

**ON SOME ASPECTS OF CONVENTIONAL AND
ARTIFICIAL NEURAL NETWORK BASED
POWER SYSTEM STABILIZERS**

By

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DEPARTMENT OF ELECTRICAL ENGINEERING

Submitted

in fulfilment of the requirements of the degree of

DOCTOR OF PHILOSOPHY



to the



**INDIAN INSTITUTE OF TECHNOLOGY, DELHI
INDIA**

December, 1998

TH
681.3:621.311
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CERTIFICATE

Certified that the dissertation entitled "**ON SOME ASPECTS OF CONVENTIONAL AND ARTIFICIAL NEURAL NETWORK BASED POWER SYSTEM STABILIZERS**" being submitted by **Mr. Ravi Segal** to the Indian Institute of Technology, Delhi for the award of **Doctor of Philosophy in Electrical Engineering**, is a record of bonafide research work carried out by him. He has worked under my supervision and guidance and has fulfilled the requirement for submission of the thesis. The matter embodied in this discussion has not been submitted elsewhere in part or full for the award of any other degree or diploma.

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ACKNOWLEDGEMENTS

I take this opportunity to express my deep sense of gratitude to my research supervisor Prof. M. L. Kothari, Department of Electrical Engineering, Indian Institute of Technology, Delhi for his inspiring and stimulating guidance, invaluable thought provoking suggestions, constant encouragement and unceasing enthusiasm at every stage of this research work.

It has been my proud privilege to work with Prof. M. L. Kothari, a luminary in the field of power system engineering. His excellent and aesthetics oriented guidance has helped immensely in shaping up this thesis. I shall remain obliged and indebted to him. I also thank Mrs. M. L. Kothari for her kind gestures and the encouragement received from her during this research work.

I wish to thank Prof. T. K. Nagsarkar, Department of Electrical Engineering, Punjab Engineering College, Chandigarh for his continuous encouragement throughout this research work.

I am thankful to the management of M/s Bharat Heavy Electricals Limited, Power Sector, Northern Region, Delhi, particularly Mr. P. P. Chander, Ex-General Manager and Mr. A. Dasgupta, Ex-Sr. Dy General Manager who extended all possible support for pursuing this research work.

I am extremely grateful to the management of M/s GE Power Services (I) Limited especially, Mr. S. K. Daspatnaik, Managing Director and Mr. G. K. Upadhyay, Executive Director for their exceptional support during the critical phase of this research work.

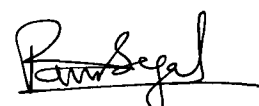
I am also thankful to Mr. Shekhar Madnani, Project Scientist and Mr. Nitin Srivastava, Project associate working on the research project entitled, "Tuning of power system stabilizers" for their sincere contributions at different stages of this work.

I sincerely acknowledge the encouragement and moral support received from my mother – Mrs. Sarla Segal, my brother– Deepak, my sister–in–law–Monica, and my parent–in–laws– Mr. A. D. Dewan and Mrs. Usha Dewan at every stage of this work. I also thank for the loving and moral boosting support received from Davender Makkar, Deepika Makkar, Ravi Dewan and Gunjan Dewan.

Thanks are due to all my relatives, friends and colleagues who have contributed directly or indirectly to the completion of this work.

Above all, I am extremely grateful to my wife Indu and my son Vishi for their excellent cooperation during the entire period of this research work. Their loving, caring and sacrificing attitude has been the driving force in this endeavor and, no word of thanks are enough.

December 1998



(Ravi Segal)

Dedicated

to

the fond memory of

My father

Late Sh. Jagdish Narain Segal

ABSTRACT

The thesis deals with some aspects of conventional (i.e., Delta–Omega), dual input, artificial neural network and radial basis function (RBF) network based power system stabilizers for an interconnected power system. The input signal to Delta–Omega PSS is deviation of the shaft speed. The dual input power system stabilizers use deviations in electrical power and shaft speed to derive the stabilizing signal.

Small perturbation dynamic models of a machine–infinite bus system in state–space form considering IEEE type ST1A model of static excitation system with and without PSS have been presented. The effect of variation of AVR gain and equivalent reactance, X_e on stable region in the P–Q plane has been investigated. The variation of loading condition (P, Q) and X_e on “Plant” phase characteristic has been analyzed. An approach for the optimization of PSS parameters using phase compensation technique has been presented. The effect of variation of degree of undercompensation and X_e on optimum PSS parameters and dynamic performance of the system has been analyzed. Explorations for selecting a most suitable loading condition and X_e , for the design of optimum PSS, such that the performance of the PSS is robust over a wide range of loading condition (P, Q) and variation in X_e , have been carried out. Investigations reveal that the optimum PSS corresponding to a low leading power factor, heavy loading condition is quite robust to wide variations in loading condition. Further studies show that an undercompensation of about 30° is desirable for the optimization of PSS parameters. Investigations also show that the optimum PSS corresponding to a weakly interconnected system (i.e., large X_e) exhibits improved performance with the stiff systems (a small X_e). However, the reverse is not true. Investigations clearly demonstrate the capability of a suitably designed PSS, in terms of significant increase in stable operating region in the

P–Q plane. Studies clearly reveal that the PSS also assists in stabilizing the system under large perturbations.

A new small signal transfer function model of a single machine–infinite bus (SMIB) system including amortisseurs in the synchronous generator model has been developed. The effect of including amortisseurs in the dynamic model of the synchronous generator on “Plant” phase characteristic and optimum parameters of the conventional PSS has been investigated. Investigations have been carried out to answer the pertinent question, “Whether the simplified model of the synchronous generator obtained neglecting amortisseurs, is adequate for optimizing the parameters of the PSS”? Studies reveal that the dynamic performance of the actual system, with PSS optimized considering simplified model of the synchronous generator is quite acceptable and hence for the purpose of optimizing the PSS, amortisseurs can be divorced comfortably from the mathematical model of the synchronous generator.

The performance of IEEE recommended models of the dual input PSS (i.e., PSS2B, PSS3B and PSS4B) has been analyzed. A systematic approach for optimizing the parameters of the dual input PSS using ISE technique, has been presented. The studies show that the performance of the system with optimum PSS4B model is quite superior to that of the PSS2B or PSS3B models of the dual input power system stabilizers. Moreover, the performance of the system with PSS4B–dual input power system stabilizer is quite robust to wide variation in loading condition provided the parameters are optimized for a suitable loading condition. Studies also reveal that the dual input power system stabilizers are quite effective in enhancing stability of the system under large perturbations.

- New approaches for real–time tuning the parameters of a conventional PSS using artificial neural network (ANN) and radial basis function (RBF) network have been proposed.

The relative merits of real-time tuning the power system stabilizer, using these alternative techniques have been examined.

The main thrust of the research work presented pertaining to the design of ANN based PSS is to address some of the important issues, e.g., selection of elements of the input vector of the training pattern, number of training patterns, selection of number of neurons in the hidden layer, selection of sampling period and evaluation of performance of the ANN based adaptive PSS (ANNAPSS). A new approach for selecting an adequate number of neurons in the hidden layer has been proposed. Studies show that the ANNAPSS provides slightly better dynamic performance than the conventional PSS at the nominal operating condition. However, the dynamic performance of the system with ANNAPSS is much superior to that with the conventional PSS for the system loadings different from the nominal. Further investigations reveal that the performance of ANNAPSS is quite robust to wide variations in loading condition and X_c .

The RBF network is trained using an efficient orthogonal least squares (OLS) learning algorithm. The effect of spread factor and number of training patterns on required number of RBF centers has been studied. An approach for the selection of adequate number of RBF centers has been proposed. The effect of variation of loading condition and X_c on dynamic performance of the system with RBF network based adaptive PSS (RBFAPSS) has been investigated. Investigations reveal that the required number of RBF centers depend on spread factor β and number of training patterns. Studies show that an adequate and parsimonious RBF network for tuning the conventional PSS can easily be realized by presenting a relatively smaller number of training patterns, randomly generated spreadover the complete operating domain. Moreover, there is no merit in training an RBF network by presenting a large number of training patterns. Studies reveal that the dynamic performance of the system with

RBFAPSS is virtually identical to that with ANNAPSS. Investigations clearly show that the performance of an RBFAPSS like ANNAPSS is quite robust to wide variations in loading condition and X_c . The structure of an RBF network is simpler to that of ANN. The RBF network also has an edge over ANN in terms of robustness and quickness of learning.

Investigations have been carried out for arriving at a maximum permissible sampling period for practical implementation of ANNAPSS as well as RBFAPSS without jeopardizing the dynamic performance. Studies show that the maximum permissible sampling period with ANNAPSS is limited to 35 milliseconds while that with RBFAPSS is limited to 45 milliseconds.

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