iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH
IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 5 Issue: VI Month of publication: June 2017

DOI:

www.ijraset.com

Call: 08813907089 | E-mail ID: ijraset@gmail.com

Volume 5 Issue VI, June 2017
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

Analysis and Implementation of PMBLDC Motor Drive with CUK Converter

SK. Nagur Basha[1], G. Sarath Babu[2]
[1]Asst.Professor, Department of EEE, Ayaan College of Engineering and Technology, Moinabad.
[2]Asst.Professor, Department of EEE, Ayaan College of Engineering and Technology, Moinabad.

Abstract:* This method is used to improve the efficiency of motor drive by power factor correction. It plays an important role in energy saving during energy conversion. A cuk dc -dc converter topology reduced the power quality problems and improve the power factor at input ac mains. A three-phase voltage-source inverter is used as an electronic commutator operates the PMBLDCM drive The concept of voltage control at the dc link proportional to the desired speed of the PMBLDCM is used to control the speed of the compressor. The proposed power factor converter topology is designed, modeled and its performance is evaluated in matlab-simulink environment. The results show an improved power quality and good power factor in wide speed range of the drive. It also compares the Total Harmonic Distortion (THD) of the Input AC current in Matlab-Simulink environment.
Keywords –Cuk converter, Permanent magnet brushless dc motor (PMBLDCM), Power factor correction (PFC), Voltage-source inverter (VSI), Total Harmonic Distortion (THD).

I. INTRODUCTION

Conventional DC motors are highly efficient and their characteristics make them suitable for use as servomotors. However, their only drawback is that they need a commutator and brushes which are subject to wear and require maintenance. When the functions of commutator and brushes were implemented by solid-state switches, maintenance free motors were realized. These motors are now known as brushless DC motors. The construction of modern brushless motors is very similar to the AC motor, known as the permanent magnet synchronous motor. The stator windings are similar to those in a poly-phase ac motor, and the rotor is composed of one or more permanent magnets. Brushless DC motors are different from ac synchronous motors in that the former incorporates some means to detect the rotor position (or magnetic poles) to produce signals to control the electronic switches

The most common position/pole sensor is the Hall element, but some motors use optical sensors. In the brushless DC motor, the polarity reversal is performed by power MOSFETS, which must be switched in synchronism with the rotor position. The brushless DC motors are generally controlled using a three-phase inverter, requiring a rotor position sensor for starting and for providing the proper commutation sequence to control the inverter. These position sensors can be Hall sensors, resolvers, or absolute position sensors. Those sensors will increase the cost and the size of the motor, and a special mechanical arrangement needs to be made for mounting the sensors. These sensors, particularly Hall sensors, are temperature sensitive, limiting the operation of the motor to below about 75 degree. Permanent magnet brushless dc motor is used for low power applications.

II. POWER FACTOR

Power factor is defined as the cosine of the angle between voltage and current in an ac circuit. There is generally a phase difference Ø between voltage and current in an ac circuit. cosØ is called the power factor of the circuit. If the circuit is inductive, the current lags behind the voltage and power factor is referred to as lagging as shown in Fig.2. However, in a capacitive circuit, current leads the voltage and the power factor is said to be leading. In a circuit, for an input voltage V and a line current I, VIcos Ø –the active or real power in watts or KW. VIsinØ is the reactive power in VAR or KVAR. VI is the apparent power in VA or KVA. Power Factor gives a measure of how effective the real power utilization of the system is. It is a measure of distortion of the line voltage and the line current and the phase shift between them. Power Factor=Real power (Average)/Apparent power Where, the apparent power is defined as the product of r.m.s value of voltage and current.

Volume 5 Issue VI, June 2017
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

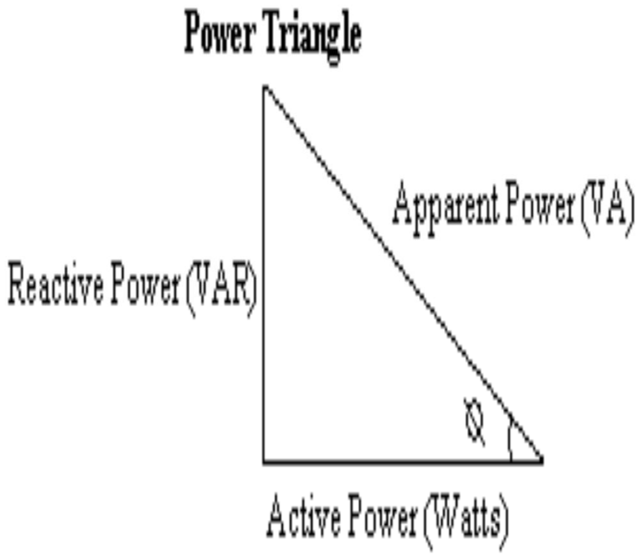

Fig.2. Power Factor Triangle (Lagging).

A. Linear Systems

In a linear system, the load draws purely sinusoidal current and voltage, hence the power factor is determined only by the phase difference between voltage and current. i.e. PF=cosθ

B. Power Electronic Systems

In power electronic system, due to the non-linear behaviour of the active switching power devices, the phase angle representation alone is not valid. A nonlinear load draws typical distorted line current from the line. The PF of distorted waveforms is calculated as below: The fourier representation for line current is and line voltage Vs are given by,

$$I_s = I_{DC} + \sum I_{sn} \, \mathrm{Sin}(n\omega t+\theta) \qquad V_s = V_{DC} + \sum V_{sn} \, \mathrm{Sin}(n\omega t+\theta)$$

The line current is non-sinusoidal when the load is nonlinear. For sinusoidal voltage and non- sinusoidal current the *PF* can be expressed as

$$PF = \frac{I_{1rms} \cos\theta}{I_{rms}} \qquad K_p = \frac{I_{1rms}}{I_{rms}}$$

Where, *cosΦ* is the displacement factor of the voltage and current. *Kp* is the purity factor or the distortion factor. Another important parameter that measures the percentage of distortion is known as the current total harmonic distortion (THD) which is defined as follows: Hence the relation between *Kp* and *THD* is

$$K_p = \frac{1}{\sqrt{1+THD^2}} \qquad THD = \frac{\sqrt{\sum_{n=2}^{\infty} I_{nrms}^2}}{I_{1rms}}$$

III. MATHEMATICAL MODEL OF PMBLDC MOTOR

Modeling of a BLDC motor can be developed in the similar manner as a three-phase synchronous machine. Since its rotor is mounted with a permanent magnet, some dynamic characteristics are different. Flux linkage from the rotor is dependent upon the magnet. Therefore, saturation of magnetic flux linkage is typical for this kind of motors. As any typical three phase motors, one structure of the BLDC motor is fed by a three-phase voltage source as shown in Fig. 4. The source is not necessary to be sinusoidal. Square wave or other wave- shape can be applied as long as the peak voltage is not exceeded the maximum voltage limit of the motor. Similarly, the model of the armature winding for the BLDC motor is expressed as follows.

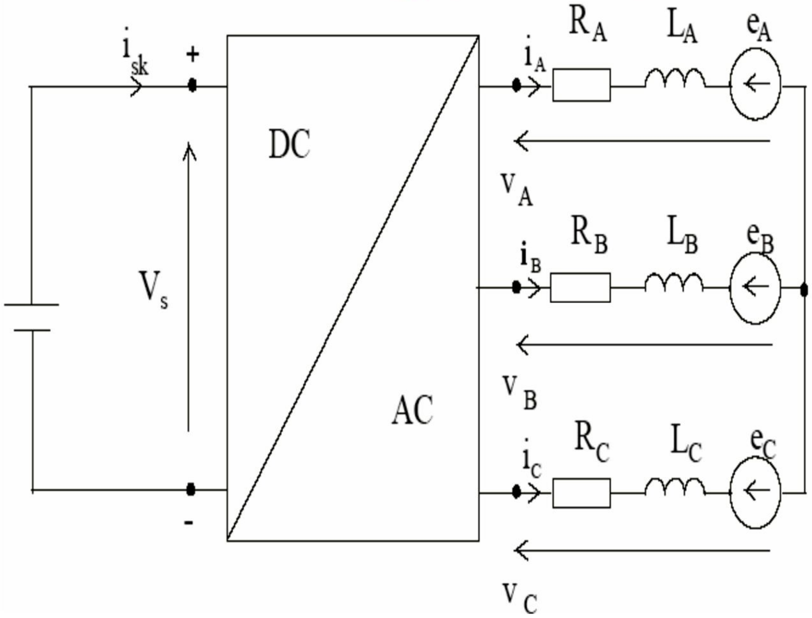

Fig.3.PMBLDC Motor Mathematical Model

For a symmetrical winding and balanced system, the voltage equation across the motor winding is as follows
Applying Kirchhoff's voltage law for the three phase stator loop winding circuit's yields:

$$V_a = R_a I_a + L_a \frac{di_a}{dt} + M_{ab} \frac{di_b}{dt} + M_{ac} \frac{di_c}{dt} + e_a \quad (3.1)$$

$$V_b = R_b I_b + L_b \frac{di_b}{dt} + M_{bc} \frac{di_c}{dt} + M_{ba} \frac{di_c}{dt} + e_b \quad (3.2)$$

$$V_a = R_c I_c + L_c \frac{di_c}{dt} + M_{ca} \frac{di_a}{dt} + M_{cb} \frac{di_b}{dt} + e_c \quad (3.3)$$

Where the back-EMF waveforms e_a, e_b, e_c are functions of angular velocity of the rotor shaft, so

$$e = K_e \, \omega_m \quad (3.4)$$

Where K_e is the back-emf constant
So the BLDC motor mathematical model can be represented by the following equation in matrix form:

$$\begin{bmatrix} L_a & M_{ab} & M_{ac} \\ M_{ba} & L_b & M_{bc} \\ M_{ca} & M_{cb} & L_c \end{bmatrix} \frac{d}{dt} \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} = \begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix} - \begin{bmatrix} R & 0 & 0 \\ 0 & R & 0 \\ 0 & 0 & R \end{bmatrix} \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} - \begin{bmatrix} e_a \\ e_b \\ e_c \end{bmatrix} \quad (3.5)$$

If we assume that the rotor has a surface-mounted design, which is generally the case for today's BLDC motors**,** there is no saliency such that the stator self inductances are independent of the rotor position, hence:

$$L_a = L_b = L_c = L$$

And the mutual inductances will have the form

$$M_{ab} = M_{ac} = M_{ba} = M_{ca} = M_{cb} = M$$

Assuming three phase balanced system, all the phase resistances are equal:

$$R_a = R_b = R_c = R$$

Rearranging the equation (2.5) yields;

$$\begin{bmatrix} L & M & M \\ M & L & M \\ M & M & L \end{bmatrix} \frac{d}{dt} \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} = \begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix} - \begin{bmatrix} R & 0 & 0 \\ 0 & R & 0 \\ 0 & 0 & R \end{bmatrix} \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} - \begin{bmatrix} e_a \\ e_b \\ e_c \end{bmatrix} \quad (3.6)$$

A. Trapezoidal Back EMF

When a BLDC motor rotates, each winding generates a voltage known as back Electromotive Force or back EMF, which opposes the main voltage supplied to the windings according to Lenz's Law. The polarity of this back EMF is in opposite direction of the energized voltage. Back EMF depends mainly on three factors:

1) Angular velocity of the rotor
2) Magnetic field generated by rotor magnets
3) The number of turns in the stator windings

In general, Permanent Magnet Alternating current (PMAC) motors are categorized into two types. The first type of motor is referred to as PM synchronous motor (PMSM). These produce sinusoidal back EMF and should be supplied with sinusoidal current / voltage. The second type of PMAC has trapezoidal back EMF and is referred to as the Brushless DC (BLDC) motor. The BLDC motor requires that quasi-rectangular shaped currents are to be fed to the machine. When a brushless dc motor rotates, each winding generates a voltage known as electromotive force or back EMF, which opposes the main voltage supplied to the windings. The polarity of the back EMF is opposite to the energized voltage. The stator has three phase windings, and each winding is displaced by 120 degree.

The back EMF is a function of rotor position (θ) and has the amplitude

$$E = K_e \omega \quad (3.7)$$

The instantaneous back EMF in BLDC is written as:

$$e_a = \frac{K_e}{2} \omega_m F(\theta_e) \quad (3.8)$$

$$e_b = \frac{K_e}{2} \omega_m F\left(\theta_e - \frac{2\pi}{3}\right) \quad (3.9)$$

$$e_c = \frac{K_e}{2} \omega_m F\left(\theta_e - \frac{4\pi}{3}\right) \quad (3.10)$$

The induced EMFs do not have sharp corners, but rounded edges. The quasi-square trapezoidal back EMF waveform and the phase current of the PMBLDC motor with respect to the rotor position is shown in the figure 4. The graph is presented for one complete cycle rotation of 360 degrees.

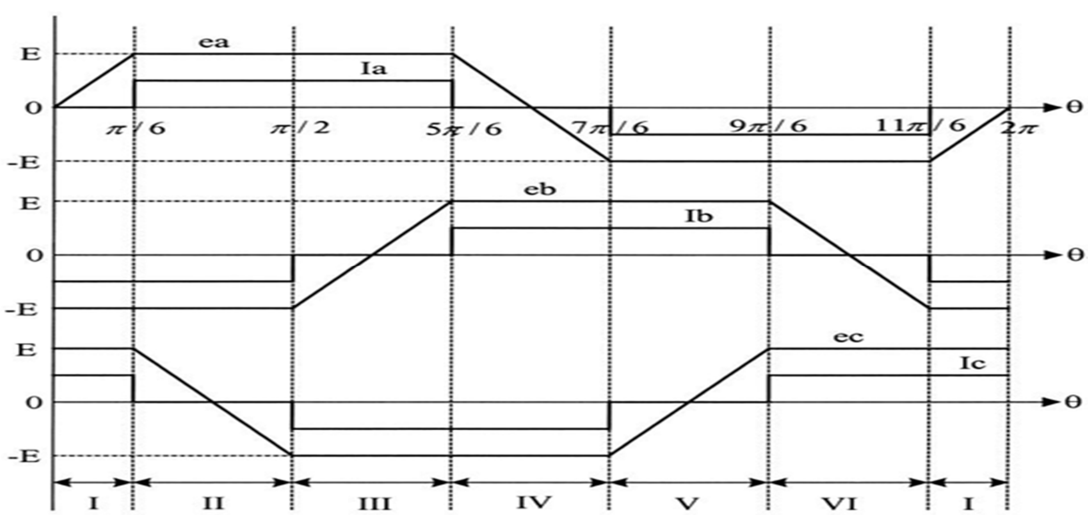

Fig.4. Back EMF and phase current waveforms of BLDC Motor

IV. RESULT AND DISCUSSION

A. Pmbldc Motor Without Power Factor Correction Controller

Circuit consists of two groups of diodes: top group and bottom group. It is easy to see the operation of each group of diodes. The current id flows continuously through one diode of the top group and one diode in the bottom group. The circuit is simulated using Simulink and input current waveform is plotted. The input current waveform consists of Total Harmonic Distortion. Fast Fourier Transform (FFT) analysis is done to get the value of THD. THD of input current and THD percentage is 79.31%. High THD will affect the equipments connected and power factor will be 0.762.

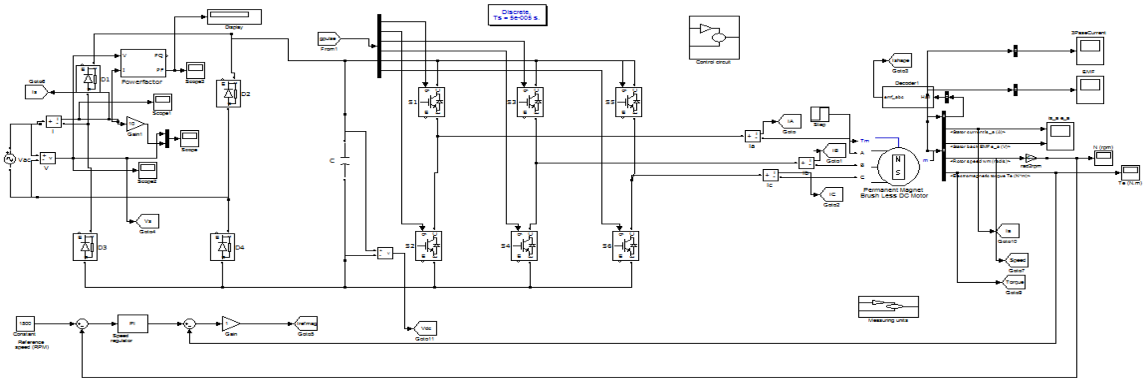

Fig.5. PMBLDC Motor without Power Factor Correction Controller.

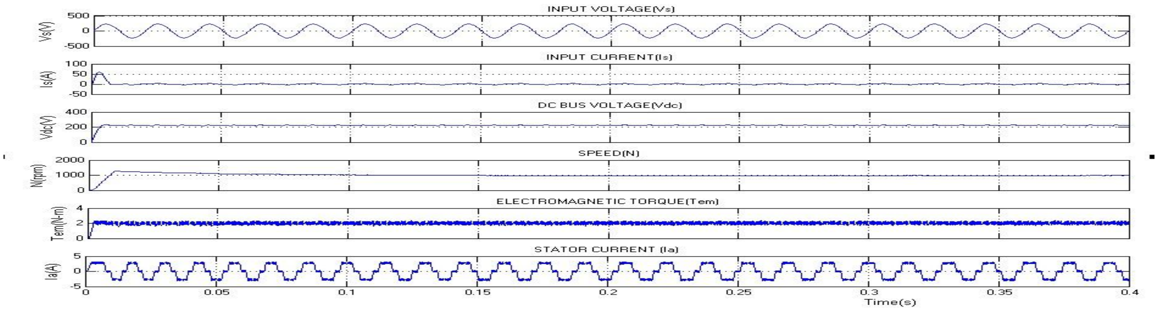

Fig.6. PMBLDC Motor without Power Factor Correction Controller Input Voltage, Current, Dc bus voltage, Speed, Electromagnetic torque and Stator current Waveforms

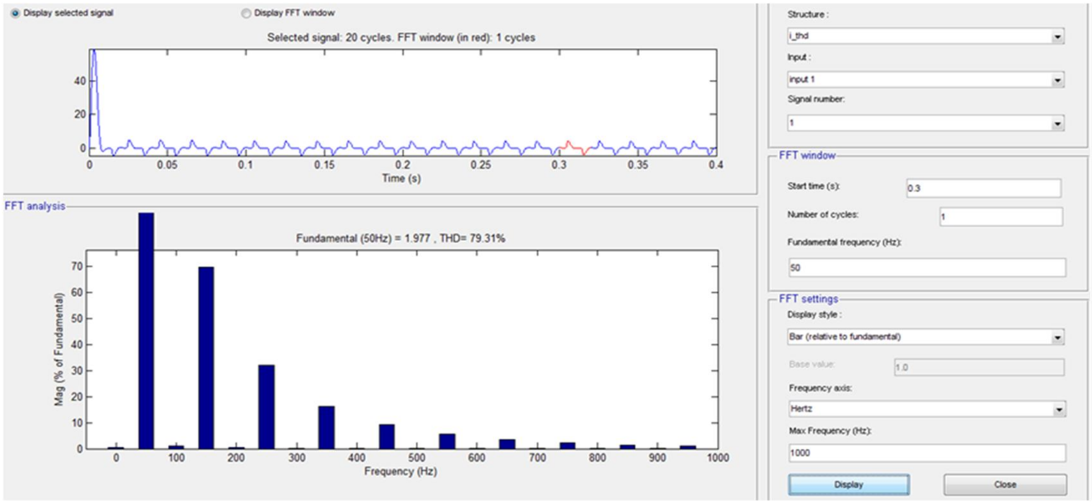

Fig.7.PMBLDC Motor without Power Factor Correction Controller Fast Fourier Transform (FFT) analysis of THD of Source current

Volume 5 Issue VI, June 2017
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

B. PMBLDC Motor with PFC controller using CUK Converter

When the IGBT'S are in ON state, the proposed topology transfers energy from the dc source into the inductors. Here, the current divides and equal currents are flowing through top inductor & IGBT and bottom inductor & IGBT. Input current waveform is plotted in graph as shown.THD reduced from 79.31% to 4.25% percentage is reduced further using this model and Power factor is raise from 0.76 to 0.97. Due to the addition of Canonical Switching Cells PFC controller is observed.

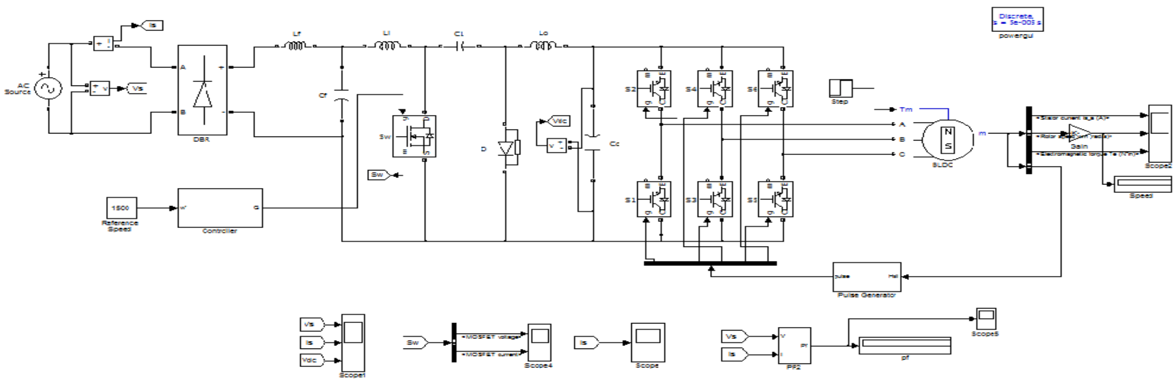

Fig.8.PMBLDC Motor Power Factor Correction CUK Controller.

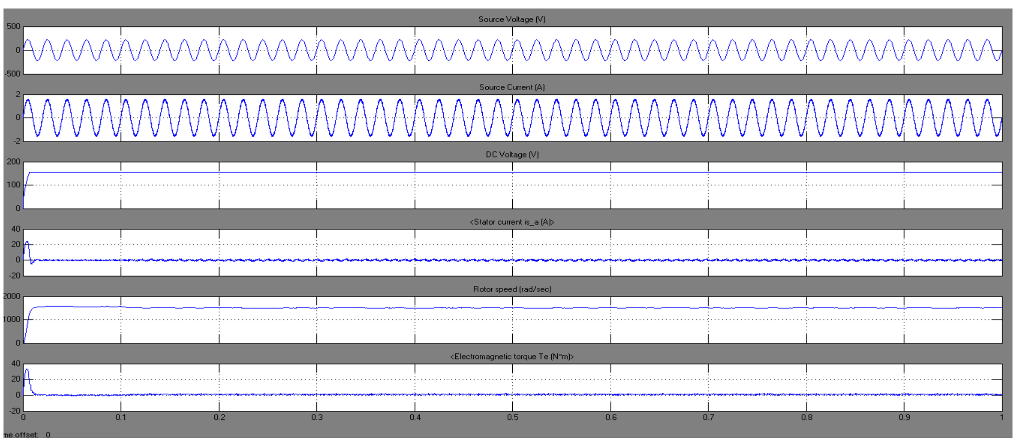

Fig.9. PMBLDC Motor Power Factor Correction Cuk Controller Input Voltage, Current, Dc bus voltage, Speed, Electromagnetic torque and Stator current Waveforms

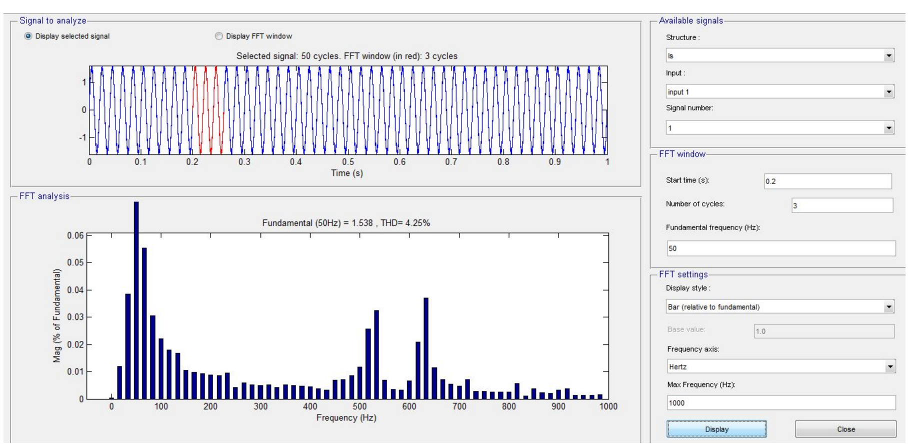

Fig.10.PMBLDC Motor Power Factor Correction Cuk Controller Fast Fourier Transform (FFT) analysis of THD of Source current

V. CONCLUSION

The Permanent Magnet Brushless DC (PMBLDC) motors are one of the electrical drives that are rapidly gaining popularity, due to

Volume 5 Issue VI, June 2017
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

their high efficiency, good dynamic response and low maintenance. A PFC circuit having Canonical switching cell converter was designed. The control strategy was based on average current mode control due to its relative advantages over voltage mode control and peak current mode control. Calculation of power factor was done for the purpose of comparison and to validate the improvement in power factor and THD for three different cases discussed. In case the power factor has improved from 0.762 to 0.97 and THD has reduced from 79.31% to 4.25%.

Method	THD of Source Current (%)	Power Factor
1. PMBLDC Motor without Power Factor Correction Controller	79.31%	0.762
2. PMBLDC Motor Power Factor Correction CUK Controller.	4.25%	0.97

VI. APPENDIX

BLDC Motor Specification

No of Poles	4
Stator Phase Resistance R_{On}	2.8750 Ω
Stator Phase Inductance L_{On}	8.5×10^{-3} H
Voltage constant K_b	146.607 V/krpm
Load Torque T_L	1.5 N/m
Torque Constant	1.4 Nm/A
Moment of Inertia J	1.25×10^{-3} Nm/S^2

REFERENCES

[1] B. Singh and G. D. Chaturvedi, ―Analysis, design and development of single switch Cuk ac–dc converter for low power battery charging application,‖ in Proc. IEEE PEDES, 2006, pp. 1–6.
[2] C. L. Puttaswamy, B. Singh, and B. P. Singh, ―Investigations on dynamic behavior of permanent magnet brushless dc motor drive,‖ Elect. Power Compon. Syst., vol. 23, no. 6, pp. 689–701, Nov. 1995.
[3] N. Mohan, M. Undeland, and W. P. Robbins, Power Electronics: Converters, Applications and Design. Hoboken, NJ: Wiley, 1995.
[4] Limits for Harmonic Current Emissions (Equipment Input Current ≤ 16 A per Phase), Int. Std. IEC 61000-3-2, 2000.
[5] S. Cuk and R. D. Middle brook, ―Advances in switched-mode power conversion Part-I,‖ IEEE Trans. Ind. Electron., vol. IE-30, no. 1, pp. 10–19, Feb. 1983.
[6] C. J. Tseng and C. L. Chen, ―A novel ZVT PWM Cuk power factor corrector,‖ IEEE Trans. Ind. Electron., vol. 46, no. 4, pp. 780–787, Aug. 1999.
[7] T. Kenjo and S. Nagamori, Permanent Magnet Brushless DC motors. Oxford, U.K.: Clarendon, 1985
[8] T.J. Sokira and W. Jaffe, Brushless DC Motors: Electronic Commutation and control. New York: Tab, 1989.

AUTHOR'S PROFILE

SK. Nagurbasha has done B. Tech in Electrical and Electronics Engineering from Eswar College of Engineering and M. Tech (PE & ED) in DVR & Dr. HS Mic College of Technology. Presently he is working as Asst. Professor, Department of EEE in Ayaan College Engineering and Technology, Moinabad.

G Sarath Babu has done B. Tech in Electrical and Electronics Engineering from RK College of Engineering and M. Tech (PE & ED) in DVR & Dr. HS Mic College of Technology. Presently he is working as Asst. Professor, Department of EEE in Ayaan College Engineering and Technology, Moinabad.