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SERIES ACTIVE FILTER CONFIGURATION AND FORMULATION FOR HARMONICS REDUCTION IN POWER 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. The active power filter has been proved to be an effective method to mitigate harmonic currents generated by nonlinear loads as well as to compensate reactive power. The methods of harmonic current detection play a crucial part in the performance of active power filter (APF). 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 and more and also size of filter is also reduced.

I. INTRODUCTION

There have been seen a rapid increment of power electronics based loads connected to the system in previous years. Such types of loads precede non-sinusoidal current from the main supply which influences the power quality by generating harmonic distortion. These types of loads are generally nonlinear loads in power distribution systems which are the prime sources of harmonic distortion. Power quality is the conception of powering and prohibiting sensitive equipment in aspect that is suitable to the operation of that equipment. Nowadays people want the quality of power and the power quality is simply the co-operation of electrical power with electrical equipment. If the electrical equipment performs correct and reliable manner without being obstructive or pressurized, we would say that the electrical power is of good quality. In the case, if the electrical equipment breakdown is unreliable, or is obstructive during normal usage, we would guess that the power quality is poor.

Harmonics are the major cause of power supply; it degrades the power factor and increases the electrical losses. These are electric voltages and currents that are appear on the electric power system which shows as a result of certain kinds of electric loads. A harmonic is the term used for unwanted and possibly destructive current flow. Harmonics results from the distortion of sine wave caused naturally by nonlinear load. Most significant harmonics are the low order integral harmonics, typically from the 2nd to the 31st. Additionally, harmonics are caused by and are the by-product of modern electronic equipment such as personal or computers, laser printers, fax machines, telephone systems, stereos, radios, TV's, adjustable speed drives and other equipment. When a sinusoidal voltage is applied to the nonlinear load we get the distorted current, an increase in voltage may cause to double the current. This is the main source of harmonic distortion in power system. 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 analysed, 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. SERIES ACTIVE POWER FILTER

Various harmonic reduction techniques have been developed to meet the requirements imposed by the current harmonic standards. In general these techniques can be classified into five broad categories:

1. Passive filters (line reactors and/or DC link chokes, series, shunt, and low pass broadband filters)
2. Phase multiplication systems (12-pulse, 18-pulse rectifier systems)
3. Active harmonic compensation systems (series, parallel)
4. Hybrid systems
5. PWM rectifiers (step-up, step-down, VSI, CSI etc.)

Series APF are operated mainly as a voltage regulator and a harmonic isolator between the nonlinear load and the utility system. The series connected filter protects benefit the consumer from an inadequate supply voltage quality. This type of approach is mostly recommended for compensation of voltage unbalances and voltage sags from the AC supply and for low applications and represents economically attractive alternatives to utility power system, since no energy storage is energy and the overall ratings of the components is smaller. The advantages of series active power are- automatic compensation for varying loads, resonance free, does not affect power factor and can be combined with passive filter network.

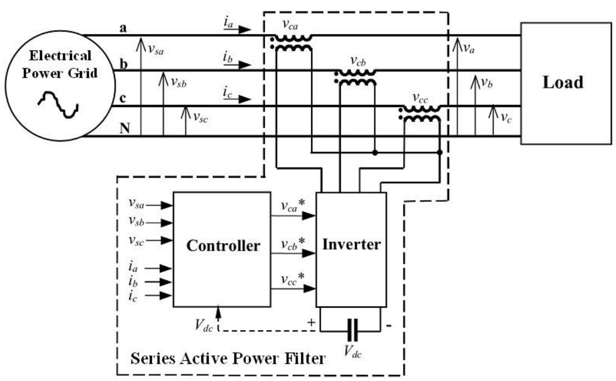

Figure 1: Series Active Power Filter

III. FORMULATION

Fig.1 shows a testing system where there are harmonics generated from the connected nonlinear load and that triple harmonics, especially 3rd order harmonics are predominant in the phases a, b, c and neutral conductor. The magnitude of 3rd order harmonics in neutral conductor is very high before compensation of series active filter.

Fig.2 shows the arrangement of the proposed active filter system. An active filter is placed in serial connection with the neutral conductor of the three-phase four-wire system. A Phase Lock Loop (PLL) sensor provides the measurement of the neutral conductor current i for the system controller. The active filter can be implemented by a hard-switched IGBT inverter operation in pulse width modulation (PWM) controlled by a control desk.

An automatic bypass switch is provided in case the active filter is shut down. A multiplication process is applied to the neutral conductor current $n\ i$ to separate the fundamental and harmonic components [3] using MATLAB simulation design. Current i is phase current multiplied by sin(ωot) and cos(ωot) respectively where ωo is the frequency of the utility grid.

The fundamental component of $n\ i$ is converted into DC and the harmonics are converted into AC after the multiplication. Note that sin(ωot) and cos(ωot) are synchronized to the utility by a Phase-Lock-Loop (PLL) circuit. The low-pass filters (cut-off at 5 Hz) are applied to extract the DC components which are then multiplied by sin(ωot) and cos(ωot) respectively and summed to synthesize the fundamental component of i (represented by , $i\ f$). A scaling factor of 2 is used for normalization. Several Synchronous Reference Frame (SRF) based active filter control schemes use similar techniques to extract the fundamental or harmonics component.

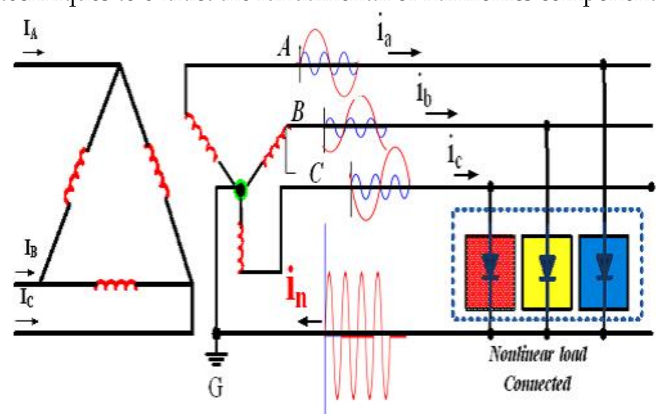

Figure 2: Testing system for a three-phase four-wire distribution

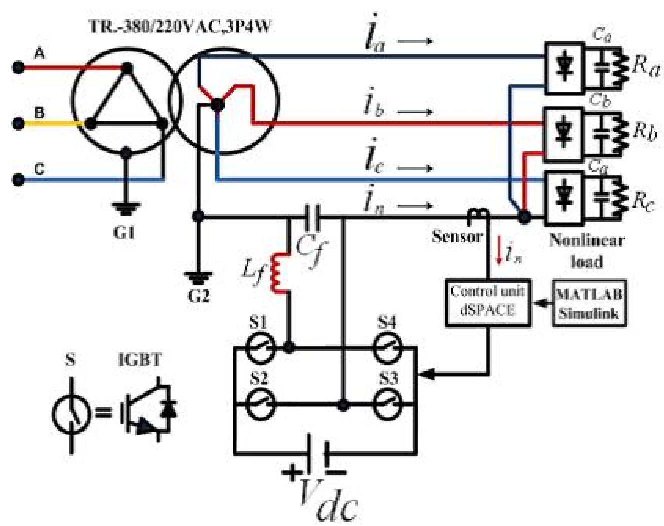

Figure 3: The proposed active filtering scheme for a three-phase four-wire Distribution system

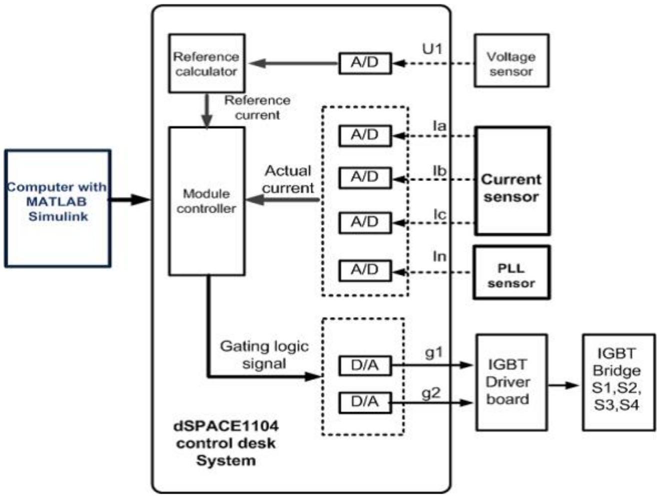

Figure 4: Hardwire configuration

IV. RESULTS

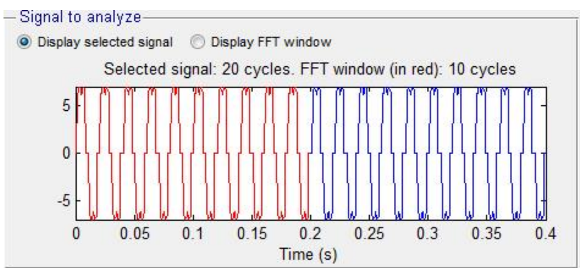

Figure 5: Signal system which is to be analysed (without filter)

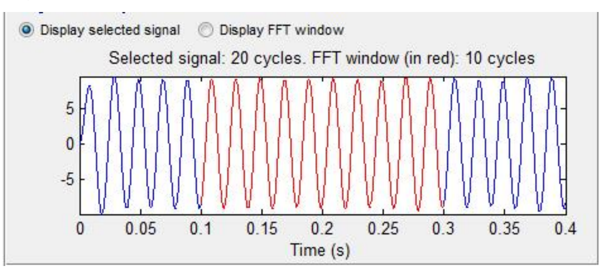

Figure 6: Bar representation of the signal (with filter)

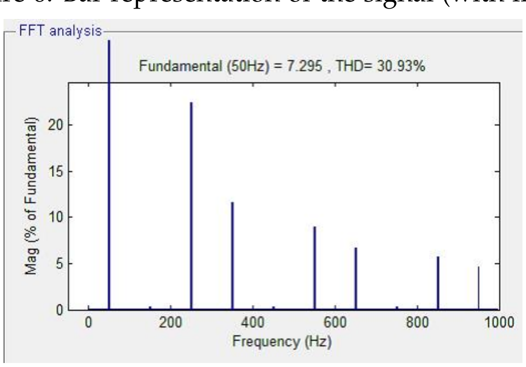

Figure 7: Bar representation of the signal (with filter)

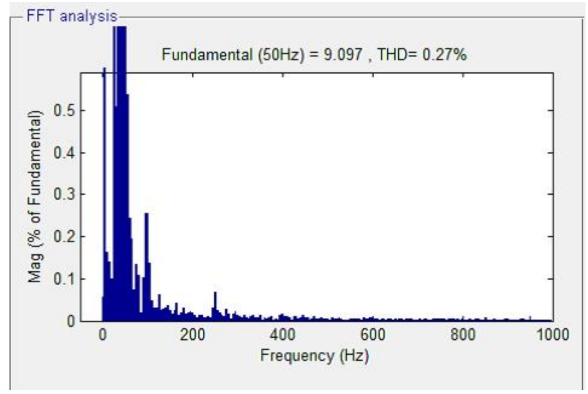

Figure 8: Bar representation of the signal (with filter)

V. CONCLUSION

A MATLAB based model of the series active power filter has been simulated for the RL load. The simulation results show that the harmonics produced due to voltage and current are reduced very effectively by utilizing the series active power filter. 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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