International Journal of Enhanced Research in Science Technology & Engineering, ISSN: 2319-7463
Vol. 3 Issue 2, February-2014, pp: (76-81), Impact Factor: 1.252, Available online at: www.erpublications.com

A literature survey on Energy Efficiency Enhancement in buildings considering harmonics in nonlinear load

Deepak Kumar[1], Pawan Rana[2]
[12]Dept. of Electrical Engineering, RPIIT Bastara, Haryana, India

Abstract: In this manuscript, the author has reviewed the technique used to improve the energy efficiency in buildings. Poor power factor caused by nonlinear loads in a building result several power quality problems from the point of view of energy consumption of buildings. Average energy consumption of an academic building is taken into consideration for estimation of the cost of energy consumption in the building throughout the year. The current and voltage RMS as well as THD is taken into account of various non-linear loads used in buildings for different analysis. The current and voltage harmonics of different order is also studied. Application of a capacitor and a resistance in shunt (as shunt passive filter) resulted a considerable amount of improvement in total harmonic distortion of current of nonlinear load present in an academic building. Widespread use of this kind of filters will ensure lesser amount of transmission loss. However the application of this filter may vary for different kind of loads.

Keywords: Efficiency, harmonics, load, energy.

INTRODUCTION

In a linear load, like a resistor, capacitor or inductor, current and voltage will have the same frequency. As long as the characteristics of the load components do not change, the frequency component of the current will not change. When we deal with non-linear loads such as switching power supplies, transformers which saturate, capacitors which charge to the peak of the supply voltage, and converters used in drives, the characteristics of the load are dynamic. As the amplitude of the voltage changes and the load impedance changes, the frequency of the current will change. That changing current and resulting complex waveform is a result of these load changes. The complex current waveform can be described by defining each component of the waveform. The component of any waveform can be defined in terms of dc, and all frequencies from 0 to infinity. The frequencies that are normally dealt while using drives are 50 or 60 Hertz. By definition, these frequencies are termed fundamental in their respective distribution systems. High energy efficiency is good for economy and the environment. Nonlinear loads cause harmonics which increase energy consumption. These loads earned the name to describe the way they draw the power. The cumulative consumption of power due to harmonic distortion, not only caused by industry but residential buildings as well, has reached at a great height. This energy consumed is extra and this is of no use therefore this power consumption is considered energy loss. When we talk about AC we are talking about alternating current. The voltage pushing that current through the load circuit is described in terms of frequency and amplitude. The frequency of the current will be identical to the frequency of the voltage as long as the load resistance/impedance does not change.

Economic growth and Fast urbanization results more building energy consumption due to non-linear loads like personal or notebook computers, laser printers, fax machines, telephone systems, stereo systems, radios, TVs, adjustable speed drives and variable frequency drives, battery chargers, UPS, and any other equipment powered by switched-mode power supply (SMPS) equipment [7].

Importance of energy

The power supply position prevailing in the country is characterised by persistent shortages and unreliability and also high prices for industrial consumer. There is also concern about the position regarding petroleum products. 70% of our oil demand is met through imports and this raises issues about energy security. These concerns have been intensified by recent upward movements in international oil prices. Electricity is domestically produced but its supply depends upon availability of coal, exploitation of hydro power sources and the scope for expanding nuclear power, and there are constraints affecting each source.

Nothing moves without energy, and no energy can be used without disturbing the environment. Energy is the prime mover of economic growth of any country and is vital to the nourishment of a modern economy. Future economic growth crucially depends on the long-term availability of energy from sources that are affordable, accessible and environment friendly. Energy is a vital input to production and this means that if India is to move to the higher growth rate that is now feasible, we must ensure reliable availability of energy, particularly electric power and petroleum products, at internationally competitive prices. The present energy scenario is not suitable.

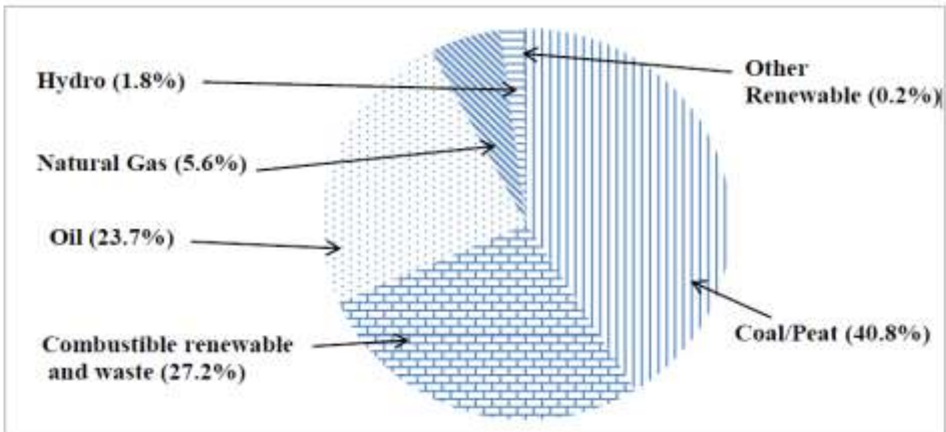

Fig.1: Sources of energy (%) in India

Under the Kyoto Protocol, industrialized countries have agreed to cut their collective emissions of greenhouse gases by 5.2% by 2008-2012, however, compared to the emissions levels expected by 2012 prior to the Protocol, this limitation represents a 29% cut. The target in Europe is an 8% reduction overall with a target for Carbon emissions to fall by 20% by 2020 and up to 50% of Carbon emissions of residential and commercial buildings are from electricity consumption. [37] Moreover, as domestic appliances, computers and entertainment systems grow; other equipment such as air conditioning and ventilation systems increase in use, electricity consumption is rising at a higher rate than other energy usage.

If newly constructed buildings perform exactly as existing stock the result by 2020 will be an increase in electricity consumption of 22%. On the other hand, if all new construction has energy consumption of 50% less than existing stock, the result is still an increase of 18%. By 2020 in most countries 80% of all buildings will have already been built, the refurbishment of existing building stock and improving energy management is vital in meeting emission reduction targets are the only potential for further savings is by reducing the amount of energy consumed [12]. The first step to taking a building energy efficiency approach is to find out which parts of building use the most energy. An energy audit will pinpoint those areas and suggest the most effective measures for cutting energy costs. [37]

Literature Review

This is a serious problem when power quality is concerned. The problem is due to some non-linear loads showing different current waveforms due to some non-linear loads showing different current waveforms. Here many solutions of harmonics are described Fast urbanization and economic growth result more building energy consumption due to the use of non-linear load equipment and new technologies in building. Harmonic current generated in distribution systems provide a new problem for electrical engineers.

Hussien et al. (2003) explained a model an active filter to resist harmonic currents injected from non-linear loads. The model of single phase shunt active power filter is prepared in Matlab Simulink based on time domain. Author performed three task; identify non-linearity, forming synchronised reference and to provide closed loop control. Analysis shows that harmonics are successfully avoided/filter by this filter.

Samra et al. (1993) studied that large amount of power electronic appliances cause large amount of non-sinusoidal energy transmission and generation of harmonics. He also felt that Harmonic content introduce a great problem measuring true real power by multiplying rms voltage and rms current with zero crossing angles between the voltage and current. He showed that digital microprocessor can perform it more smartly by adding all the power component of different frequencies.

Foertsch et al. (1994) pointed about need of predicting the need of predicting effects of nonlinear load. Author presented a general method for estimating rms values of electric currents and THD due to non-linear load. Author felt that delta-wye transformers are effective in improving power quality as shown in the simulation. They have also depicted experimental results of simulation of different harmonic reduction and compensation techniques from the experimental data gathered to validate the proposed method. However implementation of the simulated filter should be preceded by a detailed analysis of electrical system.

Akbar et al. (2007) explained that each appliance generate unique magnitude and frequency spectrum of active and reactive power. A large amount of non-linear loads are used in recent days, each of them can be identified by analysing their spectrum characteristics. Author had focussed on monitoring and analysing current harmonics based on frequency spectrum. He had gone through some FFT analysis to observe reactive power consumption, which is mainly caused by non-linear load to identify them. He found that fully glowing CFL consume more reactive energy than a fan running at full speed but speed being reduced it consume more reactive energy than CFL glowing at its minimum. Sharaf et al. (1997) studied energy efficiency can be achieved by a filter in case of non-linear load and ensured it by using a switching filter (smart modulated passive filters). The proposed current/ripple tracking controller transforms a simple tuned arm filter into flexible reactive compensation and harmonic filtering device.

Paraskevas et al. (2010) experimented the harmonic contents to determine PQ which shows that PQ events are of two natures; steady state and transient. They used Choi-William Distribution (CWD) method for better resolution to detect frequency contributions including the non-stationary signal. The simulation result is encouraging and time-frequency localization problem is solved satisfactorily. Mansoor et al. (1998) discussed several ways of harmonic current cancellation and attenuation. Electronic controlling is now used for many residential appliances is a great concern for future non-linear loads. Capacitor filtered diode bridge rectifier, high distorting loads are the main sources of current harmonics. Phase angle diversity as well as three phase and single phase load connections reduce harmonic current injection.

Abdel et al. (2004) studied to optimize LC compensation considering impedance and harmonic voltage variation and available capacitors. They found that capacitors used for power factor correction should be varied to minimise the loss (which can only be implemented using static var compensator or switched capacitors of limited no. of steps). Ranjana et al. (2010) discussed about a case study of a residential building with calculation of power consumption due to linear as well as nonlinear loads and suggested remedies for conserving energy. Kapoor et al. (1998) found importance to improve energy efficiency in harmonic related problems in nonlinear power electronic industrial and domestic loads which are massive in quantity. Author studied that active, passive, hybrid filters offer different limitation to reduce harmonics, whereas quasi passive filter, consist of parallel and series LC tank circuit of large value of capacitance, can avoid those limitations.

Bannard et al. (2003) studied that phase shifting can cause cancellation of harmonics of different order depending upon the quantity of the shifted phase. They also observed that up-to 19th order harmonics can be cancelled with different kind of transformers (like Delta-Zigzag or Double Output Delta-Zigzag transformers) with shifted phase. They have also gone through a case study which shows that unequal distribution of loads in different buses makes it difficult to achieve but problem being resolved 38% of harmonic power consumption been reduced. Subbiah et al. (2003) presented concern about increasing nonlinear load which results huge non-sinusoidal energy consumption. Author had given effort for energy efficiency improvement by reducing non-sinusoidal energy consumption. He had focused on power quality (PQ) improvement with the help of inverter based active power filter (APF) consists of simple analog circuitry which imply constant frequency integration control because the power quality problem results non-sinusoidal current consumption of the loads. This low cost circuitry carrier free, constant switching frequency operation, minimum reactive and harmonic current generation, unity power factor can be achieved.

Emad Samadaei et al. (2011) showed a new scheme for attenuation of harmonics. It depicts an algorithm of hybrid active power filter including hysteresis current control consists of feedback as well feedforward loop to increase filter accuracy. The algorithm based on harmonic extraction consisted of two loops; feedback and feedforward loop. The entire process consisted an algorithm as well as current switching technique resulted better accuracy and lesser complicacy simultaneously. The simulation reveals switching losses but the result shows that THD is limited within the standard.

N.Y. Dai et al. (2004) discussed that excessive power quality problems in buildings due to large number of nonlinear loads like PCs, printers, TV etc. To reduce current harmonics as well as neutral current author suggested application of parallel power quality compensators. Author compared two voltage source inverter topologies for 3phase-4wire compensators.

Compared result indicates four leg inverter doubles the neutral current control capability, whereas phase current harmonic reduction capability is same as 3leg center split inverter. The experimental results also show that current harmonics and neutral current can be compensated.

Bhim Singh et al. (1998) presented an active power filter based on simple control technique to provide reactive power and harmonics compensation linear and nonlinear single phase loads. A simple PI (proportional-integral) dc bus voltage controller with reduced energy storage capacitor is employed in the APF which is able to reduce the harmonics well below 5% in all the cases of extremely reactive harmonic polluted loads. A set of lagging leading power factor linear loads and diode rectifier fed capacitive load and ac voltage regulator fed inductive load as the nonlinear loads are taken on the ac mains to demonstrate the effectiveness of the proposed APF for reactive power and harmonic compensation. Leszek et al. (1990) presented decomposition of power signal which consisted basis for the physical interpretation in circuits of non-sinusoidal signal generated by non-linear or periodically time variant load sometimes has to be considered not as a receiver but as a source of energy. Nonlinear load consist of active as well passive elements which is very much complex than linear load in terms of equivalent circuit. Author had given some examples of decomposition of load decomposed into real and imaginary part in current and voltage equation. The practical decomposition is performed by a digital power analyzer consist of two channel 12bit A/D converter as well as microprocessor synchronized with sampled waveforms and a personal microcomputer. All the measurement is done in discrete format for calculation.

Tripathi et al. (2010) proposed a parallel power processing scheme to improve the power quality of uncontrolled diode bridge rectifier. Author shown his concern about various undesirable effects and power quality problems on utility supply like low system efficiency, poor power factor, derating on power supply equipment, disturbance to other consumer which are mainly introduced by nonlinear loads. In the parallel string author used synchronous link converter supplying resistive load. Active power flows through the main converter whereas auxiliary converter takes care of harmonics. To provide DC output a 2:1 turn ratio transformer is used in auxiliary converter. A PI controller is used to feedback DC output as source current reference. For experimental and laboratory result the simulation model is prepared in LabVIEW. The result show lower distortion in current as well as gives harmonic compensation. Rajan et al. (2010) developed a reconfigurable controller for Brushless DC (BLDC) motor drive using fuzzy logic technique to minimize the harmonics. BLDC offers higher energy efficiency, high reliability, low maintenance, high torque to weight ratio as well as compatible to digital system. The controller has been designed and performance has been observed from the simulated result and experimental result. Implementation of fuzzy logic controller offers better performance to reduce harmonics in voltage low energy consumption.

Theoretical Background

Linear and nonlinear loads

Load means which causes consumption of current. They can be divided into several categories according to their characteristics but here they are divided into two categories, according to their V-I characteristics, viz. 1) linear loads and 2) non-linear loads.

Linear Loads:

Electrical loads where the voltage and current waveforms are sinusoidal and the current at any time is proportional to voltage are termed as linear loads. If pure sinusoidal voltage is passed through the resistive element, then the shape of the current wave form will be purely sinusoidal without distortion. Voltage and current waveform in a circuit involving inductor make voltage lead the current. On the other hand for a circuit involving capacitor, current leads voltage. The Voltage-Current characteristic for the linear load is as shown in the Fig. below

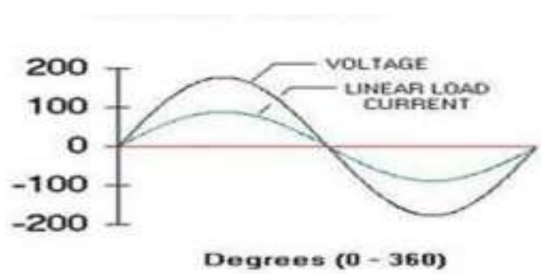

Fig. 2: V-I characteristics of linear load

International Journal of Enhanced Research in Science Technology & Engineering, ISSN: 2319-7463
Vol. 3 Issue 2, February-2014, pp: (76-81), Impact Factor: 1.252, Available online at: www.erpublications.com

Non-Linear Loads

Electrical loads where the current is not proportional to the voltage are considered as nonlinear loads. Non-linear loads generate harmonics in the current waveform that leads to distortion of the voltage waveform; under these conditions the voltage is no longer proportional to the current. The voltage-current characteristic is different than that of non-linear loads linear load.

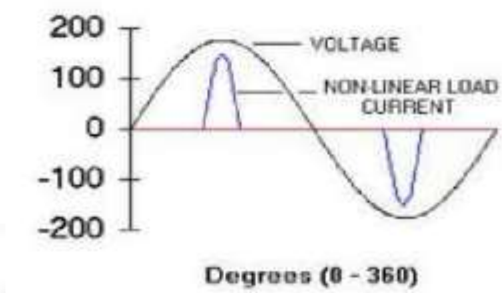

Fig. 3: V-I characteristics of non-linear load.

Harmonics

"Harmonics" means a component with a frequency that is an integer multiple (where n is the order of harmonic) of the fundamental frequency; the first harmonic is the fundamental frequency (50 or 60 Hz). The second harmonic is the component with frequency two times the fundamental (100 0r 120 Hz) and so on. As shown in Fig., harmonic distortion can be considered as a sort of pollution of the electric system which causes problems if the sum of the harmonic currents exceeds certain limits. The utilization of electrical power mainly depends up on supply of power with controllable frequencies and voltages, where as its generation and transmission takes place at nominally constant levels. So to convert nominal frequency to variable frequency power electronics circuitry (non-linear loads) is needed, which distorts the voltage and current waveforms. Therefore, the main source of harmonics in the power systems is the non-linear loads.

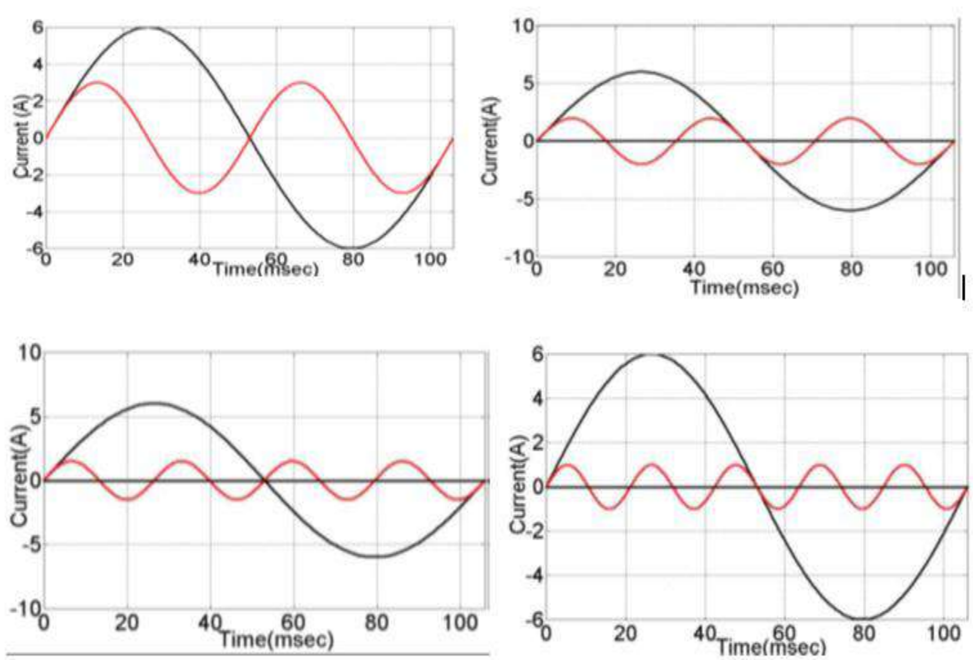

Fig. 4: A sinusoidal waveform with fundamental frequency 50 Hz and its harmonics: (a) second (100 Hz); (b) third (150 Hz); (c) fourth (200 Hz); (d) fifth (250 Hz).

Conclusions and Future Scope

The most common problem is the harmonic distortion caused by non-linear loads such as electric household appliances, lighting, personal computers or speed control units for motors. In a well-balanced system, the vector sum of the currents in the neutral was zero or close to zero. In general, even harmonics, (2nd and 4th) do not cause problems. The odd multiples of the third harmonic are added together in the neutral and can cause overheating even with balanced loads, which is extremely undesirable.

Analysis of different non-linear loads reveals a huge distortion of current is generated by them. However the distortion is very low in running mode compared to stand-by mode of those loads. Non-linear loads draw power at a low power factor with large harmonic currents. Reduction of continuous disturbances due to harmonics often requires the use of harmonic filters. In most instances, power factor correction capacitors can be installed in the form of a harmonic filter bank to provide both power factor correction and harmonic filtering capabilities. However, the application of capacitors in the presence of harmonic generating equipment may produce undesirable effects. Capacitors can amplify certain harmonics if there is parallel resonance between the capacitor bank and source of harmonic equipment. The result would be excessive capacitor currents, capacitor fuse blowing and excessive voltage distortion in the system. Special consideration must be given to the application of capacitors to a power system that contains harmonic generating equipment. Harmonic currents considerably affect the neutral wire of electric installations and pollute the AC waveform. Therefore, remedial actions taken in isolation can greatly improve the overall power quality.

References

[1]. United States Agency for International Development, Performance Monitoring and Evolution, Foreign Assistance Reference Guide, website: pdf.usaid.gov.
[2]. The Commercial Building Consortium (CBC) is public/private collaboration with the U.S. Department of Energy (DOE) with the objective of transforming the commercial building sector to net-zero energy, website: www.zeroenergycbc.org.
[3]. Tripathi Dr. R.K., Singh Mr. Chadreshver Pratap, "Power Quality Control of Unregulated Non-linear Loads" Power, Control and Embedded Systems (ICPCES), 2010 International Conference on Nov. 29 2010-Dec. 1 2010.
[4]. U.S. Department of Energy, Energy Efficiency and Renewable Energy, tips on lighting and daylighting, website: http://www.energysavers.gov (Save money and energy at home) or www.natresnet.org (home energy efficiency).
[5]. Dodroe S. J., Radmer D.T., Montgomery R., Chen J., Foertsch J.S., "Harmonic Compensation of Comercial and Industrial Power System", Transmission and Distribution Conference, 1994, Proceedings of the 1994 IEEE Power Engineering Society Digital Publication on 10-15 April 1994.
[6]. Energy Efficiency in Electrical Utilities, Guide book for National Certification Examination for Energy Managers and Energy Auditors, Bureau of Energy Efficiency, Ministry of Power, Government of India. Bureau of Energy Efficiency and Energy Conservation Building Code, website: www.beeindia.in.
[7]. Essays, Dissertations and Coursework of qualified, Oxbridge writers, website: www.oxbridgewriters.com.
[8]. Hussien Z. F., Atan N., Abidin I. Z., "Shut Active Power Filter for Harmonic Compensation of Non Linear Loads", National Power and Energy Conference (PECon) 2003 Proceedings, Bangi, Malaysia 0-7803-8203-0/03/@2003, IEEE.
[9]. Indian environmental preservation society, website: www.ecoindia.com.
[10]. Industrial Energy Efficiency Policy (IEEP) Database to information on policy measures that have been implemented or planned, website: ieep.unido.org.
[11]. Rajan A. Albert, Vasantharathna Dr. S., "Fuzzy Logic Based Reconfigurable Optimal Switching Controller for BLDC Motor for Reduced Harmonics", IPEC, 2010 Conference Proceedings on 27-29 Oct. 2010.
[12]. Said Dalila Mat, Ahmad Nasarudin and Zin Abdullah Asuhaimi Mohd, "Power Supply Quality Improvement: Harmonic Measurement and Simulation", National Power and Energy Conference (PECan) Proceedings, Bangi, Malaysia (2003).
[13]. Samadaei E., Lesan S. and Cherati S. Mahamodi, "A new Schematic for Hybrid Active Power Filter Controller" 978-1-4577-0007-1, IEEE, (18-19 April, 2011).
[14]. Samra Abdul H., "Power Measurement in The Presence of Harmonic Distortion", Florida International University Department of Electrical and Computer Engineering Miami, Florida 33199, 1993.
[15]. Sharaf A.M., Guo Caixia and Huang Hong, "An Energy Miser Scheme for Nonlinear Loads", IEEE, 10.1109/CCECE.1997.614816, (25-28 May, 1997).
[16]. Akbar Mahmood and Khan Dr. Zubair Ahmad, "Modified Nonintrusive Appliance Load Monitoring For Nonlinear Devices", IEEE, 10.1109/INMIC.2007.4557691, (28-30 Dec. 2007).
[17]. Aliouane K., Saadate S. and Davat B., "Analytical study and numerical simulation of the static and dynamic performances of combined shunt passive and series active filters", Power Electronics and Variable-Speed Drives, Conference Publication no. 399, (26-28 Oct. 1994).
[18]. Asadi M., Jalilian A. and Farahani H. F., "Compensation of Unbalanced Non Linear Load and Neutral Currents Using Stationary Reference frame in Shunt Active Filters", Bergamo, Italy, 978-1-4244-7245-1, IEEE, (26-29 Sept. 2010).