Stability improvement of wind turbine penetrated using power system stabilizer (PSS) on South Sulawesi transmission system

by Agus Siswanto

Stability Improvement of Wind Turbine Penetrated Using Power System Stabilizer (PSS) on South Sulawesi Transmission System

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Abstract. The purpose of this research is to improve the stability of interconnection of South Sulawesi system caused by penetration new wind turbine in Sidrap area on bus 2 and in Jeniponto area on bus 34. The method used in this research was via software Power System analysis Toolbox (PSAT) under MATLAB. In this research, there are two problems that are evaluated, the stability of the system before and after penetration wind turbine into the system South Sulawesi system. From the simulation result shows that penetration of wind turbine on bus 2 Sidrap, bus 37 Jeniponto give effect oscillation on the system. The oscillation was damped by installation of Power System Stabilizer (PSS) on bus 29 area Sungguminasa, that South Sulawesi system stable according to normal condition.

INTRODUCTION

The use of electric power is increasing especially in South Sulawesi in accordance with the research predictions of electrical energy consumption by[1] Impact on system stability. This condition causes the power system to operate in a condition that is very susceptible to the phenomenon of stability resulting in a voltage drop. Drop voltage is a topic that is often reviewed by researchers on electric power systems. For that researchers develop renewable energy for energy supply needed by consumers. Renewable energy includes PV, Geothermal, and Wind Turbine. A review of renewable energy has been done by[2,3], Special development of PV has been done[4], Research on Ocean Renewable Energy ORE in Indonesia[5].

To improve the stability has been installed additional equipment in the form of Power System Stabilizer (PSS). A review of PSS Tuning on the 150 kV South Sulawesi power system has been developed[6]. As well as the dynamic situation in the South Sulawesi system has been discussed by[7]. Several methods have been proposed to improve the stability of power systems such as scheduling generation in the 500kV Java-Bali system[8,9]. Other research on dynamic stability improvement using PSS based firefly Algorithm on[10] And PSS parameter design on nonlinear stability analysis on[11,12]. Currently in the islands of south Sulawesi is being developed by the Government of Wind turbine through[13] It is to increase the capacity of electric power is increasing. From the development of wind turbine capacity will have a good effect on the system However, the influence of wind turbine to the network system has a significant effect on the stability and the power system.

The power system operator should revise the operating system when renewable energy is used. Research on operation planning of power plant has been done by[14]. Therefore, the interaction characteristics between wind turbine and power systems such as transient and steady state stability have

Engineering International Conference (EIC2017)
AIP Conf. Proc. 1941, 020036-1–020036-14; https://doi.org/10.1063/1.5028094
Published by AIP Publishing. 978-0-7354-1633-8/$30.00

occurred very important. Based on this view, the application of PSS to wind turbine penetration controllers in South Sulawesi transports is proposed in this paper in order to improve travel errors through PSS Traffic.

Utilization of PSS in various power system applications as in the above research but the study of PSS applications on renewable energy has not been done, so this study. PSS control is planned to adjust the gain of control parameters due to wind turbine penetration to improve the stability of the variation system under operating conditions, the performance of the PSS control system is good and can be achieved.

EXPERIMENTAL

Materials

The power system model used in this study is shown in Fig. 1. The Representation system consists of 15 Generators, 44 bus systems, 45 networks and 34 loads. Location of generator on the bus, 10 suppa, 11 Pltubar, 18 Tello, 1 Skang, 21 Brloe, 26 Tgama, 29 Sgmsa, 31 Tlasa, 33 Pgaya, 36 Sinjai, 38 Mkale, 39 Palopo, 41 Pltapo, 5 prang, 7 bakaru . Wind turbine in. Bus jeniponto, load bus that no supplay generator. The plant uses primers The water power and thermal steam power have each capability presented by the circumstances of the rotor sutuf. Representation of synchronous machines in maintaining a stable state by maintaining a balance between mechanical torque and electric torque.

Stability System Model

Generators in thermal and water generators have their respective capabilities that can be represented through the circumstances of the rotor angle. The ability of synchronous machines in maintaining system Sync by maintaining a balance between mechanical torque and electric torque. The system in South Sulawesi is interconnected between hydroelectric and steam power engines. Under normal conditions these machines operate in their synchronous state, maintaining the frequency state according to normal limits and maintaining constant power point differences from each of the generators on a contingency basis.

Transient oscillations or transient disturbances in short and large network of sudden system changes may alter the operating state of the system may cause instability[15]. Once the power system interruption can return to the initial operating point at the point or reach the stable equilibrium point of the synchronous losses, the system is said to be stable. There are many factors affecting system stability such as total rotating kinetic energy, total power reserves, control schemes and so on.

Renewable energy (wind Turbine) entering the system, if the penetration level of the power system is significant, the stability of the system may become more vulnerable. During a rotor disturbance the engine can retrieve or slow down according to the swing equation. If the total engine spins a small inertia that may be caused by wind turbine, the difference between the acceleration and the power of the Slowdown during interruption can be significant and the entire system may lose synchronization. Therefore when a low rotating system of inertia the immersion power needs to be detected for immersion.

Wind Turbine Model

Wind Turbine to be applied in Jeneponto South Sulawesi as much as 18 turbine (windmill) with an area of 100 Ha. Each wind turbine produces 3.5 MW. In accordance with government planning on[13] And the publication of PT PLN on May 1, 2016 (PLN 2016). The first time turbine speed starts spinning produces power called a cut-in speed of 3 to 4 m / sec. For speeds above 12 to 17 m / sec the output power reaches the capability of the generator. The application of this South Sulawesi wind turbine uses an average wind speed of 15 m / s which is considered constant in analyzing voltage stability. Although the real wind velocity in the field changes according to the conditions of time and circumstances (wind power Program, 2013)

Control PSS

In analyzing the stability of the system, it can use a synchronous generator model to observe the frequency response and rotor angle. Mathematical forms of PSS and AVR machines are as follows:

$$\frac{d\delta}{dt} = \Delta\omega \tag{1}$$

$$\frac{d\Delta\omega}{dt} = \frac{1}{M}\left[P_m - E_q I_q - \left(x_q - x_d\right).i_d i_q\right] \tag{2}$$

$$\frac{dE'_q}{dt} = \frac{1}{T'_{d0}}\left[E_{fd} - E'_q - \left(x_d - x'_d\right)i_d\right] \tag{3}$$

Where, $\Delta\delta$ is rotor angel change, $\Delta\omega$ is rotor speed change, ΔP is active power, δ is rotor angel, ωo is rotor speed, Te is electrical torque, H is combined turbo-generator inertia constant, Ks is synchronizing coefficient and K_D is damping coefficient .

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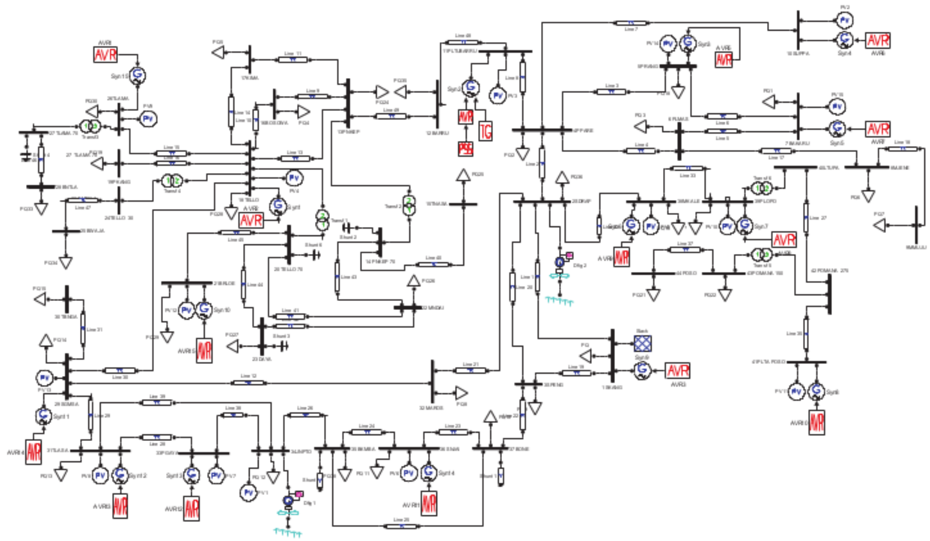

FIGURE 1. South Sulawesi System

Model Exciter

In this research the excitation model used to function to regulate generator output variables include voltage, current and power factor.

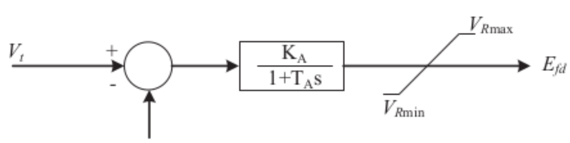

FIGURE 2. Exciter diagram block

Governor Model

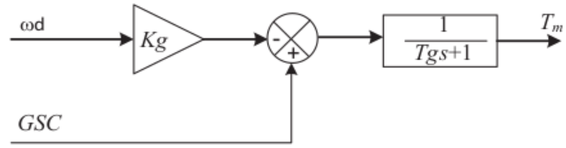

FIGURE 3. Governor Modeling

Where, T_m is mechanical torque.

Power System Stabilizer Modeling

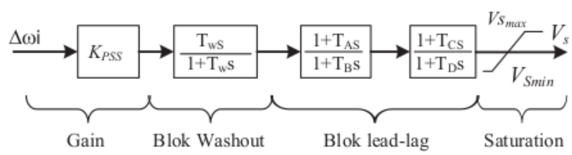

FIGURE 4. Blok diagram PSS

TABLE 1. Data P Gen and Q Gen of south Sulawesi System

No	Gen System	P Gen (PU)	Q Gen (PU)
1	10 suppa	0.311	-0.01396
2	11 PLTU bar	0.604	0.0691
3	18 Tello	0.21	3.0637
4	1 Skang	1.568	0.22349
5	21 BRLOe	0.052	-0.34558
6	26 T Lama	0.226	-0.66752
7	29 SGMSA	0.2	-1.1411
8	31 TLASA	0.79	0.32606
9	33 GAYA	1.961	-0.24962
10	36 Sinjai	0.04	0.07543
11	38 M kale	0.0082	0.26861
12	39 Palopo	0.004	0.04942
13	13 PLTA po	1.95	0.25785
14	5 Prang	0.143	0.03073
15	7 Bakaru	0.163	0.18436

RESULT AND SIMULATION

To analyze the interconnection system on Jeneponto 20 kV distribution using data obtained from PT. PLN (Persero). Data covering Single Line Diagram of Jeneponto distribution network include load data, and length of feeder and GI Transformation Data in the following table:

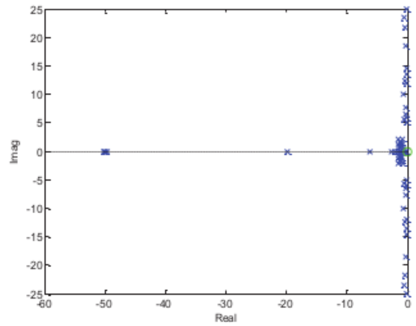

FIGURE 5. Results eigenvalue Analysis

The simulation performed obtains the Eigen values of the values on each of the Generator buses consisting of 16 generators. The value of the generator is considered stable when the value of Eigen value is all. The result sweep of the value of Eigen value is as follows;

TABLE 2. value of Eigen Value.

No	Gen System	Eigen value
1	10 suppa	-999.9999
2	11 PLTU bar	-1000
3	18 Tello	-0.36427
4	1 Skang	-999.9995
5	21 BRLOe	-0.18432
6	26 T Lama	-50.0507
7	29 SGMSA	-49.9755
8	31 TLASA	-50.001
9	33 GAYA	-49.9929
10	36 Sinjai	-0.11982
11	38 M kale	-0.00279
12	39 Palopo	-0.31949
13	13 PLTA po	-1000
14	5 Prang	-999.9999
15	7 Bakaru	-1000

from the 16 interconnected plants, there are 5 less stable generators of value Eigen value -0.36427, -0.18432, - 0.11982, -0.00279, -0.31949. The value of the Eigen value represents the stability of the generator in the system.

Result Delta Respond

Figures 6 to 12, showing the performance response of the delta generator do not use PSS during Wind Turbine Penetration. Based on simulation result of calculation of Eigen value for each generator in Table 2, from 16 generator in South Sulawesi system. Engine Delta Response Generator on All Generators. The result of this system response is not using PSS because Penetration of Wind Turbine. Response Results on Generator 1, 4, 5, 6, and Generator 7. For other generator conditions are still stable during penetration of wind turbine. The condition of the four of the cultivators needs to be stabilized rapidly so that if there is greater oscillation there is no collapse, which resulted in blackout on the system.

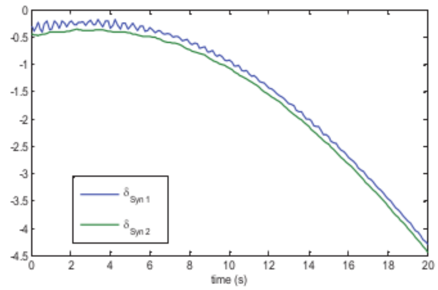

FIGURE 6. Delta Gen 1 and 2 no PSS

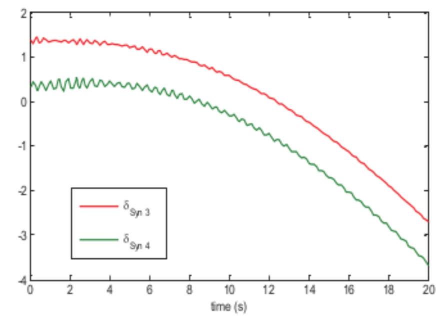

FIGURE 7. Delta Gen 3 and 4 no PSS

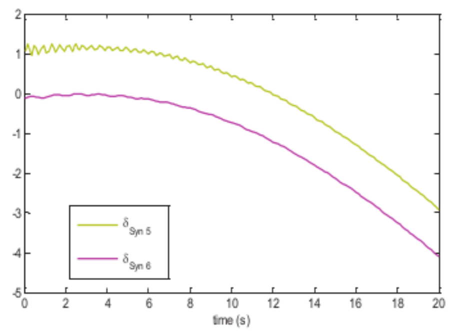

FIGURE 8. Delta Gen 5 and 6 no PSS

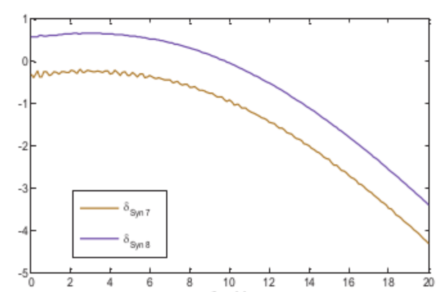

FIGURE 9. Delta Gen 7 and 8 no PSS

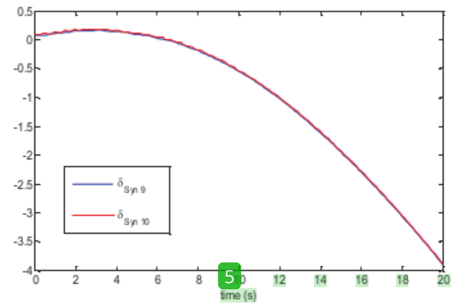

FIGURE 10. Delta Gen 9 and 10 no PSS

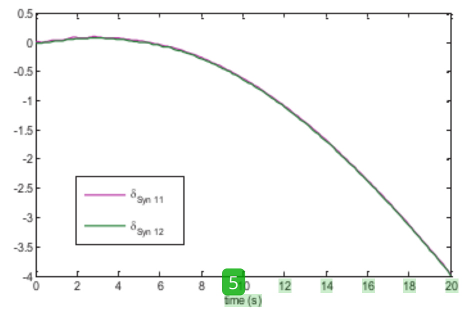

FIGURE 11. Delta Gen 11 and 12 no PSS

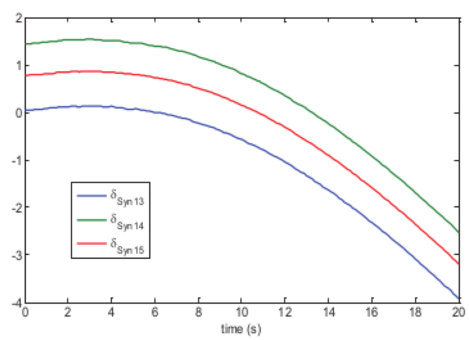

FIGURE 12. Delta Gen 13, 14 and 15

Figures 13 to 19, show the performance response of the generator delta using PSS during Wind Turbine Penetration. Response results show the advantage of using PSS on the system during wind turbine penetration. Response results of generators 1, 4,5,6 and 7 which before being mounted PSS oscillations shown 13 to 19 have been stable. This shows the success of the installation of PSS.

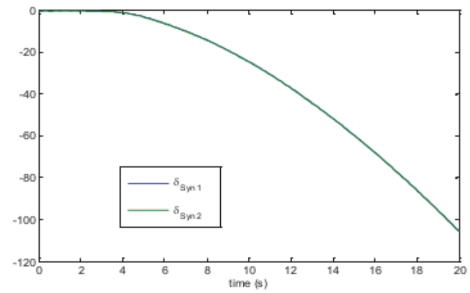

FIGURE 13. Delta Gen 1 and 3 Using PSS

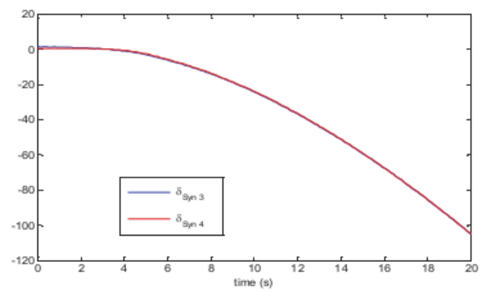

FIGURE 14. Delta Gen 3 and 4 Using PSS

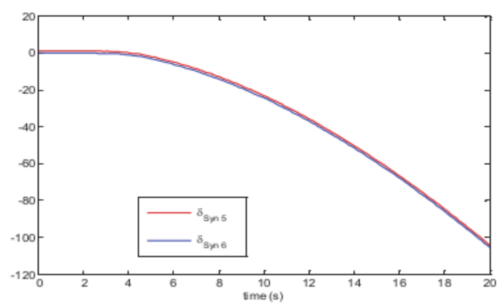

FIGURE 15. Delta Gen 5 and 6 Using PSS

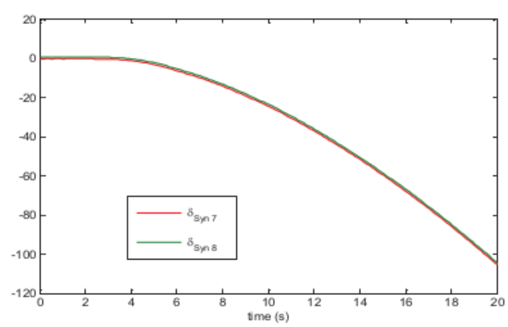

FIGURE 16. Delta Gen 7 and 8 Using PSS

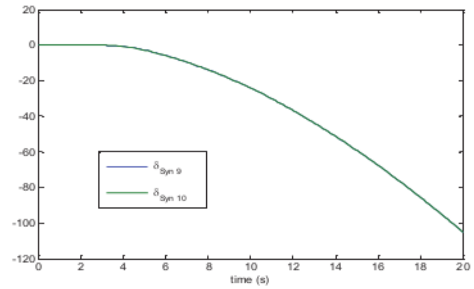

FIGURE 17. Delta Gen 9 and 10 Using PSS

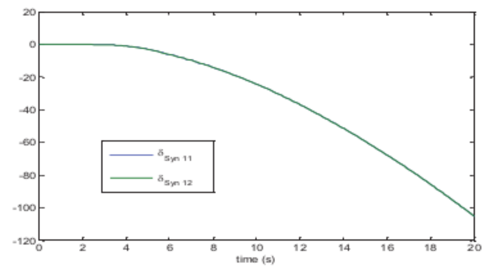

FIGURE 18. Delta Gen 11 and 12 Using PSS

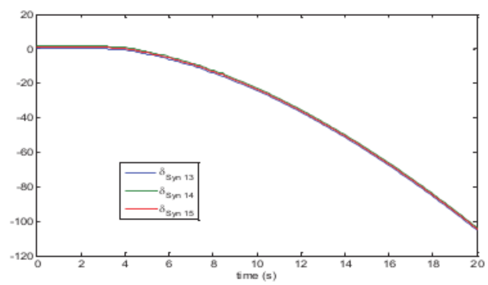

FIGURE 19. Delta Gen 13, 14 and 15 Using PSS

Result Omega Respond Without PSS

Figure 20 to 26 Omega Engine Response on Generators does not use PSS Because of Wind Turbine Penetration. Seen in Generator 1,2, 3, 7, and 10, highly oscillates as a result of the penetration. This is when there is greater disruption or changes in increase and decrease in load then the system occurs blackout. So it is necessary damping to stabilize during interference.

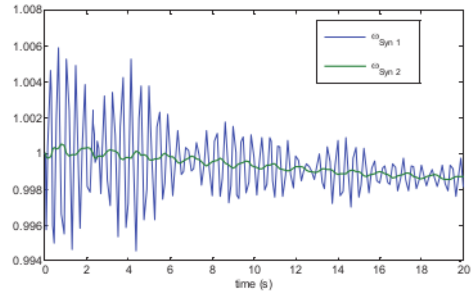

FIGURE 20. Omega Gen 1 and 2 no PSS

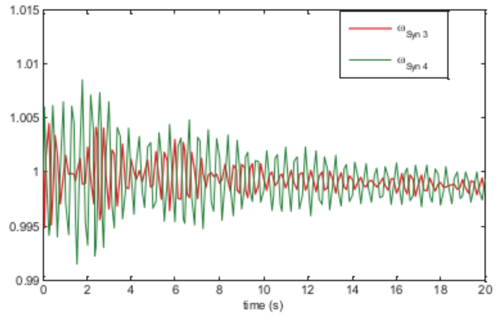

FIGURE 21. Omega Gen 3 and 4 no PSS

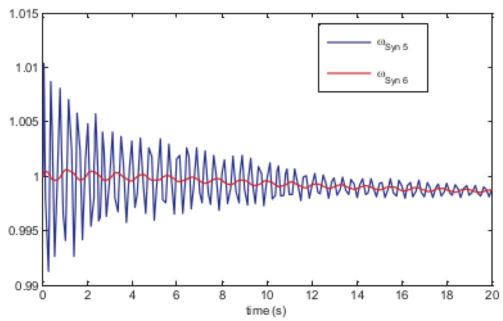

FIGURE 22. Omega Gen 5 and 6 no PSS

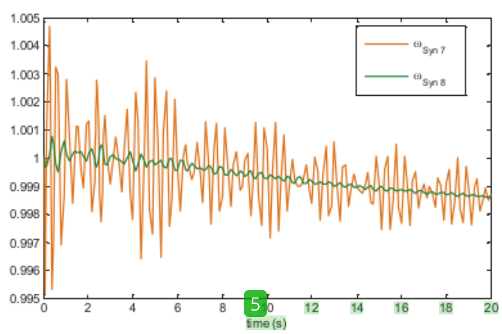

FIGURE 23. Omega Gen 7 and 8 no PSS

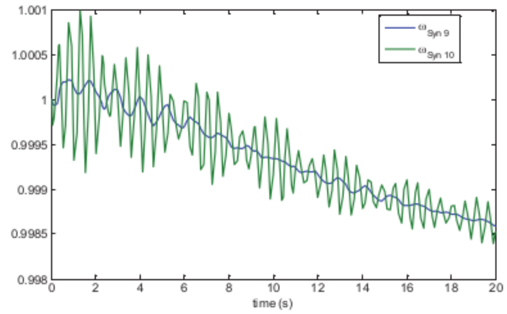

FIGURE 24. Omega Gen 9 and 10 no PSS

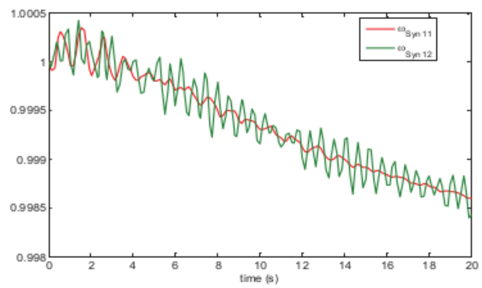

FIGURE 25. Omega Gen 11 and 12 no PSS

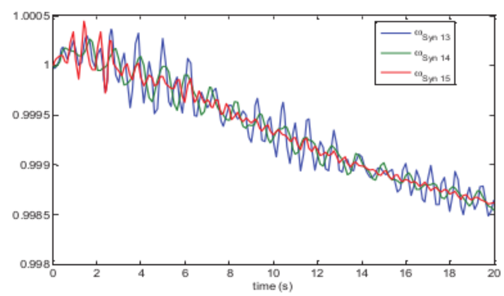

FIGURE 26. Omega Gen 13,14 and 15 no PSS

Result Omega Respond Using PSS

The results of South Sulawesi's electrical system simulation performance of the response shown in Fig. 27 to 33 response of oscillating system has been overcome by PSS. The generator conditions 1,2,3,7 and generator 10 have experienced a stable response during wind turbine penetration in Sidrap and Jeniponto areas. The success of PSS in reducing oscillations on the system on 5 generators.

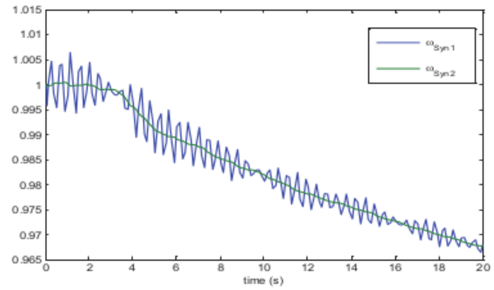

FIGURE 27. Omega Gen 1 and 2 Using PSS

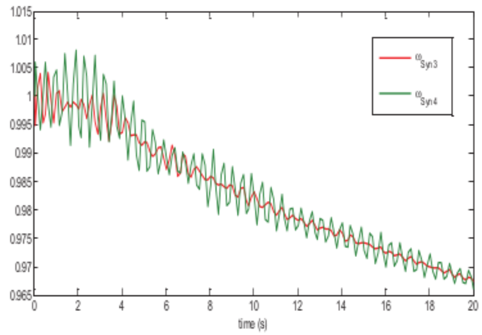

FIGURE 28. Omega Gen 3 and 4 Using PSS

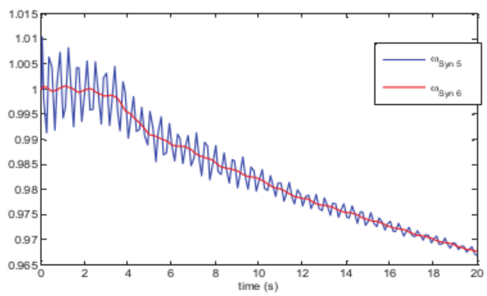

FIGURE 29. Omega Gen 5 and 6 Using PSS

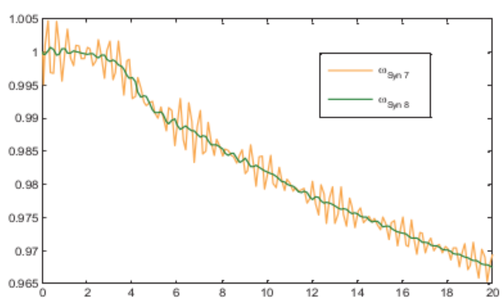

FIGURE 30. Omega Gen 7 and 8 Using PSS

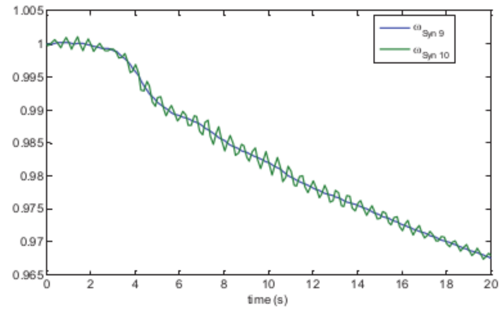

FIGURE 31. Omega Gen 9 and 10 Using PSS

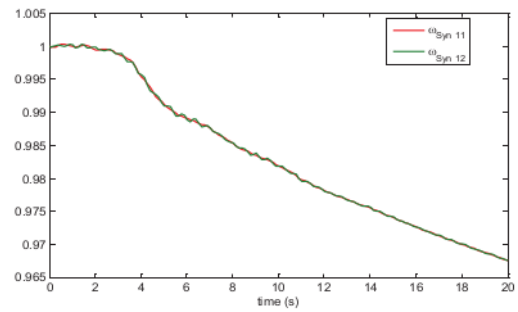

FIGURE 32. Omega Gen 11 and 12 Using PSS

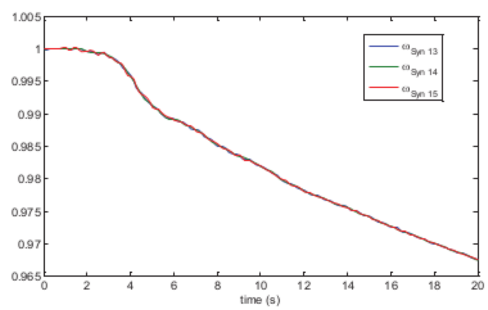

FIGURE 33. Omega Gen 13, 14 and 15 Using PSS

CONCLUSION

The results of the analysis and simulation done that the penetration of wind turbine effect on the stability of the system. Oscillations on Omega Generator 1 Gen 3 and 4 and 7 are very large before the PSS. Damping PSS on omega generator 1, 3, 4, and 7 significant while in the PSS field in South Sulawesi System. The results of this simulation is very useful in the operation of South Sulawesi system focus for operators who are operation the power plant, is expected with the inclusion of wind turbine can add power needed consumers

ACKNOWLEGEMENTS

Thanks to the author of the University of 17 Agustus 1945 Cirebon who has provided support for this research and Special Engineering Faculty provide support to carry out this research.

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