論文の内容の要旨
Thesis Summary

論文題目
Title of Dissertation

Development of Wide-Area Measurements Based PSS Design for Improving Inter-area Oscillation in Power Systems

（電力系統の地域間動揺を抑制する
ための広域計測データに基づいたＰＳＳ設計手法の開発）

氏　　名　　トラン　フィン　ノツ
Name of Author　　TRAN　HUYNH　NGOC

（本文 Body）

Power supply has become more important for the world so that many efforts have been made to prevent power systems from outage scenarios. While power system size and the demands on it are increasing, the intendancy of inter - connecting power system becomes more necessary. However, beside some benefits it could provide, such as increasing power system reliability, effectiveness of backup sources, some problems, especially instability problems, also need to be solved.

In the common power system, due to low sampling rate of Supervisory Control and Data Acquisition/Energy Management system (SCADA/EMS), it is not qualified enough to capture the dynamic of power system. Also, there is uncoordinated local actions e.g. in decentralized protection system. Meanwhile, due to the economic constrains, the power system today being operated close to its stability limits and changing the monitoring and control roles from preventive to emergency ones. In order to observe the system dynamic, the essential measurement should match following characteristics: must be taken from difference system locations, with sampling high rate and at the same time instant. A measurement device, called synchronized Phasor Measurement Unit (PMU), could possess these above features, working together with global positioning system.

For past decade, many researchers have pointed out that inter-area oscillation is the main concern in instability problems of a large scale power system. The oscillation modes, which range in 0.2Hz - 1Hz, have been detected in many networks, such as Western North America, Queensland system, Hydro - Quebec system, Nordic power system, China Southern power grid.

Years ago, power system stabilizer (PSS) has been considered as the most effective local controller which

can provide good damping to instability modes in power systems. Recent years ago, especially after Western North America blackout, many researchers have proved that a controller such as PSS or FACTS devices can provide a better behavior to an inter-connected power system if the remote signals (from other than its own area) are used as the input signals. In the other hand, the inter-area oscillation can be well damped if global signals are used for a reasonable coordination controller. By this direction, most recent research focusing on design a fixed global controller for improving inter-area oscillation of power systems.

This thesis proposes a concept of adaptive WAMs based PSS which change both configuration, that is its input and output, and parameters subjected to system change. The advantage of changing both configuration and parameters is to reduce number of required controllers while providing good damping to inter-area oscillations. The work reported in this thesis shows that for a test system, only one adaptive WAMs based PSS can enhance inter-area oscillations, instead of using each controller for each inter-area oscillation.

This thesis also proposes a new method of feedback signal selection for the MISO WAMs based PSS. This method is based on a systematic framework, and it is appropriate to not only adaptive controllers, but also robustness controllers. The difference between this method and conventional method is that it considers observability of feedback signal for not only the mode of concern, but other modes. For instance, using weighting factor added to each measurement, the method can maximize observability of feedback signal to the mode of concern, while minimizing that to others. By additional considering residue of modes other than concern mode, the proposed feedback signal can support controller to improve the mode of concern while having not much impact on other modes. Since the weighting vector for feedback signal and controller parameters are calculated based on system linearization, the precise system identification and modeling are required.

In coordination with the new method of feedback selection, this thesis proposes an algorithm of iterative design to remove modes improved by controller out of set of modes whole residues need to be minimized. By iterative design, controller can provide good damping to modes other than concern mode. Subsequently, iterative design can help for choosing the best parameters of controller, once tuning method for the controller is fixed. This iterative design is general, and independent to type of parameter tuning method.

This thesis does not proposed new method of tuning controller's parameter. In the contrary, a combination method of residue based method and eigenvalue control is used for tuning controller parameter. This tuning method focuses on improving the mode of concern and does not ensure robustness stability for the power system. However,

it is appropriate to the adaptive concept introduced by this thesis.

The general procedure of design of WAMs based PSS in this thesis is as follows:

1) The full-order nonlinear model of the test system will be built by Matlab program. All generators are modeled by 6-order dynamic model along with Gov, AVR, PSS model which are described in chapter 2.

2) Linearized state space model of the test system at an operating point, as shown in chapter 2, is calculated using Matlab program. The eigenvalues and eigenvectors are calculated. Information of mode frequencies, damped ratio and participation factor will be used to classify local modes and inter-area modes. The most dominant inter-area mode is also identified.

3) Controller output is selected. The output signal of WAMs based PSS is located by controllability measurement [4,8,17], which is a conventional method.

4) Controller input signals are selected. The measurements for the controller are selected by a proposed method by this thesis based on residue calculation. The calculated feedback signal has the maximum residue for the mode of concern and minimum residue for other modes.

5) The controller parameters are tuned using a combination method of residue based approach and eigenvalue control. The residue based approach is used for initialize parameters and eigenvalue control is used for tuning parameter focusing on the mode of concern.

6) An iterative design is proposed by this thesis will be apply so that procedure 4) and 5) will be iteratively calculated until optimal parameters for the controller are obtained. This proposed iterative design is along with the proposed method of feedback signal in procedure 4), and regardless to the method of parameter tuning in procedure 5). That mean it can be applied with any method of parameter tuning.

7) Impacts of time delay introduced by transmission are considered. The controller configuration and parameters are designed with and without time delay consideration.

8) Eigenvalues of the closed-loop system are calculated and time domain simulations are done using Matlab program to verify the effectiveness of the designed controller. Impacts of time delay on eigenvalue result and time domain simulation are evaluated.

The proposed design strategy has been tested successfully with two operating points of the IEEJ East 10-machine system and two operating points of IEEJ West 10-machine system. The results show that for each system

operating point, the appropriate inputs and output for the controller are different. Also, controller parameters vary subject to operating points. Furthermore, the proposed feedback selection in combination with the optimization tuning process can improve the dominant inter-area mode while not affect much the others.

Although the proposed method of feedback signal selection is general and can be applied with any number and type of participating measurements, just two participating measurements which are rotor speed angles are used in case studies and good results are obtained. In the future, effectiveness of various number as well as type of participating measurement on the proposed method will be studied. Also, more complex test systems with high number of operating points will be taken into account to verify the robustness of the proposed approach. The current test systems, IEEJ East and West 10-machine systems just has one dominant inter-area mode in each considered operating point so that only one WAMs based PSS is needed. In the future, if the considered system has more than one dominant inter-area mode, multiple WAMs based PSSs or multi-input multi-output WAMs based PSS need to be developed.

In the thesis, the time delay of feedback signal which is introduced by communication transmission is also considered. Pade Approximation has been used for modeling time delay block in the power system model. Case studies have shown that effectiveness of proposed feedback signal is always better than that of conventional feedback signal, regardless to the time delay. A delay time of 0.25s has been considered in design process. The result shows that if actual delay time is match to the setting delay time, the controller performance is the best. In case of actual delay time varies from setting delay time, the controller performance still provides good damping to inter-area oscillation.

The work how to identify the change of the system operating conditions for reconfiguration of the controller is also out of scope of this thesis. These issues will be considered in the future work.