Harmonics: Sources, Effects and Control Techniques

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Abstract—**Power systems are designed to operate at frequencies of 50 or 60 hertz. However certain type of load produce voltage and currents having frequency that are an integer multiple of fundamental frequency. These are called harmonics. The pure sinusoidal wave shape generated by electrical utilities is distorted by the harmonics produced by the increased use of non linear loads. The harmonics lead to adverse effects like excessive heating and transmission losses. This paper discusses various sources of power harmonics, its impacts and control techniques to minimize harmonics.**

Keywords-THD,Crest factor,Power factor,non linear load,PCC

I. INTRODUCTION

The rapid development in the field of electronics has led to the development of highly sophisticated, small size, light weight and efficient power system to meet the demand of the users. These demands can be met by using the high frequency switching transients which widely use non linear electronic devices for switching.non linear loads occur when impedance is not constant i.e. current is not proportional or same as voltage. The current drawn by non-linear load is not sinusoidal hence customer pays more for unused energy due to both voltage and current distortion [1]. This increased use of non linear electronic device has given rise to phenomena called power harmonics. The power system are designed to operate at frequencies of 50 or 60 hertz.howewer certain type of load produce currents or voltages with frequencies that are a integer multiple of fundamental frequency. These higher frequencies are a form of electrical pollution known as power harmonics. harmonics are steady state periodic phenomena that produces continuous distortion in output voltage and current. Harmonics current generated by single phase and three phase non-linear electric loads will cause significant loss of performance. The effect of harmonics using active or passive harmonic filters at power supply input point.

II. GENERAL DEFINITION OF HARMONICS

The general definition of harmonics is any periodic signal can be described by series of sine and cosine function, also known as Fourier series. There are several ways of describing the degree of distortion of current or voltage. The two terms that are frequently used are crest factor and total harmonic distortion. The crest factor of a voltage is equal to the peak value divided by effective value. In case of sinusoidal voltage crest factor is 1.414.The total harmonic distortion of a current or voltage is equal to the effective value of all the harmonics divided by effective value of the fundamental.

Current THD	Maximum true pf
20%	0.98
50%	0.89
100%	0.71

Table 1 Maximum true power factor of a non-linear load.

$$THD = I_H / I_F$$

where, I_H is rms value of combined harmonic components and I_F is the rms value of fundamental component of line current. It has been observed that the sinusoidal voltages and currents have the THD of zero. Table 1 shows the maximum true power factor of a non linear load

III. SOURCES OF HARMONICS

Harmonics are created by non linear loads that draw current in abrupt pulses rather than smooth sinosodial manner.There are two general categories of harmonic sources-saturable devices and power electronic devices.Saturable devices produces harmonics mainly due to iron saturation,as in case of transformers,machines and flurescent lamps.Flurescent lamp with magnetic ballasts are usually rather benign sources of harmonics.Their current distortion is due to arc and to the ballast.fig 1 shows harmonic current of flurescent lamp with a standard magnetic ballast.

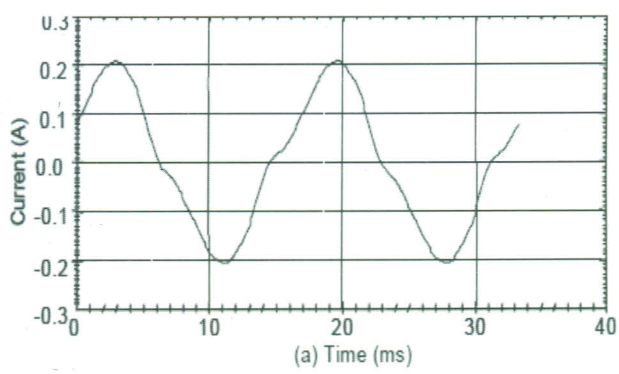
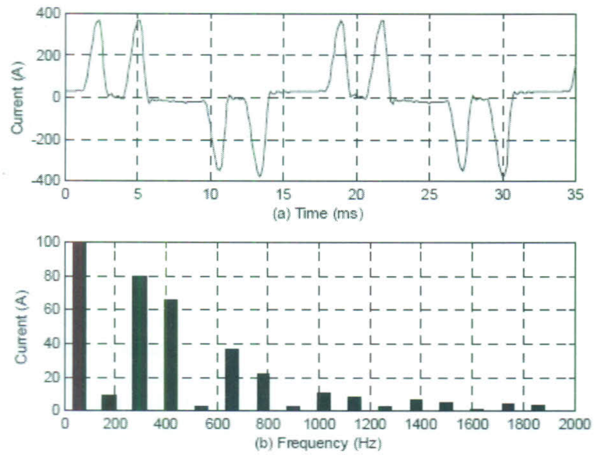


Fig. 1 Harmonic current of flurescent lamp



.Fig. 2 Current and harmonic spectrum of a typical voltage source PWM converter for ASD application.

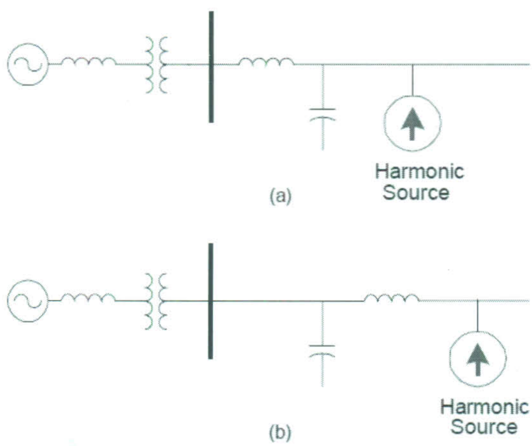


Fig. 3 Two cases of resonance (a) parallel resonance (b) series resonance

The input to the the PWM is typically a 3 phase version of single phase mode power supply[2][3]. The current THD is usually 40-60%.All circuits containing both capacitance and inductance have one or more natural resonant frequencies. When one of these frequencies corresponds to an exciting frequency being produced by non linear loads, harmonic resonance can occur. Voltage and current will be dominated by resonant frequency and can be highly distorted. Thus response of the power system at each harmonic frequency determines the true impact of non linear load on harmonic voltage distortion [4]. To better understand resonance, consider the simple parallel and series cases shown in figure 3.

Parallel resonance occurs when power system presents a parallel combination of power system inductance and power factor correction capacitors at non linear load. The product of the harmonic impedances and injection current produces high harmonic voltages. Series resonance occurs when the system impedance and capacitance are in series with respect to non linear load point[8]. For parallel resonance, the highest voltage distortion is at non linear load, however for series resonance, the highest voltage distortion is at remote point. Hence the total current given by non linear load is given by

$I_H=I_F+I_H$

I_F is fundamental current

I_H is total harmonic current

The schematic of a diode rectifier bridge used in converter is shown in fig 4

The circuit draws current during peaks of voltage waveform as shown in fig 5 to charge the capacitor to peak of line voltage. This type of power supplies drawing current in short pulses during the voltage waveform peak has improved efficiency of the equipment but at cost of generating high frequency harmonics [6].

Typical current waveform of a PC measured at power input is in Fig. 6.

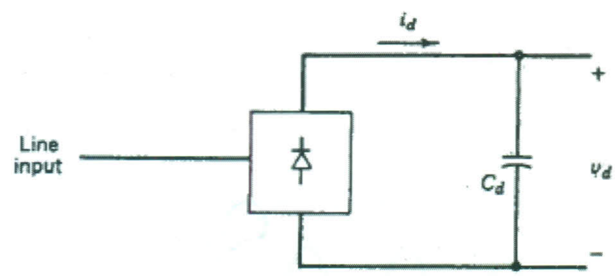


Fig. 4 Schemetic of a diode rectifier bridge

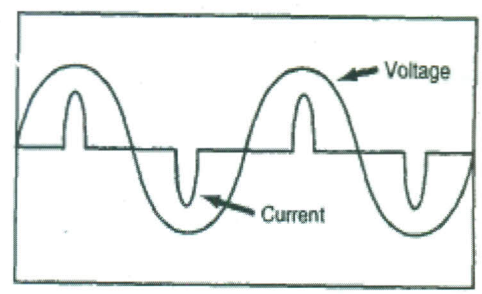


Fig. 5 Current waveform with respect to supply voltage in case of VSI.

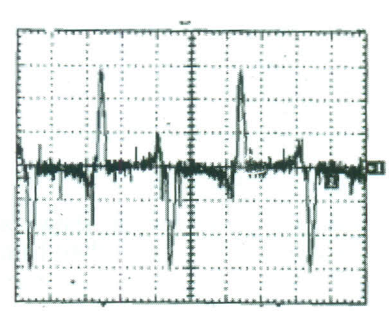


Fig. 6 Current waveform of PC measured at power input

IV. Effects of Harmonics

Harmonics have a number of undesirable effects on power system components and loads. They fall in two major categories-short term and long term.Short term effects are usually most noticeble and related to excessive voltage distortion[7]. On the other hand, long term effects often go unnoticeble and are related to increased resistance losses or voltage stresses, some of the comman problems caused by harmonic currents are as follows.

a) Neutral conductor over heating

In a 3 phase system, the voltage waveform from each phase to neutral star point is displaced by 120 degree so that each phase is equally loaded; in the combined current in neutral is zero. When the loads are not balanced, only the balance current flows in neutral, howewer the fundamental currents cancel out, harmonic currents do not, get added in the neutral which is shown in the Fig. 7.

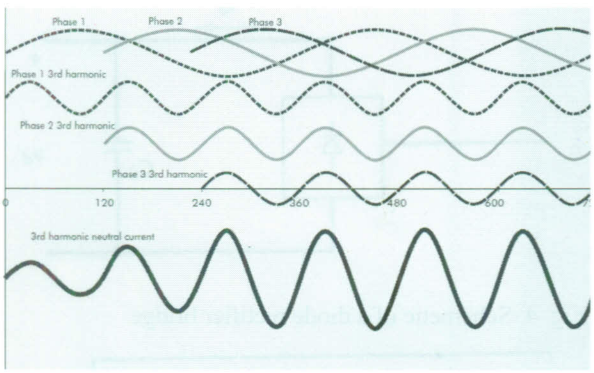


Fig. 7 Triplen currents added in neutral

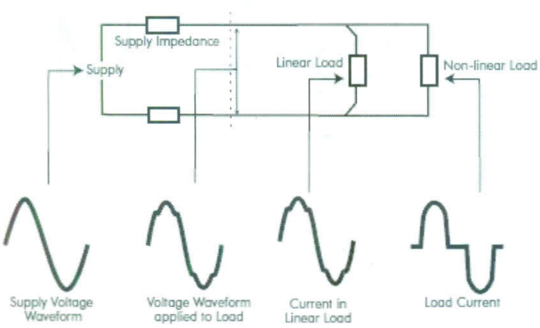


Fig. 8 Voltage distortion caused by non-linear loads

In this diagram, the phase current, shown at the top are introduced at 120 degree intervals.The third harmonic of each phase is identical being 3 times the frequency and one third of fundamental offset. The effective third harmonic neutral current is shown at bottam,In this case 70% third harmonic current in each phase results in 210% current in neutral[5].

b) Effect on transformers

Transformers are affected in two ways by harmonics. Firstly the eddy current losses, normally about 10% of loss at full load increases with square of harmonic number.The second effect concern the triple N harmonics. When reflected back to delta winding they are all in phase, so the triple N harmonic current circulate in the winding.

c) Heating effect on conductors

The increased use of harmonic producing equipment like power electronics converters in industrial management has led to increase in harmonic levels in power distribution system. Heating effect on conductors is one of the main problems caused by harmonic currents. Higher frequency harmonic current generally flow on outer sides of the conductor due to skin effect, thus effectively reducing the area of cross section. Overheating of neutral wires are caused by harmonics produced in any one of a balanced 3 phase system.

d) Effect on motors

Harmonic voltage distortion causes increased eddy current losses in motor in same way as in transformers, howewer additional losses arise due to generation of harmonic fields in stator, each of which is trying to rotate the motor at different speed either forward or backwards. This high frequency current induced in rotor furnace increase further losses.

e) Harmonic problem effecting the supply

When a harmonic current is drawn from supply, it gives rise to harmonic voltage drop proportional to source impedance at point of conman coupling(PCC) and current. Since the supply network is generally inductive, source impedance is higher at higher frequencies. The voltage at PCC is already distorted by harmonic currents drawn by other consumers and by distortion inherent in transformers, and each consumer makes an additional contribution.

V. Control Techniques for Harmonics

The mitigation methods fall broadly into three groups namely: passive filters, isolation and harmonic reduction transformers and active solutions.[7] Each approach has advantages and disadvantages of its own

a) Passive filters

Passive filters are used to provide a low impedance path for harmonic currents so that they flow in filter and not in supply. The filter may be designed for a single harmonic or for a broadband depending on requirements. Sometimes it is necessary to design a more complex filter to increase the series impedance at harmonic frequencies and so reduce the portion of current that flows back onto the supply.

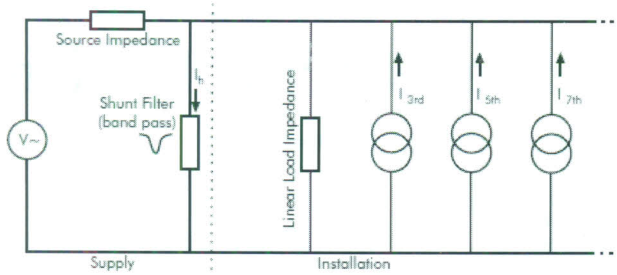


Fig. 9 Passive harmonic shunt filter.

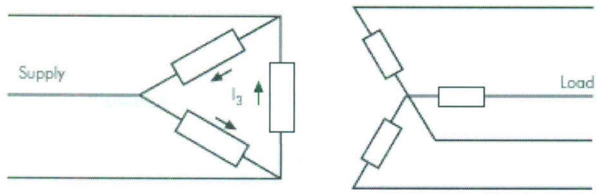


Fig. 10 Delta star isolation transformer

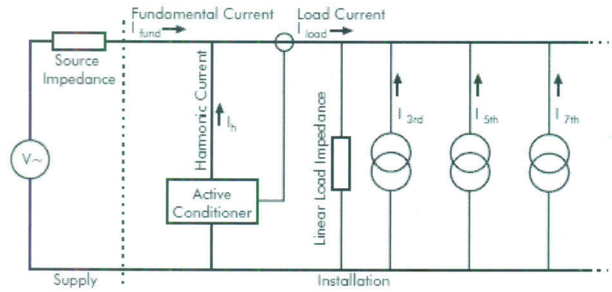


Fig. 11 Active harmonic conditioner.

b) Isolation transformers

Triplen currents circulate in delta windings of transformers. Although this is a problem for transformers manufacturers, the extra load has to be taken into account, it is beneficial to system designers because it isolates triplen harmonics from the supply.

c) Active filters

Active filter is a shunt device. A current transformer measures the harmonic content of load current. Since the harmonic current is sourced from the active conditioner, only fundamental current is drawn from the supply. In practice, harmonic current magnitude is reduced by 90% and because the source impedance at harmonic frequency is reduced, voltage distortion is reduced.

VI. IEEE Standard 519

To minimize the impact of facility harmonic distortion on utility power system and on neighboring facilities, IEEE standard 519 was developed and published in 1982. IEEE standard 519 provides recommended limits for total harmonic voltage and current distortion.

VII. Conclusion

Harmonic distortion is not a new phenomena, however, the widespread application of digital systems and power electronic based loads continue to increase concern over harmonic distortion. The current drawn by the electronic loads can be made virtually distortion free and is the subject of ongoing debate between equipment manufacturers and electric utility companies in standard making activities. Two main questions arise during these discussions

What are the acceptable levels of current distortions produced by the non linear loads.

Who should be responsible for controlling harmonics,the end user or utility companies.

IEEE 519 provides an excellent groundwork to address both concerns and practicing engineers must adhere to these guidelines.

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