HARMONIC REDUCTION SYSTEM USING ACTIVE FILTER

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ABSTRACT

In the modern power distribution system, majority of loads draw harmonic currents from ac source. This paper presents the harmonics analysis and compensation which occurred in the electrical system. We use the electrical signal analysis in order to calculate harmonics that occurred in the electrical system mainly because of non linear load. The harmonics are compensated by using active filter. Microcontroller with A/D converter is used for sampling the electrical signals via a parallel port of the computer. The active harmonic filters are controlled by PWM (Pulse Width Modulation) signal from the microcontroller. The PWM data (Switching angle) is programmed by computer. The data such as voltages, currents, the total harmonic distortion etc., can be saved as database for analysis the harmonics compensation increase high efficiency of the electrical system and decrease the damage and incorrect operation that may happen with electrical devices.

KEYWORDS: Active Power Filter, Harmonic Compensation, PWM

INTRODUCTION

In electrical systems especially the process of production of industries, which use high technology devices, harmonics cause the damage of device. The characteristic of these devices is sensitive to the changes of current and voltage. If the size and shape of signals are distorted, it may damage the devices and make the functional failure. This problem needs to be protected and solved. The main reason of signal distortion is the harmonics of electrical systems. Most of that are nonlinear device which oscillate harmonics such as converter, power rectifier, adjustable-speed drive and vice versa. Using Non-linear devices, harmonic current is applied to the electrical system itself but if non-linear devices have wide range, harmonic current may leakage into adjacent electrical system. In this paper, we present the development of harmonics reduction system by using active filter based on computer unit, which within the medium and small building. Active filter is controlled by PWM pulses from microcontroller. Active filter cancels the harmonics current on the ac system by injecting current of same amplitude and reverse phase as the harmonic currents of the load.

Figure 1: Block Diagram
HARDWARE CONFIGURATION

This system is supported with computer which works with microcontrollers. The information received from microcontroller can be recorded and used as database for reduction of harmonics. Harmonic reduction technique can be used to evaluate the occurring harmonics in the system. The harmonics can be compensated using PWM signal from microcontroller selected by computer. The system consists of microcontroller having A/D converter for Sampling of electric signal. The communication between PC & microcontroller can be established through serial or parallel port of PC for monitoring the signal. Microcontroller will generate PWM signal to control harmonics by using data from computer. PWM data can be calculated from program and sent to control Active type filter. The active filter is formed by MOSFET or IGBT power devices which are in inverters form. The triggering of active filter MOSFET will be done through microcontroller.

SOFTWARE CONFIGURATION

The software is developed by Matlab. The function of software is monitoring of electric signal, Spectrum graph from harmonic analysis, Program PWM and Harmonic filter control. All function is inside the computer. Program in microcontroller consists of program for sampling signal and generate PWM signal from data.

Control System Flowchart

Figure 2 shows control system flowchart of harmonics reduction system. First, we are sampling data from signal of system and then monitoring signal on computer. We analyze the harmonics. The next, we calculate PWM data from program PWM. Finally, we sent PWM signal to control filter.

Harmonic Analysis

Harmonic analysis program in this paper use FFT method. Harmonic is measured using total harmonic distortion (THD) which is also known as distortion factor and can be applied to current and voltage. It is a square-root of sum of all harmonic magnitudes over the fundamental. Equation (1) shows the calculation for voltage total harmonic distortion (THDv).
Harmonic Reduction System Using Active Filter

\[ THD_p = \frac{\sqrt{\sum_{n=2}^{\infty} V_n^2}}{V_1} \]  

Where: \( V_1 \) is the magnitude of fundamental frequency voltage  
\( V_n \) is the magnitude of nth harmonic frequency voltage.

This program analyzes the harmonics and sent data of harmonics to program PWM in order to calculate PWM data (switching angle). The computer will sent the properly PWM data to microcontroller in order to generate PWM signal for active filter to compensating harmonics in electrical system. Function of harmonic analysis, program PWM and control filter can be direct and automatic control.

Program PWM

A PWM waveform consists of a series of positive and negative pulses of Constant amplitude but with variable switching instance there is one pulse of fixed magnitude in every PWM period. However, the width of the pulses changes from pulse to pulse according to a modulating signal. When a PWM signal is applied to the gate of a power transistor, it causes the turn on and turns off intervals of the transistor to change from one PWM period to another PWM period according to the same modulating signal. The frequency of a PWM signal must be much higher than that of the modulating signal, as depicted in Fig. 6 (as in a power electronic PWM full bridge inverter) This PWM signal decides the switching frequency of active filter.

PROPOSED SYSTEM

The harmonics signal generating is to put the PWM signal of sine-fundamental at S1 and PWM signal of sine fundamental and harmonics at S3. The amplitude of sine-fundamental in PWM signal at S1 must equal the amplitude of sine-fundamental in PWM signal at S3 and the amplitude of harmonics in PWM signal at S3 is set to required. The signal at S2 is 180 degree out of phase with the signal at S1 and the signal at S4 is 180 degree out of phase with the signal at S3 also.

![Figure 3: Single-Phase Full Bridge Inverter [1]](image)

Active Filter

An Active Harmonic Filter is an electronic power inverter using IGBT semiconductors with various control loops to increase Power Factor and reduce harmonics by injecting a dynamic cancellation signal into the power line.

The operation of an active filter is based on a continuous monitoring and conditioning of the distorted current created by the non-linear load. The same harmonic currents, but with a 180° phase shift are generated by the filter, so that harmonic components are cancelled and only fundamental component flows from the point of common coupling of the load.
Active filters have the advantage of being able to compensate for harmonics without fundamental frequency reactive power concerns. This means that the rating of the active power can be less than a comparable passive filter for the same non-linear load and the active filter will not introduce system resonances that can move a harmonic problem from one frequency to another.

![Diagram of Active Power Filtering](image)

**Figure 4: Active Power Filtering**

Applications of active filters have been described in a number of previous publications [1-5]. The increasing use of power electronics based loads (adjustable speed drives, switch mode power supplies, etc.) to improve system efficiency and controllability is increasing the concern for harmonic distortion levels in end use facilities and on the overall power system. The application of passive tuned filters creates new system resonances which are dependent on specific system conditions. Also, passive filters often need to be significantly overrated to account for possible harmonic absorption from the power system. Passive filter ratings must be coordinated with reactive power requirements of the loads and it is often difficult to design the filters to avoid leading power factor operation for some load conditions. Active filters have the advantage of being able to compensate for harmonics without Fundamental frequency reactive power concerns. This means that the rating of the active power can be less than a conquerable passive filter for the same nonlinear load and the active filter will not introduce system resonances that can move a harmonic problem from one frequency to another.

![Diagram of Basic Circuit of the Active Power Filter](image)

**Figure 5: Basic Circuit of the Active Power Filter [3]**

Figure 5 shows the fundamental building block of the proposed parallel APF. It is comprised of a standard single phase voltage source MOSFET based bridge inverter with dc bus capacitor and dc boost voltage for an effective current control. A hysteresis rule based carrier less PWM current control technique is used to provide fast dynamic response of the APF. To demonstrate reactive power compensation capability of the APF, linear loads of lagging and leading power-
factors are considered with the step change. Non-linear loads comprising diode rectifier with capacitive loading and solid state ac regulator with inductive loading are taken on APF system to illustrate its capability for harmonic and reactive Power compensation.

The main role of the proposed APF is to eliminate harmonics and to provide reactive power requirement of the load locally so that ac source feeds only Fundamental sinusoidal active component of unity power-factor current. Since this APF system is connected in shunt with load, it improves the system efficiency because it does not process the active power delivered to the load. [3]

Control Scheme

Figure 6 shows the block diagram of an overall control scheme for the APF system. DC bus voltage and supply voltage and current are sensed to control the APE. AC source supplies fundamental active power component of load current and a fundamental component of a current to maintain average dc bus voltage to a constant value.

The later component of source current is to supply losses in VSI such as switching loss, capacitor leakage current etc. in steady state and to recover stored energy on the dc bus capacitor during dynamic conditions such as addition or removal of the loads.

![Figure 6: Control Scheme of the APF](image)

The sensed dc bus voltage of the APF along with its reference value are processed in the P-I voltage controller. The truncated output of the P-I controller is taken as peak of source current. A unit vector in phase with the source voltage is derived using its sensed value.

The peak source current is multiplied with the unit vector to generate a reference sinusoidal unity power factor source current. The reference source current and sensed source current are processed in hysteresis carrier less PWM current controller to derive gating signals for the MOSFETs of the APF.

In response to these gating pulses, the APF impresses a PWM voltage to flow a current through filter inductor to meet the harmonic and reactive components of the load current. Since all the quantities such as dc bus voltage etc. are symmetric and periodic corresponding to the half cycle of the ac source. A corrective action is taken in each half cycle of the ac source resulting in fast dynamic response of the APF. [3]

RESULTS

Harmonics Spectrum

The source current spectrum without active power filter contains odd multiple low order current harmonics (i.e. 150 Hz, 250 Hz and 350 Hz). The THD calculated up to 83.92% for the source current without active power filter.

FFT Analysis of Is without Active Filter

Total Harmonic Distortion (THD) = 83.92%
Harmonic Spectrum

The spectrum of the source current with basic shunt active filter (APF) compensation is shown in Figure 6.7. The basic shunt APF successfully filters the harmonic current components caused by the nonlinear load.

**FFT Analysis of is with Active Filter**

Total Harmonic Distortions (THD) = 4.64%

**CONCLUSIONS**

In this paper we present the harmonic reduction system using active filter to reduce total harmonic distortion value by the computer which works with microcontroller and active harmonic filter (IGBT module). Active Filter eliminates harmonics which are introduced by non linear load up to 4.6% as compare to without Active Filter 83.9%.

The results present ability of the harmonics reduction that increase the Efficiency of electric system and can improve in the real system.
REFERENCES


