Neural Network Controlled Hybrid Active Power Filter with Distorted Mains for PMSM Drive

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ABSTRACT
The present paper describes dynamic neural network controlled Hybrid Active Power Filter (HAPF) designed for harmonic compensation under variable conditions. A Neural Network based Controller is employed to extract the fundamental component of current from non-sinusoidal and unbalanced source currents of the considered supply system. Hybrid filter utilizing the merits of both shunt passive and active filter for better compensation performance is applied in this work. Simulations are carried out using MATLAB/Simulink to show effectiveness of proposed methodology. The experimental results show excellent behavior of Neural Network Controller and performances of HAPF under various conditions.

Keywords - Artificial neural network (ANN) controller, Hybrid active power filter, Permanent magnet synchronous motor (PMSM), Total Harmonic Distortion (THD)

I. INTRODUCTION
Nowadays the power quality problems are mostly faced by the equipments based on the power electronic devices which are used by the industry. The need of these devices is not only the high quality energy for proper working but also the major cause for decreasing of the power quality. By these conditions of the electric power the customers are increasingly affected. Therefore, a power quality problem exists if any of the voltage, current or frequency deviation from sinusoidal nature occurs. Power quality problems are common in industrial, commercial and utility networks as power electronics appliances are widely used in these fields. These appliances generate harmonics and reactive power. Therefore it is very important to compensate the dominant harmonics and thus Total Harmonic Distortion (THD) below 5% as specified in IEEE 519 harmonic standard [1]. On the improvement of power quality, utilities and researches all over the world have for decades worked. To the power quality problems there are many sets of conventional solutions which have existed for long time. Nowadays the equipment made up of semiconductor devices is sensitive as well as polluting. Increase in reactive power demand by the equivalent load is due to the non linear devices like power electronic converters which also results in injection of harmonic currents in distribution grid. As it is well known that reactive power demand increases the losses and cause a drop in feeder, which also results in additional losses, voltage waveform distortion and poor power quality. So it is necessary to include some sort of compensation to keep the power quality within limits proposed by standards.

The shunt active power filter (APF) is a device that is connected in parallel and cancels the reactive and harmonic currents from a nonlinear load. The resulting total current drawn from ac main is sinusoidal. Ideally, the APF needs to generate the reactive and harmonic current to compensate the nonlinear loads in the line. In an APF depicted, current controlled voltage source inverter is used to generate the compensating current and is injected into utility power source grid. It cancels the harmonic components drawn by nonlinear load and keeps the utility line current sinusoidal. A voltage-source inverter (VSI) having IGBT switches and an energy storage capacitor on dc bus are implemented as a shunt APF. The main aim of the APF is to compensate the harmonics and reactive power [3].

Active power filter is a dynamic and flexible solution for mitigation of harmonic current due to their compact size, no requirement of tuning and stable operation. Active power filter acts as harmonic current source to provide the emphatic result to compensate for harmonic currents as well as reactive power. It has the capability to inject harmonic current into ac system with the same amplitude but in opposite phase of the load [2]. As the HAPF is complex with cost effective parameter control, the hybrid active power filter has been preferable in subject of harmonic solution. HAPF gives the efficacious combination of passive and active filter, which implies the advantages of both and eliminates the short-comes of each one. [4].

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In this paper, a new hybrid filter topology is proposed to reduce torque ripples, voltage harmonics in PMSM. The filter topology consists of the IGBT active filter (AF). Power circuit for APF is proposed as an IGBT based three-phase voltage source inverter with DC storage capacitor for the better compensation of non-linear unbalanced/balanced loads. ANN controller is used to generate the fundamental from non-ideal voltage source. The extracted fundamental currents are then subtracted from the source current to evaluate the reference signal i.e. harmonic current. The proposed controller has self-learning with high accuracy and simple architecture and it can be successfully applied for the harmonic filtering under various power system operating conditions. Therefore, this paper presents a hybrid power filter using neural network-controller to control the harmonics under different non-sinusoidal and unbalanced source/load conditions for its performance [5].

II. PROPOSED TOPOLOGY

Three phase three wire hybrid power filter is used; Shunt active power filter is used to generate the compensation current in opposite phase. Power circuit for APF is proposed as an IGBT based three-phase voltage source inverter with DC storage capacitor for the better compensation of loads. In this paper the load is Permanent Magnet Synchronous Motor (PMSM). Active power filter has control scheme; neural network controller that accounts for reference current generation. ANN comprises three adaptive linear neurons to extract the fundamental components of three phase voltages from non-sinusoidal supply. The capacitors are designed to limit the dc voltage ripple to a specified value, typically 1 to 2%. In this case the capacitor should be designed for worst case. Since the active filter will operate in several modes (balanced or unbalanced load), then the injection of compensation current is done in order to nullify or mitigate the harmonic currents. Injection of this compensation current gives improved power quality. The performance of the active power filters is dependent to a great extent upon the method used for the calculation of reference current.

III. CONTROL STRATEGY

1. Neural Network Controller

ANNs have the ability to approximate the input–output relations with acceptable accuracy regardless of the complexity involved. This, in addition to many other abilities of parallel computation and adaptiveness to external disturbances, has made ANN a promising approximation technique in power system applications. The most commonly used ANN structures for fundamental and/or harmonic extraction are the ADALINE and feed-forward MNN. The focus of this paper is on how to implement the ANN techniques in power system. Power quality enhancement using shunt APF is considered for the effective illustration. The architecture of proposed ADALINE neural network has two layer (input and output) network having n-inputs and a single output [6].
The basic blocks of this network are input signal delay vector, a purelin transfer function, weight matrix and bias is shown in figure 3. The input output relationship is expressed as:

\[ Y = \sum_{n=1}^{\infty} w_n^* i_n + b \]  

(1)

Where ‘b’ is bias, ‘w’ is weight, and ‘i’ is the input to the Neural Network. The input to the network is a time delayed series of the signal whose fundamental component is to be extracted. The length of this delay series is 61, which has been decided considering expected maximum distortion and unbalance in 3-phase input signal [4].

The input of the ANN system is supply voltage and current and the output of the system is APF reference current. The weight adjustment is performed during the training process of the ADALINE using Widrow-Hoff delta rule [6]. The ADALINE is a two-layer neural network consisting of an input layer and output layer. It was invented by Widrow and Hoff when they were trying to implement their famous training algorithm, the least mean square (LMS). It can estimate functions that have linear input–output relations, and can work fairly even with some nonlinear real-world applications [6].

IV. RESULT

The system was subjected to different load conditions and the Permanent Magnet Synchronous Motor was operated for a reference speed of 52.3rad/sec under the following conditions:

Case I: At no load with rated speed.

Case II: On Load with rated speed.
Fig. 5: (a) Source Voltage, (b) Load Current, (c) Source Current, (d) THD, (e) Motor Torque, (f) Speed response
Case III: Change in load with rated speed.
Case IV: On Load with change in Speed.

V. CONCLUSION

In this paper, a new Hybrid Active Power Filter topology has been presented and analyzed. The filter topology combines the compensation characteristics of the shunt active power filter and passive filter. The proposed topology has been shown to be capable of reducing the torque ripple and current harmonics, and providing almost sinusoidal voltage to motor terminals, which was reflected in a smoother line current waveform.

REFERENCES


