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Harmonic Reduction by Shunt Active Filter in a Transformer LT Distribution Network

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Abstract – This paper is about the modelling of a power distribution network in which nonlinear loads are also placed for the generation of harmonics. Now a day's various electronic variable drives and other devices that generates harmonics are extensively used by the commercial and industrial consumers. The amount of harmonics generated by a single device is negligible but if the devices are in a large numbers that will make a considerable impacts at the point of common coupling. Several problems occur in the system like sag swell, voltage flicker, unwanted heating of the instruments or the circuit in which the devices connected so this becomes an important issue to resolve. In this a shunt active filter has been modelled with the system for the reduction of harmonics in a permissible limit. IEEE set up the standards for the harmonic limitations and the baseline standards has to follow strictly for all the industrial and commercial consumers.

Key Words: *Total harmonic distortion, non-linear loads, distribution transformer, linear-loads, SAPF shunt active power filter, Phase control, Harmonics reduction, nonlinear loads, and PCC point of common coupling*

1. INTRODUCTION

The nonlinear characteristics of many industrial and commercial loads such as power converters, fluorescent lamps, computers, light dimmers, and variable speed motor drives(VSDs) used in conjunction with industrial pumps, fans, and compressors and also in air-conditioning equipment have made the harmonic distortion a common occurrence in electrical power networks. Harmonic currents injected by some of these loads are usually too small to cause a significant distortion in distribution networks. However, when operating in large numbers, the cumulative effect has the capability of causing serious harmonic distortion levels. These do not usually upset the end-user electronic equipment as much as they overload neutral conductors and transformers and, in general, cause additional losses and reduced power factor [1]

In response to the increasing use of adjustable frequency drives in industrial facilities, IEEE 519-1992 has set guidelines for maximum current distortion present at a building service entrance. These guidelines are intended to prevent one factory from affecting the service of another, and to protect utility equipment. The determining factor in meeting IEEE 519-1992 current distortion limits is the percent of the service capacity that is used for serving non-linear loads. Typically, an industrial facility can load up to five percent of its total service capacity with six-pulse variable frequency drives without exceeding recommended limits. Beyond that, some form of harmonic abatement may be necessary. Motor drive current distortion can be reduced using filters, 12-pulse or higher drives, line reactors, drive isolation transformers or harmonic cancelling transformers. Both line reactors and drive isolation transformers use reactive harmonic attenuation effects to reduce the actual current distortion at the input terminals to the drives. This practice alone can increase the six-pulse drive load by 20 percent or more of service capacity without exceeding guideline distortions. The effectiveness of reactive harmonic attenuation varies, depending on other system characteristics. Careful system analysis is always a good idea before applying any harmonic abatement solution to ensure the intended results. [2]

Task force on industrial electronics studied the effects of harmonics on industrial systems and gave certain guidelines to maintain harmonics with in the acceptable levels. Recommendations on maximum permissible harmonic limits in systems and their control were laid down by IEEE. The basic concept of filtering of unwanted frequency components from supply waveform either by LC tuning to create resonance or current compensation using custom power devices or both. [3]

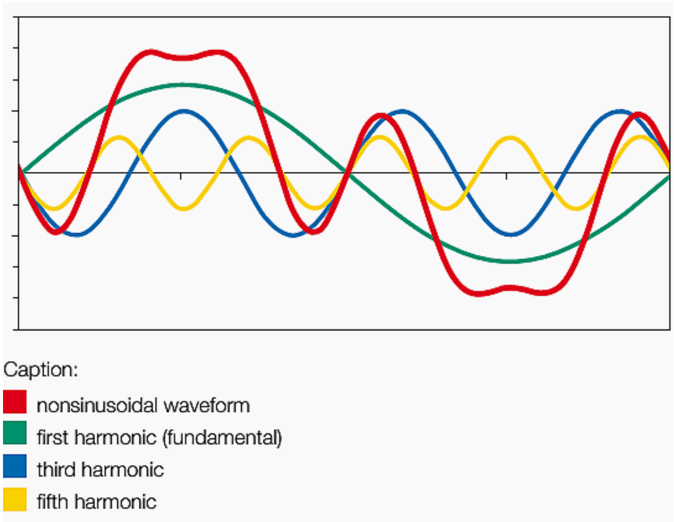

Fig -1: Effect of harmonics in the waveform

A shunt active filter has been designed based on LMS control connected with the distribution network ii a medium voltage line along with the nonlinear loads so that the harmonics generation and reduction can be easily analyzed to match with the IEEE

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defined values for the industrial consumers. This type of filters are most widely used and most preferable and as the name suggest connected in parallel. The filter is operated to cancel out load harmonic currents leaving the supply current free from any distortion.

2. IEEE Harmonic limits

Table 1- IEEE STD 519-1992 Harmonic voltage limits

Voltage Distortion Limits

Bus Voltage at PCC	Individual Voltage distortion (%)	Total Voltage Distortion THD (%)
Below 69 KV	3.0	5.0
69 to 161 KV	1.5	2.5
161 KV and above	1.0	1.5
Note- High Voltage systems can have upto 2.0% THD where the cause is an HVDC terminal that will attenuate by the time it is tapped for the user		

Table 2- IEEE STD 519-1992 Harmonic Current limits

Current Distortion Limits for general Distribution system

Maximum harmonic current distortion in percent of I_l						
Individual Harmonic Order (Odd Harmonics)						
I_{sc}/I_L	<11	11<h<17	17<h<23	23<h<35	35<h	TD
<20	4.0	2.0	1.5	0.6	0.3	5.0
20<50	7.0	3.5	2.5	1.0	0.5	8.0
50<100	10.0	4.5	4.0	1.5	0.7	12.0
100<1000	12.0	5.5	5.0	2.0	1.0	15.0
>1000	15.0	7.0	6.0	2.5	1.4	20.0
Even Harmonics are limited to 25% of the odd harmonics limits above						
Current distortions that result in a dc offset, Ex – Half wave converters are not allowed						
All power generation equipment is limited to these values of current distortions, regardless of actual I_{sc}/I_L						
Where Isc = maximum short circuit current at PCC **I_L= Maximum demand load current** **TDD= Total Demand Distortion, harmonic current distortion in % of maximum demand load current.** **PCC= Point of Common Coupling**						

3. PROPOSED MODEL

In the proposed model a three phase supply has been connected with three phase two winding transformer connected with the nonlinear load in series with some measurement blocks and in parallel with the circuit shunt active filter arrangement has been connected with few loads and snubber circuits. LMS algorithm has been placed with the source voltage, line current and DC voltage includes to process to give reference currents.

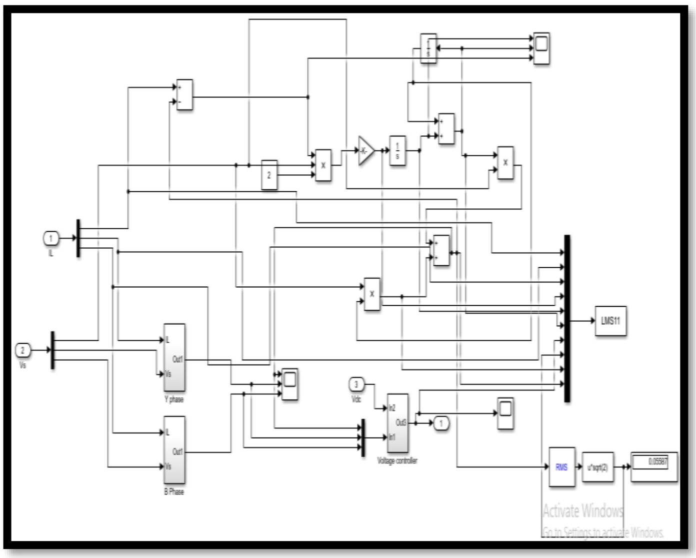

Fig -2: LMS algorithm

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LMS algorithm – In this algorithm the estimated load current is compared with load current which is a measured quantity to determine the estimation error as given by equation 2 as $i_{Lest\ (t)}$ is determined as the product of weight matrix W, and transpose of input matrix B, B and W has the size of 1X46. The elements of B matrix correspond to unit sine and cosine templates with frequency 1 to 23 times the fundamental. Similarly the elements of W matrix representing weights corresponds to the peak amplitude of the sine and cosine component of load current with frequency 1 to 23 times the fundamental. The elements of W matrix has trained with LMS algorithm which employs gradient descent method to minimize the criteria function, the gradient of which with respect to the weights is used for weight updation of W.

$$e_{Lest(t)} = i_{Load\ (t)} - i_{Lest\ (t)} \ldots\ldots (1)$$

$$i_{Lest\ (t)} = [W]_{1\ X46}\ \text{X}\ [B]^{T}_{46\ X1} \ldots. (2)$$

$$B = [\sin(wt) \quad \sin(2wt) \ \ldots\ldots\ldots \sin(23\,wt) \cos(wt) \quad \cos(2wt) \qquad]$$

$$C = [e(t)]^2$$

4. RESULTS

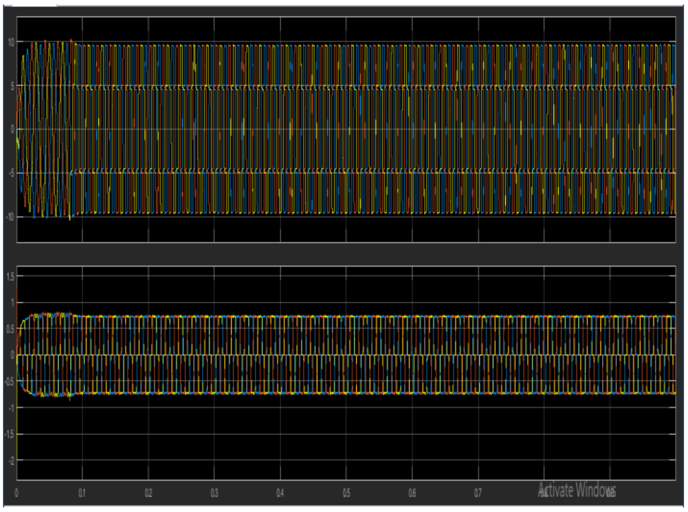

Fig -2: Three phase voltage and current

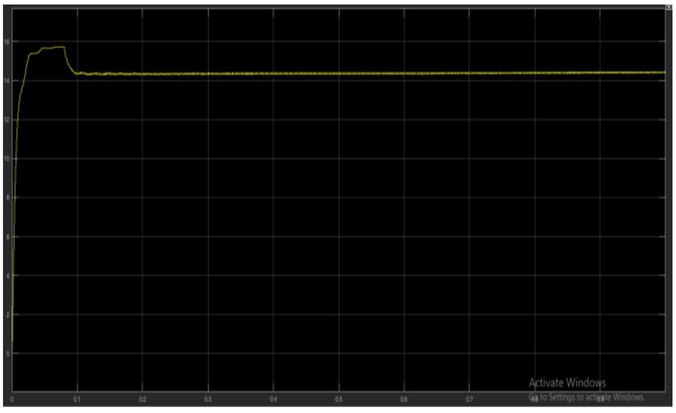

Fig -3: DC Voltage

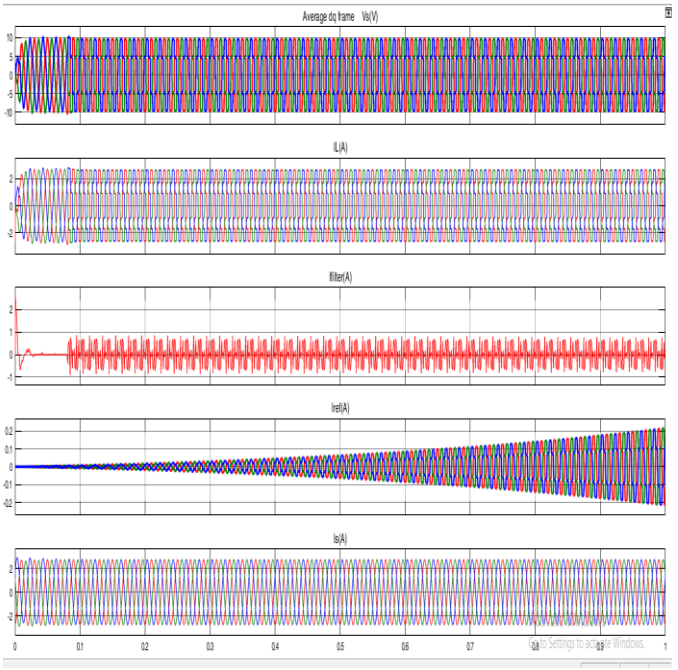

Fig -4: Parameters of proposed model

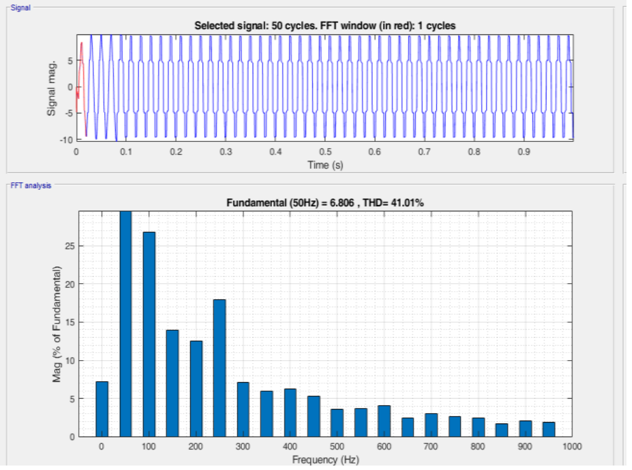

Fig -5: Current THD without filter

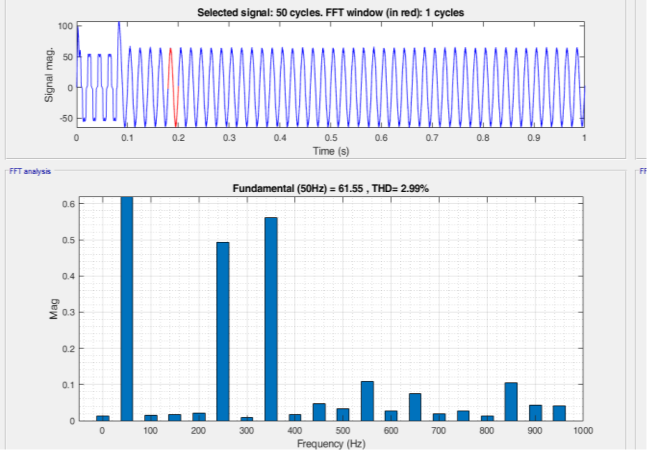

Fig -5: Current THD with Filter

5. CONCLUSION

Due to the involvement of nonlinear loads in the network by the industrial consumers the harmonics impact at the PCC point of common coupling increases and after the analysis of harmonics we can see that the current harmonics are at a higher side and after the incorporation of the shunt active filter the THD reduced up to 3 % which is specified limit by the IEEE. The model has been designed and simulated in the Matlab with the distribution network connected with the shunt active filter along with the nonlinear loads the results after the simulation has been analyzed the voltage and currents are in a specified limits.

6. FUTURE WORK

In the future works the same distribution network can be attached with the filters like passive filters and UPFC with some other class of nonlinear loads to find out the improvements in the THD by FFT analysis and some other measuring instruments to find out the practical implementation in industries and other major commercial buildings to make the system more stable.

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