ISSN 2394-3777 (Print)
ISSN 2394-3785 (Online)
Available online at www.ijartet.com

International Journal of Advanced Research Trends in Engineering and Technology (IJARTET)
Vol. 5, Special Issue 6, February 2018

POWER FACTOR REGULATION IN BLDC MOTOR USING LANDSMAN CONVERTER

Baby Salome Chandra C*, Dr. M Belsam Jeba Ananth#
*Final year M.E – Power Electronics and Drives, # Professor Head in EEE Department
*#DMI College of Engineering, Palanchur, Chennai - 600123, Tamil Nadu.
Affiliated to Anna University, Chennai – 600 113, Tamil Nadu.
babysalomechandra@gmail.com, belsamjebaananth@gmail.com

***Abstract* — This paper presents a novel configuration of (PFR) Power factor regulation based Landsman Converter feeding a (BLDCM) Brushless DC Motor Drive for low power applications. The speed control of the drive is achieved through adjusting the DC bus voltage source inverter (VSI) feeding to a BLDCM. Moreover, low frequency switching signals are used for electronic commutation of BLDCM, which reduces the switching power losses of six solid-state switches of VSI. The Landsman converter based front-end power factor corrector operating in discontinuous inductor current mode is used to control DC bus voltage and PFR is achieved inherently. The DC bus voltage of the drive is controlled by using a single DC voltage sensor. The performance of the BLDCM is also analysed for its operation at varying AC mains voltage.**

Keywords— VSI, PFR, Solid state switches, Electronic commutation, BLDCM.

I. INTRODUCTION

Among several electrical motors brushless DC Motor (BLDCM) is privileged in many medium and low power applications. BLDCM is suitable for many applications because of its ruggedness, high torque/inertia ratio, high efficiency and low electro-magnetic interference problems. Many applications including industrial tools heating ventilation and air conditioning, medical equipment, servo based control systems uses this motor. The stator of the BLDC Motor is made of three phase intense windings and its rotor has the permanent magnets. A Three leg voltage inverter is used for the electronic commutation of BLDCM based on the rotor position sensing with Hall-effect position sensors. Therefore problems such as wear and tear, sparking and EMI are eliminated.

A usual BLDCM consists of a diode bridge rectifier (DBR) with DC bus capacitor followed by a VSI. Three phase pulse with modulation signals are used for driving the six solid-state switches of the VSI feeding the BLDCM drive. Such scheme draws peaky current from the supply system and leads to low power factor at the AC mains and a high value of total harmonic distortion (THD) in source current. Many configurations of PFC converter driven BLDCM Drives have been anticipated for various applications.

II. MOTIVATION

This paper aims to improve the power factor using Landsman converter for PMBLDCM motor application. Mainly in Air conditioning systems it is used to improve the power factor. Smooth start- up of air conditioning systems without fluctuations is difficult in conventional systems. The use of PMBLDCM for driving the compressor results in energy efficiency improvement of the Air-con. The temperature in the air-conditioned zone can be maintained at the set reference smoothly while operating the Air-con. under speed control.

The main scope of the project is to improve the voltage gain in converters. Consequently improves the efficiency of the converters and decrease the high current usage in the rectifier topology. Unity power factor reduces the EMI and conduction losses and improves the load regulation also. The rotor position signals are required only for electronic commutation of BLDC using switching of voltage source inverter.

III. LITERATURE REVIEW

A. Existing System

In the existing system permanent magnet brushless DC Motor is replacing single phase induction motor used in air conditioners.

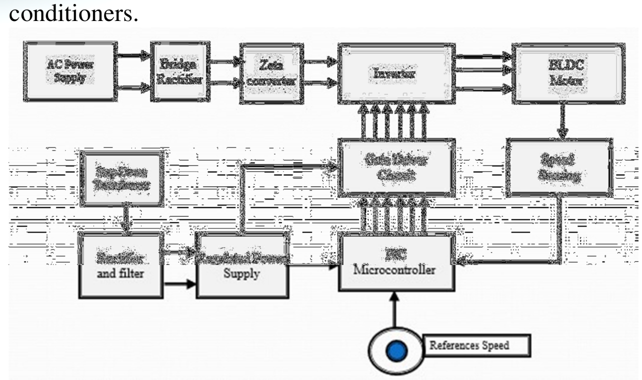

Fig 1.Block Diagram of Existing System

ISSN 2394-3777 (Print)
ISSN 2394-3785 (Online)
Available online at www.ijartet.com

International Journal of Advanced Research Trends in Engineering and Technology (IJARTET)
Vol. 5, Special Issue 6, February 2018

As shown in fig1 BLDCMs are fed from a single phase AC mains through a diode bridge rectifier and a smoothening dc link capacitor, which results in a pulsed current from AC mains having various power quality disturbances such as poor power factor, increased total harmonic distortion which reduces the power quality and causes unwanted electro magnetic interferences.

B. Proposed System

In order to improve the power factor bridgeless SEPIC Converter is used for BLDC Motor application. The bridgeless SEPIC Converter is configured from a buck controller that drives high-speed PMOSFET. The bridgeless SEPIC Converter is another option for regulating an unregulated input-power supply. The Rotor position signals are required only for electronic commutation of BLDC using switching of voltage source inverter.

IV. PROPOSED SYSTEM

The Block diagram of proposed system is shown in Fig2. The proposed system technique uses the Landsman Converter topology provides a positive output with the help of two inductors and a series capacitor known as flying capacitor.

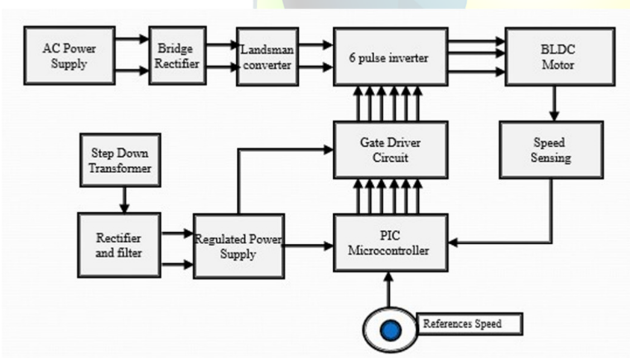

Fig2 Block Diagram of Proposed system

A. BLDC Motor

BLDC Motors-Brushless Direct Current Motors are also known as Electronically Commutated Motors (ECM) which is shown in fig3. are synchronous electric motors generated by Direct Current electricity and having electronic commutation systems.. It uses the permanent magnet external rotor, driving coils, hall effect devices to sense the position of the rotor and the associated drive electronics. The Brushless DC Motors does not have commutators and brushes physically. Hence wear and tear does not takes place. Stator windings should be energized in a sequence in order to rotate the BLDC Motor. Rotor position is sensed by Hall Effect Sensors.

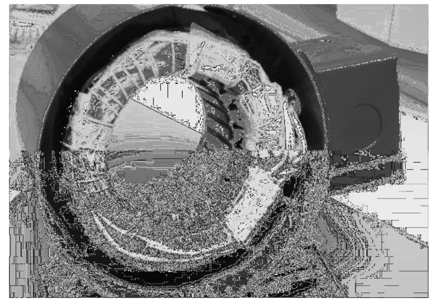

Fig 3 BLDC Motor

Compare to the alloy material has high magnetic density per volume and enables the rotor to compress further for the same torque. In addition these alloy magnets improve the size-to-weight ratio and give higher torque for the same size motor using ferrite magnets shown in fig4 & fig 5.

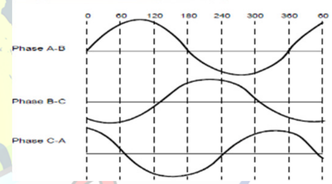

Fig 4 Trapezoidal Motor

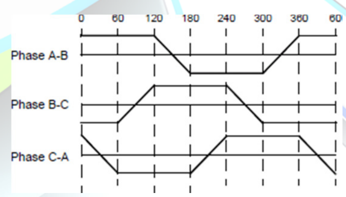

Fig 5 Sinusoidal Motor

The motor can be loaded up to the rated torque during continuous operation. The torque will remain constant until the rated speed. After that the torque will start dropping in order to run up the motor to the rated speed as shown in fig 6.

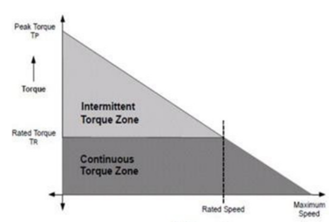

Fig 6 Torque / Speed Characteristics

ISSN 2394-3777 (Print)
ISSN 2394-3785 (Online)
Available online at www.ijartet.com

International Journal of Advanced Research Trends in Engineering and Technology (IJARTET)
Vol. 5, Special Issue 6, February 2018

One of the Hall Sensors changes the state and it takes six steps to complete an electrical cycle in every 60 electrical degrees of rotation and also the phase current switching will be updated. Rotor pole pairs will determine the number of electrical cycles to be repeated. It means that for each rotor pole pairs they are equal to one electrical cycle. To vary the speed these Pulse Width Modulation signals should have higher frequency than that of the motor frequency. When the average voltage supplied to the stator reduces, the speed will also reduce within the sequences as shown n the fig 7 & 8.

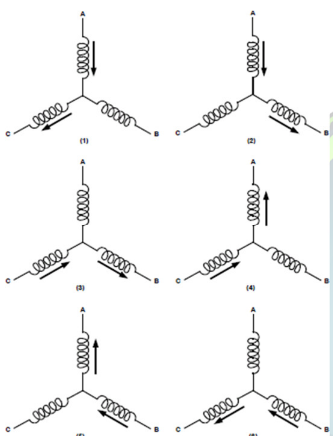

Fig 7 Winding Energizing Sequence with Respect to Hall Sensor

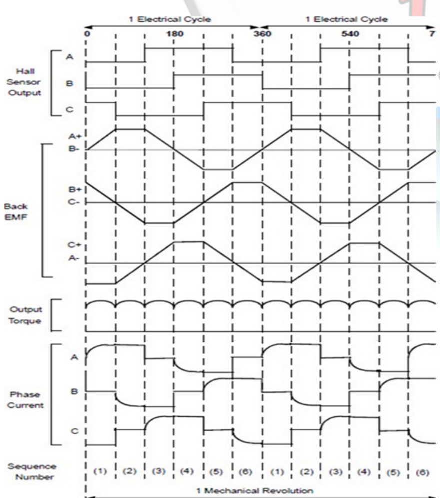

Fig 8 Hall Sensor Signal

Table 1 Comparison of BLDC Motor and Brushed DC Motor

BLDC Motor	Brushed DC Motor
Electronic commutation based on Hall position sensors.	Brushed commutation.
Less required due to absence of brushes.	Periodic maintenance is required.
Longer.	Shorter.
Flat – Enables operation at all speeds with rated load	Moderately flat – At higher speeds, brush friction increases, thus reducing useful torque.
High – No voltage drop across brushes	Moderate.
High – Reduced size due to superior thermal characteristics. Because BLDC has the windings on the stator, which is connected to the case, the heat dissipation is better.	Moderate/Low – The heat produced by the armature is dissipated in the air gap, thus increasing the temperature in the air gap and limiting specs on the output power/frame size.
Low, because it has permanent magnets on the rotor. This improves the dynamic response.	Higher rotor inertia which limits the dynamic characteristics
Higher – No mechanical limitation imposed by Brushes/commutator.	Lower – Mechanical limitations by the brushes.
Low.	Arcs in the brushes will generate noise causing EMI in the equipment nearby.
Higher – Since it has permanent magnets, building Costs are higher.	Low.
Complex and expensive.	Simple and inexpensive.
A controller is always required to keep the motor running. The same controller can be used for variable speed control.	No controller is required for fixed speed; a controller is required only if variable speed is desired.

Battery operated Vehicles, Fuel Pumps, Medical Equipments are some of the application of BLDC Motors. It is also used in industrial and aerospace applications because of its light weight, high operating speed and excellent speed torque characteristics

ISSN 2394-3777 (Print)
ISSN 2394-3785 (Online)
Available online at www.ijartet.com

International Journal of Advanced Research Trends in Engineering and Technology (IJARTET)
Vol. 5, Special Issue 6, February 2018

Table 2 Advantages of BLDC Motor

BLDC Advantage	Underlying Reasons
Smaller motor	Modern permanent magnets and no losses in the rotor enable BLDC motor to be smaller compared to both brush DC motors and induction AC motors.
More efficient motor	Permanent magnet in the rotor. Unlike AC induction motors, there are no core losses in the rotor.
Higher speeds	No brushes to limit speed, lower speed losses by design. BLDC motors have been designed for speeds as high as 100,000 RPM. The problem of retention of magnets, in a rotor spinning at high speeds, has long been solved.
No maintenance	No brushes to replace, inspect or maintain
Lower RFI (radio frequency interference)	Lower rotor inertia compared to a brushless motor or an induction motor
Linear speed-torque characteristics	No brushes
High starting torque	Internal shaft position feedback. Permanent magnet design with internal shaft position feedback gives BLDC motors linear speed-torque characteristics when compared to "open loop" AC induction motors
Adjustable speed	Internal shaft position feedback gives BLDC motors higher starting and low speed torque when compared to "open loop" AC induction motors.
Better heat removal	The commutation electronics can be used for speed control without added cost
Better Control	Linear speed torque characteristics

B Landsman Converter

Landsman Converter based PFR is designed to operate in DICM for natural PF regulation at AC Mains shown in fig9.The current in input inductor (Li) becomes discontinuous during switching period (Ts) in DICM operation. There are three operating stages of a PFR Landsman Converter. Variation of voltage and current waveforms of different variables of Landsman Converter such as switch gate voltage, inductor currents, intermediate capacitor voltage are observed.

Various Modes of operation of the Landsman converter are explained here.

Mode 1

When switch (Sw) is on the energy from the supply and stored energy in the intermediate capacitor (C1) are transferred to input inductor (Li). The output inductor (Lo) starts discharging and the voltage of intermediate capacitor (Vc1) starts reducing while DC-link voltage (Vdc) starts increasing shown in fig10.The value of intermediate capacitor is large enough to store required energy such that the voltage across the capacitor does not becomes discontinuous.

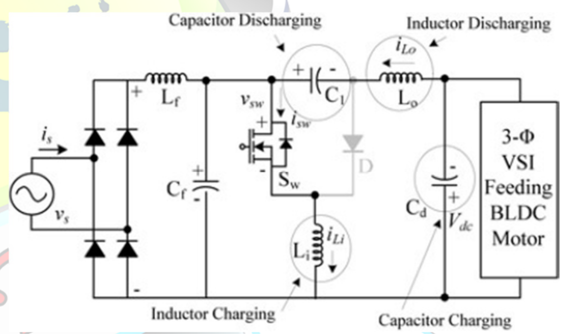

Fig 9.Mode 1 operation of Landsman converter

Mode 2

In this mode of converter operation,switch is turned off. An intermediate capacitor (C1) and dc link side inductor (L0) are charging through the supply current while output inductor (Li) starts discharging shown in fig 11.

Hence Vc1 starts increasing in this mode. Moreover the voltage across the DC capacitor decreases. The phase voltages have six steps per cycle and line voltages have one positive pulse and one negative pulse per cycle. The phase as well as line voltages are out of phase by 120-degree.So the function of the diodes is to allow the flow of currents through them when the load is reactive in nature. The line voltage waveforms represent a balanced set of three phase alternating voltages. During six intervals these voltages are well defined. Therefore these voltages are independent of the nature of the load circuit which may consist of any combination of resistances.

ISSN 2394-3777 (Print)
ISSN 2394-3785 (Online)
Available online at www.ijartet.com

International Journal of Advanced Research Trends in Engineering and Technology (IJARTET)
Vol. 5, Special Issue 6, February 2018

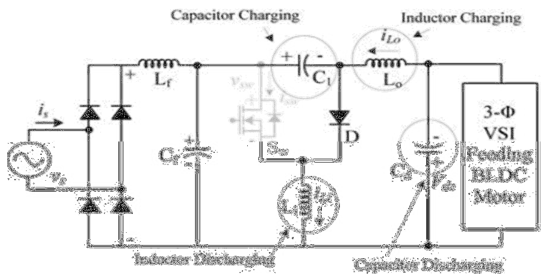

Fig.10 Mode 2 operation of Landsman Converter

Mode 3

This is the DCM for converter operation as the input inductor (Li) is discharged completely and current iLi becomes zero. The current of DC bus side inductor (iL0) starts increasing and the voltage of intermediate capacitor (Vc1) continues to decrease in this mode shown in fig.12

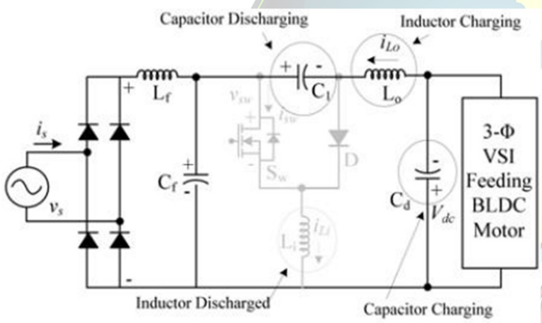

Fig.11 Mode 3 operation of Landsman Converter

C Six step Three Phase Voltage Source Inverter

The Power Circuit Diagram of the six step three phase voltage source inverter connected with the BLDC Motor is shown in fig.13.

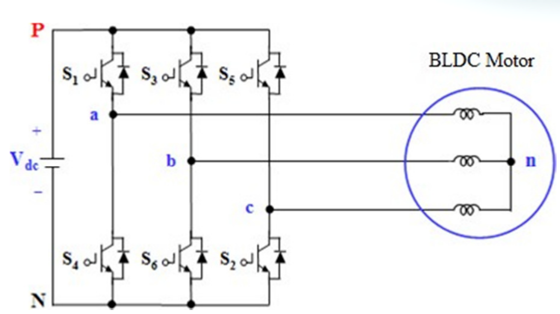

Fig.12 Six step Three Phase Voltage Source Inverter

For the 180-degree mode Voltage Source Inverter, each MOSFET conducts for 180-degree of a cycle. Like a 180° mode,120° mode inverter also requires six steps, each of 60 degree duration, for completing one cycle of the output ac voltage shown in fig 13.

The MOSFETs are numbered in the sequence in which they are triggered to obtain voltages Vab, Vbc, Vca at the output terminals a, b and c of the inverter. For each of the six steps are named as s1,s2,s3,s4,s5,s6 respectively.

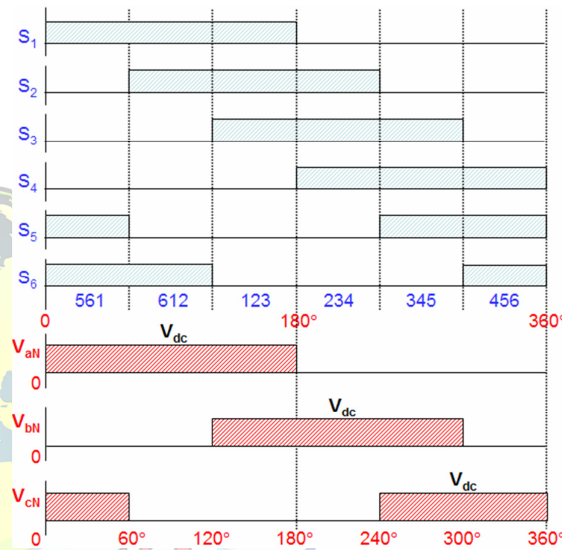

Fig.13 Waveforms of Gating signals and the switching sequence

Waveforms of Line to Neutral voltages shown in fig.14.

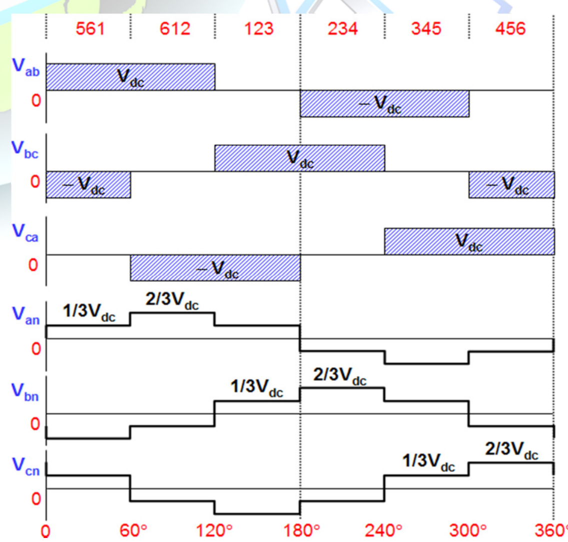

Fig.14 Waveforms of Line to Neutral Voltages

ISSN 2394-3777 (Print)
ISSN 2394-3785 (Online)
Available online at www.ijartet.com

International Journal of Advanced Research Trends in Engineering and Technology (IJARTET)
Vol. 5, Special Issue 6, February 2018

D PIC Microcontrollers

The Microcontroller is the heart of the power saving unit, which gets the data from sensor and driver circuit. It is an integrated chip that is often part of an embedded system. The Microcontroller acts like the brain of the BLDC Motor speed control system. The Microcontroller chip that has been selected for the purpose of controlling the speed of BLDC Motor. The Microcontroller chip PIC16F870 is shown in fig.15.

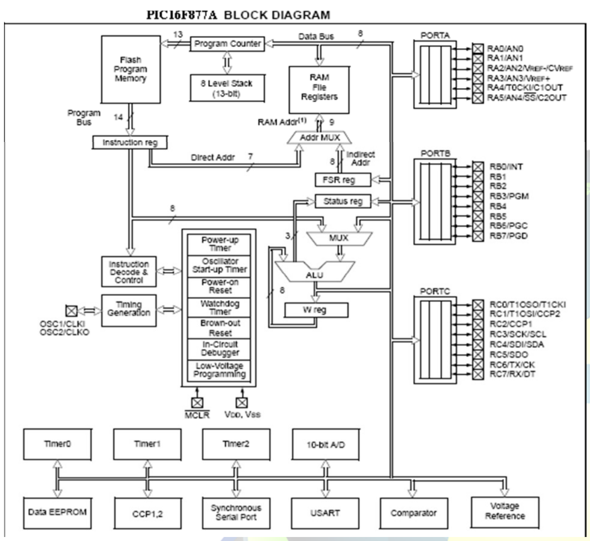

Fig.15 PIC16F70 Block Diagram

Reasons for selecting PIC16F70

- Its size is small and equipped with sufficient output ports without having to use a decoder or multiplexer
- Because of its portability and low power consumption
- It has inbuilt PWM which allows the duty cycle to be varied.
- It is a simple and powerful microcontroller, users only need to learn 35 single word instuctions in order to program the chip.

V.SIMULATION RESULTS

MATLAB is a high-performance language for technical computing. Its integration computation, visualization and programming in an easy to use environment where problems and solutions are expressed in familiar mathematical notation.

MATLAB is an interactive system whose basic data element is an array that does not require dimensioning.

Key Features

- High-level language for technical computing.
- Development environment for managing code, files and data
- Tools for building custom graphical user interfaces.
- Interactive tool for iterative exploration, design and problem solving.

In order to verify the effectiveness of the proposed system the variations in input voltage, speed, torque and power factor waveforms are analyzed and shown in the following figures.

Fig.16 Input voltage

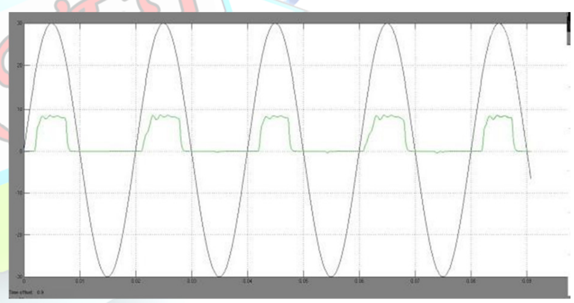

Fig.17.Rectified Voltage

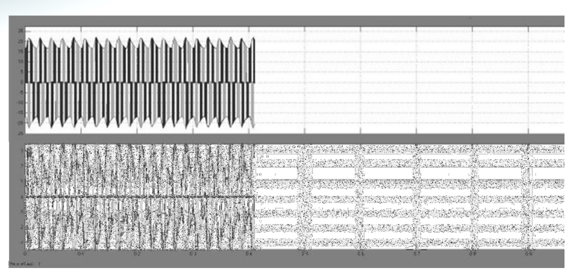

Fig.18 Motor Torque

Speed curve and the Powerfactor curve are also analyzed. From the graph improved powerfactor is also viewed.

ISSN 2394-3777 (Print)
ISSN 2394-3785 (Online)
Available online at www.ijartet.com

International Journal of Advanced Research Trends in Engineering and Technology (IJARTET)
Vol. 5, Special Issue 6, February 2018

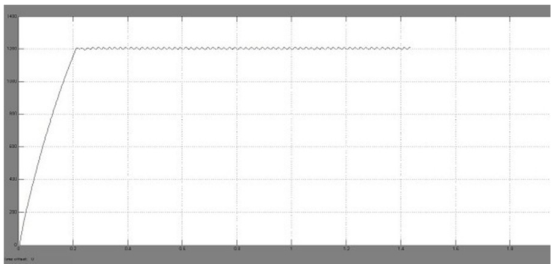

Fig.19 Motor speed

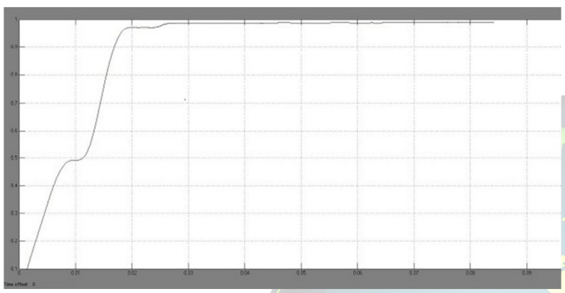

Fig.20 Powerfactor

Powerfactor Comparison

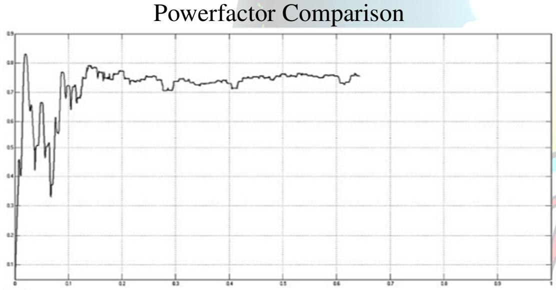

Fig.21 Zeta converter

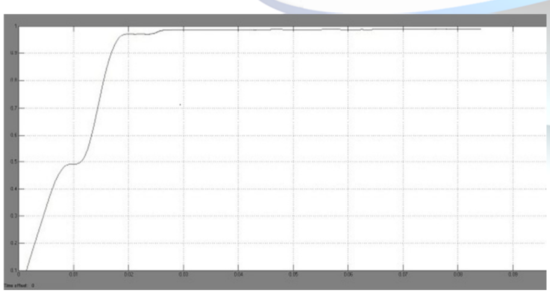

Fig.22 Landsman Converter

Thus the results are compared and verified with existing system using Zeta converter and the proposed system using Landsman converter. The power factor obtained from the proposed system is nearing unity is the gain factor for the system. The speed control of the system is also considerably satisfactory. Gain in the power system and the power quality issues are also satisfied.Power losses are reduced considerably.

VI. FUTURE ENHANCEMENTS

The Project can be extended for effectively for house hold item like Air Conditioners, Industrial, Aerospace applications like Satellites, Seat actuation, Valves, Window shades and solar array deployment.

VII. CONCLUSION

The Power factor correction has been successfully implemented using the Landsman converter. It shows a much improved result as it not only provides better power quality, but also the response. The PID Controller widely increases application range of the motor by increasing the reliability. The motor is presently used in areas such as aerospace, aircraft and mining applications because of the enhanced reliability that the motor offers. This is further enhanced by the usage of NFLC and the PFC converters. The NFLC is used to control the motor speed and the Landsman converter is used for power factor improvement. It is found that the Landsman converter is found to provide better power quality.

ACKNOWLEDGMENT

We would like to start by thanking the Almighty and our Parents, who gave us knowledge and good health and made us to finish the project successfully. We express our sincere thanks to our Principal and HOD.

REFERENCE

[1] Gieras, J.F., Wing, M.: 'Permanent magnet motor technology-design and application' (Marcel Dekker Inc., New York, 2011).

[2] Zhu, Z.Q., Howe, D.: 'Electrical machines and drives for electric, hybrid, and fuel cell vehicles', *IEEE Proc*., 2007, 95, (4), pp. 746–765

[3] Sozer, Y., Torrey, D.A., Mese, E.: 'Adaptive predictive current control technique for permanent magnet synchronous motors', *IET Power Electron*., 2013, 6, pp. 9–19.

[4] Hung, C.W., Lin, C.T., Liu, C.W., et al.: 'A variable-sampling controller for brushless DC motor drives with low-resolution position sensors', *IEEE Trans.* Ind. Electron., 2007, 54, (5), pp. 2846–2852

[5] Joice, C.S., Paranjothi, S.R., Kumar, V.J.S.: 'Digital control strategy for four quadrant operation of three phase BLDC motor with load variations', *IEEE Trans.* Ind. Inf., 2013, 9, (2), pp. 974–982

[6] Baszynski, M., Pirog, S.: 'A novel speed measurement method for a high-speed BLDC motor

ISSN 2394-3777 (Print)
ISSN 2394-3785 (Online)
Available online at www.ijartet.com

International Journal of Advanced Research Trends in Engineering and Technology (IJARTET)
Vol. 5, Special Issue 6, February 2018

based on the signals from the rotor position sensor', *IEEE Trans. Ind. Inf.*, 2014, 10, (1), pp. 84–91.

[7] Sokira, T.J., Jaffe, W.: 'Brushless DC motors: electronic commutation and control' (Tab Books, USA, 1989).

[8] Toliyat, H.A., Campbell, S.: 'DSP-based electromechanical motion control' (CRC Press, New York, 2004).

[9] Chen, Y.T., Chiu, C.L., Jhang, Y.R., et al.: 'A driver for the single-phase brushless DC fan motor with hybrid winding structure', *IEEE Trans. Ind. Electron.*, 2013, 60, (10), pp. 4369–4375.

[10] De, S., Rajne, M., Poosapati, S., et al.: 'Low-inductance axial flux BLDC motor drive for more electric aircraft', *IET Power Electron.*, 2012, 5, (1), *pp*. 124–133

[11] Nikam, S.P., Rallabandi, V., Fernandes, B.G.: 'A high-torque-density permanent-magnet free motor for in-wheel electric vehicle application', *IEEE Trans. Ind. Appl.*, 2012, 48, (6), pp. 2287–2295

[12] Singh, B., Bist, V.: 'An improved power quality bridgeless Cuk converter fed BLDC motor drive for air conditioning system', IET Power Electron., 2013, 6, (5), pp. 902–913

[13] Hwang, C.C., Li, P.L., Liu, C.T., et al.: 'Design and analysis of a brushless DC motor for applications in robotics', *IET Electr. Power Appl.,* 2012, 6, (7), cu 385–389

[14] Mohan, N., Undeland, T.M., Robbins, W.P.: 'Power electronics: converters, applications and design' (John Wiley and Sons Inc, USA, 2003).

[15] Limits for Harmonic Current Emissions (Equipment input current ≤16 A per phase phase), *International Standard IEC 61000-3-2, 2014*

[16] Singh, B., Singh, S.: 'Single-phase power factor controller topologies for permanent magnet brushless DC motor drives', *IET Power Electron., 2010, 3, (2), pp. 147–175*

[17] Singh, S., Bist, V., Singh, B., et al.: 'Power factor correction in switched mode power supply for computers using canonical switching cell converter', *IET Power Electron.,* 2015, 8, *pp. 234–244.*

[18] Singh, B., Singh, S., Chandra, A., et al.: 'Comprehensive study of single-phase AC-DC power factor corrected converters with high-frequency isolation', *IEEE Trans. Ind. Inf., 2011, 7, (4), pp. 540–556.*

[19] Huber, L., Zhang, J., Jovanovic, M.M., et al.: 'Generalized topologies of single-stage input-current-shaping circuits', *IEEE Trans. Power Electro*n., 2001, 6, pp. 508–513

[20] Shrivastava, A., Singh, B.: 'Constant on time controlled zero voltage switching electronic ballast with power quality improvement', *IET Power Electron., 2015, 8pp. 1710–17*