POWER QUALITY ANALYSIS AND HARMONIC CONTROL IN DISTRIBUTION NETWORK

by

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CERTIFICATE

This is to certify that the thesis entitled "**POWER QUALITY ANALYSIS AND HARMONIC CONTROL IN DISTRIBUTION NETWORK**" which is being submitted by Shri Chandrashekhar Narayan Bhende to the Indian Institute of Technology Delhi, for the award of Doctor of Philosophy, is a bona fide research work carried out by him. He has worked under my supervision and guidance and has fulfilled the requirement for the submission of this thesis. The thesis, in my opinion, has attained a standard required for 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 degree or diploma.

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ABSTRACT

In electric power distribution network, degradation in quality of electric power is normally caused by power-line disturbances such as voltage sag/swell with and without harmonics, momentary interruption, harmonic distortion, flicker, notch, spike and transients, causing problems such as malfunctions, instabilities, short lifetime, failure of electrical equipments and so on. To improve power quality, at the outset these disturbances need to be monitored and identified at various distribution buses. Once the disturbance is identified, the utility and/or customer has to decide which kind of mitigating action (e.g., active power filters, power conditioners, etc.) can be taken so that the disturbance does not cause any adverse effect on the equipments or processes. Since manual monitoring is tedious and may loose the important information while monitoring, a robust method for automatic classification of disturbances is highly demanded.

In this thesis different classifiers for identifying PQ disturbances are developed based on two types of methods namely rule-based and Neural Network based schemes. In rule-based scheme an integrated approach of Wavelet and Rough Set Theory is used for the classification of PQ disturbances. The number of features and the rules required for proper classification are decided through Rough Set technique. Moreover, as the proposed methodology can reduce the number of features extracted through Wavelet to a great extent, it will indirectly reduce the memory requirement for the classification procedure. Eleven types of PQ disturbances which are mentioned above are considered for classification. The simulation results show that the combination of Wavelet and Rough Set Theory can effectively classify

different power quality disturbances. Since rule based approach is easy to understand and simple to implement, the Rough Set technique is a good candidate for the classification of PQ disturbances.

On the other hand in Neural Network based scheme, the S-Transform based probabilistic neural network (PNN) classifier is developed for classification of PQ disturbances. The proposed method requires less number of features as compared to wavelet based approach for the identification of PQ events. The features extracted through the S-Transform are trained by a PNN for automatic classification of the PQ events. Since the proposed methodology can reduce the features of disturbance signal to a great extent without losing its original property, less memory space and neural network learning time are required for classification. Eleven types of disturbances are considered for the classification. The simulation results reveal that the combination of S-Transform and PNN can effectively detect and classify different PQ events. The classification performance of PNN is compared with feed forward multilayer (FFML) NN and learning vector quantization (LVQ) NN. It is found that the classification performance of PNN is better than both FFML and LVQ. In case of PNN the numbers of hidden neurons are equal to the number of training patterns and hence the structure of PNN becomes complex as far as implementation is concerned. Hence, the Modular NN is tried to reduce the structure complexity. The Modular NN has obvious advantages of simple and better learning capabilities because of its reduced sub-divided architecture. The simulation results show that the combination of the S-Transform and a Modular NN can effectively detect and classify different power quality disturbances.

Once the PQ disturbances have been identified by the classifier, the next step is to install a device which can mitigate the disturbance. Among the various PQ disturbances the harmonic mitigation through three-phase shunt Active Power Filter (APF) is carried out in this thesis. The conventional method of obtaining the coefficients of proportional plus integral (PI) controller for the active power filter (APF) utilizes a linear model of the PWM inverter. The values so obtained may not give satisfactory results for a wide variation in operating condition. In this thesis a new algorithm based on the foraging behavior of *E.coli* Bacteria in human intestine is presented to optimize the coefficients of PI controller. Through the simulation results, it is observed that the dynamic response of PI controller optimized by bacterial foraging technique (BF-PI controller) is quite superior as compared to conventional PI controller. Besides it is found that the proposed BF technique converges faster than that of Genetic Algorithm (GA) to reach the global optimum solution.

Moreover, the Takagi-Sugeno (TS) type fuzzy logic controller which is also a variable gain controller is investigated for the control of APF. The advantage of fuzzy logic control is that it does not require a mathematical model of the system. The application of Mamdani type fuzzy logic controller to three-phase shunt APF have been investigated earlier. However, it has the limitation of more number of fuzzy sets and rules. Therefore, it needs to optimize large number of coefficients, which increases the design complexity of the controller. On the other hand, TS-Fuzzy controller could be designed by using less number of rules and classes. Simulation results show that the dynamic behavior of TS-Fuzzy controller is better than the conventional PI controller and is found to be more robust to changes in load and other system parameters as compared to the conventional PI controller.

CONTENTS

4. S-TRANSFORM AND MODULAR NEURAL NETWORK BASED APPROACH FOR CLASSIFICATION OF PQ DISTURBANCES

5. BACTERIAL FORAGING TECHNIQUE BASED OPTIMIZED ACTIVE POWER FILTER FOR HARMONIC ELIMINATION