Volume 19, Issue 1, 192510 (1-10)

Majlesi Journal of Electrical Engineering (MJEE)

https://doi.org/10.57647/j.mjee.2025.1901.10

Improved sine-cosine algorithm-based power system stability under different fault conditions

Sritosh Kumar Sahoo[1], Manoj Kumar Kar [2,*], Sanjay Kumar[1], Rabindra Nath Mahanty[1]

[1] *Electrical Engineering Department, NIT Jamshedpur, India.*
[2] *Electrical Engineering Department, Tolani Maritime Institute Pune, India.*

*[*]***Corresponding author:** manojkar132@gmail.com

Original Research

Received:
27 August 2024
Revised:
3 January 2025
Accepted:
2 February 2025
Published online:
1 March 2025

Abstract:

This study examines power system stability through the application of the improved sine cosine algorithm (ISCA). To minimize the oscillation of the system, two damping controllers have been used, the first one is power system stabilizer (PSS) and second one is static synchronous series compensator (SSSC). A single machine infinite bus (SMIB) is implemented to analyze the stability performance. The various parameters of PSS and SSSC have been tuned with the use of the ISCA approach, which improves the system performance. The main aim of this work is to reduce the speed deviation of rotor. A comparative analysis has been carried out with traditional sine cosine algorithm (SCA) on performance basis. The fitness value (ITAE) of SCA and ISCA are found to be 0.0018573 and 0.0018518 respectively. The SMIB system is tested with different loading such as nominal loading (NL), light loading (LL), heavy loading (HL) condition. To check the robustness of the proposed system, various faults (LLLG fault, LLG fault, LL fault, LG fault) has been applied to the system and results are compared with ISCA optimized controller.

Keywords: Fault analysis; Improved sine cosine algorithm; Power system stabilizer; Static synchronous series compensator; Single machine infinite bus

1. Introduction

Power system stability plays a vital role in the modern power system network. Maintaining power system stability using FACTS devices is significant because it ensures the reliable operation of the grid, optimizes power transfer, supports the integration of renewable energy, and prevents large-scale blackouts. Providing for sustained electricity demand without taking system stability into account is quite difficult [1]. Rotor angle deviation gives low frequency oscillation which causes instability in power system and it causes a critical issues like blackout. So, there is a challenge for researcher to improve the stability by reducing system oscillation. The main function of the power system stabilizer is to provide additional control signal to the excitation system for minimization of both inertia and local area oscillation [2]. However, it can be achieved by tuning its control parameters. Phase compensation and integral square error techniques are used in PSS for stabilized output. PSS gives better performance in case of light loading and nominal loading condition but in case of heavy loading condition its performance is not up to the mark. The different parameters of PSS are tuned with BAT search optimization algorithm and results are analyzed with GA tuned PSS under different operating circumstances [3]. UPFC, an advanced FACTS device, was used to increase transient stability in a two-area power system network [4].

The FACTS device provides a significant advantage in the twentieth century by improving system stability, minimizing loss, raising voltage profile, and providing reactive power assistance [5]. FACTS devices also compensate the reactive power in modern power system network [6]. The performance of SSSC is validated for a multi-machine system [7]. H. F Wang implemented SSSC to SMIB and MMPS system for reducing the oscillation of the system successfully [8]. Paper [9] describes the management of parameters of damping controllers using modified GA method. The PSS and FACTS controllers were being designed and applied to a sixteen-machine system, and the residue and participation factor techniques were used to select the controller

placement [10]. The parameters of SSSC, which are introduced to both SMIB and MMPS, [11] were tuned using real-coded GA. While taking time delays into account, both local and remote signals are compared. The performance of the remote signal outperforms that of the local signal when the delay is included in [12] using DE and a time delay-based SSSC controller architecture. Newton Raphson load flow solution is used with TCSC to enhance the overall system voltage [13] in an IEEE 30 bus test system. Overall system cost was reduced with minimization of system loss. GA based method is used in [14] and detailed system analysis has been explained. Tabu search algorithm [15] is used for controlling the parameters in multi machine power system stabilizers. Subsynchronous resonance was considered while evaluating how an SSSC affected a SMIB under large loads, and the results demonstrated that the SSSC maintained operating point stability [16]. In order to reduce strong resonance in multi-machine systems, a multimodal decomposition-based tuning mechanism and an SSSC controller were explained [17]. To reduce oscillations and improve stability, the PSS and SSSC controllers were coordinated using the SOA technique. The better ability of the recommended approach is eventually acknowledged after acquiring the outcomes of the proposed multi-objective function and comparing them with those of other functions in this system [18]. Improved sine cosine algorithm is used to design both SSSC and PSS controllers to enhance the system stability [19]. In order to optimize the PSS parameters, a hybrid-modified GWO technique was applied to MMPS. The stability criteria are also met by the application of the eigenvalue analysis and damping factor [20]. A modified grey wolf optimization algorithm is used to optimize the parameters of PSS and SSSC [21]. To tackle the system nonlinearities and improve performance, a fractional order PID (FOPID) controller is also employed [22].
The primary objective of this research is to enhance the stability of power systems. In this study, the authors consider a SMIB system incorporated with series controller FACTS device known as SSSC. Advance optimization algorithm (ISCA) is proposed for optimizing the different control parameters of SSSC and PSS. Different loading and faults conditions are considered to validate the effectiveness of the proposed ISCA algorithm. The structure of this paper is explained as follows: • The structure of SMIB, PSS, and SSSC is explained in section 1. • Section 2 defines the problem statement. • Section 3 explain the methodology (ISCA) including its functional details. • Section 4 is concerned with the results and discussion, in which several case studies are displayed with appropriate explanation. • Finally, Section 5 concludes the work by presenting a summary of the research.

1.1 Structure of SMIB

The single machine infinite bus (SMIB) powers an infinite bus with the use of a transformer, a synchronous generator along with two transmission lines [21]. Fig. 1 depicts the SMIB system integrated with SSSC. VB represents the infinite bus voltage, and terminal voltage is denoted by VA. SSSC is connected between bus1 and bus2.

1.2 Structure of PSS

Power System Stabilizers (PSS) is mostly used in advanced power systems network to amplify overall system stability of the system efficiently. The main use of PSS is to adjust the generator's excitation system for providing additional damping to the system [19]. To minimize the oscillation the parameters of PSS must be optimally tuned. A two-stage phase compensation techniques are generally used to stabilize the signal. The PSS is structured as shown in Fig. 2.

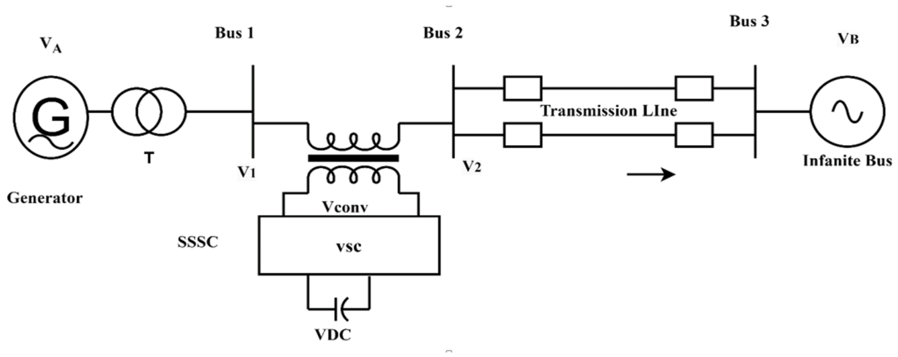

Figure 1. Structure of SMIB system.

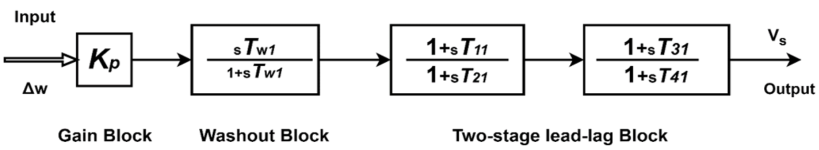

Figure 2. Structure of PSS.

1.3 Structure of SSSC

SSSC is a series flexible AC transmission (FACT) device that allows controlled power transmission [10], [11], [23]. It regulates the amount of reactive and active power flowing throughout the grid with the power lines. In compared to a phase shift controller, SSSC offers superior control with no reactive power consumptions. Reactive power is supplied by a DC capacitor provided with the system. SSSC regulates the voltage level and power flow of the transmission line. The energy storage in SSSC is provided by the direct voltage injection mode.

2. Problem formulation

The main focus of this work is to reduce the speed deviation of the SMIB system under different fault conditions with various loading using damping controllers. Integral time absolute error (ITAE) is considered as the main objective function of the work, which is presented by:

$$ITAE = \int_0^{t_s} |\Delta\omega| t dt \tag{1}$$

where, t_s denotes time required for simulation, and $\Delta\omega$ represent deviation in rotor speed.

The different constraints are defined as below:

$$\text{Minimize ITAE } (\mathrm{K_P}, \mathrm{T_1}1, \mathrm{T_2}1, textrmT_31, \mathrm{T_4}1, \mathrm{K_S}, \mathrm{T_1}, \mathrm{T_2}, \mathrm{T_3}, \mathrm{T_4}) \tag{2}$$

with subjected to

$$\mathrm{K_P^{min}} \le \mathrm{K_P} \le \mathrm{K_P^{max}} \tag{3}$$
$$\mathrm{K_S^{min}} \le \mathrm{K_S} \le \mathrm{K_S^{max}}$$
$$\mathrm{T_{xP}^{min}} \le \mathrm{T_{xP}} \le \mathrm{T_{xP}^{max}}; \quad x = 1,2,3,4$$
$$\mathrm{T_{yP}^{min}} \le \mathrm{T_{yP}} \le \mathrm{T_{yP}^{max}}; \quad y = 1,2,3,4$$

where, K_P^{min} and K_P^{max} are the lower limits and upper limits for PSS gain respectively. Similarly, K_S^{min} and K_S^{max} for SSSC gain, T_xP^{min} and T_xP^{max} for PSS's Time Constant, and T_yS^{min} and T_yS^{max} for SSSC's time constant.

3. Proposed methodology

The sine and cosine algorithm (SCA) serve as the basic novel population-based meta-heuristic approach that has been introduced to optimize the parameters of the proposed controller [18]. The SCA has a slow convergence rate, is trapped in local optima, and does not trade in exploration and exploitation. The ISCA overcame the constraints mentioned above. Additionally, it contains fewer algorithmic

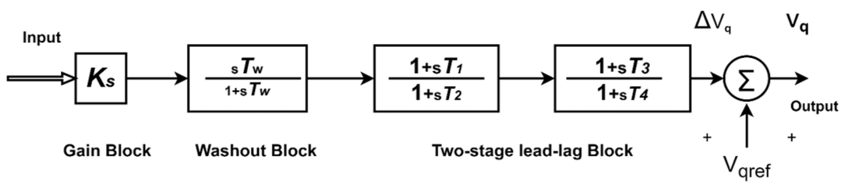

Figure 3. Structure of SSSC.

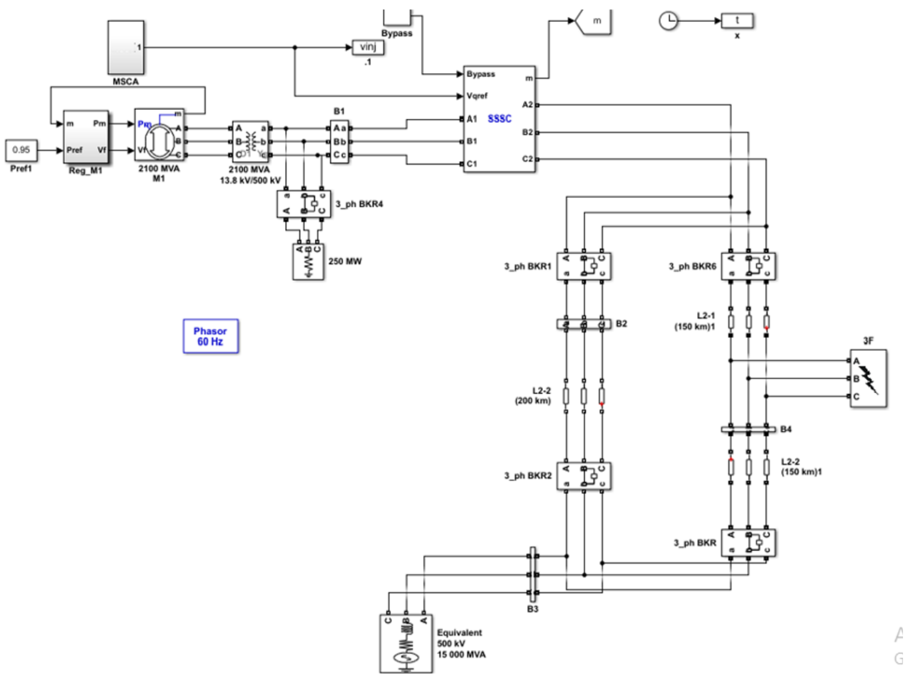

Figure 4. SMIB Simulink model with SSSC.

parameters, which helps to improve robustness. The algorithm begins with n search agents, or candidates for solutions, given by each search agent. Every member of the tth iteration's search agent is a d-dimensional vector, representing a variable that is an independent component of the problem. Using the equation, the solutions move outwards, or towards the optimal solution, until the termination requirements are met. Once the termination requirements are met, the optimization problem is resolved utilising the best required solution from the previous iterations as expressed in Eq. 4.

$$X_i^{t+1} = \begin{cases} X_i^t + r_1 \times \sin(r_2) \times |r_3 \times P_i^t - X_i^t|; & if; \quad r_4 < 0.5, \\ X_i^t + r_1 \times \cos(r_2) \times |r_3 \times P_i^t - X_i^t|; & if; \quad r_4 \geq 0.5 \end{cases} \tag{4}$$

where X_i^t, P_i^t represents the i-th location of the present solution and the final position in the present iteration. X_i^{t+1} is the i- th solution in next iteration and r_1, r_2, r_3 and r_4 are the random values of the proposed method. We can get the three parameters r_1, r_2 and r_3 by using Eq. 5, Eq. 6 and Eq. 7, respectively.

$$r_1 = a \times (1 - \frac{t}{T_{max}}) \tag{5}$$

$$r_2 = 2 \times pi \times rand(0,1) \tag{6}$$

$$r_3 = 2 \times rand(0,1) \tag{7}$$

where t is the number of iterations so far, and T_{max} denotes the maximum iteration, and rand (0,1) aids in locating a random number that is produced from an evenly dispersed range between 0 and 1. The proposed method is shown in the flowchart in Fig. 5.

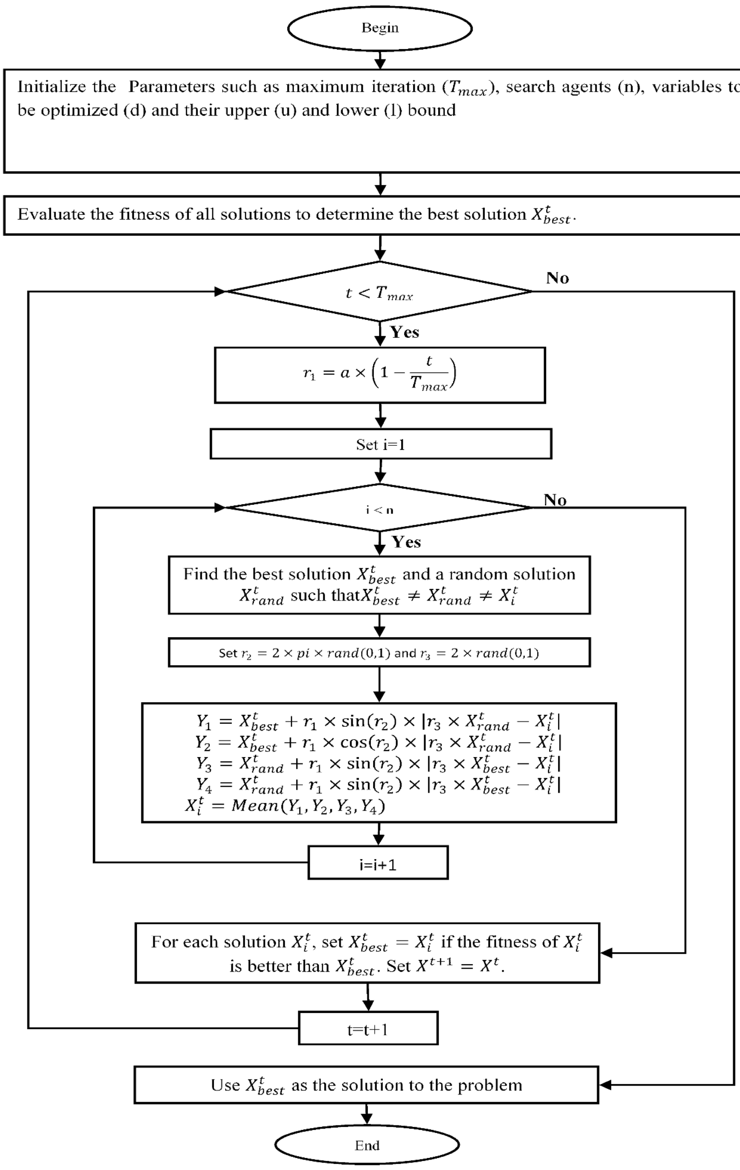

Figure 5. Flowchart for ISCA.

4. Result and discussion

After design of SMIB system, the simulation has been carried out using sim power system tool kit. The proposed SMIB system contains a 3-phase synchronous generator with rating 13.8/500 kv,2100MVA,60 HZ, step-up transformer incorporated with 300 km parallel transmission line in which SSSC has been integrated. A 3 phase five cycles fault has been implemented on the middle position of the transmission line. The system performance is tested with 3 different loading cases. First, the system is operated without controller where the oscillation is maximum. In the next step different controllers such as PSS, SSSC, PSS & SSSC, SCA tuned PSS & SSSC, ISCA tuned PSS & SSSC have been applied respectively to the system. It is observed that the system oscillation is gradually reducing step by step with the proposed controller. To observe the robustness of the system with the ISCA technique, different types of faults have been tested with system. The disturbance of the suggested system is minimized depending on the severity of the fault (LLLG, LLG, LL, LG). The stability of the system with different loading/fault conditions has been discussed step by step in the following sections.

4.1 Nominal loading condition

Under nominal loading conditions, (Pe=0.8pu) is used to validate the various controllers. The system is first run without a controller, where the oscillation is highest; thereafter, a power system stabilizer (PSS) is introduced, which reduces the oscillation significantly. The combination of PSS & SSSC improves the system stability as compared to the system consisting only PSS or only SSSC. ISCA tuned PSS & SSSC controller significantly enhances the system stability. Fig 6(i), 6(ii), 6(iii), 6(iv) shows the various response which includes the speed deviation,power angle, tie line power, injected voltage by SSSC respectively.

4.2 Light loading condition

The system's performance has been evaluated under light loading conditions (Pe=0.5 pu). The system stability criteria is tested under various scenarios. From the Fig 7, it is clearly observed that the stability of the SMIB system is enhanced and ISCA tuned controllers gives optimum stability performance as compared to the other cases. Fig 7(i), 7(ii), 7(iii), 7(iv) shows stability criteria for speed deviation, power angle, tie line power, SSSC injected voltage

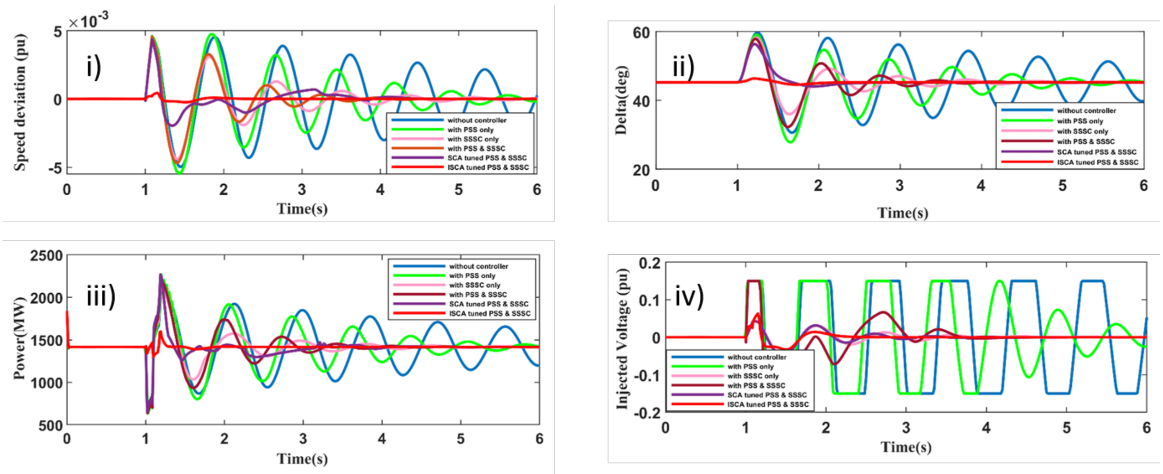

Figure 6. (i) Speed Deviation, (ii) Power Angle, (iii) Nominal Power, (iv) Injected Voltage for Nominal loading.

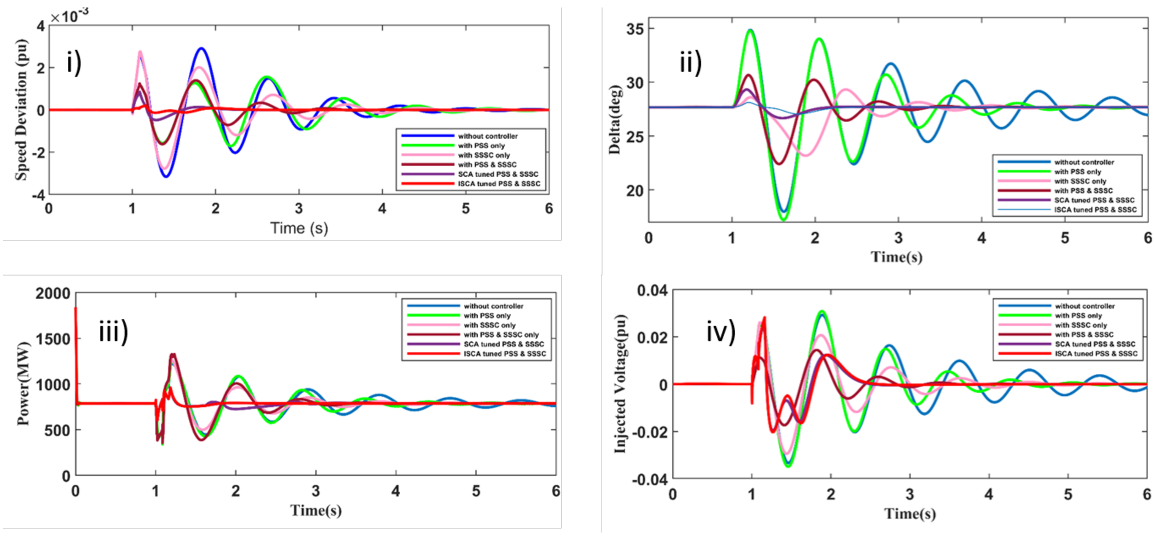

Figure 7. (i) Speed Deviation, (ii) Power Angle, (iii) Nominal Power, (iv) Injected Voltage for Light loading.

respectvely.

4.3 Heavy loading condition

In this case the system stability is validated by using Pe=0.95. The oscillation of the system is studied when the fault is utilized at the middle position of the power transmission line. The stability performance of different controllers like PSS, SSSC, PSS & SSSC has been examined. The ISCA optimized PSS & SSSC combination gives optimum result. Various stability responses which include power angle, speed deviation, injected voltage, tie line power are displayed in Fig. 8(i) to 8(iv) respectively.

4.4 Fault analysis

A three-phase fault is introduced in the center of the power transmission line, resulting in the occurrence of various faults such as LLLG fault, LLG fault, LL fault, and LG fault, as well as varied stability characteristics. ISCA optimization technique is used and optimal parameters are obtained from the objective function. Because ISCA optimization provides optimal stability performance, the stability criteria of each fault are compared to the ISCA tuned controller.

4.5 Fault analysis with nominal Loading condition

With this circumstance (Pe=0.8), we consider a three-phase, five-cycle fault. Different faults such as LLLG fault, LLG fault, LL fault and LG fault are applied during nominal loading condition. The machine's speed deviation response has been thoroughly examined in relation to different fault conditions. The system's stability improves steadily as it progresses from LLLG to LG fault. The proposed ISCA technique is used to stabilize the system from its previous state.
The different stability condition under nominal loading condition is shown in figures 9(i), 9(ii), 9(iii), 9(iv) representing speed deviation, power angle, tie line power, SSSC injected voltage respectively.

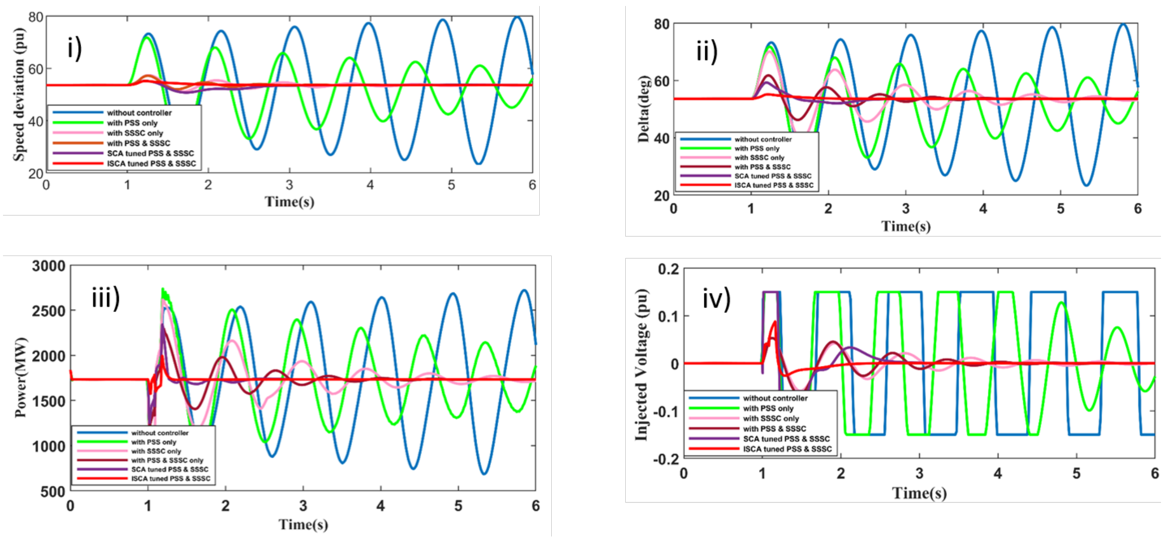

Figure 8. (i) Speed Deviation, (ii) Power Angle, (iii) Nominal Power, (iv) Injected Voltage for Heavy loading.

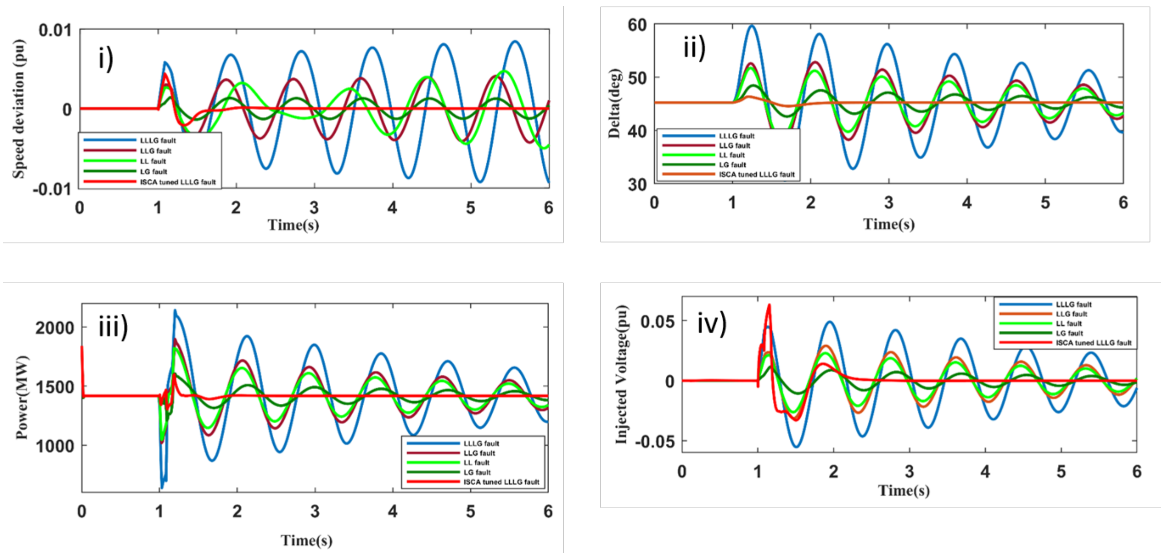

Figure 9. (i) Speed Deviation, (ii) Power Angle, (iii) Nominal Power, (iv) Injected Voltage for fault analysis with Nominal Loading.

4.6 Fault analysis with light loading condition

In this instance, the robustness of the controller is validated by Pe = 0.5 pu under light loading condition. A three-phase, 5-cycle fault has been inflicted at t =1 second. The machine's power angle, speed deviation, tie line power, and injected voltage are thoroughly examined under different fault scenarios. The proposed system's overall stability has been improved with ISCA-tuned PSS and SSSC. Fig. 10(i) - 10(iv) represent the various parameters under light loading condition. Three phase faults are used for comparison purpose.

4.7 Fault analysis with heavy loading condition

Better results are obtained when the ISCA technique is applied when heavy loading (Pe=0.95 pu) is considered. The various stability results under heavy loading conditions are displayed where 11(i) correspond to speed deviation, 11(ii)for power angle 11(iii) tie line power, and 11(iv) for injected voltage. The results by the optimally tuned controller are compared with various fault conditions starting from critical fault to less critical fault. It is clearly seen from the following figures that the system stability is significantly enhanced when the ISCA optimized controller is used.

The algorithms are independently run 20 times with 20 search agents and 50 iterations. The mean and standard deviation of the fitness values are given in the Table 1. The optimized parameters of the controllers for SMIB system have been given in Table 2.

The algorithm with better converge characteristics gives optimum result than others. In Fig. 12, the convergence characteristics of both ISCA and SCA are shown. From the

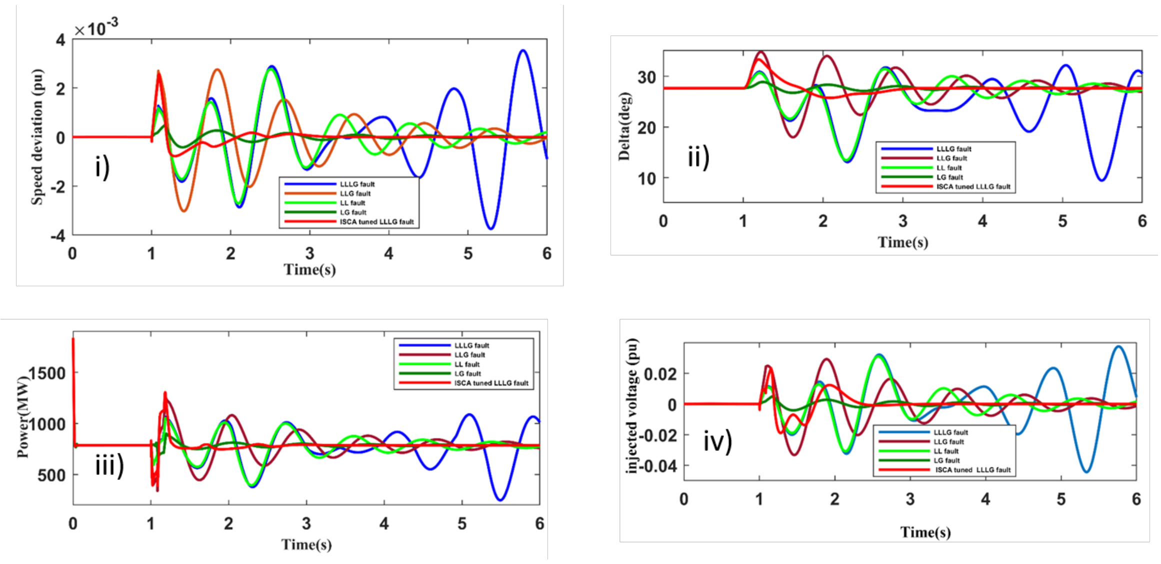

Figure 10. (i) Speed Deviation, (ii) Power Angle, (iii) Nominal Power, (iv) Injected Voltage for fault analysis with Light Loading.

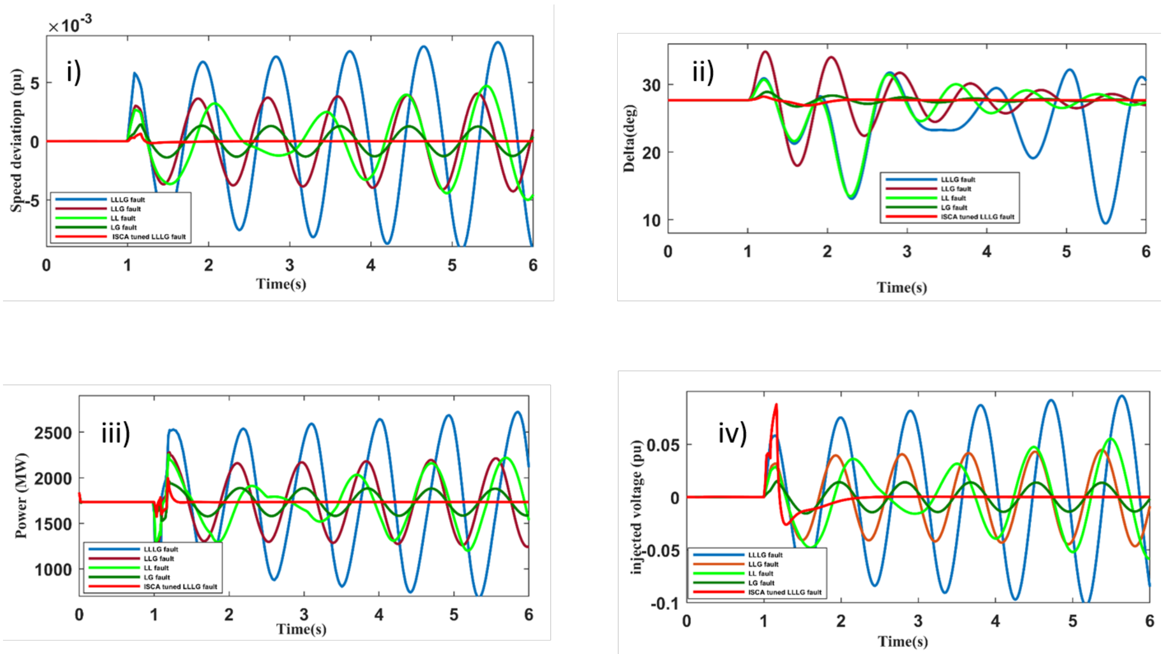

Figure 11. (i) Speed Deviation, (ii) Power Angle, (iii) Nominal Power, (iv) Injected Voltage for fault analysis with Heavy Loading.

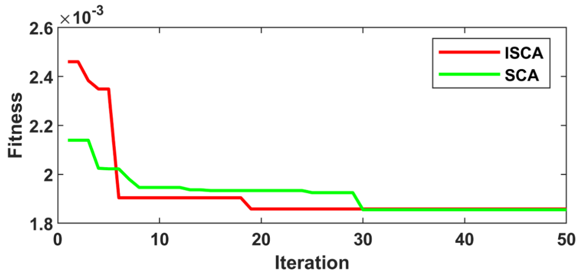

Figure 12. Convergence characteristics curve for ISCA and SCA.

Table 1. Fitness values comparison for proposed technique.

	Mean± std. Dev SCA	**Mean± std. Dev ISCA**
Fitness value	0.001857327±3.57131E-05	0.0018518±5.49E-05

Table 2. Optimized parameters of different controllers.

Controller	**parameters**	**Methods**	
		SCA	**MSCA**
PSS	$\mathbf{K_P}$	0.34414	33.806
	$\mathbf{T_{11}}$	1.4208	0.18768
	$\mathbf{T_{21}}$	0.013074	0.01
	$\mathbf{T_{31}}$	0.089861	0.44788
	$\mathbf{T_{41}}$	0.2205	0.63951
SSSC	$\mathbf{K_S}$	100	100
	$\mathbf{T_1}$	0.028908	0.012837
	$\mathbf{T_2}$	0.046214	0.016075
	$\mathbf{T_3}$	0.0289	2
	$\mathbf{T_4}$	0.014489	0.965

graph, it is clearly concluded that ISCA converges faster than SCA.

5. Conclusion

In this work, ISCA based damping controllers are used for improving overall stability of the system under various conditions. The proposed algorithm (ISCA) is implemented to analyze the speed deviation, power angle, tie-line power, and injected voltage responses under various loading conditions (such as nominal, light, and heavy). The responses are compared with different combinations of damping controllers. It is found that, the ISCA tuned PSS and SSSC controller stabilize the system more efficiently as compared to other controllers. Additionally, these responses are also studied under different types of faults (such as LLLG, LLG, LL, and LG). The different types of faults are compared with the ISCA tuned LLLG fault. It is observed that the proposed method reduces oscillation faster as compared to other cases. Finally, the superiority of the proposed ISCA over SCA is justified from the convergence curve. These advantages make ISCA a powerful method for optimizing complex systems and processes, particularly in fields like power systems, engineering design, and resource management. While the ISCA offers several advantages, it also has limitations related to computational cost, parameter sensitivity, scalability, and applicability to discrete problems. Addressing these limitations through future work such as adaptive mechanisms, hybridization, machine learning integration, multi-objective extensions, parallelization, and theoretical analysis can significantly enhance the capabilities and applicability of ISCA, making it a more robust and versatile optimization tool.

Authors contributions
All authors have contributed equally to prepare the paper.

Availability of data and materials
The data that support the findings of this study are available from the corresponding author upon reasonable request.

Conflict of interests
The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

[1] P. Kundur. "**Power system stability and control**.". *Mc-Grall Hill, New York*, 1994.

[2] K. Bhattacharya, J. Nanda, and M. L. Kothari. "**Optimization and performance analysis of conventional power system stabilizers**.". *Nanogenerators and Self-Powered Systems, IntechOpen*, 1997. DOI: https://doi.org/10.1016/S0142-0615(97)00015-X.

[3] E. S. Ali. "**Optimization of power system stabilizers using BAT search algorithm**.". *International Journal of Electrical Power and*

Energy Systems, 61:683–690, 2014.
DOI: https://doi.org/10.1016/j.ijepes.2014.04.007.

[4] D. Murali, M. Rajaram, and N. Reka. "**Comparison of FACTS devices for power system stability enhancement**.". *Int J Comput Appl*, 8(4):30–35, 2010.
DOI: https://doi.org/10.5120/1198-1701.

[5] M. K. Kar, S. Kumar, A. K. Singh, and S. Panigrahi. "**Reactive power management by using a modified differential evolution algorithm**.". *Optimal Control Applications and Methods*, 44(2): 967–986, 2023.
DOI: https://doi.org/10.1002/oca.2815.

[6] N. G. Hingorani, Laszlo. Gyugyi, and M. E. El-Hawary. "**Understanding FACTS: concepts and technology of flexible AC transmission systems.**.". *IEEE Press*, 2000.

[7] M. K. Kar. "**Stability analysis of multi-machine system using FACTS devices**.". *International Journal of System Assurance Engineering and Management*, 14(6):2136–2145.
DOI: https://doi.org/10.1007/s13198-023-02044-6.

[8] H. F. Wang. "**Static synchronous series compensator to damp power system oscillations**.". *Electric Power Systems Research*, 54 (2):113–119, 2000.

[9] A. L. B. Do Bomfim, G. N. Taranto, and D. M. Falcao. "**Simultaneous tuning of power system damping controllers using genetic algorithms**.". *in IEEE Transactions on Power Systems*, 15 (1):163–169, 2000.
DOI: https://doi.org/10.1109/59.852116.

[10] L. J. Cai and I. Erlich. "**Simultaneous coordinated tuning of PSS and FACTS damping controllers in large power systems**.". *IEEE Transactions on Power Systems*, 20(1):294–300, 2005.
DOI: https://doi.org/10.1109/TPWRS.2004.841177.

[11] S. Panda, S. C. Swain, P. K. Rautray, R. K. Malik, and G. Panda. "**Design and analysis of SSSC-based supplementary damping controller**.". *Simul Model Pract Theory*, 18(9):1199–1213, 2010.
DOI: https://doi.org/10.1016/j.simpat.2010.04.007.

[12] S. Panda. "**Differential evolution algorithm for SSSC-based damping controller design considering time delay**.". *J Franklin Inst*, 348(8):1903–1926, 2011.
DOI: https://doi.org/10.1016/j.jfranklin.2011.05.011.

[13] S. K. Sahoo, M. K. Kar, S. Kumar, and R. N. Mahanty. "**Genetic algorithm based optimal placement of TCSC for improving voltage profile**.". *in Proceedings - 11th International Conference on Signal Processing and Integrated Networks, Institute of Electrical and Electronics Engineers Inc.*, page 403–408, 2024.
DOI: https://doi.org/10.1109/SPIN60856.2024.10511762.

[14] S. Panda. "**Multi-objective evolutionary algorithm for SSSC-based controller design**.". *Electric Power Systems Research*, 79(6): 937–944, 2009.
DOI: https://doi.org/10.1016/j.epsr.2008.12.004.

[15] M. A. Abido and Y. L. Abdel-Magid. "**Robust design of multi-machine power system stabilisers using tabu search algorithm**.". *IEE Proceedings-Generation, Transmission and Distribution*, 147 (6):387–394, 2000.

[16] M. S. Widyan. "**Controlling chaos and bifurcations of SMIB power system experiencing SSR phenomenon using SSSC**.". *International Journal of Electrical Power and Energy Systems*, 49(1): 66–75, 2013.
DOI: https://doi.org/10.1016/j.ijepes.2012.12.002.

[17] T. R. Jyothsna and K. Vaisakh. "**Effects of strong resonance in multimachine power systems with SSSC supplementary modulation controller**.". *International Transactions on Electrical Energy Systems*, 23(1):24–47, 2013.
DOI: https://doi.org/10.1002/etep.637.

[18] E. Gholipour and S. M. Nosratabadi. "**A new coordination strategy of SSSC and PSS controllers in power system using SOA algorithm based on Pareto method**.". *International Journal of Electrical Power and Energy Systems*, 67:462–471, 2015.
DOI: https://doi.org/10.1016/j.ijepes.2014.12.020.

[19] M. K. Kar, S. Kumar, A. K. Singh, and S. Panigrahi. "**A modified sine cosine algorithm with ensemble search agent updating schemes for small signal stability analysis**.". *International Transactions on Electrical Energy Systems*, 31(11), 2021.
DOI: https://doi.org/10.1002/2050-7038.13058.

[20] R. Devarapalli, B. Bhattacharyya, N. K. Sinha, and B. Dey. "**Amended GWO approach based multi-machine power system stability enhancement**.". *ISA Trans*, 109:152–174, 2021.
DOI: https://doi.org/10.1016/j.isatra.2020.09.016.

[21] M. K. Kar, S. Kumar, A. K. Singh, S. Panigrahi, and M. Cherukuri. "**Design and analysis of FOPID-based damping controllers using a modified grey wolf optimization algorithm**.". *International Transactions on Electrical Energy Systems*, 2022, 2022.
DOI: https://doi.org/10.1155/2022/5339630.

[22] M. K. Kar, A. K. Singh, S. Kumar, and B. Rout. "**Application of fractional-order PID controller to improve stability of a single-machine infinite-bus system**.". *Journal of The Institution of Engineers (India): Series B*, 105(1):77–92.
DOI: https://doi.org/10.1007/s40031-023-00950-8.

[23] S.K. Sahoo, M.K. Kar, S. Kumar, and R.N. Mohanty. "**Fault Analysis of Power System Under Varying Load Conditions**.". *Recent Advances in Power Systems. EPREC 2024. Lecture Notes in Electrical Engineering, Springer, Singapore*, 1271.
DOI: https://doi.org/10.1007/978-981-97-7921-5_23.