International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395 -0056
Volume: 03 Issue: 07 | July-2016 www.irjet.net p-ISSN: 2395-0072

Analysis of Power Factor Correctors For BLDC Motors

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Abstract – *This paper presents the analysis of different DC-to-DC converters for power factor correction of BLDC motor drive for low power applications. A power factor correction converter is placed between diode bridge rectifier and VSI while feeding a BLDC drive. The power quality problems due to uncontrolled charging of dc link capacitor in a permanent magnet BLDC motor can be reduced to great extent using power factor correction converters. In this paper Boost, Buck-Boost, SEPIC, Zeta and Cuk converters are analyzed. The performance analysis is done using MATLAB/SIMULINK software. The proposed converters have been designed for achieving an improved power quality operation with low amount of total harmonic distortion (THD) of supply current at AC mains for a wide range of speed control at varying supply voltages.*

***Key Words**: Brushless DC (BLDC) Motor, Power Factor correction(PFC) Converter, Power Quality, DC-to-DC Converters*

1.INTRODUCTION

Brushless DC motors (BLDC) are an invaluable part of industry today. Use of these motors can save any industry a great save of time and money under the right circumstances. The BLDC motor actually represents least the most recent end result of a long evolution of motor technology[4].

Power factor corrector makes the load look more like a resistive element than a nonlinear one without PFC. Modern PFC circuits can achieve power factor very near to unity[3]. The conventional PFC scheme of the BLDC motor drive utilizes a pulse width modulated voltage source inverter (PWM-VSI) for speed control with a consistent dc link voltage. This offers higher switching losses in VSI while the switching losses increase as a square function of switching frequency. While the speed of the BLDC motor is directly proportional to the applied dc link voltage, hence, the speed control is accomplished by the variable dc link voltage of VSI. This enables the fundamental frequency switching of VSI (i.e., electronic commutation) and offers reduced switching losses. BLDC motors have application in biomedical area. When large number of loads connected at same time it will affect the power quality and hence IEEE and IEC standards insist the use of power factor correction converters while feeding BLDC[7][8].

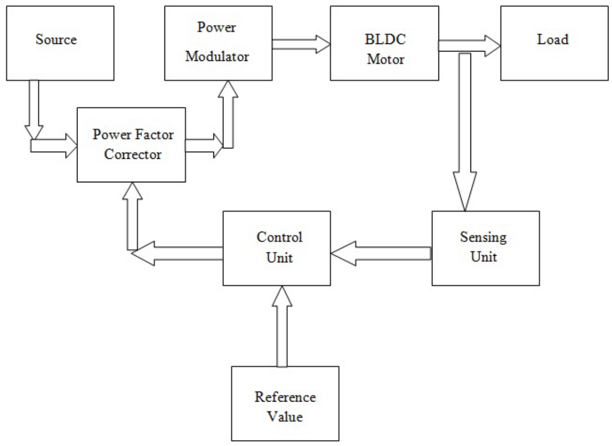

Fig -1: **Basic Block Diagram of PFC Fed BLDC Drive**

A BLDC motor when fed by way of a diode bridge rectifier (DBR) with a higher value of dc link capacitor draws peaky current which can cause a THD of supply current of the order of 65%[6] and power factor as little as 0.8.Hence, a DBR followed by way of a power factor corrected (PFC) converter is utilized for improving the ability quality at ac mains. The decision of mode of operation of a PFC converter is just a critical issue since it directly affects the price and rating of the components used in the PFC converter. The continuous conduction mode (CCM) and discontinuous conduction mode (DCM) are the 2 modes of operation by which a PFC converter is designed to operate. In CCM, the present in the inductor or the voltage over the intermediate capacitor remains continuous, but it needs the sensing of two voltages (dc link voltage and supply voltage) and input side current for PFC operation, that is not cost-effective. On another hand, DCM requires someone voltage sensor for dc link voltage control, and inherent PFC is achieved at the ac mains, but at the cost of higher stresses on the PFC converter switch; hence, DCM is preferred for low-power applications[1][2][3][14][17].

DC-DC converters have wide range of applications in area of electric drives. Converters can be used to establish dynamically boostable and well regulated output voltage for a dc motor drive. These converters are used in Electric Vehicles. Speed control of dc motor can also be achieved using dc-dc converters. Another important application of dc-dc converter is power factor correction and mitigation of supply current harmonics for permanent magnet brushless dc motor. Also loss minimization of drive can be done using dc-dc converter.

The pre regulator can be any one of the basic DC-to-DC converter topologies, for example, buck, boost, buck boost, cuk, sepic, zeta etc. These pre regulators are designed to draw an input current, which varies in direct proportion to the instantaneous input voltage. The control circuit control the root mean square(RMS) current drawn from the line. Though the circuits are more complex, power factor of almost unity is achievable with these high frequency topologies. In this work analysis of Boost ,Buck Boost, Sepic ,Zeta and Cuk converters are made.

2. Literature Survey

2.1 Brushless DC(BLDC) Motors

Brushless Direct Current (BLDC) motors are one of the motor types rapidly gaining popularity. BLDC motors are used in industries such as Appliances, Automotive, Aerospace, Consumer, Medical, Industrial Automation Equipment and Instrumentation It is a three-phase synchronous motor having torque–speed characteristics of a dc motor. It has three phase windings on the stator which are excited by a voltage source inverter (VSI) and permanent magnets on the rotor. It does not require any brushes and commutator assembly; rather, an electronic commutation based on the rotor position as sensed by Hall effect position sensors is used . Hence, the problems such as sparking, wear and tear of brushes, EMI, and noise interference are eliminated in the BLDC motor[10].

BLDC motors have many advantages over brushed DC motors and induction motors[11]. A few of these are:

- Better speed versus torque characteristics
- High dynamic response
- High efficiency
- Long operating life
- Noiseless operation
- Higher speed ranges

2.2 Power Factor Correction (PFC) Converters

When only diode bridge rectifier (DBR) is connected between the drive and utility, the smoothing capacitor gets charged and discharged during the high line periods and during that short time, high current spikes occur and the same spikes appear across the utility side[1][2][9]. This will deteriorate both power factor and overall system performance. Hence PFC converters are used. Since for the analysis converter output voltage should be made same for feeding VSI Boost, Buck Boost, Zeta, SEPIC and Cuk converters are taken as PFC converters in this work.

Power factor corrector makes the load look more like a resistive element than a nonlinear one without PFC. Modern PFC circuits can achieve power factor very near to unity[12]

PFC have the following advantages[15]

- Better source efficiency
- Overall lower power installation cost
- Lower conducted EMI
- Reduced peak current levels
- Ability to act as a filter for conducted EMI
- Common input filter for paralleled supplies

3. MATLAB/SIMULINK MODEL

The simulations for the analysis are done in MATLAB software and the models are given below.
Fig-2 Shows the simulation diagram for BLDC drive without PFC converter.

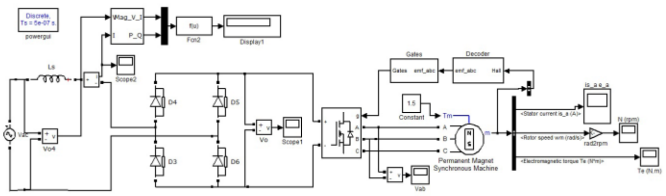

Fig -2: Simulation diagram for BLDC Drive Without PFC

Fig -3 to 7 Shows the simulation diagrams of BLDC drives with different DC-to-DC converters such as boost, buck-boost, SEPIC, cuk, zeta converters as PFC.

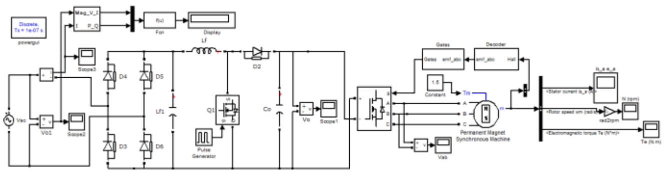

Fig -3: Simulation diagram for BLDC Drive with Boost converter as PFC

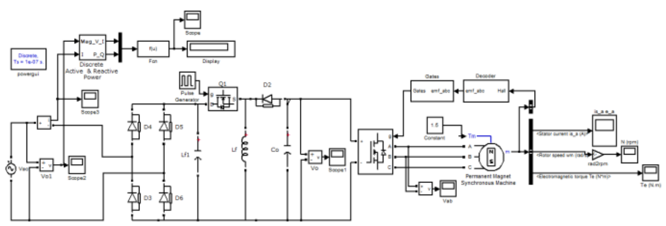

Fig -4: Simulation diagram for BLDC Drive with Buck-Boost converter as PFC

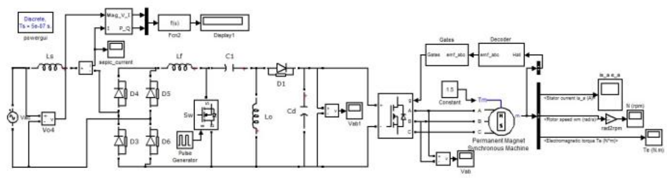

Fig -5: **Simulation diagram for BLDC Drive with SEPIC converter as PFC**

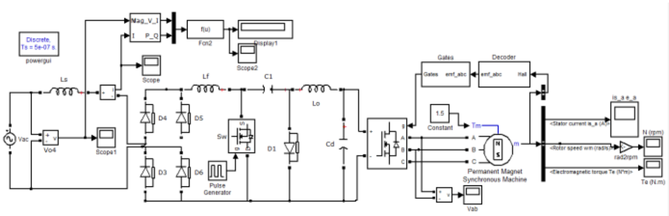

Fig -6: **Simulation diagram for BLDC Drive with Cuk converter as PFC**

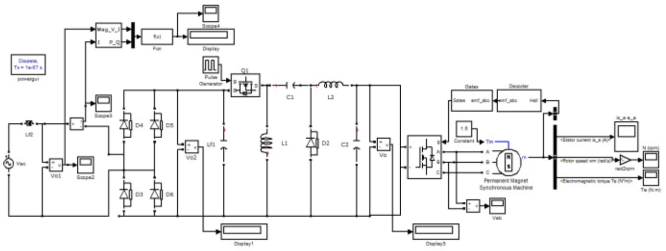

Fig -7: **Simulation diagram for BLDC Drive with Zeta converter as PFC**

4. SIMULATION RESULTS

4.1.Open loop response of BLDC Dive

The following responses are obtained from simulation of Open loop BLDC motor drive.

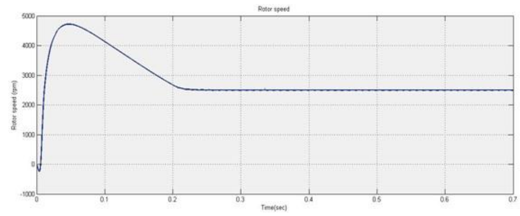

Fig -8. Speed curve

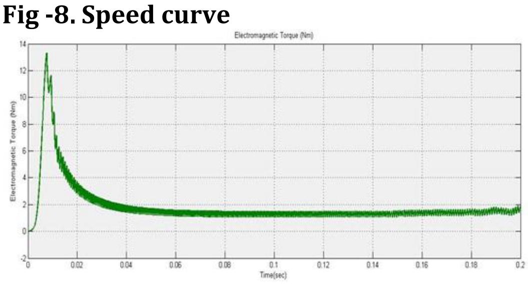

Fig -9. Torque Characteristics

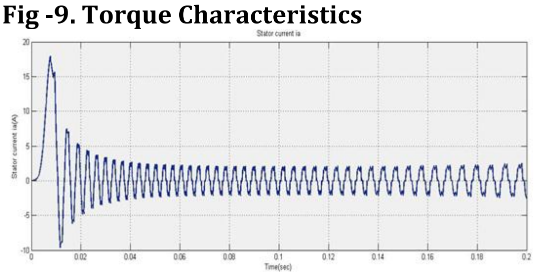

Fig -10. Stator current Characteristics

4.1.Simulation results for PFC converters

BLDC is Fed through VSI and the DC input to VSI is taken from Different DC to Dc Converters. The Converter Output Voltage for the analysis is set to 450V.

Fig-11 shows the Converter output voltage.

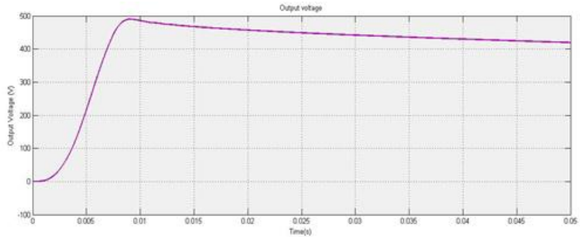

Fig -11. Output Voltage of PFC Converter

Fig-12 to 16 shows the THD levels for different PFC converters .Fig- 12 is THD level of boost converter which is more than 40%.

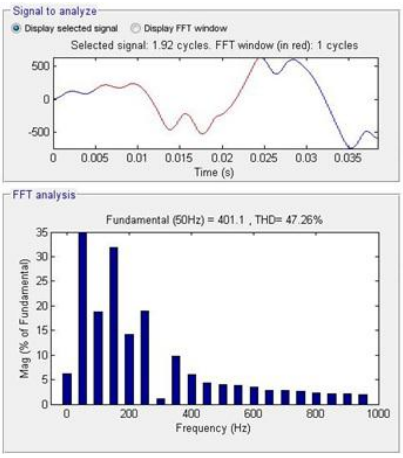

Fig -12. THD for Boost Converter FED BLDC Drive

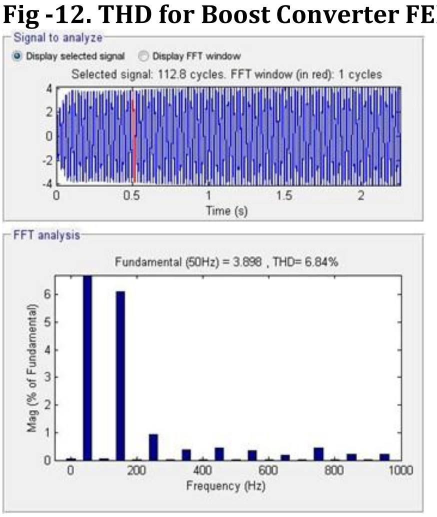

Fig -13. THD for Buck- Boost Converter FED BLDC Drive

Fig-13 Shows THD for Buck boost converter and the value is below 10%

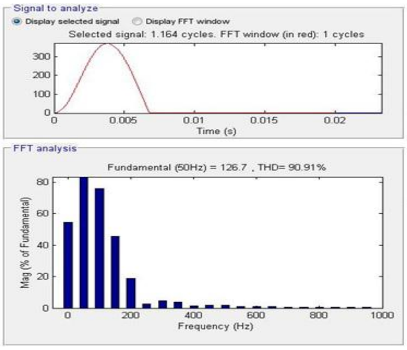

Fig -14. THD for SEPIC Converter FED BLDC Drive

Fig -14 shows THD for SEPIC converter which is much larger value even greater than buck boost converter

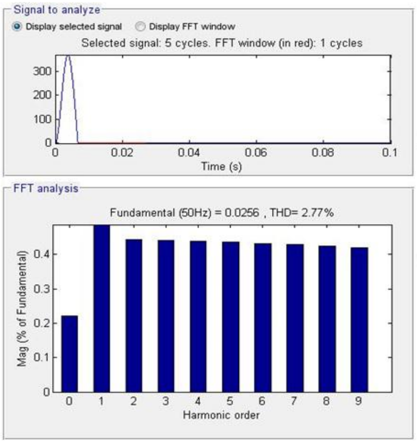

Fig -15. THD for Cuk Converter FED BLDC Drive

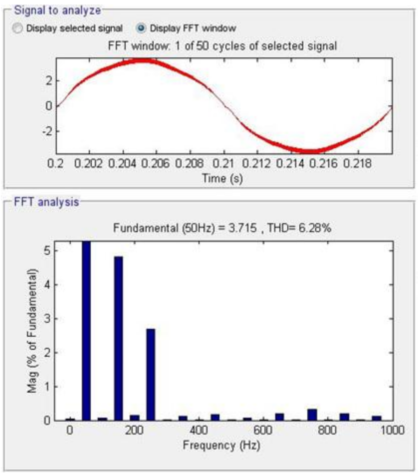

Fig -16. THD for Zeta Converter FED BLDC Drive

Fig-15 and Fig-16 shows harmonics for cuk and zeta converter respectively. Both are below 10%

4.3.Comparison

Table -1: Comparison of Power factor for different topologies

Converter Topology	Obtained Power Factor	THD(%)
Boost	0.9681	47.26
Buck - Boost	0.9732	6.84
Sepic	0.9768	90.91
Cuk	0.9954	2.77
Zeta	0.9968	6.28

Table -1 shows the comparison for power factor and THD for different PFC converters after the analysis .Its clear that Buck Boost, Zeta and Cuk converters have reduced harmonics. And the Power Factor is more near to unity for Zeta and Cuk.

5. CONCLUSION

The line current harmonics minimization is essential to comply with the standard resulting increase in degree of utilization of the grid power. This is discussed as the Power Factor Correction-PFC, in general. Five different DC –to- DC converters are proposed for the power factor correction and improving source current harmonics for BLDC drive. The simulation of these converters are presented in same working condition and From the comprehensive study Cuk and Zeta converters have power factor more near to unity with reduced THD level. The speed control for the motor drive can be made possible using these power factor correction converters.

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