Development of Less Complex Single - Phase Active Filter

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Abstract:

Harmonic pollution has become a serious problem in recent years. Harmonics are introduced into power systems due to non-linear loads or system components presenting non-linear behavior. An active power filter is one method used to minimize the effects of the harmonic. However, active harmonic filter usually requires some complicated algorithm for implementation. This paper presents a new approach to design and develop an active harmonic filter which has less complexity compared to other conventional active harmonic filters. It can be implemented by injecting the inversion form of the harmonic into the main line, which results a lower value of harmonic content. In other words, the harmonic component needed by the non-

Linear load is provided by the active filter rather than the ac source.

Introduction

The power quality issue is becoming increasingly important to electrical utilities as well as to industrial and domestic consumers and this has drawn increased attention over the past few years [1]. This is due to the increase in the number of system loads and controls that are sensitive to power quality, as well as the increase in non linear loads in the power system.

The harmonic distortion being generated by non-linear loads has been increasingly arising, it is estimated that more than 60 percent of electricity now passes through non-linear loads. These loads are highly nonlinear and they inject harmonic and

reactive current to the grid, resulting in lower power factor, lower transmission efficiency, and harmful disturbance to other appliances.

This paper explains the design of an active harmonic filter by measuring the current that is flowing to the load and extracts the harmonic signals. These signals is then inverted and amplified before it is injected back into the power supply to reduce or cancel the harmonics, which results in cleaner sinusoidal currents being drawn from the power supply. The designed active filter has been tested to reduce the harmonic content in the dc load to lower level, where the lower level is determined by the efficiency of the filtering process in sampling the harmonic signals. A model of the proposed active harmonic filter has been build and good results have been achieved.

The Active Filter in Variety of Applications

Many types of active filters have been developed due to the system requirements and needs, in order to be solving the harmonics problem. Several active filter systems have been proposed to mitigate harmonic current of industrial loads. Pure series and shunt filters are suitable for small-rating nonlinear loads.

In order to obtain a low rating and low bandwidth requirements of the active filter inverter, the Dominant Harmonic Active Filter (DHAF) prototype has been developed. The DHAF system achieves harmonic isolation at the dominant

Harmonics using square-wave active filter inverters [2].

Hybrid series and hybrid shunt active filters, which are characterized by a

combination of passive L-C filters and active filters are cost effective and practical for large-rated non-linear loads. Trend seems to be in favor of a combined of active filter and passive filter rather than passive filter alone. Such a system reduces the initial cost and improves the efficiency [3]. The hybrid filters are attractive from both practical and economical point of view, in particular, for high-power applications [4].

In HVDC systems, the limits for harmonics are continuously decreasing

and it is anticipated that in the future this system will not be feasible without active filters. The use of DC active filters offers essential advantages in performance and costs, especially if the required performance limits are low [5].

A novel hybrid filter topology and its control have been developed to prevent such harmonic currents from entering the power system [6]. The system consists of a passive filter network, a power electronic converter operating in a current-controlled mode, a static switch consisting of two back-to-back connected thyristors and an MOV for protection.

Active ac filter has been also designed to be used in HVDC converter stations [7]. In this technology, the active filter decouples the reactive-power supplying and filtering tasks that have been characterizing the traditional HVDC passive ac filters.

An alternative control strategy using a number of notch filters has been introduced into the active dc filter in the Lindom Converter Station [8]. These filters can be tuned at those frequencies that need to be damped. This controller gives such shorter system response

time and improves stability margin.

Most active filter topologies are complicated and require active switches and control algorithms, which are implemented using IGBT or Digital Signal Processing (DSP) chips. The active filter topology also needs current and voltage sensors and corresponding Analog to Digital (A/D) converters. This extra hardware increases the cost and component counts, reducing the overall reliability and robustness of the design.

Based on the conventional active

harmonic filter and the latest development of the active filter, the research on the harmonic filter is mainly on the algorithm of the active filter, harmonic extraction method and current injection method. Similarly, in this work, the designed active harmonic's topology is similar to the conventional active harmonic filter but the difference is the used method of injecting the current into the main line. The method of extracting the harmonic signal from the load current used in this project is by using a current transducer, which acts as a source voltage for RLC filter. Thus the harmonic signal is across the resistor R in the RLC circuit. Meanwhile, the injection method adopted in this project is a Class A amplifier. simple algorithm is required to implement this filter although it bears a number of disadvantages compared to other methods.

Design Specification

In order to start the designing process of this filter, the specifications of the filter were determined. First, it works like other conventional active harmonic filters where it introduces the harmonic current into the main current to cancel the harmonic created by the nonlinear load. Few formulas are involved for filtering, voltage regulation, amplification and current injection. Since it does not require a complicated algorithm the complexity of the entire circuit is thus reduced.

The general idea of the designed filter is shown in the Figure 1. At first, the current in the main line is measured instantaneously using Hall effect current transducer with its output in the form of voltage proportional to the current in the main line. The voltage is then utilized to extract the sample of the harmonic component in the main current by using an RLC filter where the circuit is tuned to 150Hz or equivalent to third harmonic. The reason of reducing the third harmonic is because it has the highest magnitude in a single-phase load. In the RLC filter, circuit sample of the harmonic is available across the resistor R. The signal is then fed into an inverting amplifier for voltage regulation and inversion of the signal or in other words 180 degree phase shift.

The following stage is buffering, the signal before is fed into the class A amplifier, it needs to be buffered so that it will be capable of supplying the input signal to class A amplifier. Isolation circuit is required in order to isolate the control circuit from the power circuit and also to isolate the dc bias of the transistor in the next stage from affecting the operation of the amplifier.

The signal is amplified in the last stage while injecting the current in the inversion form of the existing harmonic order in the main line. So the resultant of the current in the main line is the sum up of these two current components. In other words, the harmonic component needed by the non-linear load is provided by the active filter rather than the ac source. The expected result of the

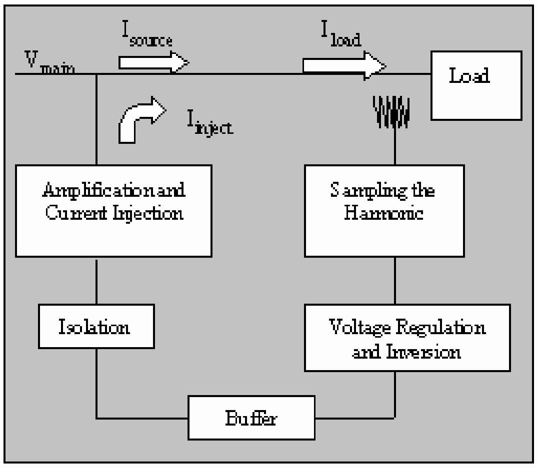

Figure 1: General block diagram of the designed active filter

current injection is that the magnitude of third harmonic current will be lower.

Experimental Setup

The entire designed circuit of the active harmonic filter is shown in Figure 2. The first step is to measure the current of the main line so that the sample of the harmonic content is measured instantaneously. The Hall Effect current transducer, PCB mounting is used, where it provides output voltage option that is proportional to the current measured. A narrow band pass filter is

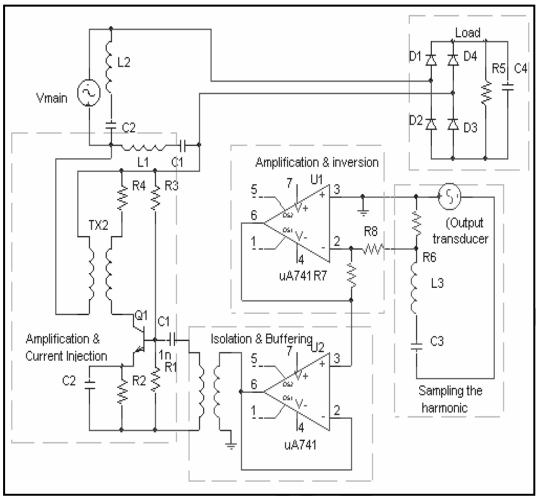

Figure 2 Schematic of the entire designed circuit

designed based on the quantitative analysis for determination of the appropriate component values. For the purpose of inverting and amplifying the harmonic signal, amplifier model μA741 is used.

After the amplification, the signal is then buffered using a voltage-follower where three buffers connected in parallel have been used to increase the maximum current, to meet the requirements of the input signal of class A amplifier.

Operational amplifier is added as a non-inverting operation amplifier in order to amplify the signal to a higher amplitude. This is because a step-down transformer is used to isolate the control circuit from the power circuit and also to isolate the dc bias of the transistor from affecting the operation of the non-inverting amplifier.

In the last stage a class A amplifier has been implemented. The amplified voltage is induced in series with the input voltage using a series transformer by connecting the secondary winding in series with the input voltage.

Harmonic Current

The results were obtained by measuring the load current and input voltage of the circuit. using the 3166 Clamp-On Power Hitester, the results of the harmonic current and voltage of the nonlinear load,

consist of all the waveform of the current and lists of the harmonics in odd order for voltage and current.

The data was analyzed using Harmonic Data Analysis Utility Program. It is shown up to 13th order of harmonic and the rest orders are not shown because their values are negligible

Since the filter is designed to reduce the third order harmonic, only the value of this

order will be highlighted during the discussion.

The waveform of the load current shows the difference before and after turning on the active filter. Figure 3 shows the waveform of the input current before the harmonic injection while Figure 4 shows the improved shape that is nearly a sinusoidal waveform when the active filter is turned on.

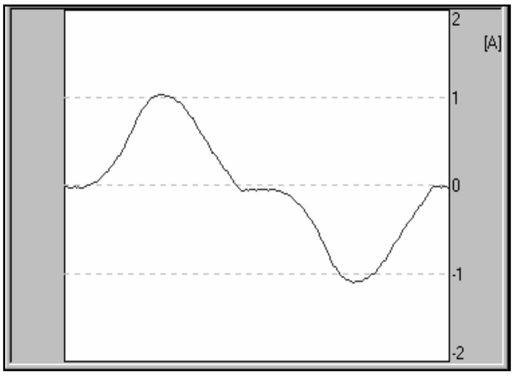

Figure 3: Waveform of the load current before turning on the active filter

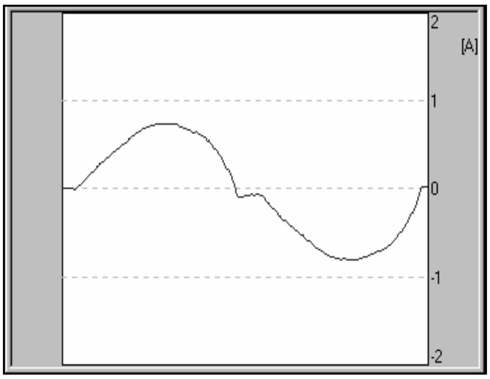

Figure 4: Waveform of the load current fter turning on the active filter

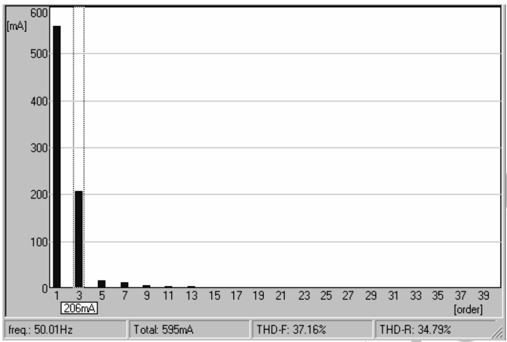

Figure 5: Waveform of the input voltage before turning on the active filter

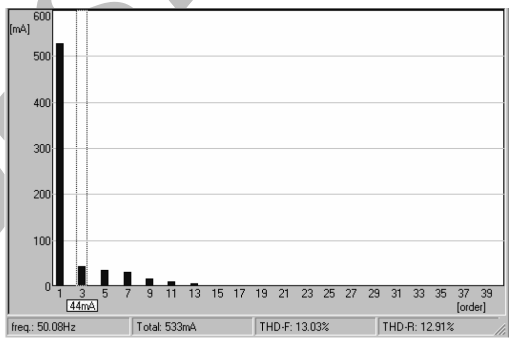

Figure 6: spectrum analysis of current waveform after tuning on the flter

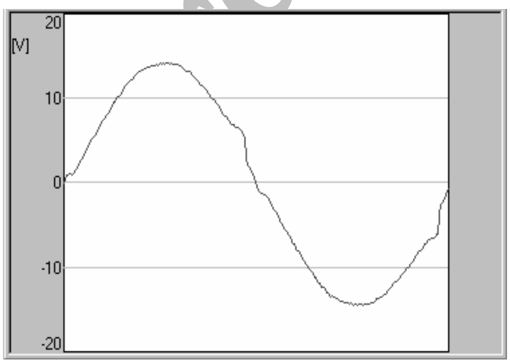

Figure 7: spectrum analysis of voltage waveform before tuning on the filter

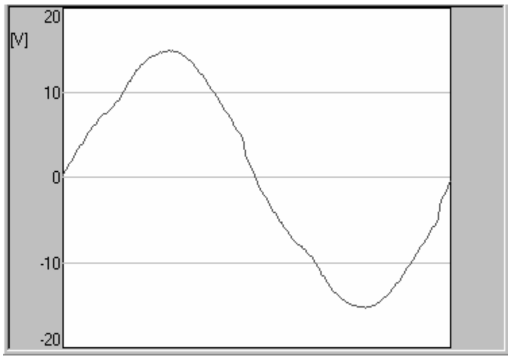

Figure 8: Waveform of the input voltage after turning on the active filter

Figures 5&6 show the spectrum analysis of the harmonic contains of the input current waveforms before and after connecting the active filter respectively.

After turning on the active filter, the third harmonic component is reduced to approximately one fifth of its original value. Also the THD factor is reduced from 37.16% to 13.03%.

Harmonic Voltage

The waveform of the voltage has also been considered in the measurement where Figure.5 shows the input voltage without harmonic treatment while Figure 6 shows an improvement of the input voltage, when the active filter is turned on.

Conclusion

This work is planned to design the a harmonic active filter that minimize the harmonic content in main line by introducing the inversion form of the harmonic without using any complicated algorithm, but requires a few simple calculations or simpler circuit.

Experimental results has been obtained from a laboratory model which showed the effect of the proposed active filter on input voltage and current waveforms due to reduction of the 3rd harmonics.

More work is required to improve the isolation between the power and electronics networks. This will be the objective of future work.

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