Proposed Design of Wide Area Damping Controller to Damp Out Inter Area Oscillation

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Abstract :-In this paper, design is proposed for a wide-area damping controller to damp out the inter-area oscillations in a large scale power system.The controlled signal obtained by geometric approach is used as a control input for the proposed damping controller to damped out the inter-area oscillations

Keywords:-Wide-Area Damping Controller, Geometric Approach, Inter-Area Oscillation, Power system Stabilizer.

I. INTRODUCTION

Damping of inter-area low-frequency oscillations is one of the main concerns for improving power system stability as those inter-area oscillations would reduce the re- serve margin of the transmission capacity between areas of power grids. The inter-area low-frequency oscillations can be suppressed by installing power system stabilizers (PSSs), which provide supplementary control action through the excitation system of generators or, alternatively, by adding supplementary damping controllers to flexible AC transmission systems (FACTS) devices which are flexible to be installed at the key corridors of the grid and thus can provide much better damping performance than PSS. These damping controllers which conventionally use the local signals as feedback inputs have limitation for providing damping for some inter-area modes due to the lack of the observability of the inter-area mode from the local signals, though some specially designed controllers, such as self-tuning and robust controller, can still provide Sufficient damping for some special inter-area oscillation modes.

The current installed capacity of electricity generation in India is 304.761 GW as of the end July 2016, [Wikipedia, 2016]. Nowadays, the continuous inter-connection of regional electric grid is the developing trend of modern power system all over the world, such as interconnection of national grids of India, Europe network, the Japan power grids, the national grids of China and North American power grids. The main reason for interconnection of electric grids is that it can efficiently utilize various power resources distributed in different areas and achieve the optimal allocation of energy resources. This also optimizes the economic dispatch of power and get relatively cheaper power, which implies that decrease of system installed capacity and the investment. Moreover, in case of fault or disturbance in operating condition, it can provide additional supporting power of each area of interconnected grids which can increase the reliability of generation, transmission and distribution system.

With the development of the wide-area measurement system (WAMS), remote signals have become available as the feedback signals to design wide-area damping controllers (WADCs) for FACTS devices. The availability of remote signals can overcome the aforementioned shortcoming of lacking observability and provide flexibility to damp a special critical inter-area oscillation mode of power systems. Various control techniques have been used to the design/synthesis of WADC, such as classical lead-lag phase compensation based control, robust control –, adaptive control, model predictive control, and neural network-based optimal control.

Oscillations in power systems are classified by the system components that they effect. Electromechanical oscillations are of the following types:

a) Intra-plant mode oscillations(2.0 -3.0 Hz)

b) Local plant mode oscillations(1.0-2.0 Hz)

c) Inter-area mode oscillations(0.1-1.0 Hz)

d) Control mode oscillations mechanical oscillations

e) Torsional modes between rotating plant (10-46 Hz).

Some other examples of power system black-outs due to inter-area oscillations are as follows:

In early 1960 and 1985 oscillations were observed when the Detroit Edison (DE), Ontario Hydro (OH) and Hydro-Québec (HQ) systems were inter-connected.

In 1969, oscillations were observed under several operating conditions in the Finland-Sweden (and Norway)-Denmark interconnected system.

In 1971 and 1972, over 70 incidents of unstable inter-area oscillations occurred in the Mid-Continent Area Power Pool (MAAP) system in North America.

In 1975, unstable oscillations of 0.6 Hz were encountered on the interconnected power system of New South Wales and Victoria.

In 1982 and 1983, the State Energy Commission of Western Australia (SECWA) experienced lightly damped system oscillations in the frequency range of 0.2-0.3 Hz.

On August 10, 1996, the Pacific AC Inter-tie (PACI) in WECC experienced unstable low frequency inter-area oscillations following the outage of four 400 kV lines.

India-2012 with a frequency range of 0.35-0.71 Hz. [CERC, 2012]

II. RELATED WORK

In this section discuss the related work to data storage with key management technique for storing and retrieving of data.

(1) In this paper, author contributed his research through an adequate selection of input–output signal pairs, WPPs were effectively used to provide electromechanical oscillations damping. In his paper, different analysis techniques considering both controllability and observability measures and input–output interactions were compared and critically examined. The best signal pairs available from WPPs were recommended to select to damp power oscillations. In this research only controllability/observability is used to choose the most adequate control signal to damp the power system oscillations.

(2) In this paper, author used wind power plants (WPP) to enhance the stability of the power system. Active or reactive power was used as input signal to the PSS in WPP. In his research work the optimal combination of input and output signals were obtained to improve the system performance. In the paper the adequate pair of input and output control and measured signals respectively were identified by using fundamental design limitation and controllability and observability concept, without designing the controller. The proposed criterion for the selection input/output pairs were illustrated on with a three synchronous machine system with a WPP connected as a PSS. *In this research the controllability / observability method of signal selection has been used to prevail the most effective input / output pair of candidate signals to damp the inter area oscillation.*

(3) In this paper, author presented a general state-space representation of a multi-machine, multi-order power system model, which may be used to carry out small-signal stability assessments. *In this research the linearized model of the multimachine has been prepared from the jacobian matrix of the power system after obtaining load flow analysis of the given system.*

(4) In this paper, author demonstrated design of wide area power system damping controller by considering resiliency either in communication system or in physical system to counter act communication failure. In the paper the location SVC has been selected to strongly influence the relevant inter area mode of oscillations by computing bus participation factor at nominal operating condition of the power system. *In this paper lead-lag compensator based PSS has been used as wide area damping controller.*

(5) In this paper, author established a systematic procedure to select wide area input/output control signals based on a signal coherency approach to damp out inter area mode of oscillation. The input/output signal selection was carried out in two steps. First the data is transferred into orthogonal space to make correlated variables uncorrelated, by applying principal component analysis. Then the principal amount of vectors were given as input to self-organizing map for final data clustering. For each clustered signal group a signal out of those with common features were selected. For clustering the data were collected from the system dynamic simulation considering few critical line contingency. The efficiency of the proposed signal selection method has been compared with the results of geometric based approach and pole vector direction based signal selection. The paper finally concluded that the proposed method provides better response compared to both geometric approach and pole vector approach and further it was proved that geometricapproach offers slightly better result compared to pole vector approach.*The research work in this dissertation includes geometric approach for selection of wide are control signal for effectively damp the inter area mode.*

(6) In this paper, author proposed a systematic procedure for designing a wide area centralized Takagi-Sugeno Fuzzy controller to improve the angular stability of a multi-machine power system. The detail can be found in. But the main focusing point to be useful in this research paper is the signal selection process. The geometric measure of controllability/observability approach has been used for the identification of most suitable stabilizing signal for the TS-Fuzzy controller. *In this research two different signal selection techniques including geometric approach has been employed with emphasis to damp the inter area mode efficiently*.

(7) This paper demonstrated the selection of proper feedback signal for power system damping controller in. In this paper he evaluated the three different methods to select the most effective signal to damp power system oscillations. The controller he used in the paper was a FACTS based damping controller. In the paper he compared the results of three different techniques namely controllability / observability, residue and hankel singular value approach and finally obtains that the residue and hankel value based signal selection are best over controllability / observability approach. Further he found that residue and hankel value based signal selection

performs similarly in small two-area power system. However hankel value based signal selection performs outstanding in medium scale system.

(8) In this paper, authorproposed wide area damping controllers with application to fuzzy logic based PSSdesign for dynamic shunt compensators. He used an SVC to damp the oscillations. Based on network configuration and modal analysis, controllability and observability study of the control signals was performed in his paper. *In this research only geometric approach has been used for controllability and observability study of system's control signals. Instead of using a Fuzzy logic PSS based SVC a lead-lag PSS has been used to damp the power system critical mode of oscillations.*

(9) In this paper, author developed a H_∞based decentralized Power System Stabilizer controller which used selected suitable wide area PMU signal as supplementary input to achieve a better damping of specific inter area modes. In this paper before selecting the supplementary remote input signals, the initial feature set was preselected first by engineering judgment and then using a feature selection technique such as K-means clustering algorithm. The final selection was carried out based on amplitude gain of the frequency responses of the signals. Then from the resulting frequency response curve resonance effect in the frequency response band of selected modes were observed. The signal with frequency response curve showing maximum value out of frequency response curves for all other remote measurements in the frequency band of the considered modes was selected as the most suitable supplementary remote feedback signal for the local decentralized PSS controller. *In this research the supplementary signals to the AVRs of generators have been identified by geometric approach to damp out the inter-area oscillations.*

(10) In this paper, authordeveloped a centralized continuous time model predictive controller (CMTDC) toimprove the angular stability of a multi-machine power system.In the paper he compared the result of proposed controller with GA tuned Conventional Power System Stabilizer. (CPSS) *In this research instead of using the PSS at all the generator only selected generators are employed with decentralized wide area damping controller.*

III. PROBLEM FORMULATION

Based on the literature reviewed in the earlier section the research was observed in the following area. Hence the researcher formulated the following gap:

- Obtain most stabilizing signal by two different methods of signal selection such as approach based on residue and based on geometric measure of joint controllability and observability on a given test system. But geometric measure of joint controllability and observability based signal selection is better one.
- Compare the power system responses under the presence of geometric measure of joint controllability and observability of signal selections in order to damp out the inter-area oscillations.

IV. PROPOSED APPROACH

The comprehensive study of the literature led to the gap as discussed in above section. Hence to reach the gap the research has met the following points:

- Linearization of the non-linear multi-machine power system
- Modal analysis of the obtained linear model of the power system
- Selection of most suitable feedback stabilizing signal by both the approach based on residue and that based ongeometric measure of joint controllability/observability to get best approach out of the two.
- Design a simple lead-lag compensator based Wide Area Damping Controller (WADC) putting emphasis on damping of inter area oscillations.

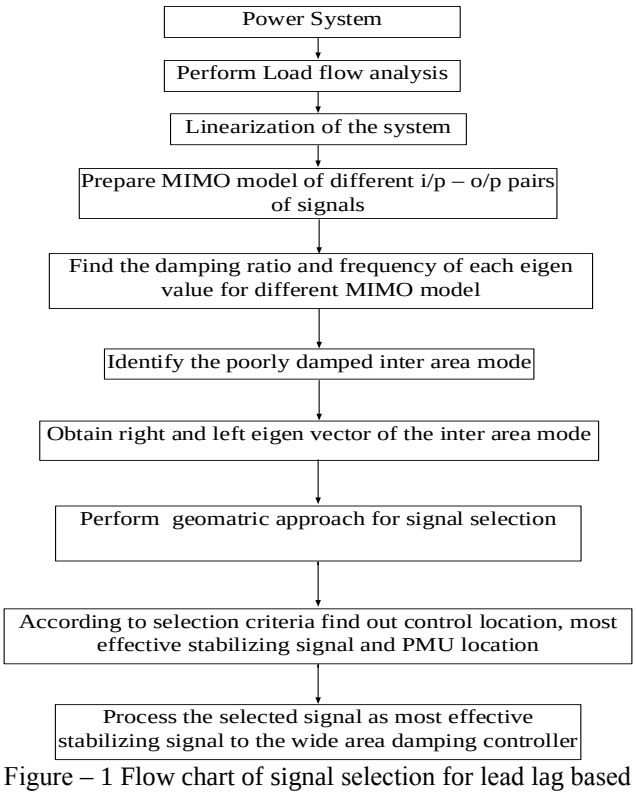

Figure – 1 Flow chart of signal selection for lead lag based damping controller.

This section provides the method that has been adopted to achieve the research gap. The research starts with

linearization of the system about a stable operating point without including PSS. Before getting the linearized model the load flow analysis of the system is performed.The next step includes the computation of eigenvalues, eigenvectors(left eigenvector and right eigenvector), damping ratio and frequency. Then weakly or negatively damped inter area mode has been recognized by proper control of frequency of oscillation and damping ratio. After identifying the critical mode of oscillation the next step involved to get the eigenvectors i.e. right and left eigenvector of the weakly or negatively damped inter area mode. In this way after getting the eigenvectors of the weakly or negatively damped inter area mode; different state space object (MIMO) of the given system were prepared for different input and output pairs of signals.

In this research work the different input output pairs of signals has been taken as excitation voltage – tie-line power, excitation voltage– speed deviation of synchronous generators, excitation voltage – bus voltage angle and excitation voltage – line reactive power of the test system. Then the most effective wide area signals for the identified mode were obtained by geometric approach. The flow chart of the complete process of selection of most effective stabilizing signal for a certain mode is given in figure1.1. In geometric approach the selection criteria is to perform the maximum controllability/observability of different measurement of remote signals. The result of signal selection provides three significant solution of effective damping of certain inter area mode. These are :

i. Most effective remote stabilizing signal

ii. Appropriate control location in order to damp out the inter area mode

iii. Placement of PMUs at different location

In this way after performance of the signal selection the non-linear model has been developed on the Mat-labSimPowerSystem environment in order to perform a time domain simulation. In this model the control signals were fed to a lead-lag compensator based wide area controller to provide auxiliary input for appropriate excitation in order to damp out the certain critical inter area mode.

V. CONCLUSION AND FUTURE WORK

The major work is to select the most suitable stabilizing feedback signal to the wide area controller. The selection of most suitable stabilizing feedback signal is the major objective of the controller design. In this proposed paper, the method of signal selection is based on geometric measure of joint controllability / observability. The controller used is as simple as a two channel lead-lag compensator based Power System Stabilizer. The methods of signal selection were illustrated on Kundur's twoarea four machinesystems. The effectiveness in damping of the critical inter area mode was assessed by both small disturbance and large disturbance stability analysis.

Explanation of proposed signal selection method on large system: The proposed work has been restricted for Kundur's two area four machine system. The effectiveness of signal selection can be held with other large test systems such as New-England 39 bus 10 machine system, IEEE 14 bus system etc.

Comparison of signal selection by different more methods: In this paper signal selection is based on geometric joint controllability / observability method. The work can be extended to execute the signal selection by some other techniques proposed by many researchers such as Sequential Orthogonalization Algorithm (SO), Combination of Coherency Identification Technique, Combination of Principal Component Analysis (PCA) and Self Organizing Map (SOM), Cluster Algorithm etc.

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