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Improving The Stability of Sulselrabar System with Dual Input Power System Stabilizer Based on Imperialist Competitive Algorithm

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***Abstract*— Disturbances in the form of electrical power oscillations are generally overcome using additional equipment such as the Conventional Power System Stabilizer (PSS). The PSS will increase the stability limit by providing damping for the generator oscillation. PSS damping means that PSS will produce an electrical torque component that is in phase with the change in speed. However, the use of PSS has many errors, namely the desired value is different from the measured value of the PSS output. This is due to shaft motion components such as lateral shaft run out or torsional oscillations. In this research, Dual Input Power System Stabilizer (DIPSS) equipment is used to reduce signal noise so that the system remains stable. With optimal DIPSS parameters, optimal system performance is obtained. In this study, a case study of the additional load on the Barru generator is used. From the test results, system performance has increased with the installation of DIPSS ICA. The increase in system performance can be seen from the speed and angle response of the generator rotor, which results in minimum overshoot oscillations and fast settling time when disturbances occur. In addition, the increase in system performance is also seen from the negative system eigenvalues.**

Keywords—DIPSS, Eigenvalue, Stability, Sulselrabar, ICA

I. INTRODUCTION

Improper use of auxiliary equipment in the power system to stabilize the system can cause many problems. Problems that often arise, among others, are due to equipment errors in retrieving the reference signal or the parameter values of the equipment are not optimal. Improvements in the electric power system that should be faster actually experience oscillations. It is more complicated, if the system has more than one machine/multimachine. The Sulselrabar system (South, Southeast and West Sulawesi) is a multimachine system consisting of several interconnected generators [1].

Disturbances in the electric power system often occur, such as network outages (transients) or load changes (dynamic). This disturbance can cause system instability. Instability in the electric power system can be in the form of frequency, rotor angle, and voltage instability. Instability is determined by the initial conditions and the magnitude of the disturbance, as well as disturbances which then have a direct impact on changes in electrical power. Changes in electrical power in the generator will have an impact on mechanical power [2]. Problems that can cause instability such as the difference in response speed between a fast electrical power response and a slower mechanical power response. Then the system oscillates as a result of this difference.

Disturbances in the form of electrical power oscillations are generally overcome using additional equipment such as the Conventional Power System Stabilizer (PSS). The PSS will increase the stability limit by providing damping for the generator oscillation. PSS damping means that PSS will produce an electrical torque component that is in phase with the change in speed. However, the use of PSS has many errors, namely the desired value is different from the measured value of the PSS output. This is due to shaft motion components such as lateral shaft run out or torsional oscillations [3]. The appearance of this component will add to the excitation signal and the torsional component so that it will cause variations in the electrical torque.

The problem faced lies in how to maintain stability and reduce the signal that interferes (noise) to avoid errors in the excitation system in a state of disturbance. With the above conditions, it is proposed an equipment, namely Dual Input Power System Stabilizer (DIPSS) which can reduce signal noise so that the system remains stable [4]. Precise parameter setting on DIPSS makes system performance more optimal. The problem is that the equipment parameter ranges are very diverse and complex, so to get the parameters quickly, many optimization methods are used. The method used is the Imperialist Competitive Algorithm (ICA). The ICA method is an algorithm that works based on the principle of power competition [5, 6]. Several previous studies on the implementation of ICA in power systems have shown good results, including the topics of economic dispatch [7], optimal power flow [8], and Static Compensator [9].

The response value is known by using the overshoot value, settling time, and eigenvalue, while for the objective function using the Comprehensive Damping Index (CDI). In this study, the 150 kV Sulselrabar electrical system was used. The current Sulselrabar system is growing, for that it is necessary to study the performance of the system. Several studies on this system include the topic of stability, [10] discusses single input for PSS and produces good oscillation attenuation for the system, but system performance can be improved with dual input PSS. [11] discusses the implementation of PSS with trial error tuning on the Sulselrabar system, in this study the performance improvement can be improved by tuning based on intelligent methods. In the proposed research, the application of Dual Input PSS needs to be studied further in the South Sulawesi system.

II. POWER SYSTEM STABILIZER MODELING

A. Power System Stabilizer Concept

The concept of Power System Stabilizer (PSS) is actually related to how to improve the damping electromechanical oscillation on the generator [12]. These improvements always involve changes in the form of oscillations in the speed and electrical power of the generator in the steady state area, while the relationship between the above components can be formulated in the Swing equation below [13].

$$\frac{2H}{\omega_0}\frac{d^2\delta}{dt} = \bar{T}_m - \bar{T}_e - K_D\Delta\bar{\omega}_r \tag{1}$$

For small disturbances, the above equation becomes:

$$\Delta T_e = T_s\Delta\delta + T_D\Delta\omega \tag{2}$$

Where:

δ = rotor angle
ω = fundamental angular rotor speed
ω_r = rotor angular speed
T_m = mechanical torque
T_e = electric torque
H = constant of inertia
K_D = damping coefficient
ΔT_e = change in electric torque
T_s = sync coefficient
T_D = damping coefficient
$\Delta\delta$ = change in rotor angle
$\Delta\omega$ = change in velocity

B. Power System Stabilizer

The block diagram illustrating this PSS is described in Figure 1. Proper tuning of these PSS parameters will provide the phase lead characteristics that are used to compensate for the phase lag between the Automatic Voltage Regulator (AVR) and the electrical torque. This result will improve the damping due to the electric torque component in phase with the speed variation [14].

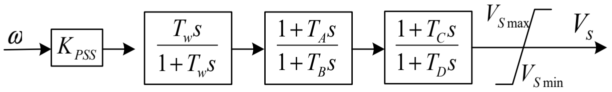

Fig. 1. Power System Stabilizer block diagram

In Figure 1, the PSS consists of a Gain Block which functions as an amplifier in order to obtain the amount of torque. The amount is in accordance with the desired damping, then the Wasout block functions as a high pass filter and provides steady state bias for PSS output. This bias is related to the generator terminal voltage. PSS is expected to respond to transient variations of the generator rotor speed signal and not to DC offset signals, and the Lead-lag Block to provide phase leads to compensate for phase lag between the AVR reference and electrical torque.

C. Dual Input Power Sistem Stabilizer

One of the functions of the Dual Input Power System Stabilizer (DIPSS) is to reduce noise signals. This noise signal can cause input reference errors for the electric power system. The noise signal can be sourced from shaft motion such as lateral shaft run-out which causes over-modulation of the generator excitation, or also from torsional oscillations caused by changes in electrical torque. The emergence of noise in the electric power system, can affect the excitation of the generator and cause an electric torque effect. Changes in rotor angular speed (Δω) and changes in electric power (ΔPe) are inputs to this type of stabilizer. Washout is used to provide a continuous condition at the output of the stabilizer, while the transducer is used to convert the input signal into a voltage signal. This input signal enters the washout and transducer circuits. Figure 2 shows the DIPSS modeling used in this study.

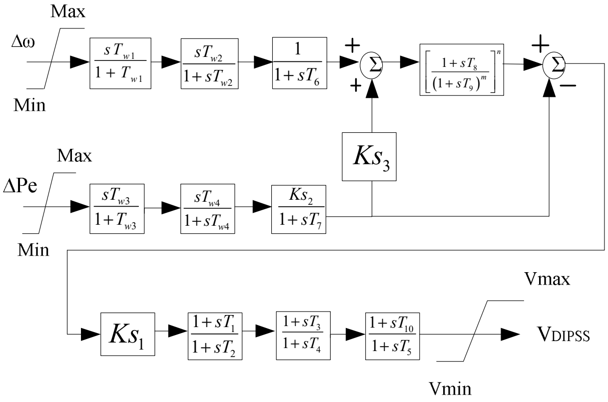

Fig. 2. Block Diagram of Dual Input Power System Stabilizer (IEEE type PSS2B)

Each input signal will be passed into a washout block diagram (T_{w1}-T_{w4}) and one transducer (T_6-T_7) and for the torque filter time constants are marked with time constants T_8 and T_9.

D. Imperialist Competitive Algorithm

Optimization methods used to find parameter DIPSS is Competitive Algorithm (ICA). This algorithm was based on the concept of competition to obtain the greatest power [15]. The initial stage of the ICA algorithm starts with initializing the population which shows the solution to the problem, while the goal to reach the final stage of the colony is the convergence value with the global optimum value of the problem. ICA computing concepts and stages are:

1. Empire Initialization

Initialization empire is an early stage of computing with the initialization process is divided into two imperialist and colony. Normalization formula and imperial power can be seen in equations 3 and 4.

$$C_n = c_n - \max\{C_i\} \tag{3}$$

$$P_n = \left|\frac{C_n}{\sum_{i=1}^{N_{imp}} C_i}\right| \tag{4}$$

2. Colony movement into Imperialist

Colony to imperialist movement is get more optimum parameter values. This happens because the cost of the colony is better than imperialist cost.

3. *Revolution*

Revolution is defined as a deviation from the baseline characteristics. In the program here is analogous to the movement between different variables within a single country evolusi.

4. *Position Exchange*

Exchange of position occurs because the cost of better than imperial colony, resulting in the exchange position and the cost of imperial colony.

5. *Empire Merging*

Merger empire occurs if the distance between the two imperialist is less than limit in computing. Limit or threshold Boundaries from imperialist can be seen in equation that described in the following equation 8.

$$Threshold\ Distance\ = 0.02\ x\ Norm(Prob.parm.var.max - Prob.parm.var.\min) \quad ....(8)$$

6. *Imperialist Competition*

Competition is one of the strategy to get many colony to find good value

7. *Empire Elimination*

Omission because the colony owned empire empirehas been exhausted.

8. *Convergence*

Convergence with empire marked the only remaining one. In this condition with the colony cost is the same with imperialist.

In research, ICA method is used to get good value of Parameter DIPSS. The parameter is search by this method is T1, T3 (constant time), and KDIPSS (gain). The purpose is Produce the settling time, overshoot, and the minimum eigen value of the system. Flow chart of computing to get the parameters of DIPSS ICA can be seen in Figure 5 [16].

III. RESEARCH METHOD

In this study, the system was analyzed using frequency response analysis, generator rotor angle, and eigenvalues. The eigenvalue analysis method uses a mathematical model of the system being analyzed. From the mathematical model obtained, it is converted into state space as in (8) and (9) below:

$$\Delta\dot{x} = A\Delta x + B\Delta u \quad (8)$$

$$\Delta y = C\Delta x + D\Delta u \quad (9)$$

From equations 8 and 9 above, Δx is the state matrix (n × 1), Δy is the output variable matrix (m × 1), u is the input variable matrix (r × 1), A is the system matrix (n × n), B is the Input Matrix (n × r), C is the measurement matrix (m × n), and D is the input matrix for output (m × r). The stability of the system can be viewed from the value of the matrix A in the system, using the following equation:

$$\det(sI-A)=0 \quad (10)$$

From equation 10 above, I is the identity matrix, s is the eigenvalue of the matrix A. The value of matrix A is n x n, then the number of eigenvalues obtained is:

$$n, \lambda = \lambda_1, \lambda_2, \lambda_3, ..., \lambda_n.$$

$$\lambda_i = \sigma_i + j\omega_i \quad (11)$$

The oscillation frequency in Hz is:

$$f = \frac{\omega}{2\pi} \quad (12)$$

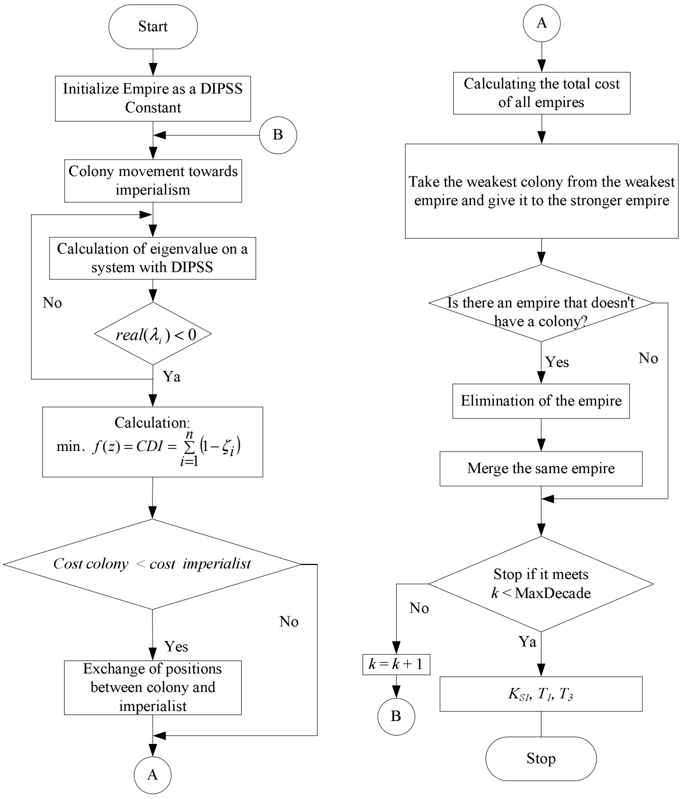

Fig. 3. Research Flowchart

From the above equation, λ_i is the eigenvalue i-th, σ_i is the real component of the eigenvalue i-th, and ω_i is the imaginary component of the i-eigenvalue.

The stability of the system can be determined from the eigenvalue A. If the real part of the eigenvalue is negative, then the system is said to be stable. Before installing the controller on a system, it is necessary to carry out a stability check. So that before giving control to a system, the system must be stable, after that it can only be installed. The damping component is the real part of the eigenvalues, while the oscillation component is the imaginary part. The damping value is determined using equation (13). The overall damping system is seen from the Comprehensive Damping Index (CDI) value shown in equation (14).

$$\zeta_i = \frac{-\sigma_i}{\sqrt{\sigma_i^2 + \omega_i^2}} \quad (13)$$

$$CDI = \sum_{i=1}^{n}(1-\zeta_i) \quad (14)$$

From the above equation, ζ_i is the damping ratio system, n is the number of eigenvalues. The objective function of the ICA algorithm in optimizing is to maximize the minimum damping of ζ_{mi}. Table I below is the parameter limitation of DIPSS that is optimized using the ICA method [15].

TABLE I. DIPSS PARAMETER LIMITATION

No	Parameter	Lower Limit	Upper Limit
1	K_{s1}	0.1	200
2	T_1	0.1	150
3	T_3	0.1	1

IV. RESULTS AND DISCUSSION

The first stage of this research is to analyze the power flow of the system, then reduce the admittance matrix to get a generator matrix of 16x16. Power flow analysis using Newton Raphson method. The results of the power flow analysis are shown in table II below. This study compares the results of previous studies using a single input PSS [16], so that the resulting differences can be seen.

TABLE II. RESULT OF LOAD FLOW ANALYSIS [16]

Bus	V (pu)	Angle (°)	Bus	V (pu)	Angle (°)
1	1.000	0.000	20	1.000	-1.612
2	1.000	-0.373	21	1.000	-1.801
3	1.000	-0.494	22	0.999	-2.059
4	1.000	-0.386	23	0.996	-2.236
5	1.000	-0.944	24	0.999	-2.049
6	1.990	-2.020	25	1.000	-1.916
7	1.000	-2.059	26	1.000	-1.822
8	1.000	-1.976	27	1.001	-0.996
9	1.000	-1.624	28	1.026	-0.884
10	1.000	-1.341	29	1.006	-1.815
11	1.000	-1.222	30	0.998	-1.580
12	1.000	-0.383	31	0.995	-1.671
13	1.100	-0.870	32	0.998	-2.072
14	1.000	-1.278	33	0.999	-2.070
15	1.000	-1.478	34	0.999	-2.018
16	1.000	-2.041	35	1.000	-2.019
17	1.001	-0.331	36	1.000	-2.019
18	1.002	-0.568	37	0.998	-2.184
19	1.001	-0.687			

A. Placement of DIPSS using Participation Factor

In this study, the placement of PSS and DIPSS used the participation factor (PF) method. PF was calculated and associated with all mechanical modes, written participation factors for each contained 144 eigenvalues and participation factors associated with the respective system state variables [16].

TABLE III. PARTICIPATION FACTORS [16]

Gen	Mode	Max. PF	Gen	Mode	Max. PF
1	9	1.615674	9	79	3.533766
2	16	5.532570	10	86	4.792765
3	23	5.051430	11	93	1.069600
4	30	11.510022	12	105	0.470722
5	37	4.810626	13	117	0.102372
6	49	0.061206	14	122	0.060962
7	58	0.280528	15	131	0.190893
8	72	0.533730	16	142	0.148595

Table III is the result of the analysis of the calculation of the mechanical mode participation factor of each generator, in the table it shows that the instability mode section, such as the 9th eigenvalue mode associated with Generator 1, the 16th mode eigenvalue associated with Generator 2, eigenvalue the 23rd mode corresponds to Generator 3, the 30th mode eigenvalue corresponds to Generator 4, the 37th mode eigenvalue relates to Generator 5, the 58th mode eigenvalue relates to Generator 7, the 72nd mode eigenvalue corresponds to with Generator 9, the 86th mode eigenvalue associated with Generator 10, the 93rd mode eigenvalue associated with Generator 11, the 105th mode eigenvalue associated with Generator 12, the 117th mode eigenvalue associated with Generator 13, eigenvalue mode The 131st corresponds to Generator 15, the 142nd mode eigenvalue corresponds to Generator 16. The eigenvalue corresponds to state s pace which has an influence on the participation factor. Based on this analysis, the positions of PSS and DIPSS installed are almost all generators except generators 6 and 14. Figure 4 shows the DIPSS installation design on the Sulselrabar system with parameter optimization based on the Imperialist Competitive Algorithm.

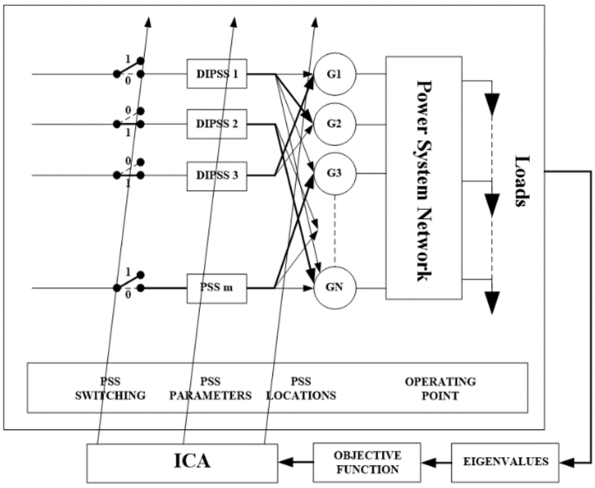

Fig. 4. DIPSS Installation Design

B. Tuning Dual Input Power System Stabilizer Using ICA

The process of tuning used using ICA method. Figure 6 shows the convergence graph of the DIPSS optimization process, where the fitness function value is 74.66 in the 36th iteration. The ICA parameters used in this study are shown in table IV, while the results of the ICA optimization for DIPSS parameters are shown in table V.

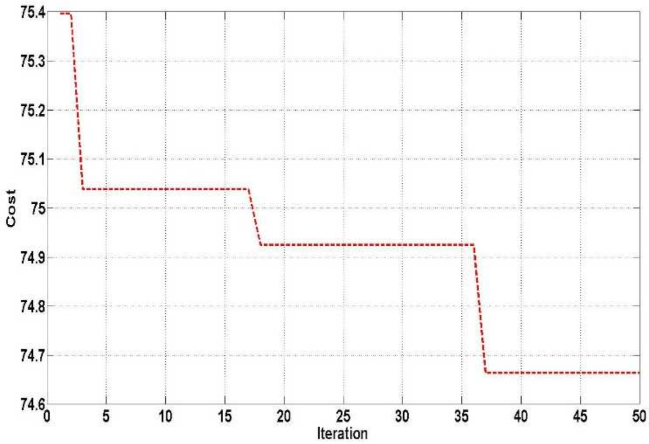

Fig. 5. Convergence Graphic of ICA

TABLE IV. ICA PARAMETERS

Number of country	100
Number of imperialist	10
Number of decade	50
Revolution rate	0.3
Coefficient of assimilation (β)	2
Zeta (ξ)	0.02
Coefficient of assimilation angle (γ)	0.5

TABLE V. TUNING RESULTS OF PSS PARAMETER

Power Plant	Ks1	T1	T3
Bakaru Hydro	119.7554	146.9645	0.4265
Pinrang Hydro	68.5460	130.6988	0.1000
Pare Diesel	110.1733	84.2213	0.2086
Suppa Diesel	61.4766	128.7114	0.4442
Barru Steam	67.8888	95.3237	0.5000
Cogindo Tello Diesel	60.0250	76.6517	0.2249
Tello lama Diesel	184.6861	76.7436	0.5000
Sgmnsa Diesel	116.0141	131.6510	0.3576
Bulukumba Diesel	50.1010	145.1726	0.5000
Sinjai Hydro	95.7917	117.1481	0.2259
Soppeng Diesel	161.7646	123.7335	0.1000
Sengkang Steam-Gas	167.6715	93.1685	0.3567
Makale Hydro	50.0000	129.5994	0.4554
Palopo Hydro	86.7168	78.1901	0.3831

C. *Load Shedding Scenario on Barru Generator*

After getting the optimal DIPSS parameter value, the next process is to test the stability of the system by giving disturbances in the form of additional load on the Barru generator. Table VI shows the overshoot response of the generator speed for each operating scheme.

The next system analysis is to observe the system's critical eigenvalues for each operating scheme. The results of the critical eigenvalues are shown in Table VII, while the interarea eigenvalues are shown in Table VIII, and the local area eigenvalues are shown in Table IX.

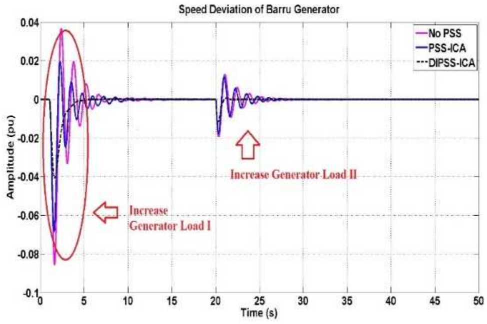

Fig. 6. Speed Deviation (Δω) Deviation Barru Generator

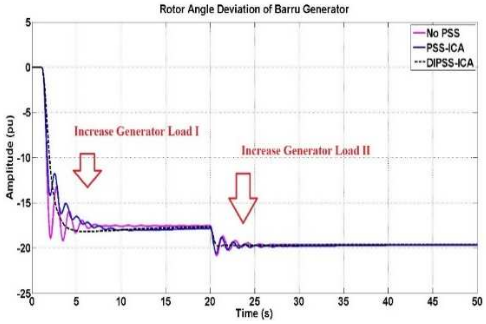

Fig. 7. Rotor Angle Deviation Barru Generator

TABLE VI. FREQUENCY OVERSHOOT IN LOAD SHEDDING SCENARIO

Power Plant	No PSS (pu)	PSS (pu)	DIPSS (pu)
Bakaru Hydro	-0.02284 & 0.005382	-0.01884 & 0.002491	-0.01343 & 0.0008854
Pinrang Hydro	-0.02396 & 0.006847	-0.02081 & 0.00391	-0.01697 & 0.0009581
Pare Diesel	-0.0247 & 0.005586	-0.02233 & 0.004146	-0.01853 & 0.0008968
Suppa Diesel	-0.02478 & 0.005984	-0.02246 & 0.004538	-0.01815 & 0.0008311
Barru Steam	-0.08557 & 0.03672	-0.06836 & 0.01959	-0.04073 & 0.000616
Cogindo Tello	-0.2119 & 0.05488	-0.2086 & 0.05169	-0.2029 & 0.04574
Tello lama Diesel	-0.2228 & 0.0913	-0.1656 & 0.01892	-0.08393 & 0.0006578
Sgmnsa Diesel	-0.05725 & 0.007836	-0.04857 & 0.0004217	-0.03692 & 9.401e-05
Jeneponto Steam	-0.02526 & 0.006169	-0.02327 & 0.00396	-0.02035 & 0.001531
Bulukumba Diesel	-0.0246 & 0.01016	-0.02208 & 0.007458	-0.01764 & 0.003657
Sinjai Hydro	-0.02645 & 0.01803	-0.02387 & 0.01494	-0.01867 & 0.006039
Soppeng Diesel	-0.02501 & 0.0113	-0.01882 & 0.004103	-0.01759 & 0.002262
Sengkang Steam-Gas	-0.02726 & 0.004633	-0.02489 & 0.003149	-0.0152 & 0.001124
Makale Hydro	-0.02414 & 0.01697	-0.0204 & 0.01202	-0.01732 & 0.007094
Palopo Hydro	-0.02458 & 0.01885	-0.02174 & 0.01486	-0.01742 & 0.007011
Borongloe Hydro	-0.06849 & 0.01622	-0.06209 & 0.01007	-0.05167 & 0.001921

TABLE VII. CRITICAL EIGENVALUE SYSTEM

NOPSS	PSS	DIPSS
-0.502+6.543i	-0.502+6.543i	-0.502+6.551i
-0.502-6.543i	-0.502-6.543i	-0.502-6.551i
-0.443+5.318i	-0.443+5.318i	-0.441+5.297i
-0.443-5.318i	-0.443-5.318i	-0.441-5.297i
-0.414+5.062i	-0.414+5.062i	-0.405+5.047i
-0.414 -5.062i	-0.414-5.062i	-0.405-5.047i
-0.305+4.694i	-0.305+4.694i	-0.306+4.697i
-0.305-4.694i	-0.305-4.694i	-0.306-4.697i
-0.311+4.533i	-0.311+4.533i	-0.325+4.525i
-0.311-4.533i	-0.311-4.533i	-0.325-4.525i
-0.197+4.465i	-0.197+4.465i	-0.189+4.438i
-0.197-4.465i	-0.197-4.465i	-0.189-4.438i
-0.120+4.328i	-0.082+4.160i	-0.138+4.270i
-0.120-4.328i	-0.082-4.160i	-0.138-4.270i
-0.083+4.161i	-0.121+4.326i	-0.197+4.314i
-0.083-4.161i	-0.121-4.326i	-0.1970-4.314i
-0.196+4.313i	-0.196+4.313i	-0.2832+4.220i
-0.196-4.313i	-0.196-4.313i	-0.2832-4.220i
-0.259+4.188i	-0.261+4.190i	-0.0412+3.900i
-0.259-4.188i	-0.261-4.190i	-0.0412-3.900i
-0.041+3.900i	-0.041+3.900i	0.0149+4.050i

-0.041-3.900i	-0.041-3.900i	0.0149-4.050i
-0.082+4.043i	-0.082+4.044i	-0.0815+4.045i
-0.082-4.043i	-0.082-4.044i	-0.0815-4.045i
-0.038+3.554i	-0.039+3.554i	-0.0400+3.549i
-0.038-3.554i	-0.039-3.554i	-0.0400-3.549i
-0.100+2.300i	-0.093+2.298i	-0.0031+2.276i
-0.100-2.300i	-0.093-2.298i	-0.0031-2.276i
1.735+0.000i	1.733+0.000i	1.7112+0.000i
-0.149+1.517i	-0.148+1.517i	-0.1430+1.510i
-0.149-1.517i	-0.148-1.517i	-0.1430-1.510i
-0.117+1.375i	-0.116+1.374i	-0.1040+1.363i
-0.117-1.375i	-0.116-1.374i	-0.1040-1.363i
-0.003+0.040i	-0.003+0.041i	0.0021+0.066i
-0.003-0.040i	-0.003-0.041i	0.0021-0.066i
-0.004+0.046i	-0.004+0.046i	
-0.004-0.046i	-0.004-0.046i	

TABLE VIII. INTERAREA EIGENVALUE SYSTEM

NOPSS	PSS	DIPSS
-0.330+4.084i	-0.514+4.933i	-2.956+4.819i
-0.444+4.615i	-0.319+4.136i	-4.312+1.889i
-0.505+4.540i	-0.426+4.626i	-3.168+3.435i
-0.512+4.534i	-0.877+4.839i	-0.616+4.595i
		-0.437+4.082i

TABLE IX. LOCAL EIGENVALUE SYSTEM

NOPSS	PSS	DIPSS
-1.002+ 9.422i	-1.097+9.741i	-1.203+8.877i
-1.006+ 8.435i	-1.035+8.526i	0.205+6.598i
-1.050+ 7.082i	-1.391+7.281i	-3.878+6.016i
-0.853+ 6.970i	-0.955+6.668i	-1.740+6.339i
-1.462+ 6.061i	-1.475+6.125i	-1.268+5.760i
-0.787+ 5.322i	-1.391+5.961i	-2.070+5.769i
-1.247+ 5.846i	-1.423+5.888i	-1.020+5.491i
-0.942+ 5.486i	-1.236+5.733i	-0.962+5.376i
-1.160+ 5.743i	-0.966+5.606i	-1.400+5.126i
-1.147+ 5.653i	-1.144+5.672i	-1.302+5.319i
-0.991+ 5.467i	-0.815+5.362i	-0.997+5.453i
-1.152+ 5.660i	-0.994+5.477i	

The test results show that the system eigenvalues are better by using DIPSS ICA. Eigen value analysis can show the stability and instability of a system. The system is said to be stable if the eigenvalues of the system are negative. While the damping ratio shows how fast the overshoot oscillations or the damping decreases in the rotor. The true value of the damping ratio comes from the components of the eigenvalues themselves. The next analysis is the system in terms of the overshoot oscillation response of each control scheme. To test the system, using the addition of a load and then see the response of the speed and angle of the generator rotor. The test results are shown in Figure 6 for the speed response and Figure 7 for the generator rotor angle response.

Table VI shows the optimal system performance with the use of DIPSS-ICA, so as to reduce overshoot and accelerate steady state conditions compared to other methods. While table VII-IX shows the comparison of critical eigenvalues for systems using single input PSS and dual input DIPSS, which shows an increase in eigenvalues. Attenuation values greater than 0.1 indicate good eigenvalue conditions and allow higher stability.

V. CONCLUSION

In this study, an artificial intelligence-based tuning method using the Imperialist Competitive Algorithm (ICA) is proposed to optimize the DIPSS parameters on the Sulselrabar multi-machine system. From the ICA optimization results, the optimal DIPSS parameter tuning results are obtained with a fast computational process. With accurate DIPSS parameters, optimal DIPSS performance is obtained. The combination of DIPSS and excitation is used to reduce the oscillations that occur in the system. In this study, to test the success of the proposed method, testing the additional load on the Barru generator is used.

Improved system performance is also increased with the installation of DIPSS optimized by the ICA method. This is indicated by the speed and angle response of the generator rotor which results in a small overshoot and a faster settling time when there is an increase in load. In addition, performance is also seen from the increasingly negative eigenvalues of the system, negative eigenvalues indicate the stability of the system.

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