ISSN: 0975-766X
CODEN: IJPTFI
Available Online through ***Research Article***
www.ijptonline.com

A SURVEY OF HARMONIC DISTORTION AND REDUCTION TECHNIQUES

Periyaazhagar.D[1], Irrusapparajan.S[2]
[1]Research Scholar, Bharath Institute of Higher Education and Research, Bharath University, Chennai-73.
[2]Faculty, Department of EEE, Mailem Engineering College, Mailem, India
Email: periyaazhagar@gmail.com

Received on: 15.10.2016 *Accepted on: 22.11.2016*

Abstract

This paper present the Harmonics in a power systems caused by highly non-linear devices degrades its performance .controlling and reducing such harmonics have been a major concern of power engineers for many years. This paper discusses the problem of harmonics pollution in electric networks and control methods. it proposes how the wave form of voltage/current is distorted and harmonics are injected to the system due to non-linear loads such as Variable Speed Drive, Arcing Devices, UPS, Personal Computer, Printers, Fluorescent Lamp, Cell Phone battery charger.

Keywords*:* Harmonics; Non-liner load; Harmonic Distortion; Neutral Current.

I. Introduction

The collision of harmonics and waveform distortion on the quality of electrical power harmonic distortion is the changes in the waveform of the supply voltage from the sinusoidal waveform. It is caused by the interaction of distorting customer loads with the impedance of the supply network. Its major adverse effects are Malfunctioning and failure of electronic equipment, Overheating and failure of electric motors, Overloading, overheating and failure of power factor correction capacitors, Resonance due to interaction of capacitors with harmonics, Excessive measurement errors in metering equipment, Spurious operation of fuses, circuit-breakers and other protective equipment, Voltage glitches in computers systems resulting in lost data.

II. Harmonics: Harmonics is one of the major power quality problems in industrial and commercial power systems. A harmonic of an electrical signal is defined as the content of signal whose frequency is an integral multiple of the fundamental frequency. IEEE Standard 519 Harmonics is defined as *"*a sinusoidal component of a periodic wave or quantity having a frequency that is an integer multiple of the fundamental frequency". Harmonic analysis is the process of calculating the magnitudes and phases of the fundamental and higher order harmonics of the power system.

III. Harmonic Distortion: Harmonic distortion is caused by nonlinear devices in the power system. A nonlinear device is one in which the current is not proportional to the applied voltage. When a sinusoidal voltage is applied to a non-linear load which causes current is distorted. Increasing the voltage by a few percent may cause current to double and take on a different wave shape. This is the source of most harmonic distortion in a power system.

IV. Harmonic Indices: Harmonic distortion measurements are normally given in “total harmonic distortion” or THD. THD defines the harmonic distortion in terms of the fundamental current drawn by a load. Thus IEEE-519 uses a term called TDD (total demand distortion) to express current distortion in terms of the maximum fundamental current that the consumer draws.

V. Non-Linear Loads and Types: If the current is not proportional to the applied voltage then it is called the nonlinear load. Typical examples of Single phase non-linear Loads are Computers, Fax Machines, Photocopiers, UPS’s, TV’s, VCR’ s, Lighting dimmers & Electronic ballasts for high efficiency lighting, Single-phase AC & DC drives, Ultra-violet disinfection systems. Similarly Three Phase Non-linear loads are Variable speed AC & DC drives, UPS systems, Arc furnaces, SCR, temperature controllers, Battery chargers, etc.

A. Variable Speed Drive: The voltage and current waveform on the line and load side of a variable speed drive (VSD) is shown in Fig.1 In that Fig. the VSD draws two current pulses for each half cycle of the voltage waveform. This is typical of most VSD’s which employ six pulse conversions to commutate the three-phase line voltage to a DC voltage**.** Six pulse converters have two switches per phase; this accounts for the two current pulses during each half cycle of the voltage waveform as shown in Fig. The current is discontinuous, i.e. goes to zero during each half cycle, because this particular VSD does not have any line inductors. A pulse width modulation (PWM) switching scheme is used in the VSD which invert the Voltage from its DC into a sinusoidal AC output. The PWM output contains noise and this phenomenon is identified by the power analyser’s measurement s.

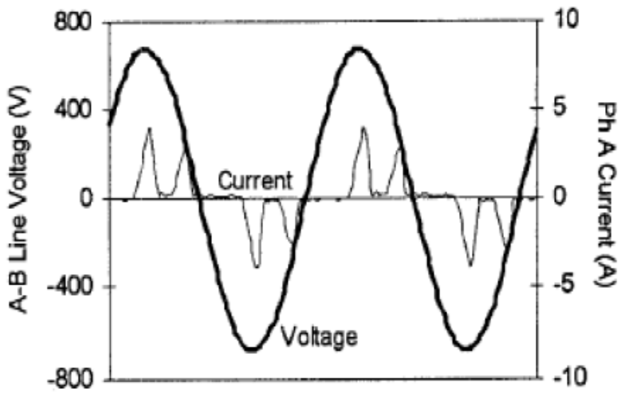

Fig:1(a) Variable speed drive of Source and load side waveform.

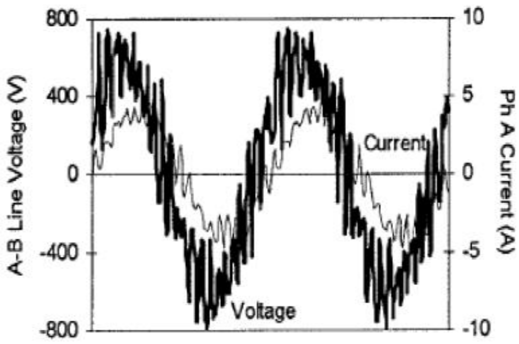

Fig.1(b) Variable speed drive of line and load side waveform.

B. Arcing devices:

ARC furnaces are used for melting and refining metals. It is one of the most important non-liner loads in the electric power network and it is a time varying, non-liner load. The voltage-current characteristics of electric arcs are nonlinear. Following arc ignition, the voltage decreases as the arc current increases, limited only by the impedance of the power system. This gives the arc the appearance of having a negative resistance for a portion of its operating cycle such as in fluorescent lighting applications. As the popularity and use of the arc furnace loads in the industry increase, so does the power-quality problem as a result of this progress. Among the most common adverse power quality effects introduced by electric arc furnace are voltage and current harmonics, voltage and current imbalance, low power factor, and voltage flicker. The energy consumed in the each basket of the melting cycle may be dividing into three main steps 1.Drilling period, 2.Melting period, 3.End of melting and reheating. The Fig.2 shows the active power consumed as function of time for the above melting period given.

C. fluorescent lamps:

Fig.3 shows the phase voltage and current and the neutral current for a lighting load of fluorescent lamp with magnetic ballasts. The harmonics in the current waveform are caused by the nonlinearity of the lamp arc itself in series with the ballast. The typical waveforms are given in figs. (3, 4).

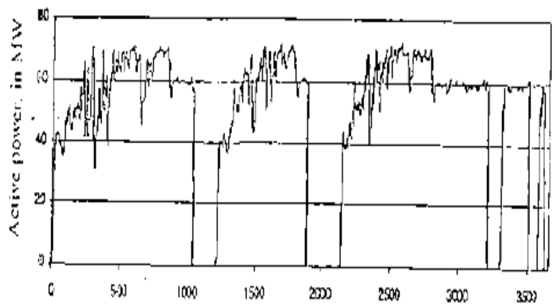

Fig. 2 Active power consumed in MW as function of time in seconds for the above melting period with reheating.

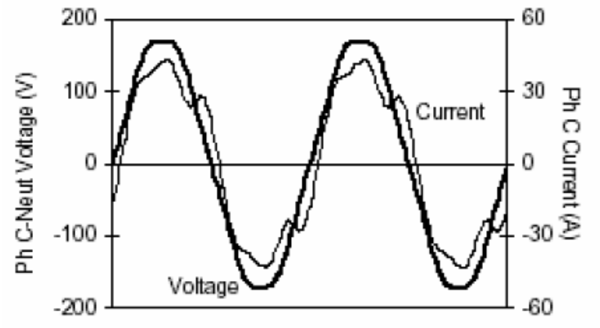

Fig.3. (a) Phase voltage and current.

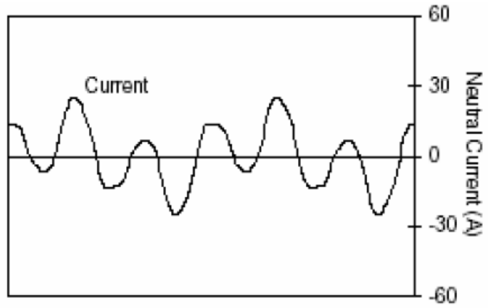

Fig.3 (b) Neutral current for a three phase, four wire

Fig.3 Waveforms for magnetic ballasts

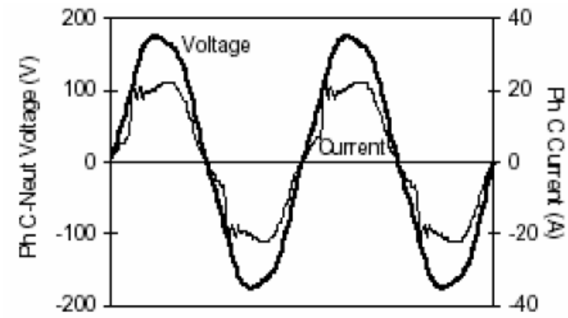

Fig : 4. (a) Phase voltage and current

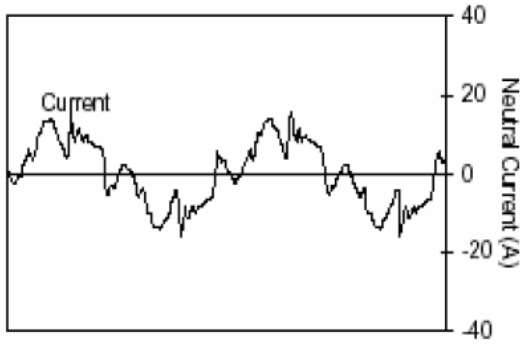

Fig: 4. (b) Neutral current for a three phase, four wire system.

Fig: 4. Waveforms for electronic ballasts.

D. Personal Computer:

A day-to-day increasing the usage of the personal computers (PC), these produces harmonics in the power system network. The experimental activity has concerned the harmonic monitoring of several PC types. Some selected results have been reported at PCC(point of common coupling) with varying impedance value are given in fig (5)

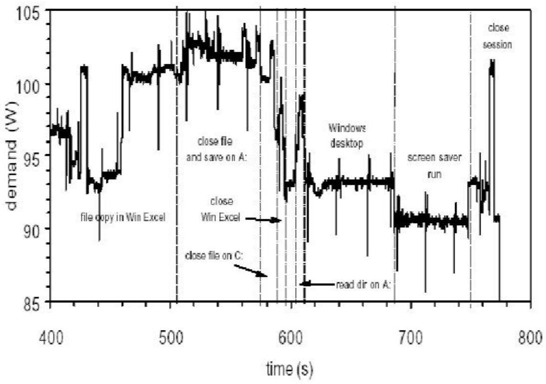

Fig: 5 Demand diagram recorded for some typical Operations of PC.

E. Cell Phone Battery Chargers

Cell phones require battery chargers (BC) equipped with single phase switching mode power supplies of very low demand. However, the high number of BC dispersed in end-user areas can determine a significant cumulative impact on distribution grid voltage quality. The continuous monitoring activity has involved several samples of cell phone BC for Li-Ion batteries are reported in the figs.6. In particular, Fig.7. Reports the BC power demand for a whole charging cycle. The demand level results decreasing with charging level increase & is reported in order to better illustrate the demand modulation operated during charge and controlled by battery charging status.

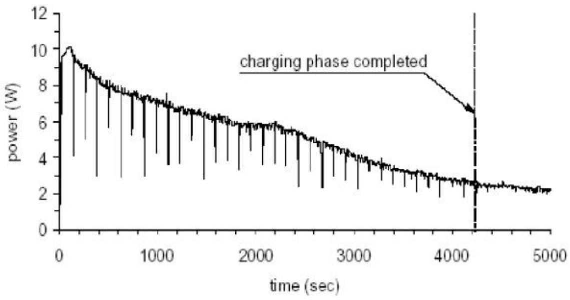

Fig: 6 Dem and diagram recorded for whole BC charging cycle.

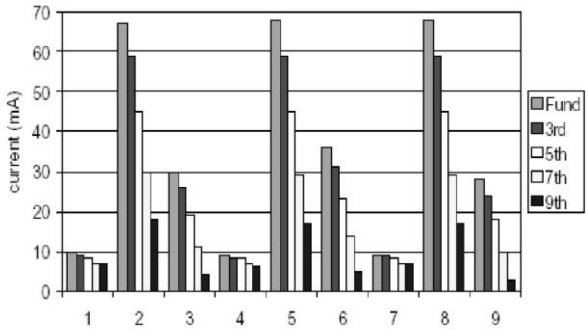

Fig.7.Harmonic currents recorded at instants.

F. Printers

A operation of the printer consists of stand-by mode, print starting and print. The demand for the above operations is different. This causes harmonics in the power system. Typical waveforms given in fig (8, 9).

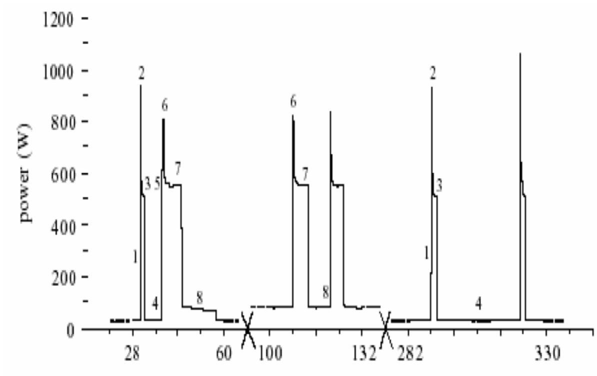

Fig: 8 Expanded view of Printer typical duty cycle.

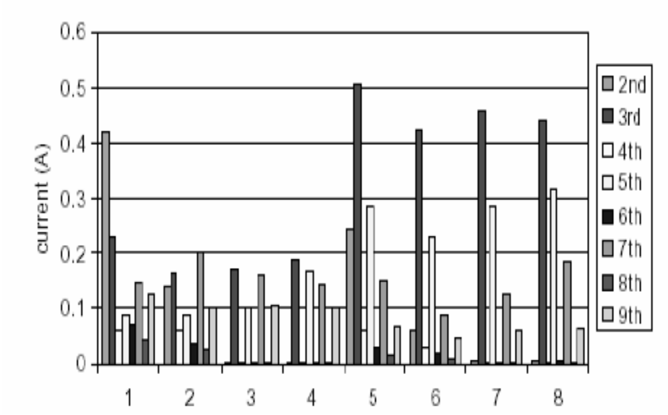

Fig: 9 Harmonic current spectrums.

Vi. Reduction Technique

There are various methods are available such as DC Choke, line reactor, 12 pulse converter, Active filter, Broadband Filter, Eaton's Clean power (18 pulse Converter), Harmonics trap filter.

A: DC Choke:

This is simply series inductances on DC Side of the semiconductor bridge circuit front end of the AFD. In many ways DC choke the is comparable to an equivalent AC-side line reactor, although the %Total Harmonic Distortion (THD) is somewhat less. The DC choke provides a greater reduction primarily of the 5^{th} and 7^{th} harmonics. On higher order harmonics the line reactor is superior so in terms of meeting IEEE guidelines, the DC chokes and line reactor are similar. If a DC choke (or line reactor) is applied on all AFDs, it is possible to meet IEEE guidelines where up to 15% to 40% of system loads are AFDs, depending on the stiffness of the line, the amount of linear loads and the value of choke inductance. A harmonic analysis is required to guarantee compliance with guidelines.

B: Line Reactor:

A line reactor is a three-phase series inductance on the line side of an AFD. If a line reactor is applied on all AFDs, it is possible to meet IEEE guidelines where up to 15% to 40% of system loads are AFDs, depending on the stiffness of the line and the value of line reactance. Line reactors are available in various values of percent impedance, most typically 1-1.5%, 3% and 5%. A harmonic analysis to guarantee compliance with guidelines.

C: 12-Pulse Converters:

A 12-pulse converter incorporates two separate AFD input semiconductor bridges, which are fed from 30° phase shifted power sources with identical impedance. The sources may be two isolation transformers, where one is a delta/wye design (which provides the phase shift) and the second a delta/delta design (which does not phase shift). A line reactor of equal impedance to the delta/wye transformer may also be used in lieu of the delta/delta transformer. The 12-pulse arrangement allows the harmonics from the first converter to cancel the harmonics of the second. Up to approximately 85% reduction of harmonic current and voltage distortion may be achieved (over standard 6-pulse converter). This permits a facility to use a larger percentage of AFD loads under IEEE519: 1992 guidelines than allowable using line reactors or DC chokes. A harmonic analysis is required to guarantee compliance with guidelines.

D: Active Filters:

This method uses sophisticated electronics and power section IGBTs to inject equal and opposite harmonics onto the power system to cancel those generated by other equipment. These filters monitor the non-linear currents demanded from non-linear loads (such as AFDs) and electronically generate currents that match and cancel the destructive harmonic currents. Active filters are inherently non-resonating and are easily connected in parallel with system loads.

E: Broadband Filters:

These filters are similar to trap filters but have some major design differences. As trap filters are connected in parallel to the AFD, broadband filters are connected in series with the AFD and carry the full AFD current. This difference provides added protection for the input power section of the AFD. Broadband filters require no tuning, improve power factor for the system and minimize all harmonic frequencies, including the 3rd harmonic. Additionally, they avoid system resonance and importation of outside harmonics.

F: Eaton's Clean Power (18-Pulse Converter):

This method is similar to 12-pulse converters, although instead of using two phase-shifted power sources and semiconductor bridges, three are used. Eaton uses a specially wound autotransformer (Differential Delta) and 18-

input semiconductors. When this arrangement is used, over 90% of harmonic currents are canceled (typical total harmonic distortion of 2 — 3%).

G: Harmonic Trap Filters:

Harmonic trap filters are usually used in conjunction with a line reactor, and are usually placed on individual AFD loads. They are usually an L-C filter installed in a shunt arrangement on the line side of the AFD, and are tuned somewhat below the 5th harmonic, which is the largest component of harmonic distortion. A significant amount of 7th harmonic distortion will also be absorbed. Additional filters tuned to higher order harmonics may also be used. More care is needed with the application of harmonic trap filters than with other methods, since they will tend to try to filter the entire distribution system of harmonic components. If additional AFD or non-linear loads are added without filtering, the previously installed filters may become overloaded (they are generally fused for protection). The line reactor is used in conjunction with the filter to minimize the possibility of this occurring and to enhance filter performance. A harmonic analysis is required to guarantee compliance with guidelines.

VII. Conclusion

Harmonics are important one of the Power Quality problem and consider their impact when contemplating additions or changes to a system. In addition, identifying the size and location of non-linear loads should be an important part of any maintenance, troubleshooting and repair program. This article was intended to identify the harmonics introduced in the system due to various nonlinear loads and helps to identify the levels of harmonic voltages and currents may be present.

References

1. IEEE Recommended Practices for Harmonic Control in Electric Power Systems, IEEE Std.519-1992.
2. Roger C.Dugan, *"Electrical Power Systems Quality," 2nd edition*, Tata McGraw-Hill Edition.
3. Leon M. Tolbert, Member, IEEE Harold D. Hollis and Peyton S. Hale, Jr. *"Survey of Harmonics Measurements in Electrical Distribution Systems"* IEEE IAS Annual Meeting, Oct. 6-10, 1996, San Diego, CA, pp. 2333-2339.
4. Grasselli.U; Lamedica.R., Prudenzi.A, *"Time-Varying Harmonics of Single-Phase Non-Linear Appliances",* Power Engg. Society winter meeting, 2002, IEEE, Vol.2,27-31 Jan 2002page: 1066-1071.
5. M.H. Rashid, Power Electronics Circuit Devices and Application, Prentice Hall, 1993, pp. 15–64.
6. G.M. Hashem, M.K. Darwish, *"Generalized symmetrical angle PWM technique for ac voltage controller",* Power Engineering Conference 2004, UPEC2004, Vol. 2, pp.898-901.

7. Z. Fedyczat, M. Jankowaki, and P. Szezesniak*, "A comparison of Basic properties of single-phase serial AC voltage Controllers using bipolar PWM chopper"* Power Electronics and Applications, 2005.
8. C. Teng. C.S. George, *Neural fuzzy system, Prentice Hall Inc 1999.*
9. S.Kaitwanidvilai, P.Piyarungsan "*Harmonic Reduction in PWM AC Voltage Controller using Genetic Algorithm and Neural network"* IMECS2007, Vol. 2, pp.1674-1679.
10. Y. Jiang, H. Mao, F. C. Lee, and D. Boroyevich, "*Simple High Performance Three-Phase Boost Rectifiers*", *Conference Record IEEE PESC* 1994, pp. 1158-1163.
11. A. R. Prasad, P. D. Ziogas, and S. Manias, *"An Active Power Factor Correction Technique For Three Phase Diode Rectifiers"*, *Conference Record IEEE PESC* 1989,pp. 58-65.
12. D. S. L. Simonetti, J. Sebastian and J. Uceda, *"Single-Switch Three-Phase Power Factor Preregulator Under Variable Switching Frequency And Discontinuous InputCurrent", Conference Record IEEE PESC* 1993, pp. 657-662.
13. J. W. Kolar, H. Ertl, and F. C. Zach, *"Space Vector-Based Analytical Analysis Of The Input Current Distortion Of A Three-Phase Discontinuous-Mode Boost Rectifier System", Conference Record IEEE PESC* 1993, pp. 696-703.
14. S. Gataric, D. Boroyevich, and F. C. Lee, *"Soft-Switched Single-Switch Three-Phase Rectifier With Power Factor Correction", Conference Record IEEE APEC* 1994, pp.738-744.
15. M. Sedighy and F. P. Dawson, *"Single-Switch Three-Phase Power Factor Correction", Conference Record IEEE IPEC* 1995, pp. 293-297.
16. E. Ismail, R. W. Erickson, *"A Single Transistor Three Phase Resonant Switch For High Quality Rectification", Conference Record IEEE PESC* 1992, pp. 1341-1351
17. Q. Huang, and F. C. Lee, *"Harmonic Reduction In A Single-Switch, Three-Phase Boost Rectifier With High Order Harmonic Injected PWM"*, *Conference Record IEEE PESC* 1996, pp. 1266-1271.
18. F. Blabjerg, J. K. Pederson, "*An Integrated High Power Factor Three-Phase AC-DCACConverter For AC Machines Implemented In One Microcontroller"*, *Conference Record IEEE PESC* 1993, pp. 285-292.
19. S. Hiti, etc. "*Average Current Control Of Three-Phase PWM Boost Converters",Conference Record IEEE PESC* 1995, pp. 131-137.