

ARTIFICIAL NEURAL NETWORK AND FUZZY LOGIC SYSTEM BASED POWER SYSTEM STABILIZERS

By

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CERTIFICATE

This is to certify that the dissertation entitled “**ARTIFICIAL NEURAL NETWORK AND FUZZY LOGIC SYSTEM BASED POWER SYSTEM STABILIZERS**”, being submitted by **Mr. Avdhesh Sharma** to the Indian Institute of Technology, Delhi for the award of the degree of **Doctor of Philosophy in Electrical Engineering**, is a record of bona fide 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 thesis, in my opinion, has attained the requisite standard for the award of a Ph.D. degree of this institute. The results contained in this thesis have not been submitted elsewhere in part or full for the award of any other degree or diploma.



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A handwritten signature in black ink, appearing to read 'Avdhesh Sharma', with a long horizontal stroke extending to the right.

(Avdhesh Sharma)

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ABSTRACT

The thesis deals with some aspects of conventional, artificial neural network, Fuzzy logic and adaptive network fuzzy inference system (ANFIS) based dual input power system stabilizers for an interconnected power system.

A linear dynamic model of a single machine-infinite bus (SMIB) system has been developed in state-space form considering governor, turbine, turbine-generator shaft and excitation system models. Modal analysis has been carried out for identifying the modes of oscillations. Investigations have been carried out considering single input (i.e., Delta-Omega) and dual input (i.e., Delta-P-Omega) power system stabilizers. A novel approach based on phase compensation and ISE techniques, has been proposed for optimizing the parameters of the PSS. The limitation on gain setting of the single-input PSS in terms of excitation of torsional modes has been studied in detail. Studies reveal that the optimum gain setting of the Delta-Omega PSS obtained using simplified dynamic model of the system is not acceptable for a realistic system, i.e., with detailed dynamic model including governor, turbine, and turbine-generator shaft models even if torsional filter is incorporated. The gain setting of the Delta-Omega PSS needs to be restricted to a low value in order to ensure that none of the modes are adversely affected with the incorporation of the PSS. However, investigations show that the gain setting and time constants of the dual input PSS obtained considering a simplified dynamic model are acceptable for the actual system, i.e., including governor, turbine, and turbine-shaft models.

A new approach for real-time tuning the parameters of the dual input PSS using a feed forward artificial neural network has been proposed. The main thrust of the research work presented pertaining to ANN based dual input PSS (ANN-DIPSS) is to address some of the pertinent issues, e.g., selection of the input vector of the training

pattern, number of training patterns, number of hidden layers, number of neurons in each of the hidden layers, and sampling period. Investigations show that ANN with one hidden layer comprising 9 neurons is quite adequate for ANN-DIPSS. The dynamic performance of the system with ANN-DIPSS is analyzed and compared with the conventional DIPSS. Studies show that the ANN-DIPSS provides slightly better dynamic performance as compared to that of the conventional DIPSS both at the nominal and off-nominal operating conditions. Investigations show that the performance of ANN-DIPSS is quite robust to a wide range of loading conditions and equivalent reactance, X_e .

Studies show that for the system investigated, permissible maximum value of sampling period is around 35 milliseconds for realizing the ANN-DIPSS.

A systematic approach for designing a Fuzzy Logic Dual Input Power System Stabilizer (FL-DIPSS) has been presented. FL-DIPSS comprising different primary fuzzy sets, and shapes of the membership functions has been designed and their performances evaluated. An approach for tuning the parameters of FL-DIPSS using ISE technique has been presented. Investigations reveal that in general the performance of FL-DIPSS based on Gaussian-shaped MFs is somewhat superior to those based on either triangle-shaped or Trapezoid-shaped MFs.

A new reduced size rule set based FL-DIPSS has been proposed. Studies show that FL-DIPSS appropriately designed with a reduced size rule set exhibits dynamic performance comparable to those based on full size rule set either with 7 or 5 primary fuzzy sets of Gaussian-shape. Further investigations reveal that the dynamic performance of the system with FL-DIPSS is quite robust to wide variations in loading condition and line reactance X_e .

Two new distinctly different forms of ANFIS based dual input PSS [i.e., (a) ANFIS based adaptive DIPSS and (b) Real-time ANFIS tuned DIPSS] have been proposed for effective damping of power system oscillations. A systematic approach for designing ANFIS based adaptive PSS and real-time ANFIS tuned dual input PSS has been presented. Investigations reveal that the dynamic performance of the system with ANFIS based adaptive PSS [ANFISPSS(A)] is virtually identical to those obtained with two alternative forms of real-time ANFIS tuned dual input PSS [i.e., ANFISPSS(T1) and ANFISPSS(T2)]. ANFISPSS (T2) may be preferred over the other two [i.e., ANFISPSS(A) and ANFISPSS(T1)] in view of its relatively simple structure and easier training process. Studies show that the performances of the ANFIS based dual input power system stabilizers using 3, 5, and 7 Gaussian shaped MFs hardly differ from each other and hence it may be recommended that a simple ANFIS based dual input power system stabilizer may be realized with 3 Gaussian shaped MFs.

A linear dynamic model of a multi-machine system with and without dual input power system stabilizers has been developed. A model analysis is applied for identifying most suitable locations of power system stabilizers in a multi-machine system. An approach based on sequential application of ISE technique for optimizing the PSS parameters of a multi-machine system has been presented.

A new approach for designing real-time tuned ANFIS based dual input power system stabilizers for a multimachine system has been presented. Investigations reveal the dynamic performance of the multi-machine system with ANFIS based dual input power system stabilizers is quite robust under wide variation in loading condition for both small and large perturbations.

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