Power System Stabilizer Design Using Local and Global signals

Chandrasekar Samudi, Kusumakumari.P

Abstract- **In this paper the feasibility of fuzzy logic based power system stabilizer with local and remote inputs is presented. Using global signals with the aid of Global Positioning System (GPS) and Wide Area Measurement (WAM) increases the possibility of global vision of power system and better damping to interarea oscillations. We have taken two input fuzzy logic controller for our study. The local input signal, generator rotor speed deviation is used to damp the local mode oscillations. The global signal obtained from WAM, such as Area differential frequency or Tie line active power deviation is used to damp the interarea oscillations. In the study, both transient and small signal stability analysis are used to determine the performance of study system.**

Key Words: Fuzzy Logic, Power system Stabilizer, Phasor Measurement Unit, Wide Area Measurement.

1. INTRODUCTION

WITH the increased loading of long transmission lines, transient and dynamic stability after a major fault are increasingly important, and they can become a transmission power-limiting factor. Stressed operating conditions can increase the possibility of inter-area oscillations between different control areas and even breakup the system. PSSs augment the power system stability limit and extend the power-transfer capability by enhancing the system damping of low-frequency oscillations associated with the electro-mechanical modes [1].

PSS with local inputs can damp the system oscillations but may not be very efficient due to their local view. New synchronized measurement techniques based on GPS system have been implemented for various problems in power system [2, 3]. The synchronized phasors over wide area, which have implication to the stability, can be measured by using the Phasor Measurement Unit (PMU). Indeed the inclusion of PMU as additional and remote inputs in feedback control loop for PSS, allows a global vision of the network [4]. Better dynamic performance for wide-areas can be achieved. In the area of large-scale power systems, interarea response (i.e., power flowing between distant points, energy-balance at distant generators) may be more effectively damped through the use of wide-area measurements [5].

The proposed PMU based PSS uses input signals from the generator where it is installed and also from a remote generator. These input signals, both local and remote are synchronized via the global positioning system 'GPS' satellites. Machine rotor speed deviation ($\Delta\omega$), is used to damp the local mode oscillations which is the main input for the conventional PSS (IEEE2B/4B Type) [6]. The deviation of rotor speed is too small to measure accurately with speed sensors and also measurement contains torsional oscillations. In PMU based measurement the rotor speed deviation is derived from phasor measurements and it is considered as a local signal. Accelerating power is combined with rotor speed deviation to eliminate inter area oscillations [7, 8, 9]. This type of PSS will give the local view of the system rather than global view. In our study rotor speed deviation is combined with remote signal such as differential area frequency ($\Delta f_{Area1-Area2}$) between two remote areas or Tie Line active power mismatch for global view. In this paper we studied about different combination of local and remote inputs and the results are compared with local feedback PSS. Fuzzy logic controller with two inputs is applied for all the studies. More discussion and simulation about PMU based PSS can be found in section-4 and 5.

2. DESCRIPTION OF THE STUDY SYSTEM

The two-area system shown in Fig. 1 has been studied extensively [1]. Two generation and load areas are interconnected by two parallel transmission lines. Each area is equipped with two identical round rotor generators rated 20 kV/900 MVA. The synchronous machines have identical parameters except for inertias which are H = 6.5s in area 1 and H = 6.175s in area 2. Dynamic data for generation and excitation system used in the study are given in appendix. The load is represented as constant impedances and split between the areas in such a way that area 1 is exporting 413MW to area 2. Since the surge impedance loading of a single line is about 140 MW the system is somewhat stressed, even in steady-state. The system exhibits three electro-mechanical modes:

- An inter-area mode, with a frequency of 0.64 Hz. in which the generating units in one area oscillate against those in the other area.

- Two local modes. One in each area. With a frequency of 1.12 Hz. and 1.16Hz In these modes the units in each area oscillate against each other.

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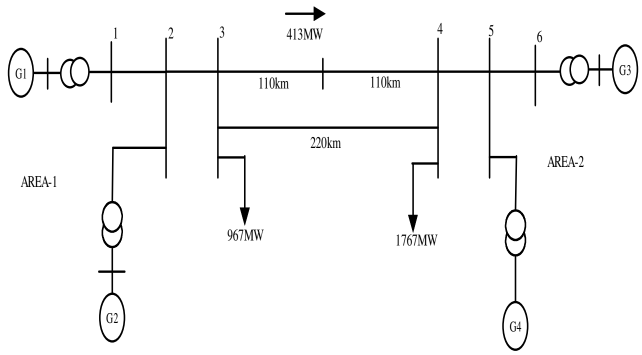

Figure-1 Sample Two area system

3. WIDE-AREA MEASUREMENT FOR CONTROL

In the last few years the wide area measurement (WAM) has emerged as a powerful tool to improve power systems performance and reliability. Wide area measurement system is most common application based on Phasor measurement Units [10]. Phasor Measurement Units (PMUs) are units that measure dynamic data of power systems, such as voltage, current, angle, and frequency. These measurements are synchronized by GPS satellites. If remote signals are applied to the controller, the system dynamic performance can be enhanced with respect to inter-area oscillations. Phasor Measurement Units provide important information about the power system in real time, an aspect that traditional measurement lack. Applications of Wide Area Control have been proposed in designing of power system stabilizer and results are reported [11, 12, 13, 14]. In this paper, we examine the theoretical aspect of using both local signal and global signal to damp the oscillations.

4. PSS WITH LOCAL AND REMOTE INPUTS

Del-Omega ($\Delta\omega$) type stabilizer is practically applied to several systems [7]. The past study shows that the Del-Omega($\Delta\omega$) type stabilizer perfectly damps the local mode oscillations but it fails to damp the inter area oscillations [7]. Del Omega ($\Delta\omega$)-Del Pa type stabilizers are most effective for complex mode oscillations such as local mode and inter area mode oscillations [7, 15]. In Del Omega ($\Delta\omega$)-Del Pa type stabilizer both the inputs are local inputs. In this study we considered one local input and one remote input. The local input signal gives the local view of the system and the remote input signal gives the global view of the system. Here we considered speed deviation as the local input, area differential frequency or Tie line power deviation is the global input. The differential area frequency and Tie Line active power deviations are obtained by PMUs. Inter area oscillations are mainly depends on the active power flow of tie-lines [16]. Therefore, the tie-line active power deviation is used as a stabilizing signal for damping the interarea modes associated with the tie-line.

5. FUZZY CONTROLLER

Applications of fuzzy logic have been proposed in designing of various types of PSS and good damping effects were reported [17, 18]. The fuzzy controller with 49 rule base is applied for this study. The table-1 shows the rule base. The input membership functions and out put membership functions are defined in Figure-3, 4 and 5.The output voltage is limited by -0.2 to 0.2. This value is chosen so as to allow sufficient control range, to provide satisfactory transient response, and to reduce the probability of a unit trip as a consequence of stabilizer failure.

The output signal was obtained using the following principle

- If the frequency/active power deviation is large but tends to decrease, then control must be moderated
- If the frequency/active power deviation is weak but tends to increase, then voltage must be significant.

	NB	NM	NS	Z	PS	PM	PB
NB	NB	NB	NB	NB	NM	NS	Z
NM	NB	NB	NM	NM	NS	Z	PS
NS	NB	NM	NM	NS	Z	PS	PM
Z	NM	NM	NS	Z	PS	PM	PM
PS	NM	NS	Z	PS	PM	PM	PB
PM	NS	Z	PS	PM	PM	PB	PB
PB	Z	PS	PM	PM	PB	PB	PB

Table-1 Fuzzy Rule Base.

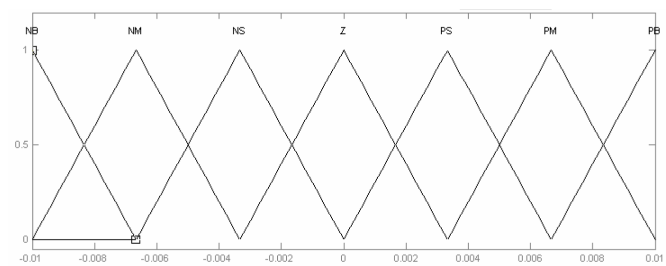

Figure-2 Local speed Deviation ($\Delta\omega$)

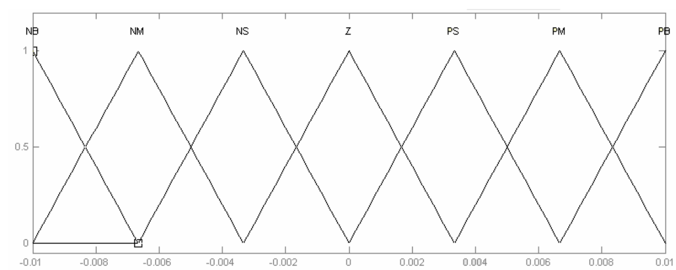

Figure-3 Area Differential frequency/ Tie line power mismatch.

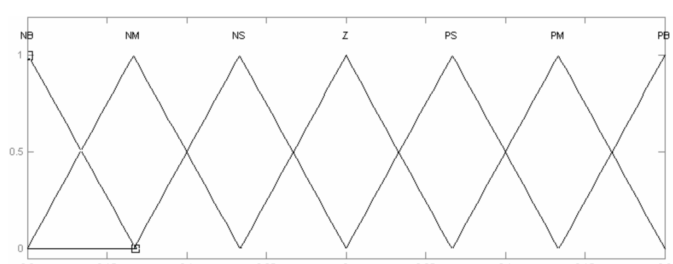

Figure-4 PSS Output voltage

6. TRANSIENT STABILITY PERFORMANCE ASSESSMENT

To analyze the large signal performance, a three phase fault is applied at middle of the line. Figure-2 shows the system responses to a three-phase fault cleared in 8 cycles by opening the breaker at both the ends. From the results, we conclude that the PSS with the inputs of tie line active power deviation and local speed deviation ($\Delta\omega$) has superior performance than the PSS with the inputs of Area differential frequency and local speed deviation ($\Delta\omega$).The natural frequency and damping of the inter-area mode depends on the weakness of the tie and on the power transferred through the tie [16]. PSS with global input has better performance than the PSS with local input. Hence, the system with tie line active power deviation feedback signal has quick settling time.

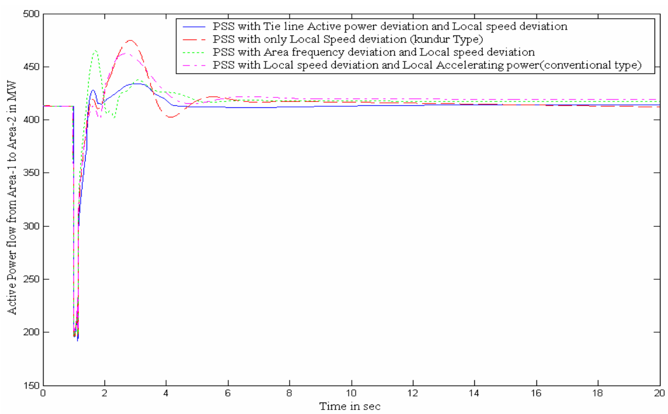

Figure.5 Large signal analysis of Active power flow from Area-1 to Area2 with PSS

7. SMALL SIGNAL PERFORMANCE ASSESSMENT

To analyze the small signal performance, a 5% magnitude pulse is applied for 12 cycles at the voltage reference of Generator-1. The figure-6 shows the small signal performance of system with out PSS. The figures-7, 8,9and 10 shows the small signal performances of Area active power deviation, generator speed deviation, terminal voltage and Accelerating power for different type of stabilizers. Speed deviation, terminal voltage and accelerating power are measured at generator-1. Small signal performance shows that PSS with Tie line active power deviation signal via PMU is more effective in damping the oscillation of power transfer and also fast on recovering rated speed and rated terminal voltage. But other types are too slow on recovering on rated speed and terminal voltage.

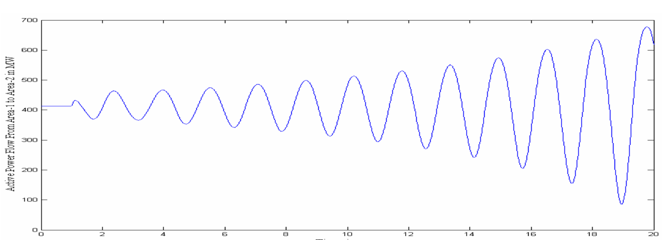

Figure-6 Active power flow from Area-1 to Area-2 with out PSS

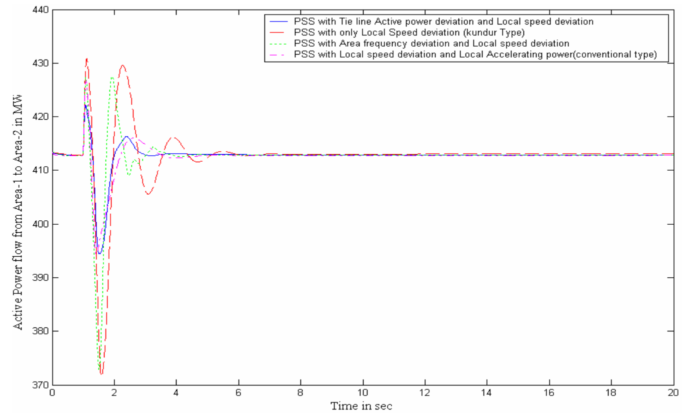

Figure-7 small signal analysis of Active power flow from Area-1 to Area2 with PSS

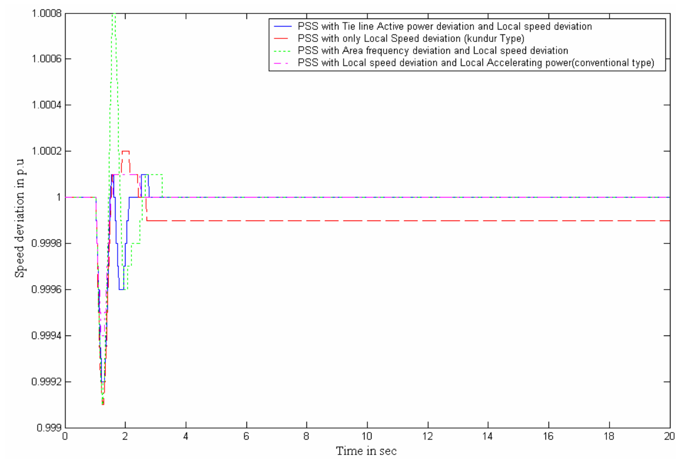

Figure-8 Speed deviation Measured at Generator-1

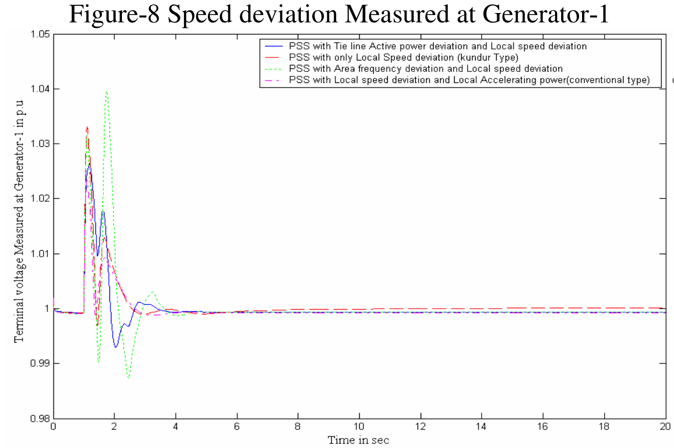

Figure-9 Terminal voltage Measured at Generator-1

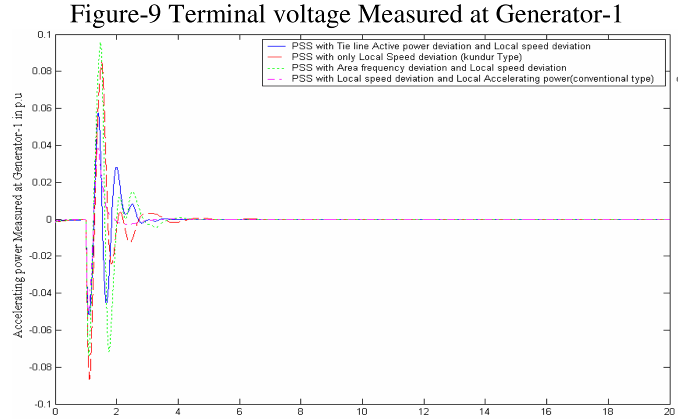

Figure-10 Accelerating power measured at Generator-1

8. CONCLUSION

In this paper, wide area measurement based PSS has been proposed with the combination of local and global inputs. Fuzzy controller with local and global signal inputs shows more effective in damping inter area oscillations and also increases power transfer limits. Simulation results show the effectiveness of the proposed stabilizer in damping low frequency oscillations and also results are compared with Del-Omega ($\Delta\omega$) and Del Omega ($\Delta\omega$)-Del Pa type. Small signal and large signal stability analysis shows the performances of proposed PSS.

9. REFERENCES

[1] P. Kundur, Power Systems Stability and Control. McGraw-Hill, 1994.

[2] Kerim Mekki, Nouredine Hadjsaid, Didier Georgrs, Rene Feuillet, Aarun G. Phadke, Felix F. Wu, " Wide-area measurements for power system oscillations and FACTS interactions", 14th PSCC, Sevilla, 24-28 June 2002.

[3] Hongxia Wu, *G.* T. Heydt, "Design of Delayed-Input Wide Area Power System Stabilizer Using the Gain Scheduling Method", Power Engineering Society General Meeting, IEEE, Volume3, 13-17 July 2003.

[4] B. Fardanesh, "Future trends in power system control", IEEE computer application in power, Volume 15, Issue 3, Pages:24 - 31 July 2002.

[5] Christian Rehtanz, Joachim Bertsch, "Wide Area Measurement and Protection System for Emergency Voltage Stability Control", IEEE, Power Engineering Society Winter meeting, Volume 2, Pages: 842 – 847, 27-31 Jan. 2002.

[6] R. Grondin, I. Kamwa, G. Trudel, L. GBrin-Lajoie, J. Taborda, "Modeling and closed-loop validation of a new PSS concept, the Multi-Band PSS", Power Engineering_Society General Meeting, IEEE, Volume 3, 13-17 July 2003.

[7] P. Kundur, M. Klein, G.J. Rogers, M.S. Zywno, "Application of Power System Stabilizers For Enhancement Of Overall System Stability", IEEE Transactions on Power Systems, Vol. 4, No. 2, May 1989.

[8] Avdhesh Sharma, M.L. Kothari, "Intelligent Dual Input Power System Stabilizer for Multi-Machine System", Transmission and Distribution Conference and Exhibition 2002: Asia Pacific. IEEE/PES, Volume 1, Page(s):168 – 173, 6-10 Oct, 2002.

[9] A. Murdoch, S. Venkataraman, R.A. Lawson, W.R. Pearson" Integral of Accelerating Power Type PSS Part 1 - Theory, Design, and Tuning Methodology", IEEE Transactions on Energy Conversion, Vol. 14, No. 4, December 1999.

[10] Yutaka Ota, Hiroyuki Ukai, Koichi Nakamura, Hideki Fujita, "PMU based Midterm Stability Evaluation of Wide-area Power System", Transmission and Distribution Conference and Exhibition 2002: Asia Pacific. IEEE/PES, Volume 3, Page(s):1676 – 1680, 6-10 Oct. 2002

[11] I. Kamwa, R. Grondin, and Y. Hebert, "Wide-area measurement based stabilizing control of large power systems—A decentralized/hierarchical approach," *IEEE Trans. Power Syst.*, vol. 16, pp. 136–153, Feb.2001.

[12] Balarko Chaudhuri, Rajat Majumder, Bikash C. Pal*,"* Wide-Area Measurement-Based Stabilizing Control of Power System Considering Signal Transmission Delay", IEEE Transactions On Power Systems, Vol. 19, No. 4, November 2004

[13] Daniel Karlsson, Morten Hemmingsson, and Sture Lindahl, "Wide area system monitoring and control Terminology, phenomena, and solution implementation strategies ", IEEE power and energy magazine, Volume 2, Issue 5, Page(s):68 – 76, Sept.-Oct. 2004.

[14] Hongxia Wu, Konstantinos S. Tsakalis, Gerald Thomas Heydt, "Evaluation of Time Delay Effects to Wide-Area Power System Stabilizer Design", IEEE Transactions on Power Systems, Vol.19, No. 4, NOV. 2004.

[15] M. Klein, G.J.Rogers, S.Moorty, P. Kundur,"Analytical Investigation Of Factors Influencing Power System Stabilizers Performance", IEEE Transactions on Energy Conversion, vol. 7, No. 3, September 1992.

[16]] Magdy E. Aboul-Ela, A.A. Sallam, James D. McCalley, A.A. Fouad, "Damping control design for power system oscillations using global signals", IEEE Transactions on Power Systems, Vol. 11, No. 2, May 1996.

[17] M. Dobrescu, Kamwa, "A New Fuzzy Logic Power System Stabilizer Performances", Power Systems Conference and Exposition, IEEE PES, vol.2, Pages: 1056 - 1061, 10-13 Oct. 2004.

[18] Ruhua You, Hassan J. Eghbali, and M. Hashem Nehrir, "An Online Adaptive Neuro-Fuzzy Power System Stabilizer for Multimachine Systems", IEEE Transactions on Power Systems, Vol. 18, No. 1, FEBRUARY 2003.

APPENDIX

Generator Data

X_d=1.8 p.u X_d'=0.3 p.u Xd''=0.25 p.u Xq=1.7 p.u X_q'=0.25 p.u

X_q''=0.25 p.u XL=0.2 p.u

T_{do}'=8s Tdo''=0.03s T_{qo}'=0.4s T_{qo}''=0.05s

R_a=0.0025 p.u

H = 6.5s for Area-1 H = 6.17s for Area-2

D=0
Generator base: 900 MVA

Exciter Data

Ka=200 Ta=0.001s Tb=0 Tc=0

Governor Parameters

Kp=1 Rp=0.05

Tsr=0.001s Tsm=0.15s

T2=0s T3=10s T4=3.3s T5=0.5s

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