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A REVIEW ON SERIES ACTIVE FILTER PERFORMANCE FOR HARMONIC REDUCTION

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Abstract: A series active power filter working as a sinusoidal current source, in phase with the mains voltage, has been developed and tested. The amplitude of the fundamental current in the series filter is controlled through the error signal generated between the load voltage and a pre-established reference. The control allows an effective correction of power factor, harmonic distortion, and load voltage regulation. Compared with previous methods of control developed for series active filters, this methodis simpler to implement, because it is only required to generate a sinusoidal current, in phase with the mains voltage, the amplitude of which is controlled through the error in the load voltage. The proposed system has been studied analytically and tested using computer simulations and experiments. In the experiments, it has been verified that the filter keeps the line current almost sinusoidal and in phase with the line voltage supply. It also responds very fast under sudden changes in the load conditions, reaching its steady state in about two cycles of the fundamental.

I. INTRODUCTION

Power quality phenomena include all possible situations in which the waveform of the supply voltage (voltage quality) or load current (current quality) deviate from the sinusoidal waveform at rated frequency with amplitude corresponding to the rated rms value for all three phases of a three-phase system. The wide range of power quality disturbances covers sudden, short duration variations, e.g. impulsive and oscillatory transients, voltage sags, short interruptions, as well as steady state deviations, such as harmonics and flicker. One can also distinguish, based on the cause, between disturbances related to the quality of the supply voltage and those related to the quality of the current taken by the load. To the first class belong, among others, voltage dips and interruptions, mostly caused by faults in the power system. These disturbances may cause tripping of “sensitive” electronic equipment with disastrous consequences in industrial plants where tripping of critical equipment can bear the stoppage of the whole production with high costs associated. One can say that in this case it is the source that disturbs the load. To avoid consistent money losses, industrial customers often decide to install mitigation equipment to protect their plants from such disturbances. The second class covers phenomena due to low quality of the current drawn by the load. In this case, it is the load that disturbs the source. A typical example is current harmonics drawn by disturbing loads like diode rectifiers, or unbalanced currents drawn by unbalanced loads. Customers do not experience any direct production loss related to the occurrence of these power quality phenomena. But poor quality of the current taken by many customers together will ultimately result in low quality of the power delivered to other customers: both harmonics and unbalanced currents ultimately cause distortion and respectively, unbalance in the voltage as well. Therefore, proper standards are issued to limit the quantity of harmonic currents, unbalance and/or flicker that a load may introduce. To comply with limits set by standards, customers often have to install mitigation equipment. In recent years, both industrial and commercial customers of utilities have reported a rising tide of misadventures related to power quality. The trouble stems from the increased refinement of today’s automated equipment, whether variable speed drives or robots, automated production lines or machine tools, programmable logic controllers or power supplies in computers. They and their like are far vulnerable to disturbances on the utility system than were the previous generation of electromechanical equipment and the previous less automated production and information systems. A growing number of loads is sensitive to Customers critical processes which have costly consequences if disturbed by either poor power quality or power interruption. For the reasons described above, there is a growing interest in equipment for mitigation of power quality disturbances, especially in newer devices based on power electronics called “active filter” able to deliver customized solutions to power quality problems.

POWER QUALITY PROBLEMS:-

- Customer Load Profiles
- Heavy Industry
- Manufacturing Industry
- Commercial Business
- Domestic Environments

II. LITERATURE SURVEY

Bhim Singh, Kamal Al-Haddad, Senior Member, IEEE, and Ambrish Chandra, Member, IEEE [1] has been studied that Active filtering of electric power has now become a mature 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. It is aimed at providing a broad perspective on the status of AF technology to researchers and application engineers dealing with power quality issues. 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. 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. It is hoped that this survey on AF's will be a useful reference to the users and manufacturers.

Joao L. Afonso, Member IEEE, H. J. Ribeiro da Silva and Julio. S. Martins, Member IEEE [2] have been described that several international standards issued to control power quality problems are briefly described and some important methods to analyze electrical circuits with non-sinusoidal waveforms are introduced and evaluated. One of these methods - the p-q theory - was used to implement the control algorithm of a shunt active filter, which his also described. Both simulation and experimental results are presented, showing that good dynamic and steady-state response can be achieved with this approach.

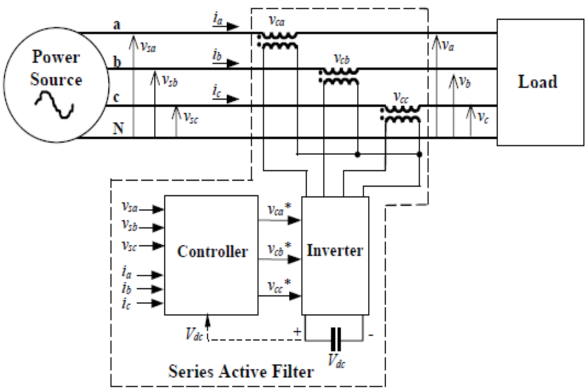

Fig. 1- Series active filter in a three-phase power system.[2]

Active filters are an up-to-date solution to power quality problems. Shunt active filters allow the compensation of current harmonics and unbalance, together with power factor correction, and can be a much better solution than the conventional approach (capacitors for power factor correction and passive filters to compensate for current harmonics).Three different methods to control active filters are presented: the FBD Method, the Synchronous Reference Method, and the p-q Theory. As an application example of these methods, the p-q theory was used as control scheme in the implementation of a shunt active filter. The solution shows to be simple and effective, since all the calculations are algebraic operations, which can be made through integer arithmetic. As a result, it was possible to implement the digital controller using a standard microcontroller, with minimum additional hardware. Experimental results and simulations show that the shunt active filter presents good dynamic and steady-state response. It can perform harmonic currents compensation, together with power factor correction. It can also compensate for load current unbalances, eliminating the current in the neutral wire.

Juan W. Dixon, Senior Member, IEEE, Gustavo Venegas, and Luis A. Moran, Senior Member, IEEE [3] has been studied that a series active power filter working as a sinusoidal current source, in phase with the mains voltage, has been developed and tested. The amplitude of the fundamental current in the series filter is controlled through the error signal generated between the load voltage and a pre-established reference. The control allows an effective correction of power factor, harmonic distortion, and load voltage regulation. Compared with previous methods of control developed for series active filters, this method is simpler to implement, because it is only required to generate a sinusoidal current, in phase with the mains voltage, the amplitude of which is controlled through the error in the load voltage. The proposed system has been studied analytically and tested using computer simulations and experiments. In the experiments, It has been verified that the filter keeps the line current almost sinusoidal and in phase with the line voltage supply. It also responds very fast under sudden changes in the load conditions, reaching its steady state in about two cycles of the fundamental.

M.A. Mulla, Member, IEEE, R. Chudamani, A. Chowdhury, Member, IEEE [4] has been studied that in the area of active power filtering, with an objective to reduce inverter capacity, the Series Hybrid Active Power Filter (SHAPF) has been taken into account increasingly. Existing method used for controlling SHAPF is either based on detecting source current harmonic or load voltage harmonics. Generalised Instantaneous Power Theory (GIPT) gives simple and direct method of defining power quantities under sinusoidal and non-sinusoidal situations. The definition of GIPT is used to decompose voltage vector into different components, which represents different parts of the power quantity. The separated components of voltage vector are used to derive reference for SHAPF. Formulation of decomposing different power quantities in terms of voltage components is presented. These components are directly associated with three phase instantaneous voltages and currents and are separated without any form of artificial coordinate transformations. Application of this decomposition in generating reference signal for SHAPF for harmonic elimination is demonstrated. The THD of supply current is 29.46% without compensation is reduces to 1.58% after connecting SHAPF, which proves the effectiveness of proposed method.

Enio R. Ribeiro, Member, IEEE, and Ivo Barbi, Senior Member, IEEE [5] has been studied that the series active filter is applied as a controlled voltage source contrary to its common usage as variable impedance. It reduces the terminal harmonic voltages, supplying linear or even nonlinear loads with a good quality voltage waveform. The operation principle, control strategy, and theoretical analysis of the active filter are presented. These aspects were proven by the results of numerical simulations. Experimental results of the series active filter demonstrated its good performance under different load conditions. The proposed series active filter acting as harmonic voltage compensator, its operating principle and its control strategy, were presented. Also, a set of its relevant equations were described. A sinusoidal waveform, from a distorted voltage source, was delivered to the load after being processed by the filter. The filter topology as well as its control strategy is simple and efficient. Experimental results were obtained and validate the theoretical analysis.

Darwin Rivas, Luis Moran, Senior Member, IEEE, Juan W. Dixon, Senior Member, IEEE, and Jose R. Espinoza, Member, IEEE [6] has been described that the performance analysis of a hybrid filter composed of passive and active filters connected in series. The analysis is done by evaluating the influence of passive filter parameters variations and the effects that different active power filter's gain have in the compensation performance of the hybrid scheme. The compensation performance is quantified by evaluating the attenuation factor in a power distribution system energizing high-power nonlinear loads compensated with passive filters and then improved with the connection of a series active power filter. Finally, compensation characteristics of the hybrid topology are tested on a 10-kVA experimental setup. The compensation performance of a hybrid filter was presented and analysed. The hybrid active power filter combines the compensation characteristics of resonant passive and active power filters. It was proved that the proposed hybrid scheme is able to compensate displacement power factor and current harmonics simultaneously. The combination of passive and active power filters allows for better performance compensation of high voltage nonlinear loads. The compensation performance of the hybrid scheme was analysed for different parameter variation and active power filter's gain. It was concluded that large values of active power filter's gain improves compensation effectiveness, independently of the passive filter performance. It is recommended that, for this type of application, the active power filter's gain must be greater than 15. The technical viability of the proposed scheme was verified by simulation using Spice and with an experimental setup of 10 kVA.

Po-Tai Cheng, Student Member, IEEE, Subhashish Bhattacharya, Student Member, IEEE, and Deepak D. Divan, Fellow, IEEE [7] has been described that dominant harmonic active filter (DHAF) scheme using small-rated square-wave inverters for supply line harmonic current reduction for high-power nonlinear loads in the range of 10 MW and above to meet IEEE 519harmonic standard. The active filter inverters are connected inseries with the fifth and seventh L–C tuned filters, respectively. A synchronous reference frame-based controller which achieves harmonic isolation for the dominant fifth and seventh harmonic load currents in the presence of supply voltage harmonic distortion is presented. Impact of mistuned passive filters on the operation and rating of the square-wave active filter inverters is examined. Simulation results validate the proposed harmonic isolation controller under mistuned fifth and seventh L–C tuned filter conditions and supply voltage harmonic distortion. The proposed scheme is general and applicable for high-power 6- or 12-pulserectifier loads. The use of small-rated square-wave inverters (approximately2% of load kilovolt ampere rating) increases the cost effectiveness of the DHAF system for high-power applications.

It has been shown through detailed system simulation that the proposed DHAF system operates effectively over a wide range of practically encountered conditions. These include:
• supply voltage harmonic distortions;
• mistuned passive filters;
• Variation in the line frequency;
• Use of square-wave inverters to extend operation to high power systems.

A new control strategy has been proposed to allow the use of low-power low-switching frequency square-wave inverters as hybrid active filters. Active filter ratings of 1.5% of load could allow realization of IEEE 519 compatible systems at power levels of 10 MW and above. The main features of the proposed DHAF system are listed as follows.
• Dynamic compensation for mistuned passive filters.
• Dynamic compensation for dominant fifth and seventh supply voltage harmonic distortion.
•Higher efficiency for high-power active filter inverters—devoid of high-frequency switching losses as in a PWM inverter.
• Accomplishes harmonic isolation at the dominant harmonic frequencies with small rating low-switching frequency square-wave active filter inverters.
• The effectiveness of harmonic isolation in the presence of supply voltage harmonic distortion is evident. However, in the absence of supply voltage harmonic distortion, the harmonic isolation controller achieves active tuning of the passive filter and improves its compensation characteristics.
• This scheme is applicable for harmonic compensation of loads connected to stiff supply systems. Stiff supply systems pose a particularly difficult problem for the design of tuned passive filters for industrial loads, since they require sharp tuning and high-quality factor so as to sink a significant portion of the load current harmonic components. However, sharp tuning of passive filter is also likely to cause severe resonance between supply and load.

M.Izhar, C.M.Hadzer, SyahdnM, S.Taib and S.Idns [8] has been studied that the analysis and design of a star delta transformer in series with active power filter linked to grid lines are carried out. The development of active power filter which consists of voltage reference, triangular generator to generate pulse width modulation with half inverters is simulated. The current injection network of half inverter in series with three phase of a star delta transformer which is interconnected to grid lines is also discussed. It is observed that the reduction of harmonics at gridlines was significantly reduced. The simulation results show that the total harmonic distortions are reduced within range of 45% -50% and 97% - 99% at distributions and Neutral lines respectively. Also, the distortions of sinusoidal waveform at gridlines were improved. The simulation design on active power filter to reduce current harmonic in the neutral conductor as well as to guarantee current reduction in Red, Yellow and Blue for three phase four wire system have been demonstrated. The suggested of a star delta transformer in series with active power filter is significantly reduced the total harmonic distortion in the lines distribution systems are within the range of 40%-50% at Red, Yellow & Blue and 97%-99% at Neutral lines respectively. Also, this work is iii progress lo validate the results between simulation and experiment in order to get better accuracies.

Subhashish Bhattacharya, Deepak Divan. Ben Banerjee [9] has been studied that the Hybrid Series Active Filter system, consisting of a series active filter and a parallel passive filter, is attractive because of the extremely small (2-596) kVA rating of the series active filter compared to the load kVA rating and its ability to provide 'harmonic isolation' between the supply and the load. A modified SRF based controller for the series active filter allows injection of controlled percentage of the higher harmonic load currents into the supply, in compliance with the IEEE519 harmonic current standards, thereby reducing the passive filter terminal voltage THD. This implementation retains all the desirable features of the original SRF controlled Hybrid Series Active Filter system. It reduces the rating and size of the passive filter system and allows the use of simpler passive filter system structures such as only a simple high pass passive filter or a simple power factor correction capacitor asthe passive filter system. This increases the attractiveness and cost effectiveness of an already attractive, practical and economically viable system.

A MSRF controller scheme for reducing the passive filter terminal voltage distortion for a Hybrid Series Active Filter system has been presented. This scheme enables controlled injection of higher load current harmonics into the supply so that IEEE 519 harmonic current THD and passive filter terminal voltage THD standards are met with reasonable margins. The effect of off-tuned passive filters on the terminal voltage THD is shown. The viability and cost effectiveness of the MSRF controller with a simple power factor correction capacitor as the passive filter and its impact on the reduction of the rating of the series active filter is shown. Experimental results establish the functionality of the SRF controller.

III. SIMULATION AND RESULTS

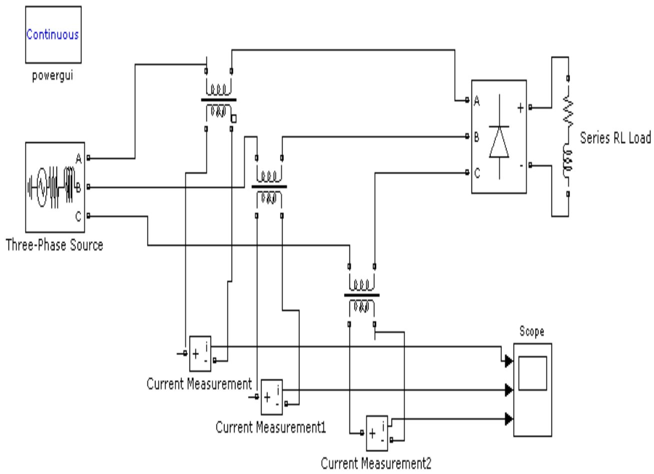

Fig 2. Three phase source before using filter

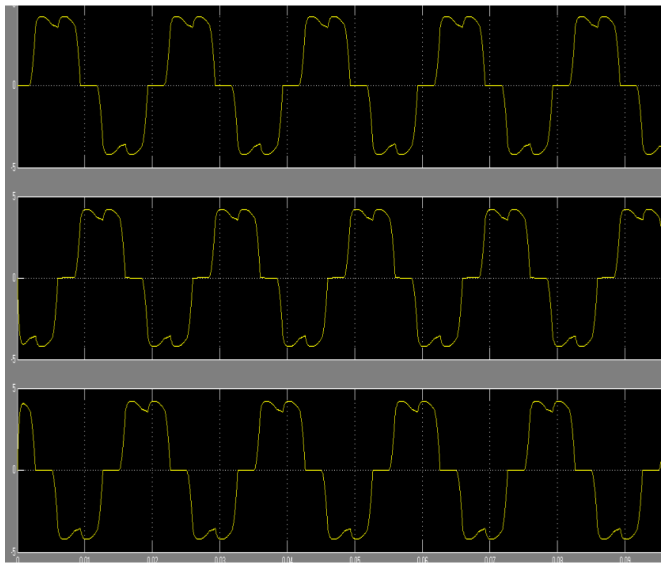

Fig 3. Current Waveform before using filter

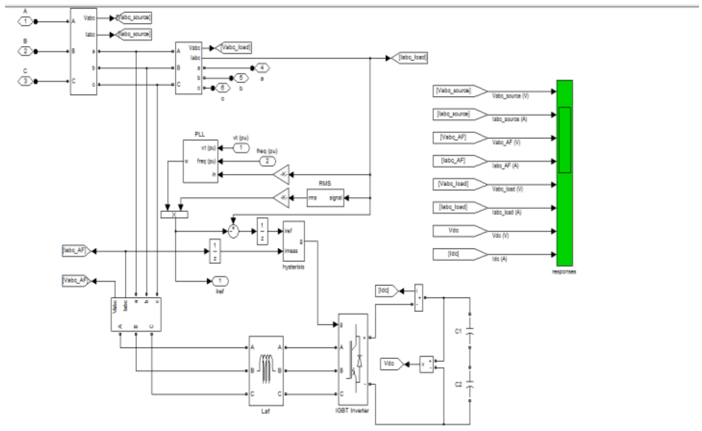

Fig 4.- series filter circuit diagram

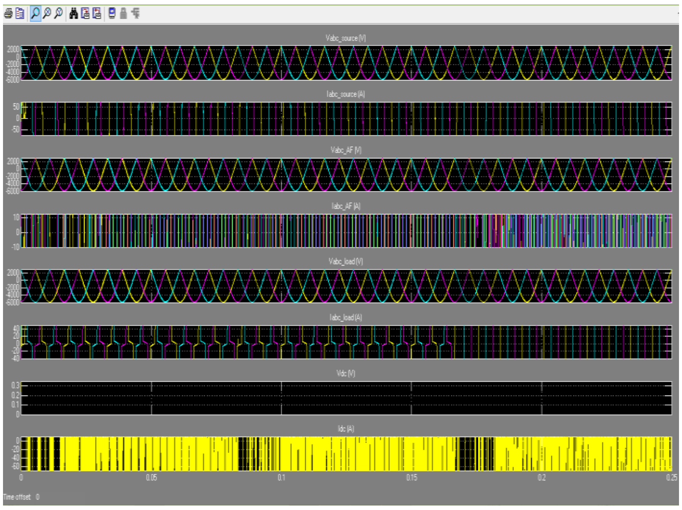

Fig.5 -filter output

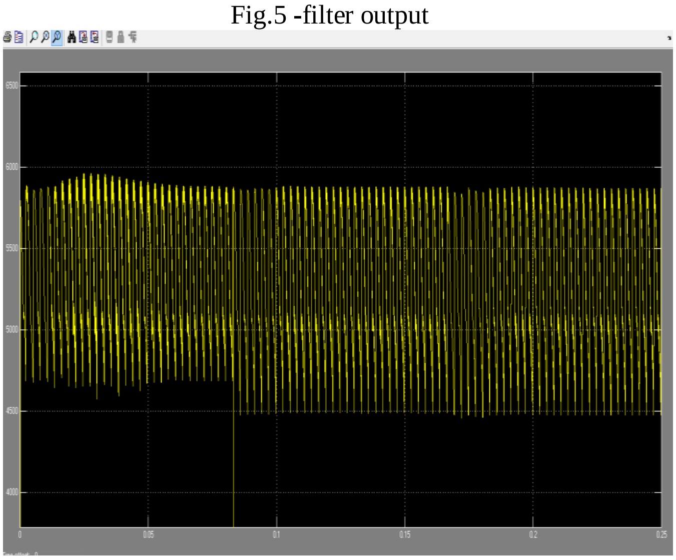

Fig. 6-Vdc1

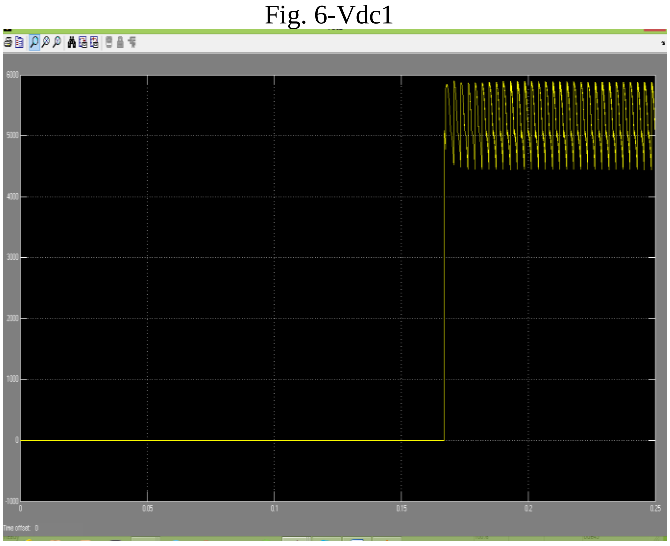

Fig 7.-Vdc2

IV. FUTURE SCOPE

The model of series active filter very useful for getting the newer control strategy or advanced technique for the filtering of nonlinear load. 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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