Advances in ENGINEERING and SCIENCES

Volume - 1

Chief Editor

Prof. K. Viswak Sena Reddy
Vice-Principal, Narayana Engineering College, Gudur,
Andhra Pradesh, India

Co-Editor

Dr. Rajesh Reddy. Duvvuru
Assistant Professor, Department of EEE, Narayana Engineering College,
Gudur, Andhra Pradesh, India

Integrated Publications
New Delhi

Published By: Integrated Publications

Integrated Publications
H. No. - 3 Pocket - H34, Sector - 3,
Rohini, Delhi-110085, India

Chief Editor: Prof. K. Viswak Sena Reddy
Co-Editor: Dr. Rajesh Reddy. Duvvuru

Publication Year: 2022

Pages: 53

ISBN: 978-93-93502-34-6

Book DOI: https://doi.org/10.22271/int.book.134

Price: ₹ 595/-

Contents

Chapter - 3
Optimal Design of Power System Stabilizers with Artificial Intelligence Techniques

Authors

P. Marimuthu
Professor, EEE Department, Malla Reddy Engineering College, Hyderabad, Telangana, India

V. Moorthy
Professor, EEE Department, KKR & KSR Institute of Technology and Sciences, Guntur, Andhra Pradesh, India

Kalyan Sagar Kadali
Assistant Professor, EEE Department, Shri Vishnu Engineering College for Women, Bhimavaram, Telangana, India

Chapter - 3

Optimal Design of Power System Stabilizers with Artificial Intelligence Techniques

P. Marimuthu, V. Moorthy and Kalyan Sagar Kadali

Abstract

The basic function of a PSS is to add damping to the generator rotor oscillations by controlling its excitation using auxiliary stabilizing signals. To provide damping, the stabilizer must produce a component of electrical torque in phase with the rotor speed deviations. Studies have shown that a well tuned PSS can effectively improve power system dynamic stability. The effect of phase compensation in reducing local and inter area oscillations is examined in this thesis. State space model of the system is considered for analysis. The model is obtained by using the effects of field circuit dynamics, field flux variations, excitation systems and damping torque components. An eigen value based objective function subject to a set of constraints based on limits of PSS parameters is considered.

Keywords: AI, Stability Analysis, PSS.

1. Introduction

Power system stability and its classifications are elaborated in this work. The causes for instability of rotor angle, voltage and frequency are discussed. The steps involved in typical power system stability study and scenario of stability are explained. Modern power systems are characterized by extensive system interconnections and increasing dependence on control for optimum utilization of existing resources. The supply of reliable and economic electric energy is a major determinant of industrial progress and consequent rise in standard of living. The increase in demand for electric power coupled with resource and environmental constraints create several challenges to system planners. The power generation plants may be located far away from load centres. However, constraints of the system lead to overloading of existing transmission lines and an impetus to seek technological solutions for exploiting the high thermal loading limits of EHV lines. With deregulation of power supply utilities, there is a tendency to view the power networks as highways for transmitting electric power from available place to required place, depending on the pricing that varies with time of the day.

Stability of power systems is a major concern in system operation. This arises from the fact that in steady state the average electrical speed of all the generators must remain the same anywhere in the system. This is termed as the synchronous operation of a system. Any disturbance small or large can affect the synchronous operation. For example, there can be a sudden increase in the load or loss of generation. Another type of disturbance is the switching out of a transmission line which may occur due to overloading or a fault. The stability of a system determines whether the system can settle down to a new or original steady state after the transients disappear.

2. Artificial Intelligence

The term Artificial Intelligence was coined by John McCarthy in 1956. AI may be defined as follows "Developing computer programs to solve complex problems by applications of process that are analogous to human reasoning process." This definition has two major parts: Computer solutions for complex problems; and processes that are analogous to human reasoning processes. For the first part regular conventional software exists. The second part of the definition is the distinguishing feature of AI programs. Interest in the field of AI gained prominence during the 1956 Dartmouth conference.

Much more impetus was provided by the Japanese Fifth Generation Computer Project. The vast developments in AI within short span is due the following reasons,

i. Quest for attaining the unattainable in the field of making computer intelligent

ii. Japanese announcement of the Fifth Generation Computers.

iii. AI has been a great tool for computer scientists, psychologists, linguists, mathematicians, philosophers, engineers and sociologists. Developments in AI are sure to have an effect on each of these fields. Contributions from these groups had a significant role in the development of AI.

iv. The demand for the technology

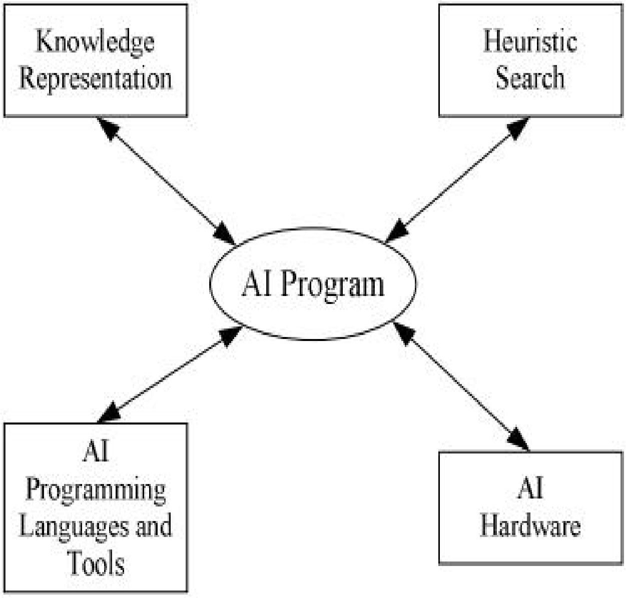

Fig 1: Major components of AI system

2.1 Heuristic Search

In computer science a heuristic algorithm or simply a heuristic is an algorithm that ignores whether the solution to the problem can be proven to be correct, but which usually produces a good solution or solves a simpler problem that contains or intersects with the solution of the more complex problem. Heuristics are typically used when there is no known way to find an optimal solution, or when it is desirable to give up finding the optimal solution for an improvement in run time. Two fundamental goals in computer science are finding algorithms with provably good run times and with provably good or optimal solution quality. A heuristic is an algorithm that abandons one or both of these goals; for example, it usually finds pretty good solutions, but there is no proof the solutions could not get arbitrarily bad; or it usually runs reasonably quickly, but there is no argument that this will always be the case. Heuristic methods are based upon intelligent search strategies for computer problem solving, using several alternative approaches. Often, one can find specially crafted problem instances where the heuristic will in fact produce very bad results or run very slowly; however, such pathological instances might never occur in practice because of their special structure. Therefore, the use of heuristics is very common in real world implementations. For many practical problems, a heuristic algorithm may be the only way to get good solutions in a reasonable amount of time.

2.2 Neural Network

Zhang et al (1995) discussed the effectiveness of an Artificial Neural Network (ANN) based PSS (ANNPSS) in damping multi-mode oscillations in a five machine power system environment. Accelerating power of the generating unit was used as the input to the ANNPSS. The proposed ANNPSS was using a multilayer neural network with error-back propagation training method which was trained over the full working range of the generating unit with a large variety of disturbances.

Guan et al (1996) proposed an ANN based PSS. The neural network based PSS (NNPSS) was trained by an improved BP algorithm. The main difference between the proposed Back Propagation (BP) algorithm and the conventional BP algorithm was that two variable factors, a learning rate factor ε and a momentum factor α, were used. This significantly improved the convergence of the ANN'S training. A four layer (7-7-4-1) ANN was used to design the NNPSS. The NNPSS was trained by samples obtained from power systems controlled by nonlinear power system stabilizers. After training by the samples, the NNPSS was tested intensively in two power systems, a single machine to infinite bus power system and a multimachine without infinite bus power system. NNPSS had the ability to attract the dynamic behavior of the system from its input/output samples. The robustness of the controller against the changes of system parameters, perturbations and system operating conditions was also as good as that of the teaching system. NNPSSs cooperated in a multimachine power system could damp out multimode oscillations quickly during a disturbance.

2.3 Fuzzy Logic

Takashi Hiyama (1994) discussed the robustness of fuzzy logic stabilizers using the information of speed and acceleration states of a synchronous generator. The input signals were the real power output and/or the speed of the synchronous generator. Non-linear simulations showed the robustness of the Fuzzy Logic PSS (FLPSS). The FLPSS did not require heavy computations on the micro-computer; therefore, the real time control was available by the FLPSS. The results explained the efficiency and the feasibility of the proposed FLPSS. Hoang et al (1996) discussed expert or rule-based controllers for a wider range of operating conditions. The fuzzy control design was implemented on uncertainties in system parameters and operating conditions. This work was directed at developing robust stabilizer design and analysis methods appropriate when fuzzy logic was applied. The advantage of this design approach was that the controller is insensitive to the precise dynamics of the system. Simulation of the response to disturbances had demonstrated the effectiveness of this design technique. Small signal and transient stability analysis gave some evidence of the robustness of the controller.

2.4 Genetic Algorithm

Abdel-Magid et al (2003) designed optimal multi objective multimachine PSSs using GA. A conventional speed-based lead-lag PSS was used in this work. The multimachine power system operating at various loading conditions and system configurations was treated as a finite set of plants. The stabilizers were tuned to simultaneously shift the lightly damped and undamped electromechanical modes of all plants to a prescribed zone in the s-plane. A multi objective problem was formulated to optimize a composite set of objective functions comprising the damping factor, and the damping ratio of the lightly damped electromechanical modes. The problem of robustly selecting the parameters of the power system stabilizers was converted to an optimization problem which was solved by a genetic algorithm with the eigenvalue-based multi objective function.

The eigenvalue analysis confirmed that the closed-loop plant performance was consistent with the design requirements in spite of changes in the operating conditions, and reveals the superiority of the PSSs tuned using the multi objective function in damping local and interred modes of oscillations. Lee (2005) discussed an optimal decentralized output-feedback PSS. The PSS design problem was converted to an optimization problem with dynamics-objective function. Output-feedback gains of the stabilizers were obtained by using genetic algorithms. Only the local and available state was taken as the input signals of each PSS. Guidelines$\delta\Delta$ and &$\omega\Delta$ variables for choosing the weighting factors affecting the system performance were also suggested. Eigen value analyses gave the satisfactory damping on system modes, especially the low-frequency modes, for systems with the proposed PSSs. Time-domain simulations explained that the oscillations of synchronous machines could be quickly and effectively damped for power systems with the introduced PSSs. Abido et al (1997) applied GA to search for optimal or near optimal settings of FLPSS parameters. Incorporation of GA in FLPSSs design added an intelligent dimension to these stabilizers and significantly reduced the time consumed in the design process. It was shown that the performance of FLPSS could be improved significantly by incorporating a genetic-based learning mechanism. The performance of the proposed HPSS under different disturbances and loading conditions was investigated. The results showed the superiority and robustness of the proposed Hybrid PSS (HPSS) as compared to classical PSS and its capability to enhance system damping over a wide range of loading conditions.

3. Optimization Technique

Optimization is the process of finding the conditions that give the maximum or minimum value of a function subject to a set of constraints. The conventional design procedures aim at finding an acceptable or adequate design which satisfies the functional and other requirements of the problem. In general there will be more than one acceptable design, and the purpose of optimization is to choose the best one of the many acceptable designs available. Thus a criterion has to be chosen for comparing the different alternative acceptable designs and for selecting the best one. The criterion, with respect to which the design is optimized, when expressed as a function of the design variables, is known as the objective function. The choice of the objective function is governed by the nature of the problem. The objective function may be of minimization type or maximization type. In many practical problems, the design variables cannot be chosen arbitrarily; rather they have to satisfy certain specified functional and other requirements. The restrictions that must be satisfied to produce an acceptable design are called design constraints. The constraints may be of equality or inequality type. In this section an eigen value based objective function subjected to a set of constraints will be formulated.

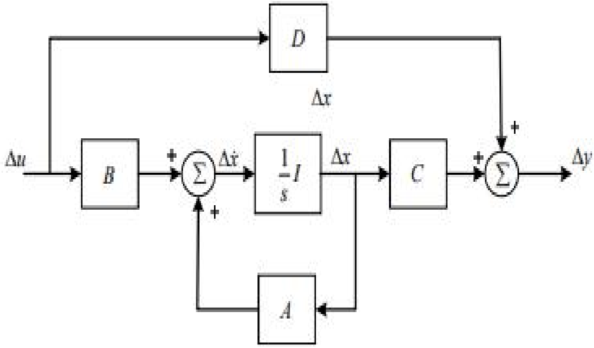

Fig 2: Block diagram of state-space representation

The method of linearization of nonlinear system to stabilize the system was discussed in this chapter. The minimization objective function was formulated based on eigen values to locate the real part of the eigen values at far most distance to the left hand side of complex s-plane. The constraints for the objective function were set based on the limits of the stabilizer parameters.

4. Testing Anlysis

In This Part of The Study, A Smib Through A Transmission Line, And Operating At Different Loading Conditions, Is Considered. The Linearized Model Of This System, Voltage Regulator And Exciter Included Is Considered. The Constants K1 To K6, With The Exception Of K3, Which Is Only A Function Of The Ratio Of Impedance, Are Dependent On The Actual Real Power (P) And Reactive Power (Q) Loading As Well As The Excitation Levels In The Machine. The Operating Points Are Selected Based On The Different Loading Conditions (El-Sherbini And Mehta 1973). The Simultaneous Damping Enhancement Of The System Is Demonstrated By Considering Five Different Loading Conditions.

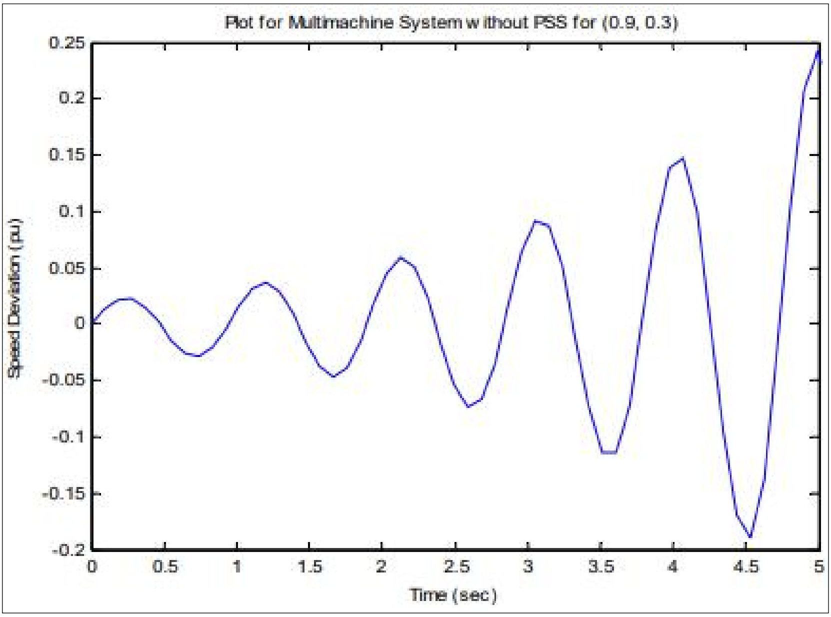

Fig 3: Response of the system without PSS for 01 01 P,Q = (0.9, 0.3)

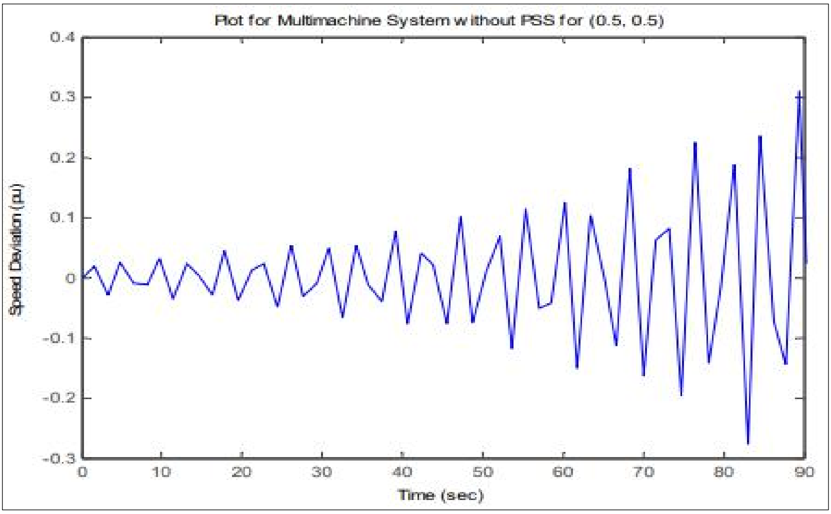

Fig 4: Response of the system without PSS for 03 03 P,Q = (0.5, 0.5)

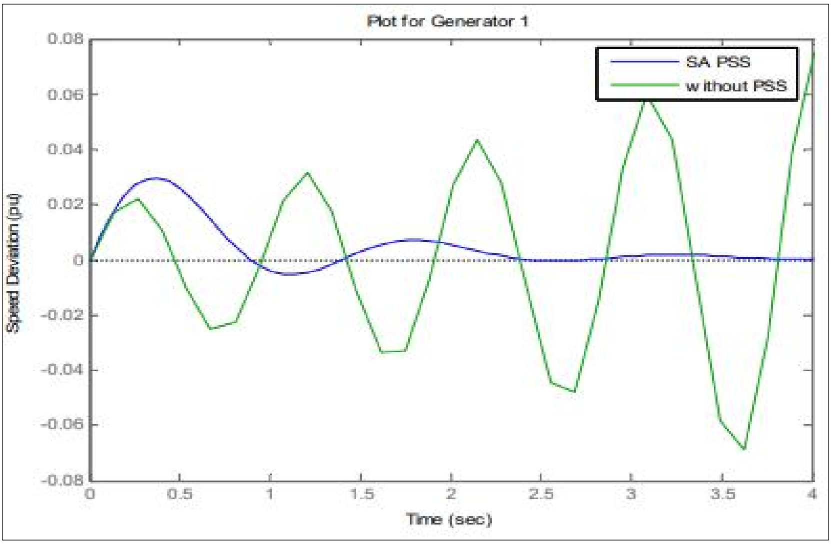

Fig 5: Response of 4- machine 10-bus system with and without PSS

Conclusion

The thesis employs artificial intelligence techniques to design robust decentralized power system stabilizers. One of the primary requirements of a good decentralized method is that the resulting PSS should be robust enough to wide variations in system parameters, at the same time being computationally manageable. In the present work robust PSS is designed for

SMIB system, 4-machine 10-bus system and 10-machine 39-bus system. The SA technique was implemented for SMIB and multimachine systems. Initially the response of the SMIB system was obtained without PSS. Then PSS was included and the responses were obtained for various operating points. The three phase faults were introduced in multimachine systems and the responses were obtained for the generators near to the fault. It was proved that the SA was efficient in reducing the generator rotor oscillations. Due to the selection of random numbers in the range of 0 to 1 for acceptance criterion, the same operating may have different settling time and peak amplitude for the same kind of fault. In 4-machine 10-bus system, the generator 3 is perturbed more than any other generators in the system due to the fault assumed. The response for generator 3 is having the settling time as 8.95 seconds which is almost near to the settling time obtained by Abide et al (2000). In 10-machine 39-bus system, a three phase fault at bus 29 at the end of line 26-29 with reclosing time of 1.0 seconds is considered.

References

1. Chiang CL. Improved genetic algorithm for power economic dispatch of units with valve-point effects and multiple fuels', IEEE Transactions on Power Systems. 2005;20(4):1690-1699.
2. Choi SS, Jia XM. Coordinated design of under-excitation limiters and power system stabilizers', IEEE Transactions on Power Systems. 2000;15(3):937-944.
3. Chow QB, Kundur P, Acchione PN, Lautsch B. Improving nuclear generating station response for electrical grid islanding, IEEE Transactions on Energy Conversion. 1989;EC-4:406-413.
4. Chuanjiang Zhu, Mustafa Khammash, Vijay Vittal, Wenzheng Qiu. 'Robust power system stabilizer design using H loop shaping approach' IEEE Transactions on Power Systems. 2003;18(2):810-818.
5. CIGRE Working Group 14.05 Report. Guide for Planning DC Links Terminating at AC Systems Locations Having Low ShortCircuit Capacities Part I: AC/DC Interaction Phenomena, CIGRE Guide, 1992, 95.
6. De Mello FP, Concordia C. Concepts of synchronous machine stability as affected by excitation control, IEEE Transactions on Power Apparatus and Systems. 1969; PAS-88:316-327.
7. Dechanupaprittha S, Ngamroo I, Pasupa K, Tippayachai J, Hongesombut K, Mitani Y. New heuristic-based design of robust power

system stabilizers, Proceedings of International conference on Power System Technology, Singapore. 2004, 618-623.

8. Demello FP, Charles Concordia. Concepts of synchronous machine stability affected by excitation control', IEEE Transactions on Power Apparatus and Systems. 1969; PAS-88(4):316-329.

9. DeMello FP, Laskowski TF. Concepts of power system dynamic stability, IEEE Transactions on Power Apparatus and Systems. 1979;PAS-94:827-833.