ADVANCES in NATURAL and APPLIED SCIENCES

ISSN: 1995-0772
EISSN: 1998-1090
2016November10(16):pages 55-65

Published BY**AENSI Publication**
http://www.aensiweb.com/ANAS
**Open Access Journal**

# Design Of H∞ Robust Power System Stabilizer Using Fuzzy And Ann Controllers Based On Eabc Optimal Power System

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Received 23 August 2016; Accepted 1 November 2016; Published 20 November 2016

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## ABSTRACT

Development and usage of new energy sources is a necessary means to minimize the emission of greenhouse gases and environmental pollution including research on solar energy in the realization of Power systems is urgent need. To address this issue and to improve the dynamic stability of power system, the new power system stabilizer using solar energy is proposed. **Background:** The basic concept of affixing a Power System Stabilizer (PSS) is to improve damping to increase the power transfer limits. The nature of a PSS controls its potency to small about a steady state operating point. The small excursions of an operating point are generally the electrical system result which is lightly damped which cause spontaneous improving oscillations, called as system modes of oscillation.
**Objective:** The objective is to design the Solar power system stabilizer for suppressing the low-frequency and tie-line power oscillations. In this paper, a fuzzy controller and Artificial Neural Network (ANN) based solar power system stabilizer is designed using Enhanced Artificial Bee Colony algorithm to improve the dynamic stability in power system. **Results:** The results of the proposed simulation of Fuzzy and ANN controllers are compared with the Conventional, ABC and Enhanced ABC algorithms. **Conclusion:** The results shows that the proposed EABC based RPSS using ANN controller outperforms the existing methods.

**KEYWORDS:** Fuzzy Logic Artificial Neural Network Power System Stabilizer Enhanced Artificial Neural Network Solar Energy

## INTRODUCTION

Power system is dynamic and modern which are highly integrated, large scale interconnections that operate in an uncertain environment where generator output, loads, and operating parameters changes frequently so that Voltage control is tough task. Maintaining voltage within specific limits help to decrease energy losses and enhances voltage regulations in the power system [14]. Dynamic stability is a basic property of power systems which defines its ability to remain in a equilibrium state under normal operating conditions and to regain an tolerable state of equilibrium under an external disturbance. It is usually observed that stability of the power system margins generally reduce, mainly due to [12].

Low-frequency oscillations in a power system is the important cause of many undesirable effects such as initiating and propagating pressure in the mechanical shaft, constraining the power transfer on the transmission lines, endangering the system's security, and minimize the whole operating efficiency of a power system[25,26]. These oscillations may grow to cause system partition if no adequate damping is available [27, 28].

**ToCite ThisArticle:** R. Sakthivel and Dr. M. Arun., Design Of H∞ Robust Power System Stabilizer Using Fuzzy And Ann Controllers Based On Eabc Optimal Power System. **Advances in Natural and Applied Sciences**. 10(16);Pages: 55-65

Beyond a specific level, the reduction in power system stability margins can lead to intolerable operating conditions and/or to continual power system instability. A solution to avoid this phenomenon is to control power systems more efficiently and it will improve power system stability margins. Normally, Synchronous generators are used with power system stabilizers (PSS) to provide additional feedback signals for stabilizing through the excitation system. The power system stability limit can be enlarged by PSS, which improves system stability at low frequency oscillations connected with electromechanical modes [7]. In [24], the robustness of PSS is enhanced using the powerful optimization tool of linear matrix inequalities through state and output feedback. Recently, the availability of phasor measurement units was utilized in [10] for the enhanced stabilizing control design based on hierarchical and/or decentralized approach.

Unfortunately, a research has recognized some lack in GA performance [29]. This degradation is evident in applications with objective functions, i.e., where the highly correlated parameters being optimized are present. The premature convergence of GA deteriorates its performance and decreases its capability of search. Particle swarm optimization (PSO) has been presented and implemented as an evolutionary technique in [30-31]. This technique uses social psychology principles in evolutionary computations and socio-cognition human agents; PSO has been improved by the organism's behavior such as bird flocking and fish schooling.

The important function of power system stabilizer (PSS) is to suppress the low-frequency oscillation in the power system to enhance the dynamic stability of power system. The traditional PSS generally used in practice is a lead controller type, a dynamic output feedback with a single or double stage and utilizes the speed deviation $\Delta\omega$ as a feedback signal.

In this proposed work, the Fuzzy logic controller and Artificial Neural Network based Power System Stabilizer is designed using $H_\infty$ robust technique. Furthermore, an Enhanced Artificial Bee colony algorithm is implemented to improve the damping performance under frequency oscillations and tie lie power oscillations. The solar power is given as input and the damping coefficients '$\alpha$' and static error '$\xi$' are taken as output. The results are tabulated and compared with Conventional and existing controllers. From the comparison, it is cleared that the ANN(Artificial Neural Network) based Power System Stabilizer using EABC(Enhanced Artificial Bee Colony) algorithm outperforms the other conventional and existing systems.

*Literature Review:*

In [20], they have presented a fuzzy logic power system stabilizer (FPSS) for stability enhancement of a single machine infinite bus system. The acceleration ($\Delta\pi$) and speed deviation ($\Delta\omega$) of the synchronous generator rotor are took as input to the controller to enhance small signal stability. They achieved a significant damping at the generator shaft mechanical oscillations due to these variables.

PSS is used to improve the damping of power system under low frequency oscillations. Due to the poorly damped oscillation modes, the PSS parameter tuning is a difficult exercise in multi-machine power systems. Further, this problem is being complicated by frequently varied operating conditions of power system. In [15], the combination of fuzzy logic and particle swarm optimization (PSO) method is used to enhance the power system stability.

Generally, the PSS signal is interfaced with the DFIG controller and the converter to facilitate its implementation and application on any basic DFIG control scheme. The conventional PSS design was developed using a linearized model around the plant's nominal operating point, which is nonlinear. This limits the PSS robustness and performance. To overcome these limitations, a fuzzy power system stabilizer (FPSS) for a wind turbine with doubly fed induction generator (DFIG) is presented in Rebiha [18].

In [11] , they have proposed a design of a low dimensional multi-input PSS with H-infinity performance. The H-infinity has not been applied in to practical because of its complicated structure and theory even the H-infinity controller has highly robust. Thus, to achieve high robustness, they dealt with the H-infinity problem under fixed PSS structure as a lead-lag compensator and added an additional reactive input power to the PSS. The Particle Swarm Optimization optimizes multi-input lead-lag PSS parameter.

In [32], $H\infty$ robust power system stabilizer design is developed for a three machine system. A control design is implemented to stabilize the uncertain system based on the recent development of $H\infty$ robust control theory using Glover-McFarlane's loop shaping design for a three machine system. Setting the feedback configuration for loop shaping and synthesis guidance is presented.

Generally, to enhance the damping of low frequency oscillations, power system stabilizers (PSSs) are implemented to excitation system. In [33], the PSS design for multimachine power system (MMPS) using feedback sliding control is presented. At various operating points, the nonlinear model of a multimachine power system is linearized and the plant linearized model is obtained. The complete states of the system does not require for feedback.

*Optimal Power System Stabilizer With Fuzzy Controller Based On Enhanced Abc Algorithm:*

$H_\infty$ techniques are popularly used in control theory for synthesizing controllers to achieve stabilization with desired performance. The advantage of $H_\infty$ methods over the traditional control techniques is that they are

readily available to the multivariate system problems with channel cross-coupling. The final controller is only optimal with the prescribed cost function and saturation like non-linear constraints are usually not well-handled. Generally, $H_\infty$ techniques are used to reduce the perturbation's closed loop impact and it is depending on the problem formulation, the impact can either be calculated in terms of performance or stabilization.

*Artificial Bee Colony:*

In this model, this colony consists of three set of bees: employed bees, onlookers and scouts. First it is assumed that for each food source, there is only one artificial employed bee and it also called colony's employed bees is equal to the food sources around the hive. Employed bees search their food source and it will come back to hive and jump on this area. The food source of employed bee has been abandoned becomes a scout and then it will start to search for a new food source. Onlookers listens the jumps of employed bees and select food sources based on jumps.

Once all employed bees finished the finding process, they share the source's position information with the onlookers on the jump area. Each onlooker computes the nectar information took from the employed bees and then selects a food source based on the nectar information of sources. If it is an employed bee, it produces a correction on the position of the source in memory and verifies its nectar amount. If its nectar is higher than the existing one, the bee forgets the old position and memorizes the new one. The sources abandoned are obtained and randomly produced new sources to be refilled with the abandoned ones by artificial scouts.

*Enhanced Artificial Bee Colony (EABC):*

The ABC is well known to be best in exploration but weak in exploitation. Its performance is reduced due to this imbalance of exploitation and exploration capabilities of the Classical ABC algorithm. Thus, a few modifications are introduced in the Classical ABC algorithm which is called Enhanced ABC for balancing the exploration and exploitation capabilities.

EABC algorithm simulates foraging behavior of honeybees like Classical ABC algorithm. EABC consists of three classes of honey bees namely employed-bees, onlooker bees and scout. At first, the employed-bees are assigned with randomly-allocated food-sources and it assess neighborhood of the assigned food-sources and nectar information. Later on, the bees convey the information to onlooker-bees. The fitness of a possible solution is obtained by the nectar-amount of a food-source. The high quality food sources are explored by the Onlooker bees. The mutation equation explores neighborhood of the food-sources.

Its performance is determined by the Mutation equation of an optimization algorithm. According to the no free lunch theorem, no single mutation equation can provide equally-better performance on optimization problems of different types. The rules of engagement among honeybees are set by the Mutation equation of an optimization algorithm. Besides, the interaction of the population elements emerges self-organized patterns. Incrementally, the gbest food-source based neighborhood exploration of a food-source increases convergence rate which may lead towards premature convergence. On other side, the neighborhood exploration of a food-source based on a randomly selected food-source curtails convergence rate but, it allows capability to avert local optima. Therefore, EABC algorithm based on three different mutation equations to get benefits of each mutation-equation, unlike the Classical ABC algorithm.

*Algorithm:*

Initialize all parameters; Repeat until termination criteria is meet
Step 1: Computing new food sources in Employed bee phase.
Step 2: Update location the food sources based on their amount of nectar in Onlooker bees phase.
Step 3: Scout bee phase for searching new food sources in place of rejected food sources.
Step 4: Memorize the best food source identified so far and forget the other sources.
End of while
Output: The best solution identified.

*Fuzzy Logic Controller:*

Fuzzy logic is logic which uses quantified and graded statement rather than using simply true or false. In fuzzy sets, it allows object membership grades from 0 to 1. Generally, linguistic variables are used to represent the fuzzy sets. It will define a specific fuzzy set in a problem, like "small", "medium" and "large" and this Controls are very much useful when plant's perfect mathematical model is not obtainable yet human operators are available for giving qualitative rules to control the plant. The set of rules of linguistic controls related by the concepts of fuzzy compositional and implication rule of inference is necessary part of fuzzy logic.

It is a fuzzy logic based control system. It can handle nonlinearity of arbitrary complexity and does not require any perfect system mathematical model. It depends on the rules with an IF-THEN basic structure, which is the base of human logic. It consists of fuzzification and defuzzification blocks. In this the, input variables are

'change in speed deviation' (dω) and 'change in acceleration' (da) and the output variable is stabilized voltage (Vstab). The basic configuration of the FLC shown in following figure.

Output: The best solution identified.

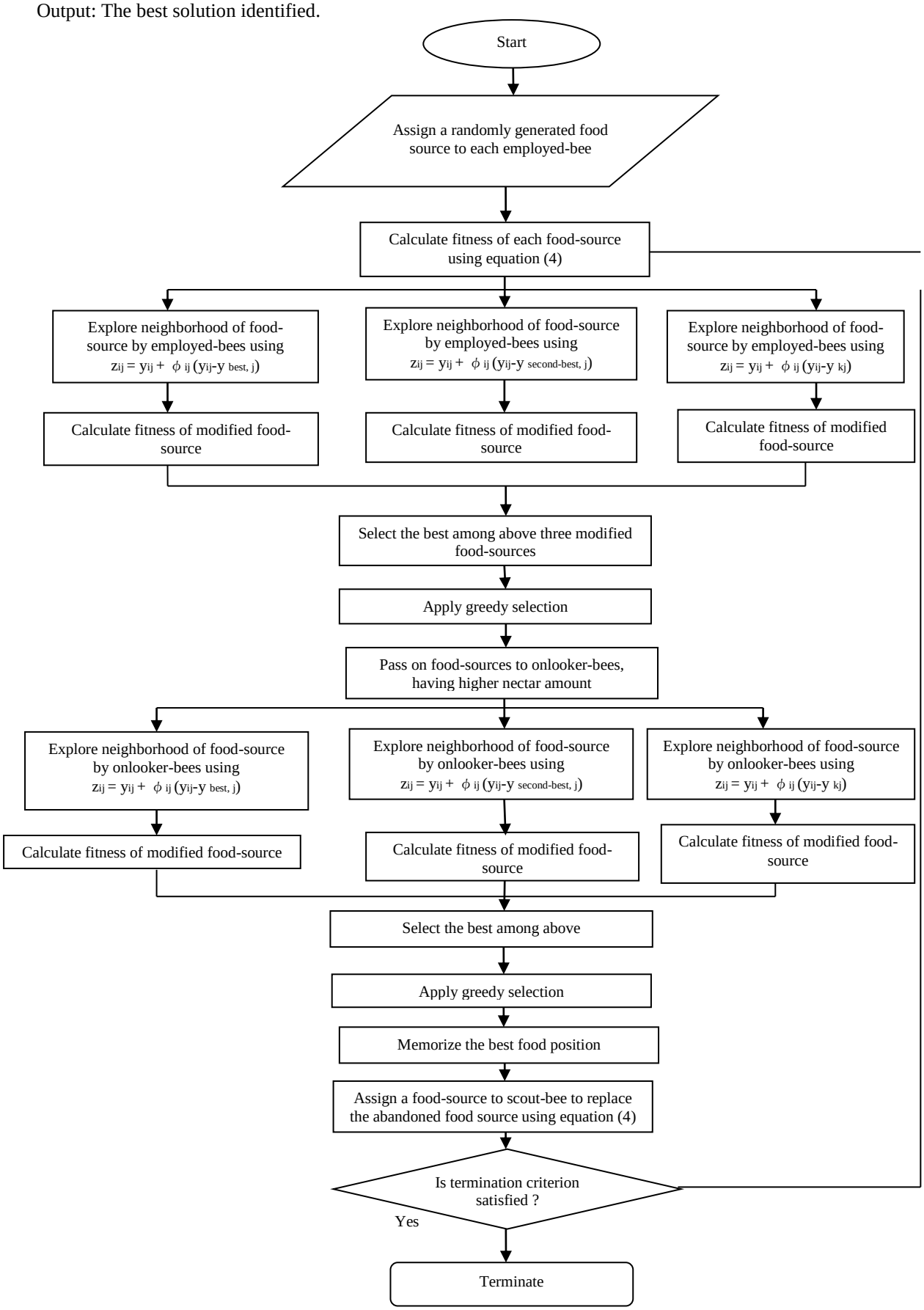



**Fig.1** Flow chart of EABC

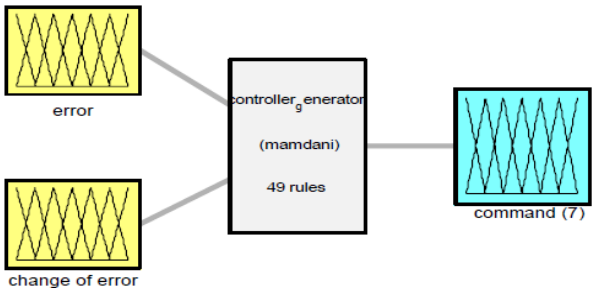



**Fig. 2:** Fuzzy Block

*Ann Controller:*

Artificial neural network (ANN) is a network which reflects the operation of biological neural networks. It is used to determine functions which will depend on a large number of unknown inputs. It is defined using three things:

- **Architecture:** defines their topological relationships and variables involved in the network.
- **Activity Rule:** local rules which defines how the neuron activities changes in response to each other. Generally, the activity rule depends on the parameters in the network.
- **Learning Rule:** This rule specifies how the weights of the neural network change with time. Generally, the learning rule depends on the neuron activities.

Ann controllers are popular learning models for their ability to meet with the demands of a dynamic environment. The analysis of the application of Artificial Neural Network (ANN) controller in power system stabilizer as a replacement of PID control to improve the damping performance. This model works with supervised learning in which data set is presented to train the model. The supervised ANN needs the sets of inputs and outputs for its training. During the training process, the output from the ANN model is compared with the target output. This training is continued until the output becomes an acceptable level.

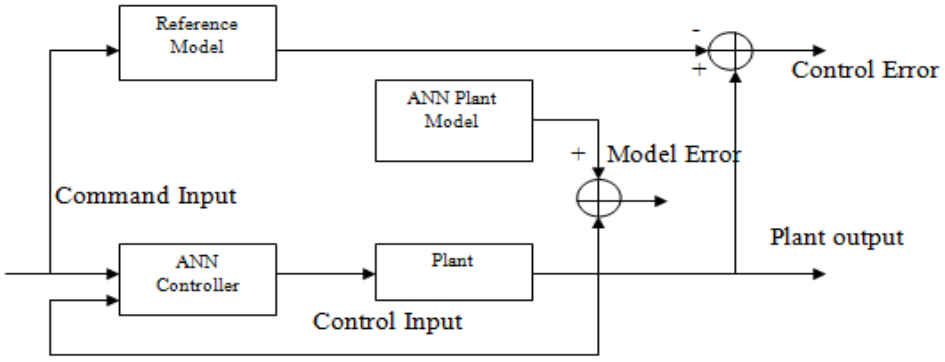



**Fig. 3:** Block diagram of ANN controller

*Modeling Of Solar Power System:*

The technical studies include steady-state analysis such as protection coordination and voltage control at distribution level. The study of Power flow is usually used to observe system losses, equipment loading, voltage rise/drop, conductor ampacity ratings and transfer capability. Protection coordination and Short circuit study is used to find out the protection settings parameter. In a study of steady state, a PV inverter may be modeled as a Traditional power source commonly with constant reactive power or power factor.

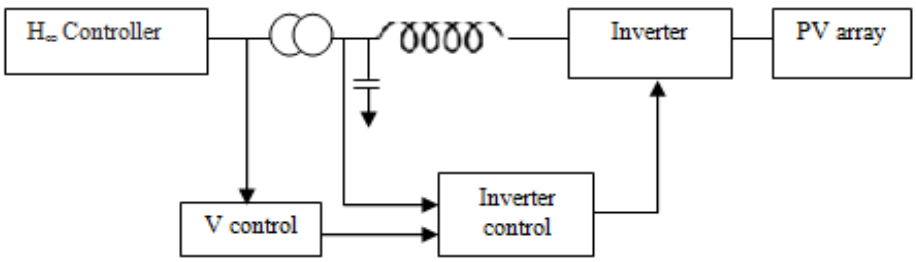



**Fig. 4:** Modeling of Solar power system

The developed Simulink model of the solar power system is shown in the following figure.

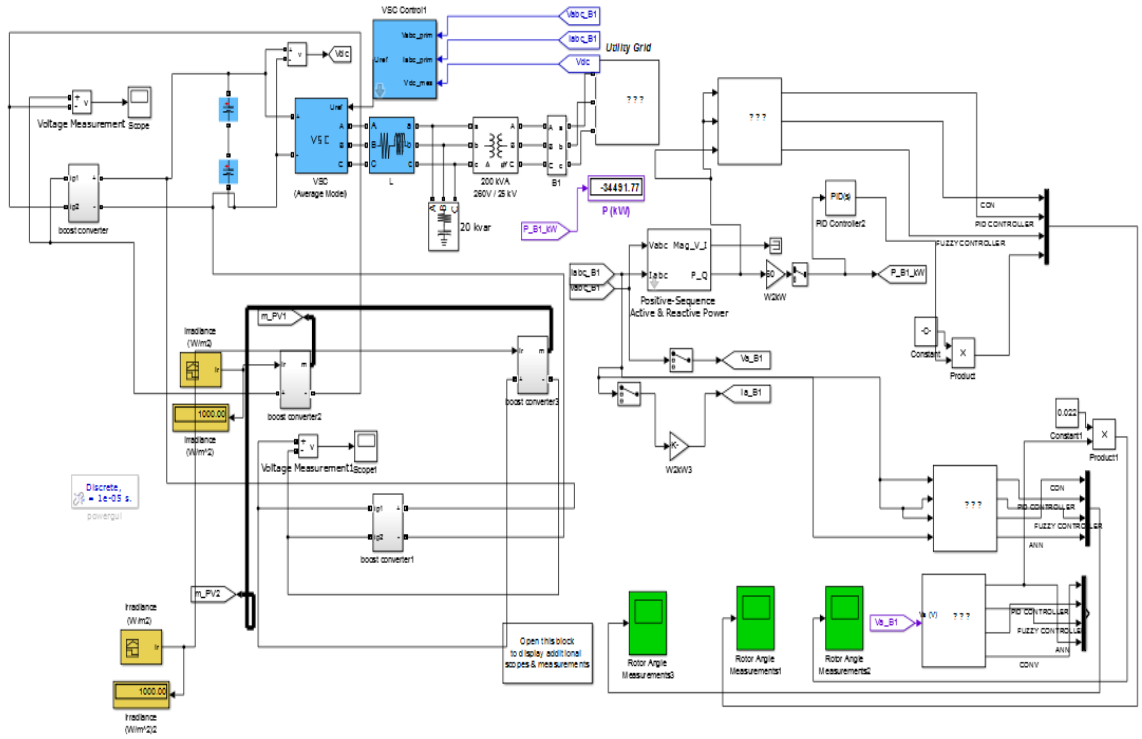



**Fig. 5:** Simulink model

*Simulation Results:*

EABC based Optimization method of RPSS using Fuzzy and ANN Controllers are examined and the response of voltage, current and power was observed. Comparison of the EABC robust optimization technique of Fuzzy and ANN controllers with the conventional PSS, PSS with H∞ technique and PSS with ABC shows that ANN based EABC robust optimization technique gives excellent robustness, while the process of design in much simpler.

The robustness of solar PSS design should be evaluated in different loading conditions and operating conditions. The change in operating conditions corresponds to variation of transmission line parameters, active and reactive powers.

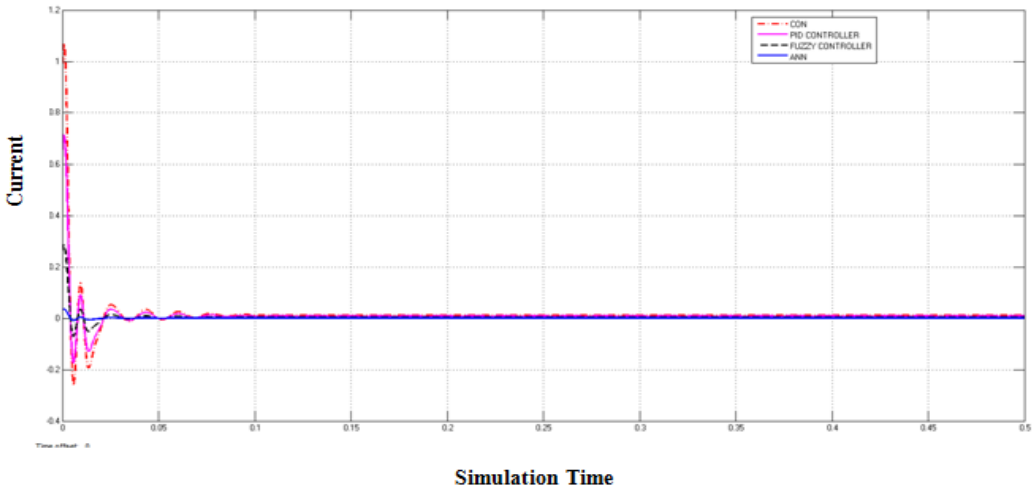
The table I and II shows the quantitative results of static and dynamic performance comparison with CPSS, solar PSS (SPSS) and [9] and [19] and also with fuzzy and ANN controllers of different parameters. The proposed Table I and Table II clearly show that the proposed RPSS with ANN outperforms the CPSS[9], [19], PSS with $H_{\infty}$, ABC based PSS with and without fuzzy and EABC based PSS with fuzzy. Comparing the system results, it can be directly identified that a very large developments in static and dynamic performances of the system.

Simulation results demonstrate the good damping performance of the robust designed EABC based solar PSS using ANN controller.

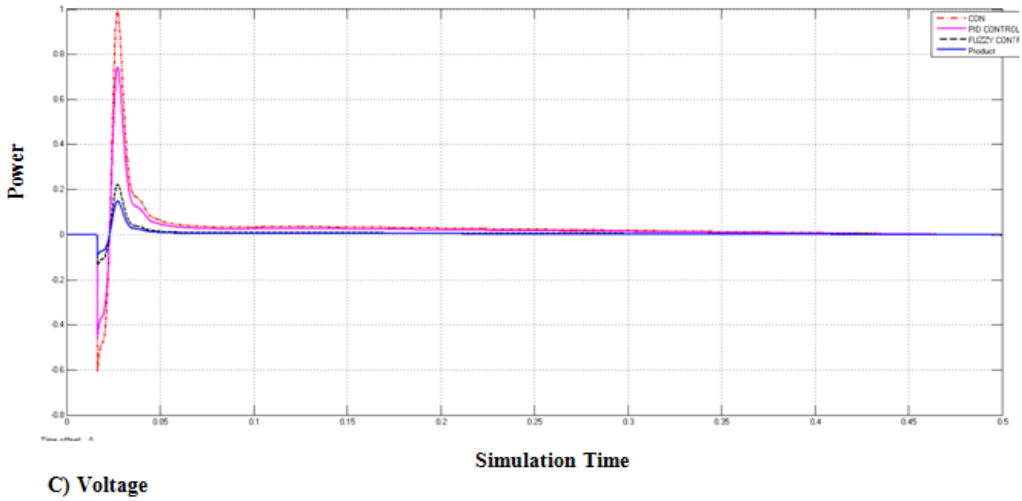
*Comparison of Conventional Pss And Eabcpss With Fuzzy And Ann Controllers:*

1. Under-exited mode x=0.5 , y=0.85 , z=0.1802

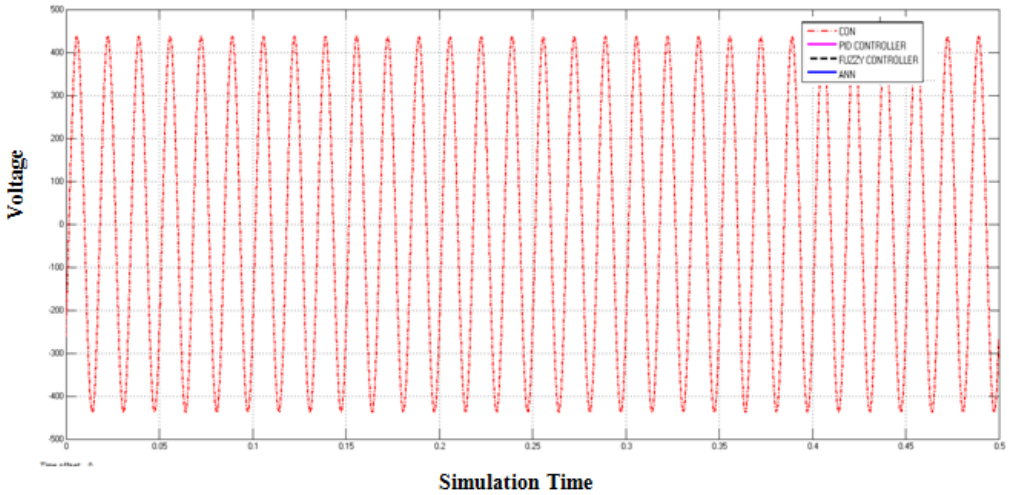
**a) Current**




**b) Power**

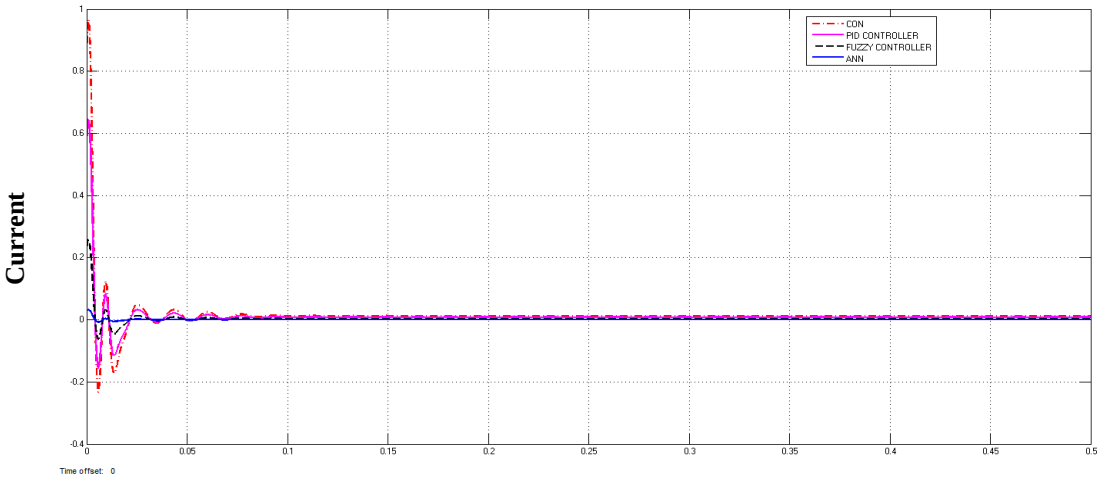



**C) Voltage**



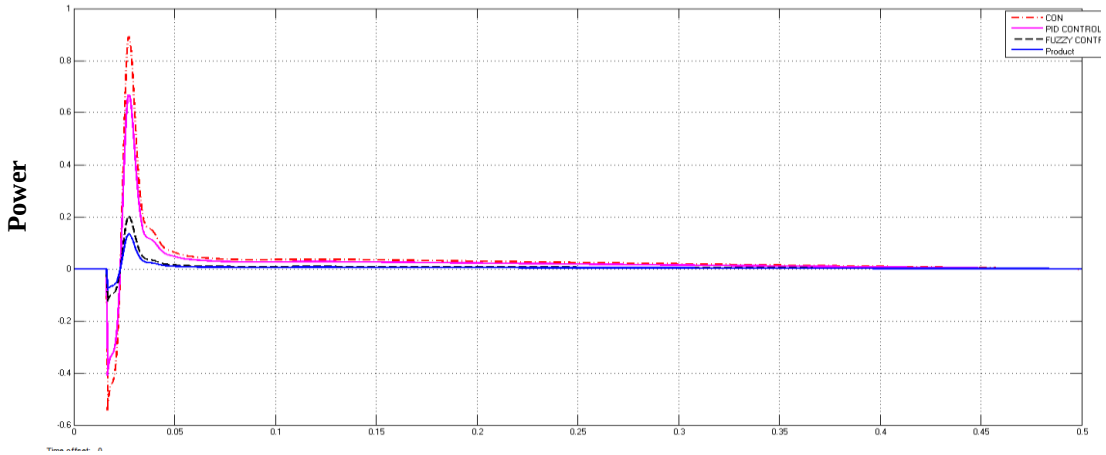
2. Nominale mode x=0.3, y=0.85, z=0.1102

**a) Current**



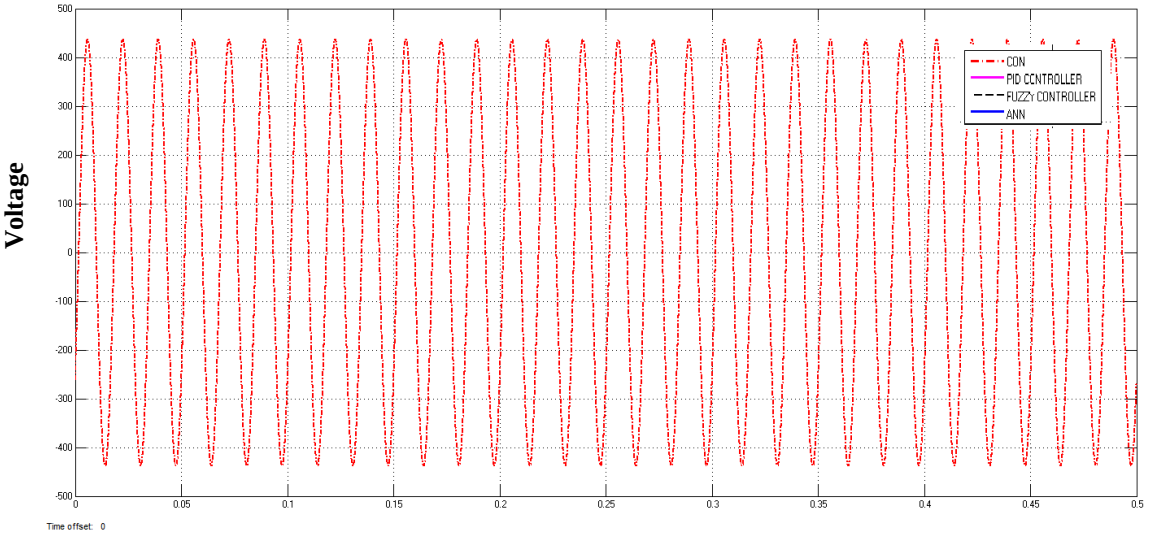

**Simulation Time**

**b) Power**




**Simulation Time**

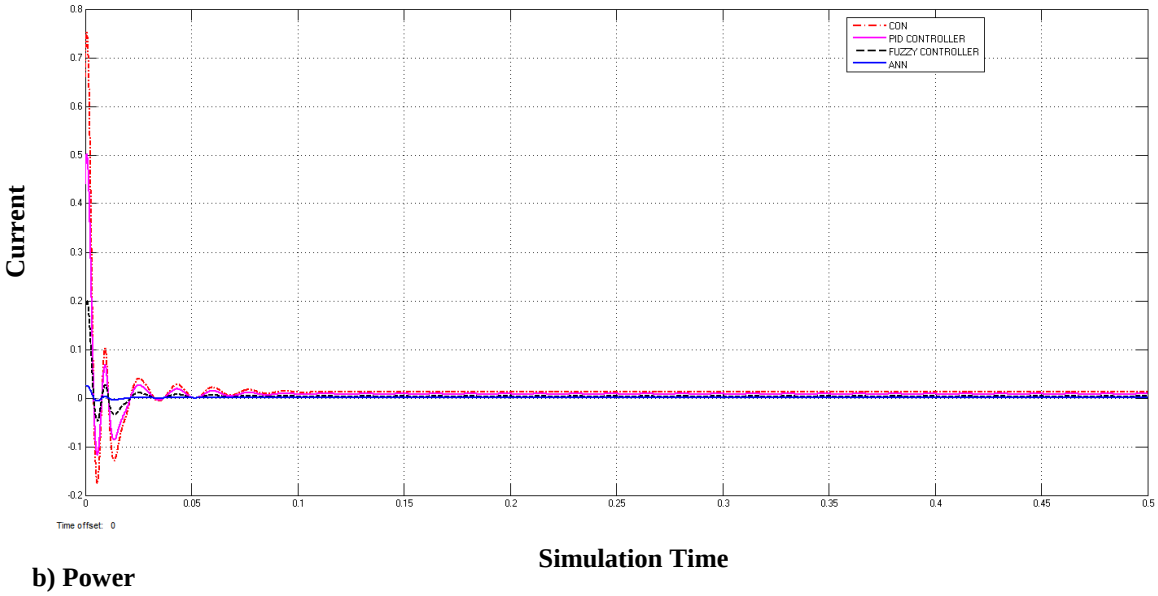
**C) Voltage**



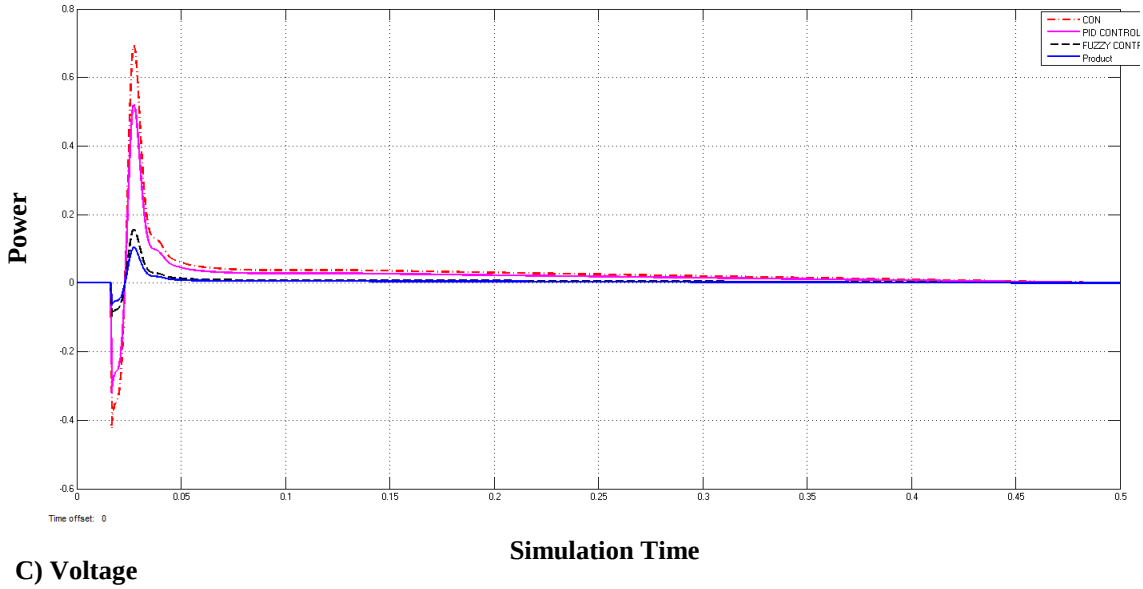

**Simulation Time**

3. Over-excited mode x=0.2,y=0.85 , z=0.6760

**a) Current**




**b) Power**




**C) Voltage**

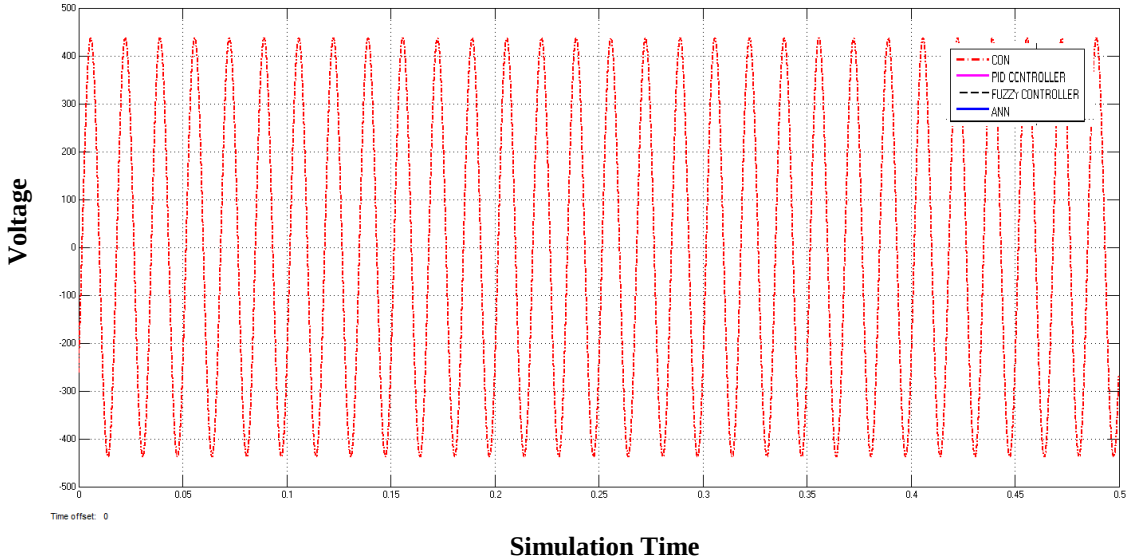


**Table I:** damping coefficients 'α' and static error 'ξ' of rpss and cpss in different operating conditions of the power system

| Reactive Power | $\alpha_{PSS}$ | $\xi_{PSS}$ | $\alpha_{PSSH\infty}$ | $\xi_{PSSH\infty}$ | $\alpha_{SPSSABC}$ | $\xi_{SPSSABC}$ | $\alpha s_{PSSEABC\ WITHFUZZY}$ | $\xi s_{PSSEABC\ WITHFUZZY}$ | $\alpha s_{PSSEABC\ WITHANN}$ | $\xi s_{PSSEABC\ WITHANN}$ |
|---|---|---|---|---|---|---|---|---|---|---|
| -0.2033 | 0.6574 | 0.00119 | 0.6721 | 0 | 0.7044 | 0 | 0.8092 | 0 | 0.8131 | 0 |
| -0.2449 | 0.6564 | 0.0012 | 0.6843 | 0 | 0.7211 | 0 | 0.8210 | 0 | 0.8221 | 0 |
| -0.1238 | 0.6695 | 0.00112 | 0.6990 | 0 | 0.7410 | 0 | 0.8243 | 0 | 0.8282 | 0 |
| -0.3402 | 0.6671 | 0.00089 | 0.7088 | 0 | 0.7484 | 0 | 0.8307 | 0 | 0.8329 | 0 |
| -0.6840 | 0.6574 | 0.00071 | 0.7007 | 0 | 0.7513 | 0 | 0.8321 | 0 | 0.8421 | 0 |

**Table II:** Settling Time '$T_s$' And Peak Time '$T_p$' Of Rpss And Cpss In Different Operating Conditions Of The Power System

| Reactive Power | $T_{S\ PSS}$ | $T_{P\ PSS}$ | $T_{S\ PSSH\infty}$ | $T_{P\ PSSH\infty}$ | $T_{S\ SPSSABC}$ | $T_{P\ SPSSABC}$ | $T_{S\ PSSEABCWITH\ FUZZY}$ | $T_{P\ PSSEABCWITH\ FUZZY}$ | $T_{S\ PSSEABCWITH\ ANN}$ | $T_{P\ PSSEABCWITH\ ANN}$ |
|---|---|---|---|---|---|---|---|---|---|---|
| -0.2033 | 0.93 | 0.51 | 0.54 | 0.414 | 0.3 | 0.28 | 0.241 | 0.208 | 0.232 | 0.200 |
| -0.2449 | 0.92 | 0.51 | 0.531 | 0.4121 | 0.271 | 0.27 | 0.231 | 0.201 | 0.224 | 0.197 |
| -0.1238 | 0.65 | 0.5 | 0.53 | 0.409 | 0.289 | 0.274 | 0.229 | 0.221 | 0.218 | 0.209 |
| -0.3402 | 0.81 | 0.46 | 0.529 | 0.406 | 0.297 | 0.249 | 0.218 | 0.204 | 0.210 | 0.198 |
| -0.6840 | 0.84 | 0.47 | 0.55 | 0.405 | 0.2546 | 0.215 | 0.209 | 0.200 | 0.203 | 0.194 |

The settling time, rise time, damping coefficients and static error of current and power are good in power system stabilizer using Artificial Neural Network compared to fuzzy logic, PID and conventional controllers under exited mode, nominale mode and over excited modes which is clearly visible in the above graphs and the same is tabulated in table I and II.

*Conclusion:*

In this paper, a new Robust Power System Stabilizer is presented to solve a sufficient condition to stabilize the linear time invariant Power systems via different controllers. The effective and convergent iterative EABC algorithm is used to improve the Power system stabilizer. The algorithm can be applied to ANN controller, and Fuzzy controller as well. Numerical values of tabulation show that the proposed algorithm produces better result than the existing methods. Simulation results based on a model of the power system confirms the ability of the proposed Power system stabilizer to stabilize the system over a wide range of operating points. The method presented illustrates the increased performance, efficiency, reliability and robustness of the solar power system stabilizer. We can try some other efficient algorithm instead of EABC to get better results in future.

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