POWER QUALITY INNOVATION IN HARMONIC FILTERING

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ABSTRACT

Power quality has become a great concern for both energy suppliers and their customers because the increasing use of sensitive devices and the significant consequences of a poor power quality for the competitiveness of the companies. The increasing developments need increasing use of electricity. While meeting this power demand, there causes a pollution in electrical system called Harmonics. The harmonics are integer multiples of fundamental currents/voltages. Substantial presence of harmonics results in excessive overheating of the equipments and other problems. Harmonics are created by non linear loads that draw current in abrupt pulses rather than in a smooth. With advancement in technology, there has been an increase in usage of power electronic converters/loads for various industrial applications and process automation. Power electronic loads inject harmonic currents into the utility causing overheating of power transformers and neutral wires, unpredictable performance of protection systems etc. In addition, electric resonances in such loads can also cause other undesirable phenomena like voltage fluctuations; radio frequency interference (RFI) etc.Different problems due to harmonics have different solutions. This paper presents the basic concept of harmonics, their generation, problems created by them and harmonic filtration as a solution for all these problems.

***Keywords**: Power, Filter, Harmonic, Load.*

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I. INTRODUCTION

Power quality is defined as the concept of powering and grounding electronic equipments in a manner that is suitable to the operation of the equipment in a way that is suitable to the operation of that equipment and compatible with the premise wiring system and other connected equipment. In modern power systems, harmonic distortion is one of the major power quality issues. Today, power electronic loads such as semiconductor rectifiers in AC and DC variable-speed drives (VSD), electronic lamp ballasts, Switch-Mode Power Supplies (SMPS) and Uninterruptible Power Systems (UPS), are the most common sources of Harmonics. In last three decades technology advancement has led to increase in usage for power electronic converters for various industrial, commercial and residential applications. These static converters draw non sinusoidal currents and hence polluting the utility supply due to the characteristics and non characteristic harmonics generated by them. Harmonics are currents or voltages with frequencies that are integer multiples of the fundamental power frequency. The fundamental frequency itself is called as the first Harmonic. The second harmonic as frequency twice that of the fundamental, the third harmonic has frequency thrice that of the fundamental and so on. For example – if the fundamental frequency is 50Hz then the second Harmonic is 100 Hz, the third Harmonic is 150Hz etc as shown in Fig. 1[1]. These harmonics interfere with sensitive electronic equipment and cause undesired power losses in electrical equipment [1, 2, and 3].

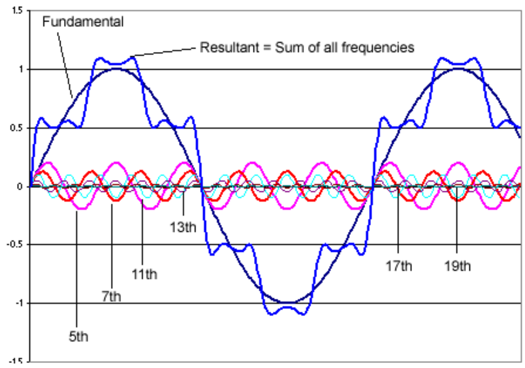

Fig.1 Harmonics of different amplitudes

The presence of harmonics distorts the waveform shape of voltage and current, increases the current level and changes power factor supply which in turn creates many problems. The electric power quality (EPQ) is characterized by a number of parameters. The first EPQ group characterizes frequency of voltage in supplying networks. The main index is the frequency deviation. The second group of parameters consists of voltage EPQ. In this case, main indexes are the voltage deviations, their oscillations, highest voltage harmonics, voltage unbalances in power networks, voltage dips and more.

II. RELATED WORK

Our work involves analysis of harmonics and their elimination. The available literature has been reviewed in this context.

S.Khalid, Bharti Dwivedi[4] describes latest innovative ideas to make the life easier using the technology depends upon the application of power electronics in turn about power quality. With increasing quantities of non-linear loads being added to electrical systems, it has become necessary to establish criteria for limiting problems from system voltage degradation. They presents the power quality problems, issues, related international standard, effect of power quality problem in different apparatuses and methods for its correction, which is most relevant to our work and helps to understand the international standards used for power quality. They also suggests that the distorted waveforms may be mathematically analyzed using Fourier transforms as a combination of vectors of the power frequency (50 Hz) and other multiples of the power frequency.

Suresh Kumar. K. S, Dr. Ashok. S, [5] describes indices and Limits for Harmonics. Total Harmonic Distortion in voltage (THD) and Total Demand Distortion in currents (TDD), are the important indices used to measure the amount of harmonics in power systems, i.e. deviation of a periodic waveform containing harmonics from a perfect sine wave. Generally, the maximum permissible harmonic levels are given in terms of % THD. The allowable limits for voltage and current distortion as specified by IEEE 519 – 1992, Recommended Practices and requirements for harmonic control in Electric Power Systems, established limits on harmonic currents and voltages at the point of common coupling (PCC).

Daniel Balan [6] defines the meaning of power quality management and its importance. The management of power quality is a multi-dimensional task. In energy applications implementation of modern technologies in the current circumstances requires increasingly stringent supply voltage is maintained within acceptable limits. The inconvenience caused by these problems requires the measurement and analysis of power quality and this increases the importance of monitoring tools for locating problems and finding solutions. Monitoring plays a significant role in finding solutions for solving power quality monitoring, but an appropriate coordination helps in minimizing troubleshooting costs. If the power quality of the network is good, then any loads connected to it will run satisfactory and efficiently and installation running costs will be minimal and vice –versa. He explains issues related to power quality management in all its complexity, correctly identifying the causes, phenomena and present solutions in the area of power quality which can help to avoid damage / failure. By analogy with intelligent data analysis systems implemented at the business level, the system aimed at collecting data on power quality and processes for intelligent analysis of these data have been grouped under the name Power Quality Intelligence (PQI). Architecture of an intelligent system for power quality analysis and the principles underlying the organization of data in a database on the subject of specific power quality could be a challenge for experts in the field.

Norbert Edomah [7] describes that the number of power quality problems has increased dramatically. This increase in electricity demand of recent years, consecutively with increasing the number of power plants along with changing the structure of energy agents and increase power receivers, led to deterioration of power quality parameters, with implications serious about working arrangements and consumer networks. the various power disturbance parameters can have very serious cost implications if not tackled. Equipment manufacturers are saddled with the responsibility to incorporate, from design stage, devices that could help minimize the effects of poor power quality. This could be expensive but in special cases where the need justifies the expense, it may be possible to arrange an alternative power source aside the grid where the various power disturbance parameters could be minimized.Most disputed aspect in terms of power quality standards is the regime's control sizes. He proposed the use of Passive filters, Input chokes, Delta/star isolation transformers; Equipment with built-in power factor correction, active conditioners removes all above problems.

Ying-Tung Hsiao [8] describes a novel means of designing power filters to reduce harmonic distortion and correct the power factor. in lieu of concerns to satisfy the safety constraints and incur a minimum purchase and installment cost.The optimization process considers the discrete nature of the size of the element of the filter. The problem of designing filters is formulated as combinatorial optimization problem with a non-differentiable objective function. In addition a solution methodology based on an optimization technique – simulated annealing is proposed to determine the size of filters with minimum cost. The proposed technique is compared with the sequential unconstrained minimization technique in terms of performance and investment cost, via the industrial distribution system.

Pecha, J. Tlusty, Z. Müller, and V. Valouch[9] describes that the new topology and control strategy of the Hybrid Power Filter (HPF) with a split passive part whose impedance is divided into two individual parts tuned to 50 Hz and 250 Hz is presented. The topology is very effective to mitigate harmonic currents of a non-linear load, especially for high frequencies. The value of the voltage of fundamental frequency at terminals of an electronic power converter is in the range of several percent of that voltage at the Point of Common Coupling (PCC) at the same time. Additionally, the functionality of this HPF is affected by changes of the grid inductance only negligibly. The behaviour and properties of the new HPF are compared with those for a usual option of the HPF and for a classic passive compensation by simulation done in the Matlab/Simulink environment. They also sates the new HPF has highest priority above other HPF topologies, which is relevant to our work.

Renato Alves, Pedro Neves,D. Gonçalves, J. G. Pinto1, José Batista, João L. Afonso[10] presents the results of electric power quality monitoring studies performed in different industries and in universities. The monitoring is made with an Electric Power Quality Monitor developed at the University of Minho. The studies are performed in different installations: textile industries, a pharmaceutical industry, a hospital and two universities. Therefore, the results are obtained in different electrical installations. It is important to emphasize that, the results presented are not intended to establish profiles for each type of electrical installation. The aim is rather to show several electric power problems that occur in these types of facilities. They also presents the functionalities of the Electric Power Quality Monitor developed at the University of Minho, working out of laboratory, in real electrical installations. The Electric Power Quality Monitor may be used to have further knowledge about the electrical installation characteristics. The information acquired may be used to implement changes in the electrical installation improving its efficiency. Also, the Monitor can be used to follow the energy spent, having an idea of the loads that more contribute for the electricity costs.

III. PROBLEM FORMULATION

In an ideal power system, voltage and current waveforms are pure sinusoids. However, in practice under different circumstances, voltage and current waveform distortions occur. The measurement of these harmonics is important to derive power quantities of power quality indices. However, despite that a harmonic is a steady-state phenomenon, in practice the measurements have to be performed in dynamic conditions as well.The problem of harmonics filtration is described as follows:

1. The presence of harmonics in power systems shortens the equipment's operating life and interfere with communication lines and sensitive equipments which results in noise.

2. The design of filter and its proper selection has become essential for industrial distribution systems. The filter size such that the total investment cost (i.e. purchase cost and instalment cost) is kept at a minimum.
3. This is the problem which was not considered in conventional filtering techniques based on trial and error approach.

A. Objectives of the Present Work

The objective is to eliminate the harmonics from the given system using a systematic approach known as harmonic filtering solution cycle, as shown in the flow chart in figure 2. The harmonics are removed using different types of filters. Each type has its own benefits and limitations. So the main objectives are:

1. To reduce power system harmonics and improve the electric power quality.
2. To select a cost effective filtering technique for the given system.
3. To keep the total investment cost at the minimum.
4. To reduce the electromagnetic interference.

A. Filter selection

In power system at the light-load condition if the reactive VArs supplied by the filters exceed the system demand, the problem of system over voltage arise. The difficulty is in how to select and deploy harmonic filter correctly, which is key to achieving a satisfactory performance. Thus to suppress harmonics effectively the filter design problem can be identified as identifying the size of filters with minimum cost in conjunction with operation constraints.

1. The reactive power supplied by the filter must be within the maximum and minimum limits.
2. Total harmonic voltage distortion must be less than or equal to maximum harmonic voltage distortion.
3. Total harmonic current distortion must be less than or equal to maximum harmonic current distortion.
4. The voltage for the given system must be within its maximum and minimum limits.
5. The selection of the filter depends upon the KVA requirements of the load and the harmonic profile of the load current.
6. The configuration of the existing or proposed system should be considered during filter selection.

Basically the harmonic filter is an array of capacitors, inductors, and resistors that deflect harmonic currents to the ground. Each harmonic filter could contain many such elements, whose function is used to deflect harmonics of a specific frequency.

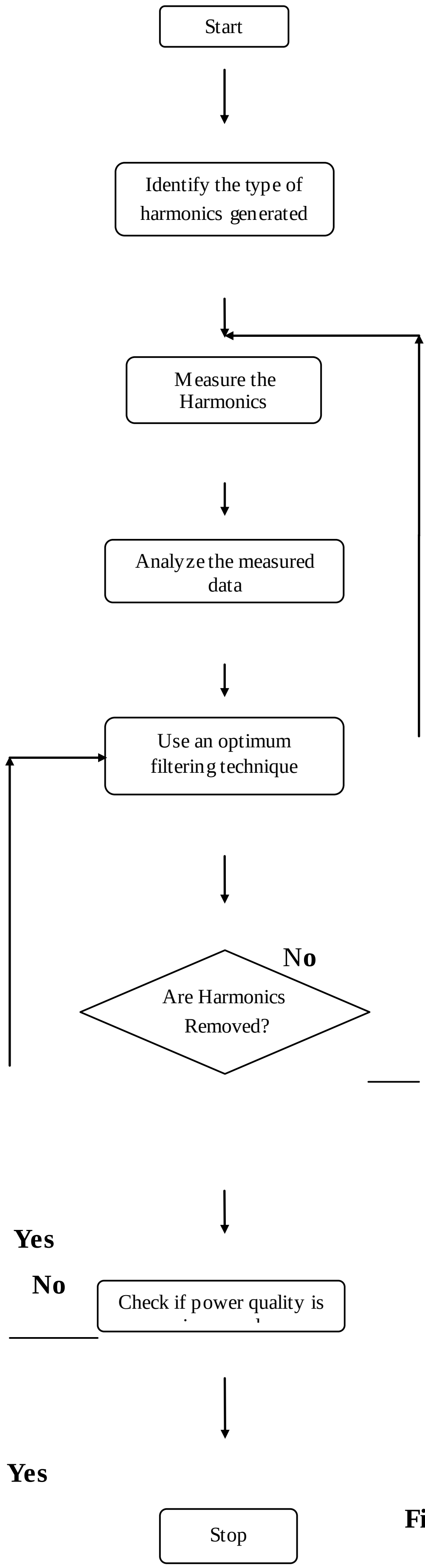

Fig.2 Harmonic Filteration flow chart

B. Types of Filters

Traditionally, series reactors are used for variable speed drives and three phase rectifiers. It is connected in series upstream of a non-linear load. A reactor is not expensive, but has limited effectiveness. Tuned passive filter are also used to "trap" the harmonic currents in L/C circuits tuned to the harmonic orders requiring filters. Therefore it comprises a series of "stages", each corresponding to a harmonic order, out of which 5 and 7 are the most commonly filtered. It is not flexible and is virtually impossible to upgrade. It needs to be re-tuned if circuit environment changes. Due to these limitations series reactors and tuned filters become obsolete. To overcome these problems, following harmonic filters are in use. They are broadly classified into two basic types: active and passive. An active harmonic filter (AF) ***acts*** like a boost regulator. The concept used in an active filter is the introduction of current components using power electronics to remove the harmonic distortions produced by the non-linear load. The duty cycle and power factor are thus improved.

IV. PRESENT WORK

These filters have the disadvantage that they are only used for low-voltage networks where reactive power requirement is low. Due to the presence of harmonics in both current and voltage, active filter may not be able to resolve the issue in certain typical applications.

On the other hand passive filters (PF) consist of resistors, inductors and capacitors. They are not expensive and are often used to restrict the harmonic currents from entering the power system thus minimizing the effect of harmonics due to nonlinear loads. Also, the passive filters are kept close to the source of harmonic generation i.e. the nonlinear loads. They are used for different voltage levels. In this filtering scheme, the harmonics are reduced by using series or parallel resonant filters. Hence the passive filters produce better results in reducing the harmonic effect. Fig.3 shows a single phase representation of distribution system with the nonlinear load and passive shunt filter.

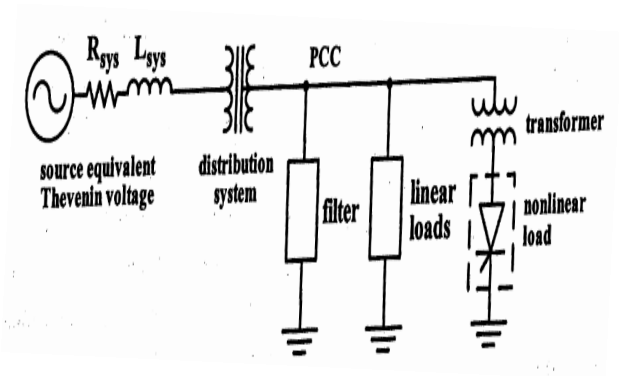

Fig.3 Single Phase Representation of Non Linear load and Passive Shunt filter.

Passive Filters (PFs) for harmonic filtration and reactive power compensation have many disadvantages that restrict their efficiency and reliability. Thus, Active Power Filters (APFs) represent a perspective solution to improve the power quality in transmission and distribution networks. Nevertheless, the higher price of APFs is the main obstacle of their broad utilization, apart from difficulties if an APF is used in high voltage applications. For the conditions where both voltage and current are leading to a deterioration in power system, more complex filters are used which are made up of combination of active and passive filters. Such filters are called as Hybrid Filters. Figure 4 gives the block diagram of hybrid filter. It may be either of the series or parallel type. The passive filter carries out basic filtering (5^{th} order, for example) and the active filter, through its precise and dynamic technique covers the other harmonics. This new filtering solution offers the advantages of both types of filters and covers a wide range of power and performance levels.

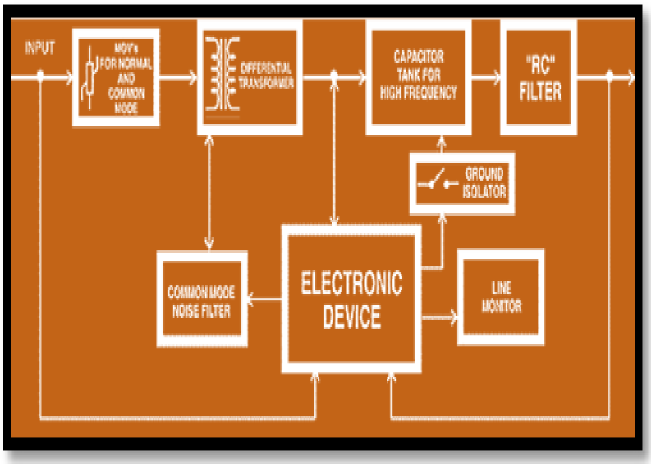

Fig. 4 Block diagram of hybrid filter.

V. RESULTS

Power system harmonic analysis is carried out to determine the impact of harmonic producing loads on power system. Harmonic analysis has been widely used for system planning, equipment design, troubleshooting, and verification of standard compliance and so on. Harmonic studies are becoming an important component of power system analysis and design.Voltage stability and high power quality are the two main necessities for the equipments used today. It is therefore necessary for the power system to be free from harmonics and other electrical disturbances. Hence, hybrid harmonic filters play an important role in ensuring a 'clean' power supply. The main benefits of this scheme are

- Reduce harmonics in the network to the desired level.

- Reduced line currents and losses and hence lower energy bills.
- Due to lower operating temperature operating life / reliability of equipment is increased.
- Improvement in power factor and avoided penalty for low power factor.
- Preventing the occurrence of series or parallel resonance.
- Reduction in maximum demand and demand charges.
- Improvement in voltage profile and consequent efficient operation of power equipment.

VI. CONCLUSIONS AND FUTURE WORK

Power quality is a critical issue that needs to be addressed as it is very important to commercial and industrial power system designs. An important concern to the operation of equipments is the effects of harmonic distortion in the voltage and current waveforms, caused by non-linear loads. Over the past two decades,significant efforts and progresses have been made in the area of power system harmonic analysis and reduction. In order to reduce the rating of active power filter a control strategy which utilizes the advantages of both passive and active filter for nonlinear load compensation is presented in this paper. The control strategy not only reduces the rating of active filter but also improves the performance under distorted mains condition.The topology is very effective to mitigate harmonic currents of a non-linear load, especially for high frequencies. The same study can be extended to different types of industrial and commercial loads having a high content of harmonic impurity. New mitigation schemes can be designed that not only prevent the injection of harmonic impurity by load but also from the supply side.

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