

Study of Harmonics in Electrical Circuit

Dr.P.Pradeepa, Yashaswini H K,

Faculty of Engineering and Technology, Jain (Deemed-to-be University), Ramnagar District, Karnataka – 562112

Email Id- p.pradeepa@jainuniversity.ac.in

ABSTRACT: With the internationalization of every industry the quality of power has been changing year by year. For now, technology starts shifting towards digital so electrical equipment and their need is low as compared to digital equipment. But harmonics or disturbance in electrical grabs engineers attention towards it. Harmonics is something that can reduce or affect electrical network efficiency so power engineers are concerned about the harmonics and reduction technique of harmonics. Applications of power systems have been increased in day to day life and also with the use of power electronics and power electronics also responsible for harmonics production. In an electrical circuit two types of load present which is non linear load and linear load in which nonlinear load is responsible for zero sequence current which is also known as harmonics current, and that generated harmonics current in the neutral conductor that can affect the voltage and current level of the circuit which disturbs its waveform. Harmonics is a major problem which can be decreased by using proper filters, voltage-current ratings. Filters such as LC filters are used at many places in the electrical network this can neutralize the zero sequence harmonics but also some more harmonics present in the system and this can improve power factor rating also. This paper gives information about the harmonics distortion and their reduction technique.

KEYWORDS: Power system, Power electronics, Harmonics, Filter, LC filter, Power, Voltage, Current, Linear and nonlinear load.

INTRODUCTION

In power systems especially in AC reasons for harmonics are mainly due to the sudden increase of non-linear loads and that is due to some devices which do change their value when any disturbance starts in the circuit like variable frequency drive. This happens due to advancement in the technology everything going to digital so use of digital equipment causes these harmonics problems, technological advancement such as use of power electronics circuits and devices. electronics things such as microprocessor, microcontroller Arduino etc. responsible to give variation in output due to highly sensitive in nature [1]. Figure 1 illustrate the types of filter.

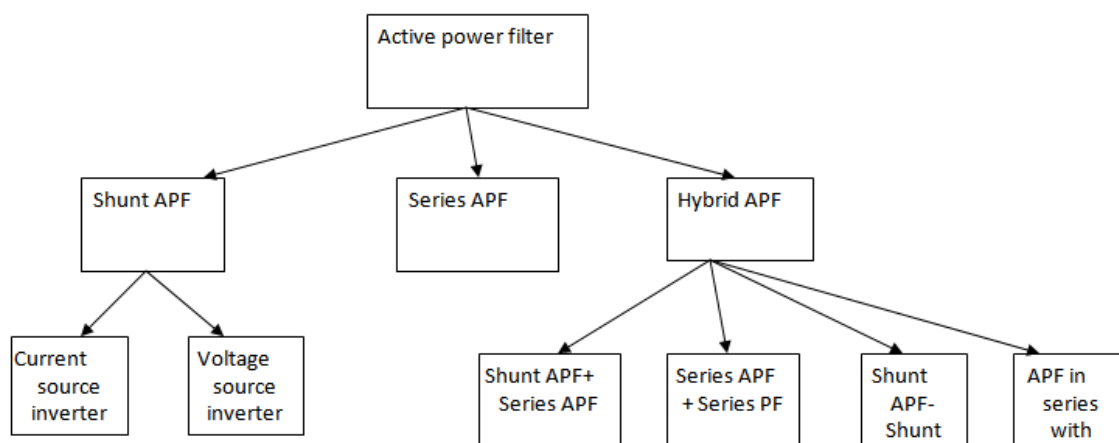


Figure 1: Types of filter

In AC/DC transmission links or load either load is heavy or low, it is controlled by a power system using power electronics elements which creates harmonics in the whole system. Harmonics are classified into three parts:

- (a) Domestic load
- (b) Industrial load

(c) Control device

Harmonics cases due to non linear load and non linear load is produced due to none obeying the ohm's law, when harmonics current or voltage it has distorted waveform so a compensator used to minimize or normalize the effect of non sinusoidal wave on it. A compensator can be comes in use only when all the component of the electrical circuit able to work accurately and have connection between the loads.

1. *How to measure Harmonics?*

Measurement of harmonics of a circuit is by harmonics analyzer or digital storage oscilloscope. Oscilloscope is of two type analog and digital so it is used to measure the amount of distortion in the sinusoidal wave. Each harmonic frequency (f_n) is given by the equation $f_n = n \times f_1$ where n is the harmonic number and f_1 is the frequency of the first harmonic [2].

2. *Effects of Harmonics?*

Harmonics can affect any electrical and electronics device because sudden rise in current may lead to heating problems and low voltage can cause speed problems in the device also increase in voltage leads to the insulation failure [3].

Effect of harmonics on transformer also transformer is a static device used to convert voltage from lower to higher or from higher to lower named as step up transformer and step down transformer, transformer is a nonlinear device means it does change its resistive value when voltage starts fluctuating. Major effect of the harmonics on the transformer is the heat losses, and that heat loss is additional loss caused by the harmonics current. Some more problems associated in transformers due to harmonics like resonance between transformer inductance and system insulation, capacitance, mechanical insulation and stresses due to core of transformer (iron core) vibration and temperature rise. In transformers various types of losses present in which heat loss, iron loss, copper loss, hysteresis loss and humming loss present, these losses can induce due to harmonics, means due to harmonics eddy current loss in the transformer increases due to which efficiency of the transformer decreases [4].

Harmonics for any circuit is the amount of unwanted rise in frequency wave which is superimposed on the input wave and distort it which causes many equipment failure and losses in the electrical circuit. Harmonics can be found out by $n \times f$ where f is the fundamental frequency of India (50Hz) [5]. Figure 2 and 3 illustrate the harmonics waveform and harmonics formation respectively.

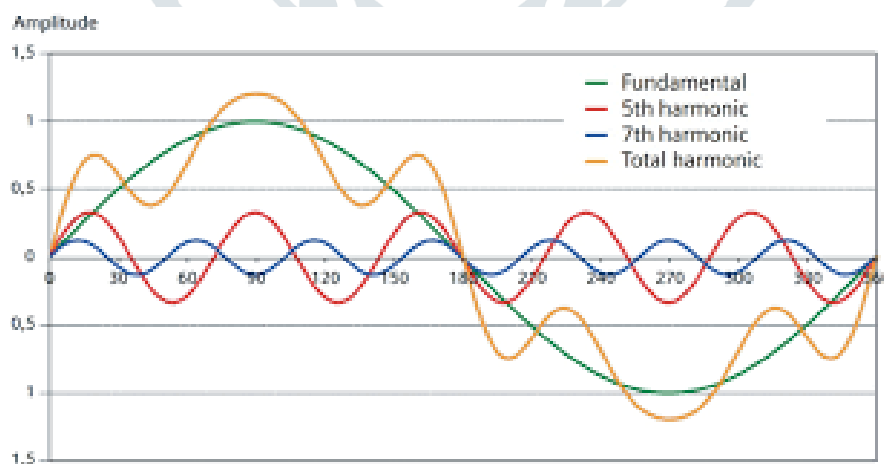


Figure 2: Harmonics waveform

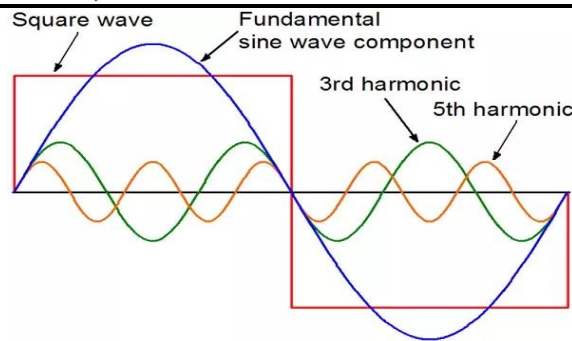


Figure 3: Harmonics Formation

Every equipment is sufficient for producing a signal that will produce Even/Odd harmonics. Some of the equipment produced either ODD or EVEN harmonics.

Research Question

- Harmonics distortion technique?
- How are harmonics controlled digitally?
- Failure in equipment due to harmonic distortion?

LITERATURE REVIEW

In the field of harmonics many papers have been published and still research is going on in this field to reduce harmonic distortion and make circuit efficient, among many research papers one research paper titled “harmonics in power system and its mitigation technique” by A.J. Mehta and K.L. Mokariya discussed the harmonics and its cause and its prevention. LC circuits mostly used in electrical networks to reduce the harmonics and increase the power factor. Techniques for normalization of harmonics in the circuit are of two types: active filtering and passive filtering, effect of harmonics on transformer and on other devices, effects of harmonics on load. Simulation of electrical circuit on MATLAB to detect behavioural waveform of voltage and current. Effect of harmonics on load and device which affects the load rupture (abnormal operation), insulation stress (voltage effects), thermal stress (current effect). Designing of active and passive filter, analysis of single frequency tuned filter for 5th, current waveform with filter has also been shown in this paper [6].

A research paper titled fundamental of harmonics and its effect on the power system is a case study by Ritesh Dash, Aradhana Pradhan, Manas Ranjan Sarang, Pratik Ranjan Behera, in this paper they discussed about the concept of fourier transform and how it can help to reduce the harmonics, MATLAB simulation also study of different types of load like linear load, inductive load, capacitive load. Linear load is a type of load which converts its electrical energy into another form of energy completely; it has 100% active power and 0% reactive power. Linear load is never responsible for the production of harmonics. This paper also discussed the fundamentals of harmonics [7].

METHODOLOGY

1. Design:

There have been many cases where harmonics destroy the electrical circuit, this research work designed in such a way that it calculates the fundamentals of harmonics, like even and odd harmonics. Harmonics is the disturbance in the electrical circuit or electrical wave. Waveform of current and voltage is sinusoidal in nature and works on 50Hz but due to non linearity in load means changing the voltage changes the resistance of the circuit causing harmonics. Take reading of the input waveform and output waveform and calculate the number of harmonics in it. Harmonics is the integral of the 50Hz. Calculate the harmonics and use LC filters [8].

2. Sample:

Non sinusoidal current in the circuit is known as harmonic current and that harmonic current multiply with the voltage of the circuit which cause reactive power so that is the way harmonic current related with reactive voltage [9]. Figure 4 and 5 illustrate the simulation of passive and active filter respectively using MATLAB.

Design of passive filter to reduce harmonic distortion:

Q = Reactive Power Consumed in VA

V_s = Supply Voltage in Volts

f = Supply Frequency in Hz

n = Harmonic Order

QL = Quality Factor

$XC = (V_s^2) (n^2)/Q (n^{2-1})$

$XL = Xc/(n^2)$

$L = X_L/(2 \times 3.14 \times f)$

$R = (n \times XL)/QL$

$R = 0.032$ ohm

$L = 28.2$ mh

$C = 14.7$ microfarad

$R_s = 1.9$ ohm

$L_s = 2.5$ mh

$CL = 150$ micro farad

$RL = 18$ ohm

$V_f = 0.4$ volt

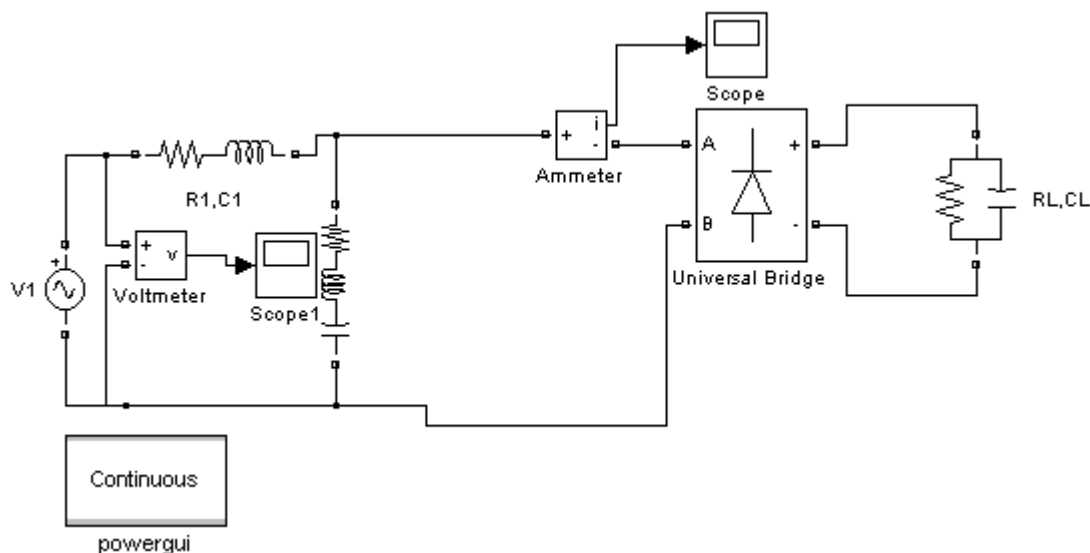


Figure 4: Simulation of passive filter using MATLAB

Design Parameters of Active Filter:

$R1=0.23 \text{ ohm}$

$L1=2.2\text{mh}$

$RG=1.2\text{ohm}$

$LG=2.0\text{mh}$

$RL=30\text{ohm}$

$CL=100.5\text{micro farad}$

$KP=0.4$

$KI=0.9$

$Cf1=1100 \text{ microfarad}$

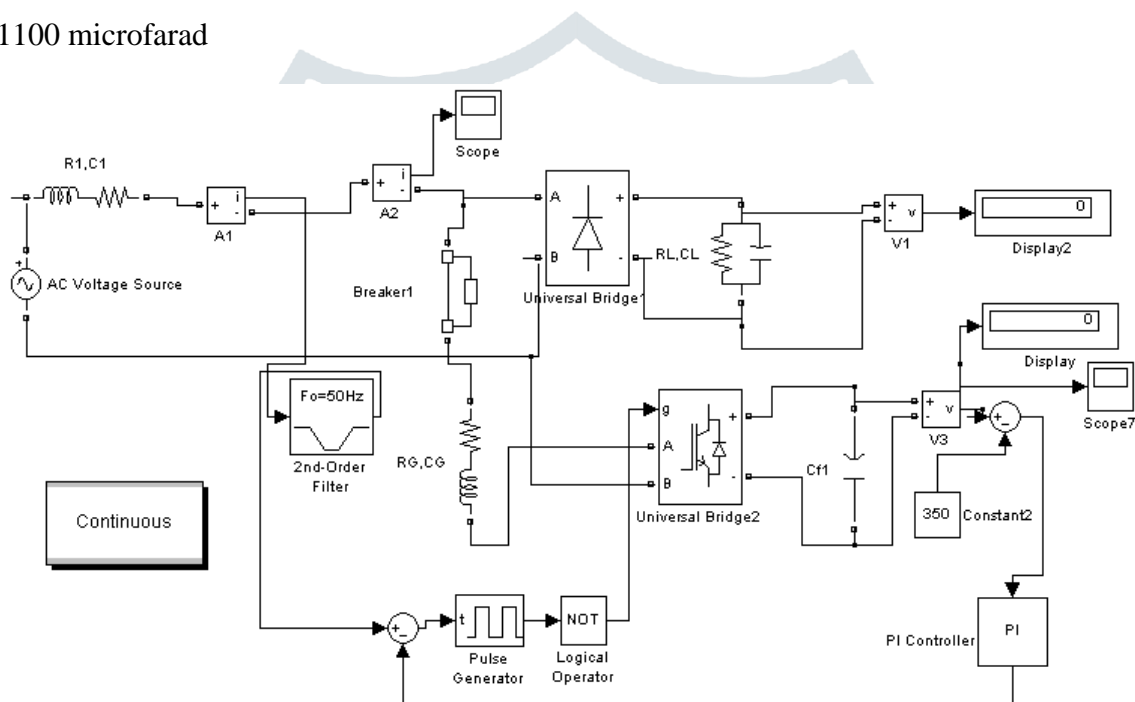


Figure 5: Simulation of Active filter using MATLAB

3. Instrument:

3.1.MATLAB:

MATLAB is a software used for matrix manipulation, algorithm, and simulation of control electric circuits. MATLAB used to simplify the complex circuit this software can be used in various operations like machine learning, data mining and for other applications. MATLAB burns the C, C++, JAVA and Fortran code and runs it on API (application programme interface) [10].

3.2.Oscilloscope:

Oscilloscope is of two types–digital and analog oscilloscope. It is a device used to plot the waveform of the output. Output wave fluctuation, peak value maximum value all can be found by this device [11].

3.3.Multimeter:

It is a device used to measure the value of current, voltage and resistance of any circuit. It is very basic and most use devices of electrical equipment, basically it is used to check the continuity of the supply [12].

3.4. Compensator:

Compensator is a device used to measure or reduce the harmonic impact on waveform of current and voltage. Compensator in a circuit used to compensate the output according to input supply [13], compensator is of three types

- (a) Lag compensator
- (b) Lead compensator
- (c) Lag-Lead compensator

Harmonic Analyzer: It is used to measure the number of harmonics in the waveform.

4. Data Collection:

Figure 6 illustrate the passive filter output, Figure 7 illustrate phase and magnitude of active filter and Figure 8 illustrate output of active filter.

Furnace Rating for detection of harmonics distortion

Furnace Rating: -750 kw

V=463.7 volt

I=560 Amp

Leakage current= 8.9 Amp

O/P voltage=2000volt

O/P Frequency=850 Hz

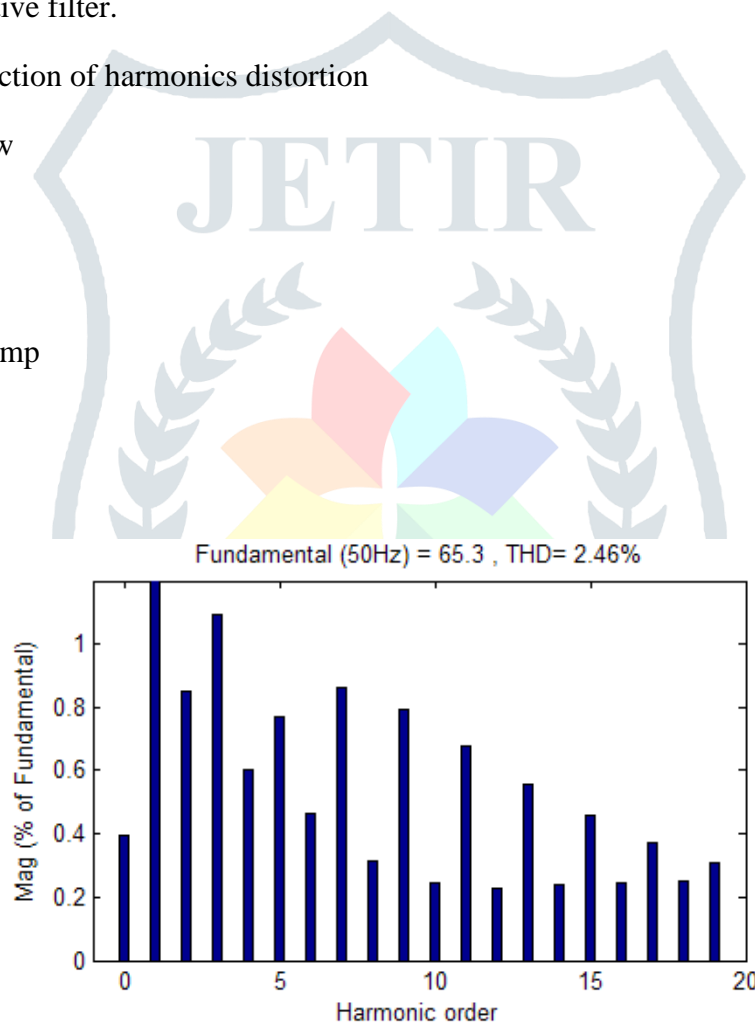


Figure 6: Graph to show passive filter output

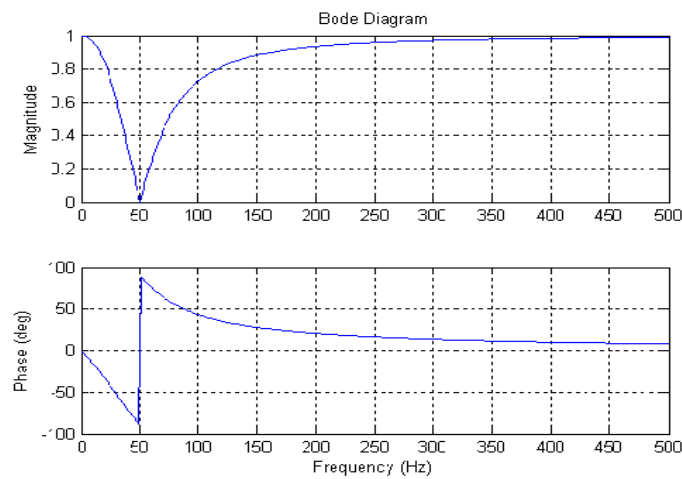


Figure 7: Graph to show phase and magnitude of Active filter

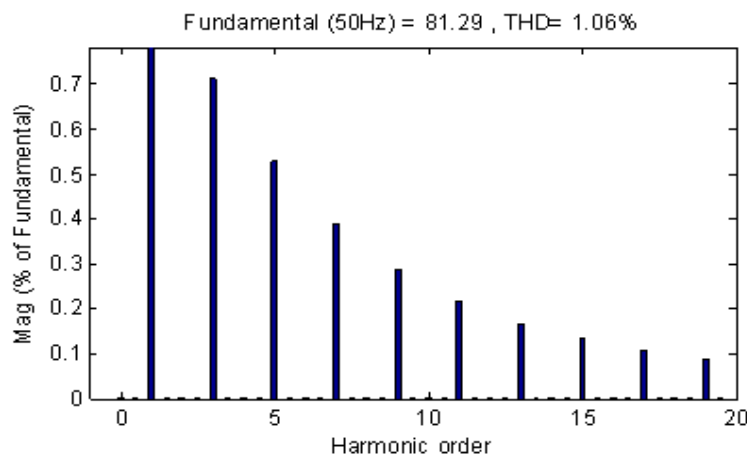


Figure 8: Graph to show output of Active filter

RESULTS & DISCUSSIONS

Harmonics is the amount of energy waste when current and voltage waveform distort. Use of vast power electronics equipment may cause harmonic effects and in digital equipment specially switched mode power supply. The transmission line of higher to lower rating is designed to take care of these kinds of distortion current produced due to harmonics, short circuit effect and other causes. To reduce the harmonics effect in a circuit LC filter used by engineers to supply reactive power to the circuit, filters such as active filter and passive filter used to show the improved output of the system. Simulation of the circuit diagram shown in Figure 2 with Measurement of Harmonics V harmonics 106.7 % (Fundamental), 35.4% (3rd), 26.4 % (5th) 33.3 % (7th), 41.9 % (9th) and 49.1 % (11th)

CONCLUSION

Harmonics in the power system are due to nonlinear load which is changing its resistive value on changing the value of voltage, in nonlinear equipment such as variable frequency drive etc used in electrical circuits can produce harmonics in it. Linear loads have only active power and have zero reactive power because there is no variation in resistance when voltage is changed. Active power of any circuit is the changed form of electrical energy either in the form of light energy or heat energy so active power is the amount of energy used by the circuit and reactive power is the amount of energy passed through the circuit or the return amount of energy. Harmonics is the amount of energy waste when current and voltage waveform distorts. Use of vast power electronics equipment may cause harmonic effects and in digital equipment especially switched-mode power supply. The transmission line of higher to the lower rating is designed to take care of these kinds of distortion current produced due to harmonics, short circuit effect and other causes. To reduce the harmonics effect in a circuit LC filter is used by engineers to supply reactive power to the circuit, filters such as the active filter and the passive filter used to show the improved output of the system.

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