Middle-East Journal of Scientific Research 23 (7): 1461-1469, 2015
ISSN 1990-9233

DOI: 10.5829/idosi.mejsr.2015.23.07.22242

Harmonic Analysis and Simulation of Shunt Activefilter for Three Phase Induction Motorpower Backup Systemusing Matlab/Simulink

T.D. Sudhakar and H. Prasad

Department of Electrical and Electronics Engineering,
St. Joseph's College of Engineering, Chennai - 119, India

Abstract: Harmonic filtering by means of filters have become an essential part of every electrical system due to the advent of power electronic switching circuitry. Choice of correct filter with appropriate design methodology has become an issue of concern to engineers. In this regard active harmonic filter is the current trend towards improving power quality in a system affected by harmonics. This paper discusses the harmonic distortion levels of a three phase system feeding a motor load through a battery bank backup. Subsequently active harmonic filter is implemented using MATLAB/Simulink to mitigate source side current harmonics.

Key words: Harmonic components · Parameters of APF · Current harmonics · FFT analysis · Harmonic sources

INTRODUCTION

Modern day digital electronics and control equipments require high degree of precision for perfect operation and thus they cannot yield expected results with a system affected by harmonics. Harmonics and their impact on power systems were studied by many researchers around the world. Kuldeep Kumar Srivastava *et al* [1] presented the effects of harmonics on real time electrical systems and explained in detail the phenomenon of harmonics mitigation using active power filters. FZ Peng [2] elaborated on various harmonic sources and how they impact the power quality along with suggested mitigation techniques. A survey of sources of harmonics in industrial systems their impacts and feasible control techniques was presented by Ali. L. Massod and M.H. Haque [3]. The concept of harmonics as a power quality issue was dealt in detail by J. Grillage [4] and R.C. Dugan ET. Al [5] in their works on power quality. An in depth analysis of power system harmonics and their mitigation techniques was carried out by G.W. George in his work [6] and mathematical interpretation to the problem of harmonics by Russel Brown paved way for logical and systematic understanding of power system harmonics. Harmonics seriously impact the operating costs of a power system which is why they are considered with much importance. The influence of harmonics on cost function formulations for power system operation was discussed in detail by J. Linderset. Al. IEEE.

Task force on Industrial electronics studied the effects of harmonics on industrial systems and gave certain guidelines to maintain harmonics within acceptable levels. Recommendations on maximum permissible harmonic limits in systems and their control were laid down by IEEE. The basic concept is the filtering of unwanted frequency components from supply waveform either by LC tuning to create resonance or current compensation using custom power devices or both in case of hybrid power filters was discussed [1]. Traditionally used harmonic filters were of passive type which consisted of LC components which were based on the principle of harmonic filtering by means of creating electrical resonance corresponding to the frequency of the harmonic component to be filtered [2]. Passive harmonic filtering possesses some issues which affect the overall system performance. They are based on lumped LC components that are tuned to a single frequency and obviously particular order of harmonics thus there is a need of large number of tuned filters in order to eliminate a larger portion of harmonics. Bhonsle and Kelkar [7]

Corresponding Author: T.D. Sudhakar, Department of Electrical and Electronics Engineering, St. Joseph's College of Engineering, Chennai - 119, India.

conducted a harmonic pollution survey with laboratory computer systems and further the design and implementation of passive harmonic filters was simulated and analyzed. The recent trend is that active power filters are being looked upon as a viable alternative. The objective of the active filtering is to solve these problems in a dynamic way rather than using components whose rating is predetermined, along with a much-reduced rating of the necessary passive components. The idea of active filters is relatively old, but their practical development was made possible with the new developments in power electronics and control strategies as well as with reduction in cost of electronic components [3]. Depending on the problem nature, active filters can be implemented in three basic topologies as shunt type, series type, or a combination of shunt and series active filters (shunt-series type). Shunt active power filters compensate load current harmonics by injecting equal-but opposite harmonic compensating current [4]. In this case the shunt active power filter operates as a current source injecting the harmonic components generated by the load but phase-shifted by 180°. Series active power filters act as a voltage regulator and as a harmonic isolator between the nonlinear load and the utility system [6]. The various harmonic extraction methods used for the control of Active Power filters were discussed by K.L. Areerak *et al* [9] and the time domain technique based methods were dealt with in detail by Vedat Karsh *et al*. [10] in their research papers. Harmonic extraction is the most important part of active filtering. Proper choosing of the correct harmonic extraction method is the key to effective separation of harmonic components. Voltage Source Inverter or VSI is generally preferred due to its various advantages over traditional current source inverters. VSI is used to generate the compensation current for the active filter [9]. The operation of VSI is based on proper generation of gating pulses which is taken care by suitable PWM techniques which were discussed by Muhammad H. Rashid *et al.* [11]. Many simulations as well as experimental studies with active power filters were carried out by researchers across the globe with real time systems for performing harmonic analysis thereby evaluating the performance of the system under the influence of non – linear loads. Haran Farooq, Chengke Zhou *et al.* [12] presented the harmonic analysis of a distribution system using ETAP software with personal computers connected as non linear loads at load terminals. This analysis proved really useful to analyze the cumulative effect of harmonics in a particular distribution system as seen by the utility. Personal computers are the most common source of harmonic causing non linear loads in the customer site. Thus the mathematical analysis of harmonics caused by personal computers was done by Rana Abdul Jabbar Khan and Muhammad Akmal [13] in their research. Further the simulation study of harmonics caused by personal computers was done by Shwedi [14] and Ismail by analyzing the harmonics caused by personal computers in their university site. Active filters have been extensively discussed for systems involving a three phase ac supply. An analysis of harmonics in a real time system shall be considered as a valuable contribution in this regard. Of the methods of harmonic extraction discussed, synchronous reference frame theory and synchronous detection method are the most widely used inthree phase active filters. In this work, synchronous reference frame theory is used for reference current extraction. Here the three phase APF setup is implemented in a normal induction motor power backup system which feeds the motor load through a battery bank. The system taken for analysis is described as follows.

Test System: The system to be taken for consideration consists of a typical circuit which closely resembles the backup power circuit of a three phase ups including its battery and various power converters for catering the needs of various non – linear loads.All these motor loads require extensive converters and inverters to get their rated voltage as input. The input to the loads is through a battery bank setup while this battery is being charged by a battery charging circuit which consists of a rectifier. The battery bank discharges through the inverter to provide supply voltage to the motor. The inverter is a special type of inverter known as ZSI or Z source inverter. This is unique buck-boost feature to the inverter. The schematic of the system is given below in Figure 1 [15-20].

The various parameters pertaining to the system and the motor load are given in Tables 1 and 2. Table 1 gives the parameters of the battery charging circuit and various components involved in the circuitry.

Initially the battery will discharge providing voltage to the load. For study purpose, the battery discharges for a certain amount of time and then it is cut off from the load and then it is charged via the charging circuiti.e the converter. While this charging process happens, the source current drawn from the supply is analyzed for THD. As a second case, the battery is allowed to discharge continuously and as the charge drops after a

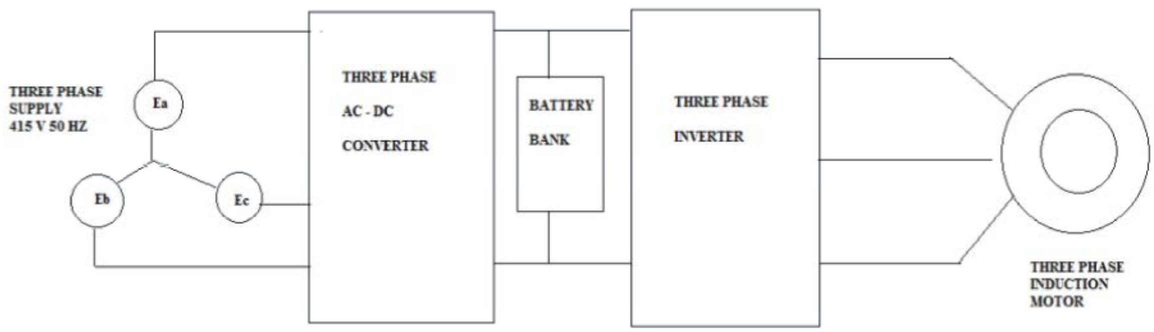

Fig. 1: Schematic of the System

Table 1: Circuit Parameters

Parameters	Values
Supply	415 V, 50 HZ AC
Converter Capacitor	1000uF
Cross arm inductor for ZSI	2.3mH
Cross arm Capacitor for ZSI	100uF
Battery	40 v, 1.5 Ah, Lithium ion type

Table 2: Load Specifications

Load Type	Simulation Component	Parameters
Three Phase Induction Motor	Asynchronous motor SI units	415 vph -ph, 50 Hz Torque constant 1.8

certain time of operation, the charging circuit is also switched ON. THD analysis is carried out for source current waveform for this setup also. The load specifications are given in the following Table 2.

Simulation and Results: The simulation of the above mentioned test system was carried out using MATLAB/ Simulink environment. The inverter hasMOSFET switches while the converter has diode switches. This setup charges a battery through a time controlled switch. The loads are connected to thebattery through another time controlled switch. The MATLAB simulation diagram of the entire setup is given in the following Figure 2.

Here there are two cases to be noted. In the first case initially the battery discharges and provides supply to the load. Then after some time (say 0.4s) the battery is disconnected from the load and it is charged by the charging circuit. The sourcecurrent is analyzed for harmonics using FFT analysis to find the THD. In the second case the battery isallowed to discharge for a certain amount of time (0.4s) after which the charging circuit is switched on but the loadsarenot disconnected from the battery. In this case also, THD analysis is performed for source side current waveformand the results are tabulated.The FFT analysis given in Figures 3 to7 (for both cases respectively). FFT analysis gives an idea of how various orders of harmonics are being distributed in a frequency spectrum. In simpler terms it gives the magnitude of harmonic current with respect to its corresponding harmonic frequency. Thus FFT analysis is an essential tool for harmonic analysis [21-24].

The FFT analyses show the increased magnitude of harmonic components which will cause certain mal effects on the system. The high level of THD indicates that the magnitude of harmonic components is very high and their totality in magnitude is even more than the required fundamental waveform. This is evident from the THD value above 100 %. Now in order to reduce this high level of distortion caused in the waveform due to harmonics, APF is implemented to filter the harmonics in the source current waveform. The Parameters of APF are given in the table below.

The MATLAB diagram of the system with APF is given as follows.

The FFT analysis is done after the implementation of filters for both case I and case II which is given from Figures 9 to 15 as follows.

The results tabulated in Table 4 and the same are compared and the performance of filter with regards to the mitigation of harmonics is analyzed.

Table 3: APF parameters

Parameters	Values
DC Source	100 V
Filter Inductor	2.5 mH
Filter Resistor	25 ohms
Carrier frequency for PWM	2000 Hz
'ωt' value for PLL	50 Hz
Extraction technique	Synchronous reference frame theory

Table 4: Results without and with Active Power Filters for both CASE I and CASE II

Harmonic Orders	Distortion in % Before Filtering			Distortion in % After Filtering		
Case I: Charging Circuit connected to battery without loads						
PHASE	A	B	C	A	B	C
Third (150 HZ)	12.46	2.13	10.95	6.13	1.01	5.59
Fifth (250 HZ)	50.08	58.76	42.18	24.71	28.36	21.51
Seventh (350 HZ)	25.93	33.15	16.28	12.79	15.99	8.30
Ninth (450 HZ)	11.93	3.22	13.48	5.89	1.55	6.85
Eleventh (550 HZ)	12.79	5.11	8.74	6.31	2.47	4.44
Thirteenth (750 HZ)	9.07	6.80	2.74	4.48	3.31	1.39
THD	84.26	73.14	76.68	42.08	35.77	39.22
Case II: Charging Circuit connected to battery with load.						
PHASE	A	B	C	A	B	C
Third (150 HZ)	31.58	5.52	31.05	12.02	2.20	14.69
Fifth (250 HZ)	47.03	66.44	17.70	20.50	26.19	8.40
Seventh (350 HZ)	38.51	38.84	6.07	16.78	15.35	2.86
Ninth (450 HZ)	29.92	7.14	30.01	10.00	2.84	14.21
Eleventh (550 HZ)	34.83	2.26	31.40	15.22	0.89	14.88
Thirteenth (750 HZ)	23.29	3.74	21.92	10.12	1.48	10.39
THD	171.89	112.59	148.80	75.47	44.85	70.34
OVERALL THD	132.59	95.06	112.39	58.84	39.86	53.73

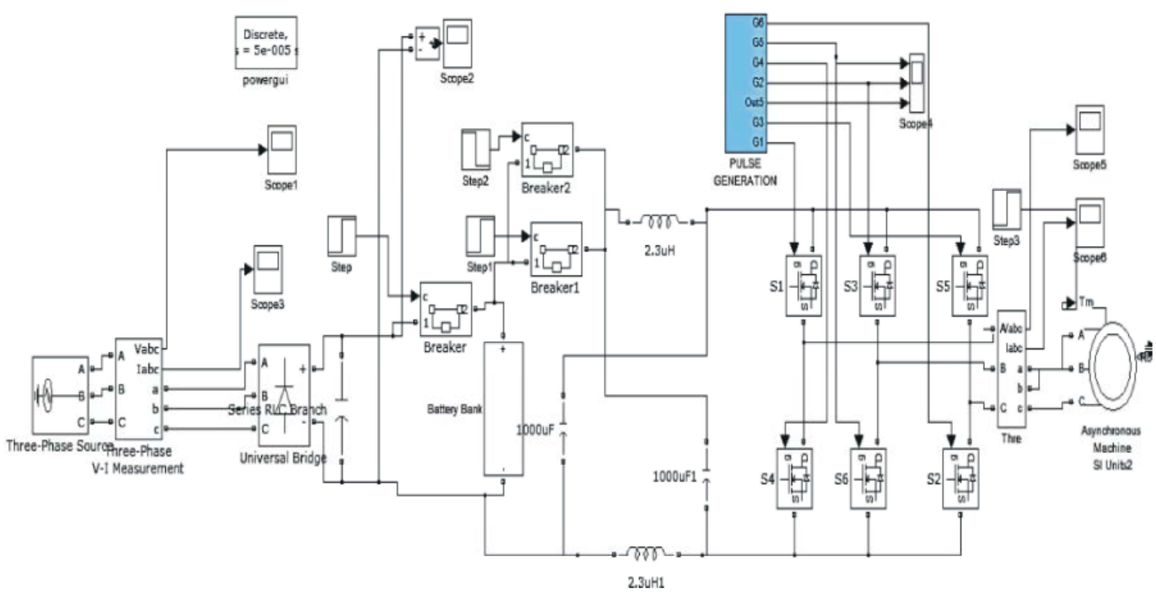

Fig. 2: Simulation without APF using MATLAB/ Simulink

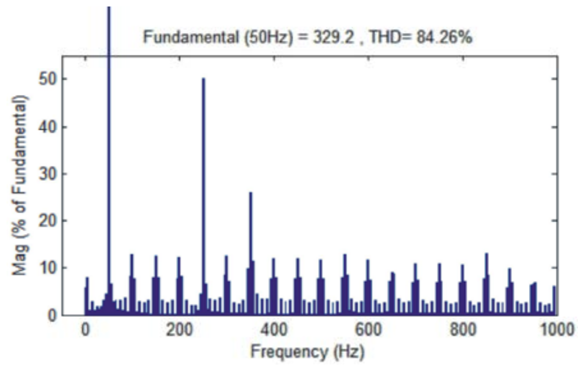

Fig. 3: FFT analyses with Charging Circuit only (Case I) Phase A

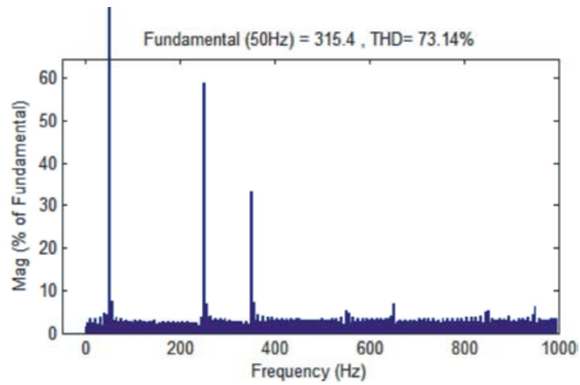

Fig. 4: FFT analyses with Charging Circuit only (Case I) Phase B

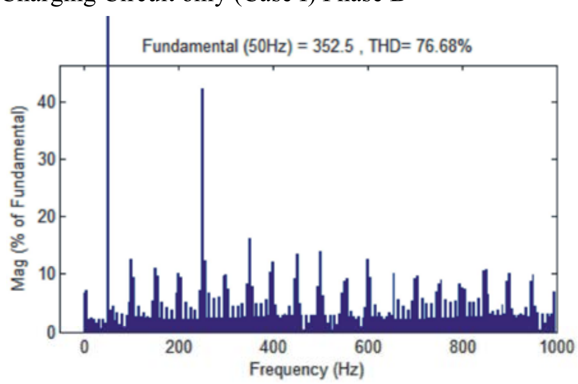

Fig. 5: FFT analyses with Charging Circuit only (Case I) Phase C

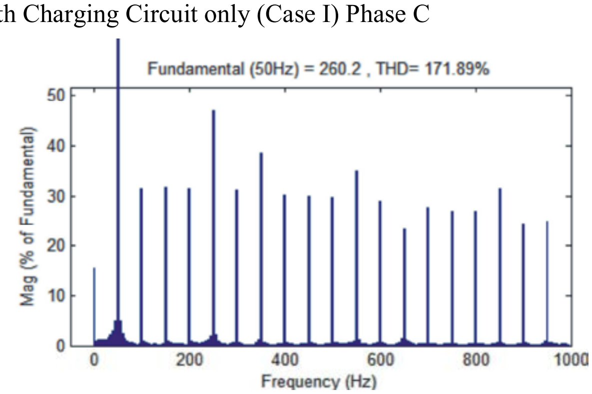

Fig. 6: FFT analyses with Charging Circuit and Battery Connected to loads. (Case II) Phase A

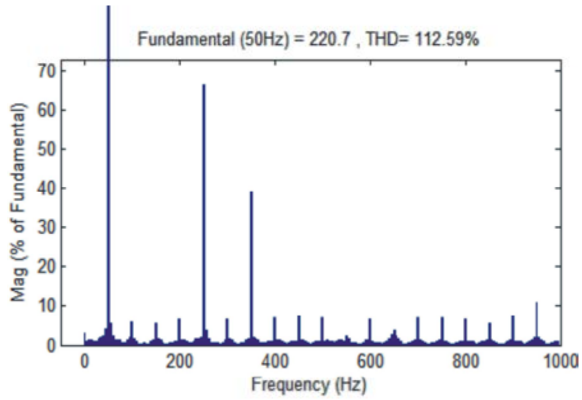

Fig. 7: FFT analyses with Charging Circuit and Battery Connected to loads. (Case II) Phase B

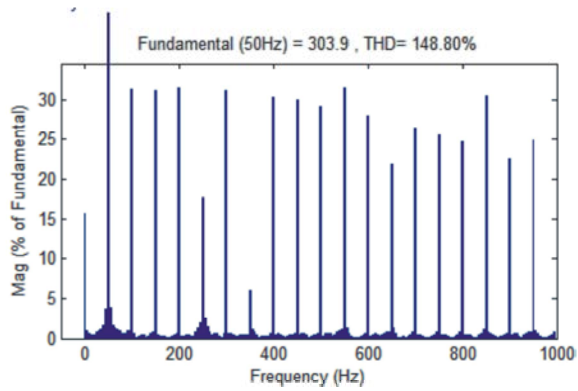

Fig. 8: FFT analyses with Charging Circuit and Battery Connected to loads. (Case II) Phase C

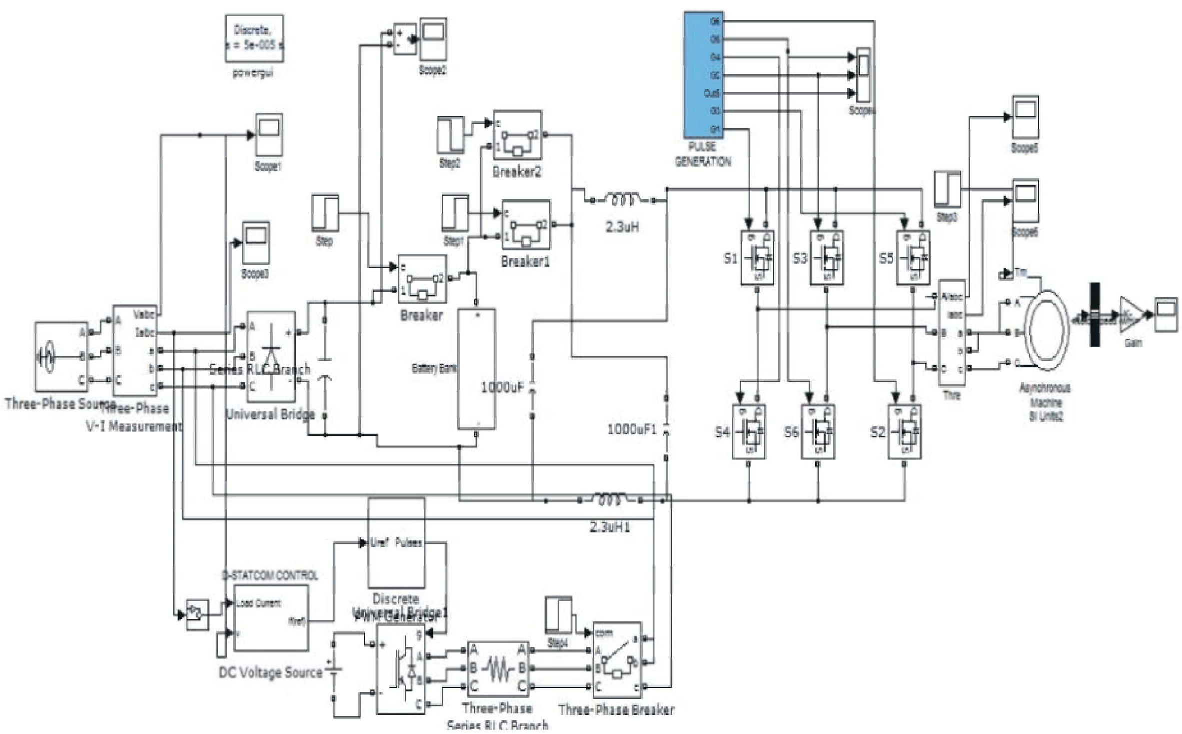

Fig. 9: System with APF

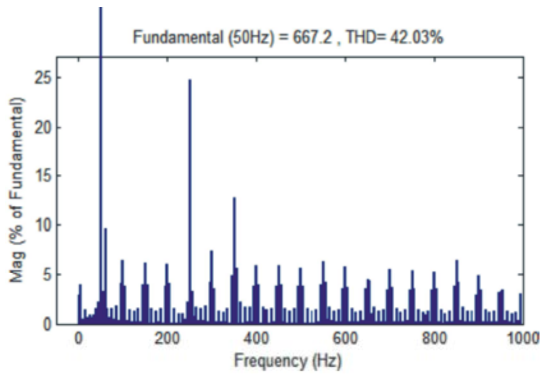

Fig. 10: FFT analyses with Charging Circuit only with APF (Case I) Phase A

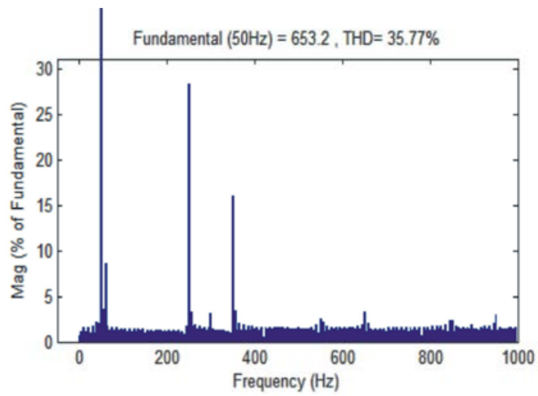

Fig. 11: FFT analyses with Charging Circuit only with APF (Case I) Phase B

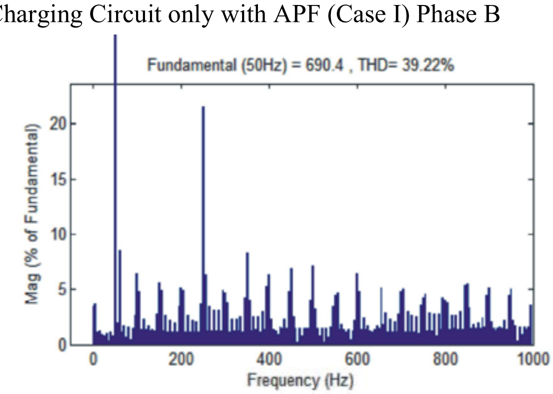

Fig. 12: FFT analyses with Charging Circuit only with APF (Case I) Phase C

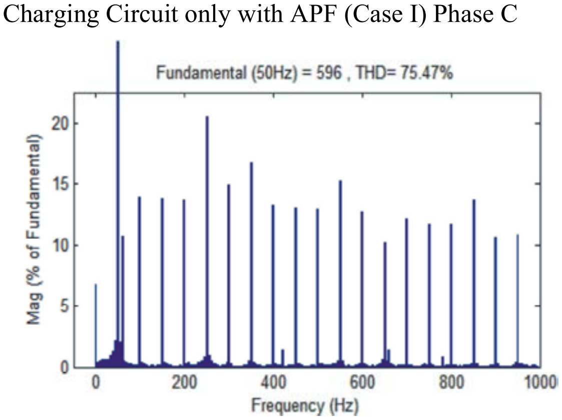

Fig. 13: FFT analyses with Charging Circuit AND Loads with APF (Case II) Phase A

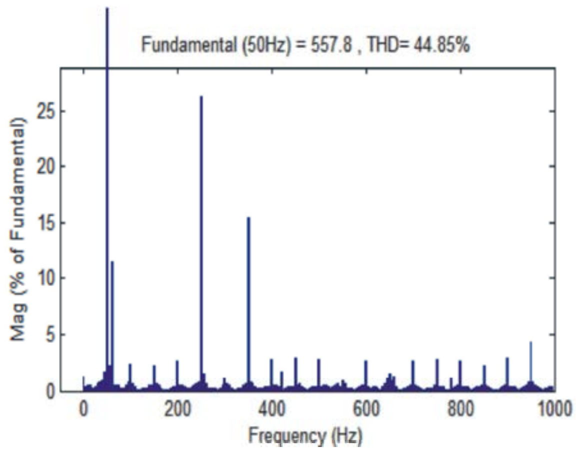

Fig. 14: FFT analyses with Charging Circuit AND Loads with APF (Case II) Phase B

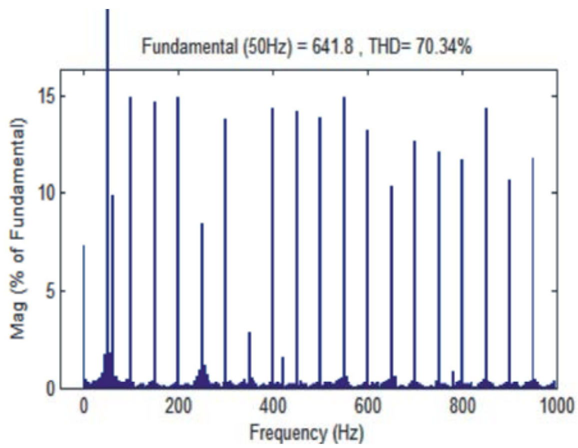

Fig. 15 FFT analyses with Charging Circuit AND Loads with APF (Case II) Phase C

The THD was found to reduce by more than 50 % of the value which was there initially when filters were not implemented. This active filter so designed is found to have a constant DC source for providing DC bus voltage to the APF VSI. Thus it has eliminated the need of monitoring DC bus voltage and addition of DC bus loss component during reference current extraction.

CONCLUSION

The implementation of three phase shunt active power filters for harmonics mitigation in the real time backup system was carried out and the results were analyzed. It can be seen that the implementation of active filters is useful in reducing several order harmonics in the system thereby improving the quality of supply. This simulation yielded interesting results in terms of reduction in magnitude of particular order harmonics and also the total THD. On analyzing the different cases (Case I and II), it was seen that whatever be the condition of charging or discharging or both, APFs are a feasible and effective solution for mitigation of harmonics in real time three phase systems.

REFERENCES

1. Srivastava, Kuldeep Kumar and SaquibShakil, 2013. Harmonics & Its Mitigation Technique by Passive Shunt Filter, International Journal of Soft Computing and Engineering (IJSCE) ISSN: 2231-2307, 3(2).
2. Peng, F.Z., 2001. Harmonic sources and filtering approaches, IEEE Ind. Appl. Mag, 7: 18-25.
3. Maswood, Ali I. and M.H. Haque, 2002. Harmonics, Sources, Effects and Mitigation Techniques, School of EEE, Nanyang Technological University Second International Conference on Electrical and Computer Engineering ICECE 2002, 26-28 December Dhaka, Bangladesh.
4. Arrillaga, J., D.A. Bradley and P.S. Bodger, 1985. Power System Harmonics. New York: Wiley.

5. Dugan, E.C., M.F. McGranagham, S. Santoso and H.W. Beaty, 2002. Electrical power systems quality., McGraw-Hill.
6. George, J.W., 2001. Power Systems Harmonics Fundamentals, Analysis and Filter Design, Springer.
7. Bhonsle D.C. and R.B. Kelkar, 2011. Harmonic Pollution Survey and Simulation of Passive Filter using MATLAB, IEEE International Conference on Recent Advancements in Electrical, Electronics and Control Engineering.
8. Areerak, K.L. and K.N. Areerak, 2010. The Comparison Study of Harmonic Detection Methods for Shunt Active Power Filters, World Academy of Science, Engineering and Technology.
9. Karsh, Vedat M., Mehmet Tümay and BerrinSüslüoğlu, An evaluation of time domain techniques for compensating currents of Shunt Active Power Filters.
10. Muhammad H. Rashid, Power Electronics - Circuits, Devices and Applications, Third Edition, Pearson, New Jersey, USA, 46: 243-248.
11. Farooq, Haroon and Chengke Zhou, 2011. Investigating the Power Quality of an Electrical Distribution System Stressed by Non-Linear Domestic Appliances, International Conference on Renewable Energies and Power Quality (ICREPQ'11) Las Palmas de Gran Canaria (Spain), 13th to 15th April.
12. Khan, Rana Abdul Jabbar and Muhammad Akmal, 2008. Mathematical Modeling of Current Harmonics Caused by Personal Computers, World Academy of Science, Engineering and Technology, 2-03-26.
13. Shwehdi, M.H. and F.S. AL-Ismail, 2012. Investigating University Personnel Computers (PC) Produced Harmonics Effect on line Currents, International Conference on Renewable Energies and Power Quality (ICREPQ'12) Santiago de Compostela (Spain).
14. Singh Bhim, Kamal Al-Haddad and Ambrish Chandra, 1999. A Review of Active Filters for Power Quality Improvement, IEEE Transactions on Industrial Electronics, 46(5): 960-970.
15. Khalid, S. and Bharti Dwivedi, 2011. Power Quality Issues, Problems, standards & their effects in industry with correctivemeans, International Journal of Advances in Engineering & Technology.
16. Morán, L., J. Dixon, J. Espinoza and R. Wallace, Using Active Power Filters to Improve Power Quality, 5th Brasilian Power Electronics Conference, COBEP' 99.
17. Akagi, H., 1996. New trends in active filters for power conditioning, IEEE Transactions on Industrial Applications, 32(6): 1312-1322.
18. Akagi, H., 2006. Modern active filters and traditional passive filters, Bulletin of the Polish Academy of Sciences, Technical Sciences, 54(3): 255-269.
19. Sood, Vijay K., 2004. HVDC and FACTS Controllers-Applications of Static Converters in Power Systems, Kluwer Academic Publishers.
20. Zainal Salam, Tan Perng Cheng and Awang Jusoh, 2006. Harmonics Mitigation Using Active Power Filter: A Technological Review, ELEKTRIKA, 8(2): 17-26.
21. Linders, J.R., 1979. Electric Wave Distortions: Their Hidden Costs and Containment, IEEETransactions on Industry Applications, 15(5): 458-471.
22. IEEE Task Force and the Effects of Harmonics, 1993. Effects of Harmonics on equipments, IEEE Trmts. on Power Delivery, 8(2): 681-688.
23. Lecture notes: Harmonic analysis Russell Brown, Department of mathematics University of Kentucky Lexington, KY 40506-0027 12 June 2001.
24. Recommended Practice and Requirements for Harmonic Control in Electrical Systems, IEEE Std.