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Performance Analysis of Passive Filter for Harmonics Due to Non-Linear Load in Power System

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Abstract: As end users of Power supply system, we load the power system with large and different linear and non-linear loads like printers, computers etc. These devices load the power system and change the sinusoidal nature of the line current and voltage to a distorted wave form, which is undesirable. The undesirable change may generate heat and damage other devices so it is necessary to mitigate this distortion by the use of filter. The problem is solved by the use of the proposed filter which is a combination of Inductors and capacitors. This single Filter is designed to filter out or mitigate harmonics of different order before they could change the electrical property of the power system unlike other Filters which are designed for filtering a specific

Keywords: Harmonics; Mitigation; Nonlinear loads; Passive Filter

I. INTRODUCTION

High power non-linear and loads that vary with time like AC to DC converters, computers, FAX, printers, and variable electric speed drives like motors e.g. Lifts, Ventilators, vending machines cause un desirable phenomenon in the power system and this is called harmonic pollution [1] and demands reactive power restoration. These electronic equipment contribute more in changing the electrical parameters, the distortion would change the wave shape of input voltage and current in the system under consideration. The current and voltage wave form may take other wave shapes due to the disturbance introduced, this is called harmonic distortion.

Harmonics in power system is just the integral multiple of fundamental frequency of the input current. The harmonic distortion [2] has been handled from long years ago but it needs great attention today as the number of equipments causing distortion to the input characteristics has increased. In olden years the conservative design of Power system and the use of a grounded & wye connection in transformer and of course the limited use of today's modern loads, did little to harmonic distortion. During that period the distortion was due to the transformer saturation, industrial arc furnaces, use of electrical large welding machines, and interference of communication system .Use of all the devices ended up with the need for power factor correction which in turn required large capacitors leading to faults caused from the overvoltage condition across the capacitor.

The arise of harmonic current in system is going to further distort the input voltage of the system that gradually affect its performance and pave way to give adverse situation like overheating , mechanical & electrical oscillation in rotary devices, insulation failure problems & erratic behavior of protective devices in System .

As all the above said problems are severe from both utilities & consumer end, harmonic alleviation is inevitable. Use of Passive filters is been in practice for Harmonic filtering from long time as they are cost effective[4] and have a very simple design[8] . Passive filters are provided usually in the power system to allow the harmonic currents to flow through them as they offer low resistance path thereby preventing the distorting current from flowing into the supply.. The passive filter can be designed to either offer low resistance path for a specific harmonic or a range harmonic frequencies as demanded by the kind of load used. An ordinary series band stop filter is recommended to be connected in series with the line or neutral so as to block harmonic currents. This arrangement does not provide a controlled path for the flow of current , a large harmonic voltage drop appears across it and across the supply .

II. RELATED WORKS

In existing system the cost of filter used is very high as separate capacitor is used for tackling different harmonics of different order.

- Use of high value capacitor produces over voltage in the power system.
- Employing large capacitors lay demand for large space for installations
- Heat and harmonics are also the results of active filters used so far in the power system
- Shunt and Hybrid harmonic filters available are good at performance at light and full load respectively.

- A need for a cost effective filter that does not produce over voltage in the Power system under no load condition, arises from the study.
- This research will provide design analysis of a passive filter which is low in cost and mitigate distortion due to current harmonics.

Luiz A.R. de Sousa, Paulo F. Ribeiro et .al[1] in the work describes a method of designing harmonic distortion reducing filter as well as power factor correction. The advantage is that these filters do not respond to frequency variations over frequency to which it's tuned, but needs large reactive power to attain the same efficiency of a tuned filter with lower reactive capacity. As the order of the filter to tackle different harmonics increase, loss at resistor is less whereas loss is more for filters which are designed to sink harmonics of fundamental frequency.

Rarison R.A. Fortes et al, Centro de Ciencias Exactas Technologies. The author worked on resonant harmonic filter not just to compensate the fundamental harmonics but also strived to achieve a cost effective filter design with maximum efficiency. The author also has worked on the operational limits of capacitor used as filter to improve the efficiency.
D. Maheswaran, N. Rajasekar and L. A. Kumar et.al[3]worked on Genetic algorithm is to design the filter for optimizing the harmonics filtering capacity .The paper discusses well in detail how a capacitor size can be chosen for input filter of a two pulse diode rectifier. The disadvantage of this filter design is that it is designed for a constant load.
The increased use of linear and non-linear loads has created more distortions in current and voltage waveforms [6]. The disturbances introduced into the power system by these distortions, increased problems power quality [6] . So analysis of harmonics from non-linear loads becomes significant. The author also provides details of harmonics present in different non-linear loads he had considered for experimentation.
O. Fatih Kececioglu, HakanAcikgoz, Mustafa Sekkeli et al[9]. In their work said that Hybrid filters are capable of handling voltage source type and current source type variable loads. But the disadvantage is that they are not suitable for suddenly changing non-linear loads.
Serhat BeratEfeBitlis[10] concluded in his research that It is suitable to use passive filters for steady loads so as to take advantage both of cost and ease of operation . But the use of the parallel passive filters leads introduced parallel resonance problem in the power system. So It is necessary to determine very carefully the constituents of filter and their connection to avoid this problem. If the problem is not addressed seriously, the filter will cause more harm than providing harmonic reduction.

The conventional filter design suffers from the disadvantage of not being able to reduce the number of capacitors used for managing harmonics of higher order and also the design acts as non-linear load to the power system which distorts the input voltage and current nature. Use of Common Passive filter enables handling of harmonics of higher order with simple space saving design as there are fewer components and due to compensation of distortions the current flowing into the circuit is perfect sinusoidal. The Analysis of the common Passive filter Design will provide information how the filter works for various non-linear loads without much complication in design and implementation.

III. METHODOLOGY

A. Scope and Limitation

This study focuses on analysing the design efficiency of Filter to compensate current harmonic distortion in Variable frequency drives and see that the input current in the power system is undisturbed or not distorted.
The study may be extended to. ac-dc converter which suffers from operating problems of poor power factor, introduction of harmonics into the ac mains, variations in dc link voltage of input ac supply, equipment overheating due to harmonic current absorption, due to the voltage drop caused by harmonic currents flowing through system impedances, interference on telephone and communication line. The filter design and analysis is specifically for variable frequency drives and the filter is designed or tuned to the specific non-linear load [9] and to filter a predetermined harmonic frequency range.

B. Conceptual Framework

The block diagram of the Common Passive filter capable of filtering current distortions of different orders, introduced between non-Linear load and Power system.
The process of study involves simulation of Passive filter in the simulated power system and to analyze the input current and voltage waveforms before and after the introduction of filter. The Proposed filter design is expected to mitigate harmonics of wide frequency range. The study is represented in the form of process Diagram, the filter design and analysis is done in two stepsons to construct the circuit using MATLAB and comparative study of both to understand the performance of filter.

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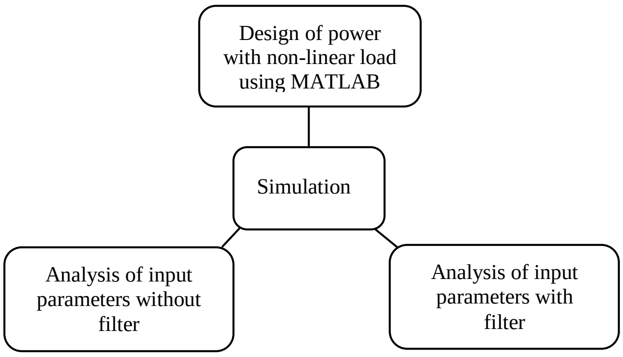

Fig. 1 Process Diagram of Study of filter Design

C. Research Design

Usually Inductive Loads are the ones which are considered as non-Linear Loads as they draw non-sinusoidal currents which in turn flow through system Impendence, distorting the original sinusoidal voltage.

So the simple structure of Filter Design is employed to mitigate the current harmonics of lower, middle and higher unlike the conventional ones. The design doesn't have any complicated electronic circuits or algorithm to solve the harmonics issue, so it is cost effective as well as improves power factor. The filter is connected between the Source and the Load Side.

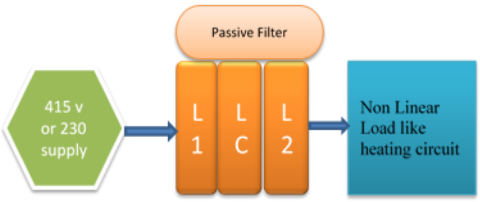

Fig. 2 Block Diagram of Filter between the Load and Power system

The Filter is design consists of different combinations of Inductors and Capacitors to absorb harmonics of various order. The inductors are included in series with the 3 phase Source side and 3 phase Load side of the simulated Electrical System. The inclusion of the inductors in series provides high impedance path for the high frequency harmonic currents, thereby blocking the harmonics from entering the system. An LC Combinational block is connected parallel between the load side and source side Inductances. The LC Combinational block consists of Delta connected Capacitor bank connected in series with the Inductances. The Parallel Reactance provides low impedance path for the harmonics of Intermediate order.

The Inductors in the Source side is L1 whose value is chosen to be 10.4mH by calculating the inductance considering the each line as single phase. Inductors L2 are connected to the Load side and L3 to the Capacitor Bank. .Similarly L2 and L3 values are calculated to be of values 5.85mH and 26.7mH respectively. For the calculation of L1 value the total reactance required is assumed to be 20% and for L2 it is assumed 4%..The capacitance value C is calculated to be 16.44µF by choosing 1KVA rating. The Circuit diagram of the proposed Filter is as shown below.

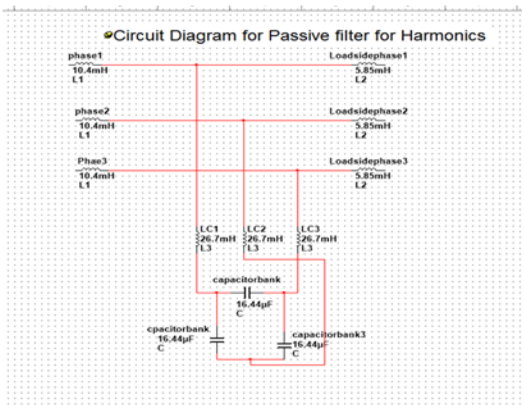

Fig. 3 The Proposed Filter

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D. Results and Discussion

The work in this research starts with designing the filter and then simulating the application of the proposed passive filter in the Electrical system using MATLAB software and analyzing the harmonic currents in the lines. For simulation Purposes the major components are chosen as listed below

•Source feeder: The 11kv, 30MVA generator generate the AC supply for the distribution purpose.
•Bus: The main supply cannot be connected directly to the transformer so we connect it with help of 11kv bus.
•Transformer: The 11kv/415v transformer with 4.5% impedance will receive the supply from bus.
•Passive filter: This filter is the combination of inductor and capacitor to filter the harmonics.
•Nonlinear load: To generate the harmonic current in the transmission lines, non- linear loads of any kind can be chosen e.g. Rectifier, any heating device.
•The figure below is the block diagram for simulation and analysis purpose.

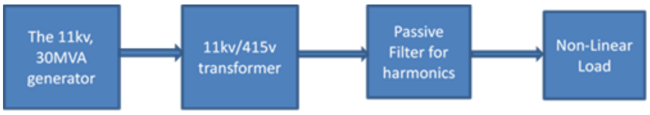

Fig. 4 Block Diagram for simulation

After the filtering process the current requirement for the load is reduced, because there is no harmonic current to oppose the input current and destroy the flow of electrons in the input current. This will improve the system and also reduces the cost of supply.

The perfect sinusoidal current waveform will give very efficient output with improved performance and don't make any damage to the devices and also increase the life of the equipment considered as non-Linear Loads as they draw non-sinusoidal currents which in turn flow through system Impendence, distorting the original sinusoidal voltage. Uncompensated Current and Voltage waveforms before including the Proposed Filter Figure 5 and Figure 6 shown below depicts the Input current and voltage before Including the passive filter designed in the simulated power system .This can be found from the scope connected at the output of 11Kv Bus or 415V bus. The output measure here is at the output of the 11KV/415V transformer.

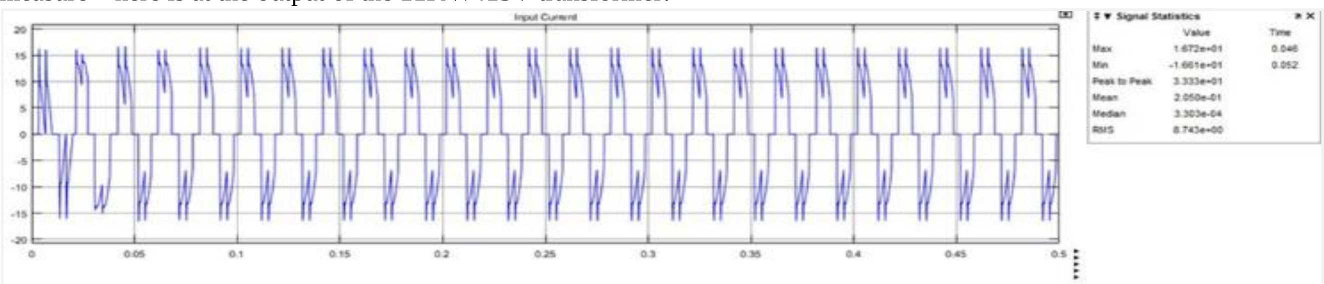

Fig. 5 Input current waveform before filtering

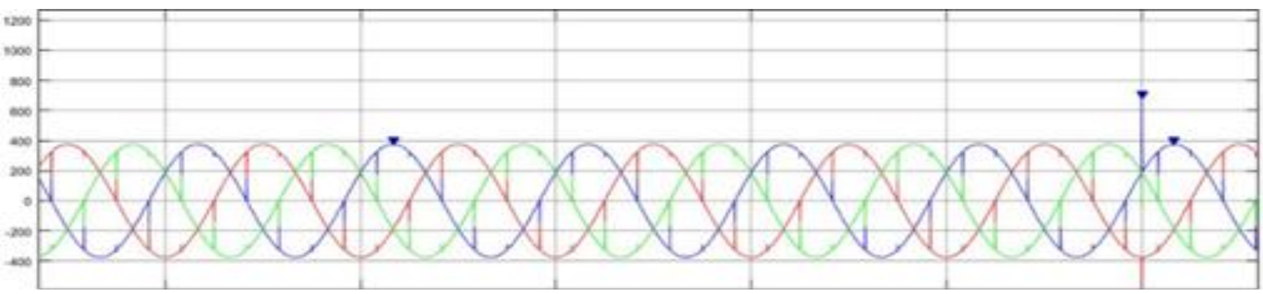

Fig. 6 Input Voltage waveform waveform before filtering

Compensated Current and Voltage waveforms after including the Proposed Filter is shown by Figure 7 and Figure 8 after Including the passive filter designed in the simulated power system.

Table 1 shows the harmonics and corresponding magnitude measured during the simulation. Odd Harmonics from 5 to 19 are tested and the total harmonic distortion is found to be 23.63 .The aim of the research is to examine how high is the harmonics for nonlinear load and how that gets mitigated when the proposed filter is inserted in the circuit. This can be seen in the table 1 also which shows the harmonics and corresponding magnitude measured during the simulation after inclusion of the proposed passive filter. The higher order Odd Harmonics tested shows the total harmonic distortion to be 5.12.

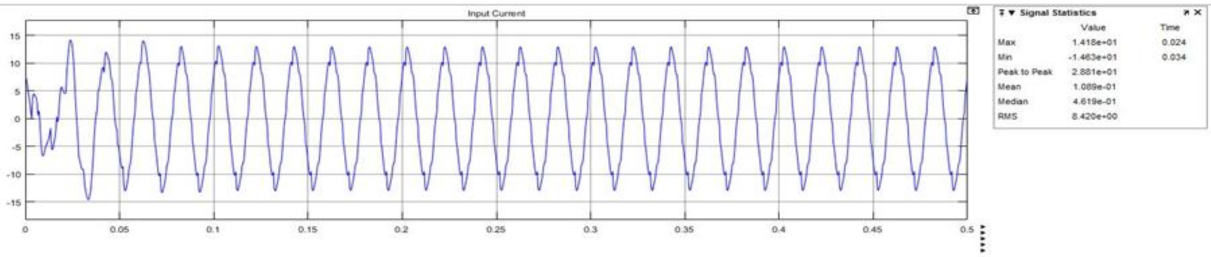

Fig 7. Input current waveform after filtering

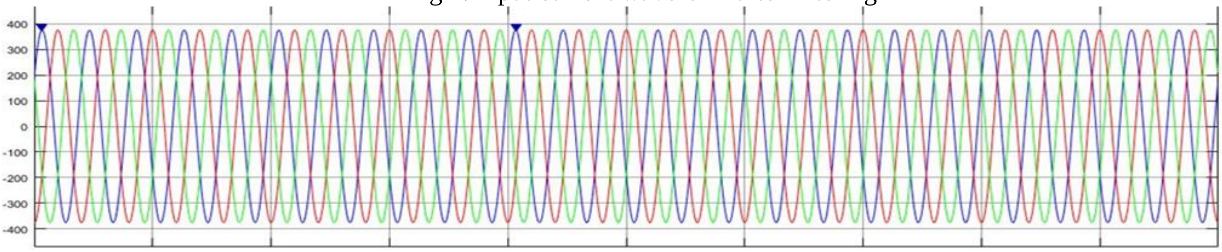

Fig 8. Input Voltage waveform waveform after filtering

TABLE I TOTAL HARMONIC DISTORTION BEFORE AND AFTER FILTERING

Harmonics	Total Harmonic Distortion	
	THD before filtering	THD After Filtering
THD	23.63	5.12
H5	19.15	1.47
H7	9.18	0.49
H11	5.82	0.23
H13	3.29	1.60
H17	3.82	2.22
H19	2.90	1.78

IV. CONCLUSION

Most of the active filtering techniques have common drawback of higher cost compared to passive filtering techniques. Consequently, the passive harmonic filtering techniques are still the most commonly used for current harmonics mitigation. As the structure of the proposed passive filter is simple and as it filters out even harmonics of higher order, it finds extensive application in power systems. No involvement of electronic circuit hardware and complicated control algorithm enables the proposed passive harmonic filter to be a relatively inexpensive means for eliminating current harmonics distortion. Because of these two in one improvements our passive filters usually have edge over the other effective filtering methods. Shunt filters still dominate the harmonic compensation at medium/high voltage level, whereas active filters suit for low/medium voltage ratings.

With diverse applications involving reactive power together with harmonic compensation, passive filters are found suitable. The Passive filters are used in the distribution system and not extended to places where converters are used where there are great chances of injections of harmonics of higher order in to the parent system. The Future Study of the proposed filter can be extended to the study of improvement of power factor and in ac-dc converter which suffers from operating problems of poor power factor, injection of harmonics into the ac mains, variations in dc link voltage of input ac supply, equipment overheating due to harmonic current absorption, voltage distortion due to the voltage drop caused by harmonic currents flowing through system impedances, interference on telephone and communication line.

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