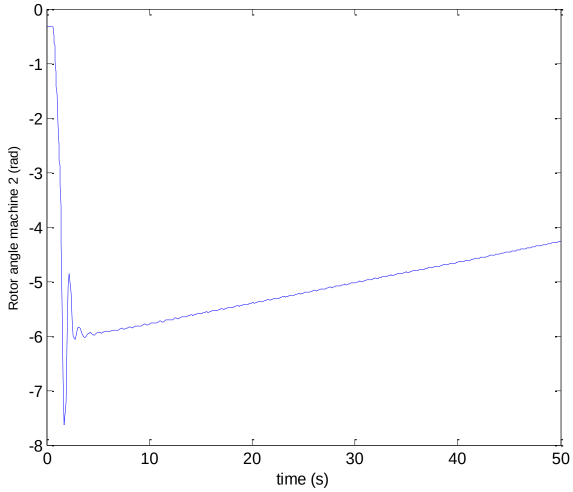

Figure5. Rotor angle deviation of machine 2

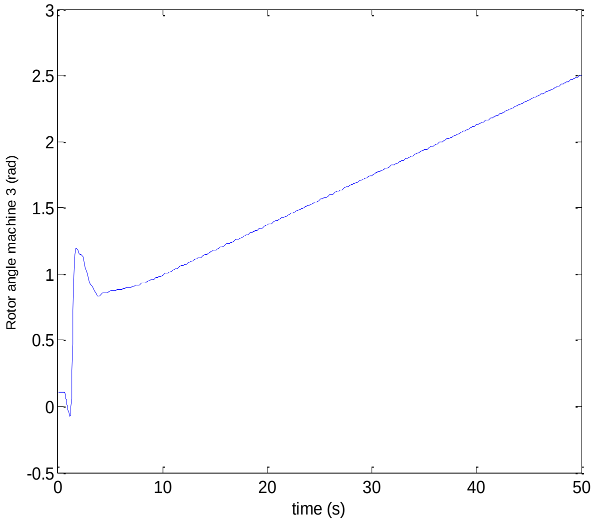

Figure6. Rotor angle deviation of machine 3

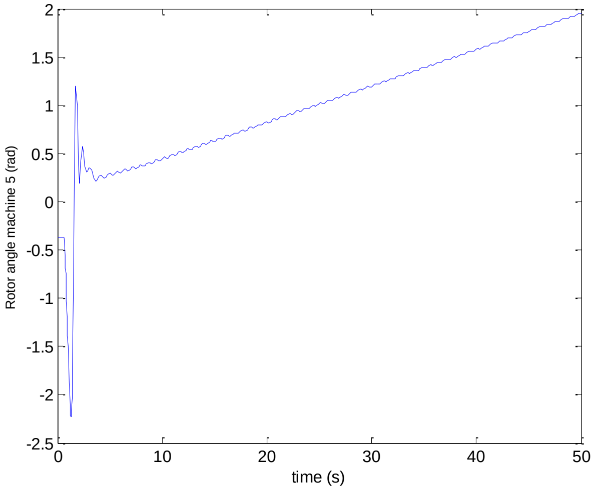

Figure7. Rotor angle deviation of machine 5

From figure 5, figure 6 and figure 7 it can be seen that because of the effect of three phase fault, rotor angles are much deviated and the system remains in unstable state.

As the second step, central area controller is included in modified IEEE 14-bus test system with three phase fault and central area controller is shown in figure 8.

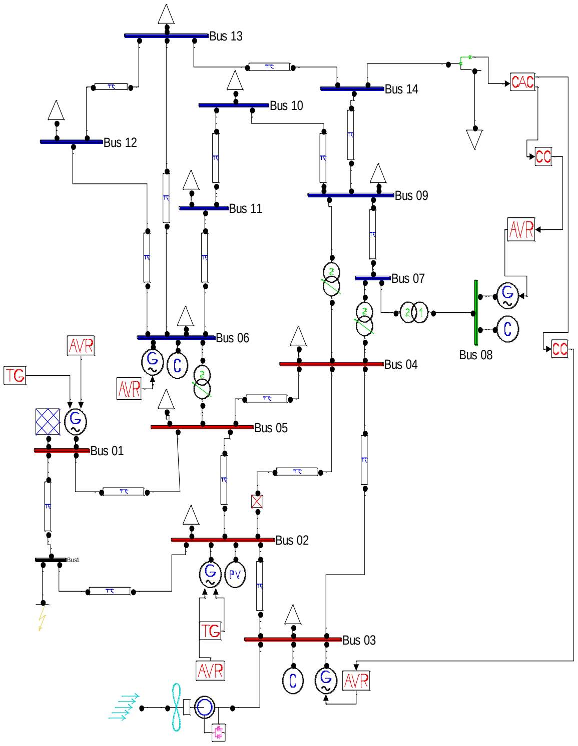

Figure8. Modified IEEE 14 bus system with central area controller

Time domain simulations are done and rotor angle deviations are noted.

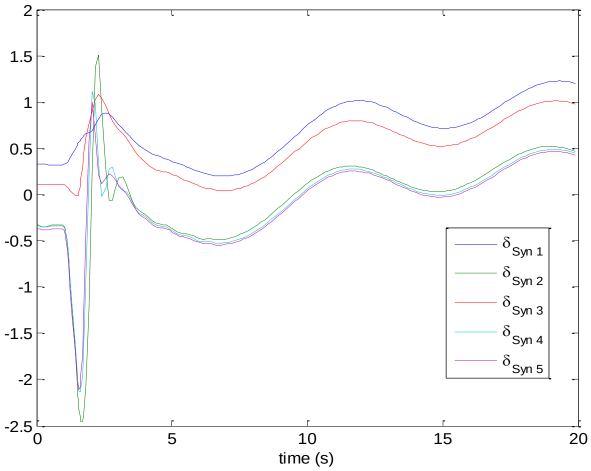

Figure9. Rotor angle deviation of machines

From the simulation results obtained, it is clear that rotor angle deviation settles and stability of the system is regained by the incorporation of central area controller in wind integrated IEEE 14-bus test system.

### 4.2 Southern Kerala Grid

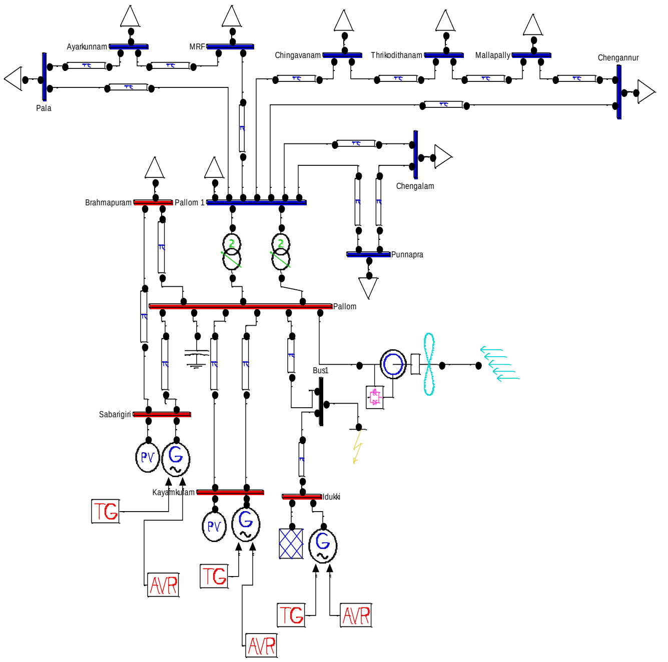

Figure10. Southern Kerala Grid – test system

Time domain simulations are done and rotor angle deviations are noted.

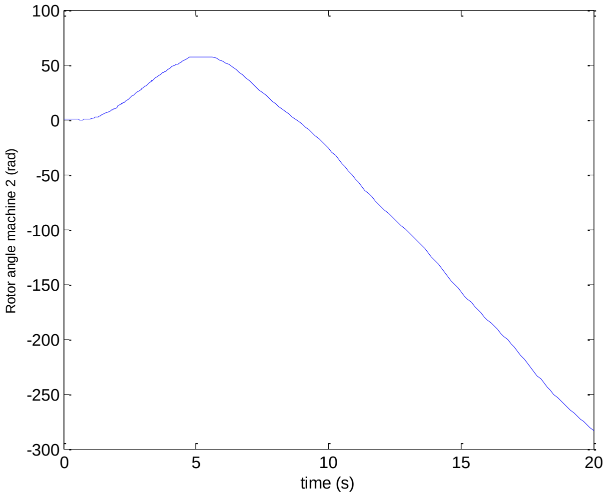

Figure11. Rotor angle deviation of machine 2

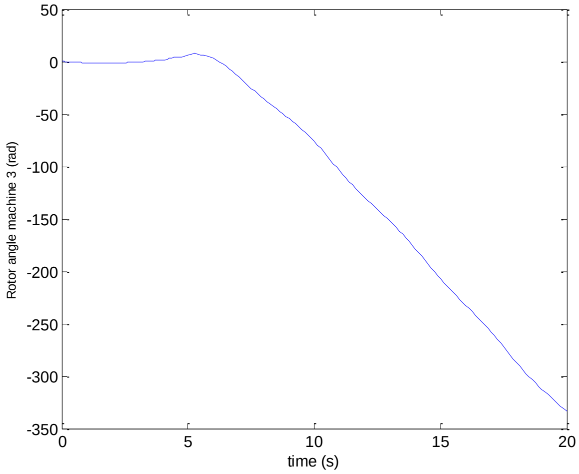

Figure12. Rotor angle deviation of machine 3

From figure 11 and figure 12 it can be seen that because of the effect of three phase fault, rotor angles are much deviated and the system remains in unstable state.

As the second step, central area controller is included in southern Kerala grid test system with three phase fault and central area controller is shown in figure 13.

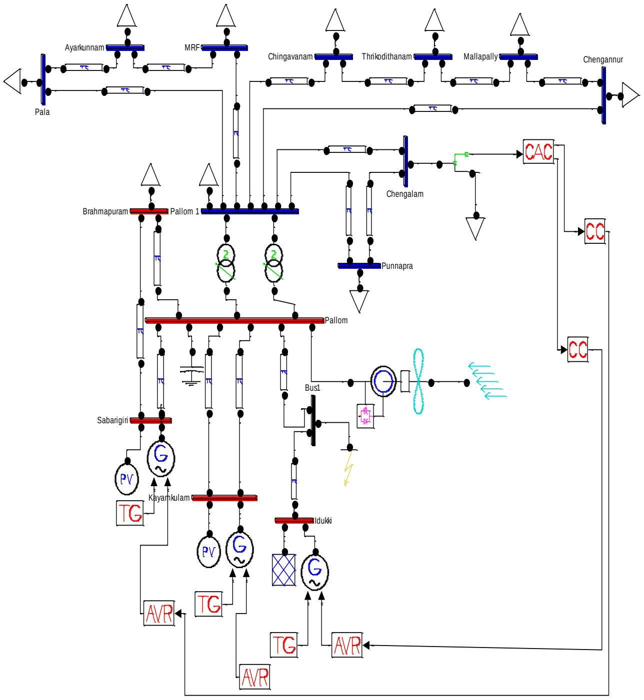

Figure13. Southern Kerala Grid – test system with area controller

Time domain simulations are done and rotor angle deviations are noted.

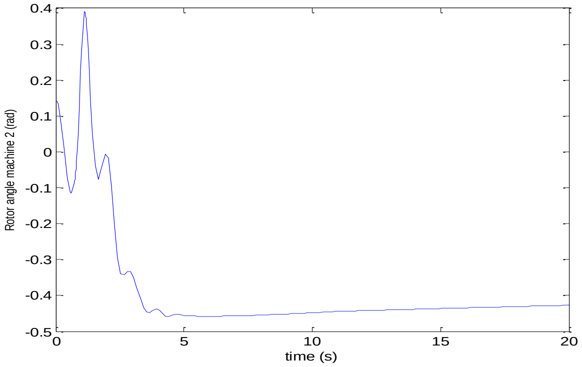

Figure14. Rotor angle deviation of machine 2

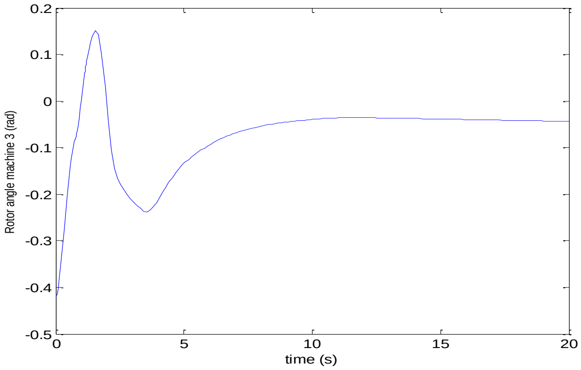

Figure15. Rotor angle deviation of machine 3

## 5. CONCLUSION

In this paper, a new concept has been proposed for the transient stability analysis of power systems. Central Area controller has been used to acquire the transient stability of the test system considered. The results are verified on wind integrated IEEE 14-bus system and southern Kerala grid.

## 6. ACKNOWLEDGMENT

The authors gratefully acknowledge Dr Federico Milano, for his excellent simulation software PSAT.

## 7. REFERENCES

[1] D. Ruiz-Vega, M. Pavella: "A Comprehensive Approach to Transient Stability Control: Part I - Near Optimal Preventive Control", *IEEE Transactions on Power systems*, Vol. 18, pp. 1446 - 1453, Nov. 2003

[2] P. Kundur, *Power System Stability and Control*, New York : Mc Graw-Hill, pp. 104-120, 1994..

[3] W. D. Stevenson, *Elements of Power System Analysis*, New York : Mc Graw-Hill, 1982.

[4] P. W. Sauer and M.A. Pai, *Power System Dynamics and Stability*, New Jersey: Prentice-Hall, pp.161-180, 1998.

[5] A. A. Fouad and V. Vittal, *Power System Transient Stability Analysis*, Prentice Hall, New Jersey, 1992.

[6] X. Yu and C. Singh, "Probabilistic Analysis of Loadability in Composite Power Systems Considering Security Constraints", *IEEE Transactions on Power Systems*, pp. 832-838, 2006.

[7] Milano, F., An open source power system analysis toolbox. *IEEE Transactions on Power System*, Vol. 20, No.3, pp.1199-1206, 2005.