AIN SHAMS UNIVERSITY
FACULTY OF ENGINEERING

ELECTRICAL POWER AND MACHINES DEPARTMENT

AI-Based Filter for Harmonic Suppression and Harmonic Flow Control in Electrical Power Networks

This Thesis is submitted in partial fulfillment of the requirements for the

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in

Electrical Engineering (Power and Machines)

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APPROVAL SHEET

AI-Based Filter for Harmonic Suppression and Harmonic Flow Control in Electrical Power Networks

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The examining committee approve that the thesis meets the standard of the Ph.D. degree in electric power engineering.

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بسم الله الرحمن الرحيم

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مِنْ عَلَقٍ (2) اقْرَأْ وَرَبُّكَ الأَكْرَمُ (3) الَّذِي

عَلَّمَ بِالْقَلَمِ (4) عَلَّمَ الإِنسَانَ مَا لَمْ يَعْلَمْ (5)

صدق الله العظيم

سورة العلق

STATEMENT

This thesis is submitted to Ain Shams University in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Electrical Engineering (Power and Machines).

The work included in this thesis is carried out by the author at the Electrical Power and Machines Department, Ain Shams University. No part of this thesis has been submitted for a degree or a qualification at any other university or institute.

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Dedicated to my mother, father and sister, the greatest family on earth.

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They were always there to encourage and support me.

ABSTRACT

Nonlinear loads and all kinds of static power converters inject harmonics into electrical power systems and, consequently, can affect other loads connected to the same system if significant harmonic voltage distortions are caused.

The main objective of the this thesis is to develop a new simple, efficient and reliable optimal Active Power Filter (APF) controller based on artificial intelligence techniques that could effectively capable to compensate and reduce current and voltage harmonic distortion to the limits defined by international standards.

The shunt APF topology is used for this study in conjunction with the shift method of the Multi-layer Artificial Neural Network (ML-ANN) for estimation of the power system harmonic currents and voltages at a dedicated point.

The simple structure of the shift method of the ML-ANN applied for estimating the value of the fundamental current is found to be powerful and accurate enough in the field of adaptive filtering.

A control scheme making use of two independent ML-ANNs is developed. The first ANN extracts the harmonic current components of the distorted line current signal and the second ANN estimates the fundamental component of the line voltage signal. The outputs of the two ANNs are used to construct a modulating signal by subtracting the desired source currents (fundamental frequency components) from the load signals (distorted signals) then divided by the fundamental signal to obtain the final compensation signals used in the modulation process.

The control technique used is based on the multi-loop feedback control schemes, which was originally used in the single-phase uninterruptible power supply equipment. This multi-loop feedback control method is used to implement the compensation scheme for the proposed APF design.

The proposed control strategy for the APF has been tested by applying it to a 13 bus test system consisting of Balanced Industrial Distribution System which is a typical medium-sized industrial plant. The system is extracted from a common system that is being used in many of the calculations and examples in the IEEE Color Book series.

The proposed controller and the test system were simulated by Matlab-Simulink software for many cases. Results showed that the proposed APF

control strategy effectively fulfills the required constraints with an optimal value of the performance index. With the new design, it requires less effort on the realization of the filter control circuit while maintaining a good filter performance when different constraints imposed on the filter as well as on the nonlinear load are under considerations.

The proposed shunt active filter using adaptive neural network (NN) extraction algorithm and PI-controller with Particle Swarm Optimization (PSO) control algorithms approach is adaptive, reliable and fast for harmonic compensation in the various changes in system operating conditions.

The proposed filter is used to reduce the harmonic current distortion resulting from some typical nonlinear loads. The nonlinear loads under study are an adjustable speed drive with a 6-pulse converter. The results showed that considerable reduction in the total harmonic current distortion is achieved for each of these applications.

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