Dingo optimization algorithm for designing power system stabilizer

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ABSTRACT

The dingo optimization algorithm (DOA) adopts the social life of dingo dogs. The dingo is a breed of ancient dog originating from Australia. Dingo hunting strategies such as assault with persecution, flocking, and scavenging behavior became the inspiration for DOA. In this paper, DOA is applied to a power system stabilizer (PSS) to dampen low-frequency oscillations (LFO) in a single-machine infinite bus (SMIB). DOA is used to obtain optimal parameters for PSS. The damping controller is designed for optimal lead-lag control. To obtain the performance of the DOA method, the results were compared with the uncontrolled method, conventional PSS, whale optimization algorithm (WOA), and grasshopper optimization algorithm (GOA). Simulation using MATLAB with three different operating conditions, namely light load (20%), medium load (50%) and high load (100%). From the simulation using MATLAB with SMIB modeling, it was found that the application of the DOA method on PSS has the ability to reduce the average undershoot value by 28.16% and reduce the average undershoot value to 65.57% compared to the conventional PSS method.

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1. INTRODUCTION

Rapidly developing technology requires a reliable power system [1]. Changes in load will be increasingly non-linear and complex [2], [3]. The challenge of future electric power systems is operation and control with various operating conditions and configurations [4], [5]. This is a challenge for power system experts in reducing various disturbances [6], [7]. Generators in an interconnected power system will experience a loss of synchronization and oscillation. The oscillations that occur even on a low frequency scale have an influence on the stability of the power system [8]. Increasing the damping capability of low-frequency oscillations (LFO) plays a key role in keeping and improving the system.

Oscillations in the power system are caused by variations in operating points due to changes in load and short circuits [9], [10]. The frequency oscillation must be regulated and controlled according to the required limits [11]. Frequency oscillation will cause instability. Power system stabilizer (PSS) is a tool that is used to dampen oscillations which is most commonly used to solve oscillation stability problems [12]. PSS has long been used as a solution to dampen low-frequency oscillations. PSS is good for power systems. Conventional PSS uses a linear approach that considers the nominal operating point in determining PSS parameters [13]. The increasingly complex, fluctuating, and non-linear system with a broader limit makes conventional PSS reach the limit to work optimally and efficiently.

Currently, the optimization of PSS parameters by artificial intelligence methods is increasingly being presented. One of the artificial intelligence methods is the metaheuristic algorithm. This algorithm has been widely presented as an alternative method for optimizing PSS parameters under various operating conditions. Several metaheuristic methods have been presented in the optimization of PSS parameters, namely: whale optimization algorithm (WOA) [14]-[17], Farmland fertility algorithm [18], Atom search optimization [19], Slime mould algorithm [20], Bacterial foraging [21], [22], Cuckoo search optimization [23]-[25], Sine Cosine Algorithm [26] and Particle swarm optimization [27]-[29]. However, optimization of PSS parameters is still a popular theme in the context of power system stability.

In this article, the latest optimization method, namely the dingo optimization algorithm (DOA) is used to determine the optimal parameters for PSS. DOA is based on a simulation of the dingo hunting strategy of attacking, grouping tactics, and scavenging behavior [30]. The DOA method was tested and compared with the PSS Lead-lag, WOA and grasshopper optimization algorithm (GOA) methods. Tests were carried out with WOA and GOA in terms of convergence efficiency and found the optimal PSS parameters for the dynamic stability of the power system. Time domain simulation analysis was carried out using MATLAB/Simulink with variations in loading.

The paper is described as follows: Session 2 describes the DOA and PSS structure. Section 3 presents the proposed DOA for PSS design. Section 4 presents the simulation results and PSS design analysis. Section 5 is the conclusion section.

2. METHOD

2.1. Dingo optimization algorithm (DOA)

DOA is inspired by the life of a dingo dog. Dingo is a carnivore originating from Australia. Dingoes are opportunistic hunters but will also scavenge for food when they explore new territory to find dead prey. This dingo hunting behavior is duplicated in DOA which has 3 strategies, namely attacking, grouping and scavenging [30].

Tactic 1: Team attacking

Predators have good hunting skills. Dingo has the ability to sort prey in hunting. Dingoes hunt individually when prey is small and hunt in groups when prey is large. Dingo has instinct like a wolf that can find the position of prey and surround it. Tactic 1 can be modeled in (1).

$$\vec{a}_i\,(t+1) = \beta_1 \sum_{k=1}^{m} \frac{\left[\overrightarrow{\varphi_k(t)} - \overrightarrow{a_\iota(t)}\right]}{m} - \overrightarrow{a_*(t)} \tag{1}$$

Where the new position of the search agent is denoted by $\vec{a}_i\,(t+1)$, m is a random integer. The subset of search agents is denoted by $\overrightarrow{\varphi_k(t)}$. The current search agent is denoted by $\overrightarrow{a_\iota(t)}$. The best search agent obtained from the previous iteration is denoted by $\overrightarrow{a_*(t)}$. β_1 is a uniformly generated random number in the interval [− 2, 2].

Tactic 2: Molestation

When dingoes hunt for small prey, they will chase until they are caught one by one. Tactic 2 can be modeled in (2).

$$\vec{a}_i\,(t+1) = \overrightarrow{a_*(t)} + \beta_1 \cdot e^{\beta_2} \cdot (\vec{a}_{ri}\,(t) - \vec{a}_i\,(t)) \tag{2}$$

Where β_2 is a random number uniformly generated in the interval of $[-1,1]$, ri is the random number generated in the interval from 1 to the size of a maximum of search agents, and $\vec{a}_{ri}$ is the ri -th search agent selected,where $i \neq ri$.

Tactic 3: Scavenger

Scavenging is the behavior of a dingo when it finds carrion to eat while roaming randomly within its community. This tactic can be in (3).

$$\vec{a}_i\,(t+1) = \frac{1}{2}\left[e^{\beta_2} \cdot \vec{a}_{ri}\,(t) - (-1)^{\sigma} \cdot \vec{a}_i\,(t)\right] \tag{3}$$

Where σ is a binary number randomly generated, $\sigma \in \{0,1\}$.

2.2. Power system stabilizer (PSS)

Power system stabilizer (PSS) is a tool implemented to regulate system stability. The power system stabilizer (PSS) is an auxiliary device that provides an additional feedback stabilizing signal to dampen generator rotor oscillations in the excitation system [31]. Electric torque provides damping according to speed variations. The PSS block diagram consists of the following blocks in Figure 1.

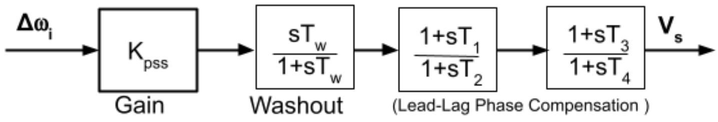

Figure 1. Block diagram of PSS

2.3. Proposed PSS based on DOA

The single machine system used in this article is the Heffron-Philips model. Figure 2 includes the popular Heffron-Philips model variables, namely $K_1 - K_6$. ω and δ are the rotor speed and the rotor angle. The damping factor are D. K_A and T_A are DC gain and time constant of AVR. A single machine installed with DOA-based PSS can be seen in Figure 2. DOA optimizes PSS parameters which include gain, washout and lead lag. The number of optimized PSS parameters is 7. PSS parameters are optimized using the integral of time multiplied absolute error (ITAE) with the (4):

$$ITAE = \int_0^{Ts} t.\,|\Delta\omega(t)|.\,dt \tag{4}$$

where $\Delta\omega(t)$ is the deviation of the rotor speed following the disturbance. Ts is the time of simulation.

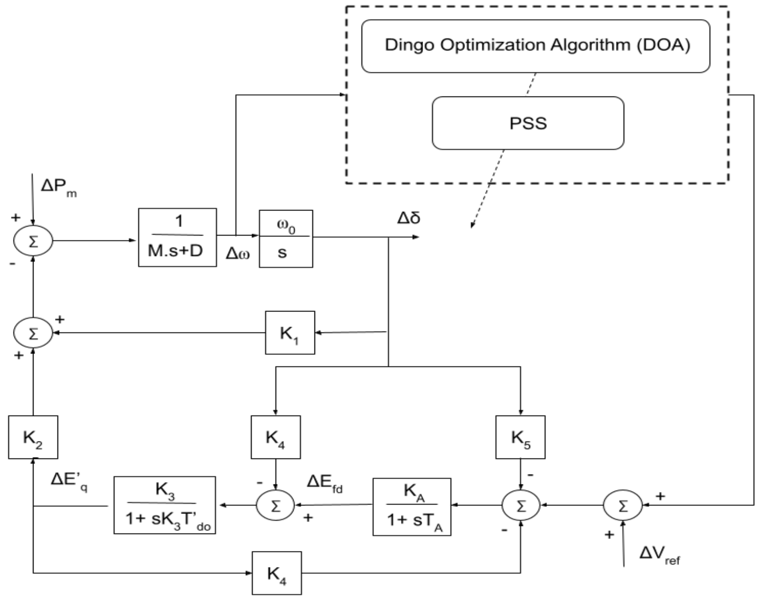

Figure 2. Block diagram of proposed PSS

3. RESULTS AND DISCUSSION

MATLAB 2015 software is used to perform simulations. Ability to determine performance, the DOA method is compared with the WOA and GOA methods. The convergence curve for comparing the DOA method with the WAO and GOA methods can be seen in Figure 3. The curve uses a time value of 0 at 30 seconds.

To determine and measure the performance of the DOA method used in PSS, the test uses 3 variations of loading, namely light load (20%), medium load (50%) and high load (100%). The first test is to give 20% load to the system. The transient response to the rotor speed and angle can be seen in Figure 4 and Figure 5. The transient response of Test 1 can be seen in Table 1. In Table 1, the under-shoot value of the DOA method has the same value as the GOA method, which is -0.0257. This value is the best speed undershoot value in the first test. The undershoot speed value of the DOA method is 28.4% better than the lead-lag method and 5.83% than the WOA method. Figure 4 is the graphic result of the speed in test 1. Meanwhile, the best under shoot value from the rotor angle in test 1 is the DOA method. Figure 5 is a comparison graph of the angle rotor in test 1.

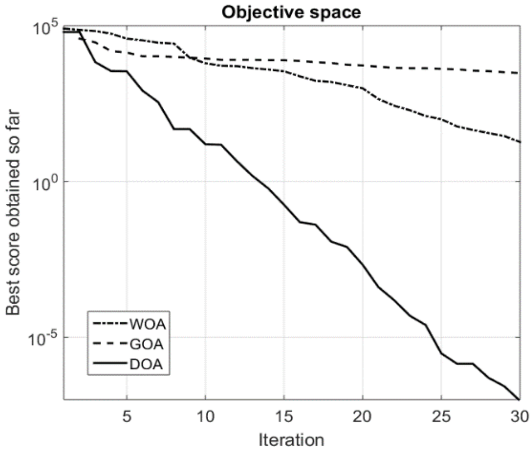

Figure 3. The convergence curve

Tabel 1. Test 1: 20% of load

Method	Speed response Undershoot	Overshoot	Settling time (s)	Rotor angle response Undershoot	Overshoot	Settling time (s)
No – PSS	-0.0791	0.0626	956	-0.3	No Overshoot	986
Lead – Lag PSS	-0.033	0.0165	600	-0.2249	0.0177	892
WOA PSS	-0.0272	0.0051	534	-0.1479	No Overshoot	606
GOA - PSS	-0.0257	0.0028	679	-0.11	No Overshoot	978
DOA – PSS	-0.0257	0.0033	636	-0.12	No Overshoot	850

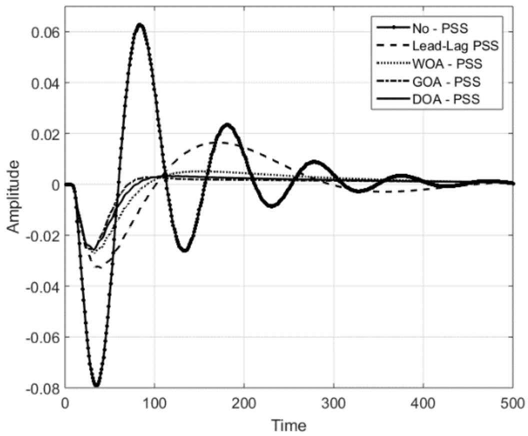

Figure 4. Speed in 20% load

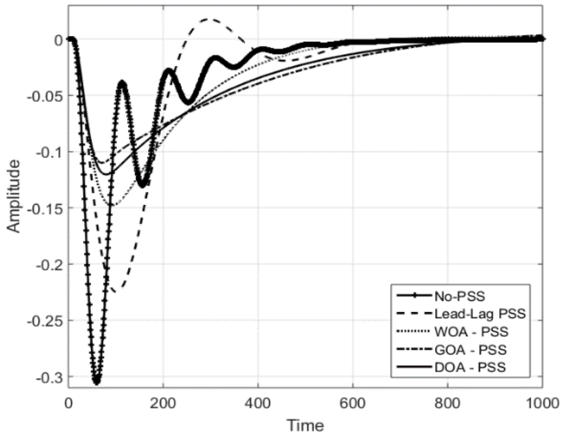

Figure 5. Rotor angle in 20% load

Table 2 is the transient response of test 2. The under shoot of the DOA method has the best value, which is -0.0641. The undershoot speed of the DOA method was 26.95% better than the lead-lag method, 5.9% than the WOA method, and 0.47% compared to the GOA method. Figure 6 is the graphic result of the speed in test 2. Meanwhile, the best under shoot value of the rotor angle in test 2 is the GOA method. Figure 7 is a comparison graph of the rotor angle in test 2.

In test 3, the under shoot value of the speed of the DOA method has the best value, which is -0.1284. The details of the response transients from test 3 can be seen in Table 3. Figure 8 is the graphic result of the speed in test 3. Meanwhile, the best under shoot value of the rotor angle in test 3 is the GOA method. Figure 9 is a comparison graph of the rotor angle in test 3.

Table 2. Test 2: 50% of load

	Speed response			Rotor angle response		
Method	Undershoot	Overshoot	Settling time (s)	Undershoot	Overshoot	Settling time (s)
No – PSS	-0.1976	0.1566	898	-0.7639	No Overshoot	887
Lead – Lag PSS	-0.0824	0.041	702	-0.5622	0.0154	893
WOA PSS	-0.679	0.0128	545	-0.3697	No Overshoot	807
GOA - PSS	-0.0644	0.007	681	-0.275	No Overshoot	980
DOA – PSS	-0.0641	0.0083	638	-0.3	No Overshoot	852

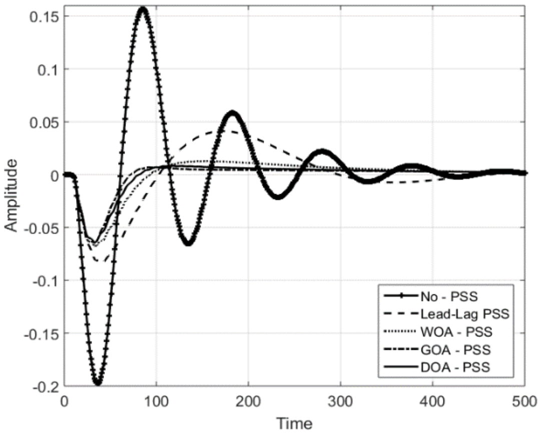

Figure 6. Speed in 50% load

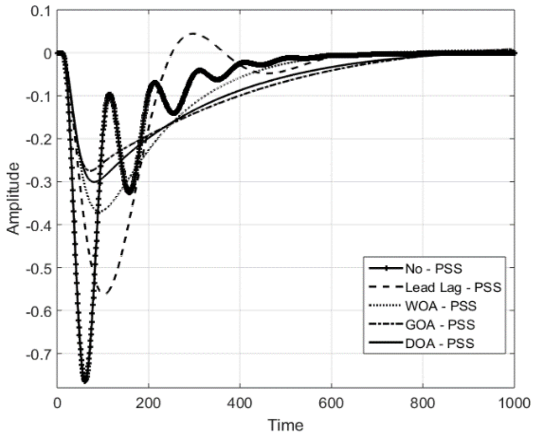

Figure 7. Rotor angle in 50% load

Table 3. Test 3: 100% of load

	Speed response			Rotor angle response		
Method	Undershoot	Overshoot	Settling time (s)	Undershoot	Overshoot	Settling time (s)
No - PSS	-0.3951	0.3131	810	-1.527	No Overshoot	888
Lead - Lag PSS	-0.1647	0.0823	602	-1.1244	0.0887	893
WOA PSS	-0.1359	0.0257	405	-0.7395	No Overshoot	807
GOA - PSS	-0.1287	0.0141	215	-0.55	No Overshoot	980
DOA - PSS	-0.1284	0.0.167	201	-0.6014	No Overshoot	852

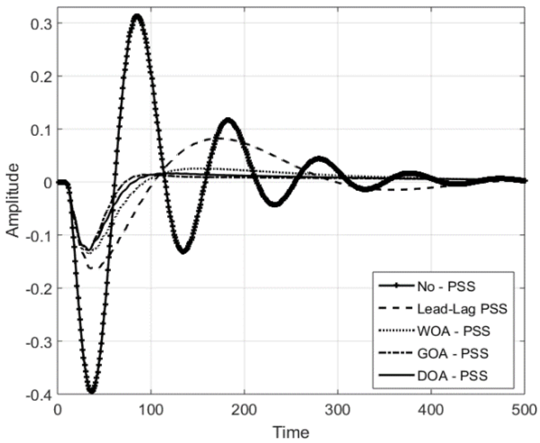

Figure 8. Speed in 100% load

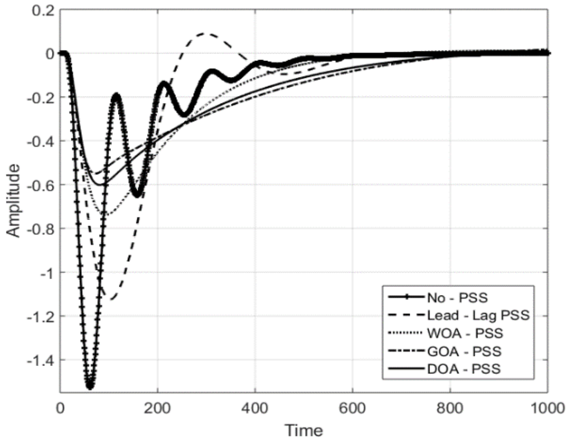

Figure 9. Rotor angle in 100% load

4. CONCLUSION

A power system stabilizer (PSS) is a control device that acts as feedback to reduce rotor oscillations induced by minor signal interruptions. One of the most recent metaheuristic algorithms inspired by dingo behavior is the dingo optimization algorithm (DOA). The goal of this research is to use the DOA approach to PSS in order to attenuate the oscillations that occur. The simulation employs three issues to assess the performance of the DOA approach. The simulation using the first test revealed that the DOA approach can minimize undershoot speed by 27.97% when compared to lead-lag PSS. Meanwhile, as compared to the PSS lead-lag approach, the undershoot rotor angle value can be lowered by 22.21%. In the second test, the DOA approach reduced undershoot speed by 28.54% as compared to lead-lag PSS. Meanwhile, as compared to the lead-lag PSS approach, the value of the undershoot rotor angle can be lowered by 87.4%. In the third test, the DOA approach reduced undershoot speed by 27.97% when compared to lead-lag PSS. Meanwhile, as compared to the lead-lag PSS approach, the value of the undershoot rotor angle can be lowered by 87.4%.

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