Ain Shams Engineering Journal (2011) 2, 161–172

Ain Shams University

Ain Shams Engineering Journal

www.elsevier.com/locate/asej
www.sciencedirect.com

ELECTRICAL ENGINEERING

Active power filter controller for harmonic suppression in industrial distribution system

Wael M. El-Mamlouk [a], Hossam E. Mostafa [b,*], Metwally A. El-Sharkawy [c]

[a] Shaker Consultancy Group, Cairo, Egypt
[b] Electrical Department, Faculty of Industrial Education Suez Canal University, Suez, Egypt
[c] Department of Electrical Power and Machines, Faculty of Engineering, Ain Shams University, Cairo, Egypt

Received 12 March 2011; revised 22 July 2011; accepted 5 September 2011
Available online 28 October 2011

KEYWORDS

Active power filter;
Artificial neural network;
Harmonics compensation;
Power quality

Abstract In this paper, an efficient active power filter (APF) scheme is developed to estimate and compensate for harmonic distortion in an electrical power network. The developed APF control scheme is based on a double proportional feedback controller and a single-phase voltage-source half-wave bridge inverter. The proposed filter uses a Multi-layer Artificial Neural Network (ML-ANN) with a shift method for estimating system harmonic currents and voltages at a dedicated point. The proposed scheme is tested on a 13 bus industrial distribution system. The obtained results ensure the effectiveness of the proposed filter. The system is simulated in MATLAB-Simulink and simulation results prove that the polluting harmonics have been greatly reduced.

1. Introduction

Due to the increase of non-linear loads drawing nonsinusoidal currents, power quality distortion has become a serious problem in electrical power systems.

* Corresponding author. Tel.: +20 127213772.
E-mail addresses: welmamlouk@ieee.org (W.M. El-Mamlouk), hossam.mostafa@ieee.org (H.E. Mostafa), masharkawy@yahoo.com (M.A. El-Sharkawy).

Peer review under responsibility of Ain Shams University.
doi:10.1016/j.asej.2011.09.004

Production and hosting by Elsevier

Most utilities have established their own harmonic voltage and/or current limits to reduce harmonic effects on customer loads and power system equipment. Harmonic voltages are categorized into [1]:

1.1. Background harmonics

These are the harmonics existing in a network as a result of all harmonic sources connected to it.

1.2. Additional harmonics

These are the harmonics generated by new harmonic sources to be connected to the network at some point of common coupling (PCC).

Both of these categories of harmonic voltages may require compensation. Active filters have been known as a good tool for harmonic mitigation as well as reactive power compensation, load balancing, voltage regulation, and voltage flicker compensation.

The quality of the active power filter (APF) depends on three considerations [2].

- The method used to extract the harmonic content
- Power circuit configuration
- The modulation and control method used to implement the compensation scheme.

Considerable efforts have been done in recent years to improve the management of harmonic distortion in distribution systems [3–10].

A current source converter (CSC) topology is proposed in [3]. This topology utilizes two ADALINEs to process the signals obtained from the power-line; one for the distorted line current signal and the other for fundamental component of the line voltage signal. The outputs of the two ADALINEs are used to construct the modulating signals of a number of CSC modules, each of which is dedicated for eliminating a specific harmonic.

Ref. [4] proposes the use of four adaptive linear neurons (ADALINEs) networks for online extraction of the direct, inverse, and homopolar voltage components from a composite voltage. This neural network approach is based on a new voltage decomposition technique of unbalanced three-phase systems.

An algorithm for harmonic estimation is presented in [5]. It utilizes a particle swarm optimizer with passive congregation (PSOPC) to estimate the phases of harmonic components. Alongside a least-square (LS) method is used to estimate the amplitudes of these components. The PSOPC and LS methods are executed alternately to minimize the error between the original signal and the signal reconstructed from the estimated parameters during the estimation process.

Ref. [6] proposes the application of a combined adaptive controller for current control loop of a shunt active power filter. The proposed approach uses a variable structure controller (VS) together with a robust model reference adaptive controller (RMRAC) leading to a VS-RMRAC algorithm. The VS parameters are used to improve the transient response, and its effect increases when the estimation error increases.

A control algorithm for a three-phase hybrid power filter constituted by a series active filter and a shunt passive filter is proposed in [7]. The control strategy is based on the dual formulation of the compensation system principles. The control target used provides high impedance for the harmonics while providing zero impedance for the fundamental. This strategy is achieved when the APF generates a voltage proportional to the source current harmonics.

Ref. [8] establishes and analyzes a model for the current closed-loop control of hybrid APF with injection circuit (IHAPF). The iterative learning control algorithm based on the PI-type learning law is presented. The system robustness is enhanced by using a forgetting factor.

A novel selective control algorithm is presented in [9] to drain the control currents of the active filter in order to improve the performance of the passive filters and also to minimize a specific harmonic component of the system voltages. The control algorithm is derived from the instantaneous power theory (*pq-Theory*), together with a synchronizing circuit. The introduced one is simpler to be implemented but is slowly and required lot of calculations.

An analysis of the control strategies of the shunt hybrid injection type active filter (SHIAPF) installed in the distribution network after the distributed power is connected is presented in [10]. It proposes a composite control strategy considering the currents of both load and system, which can effectively inhibit the influence on the control performance due to the variations by distributed power.

Ref. [11] employs the recurrent artificial neural network (RANN) for harmonic extraction. It uses the double proportional feedback control loop APF for uninterruptible power supply (UPS) application. The controller used as a single phase filter for a dedicated harmonic load and with a fixed voltage source.

In this paper, a shunt active filter scheme with two proportional feedback controllers is proposed. The scheme is applied on a 3-phase 13 bus industrial balanced distribution system. The fundamental components of distorted 3-phase currents and voltages are extracted using two multi-layer artificial neural networks (ML-ANNs) with shift method. The resulting shunt active filter can compensate for most voltage and current harmonics at the chosen point of common coupling (PCC).

2. Proposed APF scheme

The proposed APF scheme uses two independent ML-ANNs with shift method (sample by sample investigation) to estimates the fundamental voltage and current components for the electrical network.

The fundamental frequency voltage and current components are subtracted from the polluted power line voltage and current, respectively, to get the harmonic components.

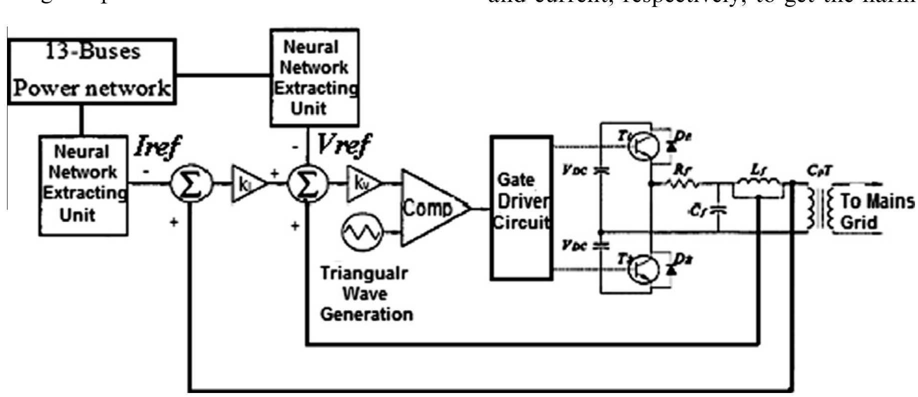

Figure 1 The structure of current compensation scheme based on the inductor voltage with two proportional controllers.