ISSN(Online): 2320-9801
ISSN (Print): 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 3, March 2015

Analysis of the Effect of Harmonics Due To Switching Devices W.R.T. Experimental & Simulation Point of View

Rajesh Maharudra Patil[1], Dr. M.S. Nagaraj[2], Dr. P.S.Venkataramu[3]

Asst. Prof., Dept. of EEE, Balekundri Inst. of Tech., Belgaum, Karnataka, India [1]

Professor & Head, Dept. of EEE, BIET, Davanagere-4, Karnataka, India[2]

ABSTRACT: Effect of harmonics plays a very important role in the successful operation of any equipment. If the harmonics are not taken care of properly, then it may lead to the output distortion & further adds to the reliability, safety of the systems. Harmonic distortion is an undesirable effect for electrical systems. Extensive survey is being conducted on the topic chosen with a large number of research papers, after which analyzing the problem formulation being done. Finally, in the research work considered, new control algorithms are going to be developed in to suppress the harmonic contents in the power supply systems & to improve the power quality, reliability & safety of the power system.

KEYWORDS: Harmonics, Power semiconductor devices, Current, Voltage, Control, Distortion, THD, Suppression, Quality.

I. INTRODUCTION

Our technological world has become deeply dependent upon the continuous availability of electrical power. Commercial power literally enables today's modern world to function at its busy pace. Sophisticated technology has reached deeply into our homes and careers, and with the advent of e-commerce is continually changing the way we interact with the rest of world. Electric energy is an essential ingredient for the industrial and all-round development of any country. The optimum utilization of this form of energy can be ensured by a quality power. The situation with electricity is similar, the reliability of the supply must be known and the resilience of the process to variations must be understood [1].

In reality, of course, electricity is very different from any other product - it is generated far from the point of use & is fed to the grid together with the output of many other generators and arrives at the point of use via several transformers and many kilometers of overhead and possibly underground cabling. Where the industry has been privatized, these network assets will be owned, managed and maintained by a number of different organizations. Assuring the quality of delivered power at the point of use is no easy task-and there is no way that sub-standard electricity can be withdrawn from the supply chain or rejected by the customer [2].

Harmonics have a number of undesirable effects on the distribution system. They fall into two basic categories : short-term and long-term. Short-term effects are usually the most noticeable and are related to excessive voltage distortion. On the other hand, long-term effects often go undetected and are usually related to increased resistive losses or voltage stresses [4]. In addition, the harmonic currents produced by non-linear loads can interact adversely with a wide range of power system equipment, most notably capacitors, transformers, and motors, causing additional losses, overheating, and overloading. These harmonic currents can also cause interference with telecommunication lines and errors in metering devices [2] - [3]. Because of the adverse effects that harmonics have on PQ, standard has been developed to define a reasonable framework for harmonic control [5]. Its objective is to ensure steady-state harmonic limits that are acceptable by both electric utilities and their customers [5].

Harmonic distortion in power distribution systems can be suppressed using two approaches namely, passive and active powering. The passive filtering is the simplest conventional solution to mitigate the harmonic distortion [6] - [8].

ISSN(Online): 2320-9801
ISSN (Print): 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 3, March 2015

Although simple, the use of passive elements do not always respond correctly to the dynamics of the power distribution systems [9]. Over the years, these passive filters have developed to high level of sophistication. Some even tuned to bypass specific harmonic frequencies. Harmonics are voltage and current frequencies riding on top of the normal sinusoidal voltage and current waveforms. The harmonic problems are mainly due to the substantial increase of non-linear loads due to technological advances, such as the use of power electronic circuits and devices, in ac/dc transmission links, or loads in the control of power systems using power electronic or microprocessor controllers. In general, sources of harmonics are divided into the following categories of loads [6]:

- Domestic loads
- Industrial loads and
- Control devices.

Any distribution circuit serving modern electronic devices will contain some degree of harmonic frequencies. The harmonics do not always cause problems, but the greater the power is drawn by these modern devices or other non-linear loads, the greater is the level of voltage distortion. Potential problems attributed to harmonics include the following [7]:

- Malfunction of sensitive equipment.
- Random tripping circuit breakers.
- Flickering lights.
- Very high neutral currents.
- Overheated phase conductors, panels, and transformers.
- Premature failure of transformers and uninterruptible power supplies.
- Reduced power factor.
- Reduced system capacity.

The best way to deal with harmonics problems is to prevent : choosing equipment and installation practices that minimize the level of harmonics in any one circuit or portion of a facility. If the problems cannot be solved by these simple measures, there are 2 basic choices, viz., to reinforce the distribution system to withstand harmonics or to install the device to attenuate or remove the harmonic [3]. Strategies for attenuating harmonics, from cheap to more expensive, include passive harmonic filters, isolation transformers, harmonic mitigating transformers, the Harmonic Suppression System (HSS) and active filters [6].

Effect of harmonics in the system voltage and current is measured in terms of harmonic distortion, total harmonic distortion, distortion factor, and lower order harmonics. Most of the industrial applications demand, the load voltage with less than 5% harmonics. Review of literature reveals that many methods have been developed to reduce total harmonic distortion [5]. There are varieties of engineering solutions available to eliminate or reduce the effect of supply quality problems and it is very active area of innovation and development. As such, customers need to be aware of range of solutions available and the relative merits and costs. Some of the important methods to minimize harmonics are :

- Passive filters,
- Active harmonic filters,
- Isolation transformers,
- Harmonic mitigating transformers,
- Harmonic limited harmonic suppression system etc. [9].

II. BACKGROUND RELATED WORK (LITERATURE SURVEY) W.R.T. THE RESEARCH WORK

A brief introduction about the research work & its background was revealed in the introductory section w.r.t. the effect of harmonics due to switching devices on the power quality. In the modern day world, harmonics play a very important role in the supply of power & its distribution. In this section, an exhaustive survey is conducted on the chosen research topic, "Effect of harmonics due to switching devices on electrical power quality & development of new strategies for its reduction" and is presented in the form of an exhaustive literature survey [1] - [20].

In majority of the work done by the various authors / researchers presented in the previous paragraphs, there were certain drawbacks / disadvantages / lacunas such as they had developed the algorithms only for linear loads, higher harmonics could not be eliminated, performance indices were low, very few worked on non-linear loads, etc... Some of

ISSN(Online): 2320-9801
ISSN (Print): 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 3, March 2015

the drawbacks [1] - [20] are going to be considered in our research work & new algorithms are going to be developed in order to suppress the harmonics, which is going to be verified through effective simulation results.

III. Main objective of the research work

The main objective of the research work is to develop some novel control algorithms using advanced power electronic theories in order to study the effect of harmonics that is caused due to the devices & to suppress the harmonics in power supply systems. It was found that not much of research work was done in harmonic reduction field as a number of factors in constrained & unconstrained environments, further w.r.t. the non-linear loads such as capacitive & inductive loads. Further, there were lot of drawbacks & dis-advantages in the various types of works considered by the different researchers. Some of these problems are going to be considered in our research work & efficient algorithms are going to be developed for successful reduction of the harmonics & to improve the power quality in the distribution systems.

This has led us to take up the work in this exciting field of harmonic reduction caused because of different types of devices such as VSI, converters, inverters, STATCOMS, FACTS, etc… The objective of this research work is to develop sophisticated algorithms for harmonic reduction, improve the power factor & the power quality. Also, the work aims at developing some hybrid algorithms for total harmonic suppression. The emphasis will be only on the software for performing the simulation work. The software tool that could be used for the research work could be Matlab / Simulink / PSpice, in our research work as Matlab / Simulink / PSpice has been used as the software tool for performing the simulations. Coding is going to be done in Matlab, simulation will be performed & the results are going to be observed. Of course, some Simulink model is also going to be developed in our proposed work.

Most of the work on the harmonics survey assumes a single load, linear or non-linear fed from a power system. This research work deals with the study of harmonics and its effect due to various power semiconductor devices on quality of electrical power [7] [8] along with the development of some new strategy to reduce the harmonics and to improve the power quality. Some of the strategies going to be considered in our research work are listed one by one as below …..

- The Active Power filters (APF) technologies that are commonly designed to minimize effect of harmonics on electrical power.
- Since impeding harmonic currents will result in increased THD, the best tolls at our disposal are the strategic reduction of zero-sequence impedance and cancellation of positive & negative sequence harmonic current, i.e., Zero-Sequence Harmonic Filter (using this filter in our design work).
- Using boost convertor type harmonic elimination circuit due to which harmonics elimination may takes place.
- The usage of different configuration of PWM technologies for harmonic reduction and improvement of fundamental peak voltage.
- An attempt is going to be made in order to minimize the effect of harmonics using pulse width modulation technique. Also, an artificial intelligent technique is going to be used to analyze the effect of harmonics.
- A neuro-fuzzy scheme is also going to be proposed to reduce the effect of harmonics in the power semiconductor devices.
- Voltage Source Inverter (VSI) with neutral wire concept could be used for the harmonic reduction.
- Designing of an LC filter bank to reduce the harmonic contents in the input supply.

3.1 Short range objectives

1. Applying for the Ph.D. course to the VTU.
2. Passing of the written / entrance test.
3. Passing of the interview
4. Passing of the course work
5. Getting eligible for registration.
6. Collection of data, literatures in the chosen research field.
7. Developing some models.

ISSN(Online): 2320-9801
ISSN (Print): 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 3, March 2015

8. Harmonic system design.
9. Coding in Matlab.
10. Modeling in Simulink
11. Modeling in PSpice
12. Observation of the simulation results.
13. Submission of the half-yearly & yearly progress reports.
14. Discussion on the same with proper justification.
15. Publication of the work done in reputed journals & conferences.

3.2 Long range objectives

16. Implementing the developed conceptual algos in RT applications using experiments/kits.
17. Developing a highly reliable & sophisticated system even during power fluctuations.

3.3 Achieved objectives till date

1 After enrolling for the Ph.D. Programme, efforts were made to contact learned men, renowned researchers and scholars and discussions were made at length in the area of research in the field chosen by myself.
2 During this period, reference books and conference papers covering the fundamental theoretical concepts which would be a background for the research work were collected & studied. Hundreds of related research papers were collected from various sources such as internet, library, several IITs, NITs, IISc., Deemed Universities, Different college libraries, Research Center of VTU-Belgaum, VTU Belgaum Library, Balekundri Inst. of Tech., from friends, other colleges and in other college libraries.
3 After clearing the written test & the interview, the research process was started.
4 The completion of the coursework of the 4 selected theory subjects was done successfully in good grades.
5 Papers were submitted for possible publication in good refereed national & international journals & conferences, results are awaited.
6 One workshop on research methodologies & latex was attended, which was a mandatory requirement for the ful-fillment of the Ph.D. course.

The possible outcome of the research work is to show that when the designed algorithm / controller are placed with this power system, output of the analyzer will be devoid of harmonics & restores smooth supply (to a maximum extent). Still a lot of research is still going on in this exciting field, which we are carrying it forward in our research work.

IV. WORK CARRIED OUT SO FAR

Extensive literature survey was carried out on the identified research problem, "*Effect of harmonics due to switching devices on electrical power quality*"& development of new strategies for its reduction. Nearly 100 papers in the relevant filed was collected, studied, analyzed & the problem was identified. One novel algorithm is going to be proposed which is still in the developmental stage. 3 simple experiments were conducted to check the effect of the harmonics & how it is reduced. Based on these simple laboratory experiments, new strategies are going to be proposed in the near future of the research work which will be dealt with in the later stage.

ISSN(Online): 2320-9801
ISSN (Print): 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 3, March 2015

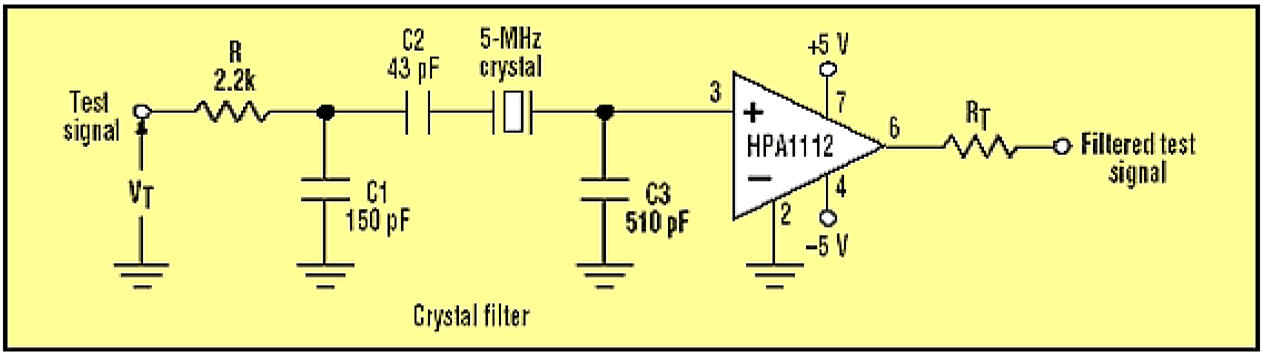

Figure 1 : Laboratory set up to reduce the harmonics

V. Results & Discussions

One novel algorithm is going to be proposed which is still in the developmental stage. Circuit design, modeling, coding is still in the progress. To begin with (to start the research), simple experiments are being performed in the laboratory to study the effect of harmonics due to various devices & how to reduce it by building simple circuits in the power electronics laboratory.

5.1 Laboratory set up to reduce the harmonics

An in-expensive sine-wave generator (simple experiment) was set up in the power electronics laboratory to reduce the second harmonic distortion. The test signal is given as the input (V_t). The crystal filters the distortion from the signal prior to the measurement. The output is observed on a textronic oscilloscope. It is found that the designed circuit reduces the second harmonic distortion is reduced by 70 dB after measuring from the scope as shown in the Fig. 2 below.

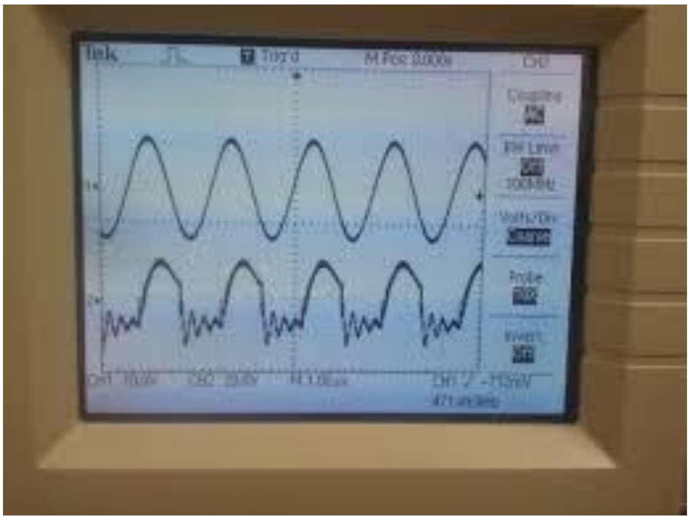

Figure 2 : Output observed on the scope

ISSN(Online): 2320-9801
ISSN (Print): 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 3, March 2015

5.2 Incorporation of a DC choke in the system for reduction of harmonics

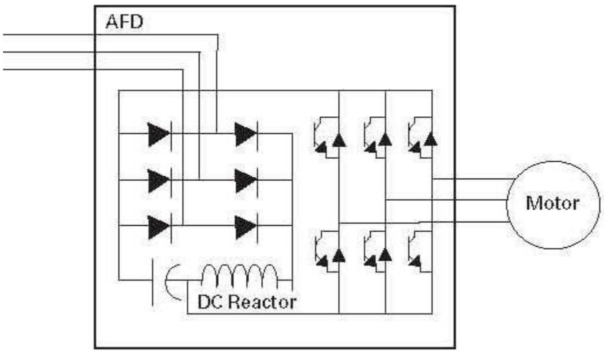

Figure 3 : Designed circuit for harmonic suppression using choke

A DC choke can be used in the system for the reduction of the harmonics as shown in the Fig. 3. This is simply a series inductance on the DC side of the semiconductor bridge circuit on the front end of the AFD. In many ways, the DC choke 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 5th and 7th harmonics. On higher order harmonics, the line reactor is superior, so in terms of meeting IEEE guidelines, the DC choke 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. The waveform & the harmonic contents reduction are shown in the Fig. 4. A harmonic analysis is required to guarantee compliance with guidelines. The main advantages of the choke design used are ….

- Packaged integrally to the AFD
- Can provide moderate reduction in voltage and current harmonics
- Less voltage drop than an equivalent line reactor

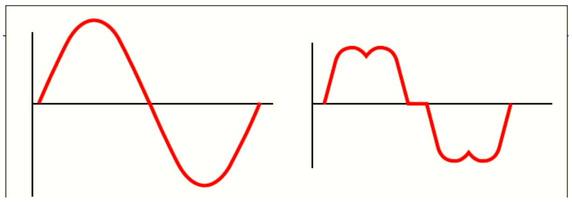

Figure 4 : Waveform & harmonic contents reduction

5.3 Harmonic trap filters

Harmonic trap filters are usually used in conjunction with a line reactor as shown in the Fig. 5 and are usually placed on individual AFD loads. They are typically 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, because they will tend to try to filter the entire distribution system of harmonic components. If additional AFD or nonlinear 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 is very much enhance filter performance. The harmonic trap filter as shown in the Fig. 5 coupled along with a AFD is connected to the motor and is used for harmonic suppression. A harmonic analysis is required to guarantee compliance

ISSN(Online): 2320-9801
ISSN (Print): 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 3, March 2015

with guidelines. The main advantages of this type of design is, it allows a higher percentage of AFD system loads than line reactors and chokes.

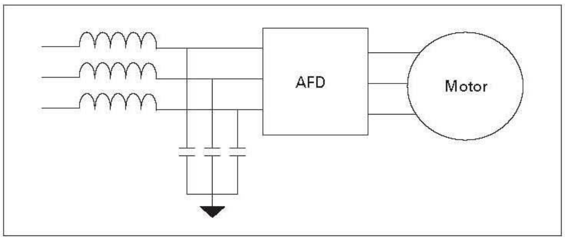

Figure 5 : Designed harmonic trap filter circuit for harmonic suppression

The synthesized wave is shown in the Fig. 6, which was observed on a Textronic Oscilloscope.

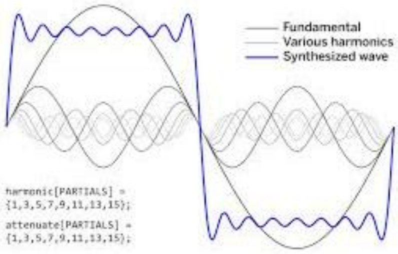

Figure 6 : Synthesized wave observed on the Textronic Oscilloscope

VI. FUTURE WORKS TO BE CARRIED OUT

The following work is supposed to be carried out during the course of the research work.

(a) The Active Power filters (APF) technologies that are commonly designed to minimize effect of harmonics on electrical power.
(b) Modeling of a filter bank in Simulink & check it with the existing method.
(c) Since impeding harmonic currents will result in increased THD, the best tolls at our disposal are the strategic reduction of zero-sequence impedance and cancellation of positive & negative sequence harmonic current, i.e., Zero-Sequence Harmonic Filter
(d) Boost convertor type harmonic elimination circuit due to which for some extent the cost of harmonics elimination takes place.
(e) The different configuration of PWM technologies for harmonic reduction and improvement of fundamental peak voltage.
(f) An attempt is made to minimize effect of harmonics using pulse width modulation technique. Also, an artificial intelligent technique is used to analyze the effect of harmonics.
(g) A neuro-fuzzy scheme is also going to be proposed to reduce the effect of harmonics in the power semiconductor devices.
(h) Voltage Source Inverter (VSI) with neutral wire concept could be used for the harmonic reduction.
(i) Designing of an LC filter bank to reduce the harmonic contents in the input supply.

VII. CONCLUSIONS

Early detection & suppression of harmonics in electrical, electronic, computer & instrumentation systems is a very important parameter which has to be considered w.r.t. the safety, reliability, efficient operation of power systems, which has to be tackled. Keeping this in mind, a number of research papers done by various researchers across the world were collected, studied, analyzed and the problem was formulated as “Effect of harmonics due to switching

ISSN(Online): 2320-9801
ISSN (Print): 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 3, March 2015

devices on electrical power quality" & development of new strategies for its reduction. The main aim of the proposed research work will be to develop efficient & robust algorithms along with modeling which will be used to suppress the harmonics in electrical, electronic, instrumentation & computer based power systems. In order to show the efficacy of the proposed harmonic suppression, the experimental evaluation (implementation) of the developed control algorithms may be carried out if time permits (if we get a grant) by using dSPACE / DSP / NI / TI / Labview / PSpice cards (involves cost minimum Rs. 8 - 10 lakhs).

REFERENCES

1. Zainal Salam, Tan Perng Cheng and Awang Jusoh, "Harmonics Mitigation Using Active Power Filter : A Technical Review", Elektrika, Vol. 8, No. 2, pp. 17-26, 2006.
2. Fanghua Zhang & Yangguang, "Selective harmonic elimination PWM control scheme on a three-phase four – leg voltage source inverter", IEEE Transaction on Power electronics, Vol. 24, No. 7, pp. 1682-1689, Jul. 2009.
3. Mahesh A. Patel, Ankit R. Patel, Dhaval R. Vyas and Ketul M. Patel, "Use of PWM Techniques for Power Quality Improvement", International Journal of Recent Trends in Engineering, Vol. 1, No. 4, pp. 99 – 102, May 2009.
4. Ming-Yin Chan, Ken KF Lee & Michael WK Fung, "A case study survey of harmonic currents generated from a computer center in an office building", Architecture Science Review, Vol. 50, No. 3, pp. 274-280, 2007.
5. G.N.C. Fergusson, "Power quality improvement in a harmonic environment", A paper reprint from the International Electrical Testing Association (NETA) Annual Technical Conference, Mar. 1997.
6. Thomas S. Key and Jih-Sheng Lai, "Costs and Benefits of Harmonic current reduction for switch mode power supply in commercial office building", IEEE Trans. on Industry Applications, Vol. 32, No. 5, Sept.-Oct. 1996.
7. V. Suresh Kumar, Ahmed F. Zobaa, R. Dinesh Kannan and K. Kalaiselvi, "Power Quality and Stability Improvement in Wind Power System using STATCOM", International Conference and Exhibition on Green Energy and Sustainability for Aride regions & Mediterranean Countries, 2009.
8. Alexander Kusko and Mart C. Thomson, "Power quality in electrical systems", Tata Mc. Graw Hill., New Delhi, 2010.
9. Gregory N.C. Ferguson "The cost and benefits of harmonic current reduction in low voltage distribution systems", Int. Jr. of Power Quality, Vol. 3, No. 5, pp. 45-51, May 2013.
10. Jonathan K. Piel & Daniel J. Carnovale, "Economic and electrical benefits of harmonic reduction methods in commercial facilities", Proc. Cutler Hammer, USA, Jul. 2004.
11. M. Aredes, J. Hafner, and K. Heumann, "3-phase four-wire shunt active filter control strategies," IEEE Trans. Power Electron., Vol. 12, No. 2, pp. 311–318, Mar. 1997.
12. C. J. Zhan, A. Arulampalam, and N. Jenkins, "Four-wire dynamic voltage restorer based on a three-dimensional voltage space vector PWM algorithm," IEEE. Trans. Power Electron., Vol. 18, No. 4, pp. 1093–1102, Jul. 2003.
13. N.Y. Dai, M.-C.Wong, andY.-D. Han, "A FPGA-based generalized pulse width modulator for three-leg center-split and four-leg voltage source inverter," IEEE Trans. Power Electron., Vol. 23, No. 3, pp. 1472–1484, May 2008.
14. H.L. Jou, J.-C. Wu, K.-D. Wu, W.-J. Chiang, and Y.-H. Chen, "Analysis of zig-zag transformer applying in the three-phase four-wire distribution power system," IEEE Trans. Power Del., Vol. 20, No. 2, pp. 1168–1173, Apr. 2005.
15. P. Sanchis, A. Ursua, E. Gubia, J. Lopez, and L. Marroyo, "Control of three-phase stand-alone photovoltaic systems with unbalanced loads," Proc. IEEE ISIE, pp. 633–638, 2005.
16. G. Kamath, N. Mohan, and V. D. Albertson, "Hardware implementation of a novel, reduced rating active filter for 3-phase, 4-wire loads," Proc. IEEE APEC, pp. 984–989, 1995.
17. S. Choi and M. Jang, "Analysis and control of a single-phase-inverter zigzag-transformer hybrid neutral-current suppressor in three-phase four wire systems," IEEE Trans. Ind. Electron., Vol. 54, No. 4, pp. 2201–2208, Aug. 2007.
18. S.Kim and P.N. Enjeti, "A new hybrid active power filter (APF) topology," IEEE Trans. Power Electron., Vol. 17, No. 1, pp. 48–54, Jan. 2002.
19. G. Casaravilla, G. Eirea, G. Barbat, J. Inda, and F. Chiaramello, "Selective active filtering for four-wire loads: Control and balance of split capacitor voltages," Proc. IEEE PESC, pp. 4636–4642, 2008.
20. N.Y. Dai, M.C. Wong, and Y.-D. Han, "Application of a three-level NPC inverter as a three-phase four-wire power quality compensator by generalized 3D SVM," IEEE Trans. Power Electron., Vol. 21, No. 2, pp. 440–449, Mar. 2006.