International Journal of Advanced Engineering and Technology
ISSN: 2456-7655
Impact Factor: RJIF 5.54
www.newengineeringjournal.com
Volume 2; Issue 3; September 2018; Page No. 39-46

Comparative study of passive filter for VSI fed PMBLDC motor

Atul Deshmukh[1], Prem Kant[2]
[1, 2] Department of Electrical Engineering, M.I.T.R.C. Alwar, Rajasthan, India

Abstract
The aim of this paper is to provide an improved model of PMBLDCM system which could reduce the harmonic content. A filter is connected before the conventional diode bridge rectifier (DBR). Each one the filters are analysed, modelled and simulated in SIMULINK environment. From comparison, it would be easy for any user to make a judicious choice for the PMBLDCM application as per the user requirements.

Keywords: power quality, THD, PMBLDCM, filter, converter, VSI

1. Introduction

The Power quality (PQ) standards for low power equipments such as IEC 61000-3-2 [20], requires a sinusoidal current to be drawn from AC mains. The permanent magnet brushless DC motors (PMBLDCM) [10] are now more popular in small and medium power applications due to its high starting torque, wide speed range operation, high efficiency, better reliability, low noise level, long lifetime, brushless construction and its ease to control. It is used for various applications in household equipment's such as mixer, washing machines, fans, air conditioners, refrigerators etc., industrial and automobile sectors such as power tools, electric vehicles and medical equipment's. The PMBLDCM [12] is a synchronous motor with permanent magnet on its rotor and three-phase concentric windings at the stator.

A VSI fed PMBLDCM drive suffers from PQ disturbance such as increased harmonic distortion (THD) at the input supply mains. A conventional VSI fed PMBLDCM drive powered by diode bridge rectifier followed by AC mains. DC link capacitor is connected to rectifier for constant DC supply for inverter. Due to uncontrolled charging of the DC link capacitor which results in a pulsed current waveform having a peak value higher than the amplitude of the fundamental input current at AC mains, Therefore the use of filters topologies is mostly recommended for PMBLDCM drive

The filters are connected between the single phase supply AC mains and the DBR, is mainly used as a harmonic correction feeding the PMBLDC motor, which is controlled by DC voltage of the VSI. There are many filters topologies available and amongst which L-type, T-type and Pi-type filters are selected for harmonic reduction due to its low current ripples, low conduction of losses, low cost. Amongst the filters topologies filter selected on the basis simplest construction, minimum component and cost requirement. The filters are designed in order to reduce the harmonic distortion with the desired speed control. A VSI fed PMBLDCM is preferred for low and medium power (200 W to a few kilowatts) applications [8].

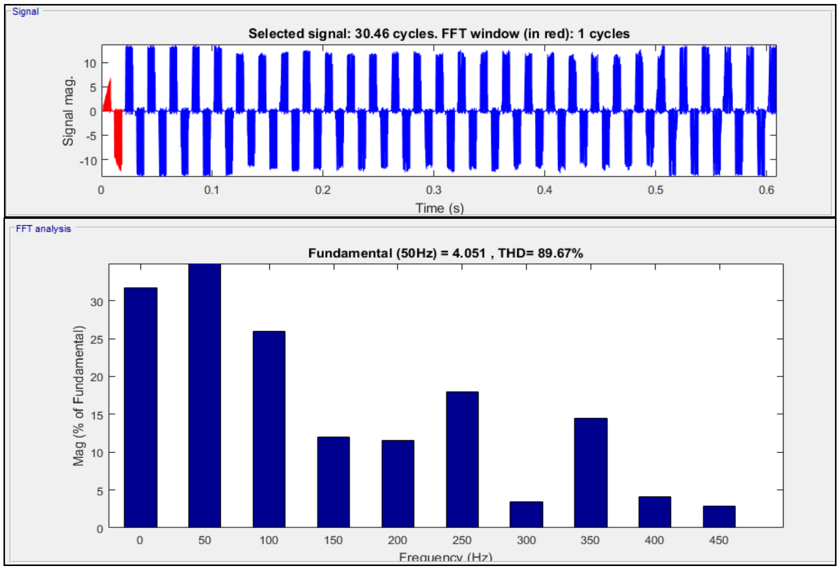

Fig 1: Input current and Harmonic spectrum of a VSI fed PMBLDC motor without filter.

A PMBLDCM is a kind of three phase synchronous motor with a trapezoidal back EMF waveform, having permanent magnets (PMs) on the rotor, replacing the mechanical commutator and brush gear.

PMBLDC Motor is controlled through 3-phase VSI operated as an electronic switch on the basis of Hall-effect position sensor signals [10]. The VSI is fed from AC mains through a diode bridge rectifier (DBR) using a capacitive DC link. The DBR draws a pulse shaped current resulting in poor power quality at AC mains. In the Fig. 1, The high value of THDi is due to uneven charging of the DC link capacitor and due to which the input current shoots up all of a sudden when source voltage magnitude becomes more than the DC link voltage and the ripples are observed in the input supply current having the THDi 89.67%. There are various international standards for electrical power quality out of which IEC-61000-3-2 presents the limits of current harmonics for drives [5].

This paper presents use of a passive filter for a PMBLDCM drive to achieve improved THD of the drive system while satisfying the PQ norms.

2. Proposed filter for VSI fed PMBLDCM

The Proposed filter is connected on the AC supply mains, the current due to nonlinear load connected to the system. The filter consist of various combinations of Inductance (L) and Capacitor (C). Filter connection on the AC side is more convenient than after DBR in terms of cost and complexity Fig. 2 shows the block diagram of the system. The filters used will be passive in nature and values are so chosen that it will reduce the harmonic distortion of the VSI fed PMBLDC.

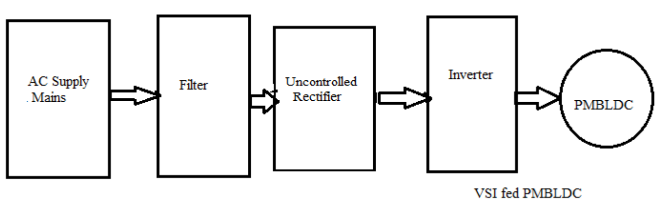

Fig 2: Proposed model of VSI fed PMBLDC with filter

3. Design of PMBLDC drive

The design of improved power quality of PMBLDC drive consist of selection of filter, intermediate DC link capacitor and switching device for a VSC and a VSI.

3.1 Parameter of voltage source inverter

The VSI consist of six IGBTs and diode switches. The selection of IGBTs is based on rated current of a PMBLDC.*

Table 1

Voltage source inverter(IGBT/ diodes)	Specification
Ron (IGBT is on)	1 milli ohm
Snubber Resistance	5000 ohm
Snubber Capacitance	1 pico farad
Forward voltage drop	0.8 V

3.2 Parameter of voltage source converter

The voltage source converter is designed on the basis apparent power through it.

V (Peak) D.C. = 0.90 X Sec. VA.C …… (i)

V (Avg) D.C. = 0.90 X Sec. V A.C. …… (ii)

I D.C. = 0.94 X Sec. I A.C ……. (iii)

Maximum current and voltage can be obtained using equations ().

Table 2

Voltage source converter (diodes)	Specification
Ron (IGBT is on)	1 milli ohm
Snubber Resistance	10000 ohm
Snubber Capacitance	20 pico farad
Forward voltage drop	1.3 V

3.3 Selection of Filter

Harmonic filtering is used to compensate the harmonic currents [20] produced by non-linear components such that it does not flow back to the supply. The harmonic current originates from the load and flows back to the supply, while connecting a accepter filter will reduce the magnitude of the harmonic current and reduce the harmonic distortion. The acceptor filter divides the current in the inverse proportion to impedances. These filter are connected in line to reduce the high frequency of harmonic content. The commonly used filters are L-type, T-type and Pi-type.

Case 1: L-type filter: First order filter is L-type filter. 20dB/dec is attenuated over the whole range of frequency. While keeping the switching frequency of the voltage source Inverter (VSI) high this L-type is used for suppressing the harmonics which is generated by high switching caused by PWM converter.

Case 2: T-type filter: T-type filter produces -60dB/decade in excess of the resonance frequency which is better than the L-type filter. With less overall stored energy and lower switching frequency it is possible to achieve reduce level of harmonic distortion.

Case 3: Pi-type filter: It is basically a capacitive filter followed by an LC, since its shape (C-LC) is like the letter π it is called π – filter or CLC filter. Capacitance offers a more reactance to dc component and low reactance to ac component and dc component flows through chock L. The ripple factor in a π-section filter is given by $\gamma = 2XC1XC2\ XLRL$

4. Filter Design

The equivalent circuit design of input filter for each phase are shown in Fig. 3 and Ii, n is the nth harmonic current generated by the inverter circuit and Is, n, is the source current composed of n harmonics. L and C are the inductance and capacitance of the three phase circuit.

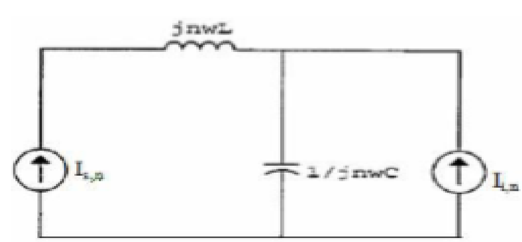

Fig 3: Input filter circuit per phase

$$Is,n = Ii,n\left(\frac{1/nj\omega C}{nj\omega L + 1/nj\omega C}\right) \quad (1)$$

Current division analysis of source and now rearranging the values.

$$LC = \frac{1}{(n\omega)^2}\left[\frac{I_{s,n}}{I_{i,n}} + 1\right] \quad (2)$$

The product of LC depends on nth harmonic frequency of ώ where ώ = 314 radians. Dominating frequency can be obtained by simulating without filter.

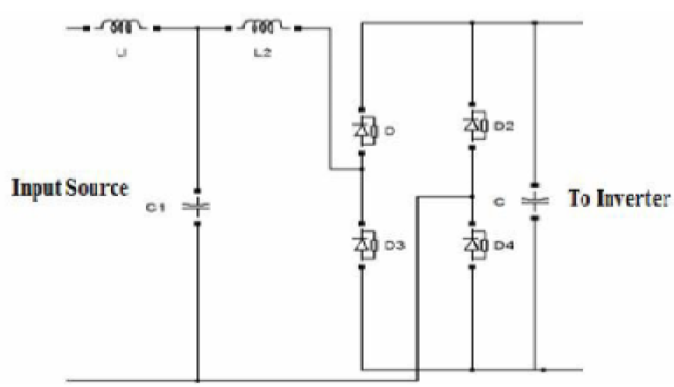

Fig 4: T-filter with Rectifier circuit

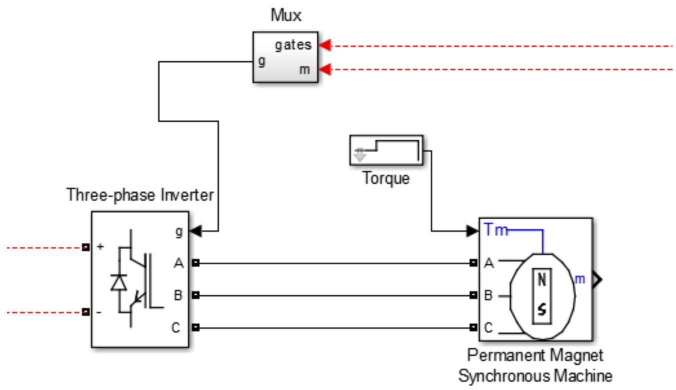

Fig 5: Three phase inverter using IGBT

Fig. 4 shows the T-type filter with diode bridge rectifier and Fig. 5 shows the three phase inverter using IGBT as switch. The output voltage of the inverter is applied to the stator coil of PMBLDC motor. The torque and the speed of PMBLDC motor depends on stator phase voltage. Table 3 shows the specifications of components and their specifications used during conduction mode.

Table 3: Components and specification used in inverter circuit

Device (IGBT)	Specification
Ron (IGBT is on)	1 milli ohm
Internal diode resistance	0.001
Snubber resistance	5000 ohm
Snubber capacitance	1 micro F

5. Result and Discussion
5.1 VSI fed PMBLDC with l filter

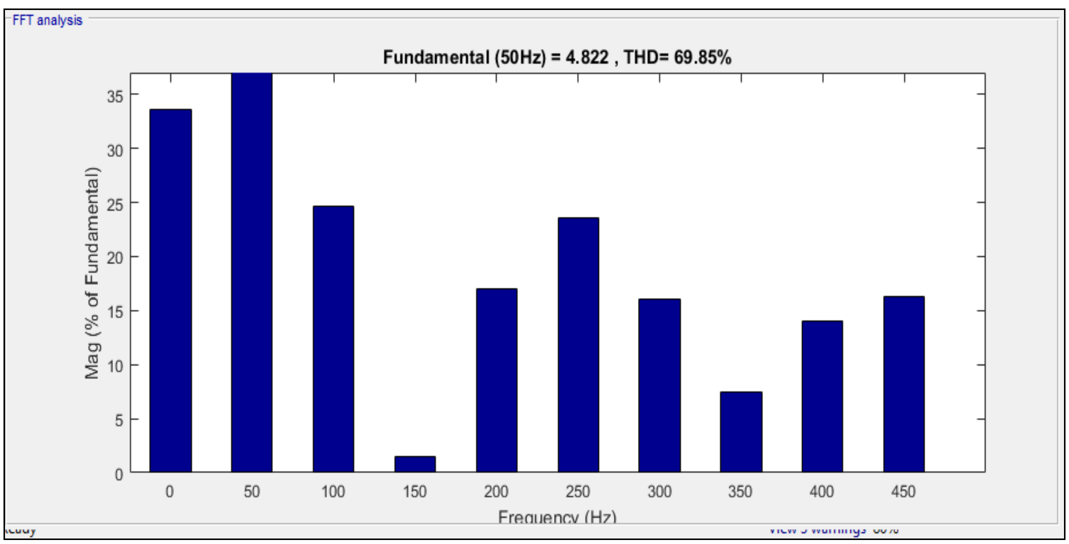

Fig 6

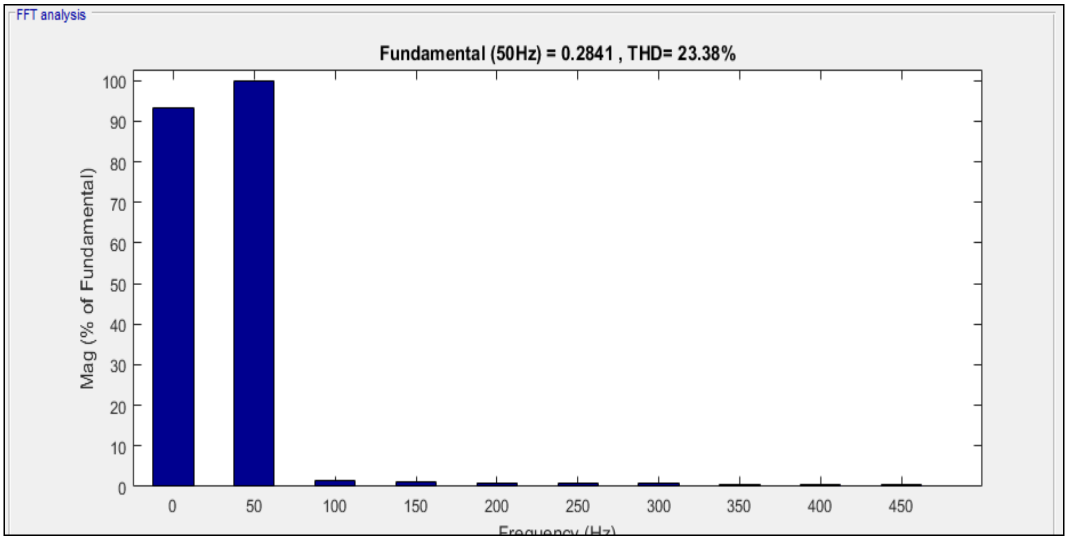

Fig 7

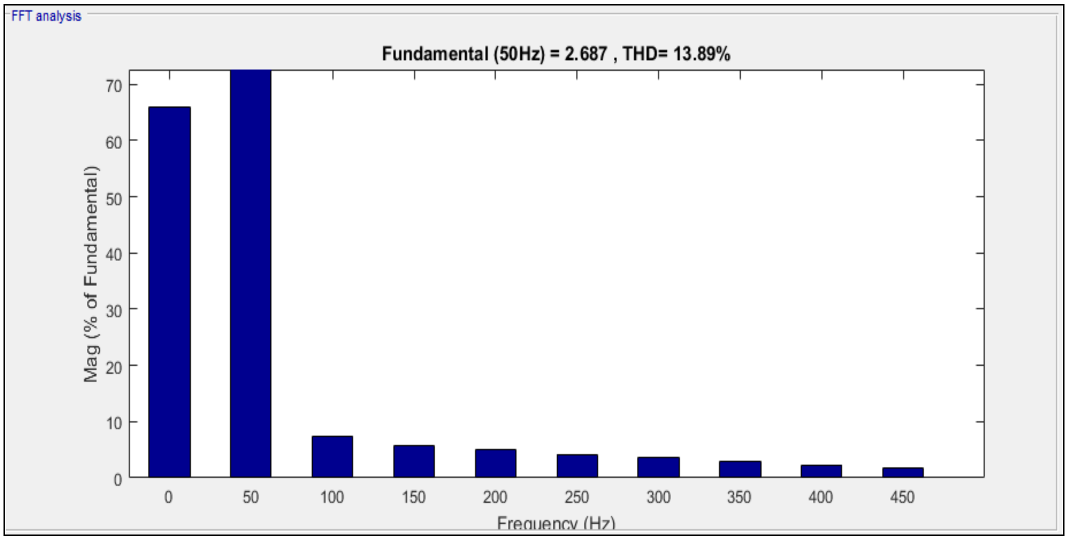

Fig 8

Figure 6, 7 & 8 shows the value of Total harmonic distortion (THD) for different values of Inductor (L) and Capacitor (C). Table 4 shows the values for which reduced total harmonic distortion is achieved.

Table 4: Specification of L and C for L-type filter

Inductor (L) in Henry	Capacitance (C) in Farad	Total Harmonic Distortion (% THD)
20 m H	300 m F	69%
20 m H	3 mF	66.87%
200 m H	30 micro F	28.48%
200 m H	30 micro F	23.48 %
200 m H	300 m F	17.82 %
200 m H	0.3 micro F	16.76 %
200 m H	500 micro F	13.89%

5.2 VSI fed PMBLDC with T Filter

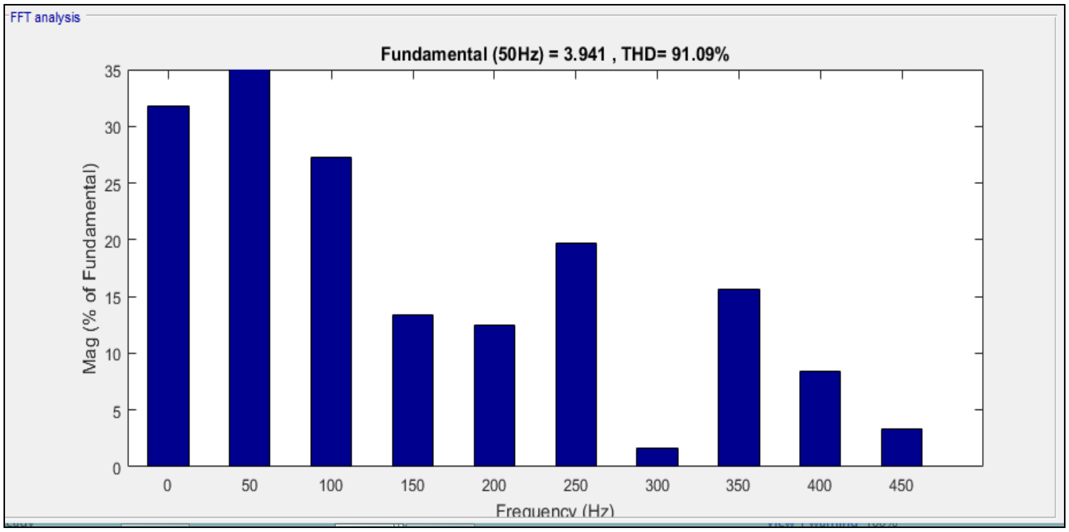

Fig 9

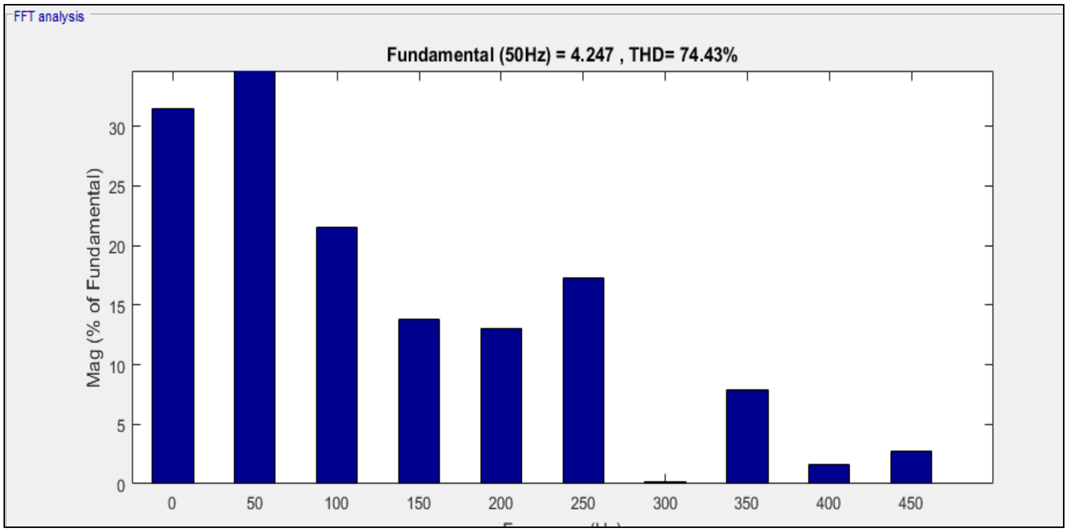

Fig 10

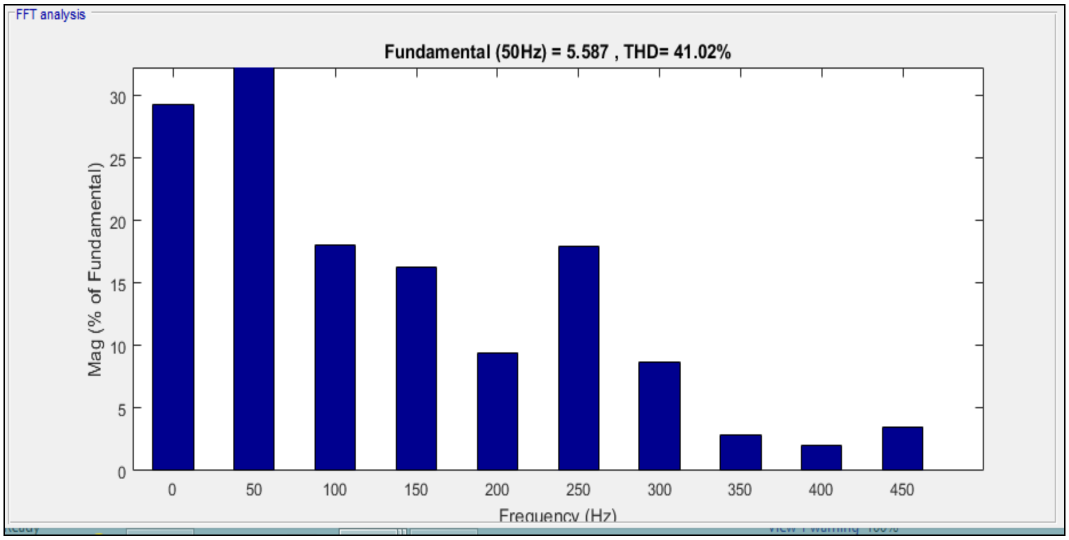

Fig 11

Table 5: Specification of L and C for T-type filter

Inductor (L1) in Henry	Capacitance (C) in Farad	Inductor (L2) in Henry	Total Harmonic Distortion (% THD)
20 micro H	30 m F	20 micro H	91%
2 micro H	300 m F	2 micro H	88%
200 micro H	300 m F	200 micro H	80.62%
2 m H	3 m F	2 m H	74.34%
2 m H	30 m F	2 m H	59.12%
20 m H	30 m F	20 m H	47.76%
20 m H	3 m F	20 m H	41.02%

Figure 9, 10 and 11 shows the different values of total Harmonic distortion (THD) for different values of Inductor and capacitor.

Table 5 shows the specification of L and C and obtained values of harmonic distortion.

5.3 VSI fed PMBLDC with π Filter

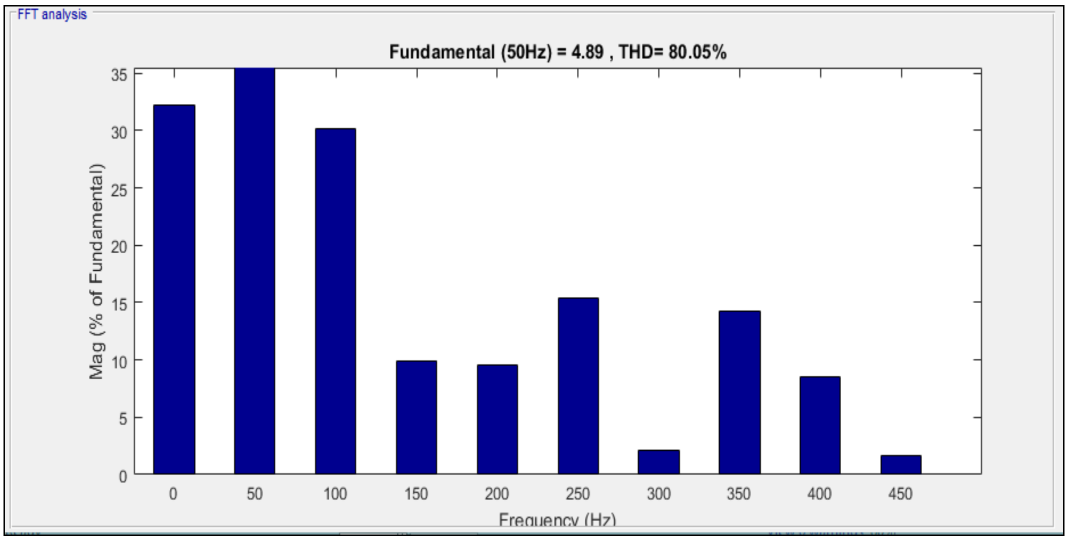

Fig 12

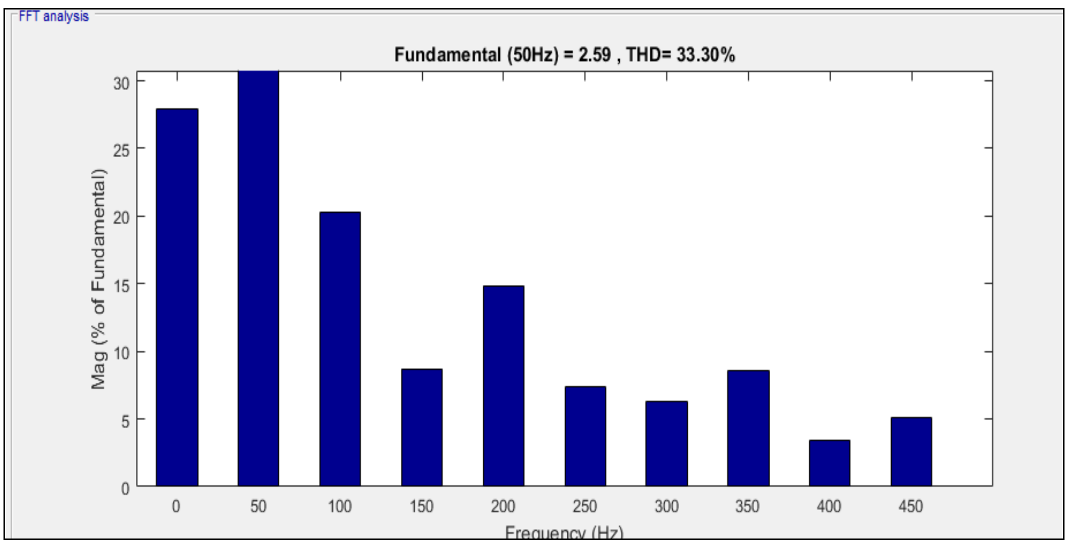

Fig 13

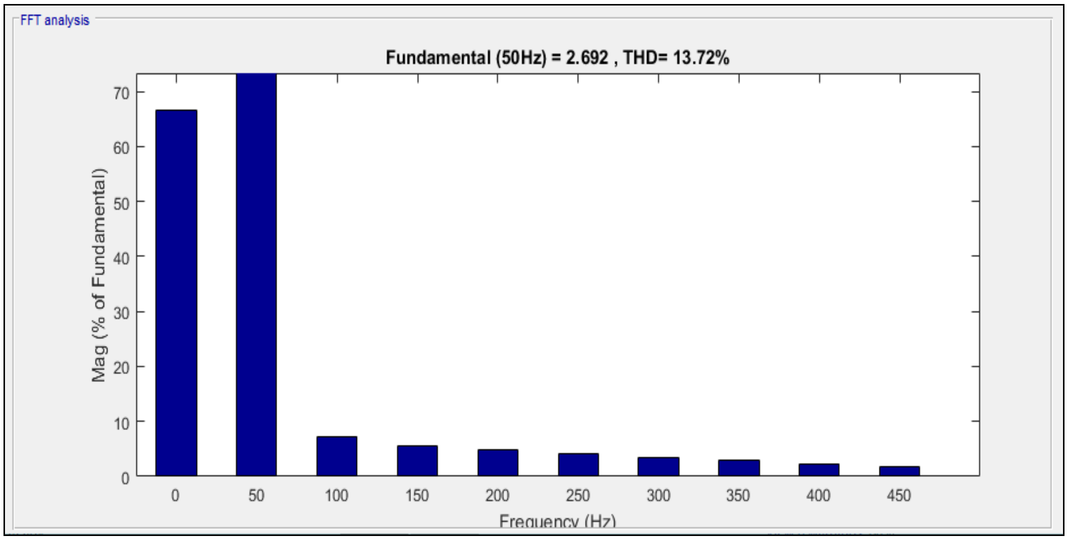

Fig 14

Table 6: Specification of L and C for Pi-type filter

Capacitance (C1) in Farad	Inductance (L) in Henry	Capacitance (C2) in Farad	Total Harmonic Filter (%THD)
3 m F	2 m H	3 m F	80.05%
3 m F	20 m H	3 m F	73.12%
300 m F	200 m H	300 m F	49.12 %
30 micro F	200 m H	300 micro F	28.12%
0.3 micro F	200 m H	0.3 micro F	13.72%

6. Conclusion

The performance of PMBLDC motor drive is with and without filter is verified using simulated result and observed from table 3, 4 & 5 that the THD of L-type filter is reduce to 13.89%, T-type is 41.02% and π-type is 13.72%. This investigation shall be helpful for consumer using PMBLDC motor for low and medium rating equipments.

7. References

1 Bhim Singh, and Sanjeev Singh. Half 'Bridge Boost Converter for Power Quality Improvement in PMBLDCM Drive. Second International Conference on Emerging Trends in Engineering and Technology, ICETET, 2009, 753-758.

2 Sanjeev Singh, Bhim Singh. Power Quality Improved PMBLDCM Drive for Adjustable Speed Application with Reduced Sensor Buck-Boost PFC Converter. Fourth International Conference on Emerging Trends in Engineering & Technology, 2011, 180-184.

3 Saurabh Shukla, Sanjeev Singh. Improved Power Quality PMBLDC Motor Drive for Constant Speed Variable Torque Load using NonIsolated SEPIC Converter. Annual IEEE India Conference (INDICON), 2014.

4 Kanwar Pal, Saurabh Shukla, Sanjeev Singh. Single Current Sensor PMBLDC Motor Drive with Power Quality Controller for Variable Speed Variable Torque Applications. The 5th International Conference on Electrical Engineering and Informatics Bali, Indonesia, 2015.

5 Medapati Joga Abhinay, Balamurugan P. Power Factor Correction of PMBLDC Motor Drive Using Cuk Converter.

6 Bharat Singh Parihar, Shailendra Sharma. Performance Analysis of Improved Power Quality Converter Fed PMBLDC Motor Drive.

7 Enjo TK, Nagamori S. Permanent Magnet. Brushless DC Motors. Oxford, U. K.: Clarendon, 1985.

8 Gieras JF, Wing M. Permanent Magnet Motor Technology- Design and Application, Marcel Dekker.

9 Bhim Singh, Vashist Bist. Reduced Sensor Based Improve Power Quality CSC Converter fed BLDC Motor Drive", 2012 IEEE International Corif. Power Electronic, Drives and Energy Systems, Bengaluru dEc, 2012, 16-19.

10 Singh B, Singh S. State-of-Art on Permanent Magnet Brushless DC Motor Drives, Journal of Power Electronics. 2009; 9(1):117.

11 Limits for Harmonic Current Emissions (Equipment input current less than 16 A per phase), International Standard IEC 61000-3-2, 2000.

12 Puttaswamy CL, Bhim Singh, Singh BP. Investigations on dynamic behavior of permanent magnet brushless dc motor drive, Electric Power Comp. & Sys. 1995; 23(6):689-701.

13 Bollen M. Understanding Power Quality Problems – Voltage Sags and Interruptions, IEEE Press Series on Power Engineering – John Wiley and Sons, Piscataway, USA, 2000.

14 Khalid S, Bharti Dwivedi. Power quality issues, problems, standards & their effects in industry with corrective means. International Journal of Advances in Engineering & Technology. 2011; 1(2):1-11

15 IEEE. IEEE Recommended Practices and Requirements for Harmonic Control in Electrical Power system, IEEE Std. 519-1992, revision of IEEE Std. 519-1981.

16 Alok Thapar, Tapan Kumar Saha, Zhao Yang Dong. Investigation of power quality categorisation and simulating it’s impact on sensitive electronic equipment.

17 Venkateswara Rao T, Mahesh Babu B. Power Quality Improvement in a PMBLDCM Drive Using a 1forward Buck Converter. International Journal of Scientific and Research Publications. 2012; 2(11).

18 Ibrahim H, Ilinca A, Perron J. Energy Storage Systems – Characteristics and Comparisons," Elsevier Renewable & Sustainable Energy Reviews.2008; 12:1221-1250.
19 Sandeep GJSM, Rasoolahemmed SK. Importance of Active Filters for Improvement of Power Quality. International Journal of Engineering Trends and Technology (IJETT) - Volume4Issue4- April 2013
20 https://en.wikipedia.org/wiki/IEC_61000-3-2