Design Fuzzy Logic Controller PSS (Power System Stabilizer) to Stability Improvement of Wind Turbine Penetrated on South Sulawesi Transmission System

Agus Siswanto[1], Arif Sumardiono[1], and Endang Prihastuty[2]

[1]*Electrical Engineering Study Program University of 17 Agustus 1945 Cirebon Addresses, Perjuangan no 17 Cirebon, West Java, Indonesia*

[2]Machine Engineering Study Program University of 17 Agustus 1945 Cirebon Addresses, Perjuangan no 17 Cirebon, West Java, Indonesia

Keywords: Stability, wind turbine, FLC, PSS, South Sulawesi system

Abstract: The aim of this research is to improve stability of South Sulawesi system interconnection caused by penetration of new wind turbine in Sidrap area on bus 2 and in Jeniponto area on bus 34. The method used in this research is through System Power Toolbox (PSAT) analysis software in under MATLAB. In this research, there are two problems that are evaluated, namely the stability of the system before and after the penetration of wind turbine to the system of South Sulawesi system. Conventional PSS signals are added to control the Stability System at naturally occurring operating points, this limits PSS performance and robustness. To solve this deficiency, the proposed design uses FLC. From the simulation result shows that the penetration of wind turbine on bus 2 Sidrap, bus 37 Jeniponto gives oscillation effect to the system. The oscillation was muffled by the installation of FLC Power System Stabilizer (PSS) in the bus area of 33 sinjai, that the South Sulawesi system was stable according to normal conditions.

1 INTRODUCTION

Historically South Sulawesi's transmission system is more vulnerable to operating limiting customers and uncertainty problems due to the lack of reactive data requirements, the deregulation of the electricity industry and the use of various renewable energy sources and different operations. At present the electric power system has evolved continually the growth of the load is always followed by transmission to connect power plants sourced from renewable energy such as wind turbines and PV(Setiadi et al., 2017). The growth of load and pattern is based on system stability. Due to the tapering of the membrane and the burden of stability, stability appears according to the operating pattern so that the use of new technology and control is needed, to increase operation in conditions of oscillation. Improper operating patterns can result in frequency stability, voltage stability and interred oscillation. However, at this time the power stabilizer system has been used to generate and control the voltage and frequency tuning using the metaphorical method of the fuzzy logic controller. There have been many successful studies on system stability presented in the literature (Gunadin et al., 2017), (Bian, et al., 2011), On (Rahman et al., 2018) has discussed the stability improvement using DG spread to correct the voltage drop that occurs due to changes in load. Research has been done on the penetration of wind turbines ("Stability improvement of wind turbine penetrated using power system stabilizer (PSS) on South Sulawesi transmission system.," 2018), However, the conventional PSS strategy still needs to be developed using artificial intelligence, namely fuzzy logic controller, so that in this study it is proposed that the improvement of wind turbine penetration using fuzzy logic controller for mental gain value in PSS is more appropriate so that the system stability becomes more robust. The proposed method is implemented on the South Sulawesi 44 system bus using PSAT software. The Sulawesi system displays using the PSAT bus voltage profile before being

Siswanto, A., Sumardiono, A. and Prihastuty, E.
Design Fuzzy Logic Controller PSS (Power System Stabilizer) to Stability Improvement of Wind Turbine Penetrated on South Sulawesi Transmission System.
DOI: 10.5220/0009009002340239
In *Proceedings of the 7th Engineering International Conference on Education, Concept and Application on Green Technology (EIC 2018)*, pages 234-239
ISBN: 978-989-758-411-4

penetrated when the wind turbine is before and after it is installed. Voltage controllers in Sulawesi systems with functions for fluctuations with oscillation due to variations in wind turbine output.

2 FUNDAMENTAL THEORY

2.1 Generator, exciter, and governor Modelin

In this study the excitation model representation used to regulate the variables in the generator output system includes voltage, current and power factor in Figure. 1 and Figure 2.

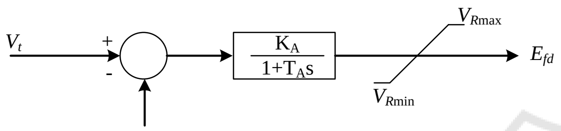

Figure 1: Exciter diagram block.

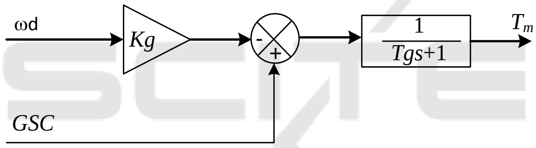

Figure 2: Governor Modeling

The representation of the wind turbine model is shown in Figure 3 from ref (Bevrani, 2014). On fig 4, shows from MPPT Output without measuring wind speed, where it is noted that the maximum power captured can be expressed as a rotation speed cube (MPPT = ω r3) (Rosyadi and et al., 2012) Characteristic model of wind turbine and MPPT of difference wind speed is shown in Figure 4.

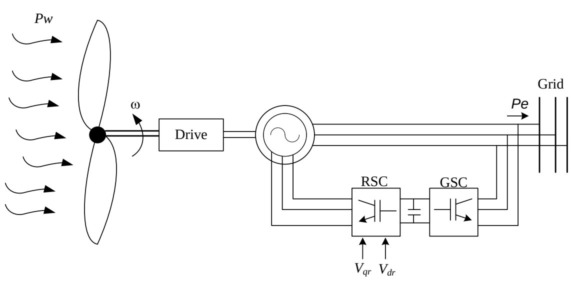

Figure 3: Wind Turbine.

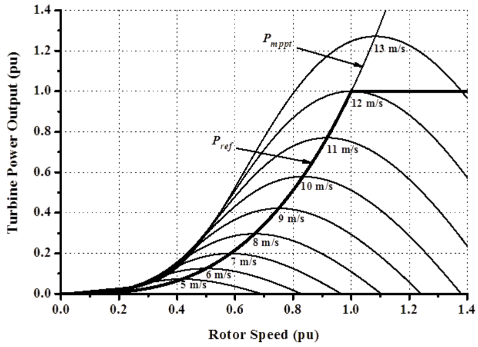

Figure 4: Characteristics of wind turbine and MPPT Curve.

2.2 Voltage Stability Margin (VSM)

In the VSM balance system is divided into VSM (P) and VSM (Q). VSM (P) states that the index is stable at active power loads and VSM (Q) for the freedom index in the reactive load (Q). For that system condition P critical conditions and Q are active and reactive power at critical stress points, respectively. The critical voltage in the system is the value of the voltage at the point of collapse or drop which is caused far from the voltage or performance of the conductor. The system will discuss the collapse voltage from zero, where the VSM critical voltage value is zero. Equation (1) to determine VSM:

$$VSM = \frac{V_{initial} - V_{critical}}{V_{critical}} \quad (1)$$

2.3 Simplified Voltage Stability Index (SVSI)

In the system stability study, there are several indicators that can be used to prescribe the state of the system that is not sturdy, which includes Voltage collapse prediction index, L-index and voltage stability index. Some indicators of voltage bus stability in reference are: voltage collapse prediction index (VCPIbus) (Balamourougan et al., 2004), L-index (Dike and Mahajan, 2008) (Du and Deng, 2012) (Ram and Haneesh, 2016), voltage stability index (VSIbus) in transmission system (Kamaruzzaman and Mohamed, 2014).

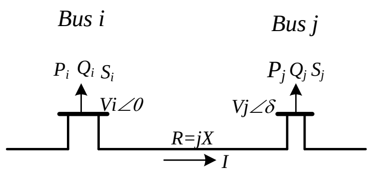

Figure 5: Representation of two bus power system.

In Figure 5, shown the representation of two bus systems for this study, SVSI is a derivative of the VSI index function that is used to determine the weak bus in the power system due to transmission distance, definition of SVSI can be expressed as:

$$SVSI_i = \frac{\Delta V_i}{\beta * V_i} \tag{2}$$

Voltage deviation (ΔV_i) is difference between the nearest generator with load buses. The correction factor β [8] is expressed as :

$$\beta = 1 - Max(|V_m| - |Vl|)^2 \tag{3}$$

The SVSI threshold value for keeping the system stable refers to inequality:

$$Max\ (SVSI) < 1 \tag{4}$$

In the high voltage system can use this equation, so that the advantages of this indicator are applied to large networks. For this reason, calculations require that the system bus voltage parameters from the sender and receiver side can be measured from both sides.

2.4 Power System Stabilizer (PSS)

The basic purpose of PSS installation is to widen the stability limit by modulation of the excitation generator to provide attenuation to synchronous when oscillations occur due to changes in load. Alitically, PSS can function as a transfer obtained by PSS from wash-out and the leadlag shown in Figure 6. The lead-lag aims to provide a suitable phase lead to compensate for the phase of the excitation lag and the torque generator in the system.

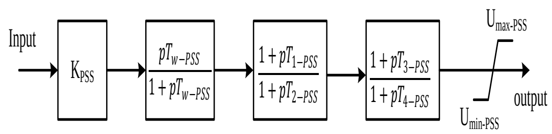

Figure 6: Typical controller with two lead lag stages.

2.5 Fuzzy Logic Controller (FLC))

Fuzzy logic controller is a model for the South Sulawesi power generation system in this study. The input of FLC is frequency (f) and the rate of change in frequency (d_f/d_t). The output is to determine the gain value on PSS. Depending on the input value, fuzzy logic will estimate the amount of load. FLC consists of Fuzzification, rule base, machine interface and deffuzification steps as shown in Figure. 7

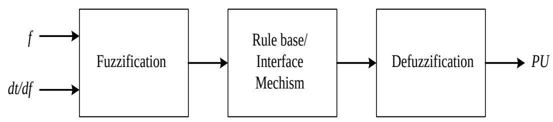

Figure 7: Fuzzy Logic Controller.

From Table 1 below, a rule in fuzzy logic controller is marked that each entry represents certain rules and the output of the system is achieved by using special rules articulated in the membership function method. In this study the names for representation used are Small Positive (PS), Positive Medium (PM) and Positive Large (PL), Big Negative (NL), Medium Negative (NM), Negative Small (NS) and Zero (ZE)

Table 1: Rule for FLC.

	NL	**NM**	**NS**	**ZE**	**PS**	**PM**	**PL**
NL	NL	NL	NM	NM	NS	NS	ZE
NM	NL	NM	NM	NS	NS	ZE	PS
NS	NM	NM	NS	NS	ZE	PS	PS
ZE	NM	NS	NS	ZE	PS	PS	PM
PS	NS	NS	ZE	PS	PM	PM	PL
PM	NS	ZE	PS	PM	PM	PL	PL
PL	ZE	PS	PM	PM	PL	PL	PL

3 PROPOSED METHODE

In testing the penetration of wind turbines with FLC-PSS installations in the South Sulawesi system network, using Figure 8, the wind turbine used was 70MW installed on bus 2 in Sidrap. PSS in Padang on bus 33, Sinjai, this is done because the bus has a voltage drop. This system consists of a swing bus, fifteen bus generators, 44 bus substations. This simulation uses Matlab Toolbox to analyze and simulate an electric power system.

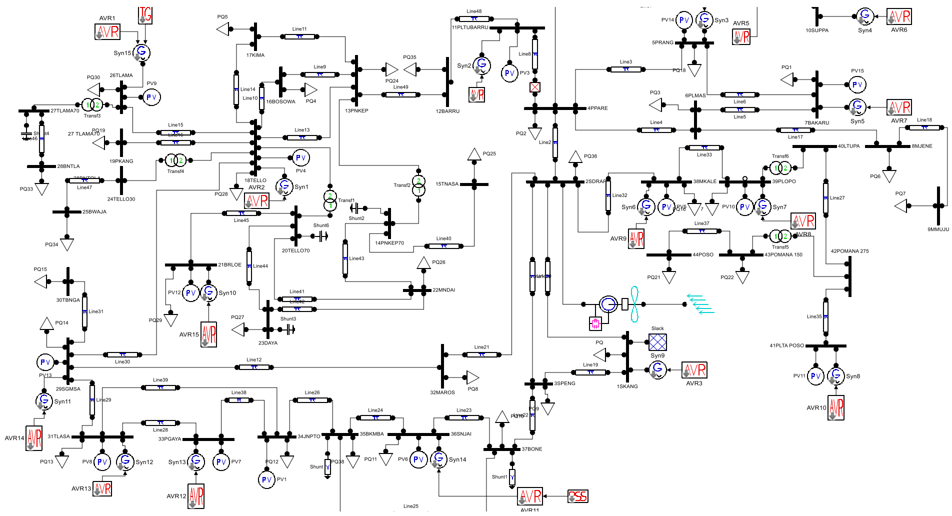

Figure 8: Sulawesi bus system.

4 SIMULATIAN AND RESULT

The simulation was tested on the 44 Sulawesi bus system using PSAT software. This simulation aims to obtain the influence of wind turbines on the 2 sidrap bus on the stability system using the SVSI indicator. Figure 9 shows the Eigen value analysis of the South Sulawesi system. Figure 10 shows the voltage Magnitude Profile before FLC-PSS and wind. In Table 2, address dynamic orders, number of buses, Positive Eigen, Negative Eigen, Complex pairs and Zero Eigen. Test system parameter values are explained in Table 3. The result of analysis of real power generator and reactive power generator explained in two curve. Figure 11 shows the result without FLC-PSS and Wind Turbine and Figure 12 shows the result with FLC-PSS and Wind Turbin.

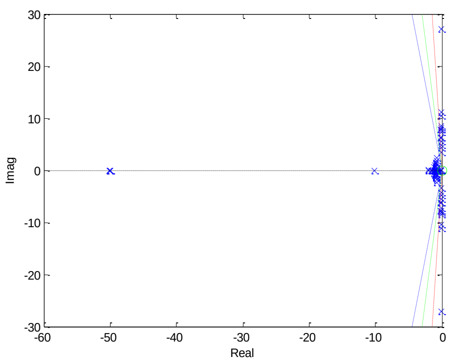

Figure 9: Eigen value Analysis.

Table 2: Eigen Value Analysis of System With SVC.

	Without FLC-PSS and Wind	With FLC-PSS	With FLC-PSS and wind
Dinamic Order	108	112	117
Buses	44	44	44
Positive Eigen	0	0	0
Negative Eigen	107	110	115
Complex pairs	28	26	26
Zero Eigen	1	2	2

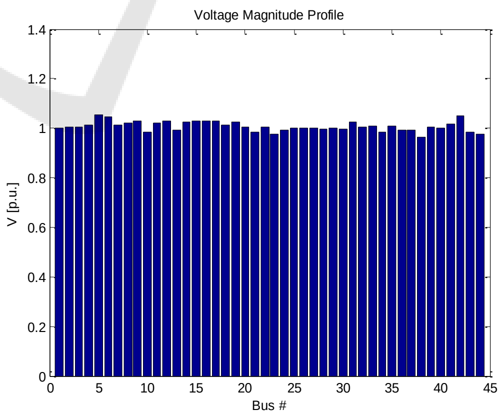

Figure 10: Voltage Magnitude Profile before FLC-PSS and wind.

Table 3: Test system parameter values.

bus	Real power generation [pu] Without FLC-PSS and Wind	Reactive power generation [pu] Without FLC-PSS and Wind	Real power generation [pu] with FLC-PSS and Wind	Reactive power generation [pu] with FLC-PSS and wind
Bus 1	1.2741	0.15092	2.3267	0.7078
Bus 2	-0.265	-0.103	-0.265	-0.103
Bus 3	-0.141	-0.034	-0.141	-0.034
Bus 4	-0.187	-0.047	-0.187	-0.047
Bus 5	0.099	-0.483739	0.099	-0.35991
Bus 6	-0.171	-0.041	-0.171	-0.041
Bus 7	0.013	0.86583	0.013	0.89607
Bus 8	-0.233	-0.037	-0.233	-0.037
Bus 9	-0.096	-0.048	-0.096	-0.048
Bus 10	0.311	-0.09708	0.311	0.12632
Bus 11	0.604	-0.18632	0.604	-0.10614
Bus 12	-0.101	-0.024	-0.101	-0.024
Bus 13	-0.221	-0.08	-0.221	-0.08
Bus 14	0	0.13352	0	0.13354
Bus 15	-0.189	-0.0206	-0.189	-0.0206
Bus 16	-0.331	-0.0154	-0.331	-0.0154
Bus 17	-0.18	-0.058	-0.18	-0.058
Bus 18	-0.432	3.2572	-0.432	3.261
Bus 19	-0.638	-0.177	-0.638	-0.177
Bus 20	0	0.21456	0	0.21454
Bus 21	-0.062	-0.28016	-0.062	-0.27972
Bus 22	-0.243	-0.026	-0.243	-0.026
Bus 23	-0.245	0.18617	-0.245	0.18615
Bus 24	0	0	0	0
Bus 25	0	0	0	0
Bus 26	0.029	-0.7146	0.029	-0.7146
Bus 27	0	0.12435	0	0.12435
Bus 28	-0.265	-0.077	-0.265	-0.077
Bus 29	0.043	-1.1396	0.043	-0.80553
Bus 30	-0.552	-0.167	-0.552	-0.167
Bus 31	0.584	0.45407	0.584	0.49081
Bus 32	-0.186	-0.005	-1.186	-1.005
Bus 33	1.961	-0.37138	1.961	-0.37981
Bus 34	0.451	-0.03284	0.451	-0.0296
Bus 35	-0.271	0.00095	-0.271	0.00094
Bus 36	0.031	0.0642	0.031	0.10058
Bus 37	-0.321	-0.01589	-0.321	-0.01661
Bus 38	-0.1108	0.25944	-0.1108	0.36008
Bus 39	-0.488	-0.02359	-0.488	-0.02359
Bus 40	0	0	0	0
Bus 41	1.95	0.25782	1.95	0.25782
Bus 42	0	0	0	0
Bus 43	-0.049	-0.005	-0.049	-0.005
Bus 44	-0.995	-0.018	-0.995	-0.018

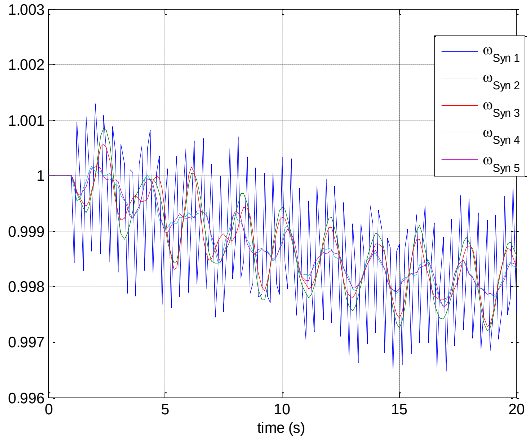

Figure 11: Without FLC-PSS and Wind Turbine.

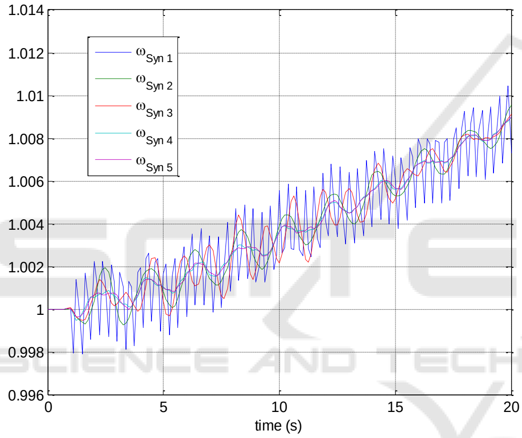

Figure 12: With FLC-PSS and Wind Turbine.

5 CONCLUSIONS

In this paper, the problem of stability due to wind turbine penetration in the 44 South Sulawesi system is measured using SVSI. This study shows that wind turbine integration penetration affects the stability value of the interconnect system voltage with the omega state indicator ω decreasing. Changes in load and penetration rate of wind turbine determine the critical value of the load bus which can harm the system. The swing bus value at the beginning without FLC-PSS is the active power value of 1.2741 and reactive power of 0.15092 then becomes 2.3267 and reactive power of 0.7078. Fuzzy tuning in the right PSS value can improve voltage stability in the system.

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