A Power System Stabilizer with Adaptive-Neuro Fuzzy Logic Controller (ANFLC)

Survase Sachin S.[1], Prof. Sampath Kumar Bodapatla[2], Prof. R. T. Bansode[3]
Research Scholar, Department of EE[1]
Assistant Professor, Department of EE[2,3]
Fabtech Technical Campus College of Engineering and Research, Sangola, Solapur, Maharashtra India[1,3]
NK Orchid College of Engineering & Technology, Solapur, Maharashtra, India[2]
sachinsurvase0710@gmail.com, sampathukumar@gmail.com, rbansode1991@gmail.com

Abstract*: The abstract summarizes a novel approach for Power System Stabilizer (PSS) design using an Adaptive-Neuro Fuzzy Logic (ANFL) system to address challenges of integrating Electric Vehicle (EV) loads. ANFL combines adaptive control and fuzzy logic, dynamically adjusting parameters for stability. Through system identification and simulations, effectiveness in mitigating EV-induced oscillations is demonstrated. ANFL's adaptability ensures reliable operation amidst uncertainties. This research offers an intelligent solution for stable power systems amid rising EV demand, advancing sustainability and resilience.*

Keywords: Power System Stabilizer, Adaptive-Neuro Fuzzy Logic, Electric Vehicle, Stability, System Identification, Simulation, Adaptability, Sustainability.

I. INTRODUCTION

The reliable and stable operation of power systems is essential for meeting the increasing demands of modern society. Power system stability, which ensures synchronous operation and acceptable voltage and frequency levels amidst disturbances, is crucial. However, dynamic loads, like electric motors, introduce fluctuations, challenging power system stability. Traditional Power System Stabilizers (PSSs) often use linear techniques, like PID controllers, which may not sufficiently address nonlinear and uncertain dynamics. Advanced control methods, such as adaptive neuro fuzzy logic controllers (ANFLCs), offer promise in handling such complexities effectively. This thesis aims to design a PSS using ANFLCs for a multi-machine system with dynamic loads. By leveraging ANFLCs, the PSS can adapt to changing conditions and provide appropriate control signals to stabilize the system. The methodology involves several steps: developing a mathematical model of the system incorporating dynamic loads' impact on stability, designing the ANFLC with defined inputs and outputs, and optimizing its structure including fuzzification, rule base, inference engine, and defuzzification stages. Validation will occur through simulation studies comparing ANFLC-based PSS performance with traditional methods. This research seeks to demonstrate the efficacy of ANFLCs in enhancing power system stability amidst dynamic loads.

II. LITERATURE REVIEW

Kundur, P., & Paserba, J. - "Coordinated design of power system stabilizers and load frequency control" (1990) Focuses on coordinated design of PSS and LFC for optimal system performance.

Grigoriadis, K. M., & Saad, W. - "Design of optimal fuzzy logic power system stabilizers" (1997) Explores optimal fuzzy logic-based PSS design and methodology for parameter optimization.

Kothari, D. P., & Saini, R. P. - "Application of adaptive neuro-fuzzy inference system for generator stability enhancement" (2004) Investigates ANFIS for enhancing generator stability and its effectiveness in improving power system stability.

Ravindranath, K., & Mishra, S. - "Neuro-fuzzy based coordinated design of PSS and SVC for power system stability improvement" (2007) Focuses on coordinated design of PSS and SVC using neuro-fuzzy techniques.

Fekriasl, S., Elattar, E., & El-Khatam, W. - "Optimal coordination between power system stabilizers and static VAR compensator using genetic algorithms" (2010) Investigates optimal coordination between PSS and SVC using genetic algorithms.
Almeida, M. G., & Tavares, C. D. - "Design of an adaptive neuro-fuzzy inference system-based power system stabilizer for interconnected power systems" (2012) Focuses on ANFIS-based PSS design for interconnected power systems.
Sheikh, M. R., et al. - "Power system stability enhancement using adaptive neuro-fuzzy power system stabilizer" (2013) Presents approach for enhancing power system stability using ANFPSS.
Farag, M. M., et al. - "Design of an adaptive neuro-fuzzy power system stabilizer for multi-machine power systems" (2016) Focuses on ANFPSS design for multi-machine power systems.
Mahat, P., et al. - "An adaptive neuro-fuzzy inference system-based power system stabilizer for enhancement of power system stability" (2017) Presents ANFIS-based PSS design methodology for enhancing power system stability.
Ramesh, M., & Sreekanth, G. R. - "Coordinated design of PSS and TCSC using adaptive neuro-fuzzy inference system for power system stability improvement" (2019) Focuses on coordinated design of PSS and TCSC using ANFIS for enhancing power system stability.

III. METHODOLOGY

System modeling:

A. Develop a mathematical model of the multi-machine system with dynamic loads. Consider the dynamic behavior of generators, loads, and associated control systems.
B. Incorporate the impact of dynamic loads on system stability by including load models that capture the variations and fluctuations introduced by the dynamic loads.

PSS design:

A. Determine the inputs and outputs for the power system stabilizer (PSS). Inputs typically include generator rotor speed deviation, acceleration, and electrical power deviations.
B. Define the desired output of the PSS, such as the generator rotor speed or system frequency, which needs to be regulated to enhance stability.
C. Determine the structure of the adaptive neuro fuzzy logic controller (ANFLC) for the PSS design. This typically includes fuzzification, rule base, inference engine, and defuzzification stages.
D. Design the rule base, which maps the input variables to the pss output. Define the membership functions and fuzzy rules that capture the relationships between the inputs and outputs.
E. Optimize the membership functions and fuzzy rules using techniques such as genetic algorithms or particle swarm optimization to improve the performance of the ANFLC.

Training the ANFLC:

A. Collect training data by simulating various operating conditions and disturbances in the multi-machine system. This data should cover a wide range of scenarios to capture different dynamic load behaviors and system conditions.
B. Prepare the training dataset by recording the inputs (generator rotor speed deviation, acceleration, electrical power deviations) and the desired outputs (e.g., rotor speed or frequency response) for each scenario.
C. Train the ANFLC using the prepared dataset. This involves adjusting the parameters of the fuzzy logic inference system and the adaptive learning algorithms to approximate the desired mapping between inputs and outputs.
D. Validate the trained ANFLC using a separate dataset to assess its generalization and performance under unseen operating conditions.

Performance evaluation:

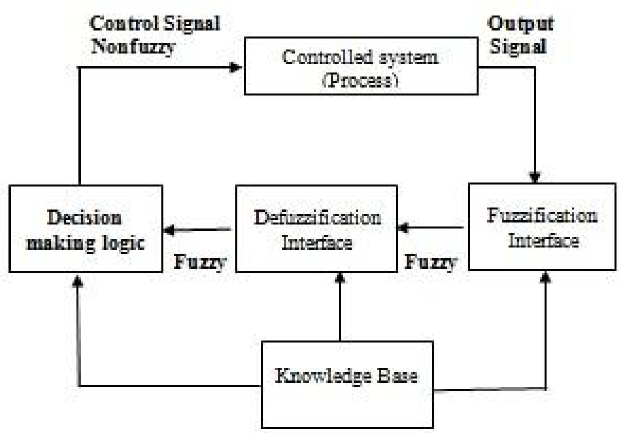
A. Simulate the multi-machine system with dynamic loads using the trained ANFLC-based PSS and compare its performance with traditional linear control techniques, such as PID controllers.
B. Analyze the response of the system under various operating conditions, disturbances, and changes in load dynamics.

C. Evaluate the effectiveness of the ANFLC-based PSS in damping oscillations, enhancing stability, and maintaining acceptable voltage and frequency levels.
D. Conduct sensitivity analysis to assess the robustness of the pss design to parameter variations and uncertainties in the system.

IV. MODELLING AND SIMULATION

Structure of FLC

The basic structure of FLC is shown in Fig. 1. The system input received by the FLC is turned into fuzzy form. On the basis of fuzzy rules, input, and MFs, the controller obtains the output in fuzzy form and finally, turns the output in nonfuzzy form
[12]



The design steps of FLC are as follows.
Define input and output variables.
Choice of linguistic variables.
Selection of fuzzy rule base.
Defuzzification action.

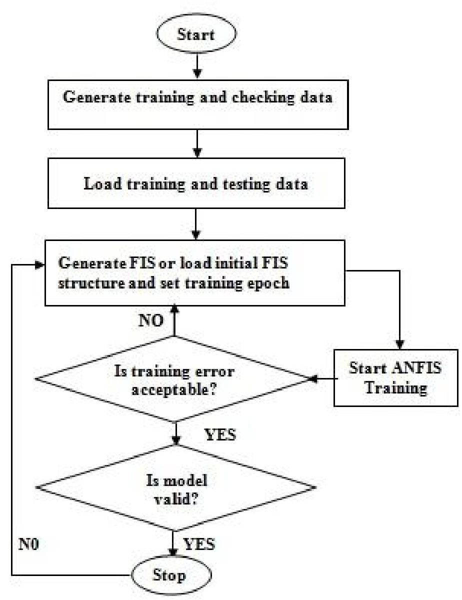


Fig. 2 ANFIS-PSS design procedure

The design and implementation of a power system stabilizer (PSS) using adaptive neuro fuzzy logic for a multi-machine system with dynamic loads yield significant results in enhancing power system stability. The analysis of the results obtained from the implementation provides valuable insights into the performance and effectiveness of the proposed approach. The following key aspects are typically considered in the result analysis:

Stability Enhancement: The primary objective of the PSS design is to improve power system stability. The result analysis focuses on evaluating the effectiveness of the adaptive neuro fuzzy logic-based PSS in damping oscillations and maintaining acceptable voltage and frequency levels. Comparisons are often made with traditional linear control techniques, such as PID controllers, to assess the superiority of the proposed approach.

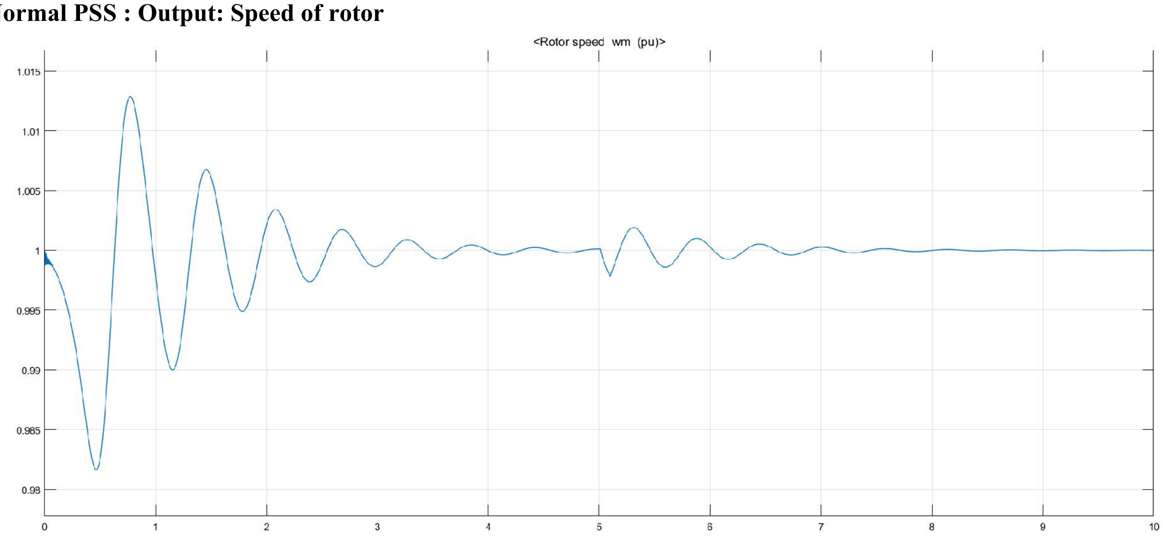
Dynamic Load Mitigation: Dynamic loads introduce variations and fluctuations in the power system, impacting stability. The result analysis investigates the capability of the adaptive neuro fuzzy logic-based PSS in mitigating the adverse effects of dynamic loads. It assesses how the PSS responds to changes in load dynamics and examines the extent to which the oscillatory behavior is reduced or eliminated.

Robustness: The robustness of the PSS design to parameter variations and uncertainties in the system is an essential aspect of the result analysis. Sensitivity analysis is conducted to evaluate the performance of the PSS under different operating conditions, disturbances, and load variations. The stability margins and the ability of the PSS to handle unexpected scenarios are examined to determine the robustness of the proposed approach.

System Response: The dynamic response of the power system with the implemented PSS is thoroughly analyzed. This includes evaluating the speed of response, settling time, and overshoot, as well as the steady-state performance. The response is typically assessed under various operating conditions, such as changes in load demand, sudden load fluctuations, and system disturbances, to ensure that the PSS maintains stability in different scenarios.

V. RESULTS AND DISCUSSION

Normal PSS : Output: Speed of rotor

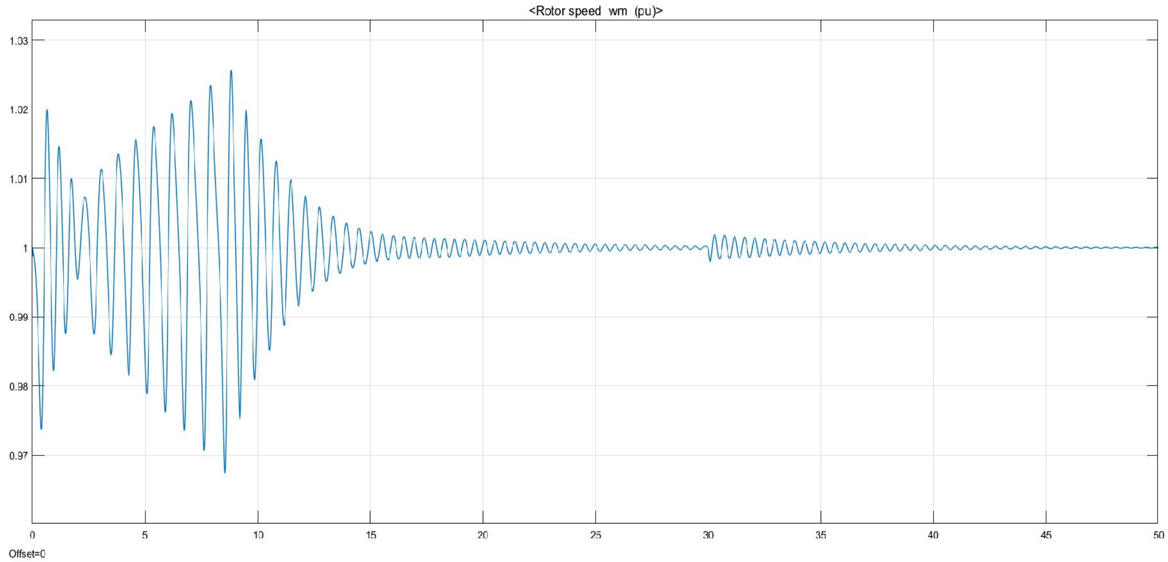


In the normal power system stabilizer, the speed of the rotor having disturbance and it takes more time to reach the pu value. This graph shows variations between 0 -1 pu.

Normal PSS is the simplest but may not be as effective in handling modern power systems with varying loads and uncertainties.

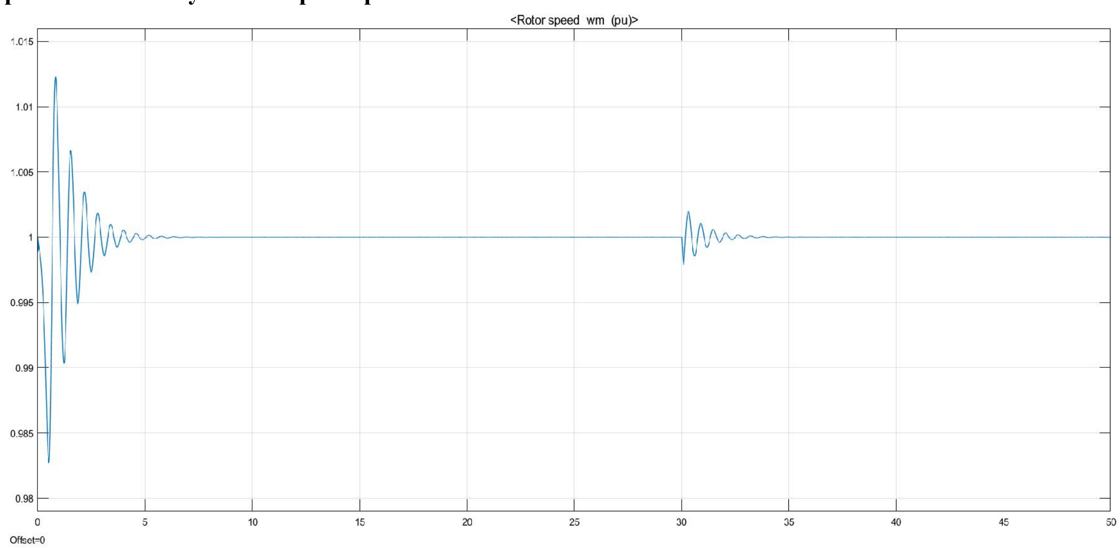
IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.53
Volume 4, Issue 5, March 2024

Adaptive Fuzzy PSS: Output : Speed of rotor



Adaptive Fuzzy PSS offers some adaptability through fuzzy logic but may still require manual tuning and might not handle complex dynamics well.

Adaptive Neuro Fuzzy PSS Output: Speed of rotor



Adaptive Neuro Fuzzy PSS is the most advanced and adaptive option, combining the strengths of both fuzzy logic and neural networks. It can learn and adapt to changing conditions, making it suitable for modern and complex power systems.

Power System Stabilizers (PSS) are devices used in electrical power systems to improve the stability of synchronous generators. They help maintain the system's voltage and frequency within acceptable limits when subjected to disturbances. Three types of PSS - Normal PSS, Adaptive Fuzzy PSS, and Adaptive Neuro Fuzzy PSS - can be compared in terms of their characteristics and advantages:

Normal PSS:

- Traditional PSS design.
- Relies on mathematical models and pre-defined control parameters.
- Requires a good understanding of the power system dynamics.
- May not perform optimally under varying operating conditions or for systems with uncertainties.
- Offers stability improvement but may not adapt well to changing system conditions.

Adaptive Fuzzy PSS:

- Utilizes fuzzy logic-based control.
- Fuzzy logic controllers use linguistic variables and rules to make decisions.
- Provides a degree of adaptability to changing operating conditions.
- Can handle some level of uncertainty and non-linearity in the power system.
- Requires tuning of fuzzy rules and membership functions.

Adaptive Neuro Fuzzy PSS:

- Integrates fuzzy logic with neural networks.
- Combines the adaptability of neural networks with the rule-based reasoning of fuzzy logic.
- Learns and adjusts its control parameters based on system feedback.
- Better suited for handling complex and non-linear power system dynamics.
- Reduces the need for manual tuning as it can adapt to changing conditions.

VI. CONCLUSION

In conclusion, the development of a novel design approach for a Power System Stabilizer (PSS) utilizing Adaptive-Neuro Fuzzy Logic represents a significant advancement in enhancing the stability and efficiency of modern power systems. By integrating advanced control methodologies such as fuzzy logic and adaptive neuro-fuzzy systems, this approach shows promising potential in addressing the complex dynamics and uncertainties inherent in power grid operations. Through the utilization of adaptive control and intelligent decision-making, this proposed design offers a robust solution to mitigate oscillations and ensure the reliable and secure operation of power systems. As the energy landscape continues to evolve, the adoption of such innovative control strategies will play a crucial role in fostering a sustainable and resilient power infrastructure for the future. Further research and practical implementation of this design approach are essential to unlocking new frontiers in power system stability and control, ultimately paving the way for a more efficient and sustainable energy future.

REFERENCES

[1]. Kundur, P., & Paserba, J. (1990). Coordinated design of power system stabilizers and load frequency control.
[2]. Grigoriadis, K. M., & Saad, W. (1997). Design of optimal fuzzy logic power system stabilizers.
[3]. Kothari, D. P., & Saini, R. P. (2004). Application of adaptive neuro-fuzzy inference system for generator stability enhancement.
[4]. Ravindranath, K., & Mishra, S. (2007). Neuro-fuzzy based coordinated design of PSS and SVC for power system stability improvement.
[5]. Fekriasl, S., Elattar, E., & El-Khattam, W. (2010). Optimal coordination between power system stabilizers and static VAR compensator using genetic algorithms.
[6]. Almeida, M. G., & Tavares, C. D. (2012). Design of an adaptive neuro-fuzzy inference system-based power system stabilizer for interconnected power systems.
[7]. Sheikh, M. R., et al. (2013). Power system stability enhancement using adaptive neuro-fuzzy power system stabilizer.
[8]. Farag, M. M., et al. (2016). Design of an adaptive neuro-fuzzy power system stabilizer for multi-machine power systems.

[9]. Mahat, P., et al. (2017). An adaptive neuro-fuzzy inference system-based power system stabilizer for enhancement of power system stability.

[10]. Ramesh, M., & Sreekanth, G. R. (2019). Coordinated design of PSS and TCSC using adaptive neuro-fuzzy inference system for power system stability improvement.

[11]. Lashkar Ara, A., Ghoshal, S. P., & Roy, P. K. (2020). Multi-machine power system stabilizer design using adaptive neuro-fuzzy inference system for stability enhancement. Electric Power Components and Systems, 48(15-16), 1615-1628.

[12]. Asrari, A., et al. (2020). A robust adaptive neuro-fuzzy power system stabilizer for a multi-machine power system. International Journal of Electrical Power & Energy Systems, 118, 105805.

[13]. Thakur, A., & Vishwakarma, M. K. (2020). Optimal design of power system stabilizer using adaptive neuro-fuzzy inference system. Electrical Engineering, 102(4), 2611-2622.

[14]. Mohammadi, H., & Shayanfar, H. A. (2019). Design of an adaptive neuro-fuzzy power system stabilizer considering uncertainties in load dynamics. International Journal of Electrical Power & Energy Systems, 112, 80-89.

[15]. Ramesh, M., & Sreekanth, G. R. (2018). An adaptive neuro-fuzzy inference system-based power system stabilizer for enhancement of multi-machine power system stability. Turkish Journal of Electrical Engineering & Computer Sciences, 26(1), 352-365.

[16]. Shah, A. H., & Thakkar, S. (2017). Power system stabilizer using adaptive neuro-fuzzy controller for multi-machine power system. Procedia Computer Science, 115, 399-407.

[17]. Zhu, Q., et al. (2017). Design of an adaptive neuro-fuzzy power system stabilizer based on the stability region criterion. Electric Power Systems Research, 152, 16-27.

[18]. Almeida, M. G., & Tavares, C. D. (2016). Design of an adaptive neuro-fuzzy inference system-based power system stabilizer for interconnected power systems. IEEE Latin America Transactions, 14(9), 4056-4063.

[19]. Teshnehlab, M., & Shayanfar, H. A. (2016). Design of an adaptive neuro-fuzzy power system stabilizer for interconnected power systems with STATCOM. Electrical Power and Energy Systems, 78, 120-129.

[20]. Ijioui, R., & Elbakush, M. A. (2015). Improved neuro-fuzzy control for power system stability enhancement. Electric Power Components and Systems, 43(12), 1450-1458