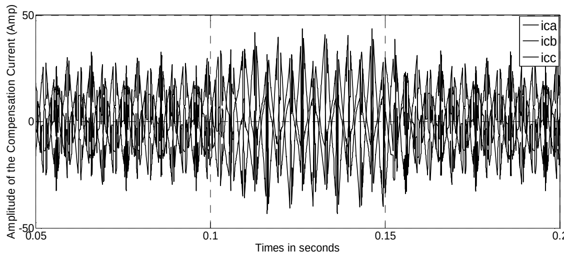
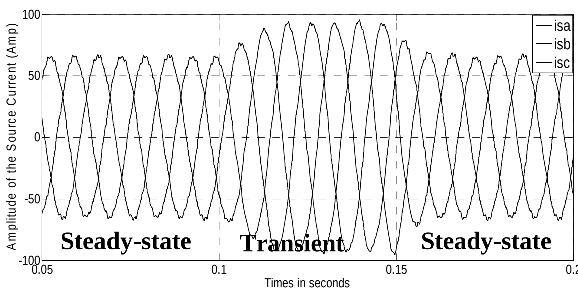


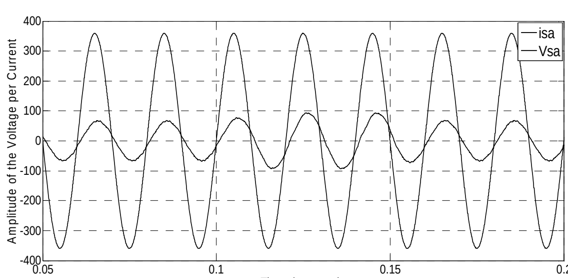
10 (d) Compensation current

Consequently current harmonics is achieved by injecting equal but opposite harmonic components at the PCC, there by cancelling the original distortion and improving the power quality on the connected power distributed system. The simulation result of source current after compensation is presented in Fig 10(e) that indicates the current is sinusoidal.



10 (e) Source current after active filter

The proposed APF system is achieved power factor correction that is shown in Fig 10(f). From the simulation we can realise a-phase voltage is in-phase with a-phase current.



10 (f) unit-power factors

The DC-bus capacitors voltage of the cascaded multilevel inverter is controlled by fuzzy logic controller. The fuzzy logic controller maintains the capacitors voltage with small ripple in steady and dynamic conditions that is shown in Fig 10(g); it serves as an energy storage element to supply a real power to operate three-phase cascaded voltage source inverter.

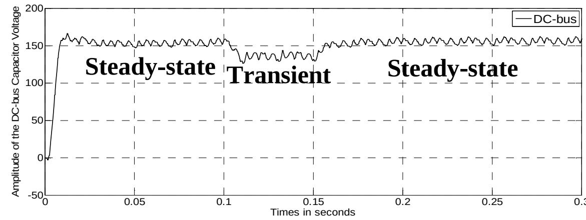


Fig 10 (g) DC-bus capacitor voltages

The Fast Fourier Transform (FFT) is used to measures the order of harmonics with the fundamental frequency 50 Hz at the source current. This order of the harmonics plotted using PI, PID and fuzzy logic-controller based cascaded active power filter systems in the supply current. The Fig 11 is plotter under FLC controller based cascaded active power system in steady state conditions.

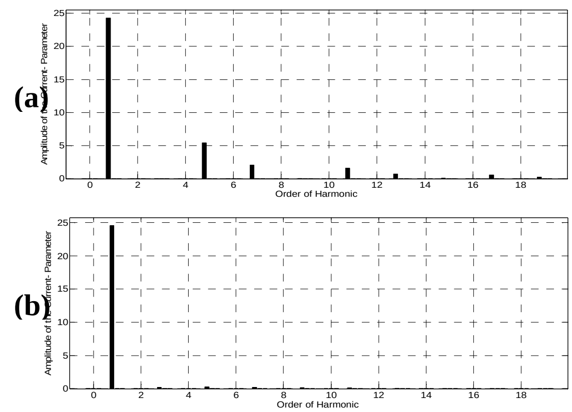


Fig 11 Order of harmonics (a) the source current without active filter (THD=25.38 %), (d)FLC based cascaded APF(THD=2.53 %)

The total harmonic distortion (THD) measured from the source current on the distribution side. The PI, PID and fuzzy logic controller based cascaded compensator filter made linear source current to the supply. The total harmonic distortion measured and compared that is presented in Table 2.

Table 2 THD measured without APF and with APF

THD conditions	Source Current(I_S) without APF	Source Current(I_S) with APF		
		PI controller	PID controller	Fuzzy logic controller
Steady state	25.38%	2.61%	2.58%	2.53%
Transient	25.32%	2.59%	2.59%	2.48%
Power factor	0.8772	0.9733	0.9721	0.9829

The simulation is done various non-linear load conditions. The PI or PID or fuzzy logic control based compensating cascaded active filter made balance responsibility even the system is non-linear load. FFT analysis of the active power filter brings the THD of the source current less than 5% into adopted with IEEE 519-1992 and IEC 61000-3 standards under non-linear load conditions.

5 Conclusions

This paper has been shown that the cascade multilevel inverter based active filter is suitable for power line conditioning in the power distribution network. The cascaded inverter provides lower costs, higher performance and higher efficiency than the traditional PWM-inverter for power line conditioning applications. A low pass filter conjunction with PI or PID or fuzzy logic control schemes has been presented for controlling the DC side capacitor voltage of the cascaded inverter and estimate the required peak reference current. The proposed PI, PID and fuzzy logic controller based APLC system is validated through extensive simulation and compared under steady state and transient condition with different non-linear loads. These simulation results reveal that the cascaded active power filter effetely filtered the current harmonics and compensated reactive volt amperes power. A comparative assessment of these three different controllers is done. The measured total harmonic distortion of the source currents is compliance with IEEE 519-1992 and IEC 61000-3 harmonic standards.

References:

[1] Hirofumi Akagi, Akira Nabae and Satoshi Atoh ‘Control Strategy of Active Power Filters Using Multiple Voltage-Source PWM Converters’ *IEEE Trans on Industry Appl*, Vol.IA-22, No.3, June-1986, pp.460-465.

[2] E. H. Watanabe, R. M. Stephan and M. Aredes ‘New Concepts of Instantaneous Active and Reactive Powers in Electrical Systems with Generic Loads’ *IEEE Trans on Power Delivery,* Vol.8, No.2, 1993, pp.697-703.

[3] Fang Zheng Peng, John W. McKeever, and Donald J. Adams ‘A Power Line Conditioner Using Cascade Multilevel Inverters for Distribution Systems’ *IEEE Trans on Industry Appl,* Vol.34, No.6, 1998, pp. 1293-98.

[4] S. A. Gonzalez, R. Garcia-Retegui, and M. Benedetti ‘Harmonic computation technique suitable for active power filters’ *IEEE Trans on Ind. Electron*, vol.54, No.5,2007,pp. 2791–2796

[5] Fang Zheng Peng & Jih-Sheng Lai, ‘Generalized Instantaneous Reactive Power Theory for Three-Phase Power Systems’, *IEEE Trans. on Instrument and Measurement.* Vol.45, No.1, 1996, pp.293-297.

[6] 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 Industry Appl*, Vol.25, No.6, 1989, pp.1025-1034.

[7] Joseph S. Subjak, JR and John S. Mcquilkin ‘Harmonics - Causes, Effects, Measurements, and Analysis: An Update’ *IEEE Trans on Industry Appl*, Vol.26, No.6, 1990, pp.1034-1042.

[8] 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, 1993, pp.411-421.

[9] Hirofumi Akagi ‘Active Harmonic Filters’ *Proceedings of the IEEE*, Vol. 93, No. 12, 2005, pp.2128-2141

[10] Bhim Singh, Kamal Al-Haddad & Ambrish Chandra ‘A Review of Active Filter for Power Quality Improvements’ *IEEE Trans on Industrial Electronics*, Vol.46, No.5, Oct-1999, pp.960-970

[11] Shailendra Kumar Jain, Pramod Agarwal and H. O. Gupta ‘A Control Algorithm for Compensation of Customer-Generated Harmonics and Reactive Power’ IEEE Trans.Power.Delivery, Vol.19, No.1, 2004, pp.357-366.

[12] W.M.Grady, M.J.Samotyj, A.H.Noyola ‘Survey of Active Power Line Conditioning Methodologies’ *IEEE Trans on Power Delivery*, Vol.5, No.3, 1990, pp.1536-1542

[13] M.El-Habrouk, M.K.Darwish and PMehta ‘Active power filters: A review’ *IEE Proc. Elertr. Power Appl,* Vol. 147, No. 5, 2000, pp.403-413

[14] Fermin Barrero, Salvador Martinez, Fernando Yeves and Pedro M. Martinez ‘Active Power Filters for Line Conditioning: A Critical Evaluation’ *IEEE Trans on Power Delivery*, Vol.15, No.1,2000, pp.319-325

[15] Zainal Salam, Tan Perng Cheng and Awang Jusoh ‘Harmonics Mitigation Using Active

Power Filter: A Technological Review' *ELEKTRIKA*, Vol. 8, No. 2, 2006, pp.17-26

[16] E.E. EL-Kholy, A. EL-Sabbe, A. El-Hefnawy, Hamdy M. Mharous 'Three-phase active power filter based on current controlled voltage source inverter' *Electric Power Systems Research*, 28, 2006, 537–547.

[17] Masatoshi Takeda, Kazuo Ikeda & Yoshiharu Tominaga "Harmonic Current Compensation with Active Filter"-*IEEE-IAS*,1987,pp. 808-815,

[18] Helder J. Azevedo, Jose M. Ferreira, Antonio P. Martins, Adriano S. Carvalho 'An Active Power Filter with Direct Current Control for Power Quality Conditioning' *Electric Power Components and Systems*, 36(6), 2008, pp.587-601.

[19] Salem Rahmani, Nassar Mendalek and Kamal Al-Haddad 'Experimental Design of a Nonlinear Control Technique for Three-Phase Shunt Active Power Filter' *IEEE Trans on Industrial Electronics*, Vol.57, No.10, 2010, pp.3364-3375.

[20] S.J.Huang and J.C.Wu 'Design and operation of cascaded active power filters for the reduction of harmonic distortions in a power System' *IEE Proc.Gener. Transm. Distrib*, Vol.146, No.2, March 1999, pp. 193-199

[21] Ahmed M. Massoud, Stephen J. Finney, Andrew J. Cruden, and Barry W. Williams 'Three-Phase, Three-Wire, Five-Level Cascaded Shunt Active Filter for Power Conditioning, Using Two Different Space Vector Modulation Techniques' *IEEE Trans on Power Delivery* Vol.22, No.4, 2007,pp.2349-61,

[22] Rajesh Gupta, Arindam Ghosh and Avinash Joshi 'Switching Characterization of Cascaded Multilevel-Inverter-Controlled Systems' *IEEE Trans on Industrial Electronics*, Vol.55, No.3, March-2008, pp 1047-1058,

[23] R. El Shatshat, M. Kazerani and M.M.A. Salama "Power quality improvement in 3-phase 3-wire distribution systems using modular active power filter" *Electric Power Systems Research*, 61, 2002, pp.185–194

[24] Murat Kale and Engin O zdemir 'Harmonic and reactive power compensation with shunt active power filter under non-ideal mains voltage' Electric Power Systems Research 74,2005, pp.363–370

[25] Abdelmadjid Chaoui, Jean Paul Gaubert, Fateh Krim, Gerard Champenois 'PI Controlled Three-phase Shunt Active Power Filter for Power Quality Improvement' *Electric Power Components and Systems*, 35, 2007, pp.1331–1344

[26] S.K. Jain, P. Agrawal and H.O. Gupta 'Fuzzy logic controlled shunt active power filter for power quality improvement' *IEE proc.electr.power.appl*,Vol 149, No.5, Sept-2002, pp.317-328

[27] S. Saad, L. Zellouma 'Fuzzy logic controller for three-level shunt active filter compensating harmonics and reactive power' *Electric Power Systems Research*, May-2009, pp.1337–1341

[28] V. S. C. Raviraj and P. C. Sen 'Comparative Study of Proportional–Integral, Sliding Mode, and Fuzzy Logic Controllers for Power Converters' *IEEE Tran Industry* Vol 33, No. 2, 1997, pp.518-524.

[29] Marcelo Godoy Simoes, Bimal K. Bose, and Ronald J. Spiegel 'Design and Performance Evaluation of a Fuzzy-Logic-Based Variable-Speed Wind Generation System' *IEEE Trans on Industry Applications*, Vol.33, No.4, 1997, pp.460-465.

[30] G.K. Singh, A.K. Singh and R. Mitra 'A simple fuzzy logic based robust active power filter for harmonics minimization under random load variation' *Electric Power Systems Research,* 77, 2007, pp.1101–1111

[31] C. N. Bhende, S. Mishra and S. K. Jain 'TS-Fuzzy-Controlled Active Power Filter for Load Compensation' *IEEE Trans on Power Delivery*, Vol.21,No.3, 2006, pp.1459-1465

[32] P.Karuppanan, S. K. Pattnaik and K.K. Mahapatra 'Fuzzy Logic Controller Based Active Power Line Conditioners for Compensating Peactive power and Harmonics' *ICTACT Journals on Soft Computing*, Vol.1, No.1, July-2010, pp.49-53.

[33] Keith Corzine and Yakov Familiant 'A New Cascaded Multilevel H-Bridge Drive' *IEEE Trans on power electronics*, Vol.17, No.1, Jan-2002, pp 125-131.

[34] Mariusz Malinowkski, K.Gopakumar, Jose Rodriguez and Marcelo A.Perez 'A Survey on Cascaded Multilevel Inverters' *IEEE Trans on Industrial Electronics*, Vol.57, No7, July-2010, pp. 2197-2205.

[35] Zhong Du, Leon M. Tolbert, Burak Ozpineci, and John N. Chiasson 'Fundamental Frequency Switching Strategies of a Seven-Level Hybrid Cascaded H-Bridge Multilevel Inverter' *IEEE Trans on Industrial Electronics*, Vol.24, No1, Jan-2009,pp.25 – 33.