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# POWER QUALITY ENHANCEMENT USING MODIFIED ACIVE POWER FILTER IN HVDC TRANSIMISSION SYSTEM.

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***Abstract:*** **Active and passive filters are essential to maintain the power quality of a HVDC link. Active filtering of electric power has now become a nature technology for harmonic and reactive power compensation in two-wire (single phase), three-wire (three phase without neutral), and four-wire (three phase with neutral) ac power networks with nonlinear loads.**

**This paper presents a comprehensive review of active filter (AF) configurations, control strategies, selection of components, other related economic and technical considerations, and their selection for specific applications. This paper mainly explains about the new AF technology and different topologies utilizing in the present scenario, economical approach etc for the improvement of power quality. Presently many countries has been using this AF technology, because of its capacity to eliminate the harmonics up to 25th level & more and also size of filter is also reduced.**

## I. INTRODUCTION

Converters and nonlinear loads absorb reactive power and produce harmonics on both sides of the d.c. transmission systems. The demand of reactive power and harmonics cancelation are usually met by employing passive and active power filters. In this paper, a conventional passive filter and a new active power filter topology are suggested in order to improve the power quality of the d.c. transmission systems. The nonlinear application chosen here is the 12-pluse Line Commutated Converter High Voltage D.C. (LCC-HVDC) link. The passive filter is tuned at fixed harmonic and constant transmitted D.C. power while the active power filter is dynamically controlled for different values of D.C. power flow through the transmission line.

To effectively control the active power filter, a modified harmonic pulse width modulation algorithm is suggested in order to minimize the source harmonics and force the a.c. source current to be in-phase with the a.c. mains. Comparison of simulation results using MATLAB/SIMULINK show that the suggested active filter is effective for transient and steady-state operating conditions. The control of ac power using thyristors and the other, semiconductor switches is widely employed to feed the controlled electrical power to electrical loads such as the adjustable speed drives. Furnaces, computer supplies etc. such controllers are also used in Hvdc Systems & the renewable electric power generation. As nonlinear loads these solid state converters draw harmonic & reactive power components of current from ac mains. In three phase system they could also cause unbalance and draw excessive neutral currents. The injected Harmonics and reactive power burden unbalance and excessive neutral currents causes' low system efficiency and Poor power factor. Active power filter (APF) provides flexible control and can be tuned to adapt the changes in system frequency and impedance [1]. Therefore, they have better filtering performance than passive power filters. In this paper, a modified APF (MAPF) with modified harmonics PWM (MHPWM) algorithm suggested by [2] is used as a controller for the shunt active power filter to improve the power quality of the 12-pulse line commutated converter high voltage D.C. (12-pulse LCC-HVDC) link under different loading conditions. This filter has been used to compensate the effective power factor and also reduce the THD at both ac sides of the 12-pulse LCC-HVDC link. This is performed for a wide range of dc power flow in the transmission line. The MHPWM algorithm is analyzed, simulated and implemented into an FPGA. The VHDL code has been implemented in the FPGA-Xilinx Spartan 3 and in Matlab/system generator (SysGen) black box. Based on FPGA, a 6-pulse PWM signals have been generated and compared with Matlab/SysGen black box and Matlab/Simulink power system blocks.

The elevated austerity of harmonic pollution in power networks has attracted the deliberation of the power electronics and power system engineers to develop dynamic and adjustable solutions to the power quality problems Such equipment generally known as active filters.(AF). Are also called as active power line conditioners (APLCS), instantaneous reactive power compensators (IRPC's), Active power filter (APF's), and Active power quality conditioners (APQC's). In recent years many publications are also appeared on harmonics, reactive power, and load balancing and neutral current compensation associated with linear and nonlinear loads.

## II. BASIC CONCEPT AND SYSTEM OVERVIEW

The power circuit of the proposed APF shown in Fig. (1) is a three-phase 2-level voltage source inverter (VSI) connected at the sending and receiving ends of the 12-pluse LCC-HVDC link through transformers. A dc capacitor is connected at the dc side of the VSI to keep the voltage constant at the dc bus. The APF is modified to compensate harmonics and reactive power based on MHPWM algorithm. Therefore, it is considered as harmonics injector and PF corrector (STATCOM-APF system). The MHPWM algorithm is used

  

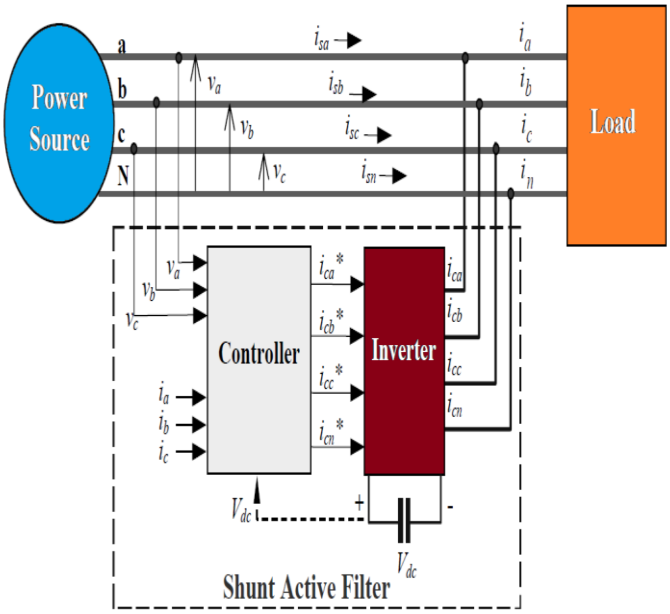


Fig.1. Modified active power filter system

to produce PWM pulses to drive the IGBTs' of the MAPF. AF technology is full-fledged for providing compensation for reactive power, harmonics and neutral current in ac networks it has evolved in the past quarter century of development with varying configurations control topologies .AF's are also used to terminate the voltage harmonics, to regulate terminal voltage, to inhibit voltage flicker and to advance voltage balance in 3- phase systems. AF's are basically classified into three types, namely two wire, three wire and four wire three phase configurations to meet the requirements of 3- types of nonlinear loads.1-phase loads, such as domestic loads such as lights and ovens, TV's, computer power supplies, air conditioners, laser printers, and Xerox machines act as nonlinear and cause power quality problems. Single-phase (two wire) AF's are examined in varying configurations and control topologies to meet the needs of 1-phase nonlinear loads. Starting in 1973, many approaches such as the active series filter, active shunt filter and combination of shunt and series filter have been refined and commercialized also for uninterruptible power supply (UPS) applications. Both concepts based on a current- source inverter (CSI) with inductive energy storage and a voltage-source inverter (VSI) with capacitive energy storage are used to develop single-phase AF's. Since hefty amounts of ac power are consumed by three- phase loads such as ASD's with solid-state control. Lately, many ASD systems incorporate AF's in their front-end design. A substantial number of publications have reported on three- phase three wire AF's. Active shunt, active series, and combinations of both, named as active power quality conditioners, as well as passive filters combined with active shunt and active series AF's are some typical configurations used. Many control methods such as instantaneous reactive power theory initially developed by Akagi *et al.* , synchronous frame *d–q* theory , synchronous detection method , and notch filter method are used in the development of three-phase AF's.

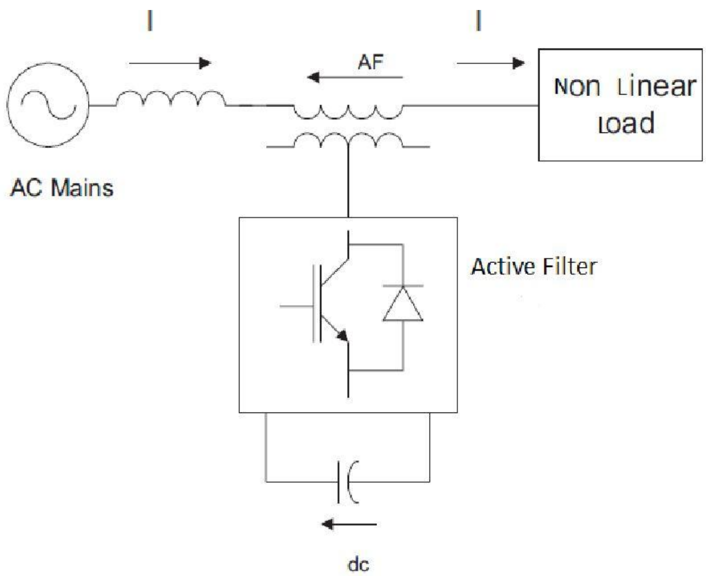


Fig.2. Current fed type active filter

*A. Active Power Filter with Load Current Detection*

Active power filter with load current detection only requires load current, source voltage and capacitor voltage. The control system acts in order to perform an indirect regulation of source currents, which must be sinusoidal and in phase with the corresponding line to neutral voltages. Here indirect regulation of the source current is achieved by introducing a closed loop control of the "filter flux", defined as the time integral of the filter voltage [6]. The block diagram of shunt active power filter with load current measurement is shown in Fig 2.

Since major amounts of ac power are consumed by three phase loads such as ASD's with solid-state control. Lately, many ASD systems incorporate AF's in their front-end design. A substantial number of publications have reported on three phase three wire AF's [5], starting in 1976. Active shunt, active series, and combinations of both, named as active power quality conditioners [18], [12], as well as passive filters combined with active shunt and active series AF's are some typical configurations used. Many control strategies such as instantaneous reactive power theory initially developed by Akagi *et al.* [8], synchronous frame *d-q* theory [14], synchronous detection method [3], and notch filter method are used in the development of three-phase AF's. The problem of excessive neutral current [3], [4] is observed in three-phase four-wire systems, mainly due to nonlinear unbalanced loads, such as computer power supplies, fluorescent lighting, etc. Resolving the problems of neutral current and unbalanced load currents has been attempted in [15]-[16] for four-wire systems. These attempts are of varying nature, like elimination/reduction of neutral current, harmonic compensation, load balancing, reactive power compensation, and combinations of these. A major volume of work is reported [17]-[12] on the theories related to the detection and measurement of the various quantities, such as real power, reactive power, etc., in the presence of harmonics in the supply systems with nonlinear loads. These theories and concepts are quite relevant to extract the control signals for AF's and for the development of instruments to measure conventional and newly defined quantities in the presence of harmonics and unbalance. For quantifying the effectiveness of AF's, it is important to develop good measuring systems, and these new concepts have given a new impetus to instrumentation technology in this field. The problems of reactive power and load unbalance were recognized long ago, and they became aggravated in the presence of nonlinear loads. Many publications [13]-[23] report on solid-state compensators for voltage flicker, reactive power, and balancing the nonlinear reactive loads, such as arc furnace, traction loads, etc. Many more terminologies, such as static var compensators, static flicker compensators, static var generators, etc., have been used in the literature. One of the major factors in advancing the AF technology is the advent of fast self-commutating solid-state devices. In the initial stages, thyristors, bipolar junction transistors (BJT's) are considered sufficiently reliable [8], [9], but have higher losses and require higher values of parallel ac power capacitors. Moreover, they cannot be used in multilevel or multistep modes to improve performance in higher ratings.

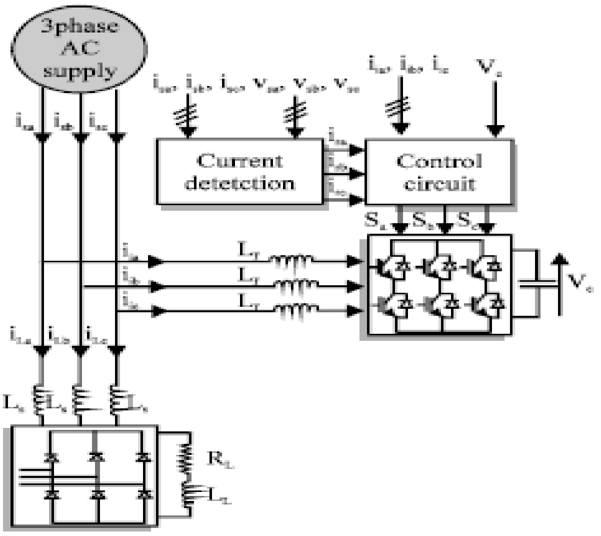


Fig.3. A.P.F with load current detection

## III. CONTROL UNIT BASED ON FPGA

The proposed block diagram shown in Fig 2 represents a gate signals generator for PWM inverter (MAPF). The carrier signals such as triangle waves are generated by 13-bit up counter devices with frequency of 3450Hz. The reference signals is error signal of harmonics of APF and supply currents, which consists of 8-bit data. The corresponding VHDL program code is generated from the system generator after verification and simulation of the design. The VHDL program is verified and simulated using Xilinx-ISE 10.1 software. Once the programs dump to FPGA kit, it acts as a controller and generates gate signals. The results are saved and compared with simulation results of System Generator black box output signals and Matlab/Simulink PWM block signals.

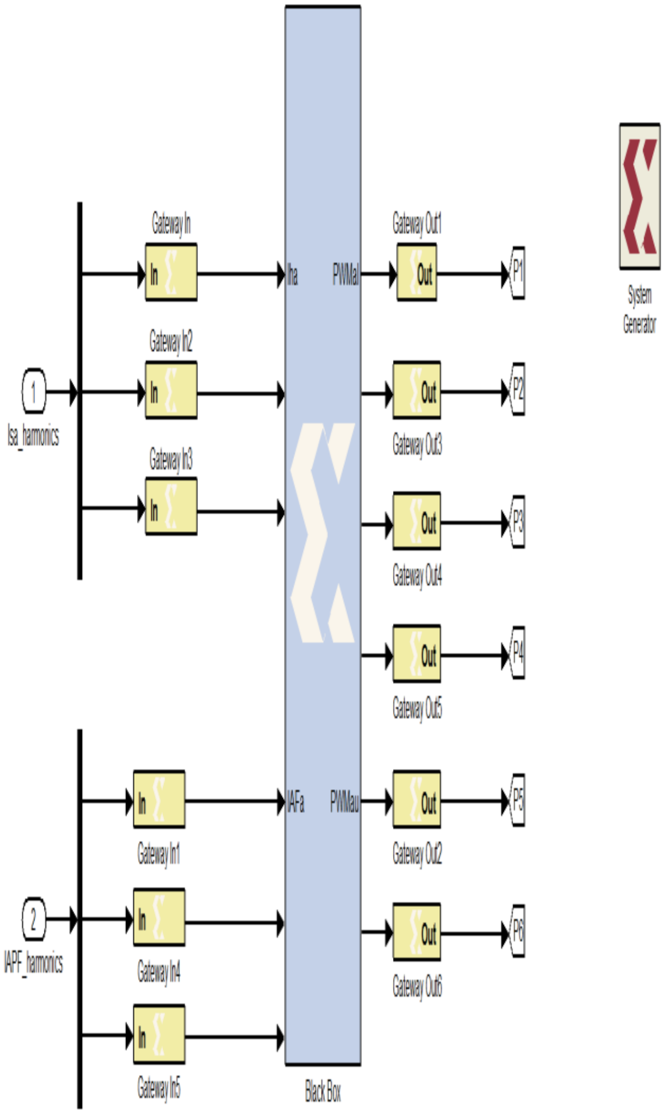


Fig.4. System Generator design model using black box block contained a VHDL code for PWM generation

## IV. CONTROL TECHNIQUES

Control strategy is the heart of the AF and is implemented in three stages. In the first stage, the essential voltage and current signals are sensed using power transformers (PT's), CT's, Hall-effect sensors, and isolation amplifiers to gather accurate system information. In the second stage, compensating commands in terms of current or voltage levels are debased on control methods and AF configurations. In the third stage of control, the gating signals for the solid- state devices of the AF are generated using PWM, hysteresis, sliding-mode, or fuzzy-logic-based control techniques. The control of the AF's is realized using discrete analog and digital devices or advanced microelectronic devices, such as single-chip microcomputers, DSP's, etc.

### *A. Signal Conditioning*

For the purpose of implementation of the control algorithm, several instantaneous voltage and current signals are required. These signals are also useful to monitor, measure, and record various performance indexes, such as total harmonic distortion (THD), power factor, active and reactive power, crest factor, etc. The typical voltage signals are ac terminal voltages, dc- bus voltage of the AF, and voltages across series elements. The current signals to be sensed are load currents, supply currents, compensating currents, and dc-link current of the AF. Voltage signals are sensed using either PT's or Hall- effect voltage sensors or isolation amplifiers. Current signals are sensed using CT's and/or Hall-effect current sensors. The voltage and current signals are sometimes filtered to avoid noise problems. The filters are either hardware based (analog) or software based (digital) with either low-pass, high-pass, or band pass characteristics.

### *B. Development of Compensating Signals*

Development of compensating signals either in terms of voltages or currents is the important part of AF control and affects their rating and transient, as well as steady-state performance. The control strategies to generate compensation commands are based on frequency-domain or time-domain correction techniques.

*1) Compensation in Frequency Domain:* Controlled approach in the frequency domain is based on the Fourier analysis [FIT analysis] of the distorted voltage or current signals to extract compensating commands using the Fourier transformation, the compensating harmonic components are separated from the harmonic-polluted signals and combined to generate compensating commands. The device switching frequency of the AF is kept generally more than twice the highest compensating harmonic frequency for effective compensation. The online application of Fourier transform (solution of a set of nonlinear equations) is a cumbersome computation and results in a large response time.

*2) Compensation in Time Domain:* Control methods of the AF's in the time domain are based on instantaneous derivation of compensating commands in the form of either voltage or current signals from distorted and harmonic-polluted voltage or current signals. There is a large number of control methods in the time domain, which are known as instantaneous "*p–q*" theory , synchronous *d–q* reference frame method synchronous detection method ,flux-based controller notch filter method , P–I controller sliding- mode controller.

## V. SIMULATION AND EXPERIMENTAL RESULTS

The designed MAPF is simulated to demonstrate its steady state and dynamic capabilities for HVDC system. The rectifier controller controls *Idc* at certain value while inverter controller keeps *Vdc* constant at rated value to minimize the losses in the transmission line.

The steady-state behavior of the supply phase voltage (Va) and current (Ia) at the primary side of the LCC-HVDC link without filter and with MAPF are shown in Figs. 3 and 4 respectively. The D.C. power transmitted (*Pdc*) from one side to another is the reference signal for the control system. These results at the required *Pdc* equaling to 0.9 pu show that the phase voltage and current at both sides are in phase with each other, which demonstrate the effectiveness of the proposed MAPF. Also the supply voltage and current are almost free from harmonics. The noise in the voltage and current waveforms shown in Fig. 4 is due to switching frequency of the inverter IGBTs and this can be eliminated by using a simple high pass filter.

Input Voltage (Vrms) = 240V
LOAD SIDE:
Reactive Power = 40 KVAR
Active Power = 80 KW

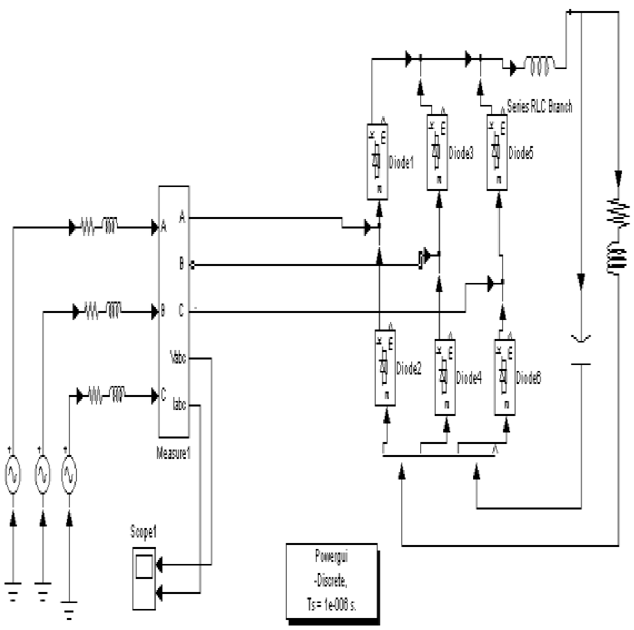


Fig.5. Phase source driving a diode rectifier load

Single phase diode rectifier load implemented in Matlab/Simulink shown in Fig. and Input Voltage and

  

Current Wave Forms for diode model shown in Fig, the THD for input current wave forms found using FFT analysis. The diode rectifier with shunt active power filters shown in Fig., input Voltage and Current Waveforms with THD for diode rectifier with APF shown in Fig.

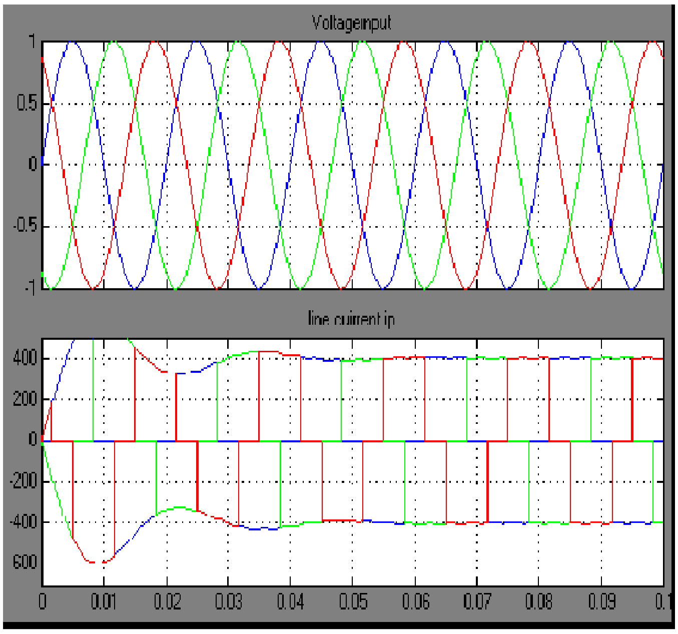


Fig.6. Input Voltage and Current Wave Forms for diode model

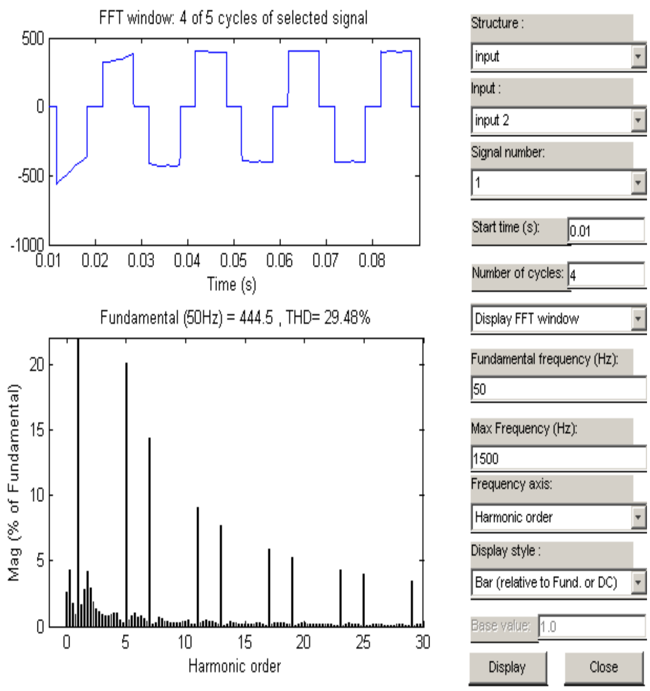


Fig.7. FFT of THD for diode model

## VI. CONCLUSION

An extensive review of AF's has been presented to provide a clear perspective on various aspects of the AF to the researchers and engineers working in this field. The substantial increase in the use of solid-state power control results in harmonic pollution above the tolerable limits. Utilities are finding it difficult to maintain the power quality at the consumer end, and consumers are paying the penalties indirectly in the form of increased plant downtimes, etc. At present, AF technology is well developed, and many manufacturers [16]-[18] are fabricating AF's with large capacities. The utilities in the long run will induce the consumers with nonlinear loads to use the AF's for maintaining the power quality at acceptable levels. A large number of AF configurations are available to compensate harmonic current, reactive power, neutral current, unbalance current, and harmonics. The consumer can select the AF with the required features. It is hoped that this survey on AF's will be a useful reference to the users and manufacturers. At present, AF technology is well developed, and many manufacturers are fabricating AF's with large capacities. The utilities in the long run will abet the consumers with nonlinear loads to use the AF's for maintaining the power quality at acceptable levels. A large number of AF configurations are available to compensate harmonic current, reactive power, neutral current, unbalance current, and harmonics. The consumer can select the AF with the required features depends upon the system.

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