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Optimal Design Power System Stabilizer Using Firefly Algorithm in Interconnected 150 kV Sulselrabar System, Indonesia

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Abstract – *Power System Stabilizer (PSS) is an additional control equipment that is capable of improving system stability by providing an additional signal to excitation equipment. The PSS provided additional damping function to the generator when an interruption occurred. The PSS uses proper coordination required to achieve good performance. In a real application, determination of PSS parameters is usually conducted by using trial and error method (Conventional Method). However, it was very difficult to obtain optimal parameters using this method. To resolve this problem, one of the Intelligent Methods for optimizing PSS parameters was proposed. Firefly algorithm is one of the intelligent methods inspired from the behavior of Firefly. The results were compared between systems: 1) without PSS and 2) with PSS by using trial & error method. From the analysis obtained, it was generated that after the installation of PSS, the oscillation occurred can be prevented and overshoot in oscillations can be reduced. Also, this process can also improve settling time and critical eigenvalue as well as indicate an increase in system stability. The system used in this research was 150 kV applied in the electrical systems of Sulselrabar Region (South, East and West Provinces of Sulawesi Island), Indonesia.* ***Copyright © 2017 Praise Worthy Prize S.r.l. - All rights reserved.***

***Keywords**: Power System Stabilizer, Firefly, Eigenvalue, Settling Time, Overshoot*

Nomenclature

PSS	Power System Stabilizer
FA	Firefly Algorithm
AVR	Automatic Voltage Regulator
CDI	Comprehensive Damping Index
V_d V_q	Stator Voltage d and q axis
V_F	Rotor Field Voltage
$V_D V_Q$	Rotor Voltage d and q axis
r	Stator Resistance
$L_d L_q$	Rotor Inductance d and q axis
$\lambda_{q0}\lambda_{d0}$	Initial flux d and q axis
kM_F	Rotating Magnetic Field
M_D M_Q	Mutual Inductance
$\Delta i_d \Delta i_q$	Stator Current d and q axis
Δi_F	Rotor Field Current
$\Delta i_D \Delta i_Q$	Rotor Current d and q axis
$\Delta\omega$	Generator Speed Change
$\Delta\delta$	Generator Rotor Angle Changes
K_A	Strengthening Parameter
T_A	Time Constant
V_{rmax}, V_{Rmin}	Exciter Output Limiter
E_{fd}	Field Output
K_g	Constant Gain
T_g	Governor Time Constant
T_m	Mechanical Torque
GSC	Governor Speed Changer
K_{PSS}	PSS Gain
T_w	Washout Filter
T_A, T_B, T_C, T_D	Lead-Lag Gain
$V_{Smax}V_{Smin}$	Limiter
Δx	State Matrix ($n \times 1$)
Δy	Variable Matrix Output ($m \times 1$)
u	Matrix Input Variables (r × 1)
A	Matrix System ($n \times n$)
B	Input Matrix (n × r)
C	Measurement Matrix (m × n)
D	The input to the output matrix (m × r)
λ_i	ith eigenvalue
σ_i	The real component of the i-th eigenvalue
ω_i	Imaginary Component of the i-th eigenvalue
ζ	Damping ratio
P_e	Electrical Power
P_M	Mechanical Power

I. Introduction

The stability system is very important in the operation of electrical power systems. The imbalance between the mechanical input power to power the electrical load on the system caused acceleration in the rotor of the generator (frequency system), and the voltage will deviate from the normal conditions that will lead to the stability of the system when compromised. Instability of the system due to the disruption caused either large or small perturbations disorders. Minor perturbations in here corresponded to sudden and periodically load change. While for large disturbances caused, errors in the

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system such as short circuit, breaking up the network, load transfer. If this problem is not addressed immediately in the form of large disturbances, as well as the timing of the interference, the system will deviate from normal conditions. Therefore, it is necessary to control equipment on electrical power system that enables the system to react automatically towards deviations. Governor control equipment, AVR (Automatic Voltage Regulator), and the excitation system control equipment must be installed in the electrical power system to maintain the stability of the power system [1],[2],[3]. In the study of dynamic stability, it was assumed that changes in torque due to governor's response were ignored due to slow responses compared to the response of the excitation system, therefore the control influenced was the excitation system. Additional reinforcement in the excitation circuit had less effect in stabilizing the system, particularly for the low-frequency oscillation. Low frequency oscillation is between 0.2 to 2.0 Hz [2],[3]. Lower frequency can be more widespread and becomes inter-area oscillations. This requires additional control device such as Power System Stabilizer (PSS). PSS is an additional control device which serves to dampen and isolate oscillation frequency and voltage locally or globally on the generator as a response towards deviations occurring in the value of a variable that has been set [4],[5]. To obtain maximum results, proper and optimal parameter's tuning of PSS is necessary to dampen oscillations and stabilize the system as a response of the stabilizing system. In tuning this parameter, intelligent optimization methods, or so-called artificial intelligent can be used. This is a smart method adopted from animal behavior in searching for something. Firefly is one of the intelligent methods that has been widely used for the computation and optimization of a problem. Several methods have been proposed in PSS tuning to determine the optimum parameter values [6]-[17], one is known to be Firefly Encryption (FA). FA is an algorithm that is inspired by the behavior of fireflies introduced by Xin-She Yang in 2007. Optimum tuning parameters had a wide impact in stabilizing the system. However, there were various and diverse ranges of equipment parameters. To achieve the value of the parameter optimization method faster, FA optimization method was utilized. Response's values were determined by analyzing the value of overshoot and settling time, while for the objective function *Comprehensive Damping Index* (CDI) was used [14]. Then, the results of the simulation were analyzed by comparing the results of the simulation systems without the use of PSS, systems with PSS, and using PSS tuned with BA.

II. Electrical System Modelling

II.1. Generator Modelling

Modeling generator is needed to analyze the effects of changes in the frequency response and the rotor angle.

By using the transformation park, the synchronous generator can be modeled into a mathematical equation and linearized into equation (1).

II.2. Exciter Modeling

Excitation equipment is one part of the system where the exciter can set the generator output variables, such as voltage, current, and power factor [4], [5].

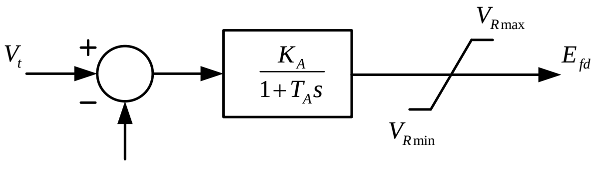

Fig. 1. Block diagram of excitations

II.3. Governor Modeling

Governor is a controller that serves to regulate the mechanical torque T_m value that becomes the input of the generator [4], [5].

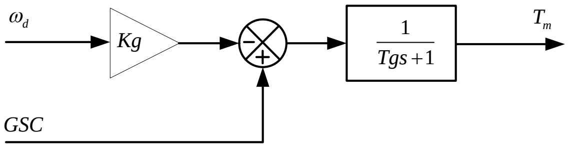

Fig. 2. Modeling Governor

II.4. Power System Stabilizer Modeling

PSS is used as a component of additional damping electricity that generates electrical torque. The following is a block diagram of PSS, in which the parameters of KPSS, T1, T2, T3, and T4 will be optimized by an intelligent method of fireflies [4], [5].

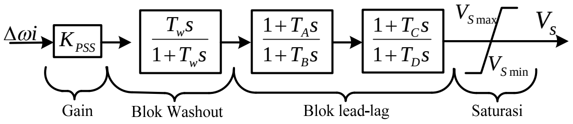

Fig. 3. Block diagram of the PSS

III. Optimum Design of PSS by Using Firefly

III.1. Optimization Process

To observe the system's response to the use of PSO and UPFC, the linear model of the system was combined with the linear model of PSS and UPFC in a state space equation (2) and (3):

$$\begin{bmatrix} \Delta v_d \\ -\Delta v_F \\ 0 \\ \Delta v_q \\ 0 \\ \Delta T_m \\ 0 \end{bmatrix} = -\begin{bmatrix} r & 0 & 0 & \omega_0 L_q & \omega_0 kM_Q & \lambda_{q0} & 0 \\ 0 & r_F & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & r_D & 0 & 0 & 0 & 0 \\ -\omega_0 L_d & -\omega_0 kM_F & -\omega_0 kM_D & r & 0 & -\lambda_{d0} & 0 \\ 0 & 0 & 0 & 0 & r_Q & 0 & 0 \\ \frac{\lambda_{q0} - L_d i_{q0}}{3} & \frac{-kM_F i_{q0}}{3} & \frac{-kM_D i_{q0}}{3} & \frac{-kM_Q i_{d0}}{3} & \frac{kM_Q i_{d0}}{3} & -D & 0 \\ 0 & 0 & 0 & 0 & 0 & -1 & 0 \end{bmatrix} \begin{bmatrix} \Delta i_d \\ \Delta i_F \\ \Delta i_D \\ \Delta i_q \\ \Delta i_Q \\ \Delta \omega \\ \Delta \delta \end{bmatrix} + \tag{1}$$

$$-\begin{bmatrix} L_d & kM_F & kM_D & 0 & 0 & 0 & 0 \\ kM_F & L_F & M_R & 0 & 0 & 0 & 0 \\ kM_D & M_R & L_D & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & L_q & kM_Q & 0 & 0 \\ 0 & 0 & 0 & kM_Q & L_Q & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & -\tau_j & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \Delta \dot{i}_d \\ \Delta \dot{i}_F \\ \Delta \dot{i}_D \\ \Delta \dot{i}_q \\ \Delta \dot{i}_Q \\ \Delta \dot{\omega} \\ \Delta \dot{\delta} \end{bmatrix}$$

$$\Delta \dot{x} = A \Delta x + B \Delta u \tag{2}$$

$$\Delta y = C \Delta x + D \Delta u \tag{3}$$

From matrix A above, the eigenvalue system can be observed and can provide information on system stability. Based on the results of the eigenvalue, system performance can be seen through the equation Comprehensive Damping Index (*CDI*) that is shown in Equations (4), (5) and(6) below:

$$\lambda_i = \sigma_i + j\omega_i \tag{4}$$

$$\zeta_i = \frac{-\sigma_i}{\sqrt{\sigma_i^2 + \omega_i^2}} \tag{5}$$

$$CDI = \sum_{i=1}^{n} \left(1 - \zeta_i\right) \tag{6}$$

CRP optimization method is used to tune the parameters of the PSS K_{PSS}, K_{PP} and K_{ip} in UPFC to generate *CDI* minimum value of the system.

III.2. Firefly Algorithm

Dr. Xin-She Yang at the University of Cambridge discovered this algorithm in 2007. In this algorithm, there are three basic formulations:

1. All the fireflies are unisex so that a firefly would be interested in other fireflies regardless of their gender.
2. The appeal is proportional to the brightness, the fireflies with brightness dimmer will move in the direction of fireflies with brighter brightness and brightness diminishes with increasing distance. If there are no fireflies that have the sunniest brightness, the fireflies will move randomly.
3. The level of brightness of a firefly determined by place of the objective function of fireflies.

In the process of optimization problems, firefly light brightness is equal to the value of the objective function. Another form of brightness can be defined in the same way for the fitness function in the genetic algorithm. Based on these three rules, the basic steps of the algorithm firefly (FA) can be summarized as the following pseudo code:

Pseudo Code of Firefly Algorithm

```
The objective function f(x), x=(x 1, ..., x)T
Initialize the population of fireflies xi(i =1, 2, ..., n)
Determine the light absorption coefficient γ
while (t <Max Generation)
for i=1: nallnfirefliesforj=1: iallnfireflieslightintensityIiatxiis
determinedbyf(xi) if (j>ii) MovefirefliesI toj indimensiondendifinterest
inthe populationat a distanceronexp[-γ r] Evaluationof
newsolutionsandupdatedlight intensityj
End for end for i
Sort ratings fireflies and find the best position new
end while
```

IV. Result and Analysis

Tuning of Power System Stabilizer using firefly algorithm in Sulselrabar (South, Southeast, and West Sulawesi Regions) system consists of 37 buses with major load centers such as Makassar, Pangkep, Maros, Barruand Pinrang Regencies. The operation data system used was a normal condition, the evening peak load was at 19:00, on Friday, 12 April 2012.

The program used was Matlab 2013 where the load flow studies, network reduction, and firefly algorithm performed in *m.* file *Matlab*, while the system modeling was carried out in *Matlab Simulink*. Figure 4 shows the single line diagram of the system applied in Sulselrabar. The first study was to simulate normal load flow. Calculation method utilized was *Newton-Raphson* method with a maximum iteration of 100. Table I shows the results of load flow.

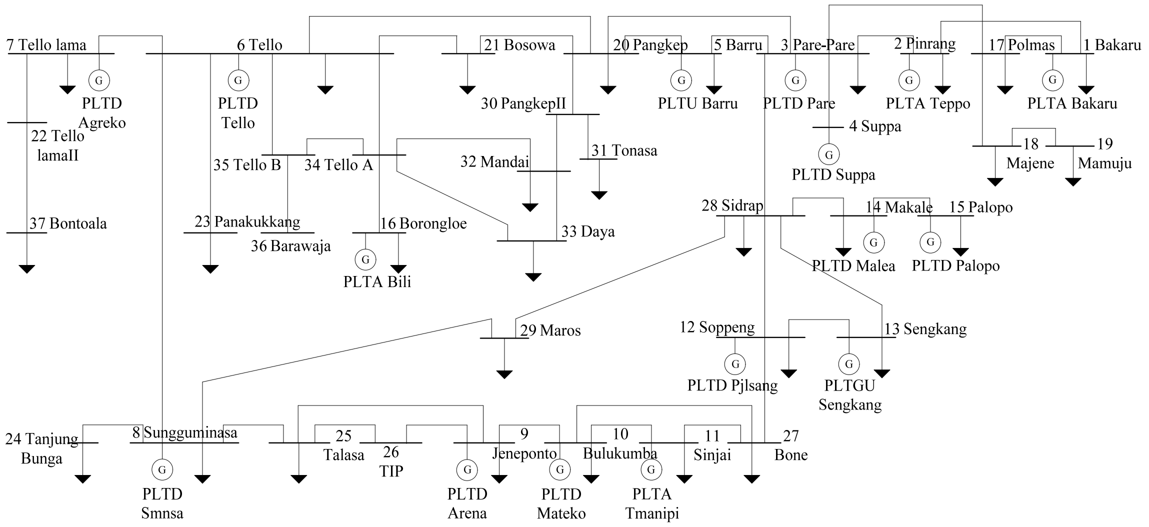

Fig. 4. Single Line Diagram of 150 kV Sulselrabar System [18]

TABLE I
RESULTS OF LOAD FLOW ANALYSIS

No Bus	V (pu)	Angle (^{o})	No Bus	V (pu)	Angle (^{o})
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	-21.966	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 results of load flow were used to reduce the number of buses except for bus generator. This will result in a 16×16 of matrix reduction. Table II shows the algorithm parameters, while Table III illustrates PSS constraints. Table IV show the PSS parameter by using trial & error method while Table V indicates the results of proposed method by using firefly algorithm.

Table VI shows that the values overshoot the frequency response of each method used. From these results, it can be seen that very small overshoot generated by the proposed method (firefly algorithm).

TABLE II
FIREFLY ALGORITHM PARAMETER

Parameter	Value
Alpha	0.25
Beta	0.2
Gamma	1
Dimension	80
Number of Fireflies	80
Maximum Iteration	50

TABLE III
PSS PARAMETER

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

TABLE IV
PARAMETER OF PSS TRIAL & ERROR

Generator	Kpss	T1	T2	T3	T4
Bakaru	48.2272	0.0478	0.8018	0.0493	0.8847
Pinrang	16.2895	0.0206	0.2886	0.3349	1.4885
Pare - Pare	13.5790	0.0472	0.3497	0.1713	2.7785
Suppa	16.5591	0.0443	0.7804	0.1024	1.6488
Barru	46.1332	0.0108	0.2612	0.1492	2.1633
Tello	35.3281	0.0425	0.3830	0.1935	1.4651
Tello lama	29.7565	0.0455	0.0864	0.3923	1.4842
Sgmnsa	38.1133	0.0045	0.0176	0.1988	1.7817
Jeneponto	29.7237	0.0246	0.7096	0.1953	1.5321
Bulukumba	99.3400	0.0394	0.9427	0.1066	2.8044
Sinjai	97.0248	0.0047	0.9107	0.1836	0.1418
Soppeng	8.5956	0.0247	0.2484	0.4776	0.8827
Sengkang	78.1453	0.0228	0.1392	0.3335	1.9848
Makale	17.9254	0.0341	0.3523	0.0405	0.5195
Palopo	14.5463	0.0565	0.4563	0.0324	0.0055
Borongloe	7.9553	0.0565	0.3653	0.0042	0.0045

TABLE V
RESULTS OF PROPOSED METHOD USING FIREFLY

Generator	Kpss	T1	T2	T3	T4
Bakaru	38.8093	0.0237	0.0249	0.7083	1.8227
Pinrang	17.5595	0.0194	0.0127	0.7722	0.7136
Pare - Pare	25.3515	0.0158	0.0353	0.6699	0.9498
Suppa	39.4244	0.0266	0.0127	0.6212	0.8639
Barru	44.5909	0.0237	0.0188	0.7384	1.2180
Tello	22.7521	0.0199	0.0235	0.1999	1.5545
Tello lama	43.4190	0.0147	0.0266	0.3763	0.3757
Sgmnsa	24.6654	0.0285	0.0297	0.4634	1.2268
Jeneponto	23.4228	0.0199	0.0346	0.6046	1.0733
Bulukumba	38.3667	0.0205	0.0147	0.4537	1.1218
Sinjai	26.9189	0.0150	0.0280	0.5582	1.4148
Soppeng	22.1375	0.0380	0.0295	0.5758	0.5457
Sengkang	41.8236	0.0186	0.0151	0.5786	1.4135
Makale	34.5080	0.0178	0.0215	0.3226	1.1659
Palopo	32.7399	0.0195	0.0255	0.5995	0.3649
Borongloe	35.6210	0.0164	0.0165	0.3212	0.7918

TABLE VI
FREQUENCY OVERSHOOT

Generator	No PSS	Conv. PSS	PSS Firefly
Bakaru	0.004681 & -0.02563	0.003435 & -0.02208	8.155e-05 & -0.01625
Pinrang	0.006884 & -0.02385	0.003607 & -0.02048	0.0001974 & -0.01588
Pare - Pare	0.004794 & -0.02424	0.003282 & -0.02148	0.0001012 & -0.01638
Suppa	0.006515 & -0.02437	0.004717 & -0.02163	2.761e-05 & -0.01436
Barru	0.03669 & -0.08466	0.02275 & -0.06871	0.000125 & -0.03623
Tello	0.05448 & -0.2119	0.05054 & -0.2079	0.04586 & -0.2027
Tello lama	0.09124 & -0.2227	0.0002114 & -0.1513	0.0003861 & -0.07753
Sgmnsa	0.007789 & -0.05721	0.0001737 & -0.04833	4.005e-05 & -0.03955
Jeneponto	0.006145 & -0.02519	0.003361 & -0.02267	0.0004483 & -0.01835
Bulukumba	0.01017 & -0.02447	0.007014 & -0.02153	0.002263 & -0.01709
Sinjai	0.01805 & -0.0263	0.01424 & -0.0233	0.006797 & -0.01885
Soppeng	0.01152 & -0.0248	0.004104 & -0.01872	0.001571 & -0.01633
Sengkang	0.005063 & -0.02694	0.003675 & -0.02409	0.0001795 & -0.01656
Makale	0.01704 & -0.02397	0.01165 & -0.01999	0.003637 & -0.01568
Palopo	0.01892 & -0.02442	0.01436 & -0.02128	0.004218 & -0.01519
Borongloe	0.01622 & -0.06846	0.008148 & -0.06095	4.962e-05 & -0.0442

For example, the frequency response in Bakaru generator without PSS had amounted to 0.004681 and -0.02563, while by using conventional methods it was found to be 0.003435 and -0.02208, and by using the firefly method, the value was 8.155e-05 & -0.01625.

Table VII illustrates the critical eigenvalue of the system of each method used. From these results, it can be seen that the more negative (critical) the eigenvalue would result in the increase of damping value leading to critical condition.

For example, without the use of PSS -0.3056 + 4.6945i and using firefly of -0.3057 + 4.6950. Thus the system becomes a more stable condition.

TABLE VII
CRITICAL EIGENVALUE

Conventional PSS	PSS Firefly
-0.3056 + 4.6945i	-0.3057 + 4.6950i
-0.3056 - 4.6945i	-0.3057 - 4.6950i
-0.3135 + 4.5323i	-0.3156 + 4.5321i
-0.3135 - 4.5323i	-0.3156 - 4.5321i
-0.1266 + 4.3271i	-0.1272 + 4.3132i
-0.1266 - 4.3271i	-0.1272 - 4.3132i
-0.1965 + 4.3135i	-0.1967 + 4.3141i
-0.1965 - 4.3135i	-0.1967 - 4.3141i
-0.2620 + 4.1920i	-0.2731 + 4.2092i
-0.2620 - 4.1920i	-0.2731 - 4.2092i
-0.0390 + 3.5539i	-0.0397 + 3.5511i
-0.0390 - 3.5539i	-0.0397 - 3.5511i

TABLE VIII
INTER-AREA AND LOCAL OSCILLATION MODE

Mode Osilasi	PSS Trial	PSS Firefly
Inter-Area	-1.1615 + 4.8368i	-3.8229 + 3.9480i
	-0.4069 + 4.8606i	-0.6089 + 4.5618i
	-0.4289 + 4.6271i	-0.8512 + 3.9889i
Lokal	-0.9937 + 9.0422i	-1.8915 +10.6205i
	-0.8805 + 8.0385i	-4.2414 + 7.2629i
	-1.2681 + 7.3358i	-2.1746 + 7.9019i
	-0.8781 + 6.5140i	-0.0298 + 6.4590i
	-1.4557 + 6.2504i	-2.3725 + 6.6950i
	-1.2580 + 6.0584i	-1.4305 + 5.7090i
	-1.3826 + 5.9573i	-1.6666 + 5.8599i
	-0.8927 + 5.6517i	-1.0645 + 5.2921i
	-1.2387 + 5.7480i	-1.5595 + 5.5898i
	-1.1386 + 5.6712i	-1.3746 + 5.5257i
	-0.8122 + 5.3715i	-1.4244 + 5.2901i
	-1.0011 + 5.4803i	-1.5117 + 5.3875i

Table VII indicates that the eigenvalue on inter-area oscillation mode of the system, of each method, used. From these results, it can be seen that a large eigenvalue in that mode was improved by using firefly. For example in the inter-area oscillation mode, obtained eigenvalues ever increasing a number of critical conditions, without the use of PSS -0.3056 + 4.6945i and using PSS amounted -0.3057 + 4.6950. Thus the system becomes amore stable condition.

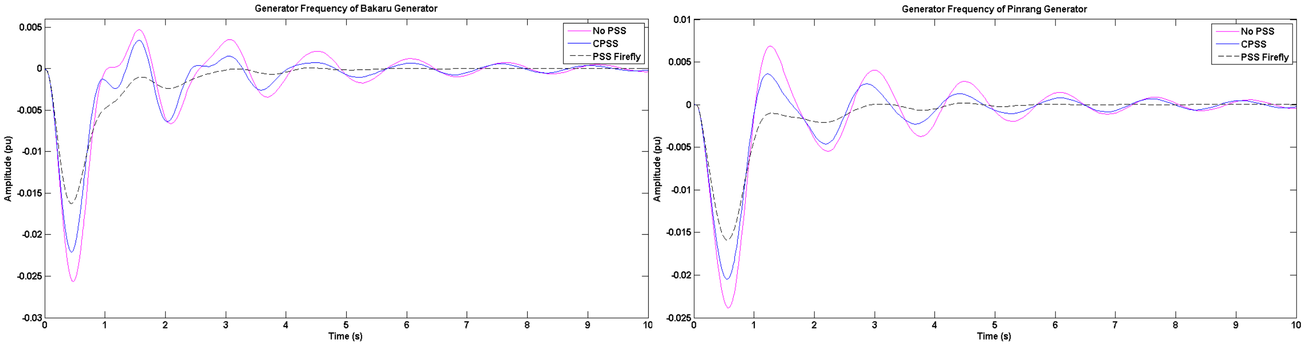

Fig. 5. Frequency of Bakaru&Pinrang Generators

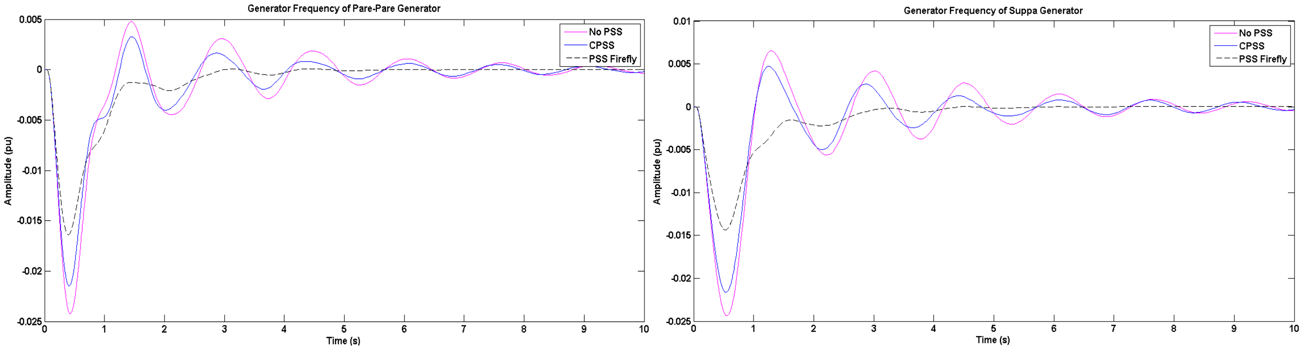

Fig. 6. Frequency of Pare-Pare&Suppa Generators

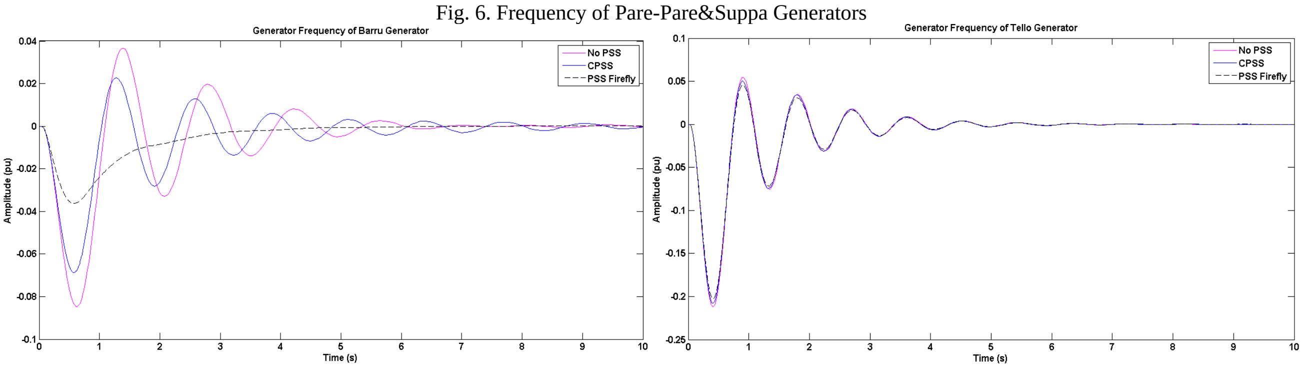

Fig. 7. Frequency of Tello&Barru Generators

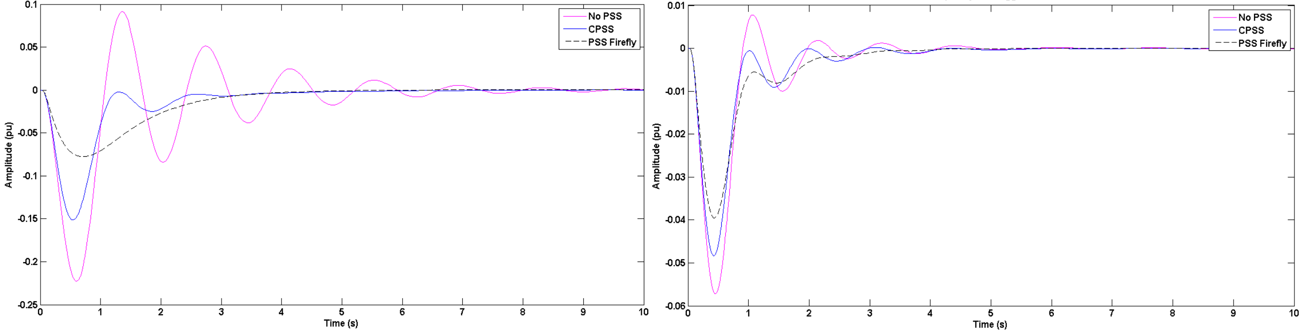

Fig. 8. Frequency of Tello Lama&Sungguminasa Generators

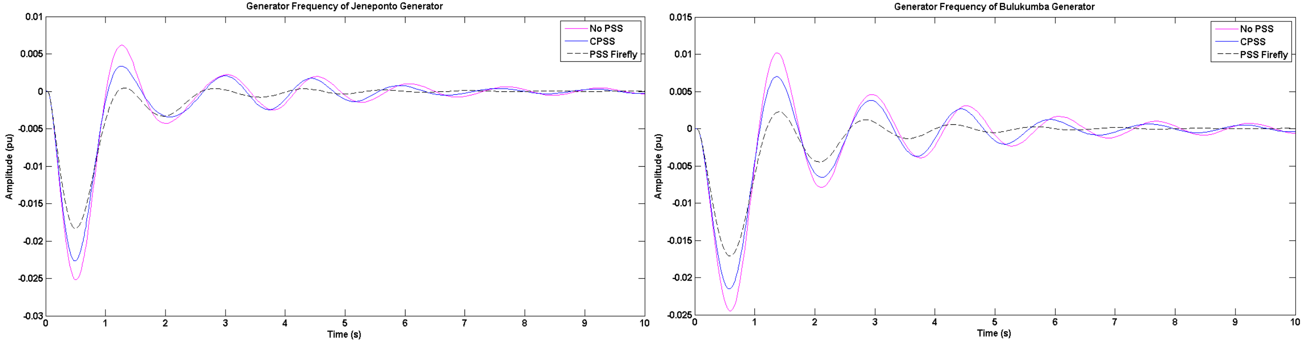

Fig. 9. Frequency of Jeneponto&Bulukumba Generators

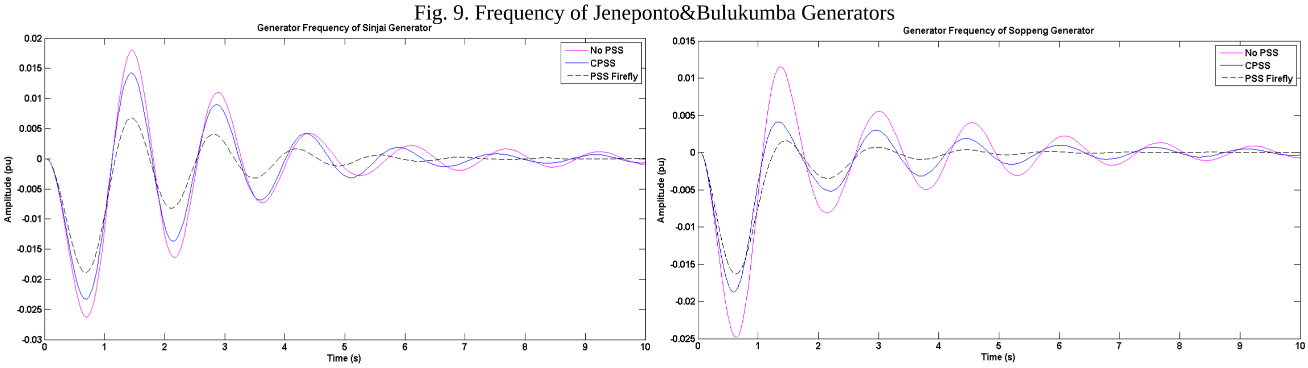

Fig. 10. Frequency of Sinjai&Soppeng Generators

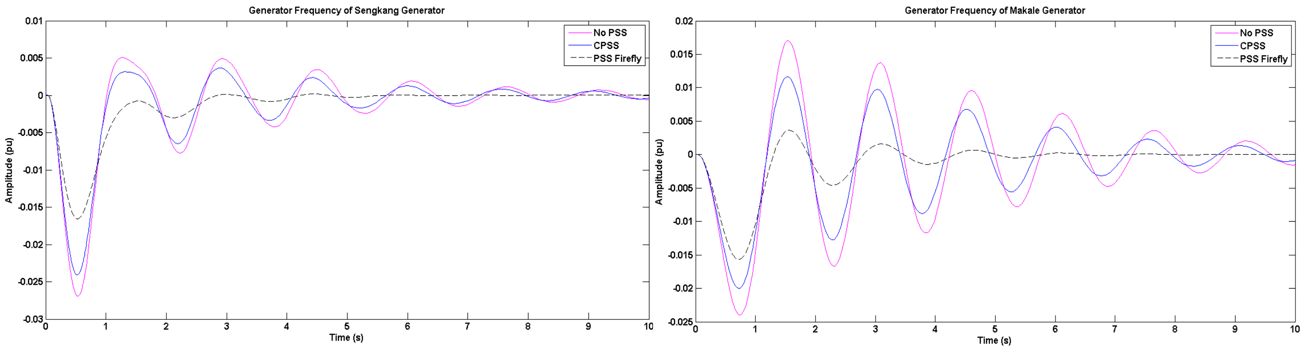

Fig. 11. Frequency of Sengkang&Makale Generators

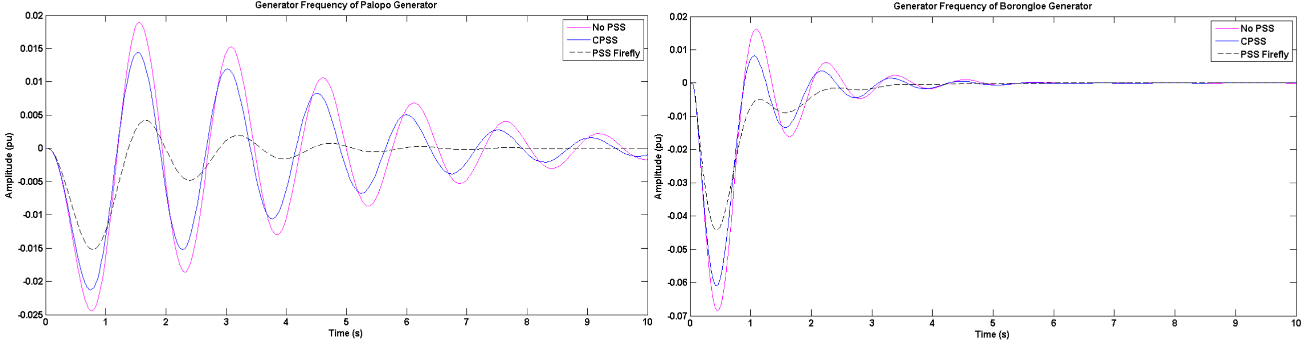

Fig. 12. Frequency of Palopo&Borongloe Generators

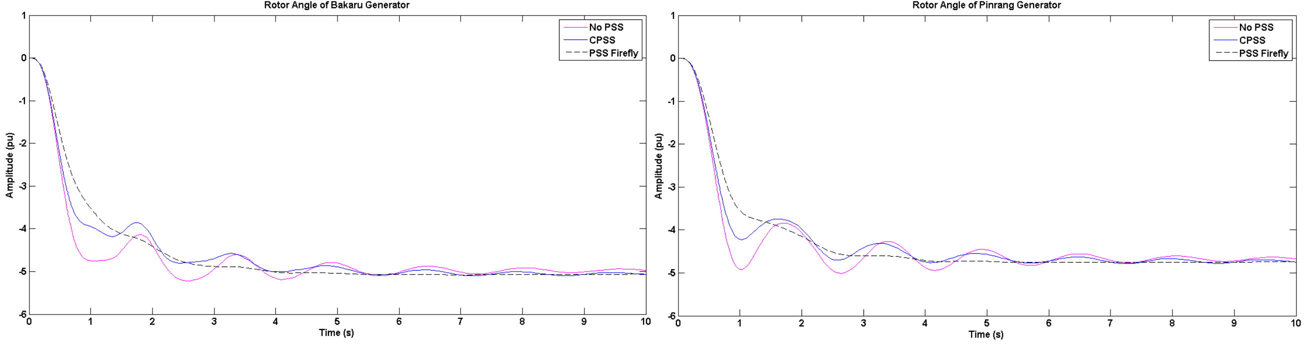

Fig. 13. Rotor angle of Bakaru&Pinrang Generators

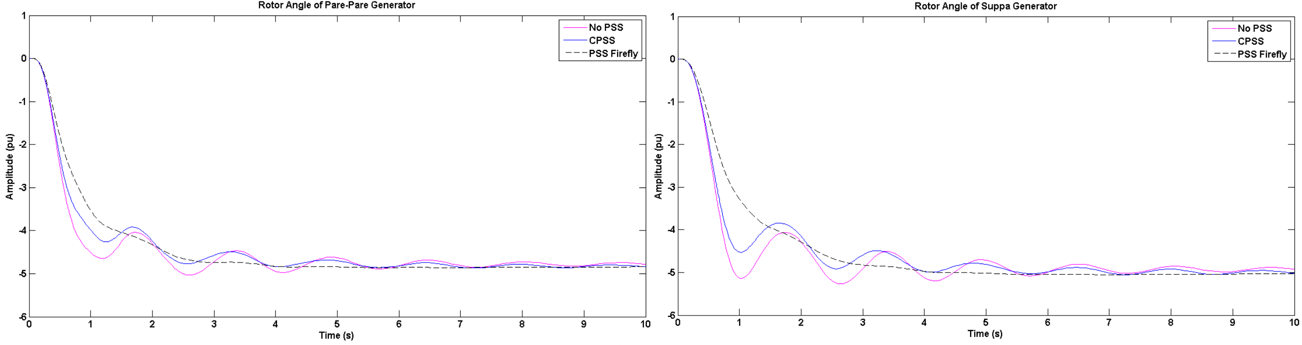

Fig. 14. Rotor angle of Pare-Pare&Suppa Generators

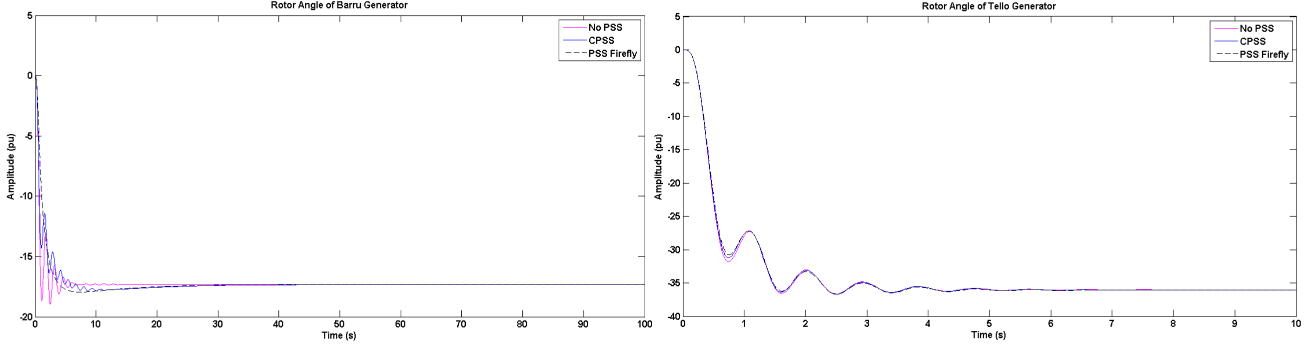

Fig. 15. Rotor angle of Barru&Tello Generators

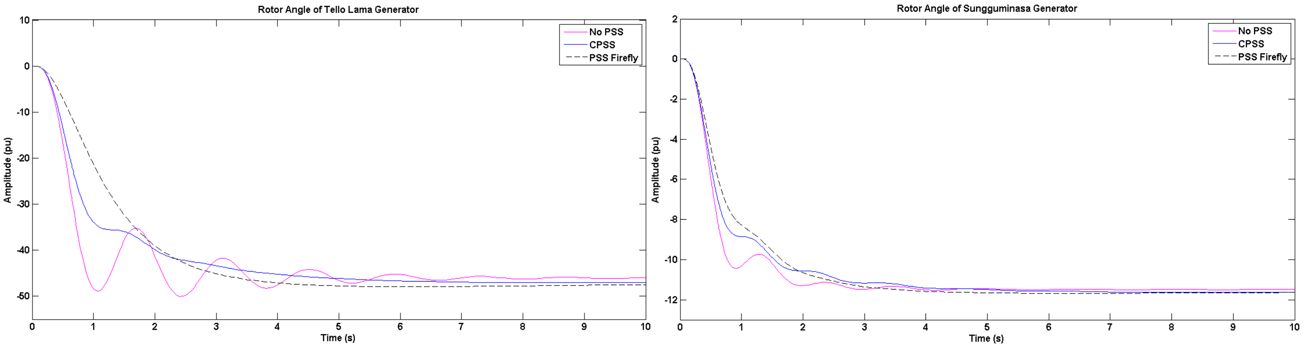

Fig. 16. Rotor angle of Tello Lama&Sungguminasa Generators

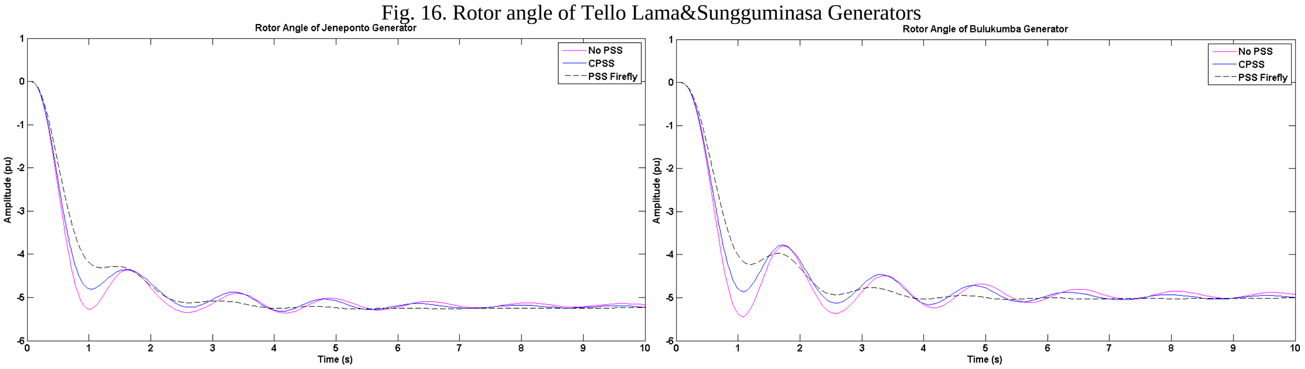

Fig. 17. Rotor angle of Jeneponto&Bulukumba Generators

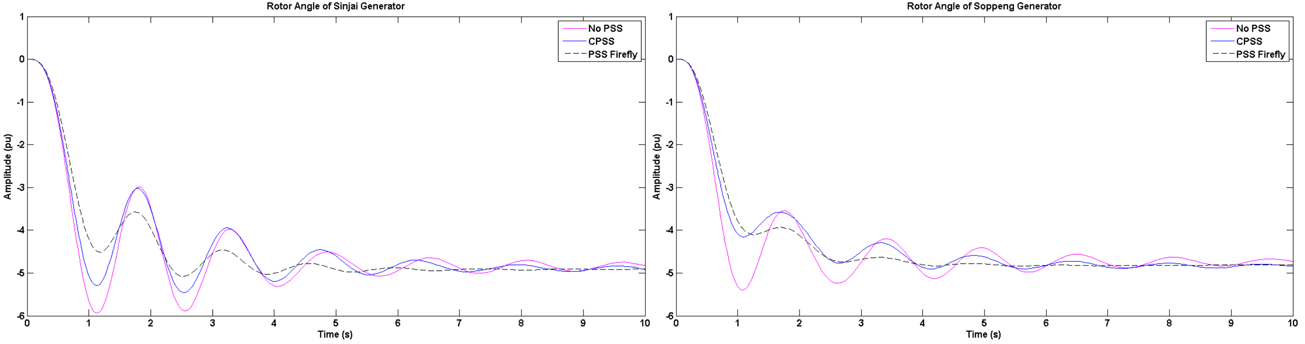

Fig. 18. Rotor angle of Sinjai&Soppeng Generators

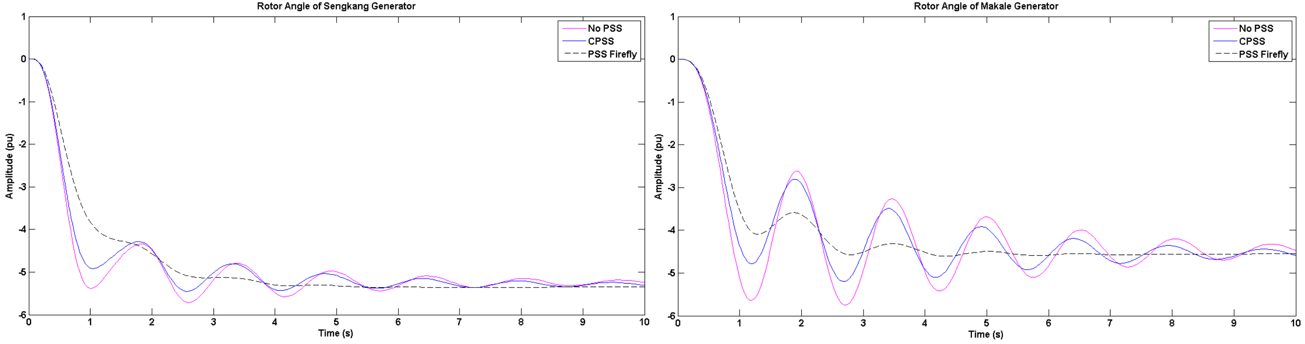

Fig. 19. Rotor angle of Sengkang&Makale Generators

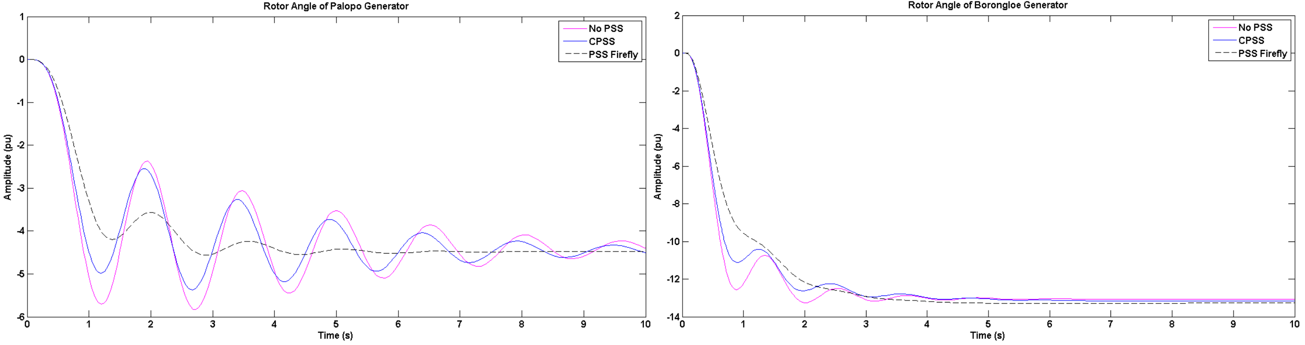

Fig. 20. Rotor angle of Palopo&Borongloe Generators

The objective function used was to maximize the minimum damping (ζ_{min}), in combination 16, the placement of PSS in each generator of Sulserabar system, was based on the following equation:

$$\zeta_i = \frac{-\sigma_i}{\sqrt{\sigma_i^2 + \omega_i^2}}$$

Smart firefly algorithm proposed in this research would find the optimum value of PSS parameter based on the objective used:

$$CDI = \sum_{i=1}^{n} \left(1 - \zeta_i\right)$$

The minimum value of minimum damping would be evaluated by the smart method proposed that used *Firefly Algorithm*. Then, it was obtained from the results the best placement of PSS with the maximum value ζ_{min} higher than ζ_0. After the placement of optimum PSS determined which was based on damping values of each probability of PSS placement, it can be later on seen and analyzed the system's responses through frequency deviation and rotor angle of each generator. Eigenvalue would also and overshoot of each comparing methods used. The linear system model was given changed demand disturbance as an input with the load 0.05 put onwards Generator Slack of PLTA Bakaru. Due to changes in loads, there were changes on the sides of loads which caused $P_m < P_e$, this has caused the frequency of generator to be down. Meanwhile, for rotor angle's response, when $P_e > P_m$,the rotor would slow down, and the rotor angle's response turned into negative:

$$M\dot{W} = P_m - P_e - DF$$

Figures 5-12 above has shown the frequency response of each generator, and this illustrated the responses of changes on rotor angle after loads enhancement at Bakaru Generator (Figures 13-20). The graph also showed the small frequency of overshoot' responses by using optimum PSS parameter compared to tunning by using the conventional method and uncontrolled system/open loop.

V. Conclusion

In this research, one of additional control for the generator, Power System Stabilizer, was used to provide a solution to the unstable system for 150 kV of Sulselrabar. PSS parameter was optimized based on objective function to maximize minimum damping (ζ_{min}) on 150 kV system in Sulselrabar. By optimizing the damping value, the results obtained from the overshoot occurred during the load changes was 0.05 pu which could stabilize the system at Bakaru generator.

From the analysis, the proposed method-Firefly Algorithm can be used as a tuning parameter optimization method of 16 PSS generators in Sulselrabar system. The results of the simulation have found that the algorithm can properly tune firefly PSS parameters. This was shown by lesser overshoot generated by the oscillation after a disruption. The firefly system could also accelerate the settling time to switch to the steady state immediately as well as has proven to increase the eigenvalue towards negative values compared to the system without PSS and with conventional PSS. Therefore, we can conclude that the system becomes more stable by the use of firefly system.

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