http://www.jctjournals.com ISSN(ONLINE):2278 – 3814

Volume-10, Issue-06,June, 2021
JOURNAL OF COMPUTING TECHNOLOGIES (JCT)
International Journal
Page Number: 01-06

# PERFORMANCE ANALYSIS OF SHUNT APF ON LOW VOLTAGE 3P4W SYSTEM

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***Abstract-*** **Power distribution systems should ideally be required to deliver an unbroken supply of energy at smooth sinusoidal voltage at a restricted magnitude level and frequency to their consumers. However, power systems, particularly distribution networks, contain varying nonlinear loads that have a major impact on the quality of electricity provided. As a result of the nonlinear loads, the purity of the supply waveform is compromised. As a result, a plethora of power quality concerns arise. While power outages occur on all electrical networks, the sensitivity of today's advanced electronic devices makes them more vulnerable to power supply quality. An impact voltage spike has the potential to damage expensive components. Voltage sags/swells, flicker, harmonic distortion, impulse transients, and interruptions are all examples of power quality issues. This paper focuses on the application of APLC to reduce current harmonics in a three phase four wire system as well as also mitigate neutral current due to unbalanced system. To validate the results, the proposed model is simulated in MATLAB. The result illustrates how the proposed system operates.**

***Keywords*— EPQ, PQ, PCC, Harmonics, Filter, APLC etc…**

## I. INTRODUCTION

The Electrical engineers are often concerned with technology, transmission, distribution, and application of electrical power. The distribution device is a key link between the creation and use of electrical energy at rated amplitude and frequency, which shows electrical power quality (EPQ) [1]. EPQ is frequently utilized to specify voltage as well as modern-day satisfaction, service dependability, and energy delivery fineness, among other things. Poor power quality resources are classified into two types: (i) non-linear loads, electric components, and equipments; (ii) Transmission and distribution structural subsystems. Power line disruptions, such as impulses, notches, voltage sags / swell, voltage and contemporary imbalance, interruption, and harmonic distortions, cause exceptional deterioration of electrical power [2].

The electric power pleasant has evolved into an important component of the power distribution system. Harmonics are the major cause of the distribution machine's poor energy great. Harmonics are described qualitatively as sinusoidal waveforms with frequencies that are multiples of the power line frequency. The time period harmonic is often employed in electrical device engineering to explain distortion in voltage or current waveforms [3]. The fundamental frequency of the energy line is 50 or 60 hertz. If the fundamental frequency is 50 hertz, the fifth harmonic is 250 hertz; the seventh harmonic is 350 hertz, and so on.

The major source of harmonic-related problems is nonlinear loads. All electrical loads are non-linear and produce harmonics within the energy device. These non-linear loads extract the most effective short pulses of current from the delivery network and mix them with the source impedance, resulting in deliver voltage distortion [4]. Current power electronics provide an appropriate architecture to reduce power best problems [5]. The alternating current power source serves only linear and non-linear loads. The major sources of harmonics in the power system are non-linear loads such as energy converters and steady state drives that employ high-speed switches [6]. Harmonics in the machine cause a variety of undesirable issues, including prolonged heating in transformers, low power issues, torque pulsation in automobiles, overvoltage by resonance, and harmonic voltage drop across the community impedance, poor utilization of distribution plant, and effects on different loads connected at the same factor of commonplace Coupling (PCC).

Historically, passive filters were employed to correct for harmonic distortion inside distribution devices. Passive filters are made up of inductive and capacitive components that are adjusted to control harmonics. The passive filter out is shunt-connected to the distribution device and is adjusted to provide low impedance to a certain harmonic modern. However, it has long been noticed that the passive filter isn't always often utilized for low voltage or medium-voltage packages due to complexity and reliability issues. It also inherits numerous flaws, such as ageing and tuning issues, resonance that affects the stability of the electrical distribution systems, being bulky in size, and extra fixed reimbursement [7]. Specific configurations of Static VAR Compensators (SVCs) have been developed to address these issues.

Unfortunately, some SVC creates lower-order harmonics, and the reaction time of the SVC device might be too long for fast-fluctuating loads. Recently, Active Power Filters (APFs) or Active Power-Line Conditioners (APLCs) have been designed to compensate for harmonics and reactive energy at the same time [8]. The APLC topology can be linked in series, shunt, or a combination of the two (unified strength acceptable conditioners), as well as hybrid topologies [9-11].

## II.HARMONICS IN POWER SYSTEM

Various standards and recommendations that specify the magnitudes of harmonic currents and voltages have been created. The Comite Europeen de Normalisation Electrotechnique (CENELEC), the International Electro-technical Commission (IEC), and the Institute of Electrical and Electronics Engineers (IEEE) all establish voltage limitations at various harmonic frequencies of the utility frequency [13]. In 1983, the IEEE Working Group published a reference on harmonic sources and their impact on the electric power system. There is a lot of work in the IEEE-Power Engineering Society and the IEEE-Industry Applications Society to identify harmonic impacts. These associations and institutes establish harmonic standards [14]. T.C.Shuter examined and reported on harmonic levels in the American Electric Power Distribution System (three classes of distribution circuits: residential, commercial, and industrial) [15]. “The Static Power Converter Committee of the Industry Applications Society recognised the harmonic related problems and began work on a standard that would give guidelines to users and engineer-architects in the application of static power converter drives and other uses on electric power systems that contained capacitors,” Christopher reported. “IEEE 519-1981, IEEE Guide for Harmonic Control and Reactive Compensation of Static Power Converters” [16] was the outcome. In the cement, steel, and carbon sectors, Joseph highlighted harmonics-causes, effects, measurements, and analysis using specific systems [17]. Alexander E. Emanuel conducted a review of harmonic voltages and currents at the consumer point of industrial, commercial, and residential applications [18]. When voltage and/or currents are distorted and/or imbalanced, an IEEE working committee established definitions for power terms in 1996 that are practical and effective. It also recommends definitions for quantifiable values that may be used to determine the degree of distortion and imbalance [19]. As a theoretical concept, Eric J. Davis reported harmonic pollution metering. He argued for the “Toll Road” idea, which forces each customer to pay based on the amount of stress (use) his equipment produces to the mitigation equipment [20]. Under IEEE Standard 1459-2000, Jacques explored the notion of apparent power in single-phase sinusoidal and unbalanced three-phase scenarios. In this context, power factor is defined as the ratio of real active power to perceived power in a power system [21]. Salvador became aware of IEEE Standard 1459. It introduces new definitions for measuring electric power values in sinusoidal, non-sinusoidal, balanced, and unbalanced circumstances [22]. Predrag presented on power component estimation for wide-range frequency variations using IEEE Standard 1459–2010. This statement specifies the use of an adaptive phase shifter, a cascaded integrator–comb filter, a finite-impulse-response comb filter, and an algorithm [23]. Yao Xiao described the harmonic summation technique in the power system for the standard IEC / TR 61000-3-6 [24]. The IEEE 1459 standard is intended to evaluate the performance of contemporary equipment or to develop and build the next generation of energy and power quantification instruments.

## III.FILTERS IN POWER SYSTEM

Due Harmonic mitigation methods are broadly classified into two types: those directed at the harmonic source and those aimed at the harmonic transmission path. In terms of the former, electrical device design should be improved in order to achieve the aim of producing fewer harmonic. Because harmonics generated by these power electronic devices account for a significant proportion, multi-phase rectifier and pulse width modulation rectifier techniques are frequently utilized in current power electronic equipment. However, this method is limited to current devices in distribution networks and is ineffective against additional forms of harmonic sources. To solve this limitation, it appears that the installation of harmonic correction devices along the transmission line is required. Based on the harmonic mitigation techniques, there are two primary types of harmonic compensation devices: classic passive power filters (PPFs) and active power filters (APFs).

### A. Mitigation by Passive Power Filter

Based on the L-C resonance characteristics, the shunt branch of passive power filters can exhibit low impedance around the resonant frequency, for example, when the LC branch impedance is 0. As a result, passive power filters tuned at a specific frequency can absorb the corresponding harmonics close to the resonant frequency by acting as low impedance. L-C passive filters are frequently utilized to provide harmonic suppression and load power factor enhancement. Passive power filters are classified into two types based on their structure: tuned filters and high-pass filters.

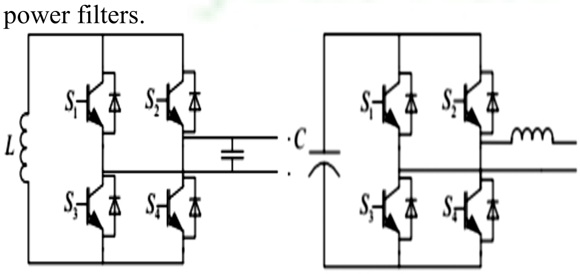
Although PPFs offer numerous advantages, such as design simplicity, cheap cost and high efficiency, no need for control connections, and ease of maintenance, among others, there are still several disadvantages in actual design and applications.

- PPFs can only reduce particular harmonics since they are typically adjusted at specific frequencies. As a result, additional devices are required to accommodate distinct harmonics.
- Harmonic suppression performance is heavily influenced by the characteristics of the passive components and grid impedances. Furthermore, if the frequency of the system harmonics varies, the efficiency of current harmonic suppression devices will be diminished.
- Due to the presence of PPFs and grid impedances, series or parallel resonance may arise. This will have a negative influence on distribution systems.
- When harmonic currents grow significantly, PPFs may get overloaded or even destroyed.

I. n addition to the limitations listed above, PPFs have enormous dimensions and a high weight, which will undoubtedly limit their broad use in current distribution networks. In terms of the influence of system harmonics and impedances, APFs are more versatile than PPFs. APFs have also become one of the most successful ways of suppressing harmonics and eliminating distortion in voltage and current waveforms due to their distinct benefits over standard PPFs, such as no risk of resonance and the realization of dynamic compensation.

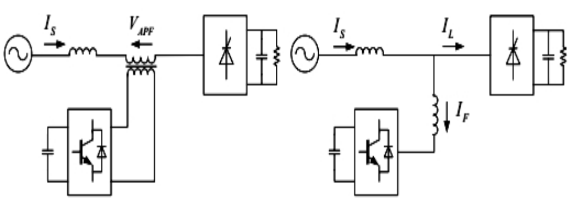
**B.Mitigation by Active Power Filter**

APFs, unlike their passive counterparts, contain energy storage elements at the DC link of inverters, which are typically DC inductors or DC capacitors. As a result, the filters can be classified as current source inverter based APFs (Figure 1.1 (a)) or voltage source inverter based APFs (Figure 1.1 (b)). There are single-phase APFs and three-phase APFs depending on the application. APFs are generally classed as MV filters or LV filters based on the voltage level. APFs are classified into two types based on their topology: series active power filters and shunt active power filters.




(a) (b)

**Fig 1: (a) CSI Based APF (b) VSI Based APF**




The series APF is connected in series with the grid via a matching transformer, as shown in Figure 2 (a). Based on the extracted harmonic current ISh from the detected grid current IS, a compensation voltage VAPF can be generated across the primary side of the transformer. The compensation voltage VAPF is equal to -GISh, where G is the grid current feedback gain. The usual architecture of a shunt APF is seen in Figure 2 (b).

**Fig 2: (a) Series APF (b) Shunt APF**

To accomplish harmonic compensation, the harmonic component ILh is extracted from the measured load current IL, and the shunt APF is regulated to create a current component IF equal to -ILh. Shunts APFs have been more frequently employed in many contexts than series APFs. Because of its benefit in flexible control realization, APFs may be used to correct only harmonics, reactive power, three-phase unbalanced currents, or all of the above instances.

Harmonic mitigation using APFs, as mentioned in the preceding section, can solve the drawbacks of PPFs; nevertheless, due to the voltage/current ratings of power electronic switches, extremely high capacity is difficult to accomplish. As a result, the cost will climb significantly as capacity increases. So, in addition to typical PPFs, pure APFs may be expanded to hybrid active power filters, which can inherit the benefits of both PPFs and APFs while avoiding the downsides as much as feasible. In addition to hybrid filters, a recent trend in APF research is focusing on innovative inverter topologies.

## IV.APLC FOR 3PHASE 4 WIRE SYSTEM

The active power line conditioner was created to provide harmonic correction, reactive power, and voltage balancing in alternating current power networks. The APLC is built using a PWM-based current source or voltage source inverter. The current supply inverter operates as a non-sinusoidal current source to meet the nonlinear load's harmonic current requirement. When used as a current-controlled voltage source, the voltage source inverter is much more convenient for active power line conditioner implementation. Although CSI and VSI are established terminology, we prefer to refer to these setups as CSI and VSI for consistency. As illustrated in Figure 3, it employs a typical three-leg inverter where the dc-link capacitor is divided and the centre of the electrical device is linked to the fourth wire to provide the return path for the neutral current. These three-phase four-wire APLC systems are used in a variety of industries to correct for current harmonics by injecting an equal but opposite harmonic compensating current.

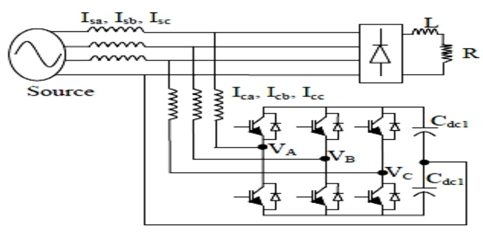


**Fig 3: Three-phase 4-wire shunt APLC system with 3-leg inverter**

## V. SIMULATION & RESULT

The entire SIMULINK model of the three phase four wire power system with suggested APLC is shown in Figure 4. In this case, APLC is utilized to compensate for the distorted wave produced by the star-connected non-linear load. For application, the circuit breaker is set at 0.2 seconds. When the breaker trips then compensatory current start to going from the VSI to the grid to compensate the neutral current.

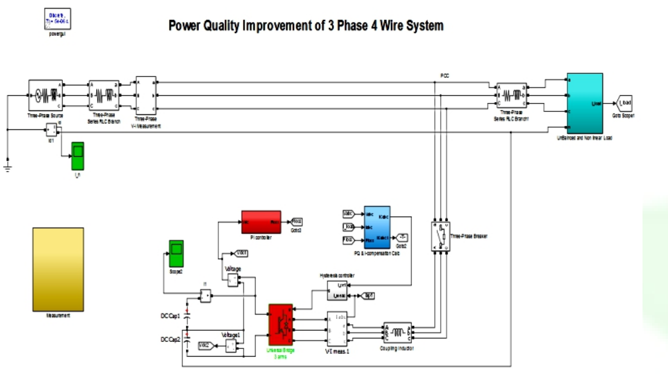



**Fig 4: SIMULINK Model of Proposed 3P4W Power System**

Table I shows the parameters utilized for simulation.

**Table I: Parameter used in SIMULATION of proposed APLC**

| Parameter | Value |
|---|---|
| Grid Voltage | 400V |
| Line parameter | Rs=10-6Ω, Ls=10-6H, |
| Y connected Load Parameter | RL= 10Ω, LL=0.1 H |
| DC Link Capacitor | 400µF |

Figure 5 shows the grid side voltage of the proposed low voltage grid. This shows the grid voltage is throughout constant and it is equal to 300 volt.

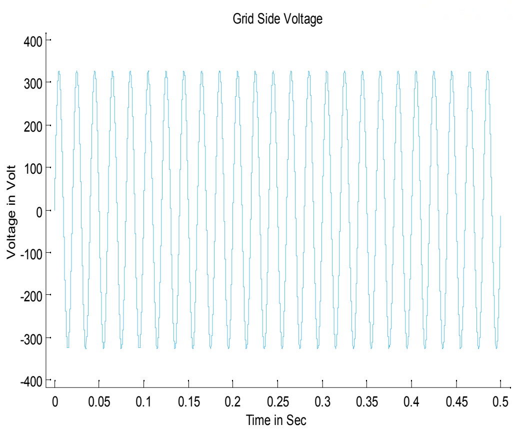



**Fig 5: Grid Side line voltage for single phase system**

Figure 6 shows grid side current of the proposed low voltage grid. In this figure it is clearly shown the variation of the proposed system. It shows the effective work of the proposed APLC.

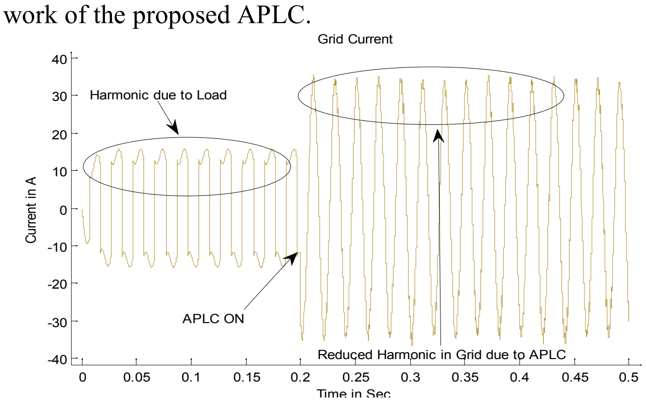



**Fig 6: Grid side current variation of the proposed APLC**

Here from the figure it is clearly shows after connection of APLC at 0.2 sec the harmonic contents of the grid current get vanished. Figure 7 shows the neutral current generated in the three phase four wire system. After circuit breaker on the neutral current also get reduced to zero.

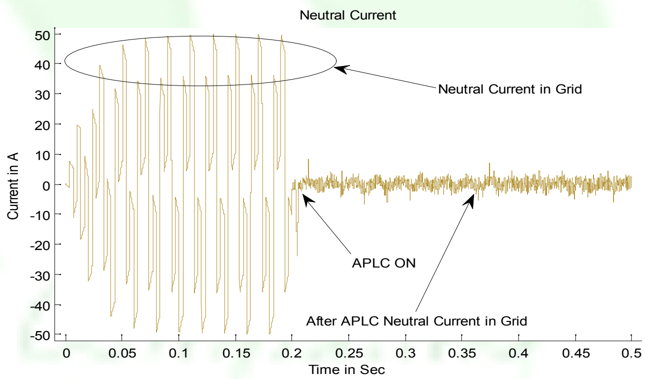



**Fig 7: Neutral current of the system**

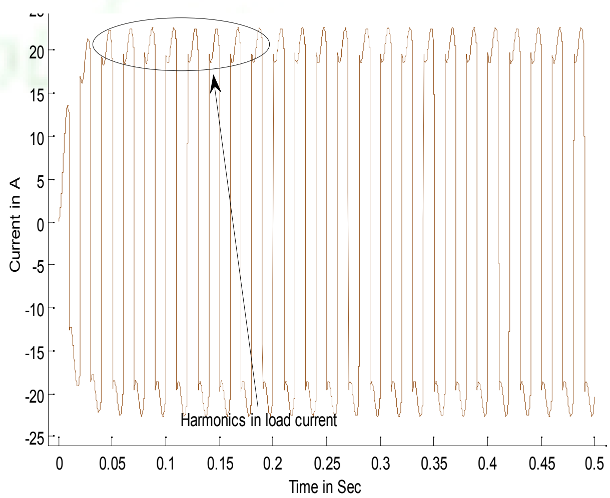



**Fig 8: Load current of the nonlinear load**

Figure 8 shows the load current of the system. Figure 9 shows the compensation current. This current is generated by the proposed system.

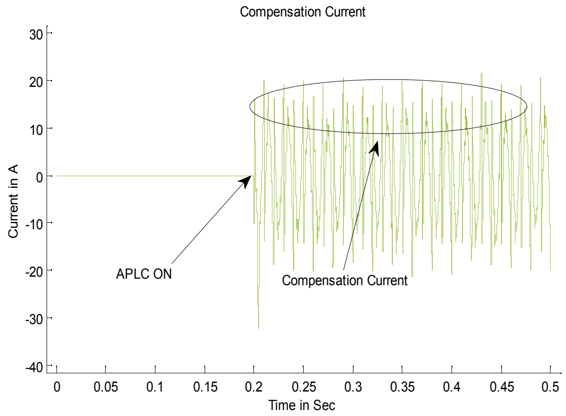



**Fig 9: Compensation current of the proposed controller of the proposed APLC**

Figure 10 and 11 shows the FFT analysis of the grid current before and after compensation by the proposed APLC. From the figure 5.9 it is shown that the current harmonic is present in the power line due to non-linear load is 42.8%. but due to application of the proposed APLC it can reduced and the current harmonics found is 3.99%.

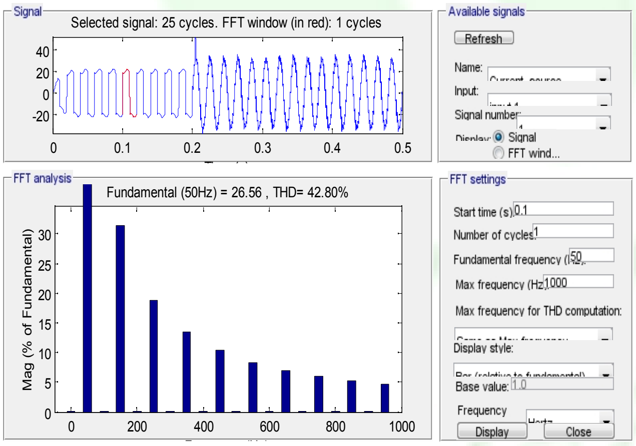



**Fig 10: FFT Analysis of the grid current without proposed APLC**

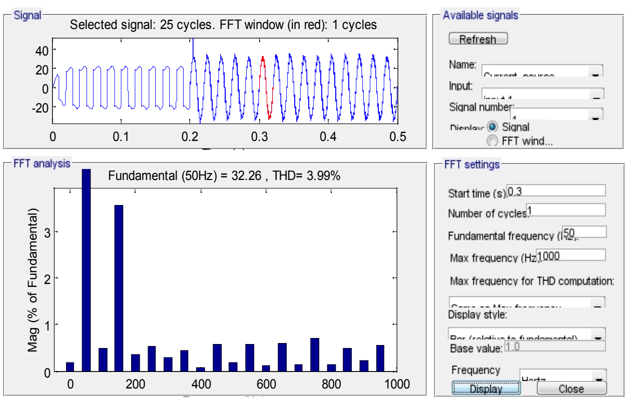



**Fig 11: FFT Analysis of Grid Current after application of proposed APLC**

## IV. CONCLUSION

Power distribution systems should ideally be required to deliver an unbroken supply of energy at smooth sinusoidal voltage at a restricted magnitude level and frequency to their consumers. However, power systems, particularly distribution networks, contain varying nonlinear loads that have a major impact on the quality of electricity provided. As a result of the nonlinear loads, the purity of the supply waveform is compromised. As a result, a plethora of power quality concerns arise. While power outages occur on all electrical networks, the sensitivity of today's advanced electronic devices makes them more vulnerable to power supply quality. This paper focuses on the application of APLC to reduce current harmonics in a three phase four wire power system as well as it also mitigate the neutral current due to unbalanced system. To validate the results, the proposed model is simulated in MATLAB. The result illustrates how the proposed system operates.

## REFERENCES


1. Arindam Ghosh, Gerard Ledwich “Power Quality enhancement using Custom Power Devices” Springer, First Indian reprint- 2009
2. E.Wald F.Fuchs, Mohammad A.S.Masoum “Power Quality in Power Systems and Electrical Machines” Academic press is an imprint of Elsevier, 2008
3. Nitin Gupta, S. P. Singh and R. C. Bansal “A Digital Signal Processor Based Performance Evaluation of Three phase Four- wire Shunt Active Filter for Harmonic Elimination, Reactive Power Compensation, and Balancing of Nonlinear Loads under Non-ideal Mains Voltages” Electric Power Components and Systems, Vol. 40, No. 10, pp. 1119–1148, July-2012
4. Naimish Zaveri and Ajitsinh Chudasama “Control strategies for harmonic mitigation and power factor correction using shunt active filter under various source voltage conditions” Electrical Power and Energy Systems, Vol. 42, No. 1, pp. 661–671, Nov-2012
5. Ray Arnold “Solutions to the power quality problem” Power Engineering Journal, Vol.15, No.2, pp.65-73, April-2001
6. Hirofumi Akagi “Active Harmonic Filters” Proceedings of the IEEE, Vol. 93, No. 12, pp.2128-2141, Dec-2005.
7. F.Z.Peng, H.Akagi, A.Nabae “A Novel Harmonic Power Filter”PESC, pp. 1151-1158, April-1988.
8. Karuppanan P and Kamala Kanta Mahapatra “PI, PID and Fuzzy Logic Controlled Cascaded Voltage Source Inverter based Active Filter for Power Line

Conditioners" WSEAS Transaction on Power Systems, Vol.6, No.4, pp.100-109, Oct- 2011.
9. Yi Tang, Poh Chiang Loh, Peng Wang, Fook Hoong Choo, Feng Gao, and Frede Blaabjerg "Generalized Design of High Performance Shunt Active Power Filter With Output LCL Filter" IEEE Trans on Industrial Electronics, Vol. 59, No. 3, pp. 1443-1452, March-2012.
10. M.A.Hannan and Azah Mohamed "PSCAD/EMTDC Simulation of Unified Series-Shunt Compensator for Power Quality Improvement" IEEE Trans on Power Delivery, Vol. 20,No. 2, pp.1650-1656, April-2005
11. W.M.Grady, M.J.Samotyj and A.H.Noyola "Survey of Active Power Line Conditioning Methodologies" IEEE Trans on Power Delivery, Vol.5, No.3, pp. 1536-1542, July-1990.
12. S. Bhattacharyya, S. Cobben, P. Ribeiro and W. Kling "Harmonic emission limits and responsibilities at a point of connection" IET Gener. Transm. Distrib., Vol. 6, No. 3, pp. 256–264, March-2012
13. Francisco C.De La Rosa "Harmonics and Power Systems" CRC press, First Indian reprint-2010
14. IEEE Working Group on Power System Harmonics "Power System Harmonics: An Overview" IEEE Power Engineering Review, Vol.3, No.8, pp. 27-28, Aug-1983
15. T.C.Shuter, H.T.Vollkommer, Jr.T.L.Kirkpatrick "Survey of Harmonic Levels on the American Electric Power Distribution System" IEEE Trans on Power Delivery, Vol. 4, No. 4, pp.2204-2213, Oct-1989.
16. Christopher K. Duffey and Ray. P. Stratford "Update of Harmonic Standard IEEE-519: IEEE Recommended Practices and Requirements for Harmonic Control in Electric Power Systems" IEEE Trans on Industrial Applications, Vol.25, No.6, pp.1025-1034, Nov/Dec-1989.
17. Joseph S. Subjak., JR and John S. Mcquilkin "Harmonics - Causes, Effects, Measurements, and Analysis: An Update" IEEE Trans on Industrial Applications, Vol.26, No.6, pp.1034-1042, Nov/Dec-1990.
18. Alexander E. Emanuel, John A. Orr, David Cyganski and Edward M. Gulachenski, "A Survey of Harmonic Voltages and Currents at the Customer's Bus" IEEE Transactions on Power Delivery, Vol. 8, No. 1, pp.411-421, Jan-1993.
19. IEEE Working group on Non-sinusoidal Situations "Practical Definitions for Powers in Systems with Non sinusoidal Waveforms and Unbalanced Loads: A Discussion" IEEE Transactions on Power Delivery, Vol. 11, No. 1, pp.79-87, Jan- 1996
20. Eric J. Davis, Alexander E. Emanuel, and David J. Pileggi "Harmonic Pollution Metering: Theoretical Considerations" IEEE Trans on Power Delivery, Vol. 15, No. 1, pp.19-23, Jan- 2000
21. Jacques L. Willems, Jozef A. Ghijselen, and Alexander E. Emanuel "The Apparent Power Concept and the IEEE Standard 1459-2000" IEEE Trans on Power Delivery, Vol. 20, No. 2, pp.876-884, April-2005
22. Salvador Orts-Grau, Jose Carlos Alfonso-Gil, Francisco J. Gimeno-Sales, and Salvador Segui-Chilet "New Resolution of the Unbalance Power According to Std. 1459" IEEE Trans on Power Delivery, Vol.25, No.1, pp. 341-350, Jan-2010.
23. Predrag D. Poljak, Miodrag D. Kusljevic and Josif J. Tomic "Power Components Estimation According to IEEE Standard 1459–2010 Under Wide- Range Frequency Deviations" IEEE Trans on Instrumentation and Measurement, Vol. 61, No. 3, pp.636-644, Mar-2012
24. Yao Xiao and Xavier Yang "Harmonic Summation and Assessment Based on Probability Distribution" IEEE Trans on Power Delivery, Vol. 27, No. 2, pp.1030-1032, April-2012
25. Muhammad H. Rashid "Power Electronics Handbook" Academic Press, An imprint of Elsevier (ISBN: 0-12-581650-2), 2001.