Matlab /Simulink Based Harmonics Analysis & Composite Passive Harmonic Mitigation Technique of three phase Induction Motor

ISSN (e) 2520-7393
ISSN (p) 2521-5027
Received on 18th Sept, 2017
Revised on 6th Dec, 2017
www.estirj.com

Assadullah Khuhawar[1], Imtiaz Ali Laghari[2], Yasir Ali bhutto[3]

[1,2,3]*Department of Electrical Engineering Quaid-e-Awam University College of Engineering Sciences and Technology Larkano*

Abstract: An electric motor is an important element of the power system. Three-phase induction motor is an industrial load, in almost 70-80% applications of industrial this kind of motor is used. When motor is started by conventional methods, it causes voltage reduction but by using soft starters better response can be achieved as compare to conventional methods, there are few main problems with soft starters such as; they are responsible for harmonics generation. The introduction of electronic devices in the power system cause harmonics and cause malfunctioning of induction motor. In this work six pulse thyristors are used to control speed of motor at different firing angles, these firing angles produces harmonics, more the firing angle, more will be harmonics issues. This paper is aimed to analysis of harmonics at different angles and mitigating harmonics by using composite passive harmonic filter in MATALB/SIMULINK.

Keywords: *Induction motor, Harmonics, Passive Harmonic Filter, Nonlinear Devices, MATLAB/Simulink*

1. Introduction

Electric motor is an industrial load, it is based on mechanism that alters electrical power into mechanical power and therefore called as an electric motor or called as asynchronous motor. Most of electrical load is inductive in nature that effects the power source is badly during starting [3]. During starting of motor large starting current is introduced and causes harmonics in the power system [8].Harmonics are undesirable waveforms which are mostly due to nonlinear loads which causes low efficiency as well as power quality issues. A.C waveform which is complex sinusoidal (complex) can be presented to comprises of waveforms (sinusoidal) of integer multiples of the system frequencies. In a 50 Hz electrical network, 250 Hz is the 5th harmonic distortion; 350 Hz is the 7th harmonic distortion [9]. Capacitor banks can be employed connected with inductors in order to decrease the effects of the distortions on a system. Today, the harmonic filtration techniques involve either; Passive Harmonic Filtering ,active Harmonic Filtering or Hybrid Harmonic Filtering are not only reducing the harmonic distortion, but also improving the power factor of system. The passive harmonic filters are generally employed due to importance of low cost and easy to fabricate.

2. Harmonics

2.1 Introduction of Harmonics

The word “harmonics” denotes to distortion in current and voltage within an alternating system. Harmonics are distortive waveforms which are integral of normal frequency it is measured in Hz[11] if there is 2f, 3f, 4f, 5f etc. where f is a fundamental frequency and 2, 3, 4, 6 are the order of harmonics. as shown in Fig 1.

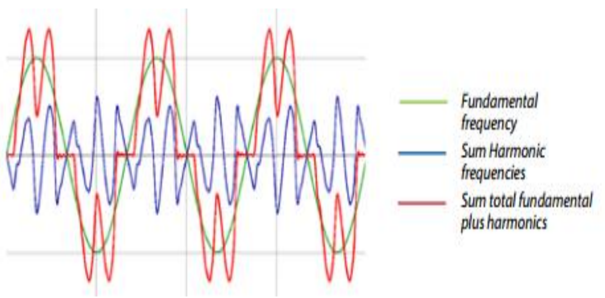

Figure.1. Fundamental and harmonics frequencies

2.2 Causes of harmonics

- Solid state power devices
- UPS
- Electronics devices such as diodes, transistors , thyristors
- Voltage controllers
- Computers etc.

2.3 Effects of harmonics on induction motor

- In stator and in rotor, winding current distortion (harmonics) causes as copper and iron loses
- Voltage harmonics causes loses (copper)
- Current distortion enhances quickly and severely effects the motor and raises mechanical vibrations, noise and heat
- Voltage reduction 5-10% in output.
- Cogging and crawling effects are due to harmonics

Corresponding author Email address: *lecturerassadali@gmail.com*

3. Motor rating & model

Parameters [Standard] of three phases IM (induction motor) are given in Table .1

Table. 1 Standard rating of induction motor

S. NO.	PARAMETERS	VALUE
1	Nominal Power	4 kW (5.4 HP)
2	Voltage (line-line)	400 V
3	Nominal Speed	1430 RPM
4	Frequency	50
5	No. of Poles	4
6	R_S	1.405 Ω
7	L_S	.005839 Henry
8	Rr	1.395 Ω
9	Mutual Inductance	0.1722 Henry
10	Inertia	0.0131 $kg.m^2$
11	Friction Factor	0.002985 N.m.s
12	Rotor Inductance	0.005839 H

The model of three phases IM with six pulse thyristors based at several firing angles as presented in Fig. 2 in MATLAB/SIMULINK.

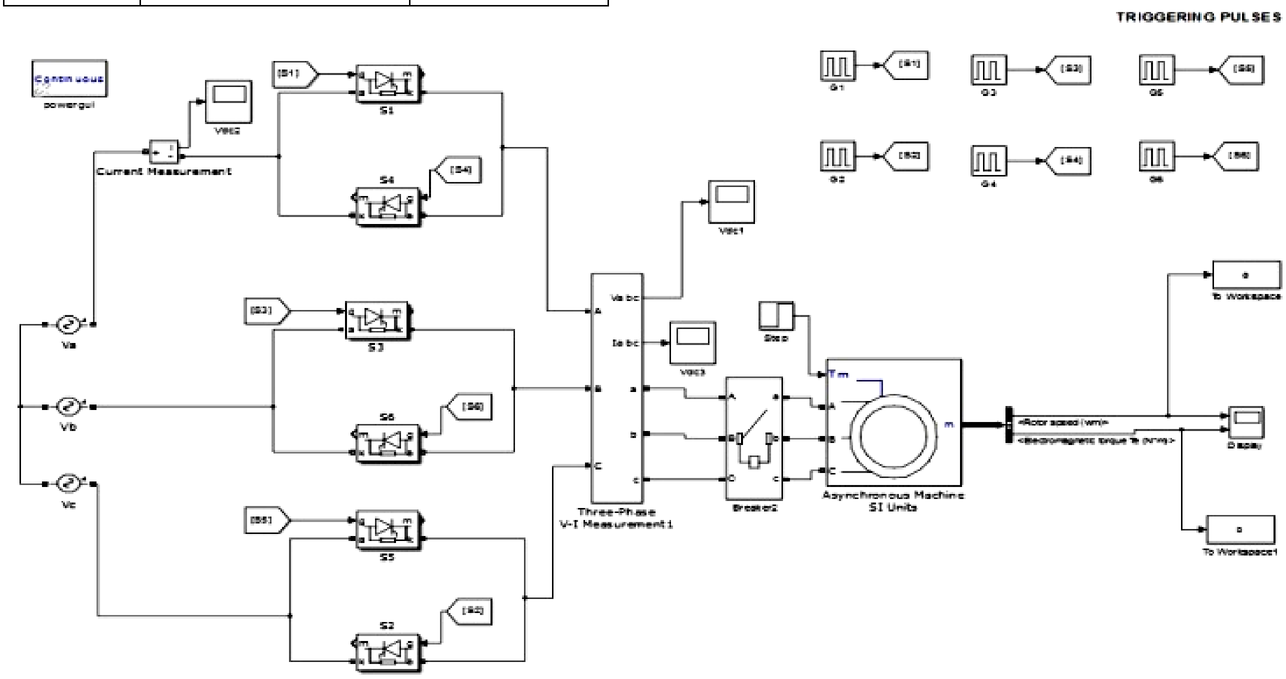

Figure.2. Model of three phase induction motor

4. Harmonic filters

Harmonic filters are optimal techniques to mitigate the harmonic distortion within the system. Almost following techniques are employed.

4.1 Passive harmonic filters

It comprises of capacitor connected in series with an inductor so the frequency of the harmonic is overall identical to the frequency of the resonance to be rejected. Passive filters, which are well-defined on a event by case origin, rendering to a specific distortions to be cleaned [9].These filters are economical and easy to design. The passive harmonic filters are further sub-divided into three classifications are as following.

4.1.1 Passive series harmonic filters

As the name of series filter is suggesting that it is connected in series with load and it is shown in Fig. 3. It is essential choose to exercise this filter as reflected as potential harmonic filtration. The functioning standard of Passive series filters is identified by constituents linked in series that the inductor rise arrangement level of inductance in tuned characteristics. Key constituents as of Passive series harmonic filter are DC link filter and AC line reactor.

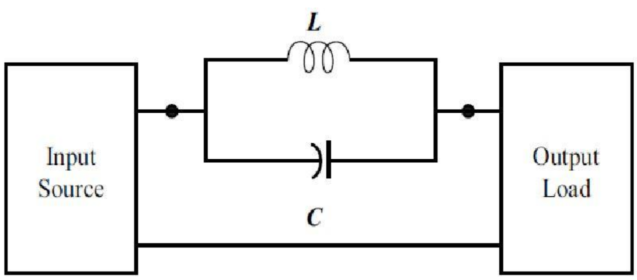

Figure.3. Series passive filter

4.1.2 Passive shunt harmonic filters

Shunt filter name is suggested because it is connected parallel with load. Such type of filters has two major applications as harmonic filtrations and improving the P.F (power factor) by neutralizing reactive power [10]. Power. The various types of passive shunt filter are given fig 4. It is picked to practice this filter as reflected as current harmonic filtration and generally employed because of low cost, better filter action and easier to design.

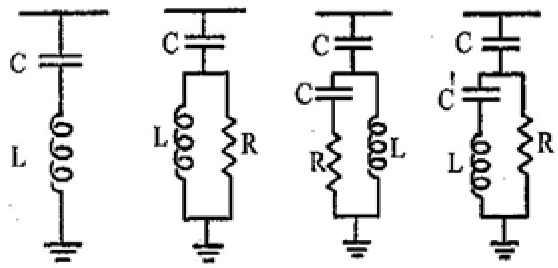

Figure. 4. Various Types of Shunt Filter

5. Proposed methodology

This paper suggested a three phase composite passive filter, it has been designed to mitigate harmonics introduced by three phase induction motor at several firing angles. Composite passive harmonic filter is made of a second order high pass filter and single tuned passive harmonic filters.

5.1 Single tuned passive filter

Single tuned passive filter is harmonic control technique and it is compulsory to select proper value of that harmonic passive filter component in order to enhance PF (power factor) at normal frequency [11-12]. This filter is employed to mitigate harmonics frequencies as low order. Fig. 5 shows single tuned passive filter.

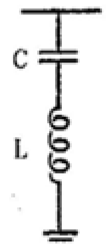

Figure.5. Single Tuned Filter

Equation Inductance reactance equation can be drawn as

$$X_L=2\pi\ F \quad (1)$$

In order to select suitable value of capacitor so it is essential to inscribe equation of capacitance reactance.

$$X_C=1/2\pi F \quad (2)$$

In the case of resonance condition capacitance reactance equal to Inductance reactance (X_L=X_C)

$$1/2\pi Fc = 2\pi\ F_L \quad (3)$$

Value of L can be obtained from equation 3

$$L=1/\ (2\pi f)\ 2\ C \quad (4)$$

$$\text{QF (quality factor)} = \sqrt{l/c}/R \quad (5)$$

Value of R rest on quality factor and both are inverse to each other, the more value of QF the smaller resistance value and vice versa. The greater value of QF, the more mitigation of harmonics and power quality will be improved more.

5.2 Second order high pass passive filter

It is also passive harmonic filter is nominated to eliminate the harmonic frequencies as high order. It provides better filtering action [12]**.** In this filter inductance resistance (L) resistance (R) are in parallel. It also decreases I^2R at fundamental frequency. Fig. 6 shows second order high pass filter. The better value of QF then this harmonic filter provides good results. The typical values of QF (quality factor) are b 0.5 to 2.

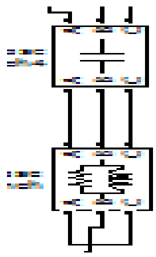

Figure. 6. Second Order High Pass Filter

Table. 2 Values of designed composite passive filter

Resistance value	**Inductance value**	**Capacitance value**
R1=0.34ohm	L1=0.0365H	C1=11.9e-6 F
R2=0.0365 ohm	L2=0.038H	C2=11.9e-6 F
R3=0.075 ohm	L3=0.075H	C3=11.9e-6 F
R4=0.21 ohm	L4=0.054H	C4=11.9e-6 F
R=49.48 o	L=0.031H	C=11.9e-6 F

6. Results and Discussion

6. 1 Harmonic analysis without filter

Three phase induction motor without filter has been studied below at various firing angle.

6.1.1 FIRING ANGLE (α = 60^o) .At this firing angle 5.77% harmonics are introduced without filter as shown in Fig.7.

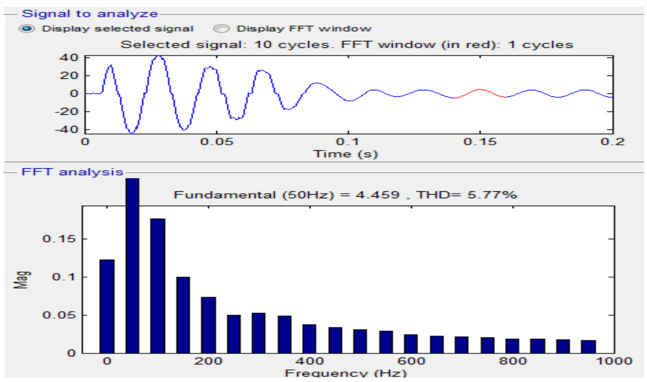

Figure.7. Harmonic analysis without filter at (α = 60o)

6.1.2 **FIRING ANGLE (α = 115^o).**

At this firing angle 49.86 % harmonics are analyzed without filter as shown in Fig. 8.

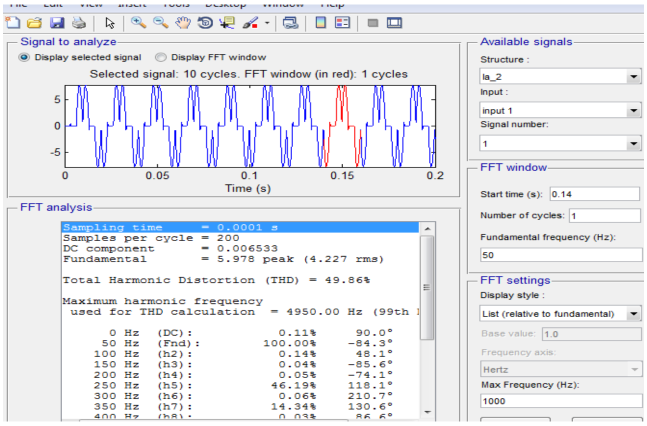

Figure.8. Harmonic analysis without filter at (α = 115o)

6.1.3 ***FIRING ANGLE (α = 120°)*** .At this firing angle 65.71% harmonics are analyzed without filter as shown in Fig .9.

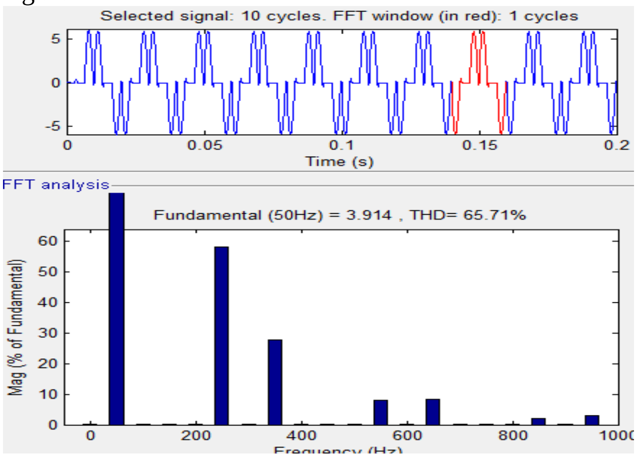

Figure.9. Harmonic analysis without filter at (α = 120o)

6.1.4 **FIRING ANGLE (α = 135°).**At this firing angle 132.35% harmonics are analyzed without filter as shown in Fig.10.

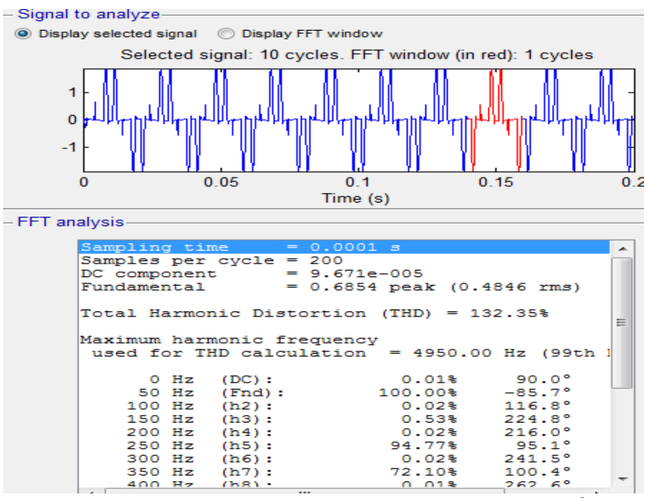

Figure. 1.0 Harmonic analysis without filter at (α = 135°)

6. 2 Harmonic analysis with filter

6.2.1 FIRING ANGLE (α = 60°). At this firing angle 0.57% harmonics are analyzed filter as shown in Fig.11.

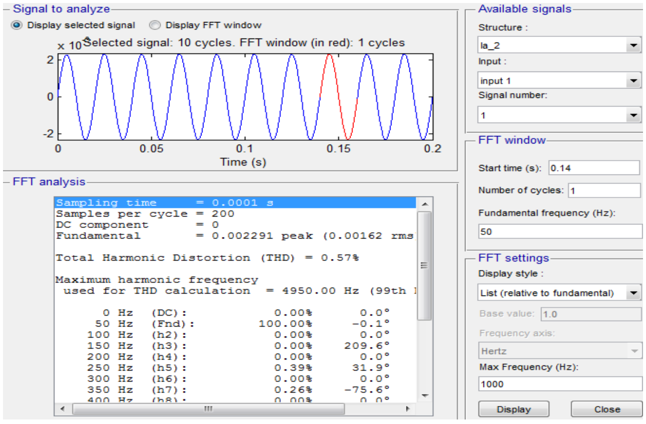

Figure. 11. Harmonic analysis with filter at (α = 60o)

6.2.2 FIRING ANGLE (α = 115°). At this firing angle 1.69% harmonics are analyzed with filter as shown in Fig 12.

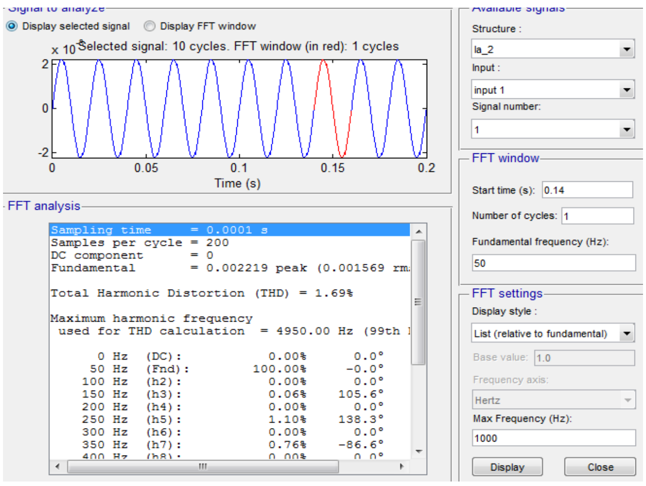

Figure.12. Harmonic analysis with filter at (α = 115o)

6.2.3 FIRING ANGLE (α = 120O). At this firing angle 1.80% harmonics are analyzed with filter as shown in Fig 13.

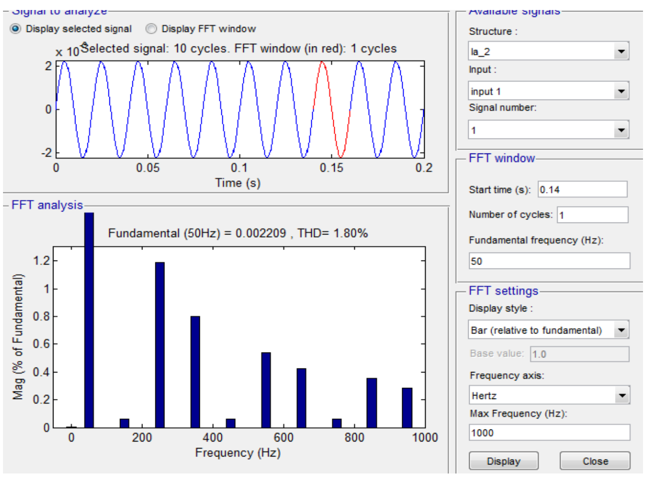

Figure. 13. Harmonic analysis with filter at (α = 120o)

5.2.4 FIRING ANGLE (α = 135°). At this firing angle 2.10% harmonics are analyzed without filter as shown in Fig. 14

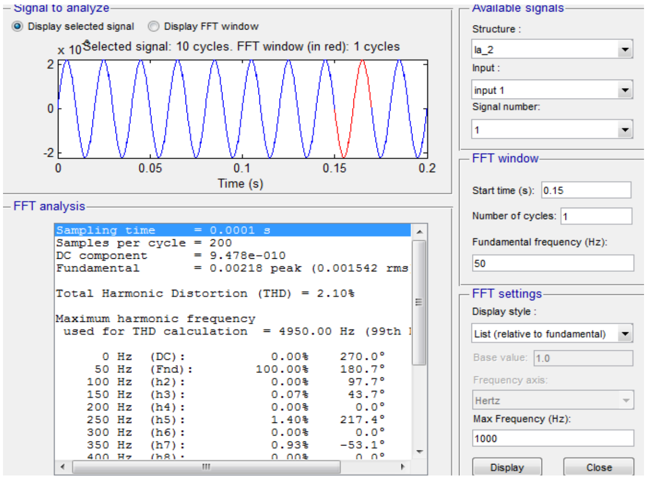

Figure.14. Harmonic analysis without filter at (α = 135o)

6.1 Total harmonics distortion (THD)

6.3.1 Total harmonics distortion without filter as shown in Table .3

Table .3 Total harmonics distortion without filter

SIMULINK MODEL	FIRING ANGLE	THD (%)
WITHOUT FILTER		
	60^{o}	5.77%
	115^{o}	49.86%
	120^{o}	65.71%
	135^{o}	132.35%

5.3.2 Total harmonics distortion with filter as shown in Table 4

Table. 4 Total harmonics distortion with filter

SIMULINK MODEL	FIRING ANGLE	THD (%)
WITH FILTER		
	60^{o}	0.57%
	115^{o}	1..69%
	120^{o}	1.80%
	135^{o}	2.10%

7. Conclusion

The design of such filter that can able to suppress the harmonics, this composite passive filter used in this paper is the best technique for mitigation low as well as high order frequencies .Simulink provides easier way to design filter for obtaining particular results .By implementing the composite passive harmonic filter the efficiency and power quality of induction can be enhanced. In this paper composite passive is suggested for harmonic reduction instead of this filter, active harmonic filter can be implemented for better response and in this paper harmonic analysis and harmonic mitigation technique have been done in MATLAB, but in future it can be verified in hardware.

References

[1] Caramia P. (2000) "Cost-Related Harmonic Limits", IEEE Power Engineering Society Winter Meeting, vol.4 Page(s): 2846 - 2851, 2000.

[2] Chang, Chen.C.I et al. (2010), "Extend Real Model of Kalman Filter for Time- Varying Harmonics Estimation", IEEE Transactions on Power Delivery, Volume 25, No. 1, pp. 17-26, 2010.

[3] Chi, H. S. et al (2014) "Current Control Methods for an Asymmetrical Induction Motor", IEEE 2014.

[4] Deokar, .S. A & Wag mare, L.M (2011) "Impact of Power System Harmonics on Insulation Failure of Distribution Transformer and its Remedial Measures", 3rd International Conference on Electronics Computer Technology, Page(s): 136 – 140-2011

[5] Desmet, J et al (2008), "Simulation of Losses in LV Cables due to Nonlinear Loads", IEEE Power Electronics Specialists Conference, Page(s): 785 - 790, 2008.

[6] Deokar, S A.Deokar1& Wagmare, L.M (2011) "Impact of Power System Harmonics on Insulation Failure of Distribution Transformer and its Remedial Measures", 3rd International Conference on Electronics Computer Technology, Page(s): 136 – 140-2011

[7] Gupta, N., Dubey, S.P., and Singh, S.P (2011)"Neural Network-Based Shunt Filter with Direct Current Control for Power Quality Conditioning", International Journal of Power Electronics, Volume 3, No. 6, pp. 597-620,2011

[8] Ippli,G.R ,Swarupa.V(2011) " power quality improvement in DTC based induction motor drive using Multilevel SATATCOM",July 2011.

9] Jabbar, R. A., Akmal1, et al (2008)"Impact of Compact Fluorescent Lamp on Power Quality" Australasian Universities Power Engineering Conference, Page(s): 1 - 5, 2008.

[10] Jamali, S, Masoum, M.A.S., and Mousavi, S.A (2008), "Influence of Controller High Pass Filter on the Performance of Shunt Hybrid Power Filter", Australasian Universities *Power Engineering Conference, pp. 1-6, 2008*

[11] Memon, Z .A, Uquaili, M. A and Unar, M. A (2012)"Harmonics Mitigation of Industrial Power System Using Passive Filters" Mehran University Research Journal of Engineering & Technology, Volume 31, No. 2, April, 2012 [ISSN 0254-7821]

[12] Memon, Z.A, Uqaili, M.A., and Soomro, M.A (2011)"Experimental Analysis of Harmonic Mitigation Effects on Three-Phase Six-Pulse Converter by Using Passive Filters", Mehran University Research Journal of Engineering & Technology, Volume 30, No. 4, pp. 653-656, 2011.

[13] Naim, M, et al (2011) "Improvement of power factor and Reduction of harmonic in three phase induction motor by PWM Techniques" July 2011

[14] Nicolae, P.M (2011) "The Impact of Currents Harmonics over the Voltage Transformers from a Power Group", IEEE International Symposium on Industrial Electronics (ISIE), Page(s): 1148 - 1153, 2011

[15] Reddy ,V.O and Sargar,P.V S(2011) " Implementation of Single phase hybrid active filter for single phase and three phase system".V.2, 2011.

[16] Sharaf, A.M, Wang, and Altas I.H. Altas (2007) “A Novel Modulated Power Filter Compensator for Distribution Networks with Distributed Wind Energy.” International Journal of Emerging Electric Power Systems. Vol.8, Issue 3, Article 6, Aug. 2007.

[17 Sharaf, A. M. (2011) “a novel FACTS based modulated power filter compensation scheme for smart electric grid stabilization and efficient utilization”, International journal of Distributed Energy Resources, vol. 7, no. 4, pp 311-327, 2011.

[18] Shuja, K .M (2011) “Implementation of passive tune filters to reduce harmonics in single Phase induction motor with varying load”. International journal of Engineering &Technology JJET-JJENS VOL: 11 NO: 03 2011

[19] Sravani K and Sastry,T.S (2013)“UPQC for Power Quality Improvement of Induction Motor Drive with Reduced DC Link Voltage” 2248-9622, Vol. 3, Issue 6, Nov-Dec 2013, pp.1374-1380

[20] Srivastava, K.D. K, Shakil.S, Pandey, A .V P “Harmonics & Its Mitigation Technique by Passive Shunt Filter “International Journal of Soft Computing and Engineering (IJSCE) ISSN: 2231-2307, Volume-3, Issue-2, May 2013.

About Authors

Assadullah Khuwahar received his B.E in electrical engineering in 2008 from QUEST Nawabshah, Pakistan. He received his masters in power system from MUET Jamshoro, Pakistan in 2016. He was working as Lecturer at QUCEST Larkano, Pakistan since 2013 to 2016. Now he is serving as a Assistant professor at QUCEST Larkano, Pakistan since 2017. His research interest includes power quality, power control, and electrical machines.

Imtiaz Ali Laghari Received his B.E in electrical engineering in 2007 from QUEST Nawabshah, Pakistan. He received his masters in power system from NED University in 2011. He is serving as Assistant professor at QUCEST Larkano, Pakistan since 2013. His research interest includes power quality, electrical machines, and embedded generation.

Yasir Ali Bhutto received his B.E in electrical engineering in 2012 from QUEST Nawabshah, Pakistan. He is currently pursuing his masters in power system from MUET Jamshoro, Pakistan. He is serving as Lab: Engineer at QUCEST Larkano, Pakistan since 2014. His research interest includes power quality, energy system, energy management and planning.