Parallel Active Harmonic Filters: Economical Viable Technology

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Abstract: This presentation discusses 1) what a parallel active harmonic filter is; 2) product design/application emphases of products so far introduced; 3) how it is applied; and 4) economic comparisons for three installations.

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Introduction

Parallel active harmonic filters (AHFs) are power electronic products employing fast switching semiconductors that inject harmonic current onto the ac lines. Microprocessor based logic circuits are required to monitor the total current of the load(s); determine the harmonic content; and control the switching sequence of the power semiconductors to generate a current waveform to remove the bulk of the harmonic current traversing the electrical system.

AHFs are installed parallel to the nonlinear loads. They employ current transducers to monitor the load current. See Fig. 1.

AHFs do not use power factor capacitors in any way. See Fig.2. The power semiconductors are insulated gate bipolar transistors (IGBTs) that move power from the ac lines to a dc bus capacitor circuit and back to the ac lines in a prescribed manner. (Before the advent of IGBTs active harmonic filters were ineffective and quite expensive.)

Some of the AHFs are designed to measure and inject reactive current for system displacement power factor correction as well.

Design/Application Emphases of AHFs

Prior to 1998 two manufacturers existed in the market. Today there are at least eight manufacturers selling AHFs in North America. However, each company appears to be directing their product at specific segments of the market. As a result the technology, although very similar, provides quite distinct application orientation.

Products are available for use 1) on utility distribution lines, 2) at the point-of-common-coupling (PCC) for facilities to the utility, 3) within the three phase distribution system inside facilities, 4) on the three phase four wire facility distribution system, and 5) to remove neutral harmonics on three phase four wire systems.

The utility distribution product appears to use fast Fourier transforms (FFT) to calculate the amount of harmonics present for each harmonic order. It then injects cancellation current for the 5th, 7th, 11th and 13th orders only. Converter response is approximately 40 msec.

Another product is clearly directed as a system replacement for tuned filters at the PCC. The product performs FFT calculations to determine the amplitude of the first 50 orders of harmonic current. Then a selection process is made to cancel the 15 most offensive orders. Response time is stated as 40 msec.

Several manufacturers have developed products for three phase balanced loads. These products do not attempt to cancel neutral harmonics even though they may be applied to three phase four wire electrical systems. They are generally applied where the electrical system has three phase loads.

Most of these products perform harmonic measurements through the 50th order. The logic then filters out the fundamental frequency so that only the harmonic content is remaining. The logic then directs the power converter to inject the inverse of the remaining data for gross cancellation of all harmonic current from the second to the 50th order. Response times are approximately 8 msec. One manufacturer refers to this as 'global' cancellation.

These products depending upon the actual rating of the products can be used 1) at the PCC, 2) anywhere in the

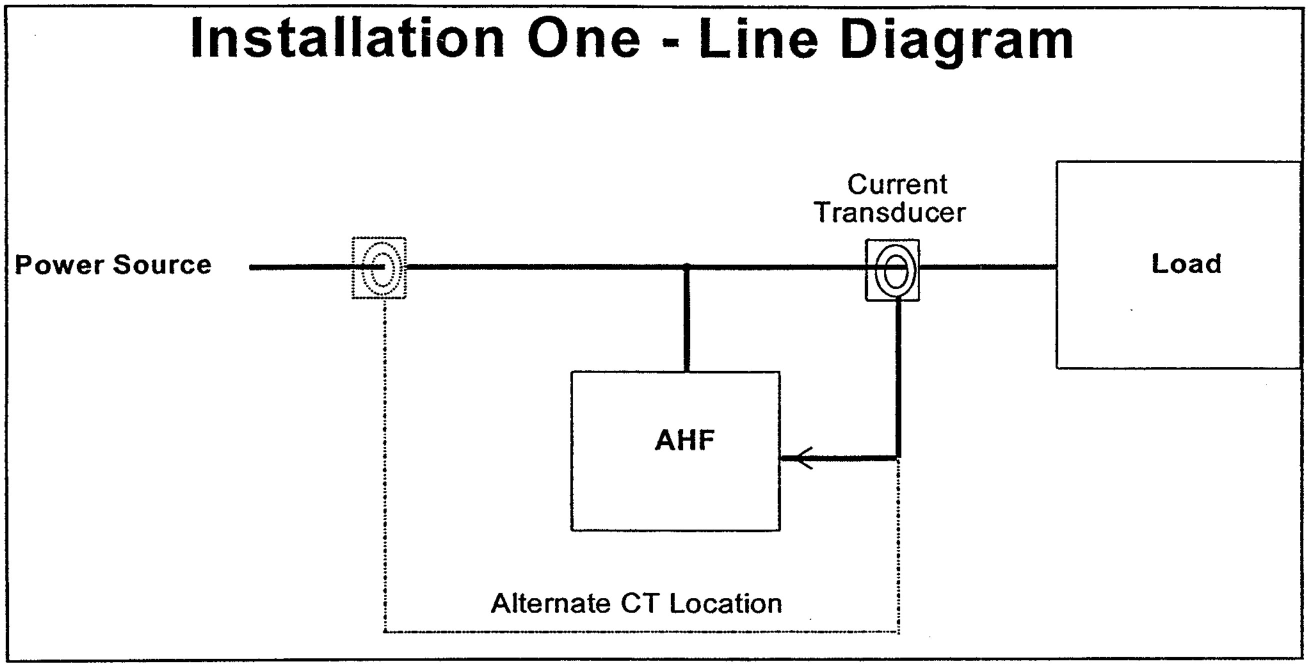


Fig.2. Typical installation one-line diagram

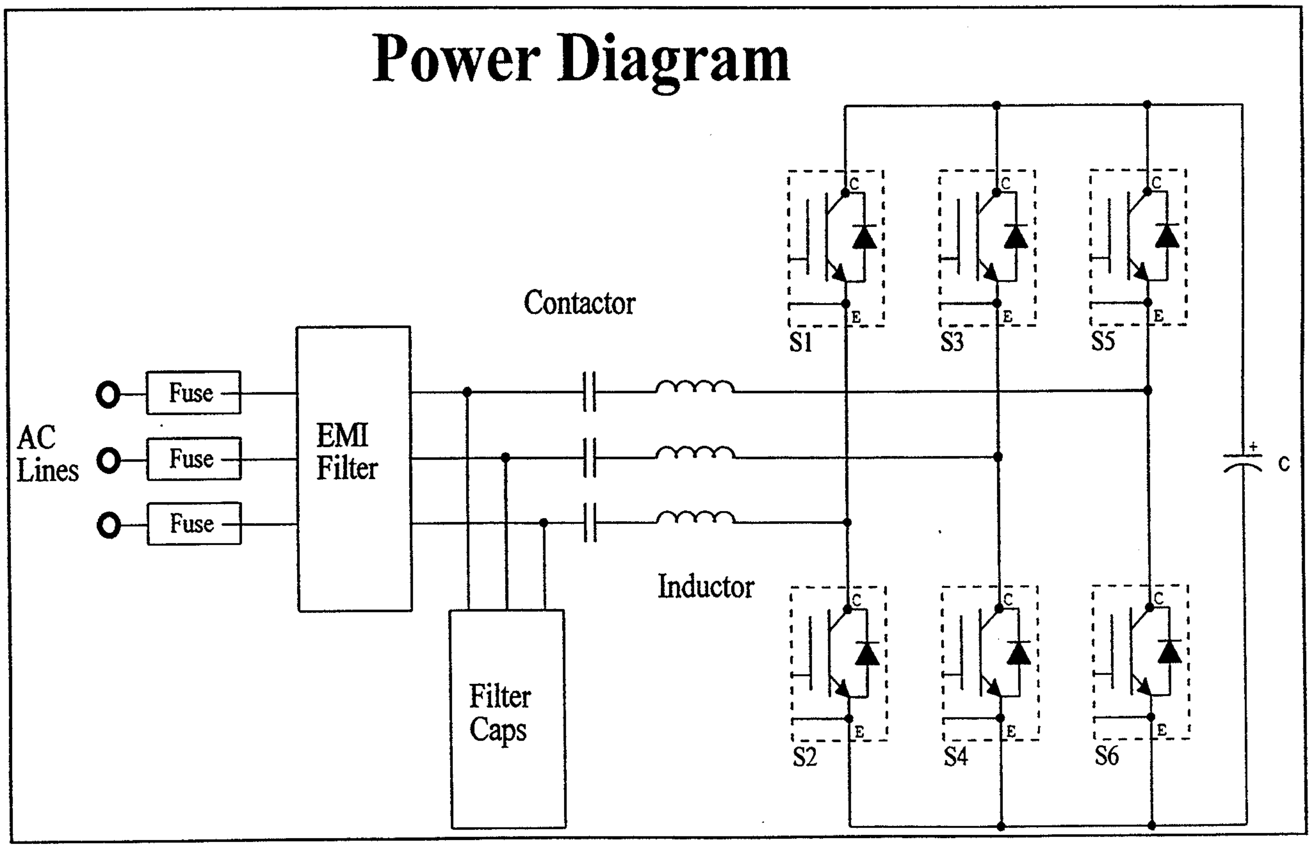
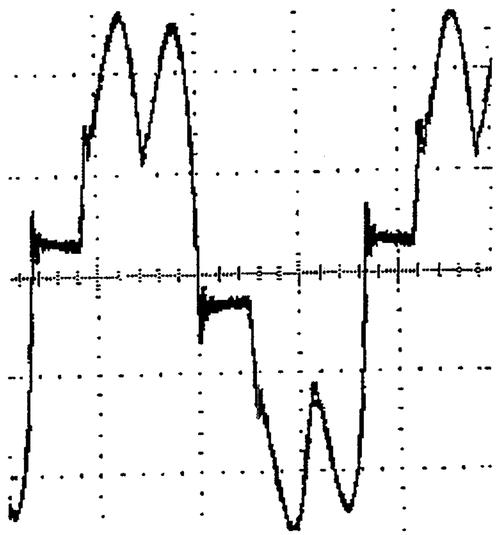


Fig. 1. Typical three phase power diagram of parallel active harmonic filters

three phase distribution system, or 3) at the individual three phase loads. See Fig.3 for a variable frequency drive (VFD) example.

'Global' Harmonic Current Injection

200 HP PWM VFD - 38.5% TDD



Same VFD with 100A active harmonic filter - 4.1% TDD

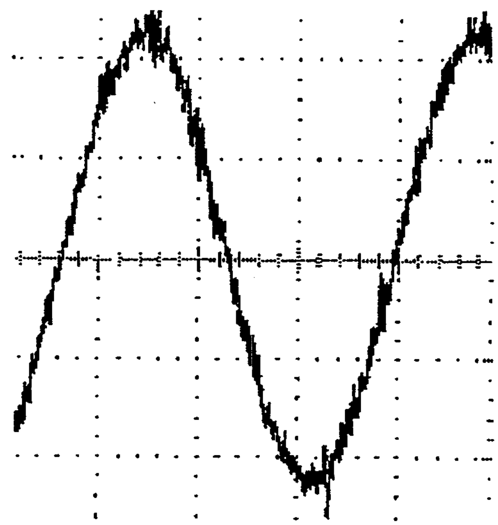


Fig. 3. Global filtering applied to a variable frequency drive

Two manufacturers produce products that are designed to eliminate all harmonic current for three phase four wire systems. This includes elimination of the triplen harmonics on the neutral. One is selectable for 'global' or FFT cancellation. The other is 'global.'

One manufacturer has a product that minimizes the triplen harmonics on the neutral. This product does not attenuate any of the positive or negative sequence harmonics on the ac lines.

The inclusion of reactive current injection for displacement power factor correction is not universal. Some offer it. Others do not include it.

The selection process of an AHF appears to be manufacturer specific as well. Some make it as complex as sizing a tuned filter by including at-site harmonic studies, engineering simulations, and post-installation harmonic analyses. All costing the customer large amounts of monies.

Others are recognizing the massive benefits of employing an AHF. Some of these include 1) dynamic response to system modifications, 2) current limited output for continuous operation even when overloaded, 3) a wide range of harmonic order elimination, 4) elimination and prevention of resonance, and 5) easy paralleling of units for capacity expansion. Typical harmonic current distortion creation can be used to select an AHF. A simple customer site and electrical one-line review will direct users to harmonic trouble spots and provide meaningful solutions. As users become accustomed to AHFs and are confident regarding their performance users will demand AHFs as the solution of choice.

Application Reviews

As a general rule, when harmonic and displacement power factor correction solutions are placed close to the causes, the user benefits immensely. The electrical system can be more fully utilized for real work. Chances of harmonic related mysterious shutdowns are eliminated. Resonance cannot occur. All have financial benefits.

Some companies are investigating placing AHFs as standard add-ons in plant distribution equipment as one method of providing a dependable, flexible and complete solution for harmonic mitigation and PF correction. Still others are looking at placing three phase four wire AHFs inside of floor placed single phase distribution systems to stop the propagation of neutral harmonics beyond these limited areas. See Photographs 1 and 2.

The following examples are real examples using customer information to compare the total costs of passive solutions to AHF solutions. Total costs include at-site harmonic studies, engineering simulations by computer modeling, equipment costs and installation costs.

Example 1: A wastewater plant upgraded the capacity of their raw sewage pumping system. This included installation of four VFDs; three 125 hp and one 60 hp. Immediately after starting the VFDs, the plant logic control system began faulting irratically. Additionally, in an adjacent power distribution panel to the VFDs, the circuit breaker to the master control system began randomly tripping.

After two harmonic studies, two consultants, and eighteen months, it was determined that the VFDs were the cause. The VFD suppliers solution was to immediately install 3% input line reactors on each VFD.

Initially, it looked like the solution worked. However, when heavy rains fell and all four pumps were required, the circuit breaker (CB) for the master logic system began tripping again.

Another at-site harmonic analysis confirmed that the harmonic voltage distortion exceeded 7.5% at the CB. A computer simulation probably would have shown that this would occur. But the customer was in no mood to pay for any more studies or costs.

The guaranteed solution was to eliminate harmonic distortion at the VFDs. AHFs were selected using typical procedures for two VFDs per motor control center (MCC). One 100 ampere rated AHF was installed per MCC. Further there was no equipment down time to install the AHFs and current transducers.

Example 2: A steel processing plant has three separate distribution systems. They are 1000 kVA, 1500 kVA, and 750 kVA. Many dc motor speed controls are used on the production lines. Power factor capacitors were installed to fix the displacement power factor to meet the utilities penalty requirements.

Power factor (PF) correction capacitors began to overheat and fail shortly after installation. An at-site harmonic study was performed. The study confirmed that resonance was occurring. The total harmonic current and voltage distortion increased from 25% and 4.5% to 76.4% and 9.4%, respectively. A look at an oscilloscope confirmed the wildly oscillating waveform.

The passive tuned filter solution called for the removal of the PF capacitors and installation of stepped tuned 5th harmonic filters. Selection of 400 kVAR, 200 kVAR, 150 kVAR tuned filters was recommended. Additionally, a computer modeling simulation was performed to insure resonance does not occur. Additionally 9 total down days were expected to occur for installation.

The AHF solution required one 100 ampere, two 50 ampere, and one 300 ampere rated units. The exisitng PF capacitor banks were repaired and used as PF correction. A bonus was no down time to install the AHF solution.

Example 3: A wastewater plant has two 700 hp VFDs with phase converters. The local utility charges for a displacement power factor below .95. Their annualized PF penalties are $39 900.

A tuned 5th harmonic filter solution was discussed. An at-site harmonic study was performed. Computer modeling to insure resonance would not occur and to select the proper size filter was done. The equipment was estimated to be 450 kVAR stepped 5th harmonic filter. Additionally, 2 down days were required

Since all the customer wanted was to correct for poor PF, an AHF with reactive current injection was selected. The active harmonic filter portion was turned off. This resulted in a need for 200 amperes of reactive current injection to correct the PF to .95 for 90% of the operating time. Additionally, no down time occurred.

Summary

AHFs have been viewed as products that either did not work well or cost outrageous amounts of money to purchase. If you compare the cost of the equipment only, AHF to 5th harmonic tuned filter, the tuned filter wins. However, if you include all the costs associated with selection and installation of both products you find that AHFs are the most economical and the most complete solution (elimination of up to the 50th harmonic order as opposed to 1 order). Additionally, not included in the economic evaluation but an important factor is plant or production line down time. AHFs can be installed with no down for operations.

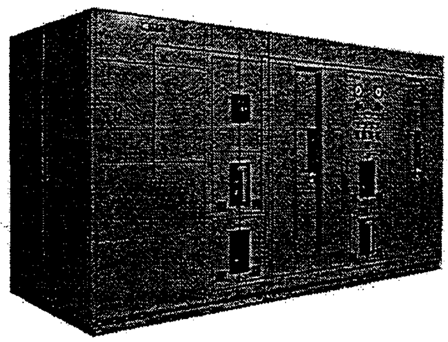


Photo 1. Plant Distribution Switchgear

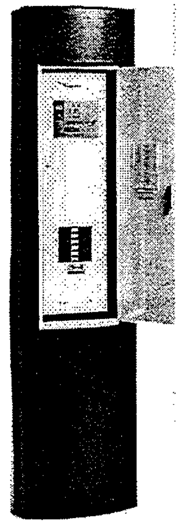


Photo 2. Floor placed 208/120 Y distribution panel

Charles A. Gougler is a graduate of Kent State University with a Bachelor of Science degree in Marketing and Business. Business experience includes over twenty years in the electrical industry, specific to power distribution, switchgear, automation and power quality. Presently, Chuck is Manager of Power Quality for Industrial Electric Manufacturing, a California and Ohio based company.

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