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Analysis and Mitigation of Harmonics Using Passive Filters

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Abstract: **Harmonics are the components of a distorted periodic waveform whose frequencies are integer multiples of the fundamental frequency caused mainly due to the non-linear loads. The effects of harmonics includes increased losses, equipment heating, loss-of-life etc. In this project we analysed the presence of harmonics due to the switching components and non-linear elements in a system. Using a fluke meter we could compare the performance of linear and non-linear elements in a power system. As it is necessary to eliminate the harmonics this project provides an explanation of the design of a passive filter for harmonic mitigation. A passive filter was designed for a 500W, 230V experimental setup and the harmonic distortion was found to be reduced. In addition to explaining the theory behind, useful observations and charts are included so that reader can use this information for the future analysis of their power system circumstances.**

Keywords: **Fundamental frequency, Harmonics, Harmonics filter, linear load, Non-linear load, Passive shunt filter**

I. INTRODUCTION

Harmonics have existed in power systems for many years. The power quality in electrical energy system has become a major challenge nowadays. Any distortion come in the sinusoidal waveform is known as Harmonic in the system. The issue has, however recently received added significance by the simultaneous setting of two trends: the electric utilities increased use of capacitor banks attempting an improved power factor , and the industries widespread application of power electronic converters seeking higher system reliability and efficiency. Harmonic is a problem which arises due to use of Non-linear load. Harmonics in power system is defined as current or voltage which is of multiple integer of system frequency or fundamental frequency. The main causes for this is, in general, by non linear devices, namely transformers, rotating machines, arc furnaces, fluorescent lamps, electronic controls and thyristor controlled equipment. The arise of harmonic current in system is going to further distorted the system voltage that increasingly affect the system performance & give undesirable situation such of them are as overheating problems, mechanical & electrical oscillation in alternator & prime movers, failure of insulation problems, failure of control system & unpredictable behaviour of protection & relay connected in system etc.

Since all these above said problems are severe for the electrical system, so the harmonic mitigation is important for both point of view of utilities & consumers end. Harmonic filtering technique using passive filters is the one of the most used & earliest technology present in the system used to address the harmonic mitigation. The filters have been used very widely because of its very simple designing process & low cost factor.

II. HARMONICS AND ITS EFFECTS

A.Basics of Harmonics Theory

A harmonic is a signal or wave whose frequencis an integral (whole-number) multiple of the frequency of some reference signal or wave. For a signal whose fundamental frequency is f, the second harmonic has a frequency $2f$, the third harmonic has a frequency of $3f$, and so on

B.Harmonic Order

In the electrical system various type of harmonics are present which are given by their order. **Harmonic order** or **harmonic number** is a reference to the frequency of the harmonic component.

The order of harmonics are decided by formula as shown below

Fh = (h) * fundamental frequency or line frequency (1)

Where h = Integer value. Now for the 3rd harmonics the harmonic component is given by above formula for the system having frequency of 50 Hz

F3 = 3 * 50 = 150 HZ (2)

Fifth harmonic is similary given by

F5 = 2 * 50 = 250 HZ &7^{th} harmonic can be given (3)

F7 = 7 * 50 = 350 HZ(4)

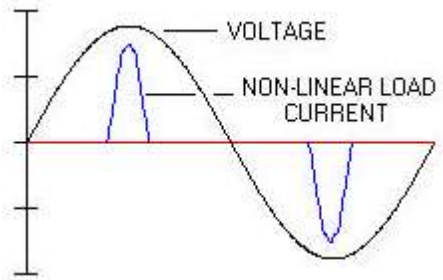
C.Effects of Harmonics

Harmonics are a major cause of power supply pollution lowering the power factor and increasing electrical losses. The effect of harmonic results in premature equipment failure and also cause of requirement of equipment of high rating. Harmonics result in increased losses and equipment loss-of-life. Triplen harmonics result in the neutral carrying a current which might equal or exceed the phase currents even if the loads are balanced. This dictates the derating or oversizing of neutral wires.

Moreover, harmonics caused resonance might damage equipment. Harmonics further interfere with protective relays, metering devices, control and communication circuits, andcustomer electronic equipment. Sensitive equipment would experience maloperation or component failure.

III. ANALYSIS OF HARMONICS

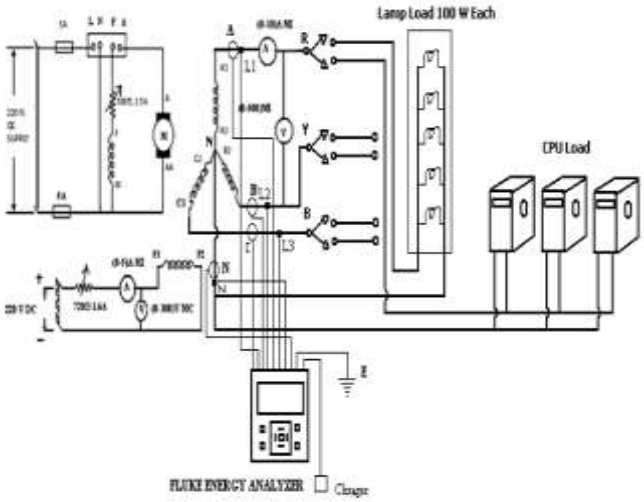
Non linear load are type of load in which the voltage waveform & current waveform does not have same waveform & not identical with the applied source due to number of reason present in the system. The much known problem of this is the use of electronic devices & switches. The electronic switches do not conduct load current during the whole power frequency period but only the fraction of that period. This is the main reason that the load voltage & current are not having identical waveform. The other thing which we also can say that the system which does not fulfill the Ohm's law can be said Non-linear load.



Fig[1] Waveform with non linear load

A.Experimental set up

In this project we did the analysis part using an experimental set up. For the comparison of the performance by linear and non linear loads, incandescent lamps 5 each of 100W comprising of 500W is arranged as the linear loads. CPU and fluorescent lamps of total 500W is taken as the non linear loads. Both the loads are connected to the supply separately for 1 hour and their performance regarding harmonics are recorded by connecting a **fluke meter** across the supply.

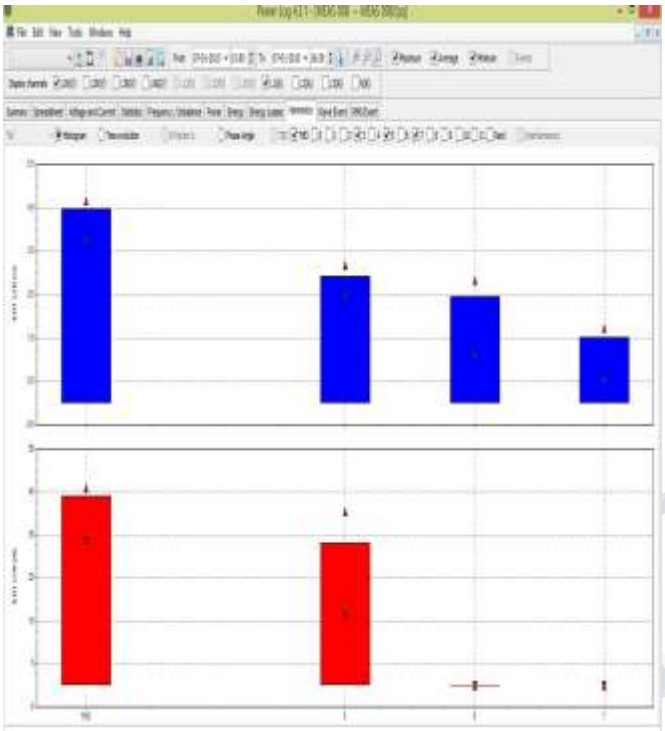


Fig[2] Experimental setup for analysis

The generator is operated by motor and the generated power is fed to the load as shown in figure.

Sl.no		¼ hour	½ hour	1 hour
1	Frequency (Hz)	50.50	51.033	51.064
2	THD V(%)	2.81	2.76	2.77
3	THD A(%)	3.53	3.36	3.37
4	Power factor	.98	.98	.98
5	Reactive Power(VAR)	30	30	30

B.The observations are For linear loads



Fig[3] Observed Waveforms from fluke meter For non linear loads

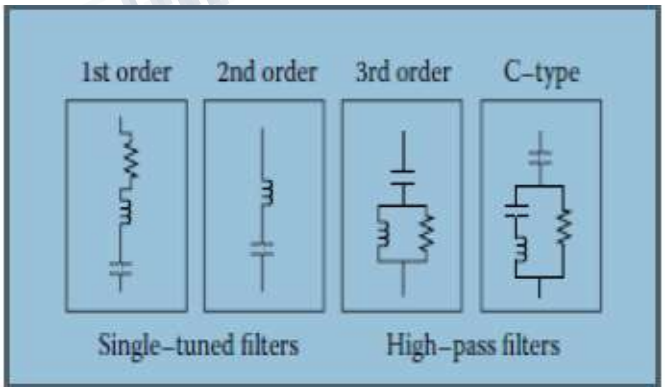
IV. FILTER DESIGN

Harmonics can be efficiently reduced through the use of a passive filter which consists, basically, of a series combination of a capacitor and a reactor tuned to a specific harmonic frequency. Filters provide a low impedance trap to a harmonic to which the filter is tuned. In series tuned filter it consists of a series combination of a capacitor and a reactor and is tuned to low harmonic frequencies. In double band pass filters a series combination of a main capacitor a main reactor and a tuning device which consists of a tuning capacitor and a tuning reactor connected in parallel.Passive filter are used for the mitigation of harmonic in the electrical society for last 3 decades & there is a continuous development has been reported in this technique for the better use of filter & convert the filter more useful to achieve the optimum approach to utilization with reduced rating & cost.

The classification of Passive filter is done on the type of harmonic generation component source present in the system & passive component sys resistor, inductor & capacitor connected in the system & are given as

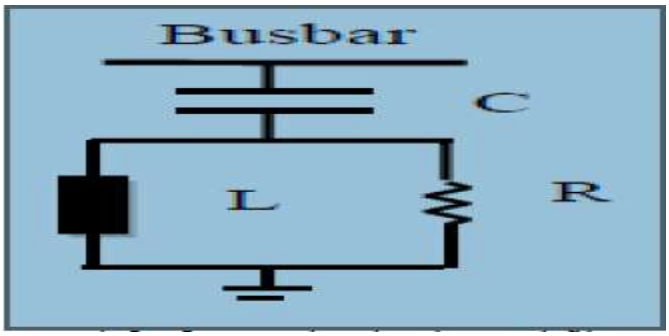
1: PASSIVE SERIES FILTER
2: PASSIVE SHUNT FILTER
3: PASSIVE HYBRID FILTER

Passive shunt filter is the most common method for the cancellation of harmonic current in the distribution system. Passive harmonic filter are basically designed on principle of either single tuned or band pass filter technology. As the name suggests shunt type filter are connected in system parallel with load. Passive filter offer a very low impedance in the network at the tuned frequency to divert all the related current & at given tuned frequency. Because of passive filter always have tendency of offering some reactive power in the circuit so the design of passive shunt filter take place for the two purpose one is the filtering purpose & another one is to provide reactive compensation purpose of correcting power factor in the circuit at desired level. The advantage with the passive shunt type filter is that it only carry fraction of current so the whole system AC power losses are reduced compare to series type filter



Designing of second order high pass filter

A very simple type of second order damped filter is shown



1. Determining the capacitor size Qc in MVAr, say the reactive power requirement of the harmonic source.

2. The capacitor's reactance is

$$X_c = KV^2/Q \quad (5)$$

3. To trap the hn harmonic, the reactor should have a size of

$$X_l = X_c/h_n^2 \quad (6)$$

4. The resistor bank has a size of

$$R = X_n * Q \quad (7)$$

$$X_n = \sqrt{X_C * X_l} \quad (8)$$

Using the values of capacitors and inductors obtained from the design we designed a filter and the harmonic contents are found to be reduced

V.CONCLUSION

Harmonics are a major cause of power supply pollution lowering the power factor and increasing electrical losses. The effect of harmonic results in premature equipment failure and also cause of requirement of equipment of high rating. Harmonics result in increased losses and equipment loss-of-life.We compared the performance of the linear and non linear loads and the effect of harmonics on the system. We saw that the harmonics can be reduced using the filters in the circuit.

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