SURVEY ON DESIGN OF PSS TO DAMPED OUT THE INTER-AREA OSCILLATIONS FROM POWER SYSTEM UNDER DISTURBANCE

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ABSTRACT

With the development of electric power system and continues interconnection of regional electric grids, the stability problem becomes more complex in nature, especially low frequency oscillation which play an important role to influence the stability and efficient operation of inter connected grids. The low frequency oscillations in the power system network especially the inter-area oscillations (0.1 to 1 Hz) is the key factor that influence the stable operation of interconnected grids and limits the transmission capacity of large-scale power system. Inter-area oscillations mainly represent the power oscillations among different generators located in different area of power systems.

I .INTRODUCTION

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 Chinaand 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. 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.

Electromechanical oscillations are of the following types:

1.Intra-plant mode oscillations(2.0 -3.0 Hz)
2.Local plant mode oscillations(1.0-2.0 Hz)
3.Inter-area mode oscillations(0.1-1.0 Hz)
4.Control mode oscillations mechanical oscillations
5.Torsional modes between rotating plant (10-46 Hz). [Pal, 2005]

Some other examples of power system black-outs due to inter-area oscillations are as follows:
1.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.

1.1 AND MOTIVATION FOR THIS RESEARCH

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2.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.
3.In 1975, unstable oscillations of 0.6 Hz were encountered on the interconnected power system of New South Wales and Victoria.
4.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.
In case of interconnected electric grids Low Frequency Oscillations (LFOs) especially inter-area oscillations are easily excited where there is fault or disturbance in the system. Such type of oscillating phenomena influence the stable operation of interconnected electric grids and sometimes black out or brown out type of abnormal phenomena occurs. Some blackouts of interconnected grids in worldwide are mention below:

1.2 Indian Power Grids

On July 30th and 31st 2012, there was a major grid disturbance which affected the large part of Indian electricity grids.

Due to high load and failure of monsoon Northern region was drawing a large amount of power from neighbouring Western and Eastern grids. Whereas due to rains in Western region demand was less and it was under drawing. A large amount of power was flowing from the Western grid to Northern grid directly as well as through the Eastern grid and the system was under stress.

Based on modal analysis of Phasor Measurement Unit (PMU) data available at WRLDC for both July 30th and 31st 2012, the following observations are made [CERC report, 2012].
1.2 Hz mode present on both days with almost zero damping but with significant amplitude.

2.Inter-area modes 0.35 Hz and 0.68 Hz was present with negative or close to zero damping

3.New inter-area modes 0.5Hz and 0.71 Hz was present with negative damping and amplitude is also significant

The presence of these modes with less damping indicate, the system was in stressed condition. The mode behaviour before disturbance, during the disturbance and after the disturbance is shown in figure 1. [CERC report, 2012]. This oscillations mode causes the power instability on the interconnected lines. Thus, the necessary damping strategy should be performed to stabilize such oscillations mode.

Figure 1. indicates the post-disturbance oscillations of the power system are neither increasing nor decreasing which shows that the damping ratio is zero. In such situations, the power system may become unstable.

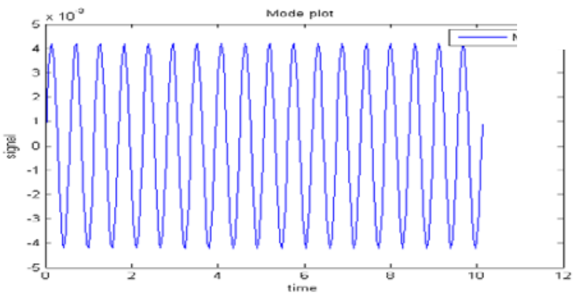

Figure 1-Undamped oscillations with frequency of 1.78 Hz (30th July 2012) mode (Damping: 0%): Post-Disturbance

Figure2.indicates the pre-disturbance inter-area oscillations with frequency of 0.53 Hz and

negative value of damping ratio. When damping ratio is negative, then amplitude of oscillation is continually increases with respect to time which make power system unstable.

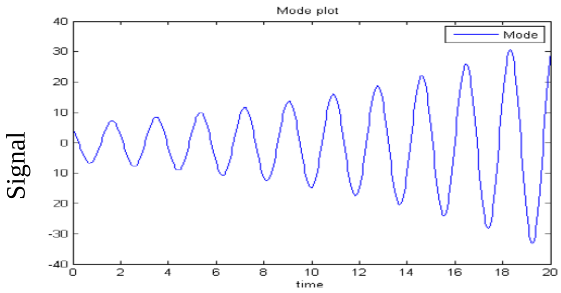

Figure -1 Inter-area oscillations with frequency of 0.53 Hz (31st July 2012) mode (Damping: -2%): Pre-Disturbance

Figure3 indicates the inter-area oscillations during disturbance with frequency of 0.55 Hz and negative value of damping ratio. When damping ratio is negative, then amplitude of oscillation is continually increases with respect to time which make power system unstable.

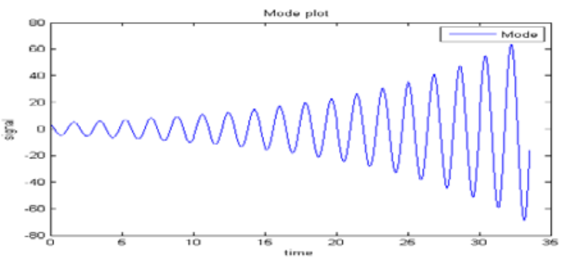

Figure 2Inter-area oscillations with frequency of 0.55 Hz (31st July 2012) mode (Damping: -2.3%): Disturbance

Figure4 indicates the inter-area oscillations of post-disturbance with frequency of 0.55 Hz and negative value of damping ratio. When damping ratio is negative, then amplitude of oscillation is continually increases with respect to time which make power system unstable.

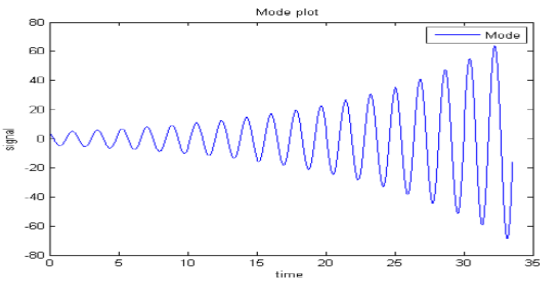

Figure 3 Inter-area oscillations with frequency of 0.55 Hz (31st July 2012) mode (Damping: -0.2%): Post-Disturbance

1.3 Chinese Power System

The Chinese Power system is divided into Central, Northern, Eastern, Southern, North-eastern and North-western China network. On 5th November 2003 there was a typical inter-area oscillation mode with the oscillation frequency 0.25 Hz. This oscillation mode causes the power instability on the interconnected lines [Xie, 2006].

1.4 European interconnected network

In European interconnected network, on 20th July, 2009 a typical inter-area oscillations mode has been detected. From this it was found that there are some typical oscillations among four areas (Athens, Stuttgart, Seville and Algiers). The oscillation frequency and damping ratio of the dominating oscillation mode is 0.15 Hz and 5.3% which is the typical inter-area oscillation mode [Lehner, 2010].

The inter-area oscillations produces serious damages on the stable and efficient operation of power system especially in large interconnected grids. If inter-area oscillations have weak or negative damping ratio then it easily leads to interconnected grids and as a result cascading failures and finally black out could be happen. Thus, to ensure the stable and efficient operation of interconnected grids system the damping strategies should be performed to prevent or eliminate such inter-area oscillation.

The traditional approach to damp out the inter-area oscillations by using Conventional Power System Stabilizer (CPSS). These controllers use local signals as a input signal and may not always be able to damped out inert-area oscillation, main cause behind this, the design of CPSS based on system components linearization around one operating point. Also local controller have not global observation and may does not be effectively damped out the inter area oscillation. The loads are varies in infinite way so in each condition operating point also changes hence it is not possible to design a controller at one particular operating condition. In resent year nonlinear control techniques gain more attention and it is applied to the power system [Panda, 2012].

The heavy power transfer needs either new lines to be added or need high voltage compensation such as series compensation to damp low frequency inter area oscillations. However there are lot of restrictions like environmental factors, cost factors etc. in expansion of new lines and installation of compensation devices. Therefore in order to achieve the maximum transfer capacity of the power system and to maintain better system security, improvement in damping of electromechanical oscillations become more important.

The traditional approach to damp out the inter-area oscillations by using Conventional Power System Stabilizer (CPSS). The basic function of PSS is to add damping to the generator rotor oscillation by controlling its excitation using auxiliary stabilizing signal. These controllers use local signals as an input signal and may not always be able to damp out inert-area oscillations, main cause behind this, the design of CPSS based on system components linearization around one operating point. Also local controller have not global observation and may does not be effectively damped out the inter-area oscillation.

It is observed that the remote signals from one or more distant locations are more effective to damp inter area oscillations. The effective damping mechanism is that the damping torque of synchronous generator is enhanced through proper field excitation. The application of remote signal for damping controller has become successful due to the recent development ofPhasor Measurement Units (PMUs). PMUs have very useful contribution in newly developed Wide Area Measurement System (WAMS) technology. The PMU is a very powerful source to provide dynamic information of the grid. The initial development of PMU based WAMS was introduced by Electric Power Research of Institute (EPRI) in 1990. The real time information of synchronous phasor and sending the control signal to major control device (e.g. PSSs, HVDC controllers, FACTs controllers) at high speed have now become easier due to the use of PMU.

The PMU can provide wide area measurement signals. The signals can be used to enhance the wide area damping characteristics of a power system. The global signals or wide area measurement signal are then sent to the controllers through communication channel. It is found that if remote signals comes from one or more distant location of power system are used as a controller input then, the system dynamics performance can be improved in terms of better damping of inter-area oscillation. The signals obtained from PMUs or remote signals contain information about overall network dynamics whereas local control signals has lack adequate observability with regard to some of the significant inter-area mode.

M.E Aboul-Ela [Aboul, 1996] has used the residue method for the selection of stabilizing signal. Residue is used for selection of control input in before him in the participation factor method has been proposed for the selection of signal for a certain mode. But the approach is not popular because it obtains state variable signals as the stabilizing signal for the damping controller.

1.5 OBJECTIVES OF THE RESEARCH

The main objective of this research includes the following prospects:

a) Propose two various signal selection techniques to identify the most effective and efficient control loop for damping of a given inter area mode.
b) Prepare a linearized model of the non-linear multi-machine power system.
c) Identify inter area mode of oscillations through modal analysis.
d) Validate the control loop identified by various signal selection methods through a lead-lag compensator based power system stabilizer.

1.6 PROBLEM STATEMENT

Based on the in depth literature review undertaken by the researchers the research gap was identified and the following problem statement was formulated:

“Design of PSS to Damped out the Inter-Area Oscillations from Power System under Small Disturbance”

1.7 LIMITATIONS OF THE RESEARCH

The following are the delimitations of the research.

a) Test system used as a Kundur’s two-area four machine power system.[Kundur, 2004]
b) The damping controller used in this research is restricted to a lead lag compensator based Power System Stabilizer.
c) Out of the various signal selection methods only two methods of signal selections have been evaluated in this research.

II.LITERATURE SURVEY

García[2014]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.

Zhang [2013] In this paper lead-lag compensator based PSS has been used as wide area damping controller. Theparticipation factor of the system has been computed for identification of al low frequency inter area mode.

Padhy [2012] proposed a systematic procedure for designing a wide area centralised 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.

III.POWER SYSTEM COMPONENTS

Synchronous Generator Modelling

Synchronous generators are the principal source of electric energy in power system. The power system stability is the main problem that deals with the inter connections of synchronous machines in synchronism. The synchronous generator mainly consists of two essential components. First one is field and the second is the armature. The field winding carries direct current and produces a magnetic field which induces alternating current and produces a magnetic field which induces alternating voltages in the armature windings. The three-phase armature windings are distributed 120^0 apart in space.

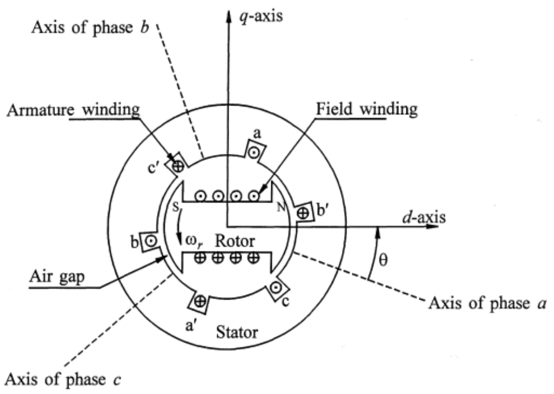

Figure 5 Schematic Diagram of a Three Phase

2.1Governor Modelling

The prime mover provides the mechanism for controlling the synchronous machine speed and hence voltage frequency. Consecutively to automatic control speed and frequency, adevice must be there to sense either speed or frequency in such a way that comparison with a desired value can be used to create an error signal to get corrective action. The control system diagram of such amodel for time constant governor 'T_G' with speed regulation 'R' is shown in figure.3.2

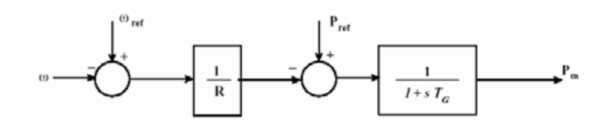

Figure 6 Block Diagram of Governor Model

2.2 Load Modelling

In study of stability modeling of load is a complex problem due to the uncertain nature of aggregate loads (e.g. a mix of fluorescent, compact fluorescent, incandescent lamps refrigerators, heater, motor, etc.). Load models are usually classified into two broad categories: static and dynamic. The loads can be modeled using constant impedance,constant current and constant power static load models. Dynamic load models are more complex in nature and mainly used for transient stability analysis. Conversely, static models are better suited for power flow and small disturbance stability analysis.

and frequency '**f**'. The variable 'k' used in the equation is known as loading factor. This kind loads are often called as ZIP model.

2.3Power System Stability

Power system stability may be broadly defined as property of power system that enables it to remain in a state of operating equilibrium under normal operating conditions and to regain acceptable state of equilibrium after being subjected to a disturbance [Kundur, 2004]

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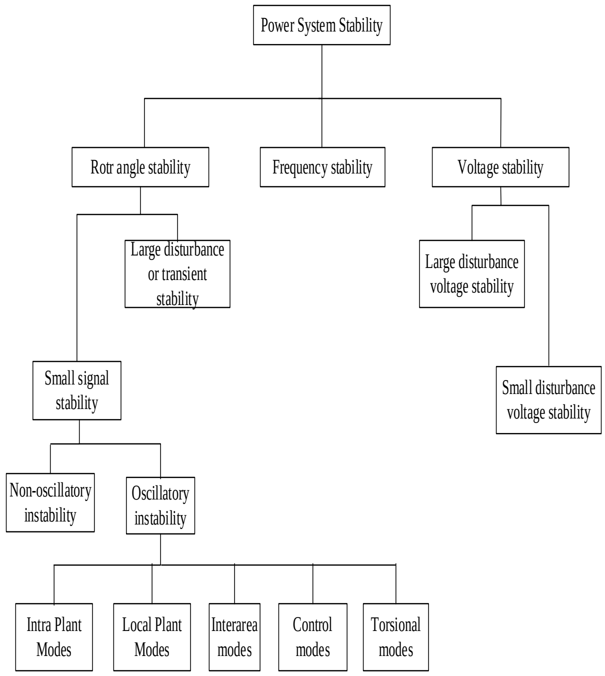

Figure 7- Classification of power system stability

IV.CONCLUSION

The kundur's two area four machine system was illustrated as test system to examine the effectiveness of the selected control signal to damp a given inter area mode. To determine the suitable control loop both residue and geometric measure of joint controllability/observability based signal selection approaches were carried out. The effectiveness of the selected control loop was performed by small disturbance stability assessment and robustness of the selected control loop was accomplished by large disturbance stability assessment.

Based on the experimental simulation of the designed WADC, the results and conclusion that can be drawn based on the interpretation of the results, in chapter 6 the following conclusion are arrived for Kundur two area four machines system..

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