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Stabilizing multimachine power systems with fuzzy logic using artificial bee colonies

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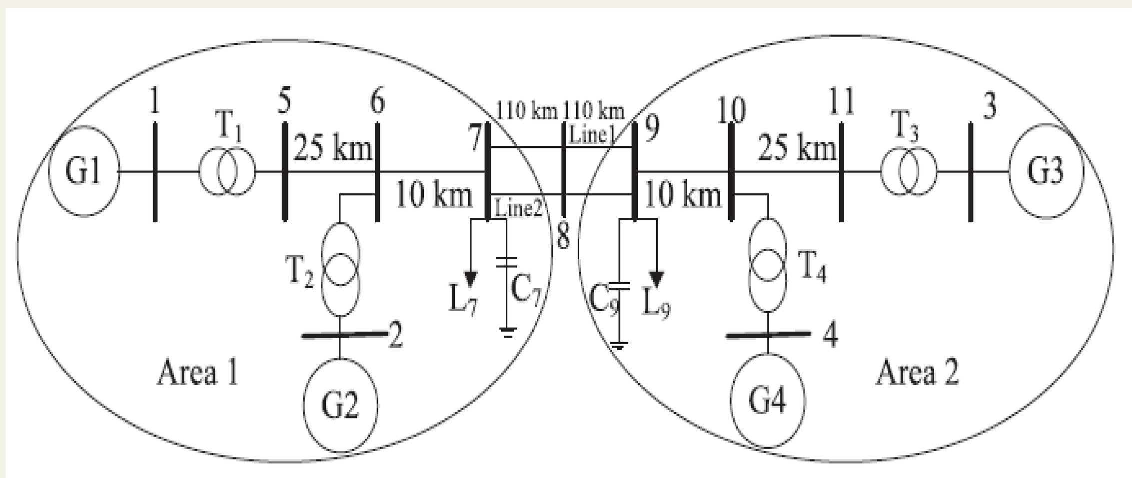
Abstract

Over the past few years, fuzzy logic systems have gained popularity due to their superiority over classical controllers when it comes to enhancing the transient stability of power systems. In this paper, a Fuzzy Logic Power System Stabilizer (FLPSS) is designed to damp local and inter-area oscillations following disturbances through the use of an Artificial Bee Colony Optimization Algorithm (ABC). The designed FLPSS is expected to significantly increase the robustness of power systems and ultimately improve the quality of power supply to end-users. This test system consists of two areas with four machines and eleven buses, with the purpose of evaluating the performance of the ABC-FLPSS under a variety of disturbances and loads. In order to optimize the scaling factors of FLPSSs, the Integral Squared Error (ISE) of rotor speed deviation is formulated as an objective function. Evaluation of the proposed controller involves simulating the test system under different conditions. These conditions range from small perturbations, such as changes in one of the system parameters, to large changes, such as removing a main transmission line, to determine its effectiveness. A comparison of ABC-FLPSS with FLPSS and Conventional Power System Stabilizer (CPSS) shows that the ABC-FLPSS controller is superior to FLPSS and CPSS.

Objectives

- Design Logic Power System Stabilizer (FLPSS) to significantly increase power systems' robustness and ultimately improve the quality of power supply to end-users.
- Design a FLPSS to damp local and inter-area oscillations following disturbances through the use of an Artificial Bee Colony Optimization Algorithm (ABC).
- Suggest two areas with four machines and eleven buses to evaluate the ABC-FLPSS performance under a variety of disturbances and loads.
- Optimize the scaling factors of FLPSSs using the Integral Squared Error (ISE) of rotor speed deviation as an objective function.
- Evaluate the proposed controller involves simulating the test system under different conditions.

Proposed System

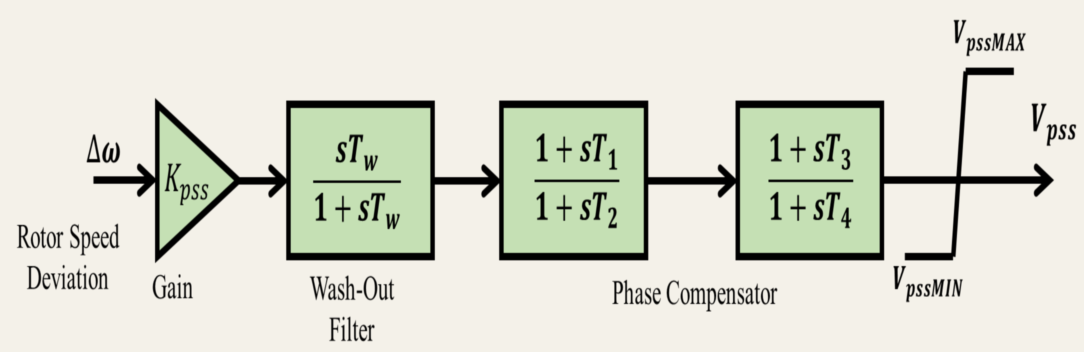


Two-area, four-machine, eleven-bus test power system

System Methodology

1. Conventional Power System Stabilizer Structure

$$V_{pss}(s) = K_{pss} \times \frac{sT_w}{1+sT_w} \times \frac{1+sT_1}{1+sT_2} \times \frac{1+sT_3}{1+sT_4}$$



2. Fuzzy Logic based Power System Stabilizer

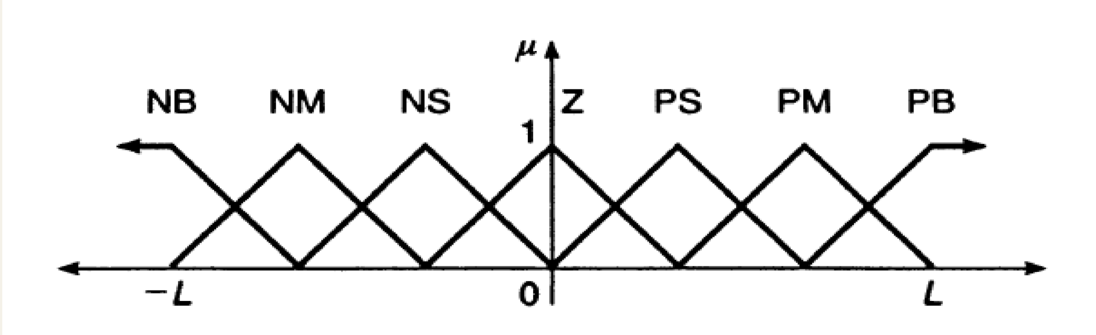
The control action of the fuzzy logic control is performing in three main steps:

A. Fuzzification,

Two steps are involved in the fuzzing process.

- The first step is to measure and scale the input variables (speed, power and acceleration).
- The second step is to transform the measured crisp values into the corresponding fuzzy variables (linguistic variables) using membership functions.

System Methodology



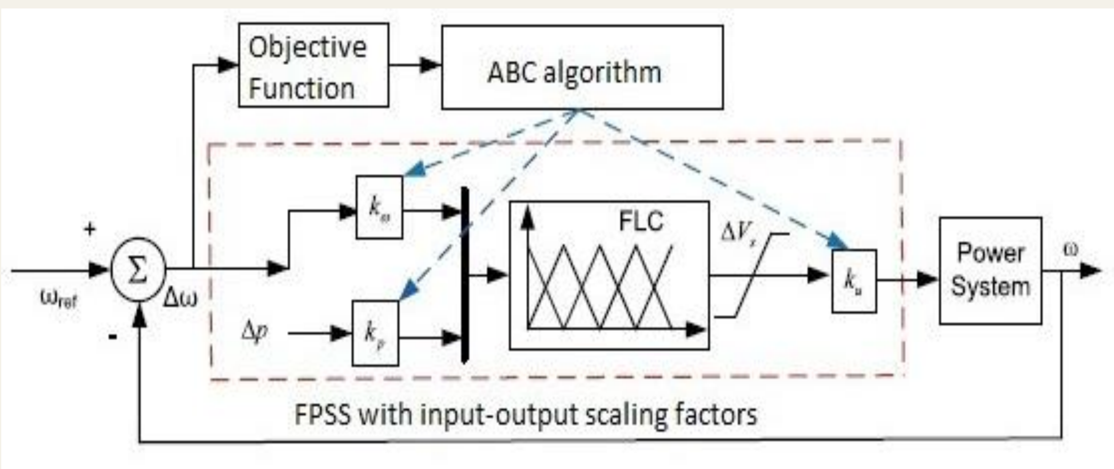
Triangular Membership Function

B. Fuzzy Inference Rules

Δω / Δp	NB	NM	NS	Z	PS	PM	PB
NB	NB	NB	NB	NB	NM	NS	Z
NM	NB	NB	NM	NM	NS	Z	PS
NS	NB	NM	NM	NS	Z	PS	PM
Z	NM	NM	NS	Z	PS	PM	PM
PS	NM	NS	Z	PS	PM	PM	PB
PM	NS	Z	PS	PM	PM	PB	PB
PB	Z	PS	PM	PB	PB	PB	PB

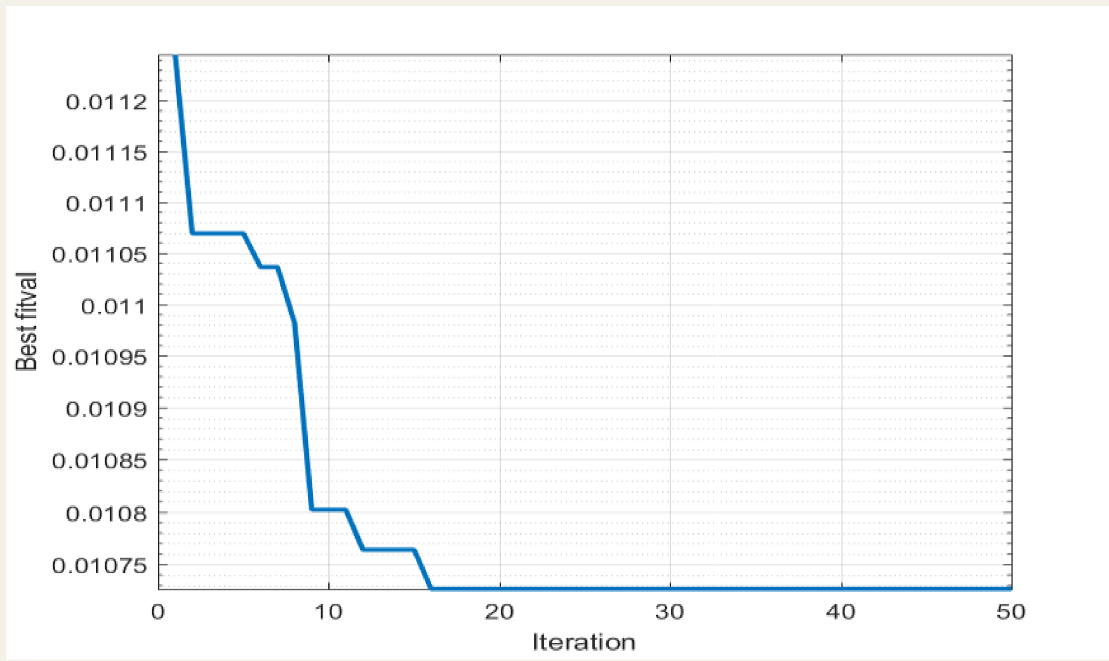
C. Defuzzification: it is necessary to get the actual values back again from their fuzzy. In the proposed controller, the centroid defuzzification method is used for this purpose.

3. Artificial Bee Colony Optimization Algorithm



ABC algorithm for tuning FLPSS input-output scaling factors

Simulation Results and Discussion



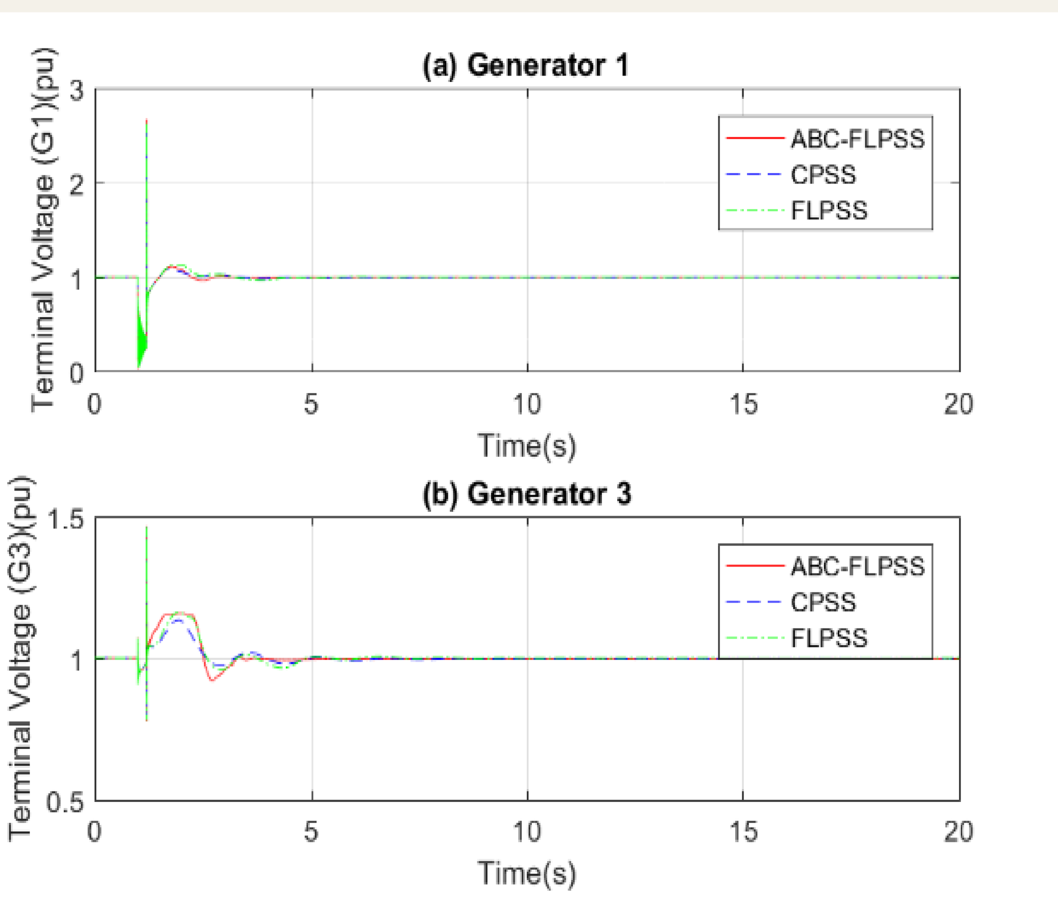
Objective Function Convergence of ABC Optimization Algorithm

The simulation is done under various disturbance imposed to the system including:

- Three-phase symmetrical fault at the terminal of generator 1.
- Three-phase symmetrical fault at the middle of transmission Line1.

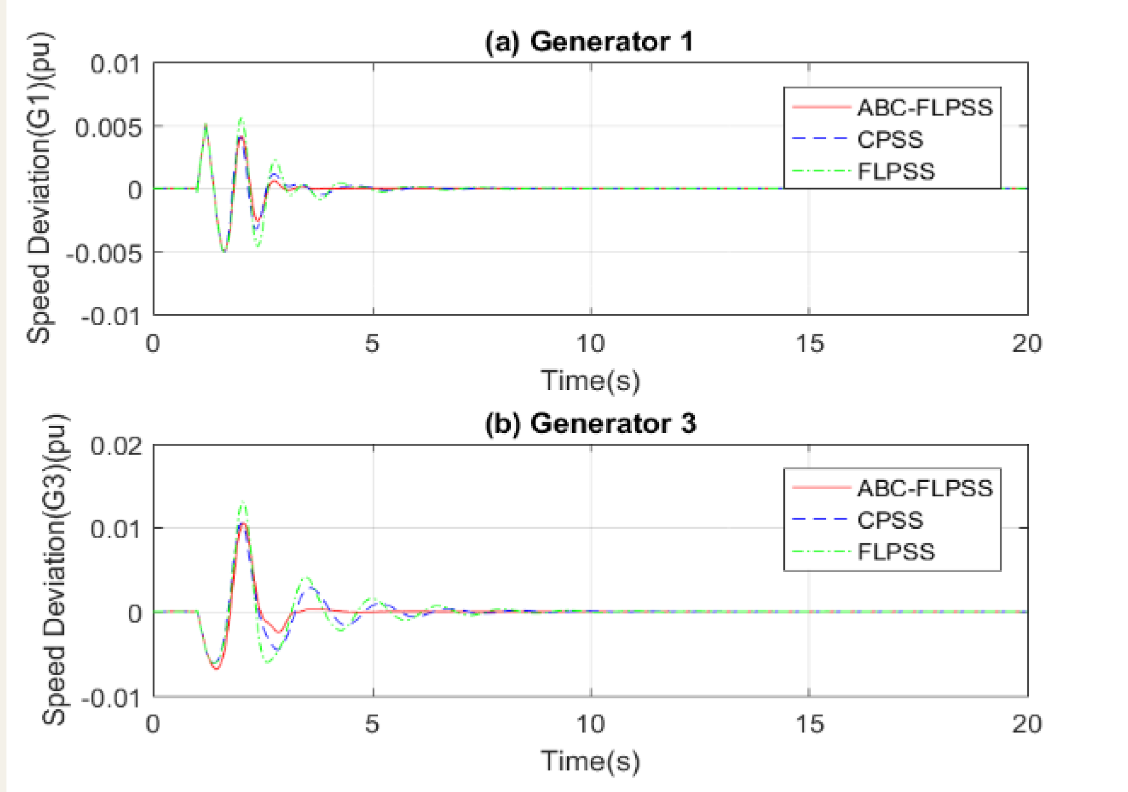
Generator Parameter	G1	G2	G3	G4
$K_{\omega i}$	1	1.0170	1.0495	2.4589
K_{pi}	1.6657	1.3569	3	1.3075
K_{ui}	1.1488	1.0150	1.7374	1.4932

1. Three-phase fault at the terminal of generator



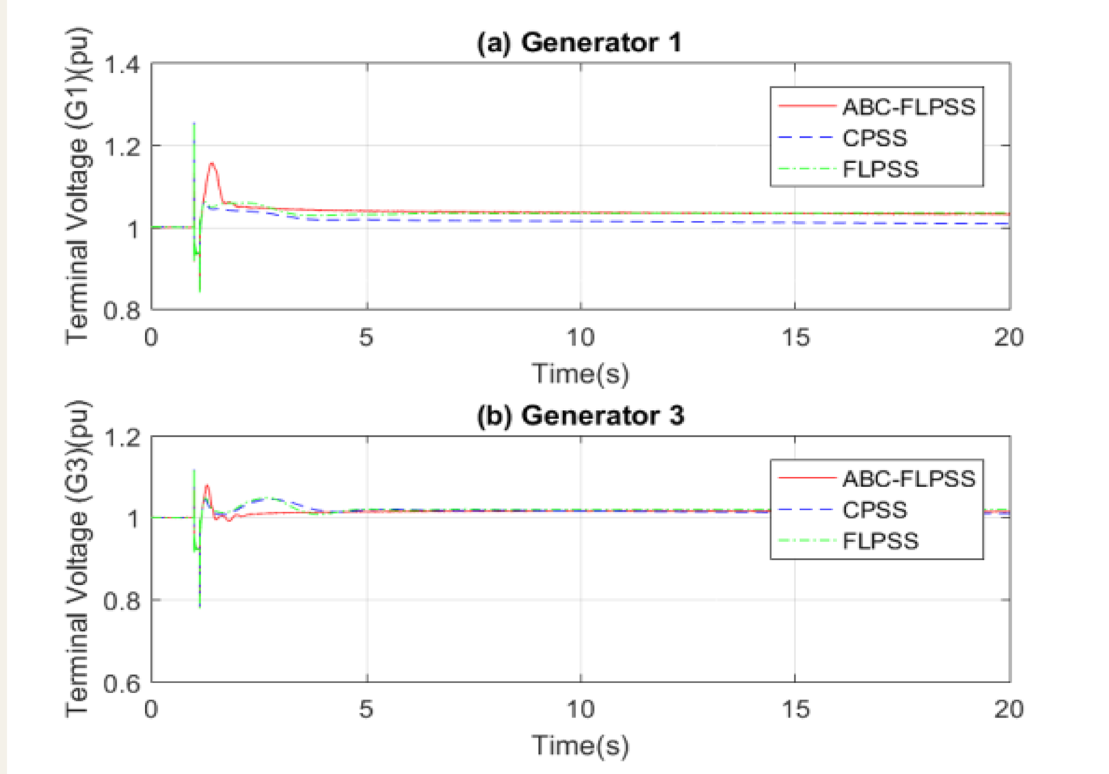
Generator #1 terminal voltages with a three-phase fault

Simulation Results and Discussion

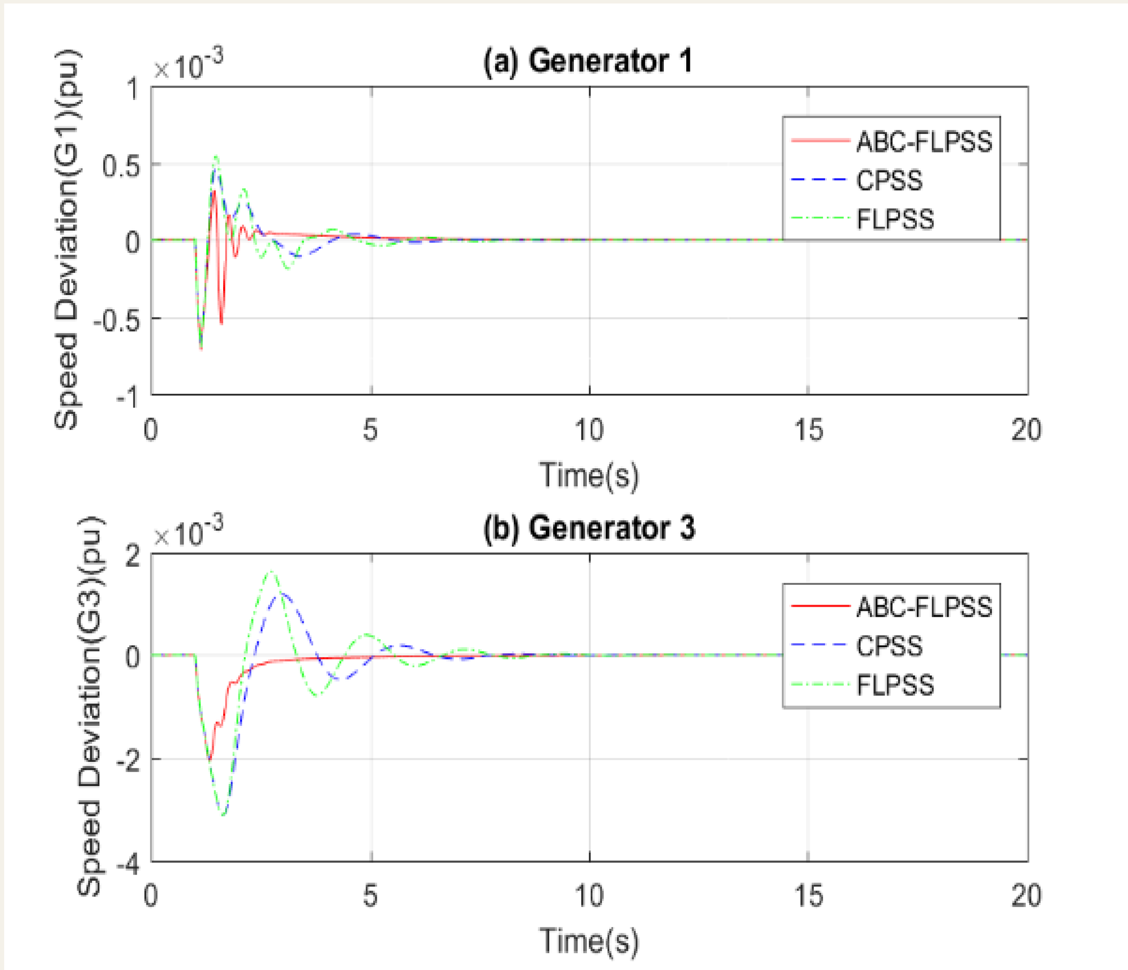


Generator #1 speed deviations with three-phase faults.

2. Three Phase Fault at the middle of Transmission Line 1



Transmission line #1 terminal voltages with a three-phase fault



Transmission Line #1 speed deviations with a three-phase fault

Conclusion

- In contrast to classical controllers that require precise mathematical modeling and measurements, fuzzy logic controllers can handle uncertainty in nonlinear dynamic systems. A fuzzy logic PSS with fuzzy logic input-output scaling factors was used in this paper for the purpose of enhancing the transient stability of multimachine power systems using the Artificial Bee Colony optimization technique. We compare the developed controller with conventional power system stabilizers through nonlinear time-domain simulations of generator rotor angles and speeds. According to simulation results, multi-machine power systems are more stable and robust when they are subjected to external disturbances when using ABC-FLPSS as opposed than CPSS. As a result of ABC-FLPSS, inter-area oscillations are dampened more effectively under small and large disturbances, despite changing operating conditions.

Acknowledgements

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