Analysis of Transient Stability Enhancement Using Multi-Band Stabilizer on South Sulawesi Power Grid

Jeremias Leda
Department of Electrical Engineering
The University of Atma Jaya Makassar
Makassar, Indonesia

***Abstract* — Interconnected system has been operated widely for increasing electrical power reliability. Stability factor in such system is very important in which stability analysis is used to define whether the rotor of interconnected generators may be still in their synchronize speed after disturbance was happen or may loss their synchronization speed. Disturbance on power system could create electro-mechanics oscillation. One may damp such oscillation using power system stabilizer. The Multi-Band Power System Stabilizer (MB-PSS) is a concept to reduce oscillation effectively due to disturbances to avoid loss of synchronization.**

This paper investigate and analyze the use of MB-PSS as a damping system in South Sulawesi power grid through a digital simulation study. The simulation result shows that MB-PSS could works nicely and more effective compare to generic PSS and may use to enhance system stability of South Sulawesi power grid.

Keywords* — *multi-band; stabilizer; oscillation; power system

I. INTRODUCTION

Interconnection of power system is needed because enable one to take advantages of diversity of loads, availability of sources and fuel consumption in order to supply electricity to the consumers at minimum cost with a required reliability. However, there are a number of stability issues that limit the transmission capability, such as transient stability, dynamic stability and steady-state stability. This paper is going to focus on transient stability problems in which the South Sulawesi power grid in Indonesia is taking into the field to study.

Various factors affect transient stability of a system such as the strength of transmission network within the system and of the tie lines to adjacent system, the characteristic of the generating units, including inertia of the rotating parts and electrical properties such as transient reactances and magnetic saturation characteristic of the stator and rotor iron. Another factor is the speed with which faulted lines can be disconnected and with the automatic reclosing transmission line, how rapidly lines can be restored to service. The speed with which the generator excitation systems give their respond is important in maintaining transient stability. According to the definition, transient stability is the ability of generating systems to remain in sysnchronism during the period following a disturbances and prior to the time at which governors can act. Ordinarily the first swing of machines rotors will take place within about one second following the disturbance but the excat time depend on the machine characteristic and transmission line.

This paper introduce the advantages of a MB-PSS to reduce electro-mechanic oscillation of South Sulawesi power grid in Indonesia. It is well known that poorly damped of oscillations typically occur in power systems with longitudinal structure or weak ties. The supplementary excitation controllers are used as additional feedback signals to enhance system damping and to improve the dynamic stability of power systems. These controllers are known as power system stabilizers. They have been widely used for years with many types.

The MB-PSS proposed in this paper has advantages of its simplicity, systematic design and combine functions of AVR and PSS. The performance of this controller is investigated for South Sulawesi power grid which is starting with collecting data, modelling, simulation, analysis, interpreting and then results discussion. Simulation work is done at laboratory of electrical engineering department at the University of Atma Jaya Makassar using multi-machine detail model under MATLAB Simulink environment.

II. BASIC CONCEPT OF STABILIZER

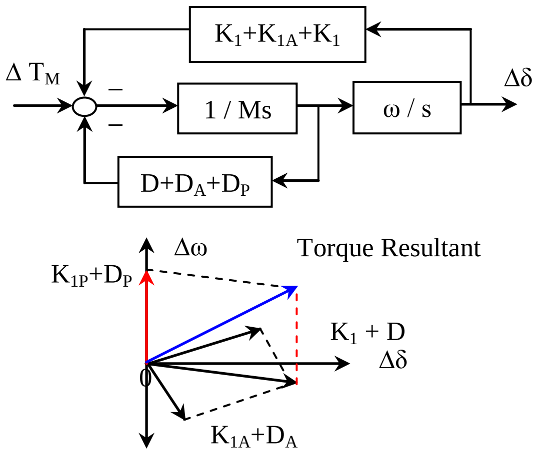

Fig. 1. AVR + PSS Torque Characteristic Diagram

PSS is designed to work together with generator excitation system in order to produce positive damping torque to ensure system stability in which can be explain by torque vector diagram as Fig.1 above. K1 is synchronizing torque, K1A is synchronizing torque by AVR and K1P is synchronizing torque by PSS. Where D is damping torque DA is damping torque by AVR and DP is damping torque by PSS.

In principle generic PSS has three components as seen on Fig.2. They are washout, gain and phase compensation. The washout block serves as high pass filter with time constant high enough to allow signal associated with electro-mechanics oscillation to pass unchanged. The gain block determines the amount of damping introduced by PSS. Phase compensation block provides an approriate phase lead characteristics to compensate phase lagging between exciter input and generator electrical torque.

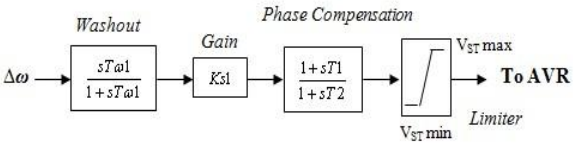

Fig. 2. Generic PSS Block Diagram

The input Δω is rotor speed which came from the relation of change among mechanical power, electrical power and accelerating power as illustrated on diagram below.

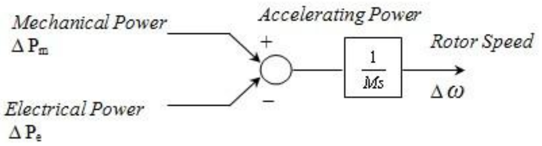

Fig. 3. Power and Rotor Speed Relation Diagram

PSS has three types of application. The simplest type is single input type such as ΔP, Δω or Δf which may be used for individual generator oscillates against the system with frequency of 1 Hz approximately and named local mode power oscillation. For this case ΔP type is more effective. The second type is used for the whole system oscillates with long distance and large power transfer system connection that known as inter-area mode power oscillation or long-cycle. In this case Δω or Δf is more effective. The third type PSS is used for complex power oscillation mode such as local mode and inter-area mode. In this case multiple input is more effective. For instance ΔP + Δω or ΔP + Δf type of PSS input. The connection of the three type of PSS is shown in next figures.

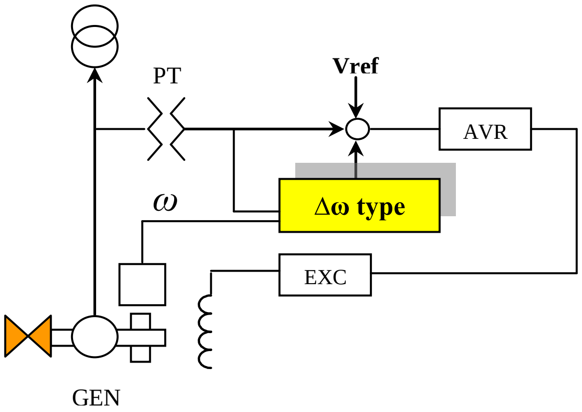

Fig. 4. Connection Diagram of Δω type PSS

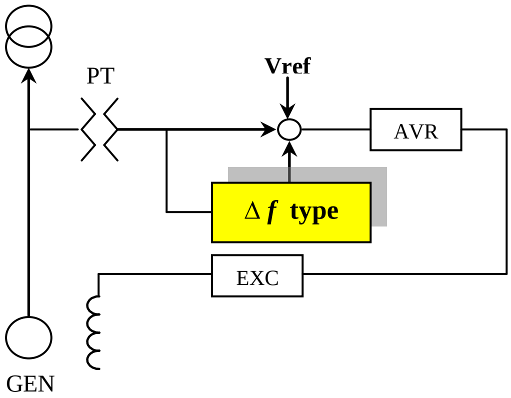

Fig. 5. Connection Diagram of Δf type PSS

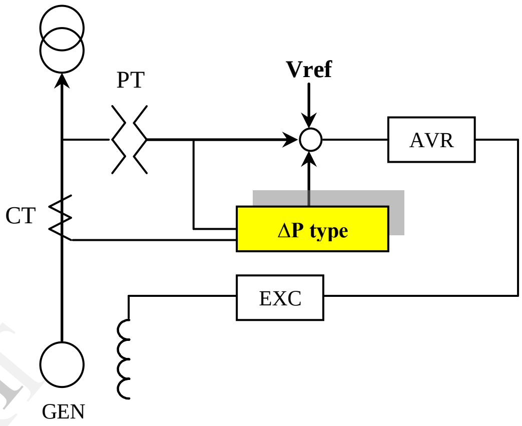

Fig. 6. Connection Diagram of ΔP type PSS

III. MULTI-BAND POWER SYSTEM STABILIZER

The multi-band power system stabilizer here is according to IEEE type PSS4b (Innocent Kamwa, Robert Grondin, IREQ Hydro-Quebec). Basically that type of stabilizer consist of three pass band that the low-pass, intermediate pass and high pass. Each of the three pass-band also have gain, lead-lag compensation and limiter respectively.

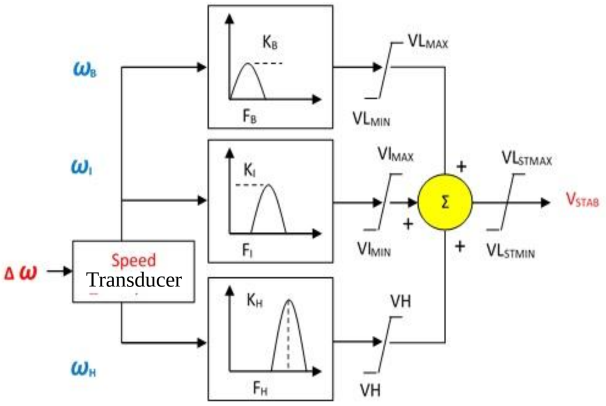

Fig. 7. Representation of MB-PSS

The need for effective damping of a wide range of electromechanical oscillations has motivated the concept of the MB-PSS. As its name reveals, the MB-PSS structure is based on multiple working bands. The low band is typically associated with the power system global mode, the intermediate band with the inter-area modes, and the high band with the local modes.

The output of MB-PSS is feed into adder block before goes into the exciter block. On the other hand input of MB-PSS is design as electric power acceleration which consist of the rotor speed deviation Δω and the change of the rotor speed dΔω as shown in fig. 8 below.

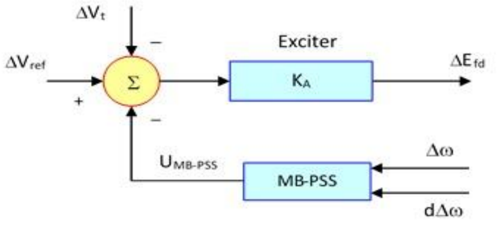

Fig. 8. Block Diagram of Exciter and MB-PSS

Two different approaches are available to configure the settings during MB-PSS tuning process:

(a) Simplified Settings: Only the first lead-lag block of each frequency band is used to tune the MB-PSS. The differential filters are assumed to be symmetrical band-pass filters respectively tuned at the center frequency FB, FI, and FH shown in fig. 7. The peak magnitude of the frequency responses can be adjusted independently through the three gains KE, KI, and KH.

(b) Detailed Settings: The designer is free to use all the flexibility to built into the MB-PSS structure to achieve nontrivial controller schemes and to tackle even the most constrained problem (for example, multi unit plant including an inter-machine mode, in addition to a local mode and multiple inter-area modes). In this case, all the time constants and gains have to be specified.

IV. SIMULATION, RESULT AND DISCUSSION

According to PLN, National Electric Power Company of Indonesia for the region of South Sulawesi, the total power installed in 2010 is 623 MW for supply the total load of 541 MW through the length of 1,926 km of transmission lines. Here, the grid-ring is simplified and created especially for this study of oscillation problem under Simulink configuration with 4 machine as shown in figure 9 which is used to examine oscillation problem. As shown in the single line diagram there are four generators, GEN1, GEN2, GEN3 and GEN4, and four 11.5/150 kV step-up transformers. There are 8 loads in the system except at bus no.7. The transformer and line impedances for the system are given in Appendix and also data of generators. Some of the set up parameters based on their preset value by MATLAB.7-Simulink is acceptable due to the lack of information.

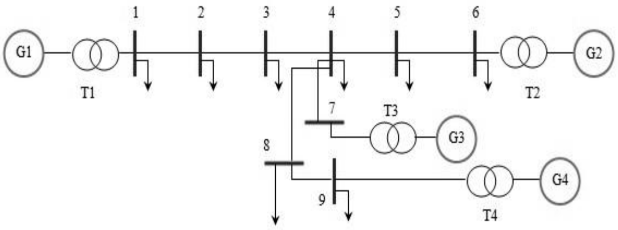

Fig. 9. Single Line Diagram of Testing System

The loads are modeled as constant impedances. A 135 MW electrical power transfer from GEN1 of area#1 to area#2 of GEN2 and area#3 of GEN3 and GEN4 is the main case study which is very stressed operating point.

This system exhibits seven electromechanical modes of oscillations. Three inter-area mode which the generating units in one area oscillates against those in the other area. The frequency of this mode varies from 0.35-0.75 Hz depending on operating conditions. And four local modes which represent oscillations generating units internally within each area against system.

The MB-PSS is used for each generating units. The test contains three inter-area. A comparison between the results of a generic PSS and without PSS due to different disturbances is presented below. Comparisons between resultant performances is needed. So we present the results values for the relation among the system with PSS dan without PSS graphically.

Models are simplifications thus there are relatively small numerical error and will not be valid exactly. However when used appropriately the simulation models provide an important results and useful information. Results of simulation are as follow:

During the simulation, there is assumption that input power is constant, no phase shifting between the rotor angle on each generating machine and the voltages respectively, bus no.7 is swing and finally fault location is on bus no.1.

A. Single Phase to Ground Fault

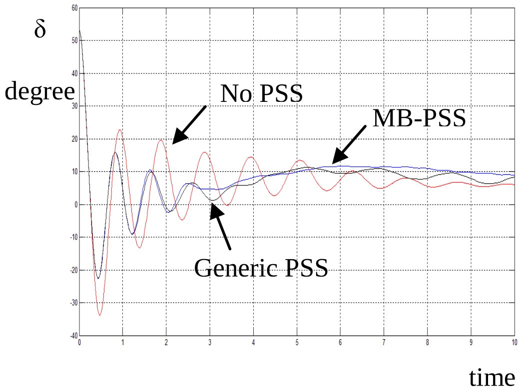

Fig. 10. GEN 1 - GEN 2 Rotor Angle Deviation

It can be seen that MB-PSS works better than Generic PSS and without PSS the deviation of rotor angle tends to produce instability problems.

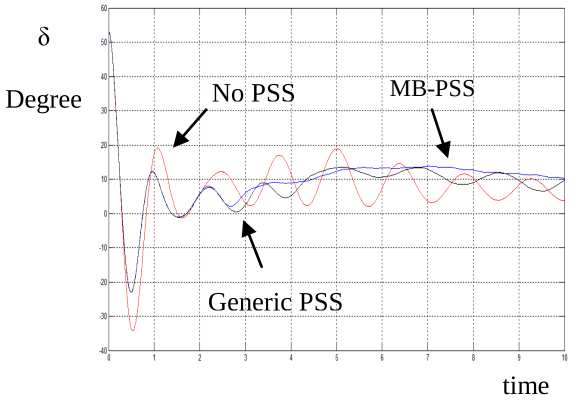

Fig. 11. GEN 1 - GEN 3 Rotor Angle Deviation

Again, it also can be seen that MB-PSS works better than Generic PSS and without PSS the deviation of rotor angle tends to produce instability problems.

B. Three Phase Fault to Ground

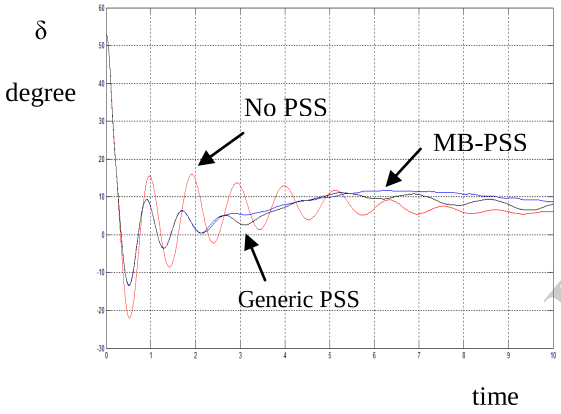

Fig. 12. GEN 1 – GEN 2 Rotor Angle Deviation

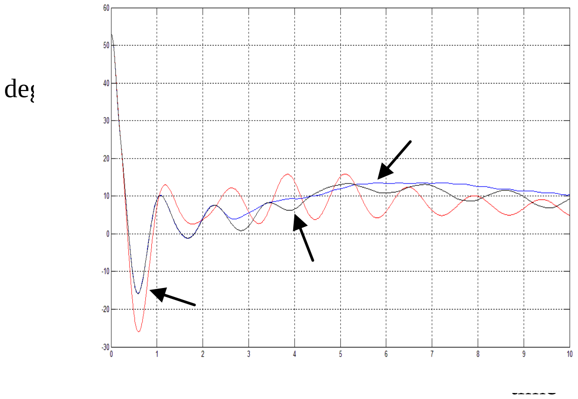

Fig. 13. GEN 1 – GEN 3 Rotor Angle Deviation

In three phase fault to ground cases, the curve results also shows that MB-PSS works more effective than generic PSS and if without PSS the system oscillation tends to unstable.

Simulation results of the single phase fault to ground and the three phase fault to ground look similar in which MB-PSS works better than generic PSS.

On the other hand if the system is designed without PSS thus the two fault will produce oscillation and potential to create electromechanical oscillations on the grid system.

V. CONCLUSION

The work on this research has been done under MATLAB environment and shows that for both fault, single phase and three phase fault to ground:

- MB-PSS is better than generic PSS and able to stabilize the grid system in which may damp the disturbances.
- The MB-PSS signal can modulate the set point of the generator voltage regulator so as to improve damping of the system.
- The MB-PSS can work on both local area and inter-area of electromechanical oscillations.

APPENDIX

SYSTEM DATA

TABLE II
GENERATORS, LOAD AND TRANSFORMERS DATA

No	Bus Name	Generator	Transformer	Load
1	Sengkang	135 MW, 11,5 kV, Xd" = 0,17417 pu	210 MVA, 11,5/150 kV, X = 0,16929 %	30 MVA
2	Soppeng	-	-	40 MVA
3	Sidrap	-	-	20 MVA
4	Pare-pare	-	-	16 MVA
5	Pinrang	-	-	21 MVA
6	Bakaru	126 MW, 11,5 kV, Xd" =0,24 pu	130 MVA, 11,5/150 kV, X = 0,1683%	20 MVA
7	Suppa	80,4 MW, 11,5 kV, Xd" =1,9679 pu	90 MVA, 11,5/150 kV, X = 0,275%	-
8	Pangkep	-	-	93 MVA
9	Tello	180 MW, 11,5 kV, Xd" =1,4125 pu	240 MVA, 11,5/150 kV, X = 0,625%	133 MVA

Data Source: PT. PLN AP2B Sistem Sulawesi Indonesia

TABLE III
GENERATORS IMPEDANCE

No	Generator	Xd	Xd'	Xd''	X1	X0
1	GEN1	3,3527	0,2903	0,17417	0,2467	0,1016
2	GEN2	1,3200	0,3829	0,2400	0,2529	0,1557
3	GEN3	14,515	2,6867	1,9679	1,9679	0,8723
4	GEN4	5,2041	0,4388	1,4125	0,3010	0,1888

Data Source: PT. PLN AP2B Sistem Sulawesi Indonesia

TABLE IV
LINE TRANSMISSION IMPEDANCE

No	Line		Length	Total Impedance (Ohm)		
	from	to	(km)	R	X_L	Y/2
1	Sengkang	Soppeng	35.4	2.369	14.253	0.00004
2	Soppeng	Sidrap	53.8	6.348	22.809	0.00004
3	Sidrap	Pare-pare	19.1	2.254	8.097	0.00001
4	Pare-pare	Pinrang	26.4	3.123	11.192	0.00003
5	Pinrang	Bakaru	58.5	6.921	24.802	0.00004
6	Pare-pare	Suppa	7.5	0.885	3.180	0.00000
7	Pare-pare	Pangkep	90	10.647	38.155	0.00010
8	Pangkep	Tello	45.3	5.359	19.205	0.00005

Data Source: PT. PLN AP2B Sistem Sulawesi Indonesia

ACKNOWLEDGEMENTS

This research was supported by Direktorat Penelitian & Pengabdian Masyarakat DITLITABMAS Ditjen DIKTI, National Ministry of Higher Education of Indonesia through Penelitian Hibah Bersaing No.005/PNL/PK-KOP.IX/2014 date 16 May 2014.

REFERENCES

[1] Ahmad Rohani, M. Reza Safari T and Reza Noroozian, Combined Design of PSS and STATCOM Controllers For Power System Stability Enhancement, Journal of Power Electronics, Vol.11, No.5, September 2011, pp. 734-742.

[2] A. Safari, R. Jahani, M. Hajinasiri, A.H. Araskalaei and H.A. Shayanfar, “COA based coordinated design of FACTs and PSS output feedback controllers”, International Review of Electrical Engineering, vol. 21, no. 6, 2010.

[3] C J Wu and Y Y Hsu, “Design of Self-tuning PID Power System Stabilizer for Multimachine Power System”, IEEE Transactions on Power Systems, vol. 3, pp. 1059-1064, Aug. 1998.

[4] Eltahir Mohamed Hussein and Bahar A.A.Elmahi, Fuzzy Logic Based VAR Stability for Power System Control, Journal of Science and Technology 12 (02) December 2011, ISSN 1605 – 427X.

[5] Francis H. Raven, 1995 Automatic Control Engineering, McGraw-Hill International Edition, Singapore.

[6] F. W. Keay and W. H. south, “Design of Power System Stabilizer Sensing Frequency Deviation”, IEEE Transactions on Power Apparatus and Systems, vol. 90, pp.707- 713, March 1971.

[7] G. P. Chen, Y.Q. Qin , G.Y. Xu and O. P. Malik, Optimization Technique for The Design of a Linear Optimal Power System Stabilizer, IEEE Transactions on Energy Conversion, Vol.7, No.3, September 1992, pp.453-459.

[8] Imam Robandi, 2006, Desain Sistem Tenaga Modern, Andi Offset, Yogyakarta.

[9] Jeremias Leda, Fuzzy Controller for Reducing Oscillation On Large Power System, IJERT International Journal of Engineering Research and Technology, Vol. 2 (01), 2013, ISSN 2278 – 0181, page 1467-1473.

[10] J H Chow and J J Sanchez-Gasca, “Pole Placement Designs of Power System Stabilizers”, IEEE Transactions on Power Systems, vol. 4, pp. 271-277, Feb 1989.

[11] M. E. Aboul-Ela, A. A. Sallam, J. D. McCally and A. A. Fouad, Damping Controller Design for Power System Oscillations Using Global Signals, IEEE Transactions on power apparatus and systems, Vol.11, No.2, May 1996, pp.767-773.

[12] Narain G. Hingorani & Laszlo Gyugyi, Understanding FACTS, Concepts and Technology of Flexible AC Transmission System (Wiley-Intersience A. John Wiley & Sons, Inc. NY, USA, 2000).

[13] P Kundur, “Power System Stability and Control”, McGraw-Hill 1994.

[14] R. J. Fleming and J. Sun, An Optimal Multivariable Stabilizer For a Multi-Machine Plant, IEEE Transactions on Energy Conversion, Vol.5, No.1, March 1990, pp.15-22.

[15] Robert H. Miller dan James H. Malinowski, Power System Operation (McGraw-Hill Co. Singapore, 1994).

[16] S. Cheng, Y. S. Chow , O. P. Malik and G. S. Hope, An Adaptive Synchronous Machine Stabilizer, IEEE Transactions on Power Apparatus and Systems, Vol. PWRS-1, No.3, August 1986, pp.101-106.

[17] Stanley M. Shinners, Advanced Modern Control System Theory and Design (John Wiley & Sons, Inc.USA, 1998).

[18] Syed A. Nasar, 1990. Electric Power Systems, Schaum’s ouT-lines, McGraw-Hill Co. USA.

[19] William D. Stanley, John R. Hackworth, Richard L. Jones, Fundamentals of Electrical Engineering and Technology (Thomson Learning, Inc. USA, 2007).

[20] William D. Stanley, Technical Analysis and Applications with MATLAB (Thomson Learning, Inc. Canada, 2005).

[21] William D. Stanley, John R. Hackworth, Richard L. Jones, 2007. Fundamentals of Electrical Engineering and Technology, Thomson Learning, Inc. USA.