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BAT ALGORITHM IMPLEMENTATION TO OPTIMALLY DESIGN THE STABILIZER POWER SYSTEM ON THE SUPPA GENERATOR

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Abstract -- *One of the control devices that can be used to strengthen the performance of PLTU Suppa is the installation of Power System Stabilizer. The problem of using Power System Stabilizer (PSS) in generator excitation is how to determine the optimal PSS parameter. To overcome these problems, the authors use a method of intelligent bats to design PSS. Bat's algorithm will work based on the specified destination function, which is an Integral Time Absolute Error (ITAE). In this research, we will see the deviation response of velocity and the rotor angle of the suppa generator in case of interference. The results of the analysis show that the uncontrolled system produces oscillation overshoot speed of -0.02437 pu to 0.006517 pu, conventional PSS about -0.02186 pu to 0.004623 pu and with PSS Bat overshoot of -0.01507 pu up to 0.0006223 pu. A loop for rotor angle response shows good results with reduced oscillation and rapidly leading to steady-state conditions. From the analysis results can be concluded, the performance of suppa generator is increased with the installation of Power System Stabilizer with optimal PSS parameters, with parameters respectively Kpss = 32.2077, T1 = 0.0173, T2 = 0.0401, T3 = 0.9174, T4 = 1.2575.*

Keywords: *Bat Algorithm; Speed; Overshoot, Settling Time; Power System Stabilizer*

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INTRODUCTION

Most of the electric power system control functions are in the governor and the exciter in each generator. However, the limited performance of the control equipment causes the generator not to work optimally. Power System Stabilizer (PSS) additional controllers are also added to the automatic voltage regulator (AVR), the function of the exciter, governor and PSS is to set the terminal frequency and voltage locally or globally at each generator. Changes in a load that occurs suddenly and periodically cannot be responded well by the generator so that it can affect the dynamic stability of the system. Poor response can cause frequency oscillations in a long period. The frequency oscillations can result in a reduction in the power transfer power that can be overcome using additional equipment called PSS.

The stability of the existing electric power system generally consists of steady-state stability and transient stability. Transient stability is associated with a large disturbance that suddenly occurs, for example, such as a short circuit, termination of the channel, removal, or termination of the load on the system. While steady-state stability is a condition where the system can return after experiencing a small disturbance. The system parameters are said to be stable if all variables are stable, system frequency, bus voltage, or generator angle, while the parameters for instability in the system such as the voltage on some buses dropped dramatically away from normal conditions so that voltage failures occur.

The South, Southeast, and West Sulawesi (Sulselrabar) system is an electrical system that connects several load center with an operating voltage of 150 kV. Several studies of electrical systems in Sulselrabar are needed, as the system increases in sulselrabar. Several studies have been conducted for the Sulselrabar system, including (Djalal et al., 2015; Djalal et al., 2014; Djalal et al., 2017; Djalal, Imran and Robandi, 2015; Djalal et al., 2017; Yunus, Djalal and Marhatang, 2017; Djalal & Faisal, 2017; Djalal et al., 2017; Djalal, 2018; Djalal et al., 2016; Djalal et al., 2018; Djalal & Setiadi, 2017; Djalal & Sonong, 2018; Muhammad & Faisal, 2019).

Study the stability of the electric power system is important to maintain the reliability of the system. The artificial intelligence method is one method that is widely used in electric power systems. In the study of the stability of the power system in the Sulselrabar system, the application of intelligent methods has begun.

Intelligent method based on Bat Algorithms is an algorithm that works based on the behavior of bats in finding food. The correlation with this research is that Bat Algorithm will find the optimal parameters of PSS by using the objective function that has been determined, which is minimizing Integral Time Absolute Error (ITAE). Some research-based on smart methods for tuning include, Firefly (Ameli et al., 2013), Particle Swarm Optimization (Shayeghi, Safari and Shayanfar, 2008), Genetic Algorithm (Hongesombut, Mitani and Tsuji, 2002), Neural Network (Jalali, Pouaghababa and Nouhi, 2008), Fuzzy Logic (Syahputra & Soesanti, 2015), Ant Colony (Linda & Nair, 2012), Bee Colony (Theja et al. 2012), Cuckoo Search (Chitara et al., 2015). Therefore, this research will propose a smart method based on Bat Algorithm to design PSS in the Sulselrabar system, especially in suppa diesel power plants, which so far have not been used in the Sulselrabar generator system.

POWER SYSTEM MODELING

Generator Modeling

The electric power system is modeled into a multi-machine linear model in the form of a d-q model. The system model is displayed using the Simulink program on Matlab and analyzed using the Matlab file (Djalal & Setiadi, 2017).

Exciter Modeling

The excitation system is an equipment used to regulate generator output variables, such as voltage, current, and power factor. The variable is set by setting the field flux on the generator. In this study, the type of excitation used is a type of fast exciter that has a fast response (Djalal & Setiadi, 2017).

$$E_{fd} = K_A(V_t - V_{ref})/(1 - T_A s) \qquad (1)$$

K_A is a parameter of reinforcement and TA is the time constant value. The output value of the exciter is limited using the saturation block $V_{Rmin} < E_{fd} < V_{Rmax}$. The exciter model, in the form of block diagrams, can be seen in Fig. 1.

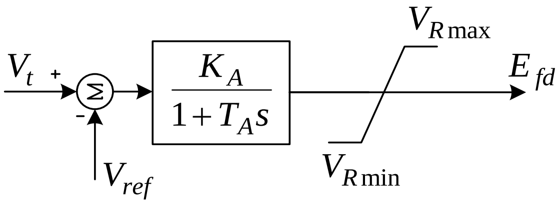

Figure 1. Fast Exciter Block Diagram

Governor Modelling

The magnitude of the change in mechanical torque T_m depends on the speed drop constant, transfer function governor, and energy source. Changes in T_m values are generated by changes in speed, changes in load, and speed reference (Governor Speed Changer-GSC). If there is a change in the generator rotor rotation, the governor will provide feedback to achieve a new balance. The shape of the block diagram of the Governor is shown in Fig. 2. Visible changes from ω_d can result in changes in the mechanical torque of the engine T_m.

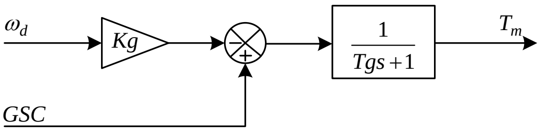

Figure 2. Governor Block Diagram

In this model, it is assumed that the GSC value is zero (GSC = 0) and the effect of combining the turbine system with a speed governor produces Pm mechanical power which can be formulated in the following Equation 1,

$$P_m = -\left[\frac{K_g}{(1+T_g s)}\right]\omega_d \qquad (2)$$

Where,

K_g = Gain Constant=*1/R*
T_g = Governor time constant
R = Droop governor constant

Power System Stabilizer Modeling

PSS is widely used in electric power systems to improve dynamic stability. PSS is used as an excitation system controller to add attenuation to rotor oscillations. To produce a damping component, the PSS produces an electric torque component that corresponds to the deviation at the rotor speed. The PSS must be properly tuned, to help the exciter in dampening the oscillations can be described in Fig. 3.

PSS accepts input in the form of changes in rotor speed to produce additional signals as exciter controllers. Exciter affects the magnitude of the field voltage generated on the rotor side and affects the magnitude of the magnetic flux generated. Magnetic flux is directly proportional to the amount of electrical torque produced on the machine. An electric torch against a large mechanical engine torque to reduce frequency oscillations that occur in the engine.

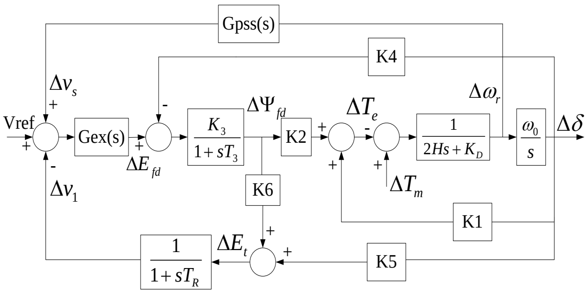

Figure. 3. Block Machine Diagrams with PSS and AVR

In order to function properly, PSS must be tuned appropriately. The PSS design method generally involves response frequencies based on the concept of increasing torque attenuation. The PSS transfer function is tuned to provide the correct phase-lead characteristics to compensate for phase-lag between the automatic voltage regulator *Δv* input reference and the electric torque. Thus, the electric torque component is equivalent to speed variations to correct attenuation. Using a simple PSS mathematical model, the PSS mathematical model can be written.

$$V_s = K_{pss}\,\frac{T_W s}{(1+T_W s)}\left[\frac{(1+sT_A)}{(1+sT_B)}\frac{(1+sT_C)}{(1+sT_D)}\right]\omega \qquad (3)$$

Assuming that the output of PSS is Vs with input Δω, then Equ. 2 can be written in the block diagram in Fig. 4.

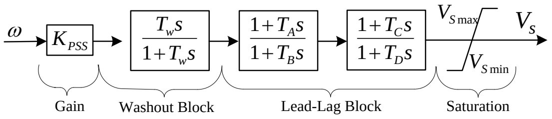

Figure 4. PSS Block Diagram

Gain Block

The input signal for PSS can be taken from a variety of signals such as rotor changes, electrical power outputs, or bus terminal frequencies. One is the gain block, and the input signal will pass through this gain block. Gain serves to regulate the amount of reinforcement to obtain the desired torque amount. This block is an amplifier that determines the amount of attenuation given by PSS.

Washout Filter Block

The washout filter serves to provide a PSS steady-state bias output that will modify the generator terminal voltage. PSS is expected to only respond to transient variations of the generator rotor speed signal and not for offset DC signals. Washout filter works as a high pass filter that will pass all desired frequencies. If only the local mode is desired, the Tw value can be selected in the range 1-2. However, if the interarea mode also wants to be muted, the Tw value must be selected at intervals of 10-20. A higher Tw value can improve the system voltage response during island operation.

Lead-Lag Block

To reduce oscillations in the rotor, PSS must produce a torque component that is in phase with the change in rotor speed. Therefore, this block is used to compensate for the lag phase produced by the AVR and the generator field circuit. In order to obtain a contribution in the form of pure attenuation from PSS, the phase compensator must be able to eliminate the lag phase. However, in practice, it is very difficult to get pure lead phase blocks, so in general, lead-lag phase blocks are used. In order to obtain a PSS response in a wide range of frequency ranges.

Limiter

PSS output is limited so that the PSS action on the AVR is as expected. For example, when the load is released, AVR acts to reduce the generator terminal voltage when PSS produces a control signal to increase the voltage (because of the generator rotor speed increases when the load is released). In this condition, it is necessary to disable PSS. The condition shows the importance of limiting the PSS output signal value that can be done by block limiter.

Fig. 5 shows the modeling of PSS on which is installed on generator 1.

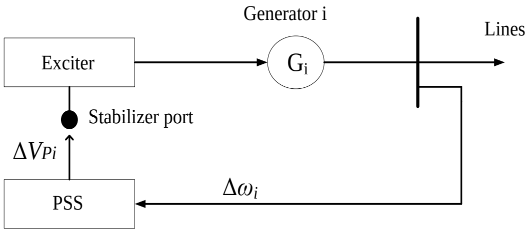

Figure 5. A PSS System in the 1st Generator

BAT ALGORITHM

The main step of BA is to start from the initialization of the population of a group of bats, each of which is determined by the initial position as the initial solution. The population of a group of bats generates pulses and noise randomly and determines the frequency. During the looping process, the bat will move from the initial solution to the best solution. After moving, if a bat is finding a better solution, then the bat will update the pulse emission level and noise. During the iteration process the best solution is always updated.

The iteration process is repeated until the criteria stop and the best solution criteria have been met. The best solution is the solution to the problems that are solved by going through this algorithm process.

The Bat Algorithm parameter used is shown in Table 1. Bat's working principle is to optimize the parameters of the PSS within a predetermined limit. The PSS parameters tuned are KPSS, T1, T2, T3, and T4. The value of TW has a value in the rank range of 1 - 50 seconds. In the study, TW is set to a constant of 10 seconds. Table 1 and Table 2 show the predefined Bat and PSS parameters.

Table 1. Parameters of the Bat Algorithm

Parameter	Value
Population Size	35
Loudness	0,25
Pulse Rate	0,5
Alpha	0,7
Gamma	0,7
Minimum Frequency	0
Maximum Frequency	100
Iteration	50
Dimension	80

Table 2. PSS Parameter Value Limitation

No	Parameter	Lower Limit	Upper Limit
1	K_{pss}	10	50
2	T_1	0	0.1
3	T_2	0	0.1
4	T_3	0	5
5	T_4	0	5

* for parameter Tw set at value 10.

RESULTS AND DISCUSSION

Sulselrabar's electricity system consists of 16 generating units, which operate at a voltage of 150 kV, and consists of 37 buses and 46 channels that connect large load centers such as, Makassar, Pangkep, Maros, Barru, Pare-Pare, Pinrang, Polmas, Majene, and Mamuju. The objective function used is to maximize minimum damping (ζ_{min}).

Then the system response is analyzed, namely Speed Deviation ($\Delta\omega$) and rotor angle of each generator. In addition, the value of the overshoot generator will be analyzed for systems without control and with PSS. Linear system modeling is given input for disturbance changes in load demand of 0.05 pu. Table 3 shows the results of the simulation of the voltage and phase angle of each bus.

Table 3. Voltage and Angle

Bus	Voltage (p.u)	Angle (^{0})	Bus	Voltage (p.u)	Angle (^{0})
1	1,000	0.000	20	0,979	-16.450
2	1,000	-3.869	21	0,983	-18.428
3	1,000	-5.124	22	0,987	-21.176
4	1,000	-4.041	23	0,960	-23.033
5	1,000	-9.839	24	0,993	-20.956
6	1,000	-20.793	25	0,994	-19.485
7	1,000	-21.192	26	0,994	-18.453
8	1,000	-20.221	27	0,990	-8.949
9	1,000	-16.359	28	0,992	-4.600
10	1,000	-13.152	29	0,992	-17.723
11	1,000	-11.792	30	0,960	-16.091
12	1,000	-2.500	31	0,933	-17.110
13	1,000	2.915	32	0,980	-21.261
14	1,000	-11.380	33	0,984	-21.251
15	1,000	-13.389	34	0,993	-20.728
16	1,000	-20.966	35	0,996	-20.760
17	0,992	-3.072	36	0,996	-20.760
18	0,974	-5.217	37	0,975	-22.476
19	0,965	-6.386			

The convergence of Bat Algorithms

Fig. 6 shows the convergence of the PSS parameter search with the bat algorithm. Where seen from the graph, the algorithm is very fast in finding the optimal value of PSS using the bat algorithm method. The fitness function value is 75.8423783057539. The results of tuning the PSS parameters are shown in Table 4.

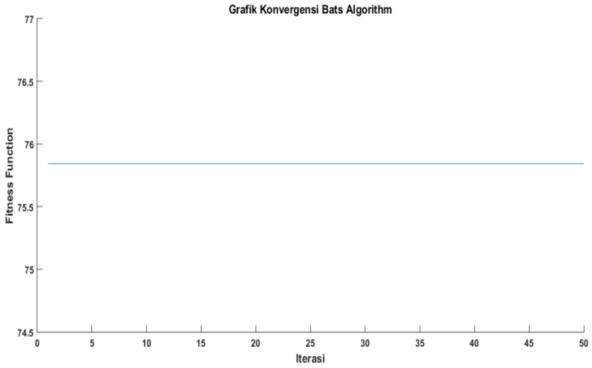

Figure 6. Graph of Bat Algorithm Convergence

Table 4. PSS PLTD Suppa parameter optimization results

Place	Kpss	T1	T2	T3	T4
G4	32.2077	0.0173	0.0401	0.9174	1.2575

After optimal placement and tuning of PSS on the suppa generator, then see the Speed Deviation response ($\Delta\omega$) and the rotor angle of each generator. Overshoot Deviation The speed of the generator will be analysed for the difference. Table 5 shows the overshoot comparison of the speed deviation of each generator.

Table 5. Overshoot Deviation Speed Generator Suppa

No PSS	PSS Conventional	PSS Bat
-0.02437 to 0.006517	-0.02186 to 0.004623	-0.01507 to 0.0006223

Fig. 7 and Fig. 8 show the Speed Deviation (Δω) response and the Variation of the suppa generator rotor angle.

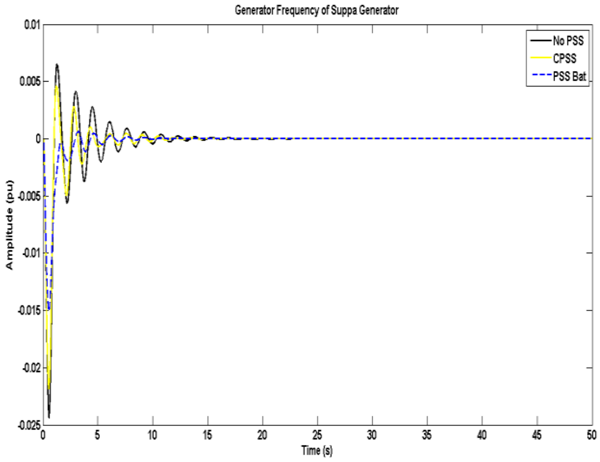

Figure 7. Speed Deviation (Δω) G. Suppa

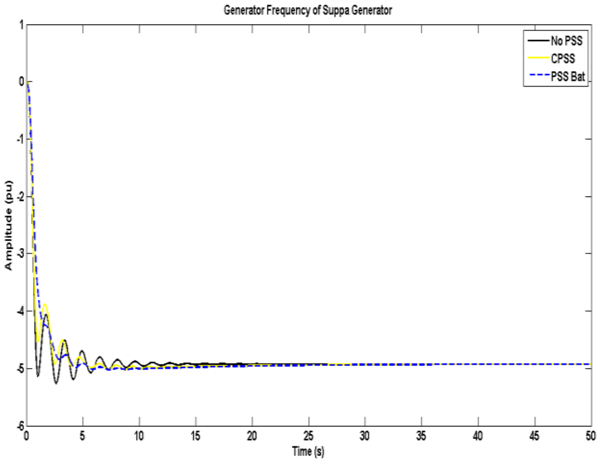

Figure 8. Suppa Rotor Angle Variations

The change in the load that occurs causes Pe> Pm so that from the graph for both case studies used, the first response to the speed of the generator is down. As for the rotor angle response, because Pe> Pm, the rotor will experience a slowdown so that the response of the rotor angle becomes negative, shown in Fig. 8. The relationship of these characteristics is as in equation 3 below.

$$MW = P_m - P_e - D\omega \qquad (3)$$

From Fig. 7 shows the speed deviation can be seen overshoot oscillation that occurs before PSS installation is -0.02437 pu to 0.006517 pu, after installation of conventional PSS, the oscillation is reduced to -0.02186 pu to 0.004623 pu, and the bat algorithm method is -0.01507 pu to 0.0006223 pu. Besides that, the settling time generated will also be faster to get to the steady-state using the proposed method of the Bat Algorithm compared to the uncontrolled system.

CONCLUSION

Installation of the Power System Stabilizer on the Suppa generator shows an increase in stability performance, indicated by improvements in frequency deviation, rotor angle of the generator, and an increase in settling time generator. From the results of the analysis it can be concluded, the performance of the suppa generator performance increases with the installation of a Power System Stabilizer with optimal PSS parameters, with the parameters of each Kpss = 32.2077, T1 = 0.0173, T2 = 0.0401, T3 = 0.9174, T4 = 1.2575.

REFERENCES

Ameli, A., Farrokhifard, M., Ahmadifar, A., Safari, A. and Shayanfar, H. A. (2013). Optimal tuning of Power System Stabilizers in a multi-machine system using firefly algorithm. In *the 12th International Conference on Environment and Electrical Engineering*, Wroclaw, Polandia. (pp. 461-466) http://doi.10.1109/EEEIC.2013.6549560

Chitara, D., Swarnkar, A., Gupta, N., Niazi, K., & Bansal, R. (2015). Optimal Tuning of Multimachine Power System Stabilizer using Cuckoo Search Algorithm. *IFAC-Papers On Line*, *48*(30), 143-148. http://doi.org/10.1016/j.ifacol.2015.12.368

Djalal, M. R. (2018). A modeling approach for short-term load forecasting using fuzzy logic type-2 in sulselrabar system. *International Journal of Artificial Intelligence Research*, *3*(1). http://doi.org/10.29099/ijair.v3i1.68

Djalal, M. R., Ajiatmo, D., Imran, A., & Robandi, I. (2015). Desain Optimal Kontroler PID Motor DC Menggunakan Cuckoo Search Algorithm. *SENTIA*, *7*(1).

Djalal, M. R., & Faisal. (2017). Intelligent Fuzzy Logic-Cuckoo Search Algorithm Method for Short-Term Electric Load Forecasting in 150 kV Sulselrabar System. *Lontar Komputer: Jurnal Ilmiah Teknologi Informasi*, *8*(3), 154-165. http://doi.org/10.24843/LKJITI.2017.i03.p02

Djalal, M. R., Haikal, M. A., Pandang, T. M. P. N. U., & Aceh, T. E. I. P. (2014). Penyelesaian Aliran Daya 37 Bus Dengan Metode Newton Raphson (Studi Kasus Sistem Interkoneksi 150 kV Sulawesi Selatan). *Jurnal Teknik Mesin SINERGI*, *12*(1), 35-49.

Djalal, M. R., Imran, A., & Robandi, I. (2015). Optimal placement and tuning power system stabilizer using Participation Factor and Imperialist Competitive Algorithm in 150 kV South of Sulawesi system. *2015 International Seminar on the Intelligent Technology and Its Applications (ISITIA)*. Surabaya, Indonesia (pp.147-152) http://doi.org/10.1109/ISITIA.2015.7219970

Djalal, M. R., Nawir, H., Setiadi, H., & Imran, A. (2017). An Approach Transient Stability Analysis Using Equivalent Impedance Modified in 150 kV South of Sulawesi System. *Journal of Electrical and Electronic Engineering-UMSIDA*, *1*(1), 1-7. https://doi.org/10.21070/jeee-u.v1i1.758

Djalal, M. R., Pangkung, A., Sonong, S., & Apollo, A. (2018). Peak Load Prediction Using Fuzzy Logic For The 150 kV Sulselrabar System. *Journal of Information Technology and Computer Science*, *3*(1), 49-59. http://doi.org/10.25126/jitecs.20183139

Djalal, M. R., Setiadi, H., Lastomo, D., & Yunus, M. Y. (2017). Modal Analysis and Stability Enhancement of 150 kV Sulselrabar Electrical System using PSS and RFB based on Cuckoo Search Algorithm. *International Journal on Electrical Engineering and Informatics*, *9*(4), 800-812. http://doi.org/10.15676/ijeei.2017.9.4.12

Djalal, M. R., & Sonong, S. (2018). Penalaan PSS pada Sistem Generator Tenaga Menggunakan Algoritma Penyerbukan Bunga. *Jurnal Teknologi dan Sistem Komputer*, *6*(3), 93-99. http://doi.org/jtsiskom.6.3.2018.93-99

Djalal, M. R., Yunus, M. Y., Nawir, H., & Imran, A. (2017). Application of Smart Bats Algorithm for Optimal Design of Power Stabilizer System at Sengkang Power Plant. *International Journal of Artificial Intelligence Research*, *1*(2). http://doi.org/10.29099/ijair.v1i2.26

Djalal, M. R., Yunus, M. Y., Nawir, H., & Imran, A. (2017). Optimal Design of Power System Stabilizer In Bakaru Power Plant Using Bat Algorithm. *Journal of Electrical and Electronic Engineeing*, *1*(2), 6. http://doi.org/10.21070/jeee-u.v1i2.1017

Hongesombut, K., Mitani, Y., & Tsuji, K. (2002). Power system stabilizer tuning in multimachine power system based on a minimum phase control loop method and genetic algorithm. *14th Ower System Computation Conference (PSCC)*, Sevilla, Spanyol. (pp. 1-7)

Jalali, M., Pouaghababa, R., & Nouhi, M. (2008). Power System Stabilizers Optimization Based on Neural Network using linear Optimal Control. *Scientific Bulletin of the University of Pitesti*, *8*(2), 7-11.

Linda, M. M., & Nair, N. K. (2012). Optimal design of multi-machine power system stabilizer using robust ant colony optimization technique. *Transactions of the Institute of Measurement and Control*, *34*(7), 829-840. http://doi.org/10.1177/0142331211421520

Muhammad, R. D., & Faisal, F. (2019). Studi Kestabilan Generator Sistem Sulselrabar (Stability Study of Sulselrabar System Generator). *JEEE-U Journal of Electrical and Electronic Engineering-UMSIDA*, *3*(1), 82-119. https://doi.org/10.21070/jeee-u.v3i1.2067

Shayeghi, H., Safari, A., & Shayanfar, H.(2008). Multimachine power system stabilizers design using PSO algorithm. *International Journal of Electrical Power end Energy Systems Engineering*, *1*(4), 226-233

Syahputra, R., & Soesanti, I. (2015). Power System Stabilizer model based on Fuzzy-PSO for improving power system stability. *2015 International Conference on Advanced Mechatronics, Intelligent Manufacture, and Industrial Automation (ICAMIMIA)*, Surabaya, Indonesia. (pp. 121-126). http://doi.org/10.1109/ICAMIMIA.2015.7508015

Theja, B. S., Raviteja, A., Rajasekhar, A., & Abraham, A. (2012). Coordinated design of power system stabilizer using thyristor controlled series compensator controller: An artificial bee colony approach. *2012 International Conference on the Communication Systems and Network Technologies (CSNT)*, Rajkot, India (pp. 606-611). http://doi.org/1109/CSNT.2012.136

Yunus, M. Y., Djalal, M. R., & Marhatang. (2017). Optimal Design Power System Stabilizer Using Firefly Algorithm in Interconnected 150 kV Sulselrabar System, Indonesia. *International Review of Electrical Engineering (IREE)*, *12*(3), 250-259. http://doi.org/10.15866/iree.v12i3.11136