



IMPROVING POWER FACTOR USING LANDSMAN CONVERTER IN PMBLDC MOTOR

E.Annie Elisabeth Jebaseeli¹, V.Geetha²,
R.Meenadevi³

^{1,2,3} Department of Electrical and Electronics

^{1,2,3} Sathyabama institute of science and
technology Chennai 119

Email:¹anniejebaseeli@gmail.com

²geethasendray28@gmail.com

³devimalathi2010@gmail.com

July 4, 2018

Abstract

Among several electrical motors, brushless DC motor is privileged in many medium and low power appliances. BLDC Motor is suitable for many applications because of its, ruggedness, high torque/inertia ratio, high efficiency and low electro-magnetic interference (EMI) problems. A three-leg voltage source inverter is used for the electronic commutation of BLDCM based on the rotor position sensing with Hall-effect position sensors. Therefore, inherent problems with brushes and mechanical commutator assembly such as wear and tear, sparking and EMI are eliminated. This paper deals with a highly reliable electrical drive utilizing the Brushless DC Motor. The motor is fed by Voltage source Inverter (VSI) with a dc-dc converter power factor correction circuit (PFC) as the VSIs predecessor. The Performance of dc-dc converters is analyzed and the results are discussed to arrive at the best suited converter. PID Logic

Controller is used as the Intelligent Controller for the BLDC motor. Reliable, low cost arrangement is thus provided to achieve unity power factor and speed regulation with accuracy.

Keywords: PMBL DC motor, power factor, Landsman converter.

1 Introduction

The single phase induction motor used in air conditioners for driving compressor and fan is now replaced by permanent magnet brushless DC motor for its low power consumption. BLDCMs are fed from a single-phase AC mains through a diode bridge rectifier (DBR) and a smoothening DC link capacitor[1]-[13]. This results in a pulsed current from AC mains having various power quality (PQ) disturbances such as poor power factor (PF), increased total harmonic distortion (THD) harmonics which reduces the power quality and causes unwanted electromagnetic interference. In this paper LANDSMAN converter topology is used to provide a positive output from an input voltage[14]-[18]. The LANDSMAN converter consists of inductors and a series capacitor, sometimes called a flying capacitor. Unlike the SEPIC converter, which is configured with standard boost converter, the LANDSMAN converter is configured from a buck converter[19]-[23]. The LANDSMAN converter is another option for regulating an unregulated input-power supply, like a low-cost wall wart. Landsman converter-based Power Factor Rectifier as shown in figure1 is designed to operate in Discontinuous conduction mode for natural PF regulation at AC mains[24]. The current in input inductor (Li) becomes discontinuous during switching period (Ts) in DICM operation. Three operating stages of a PFR Landsman converter are discussed in this section.

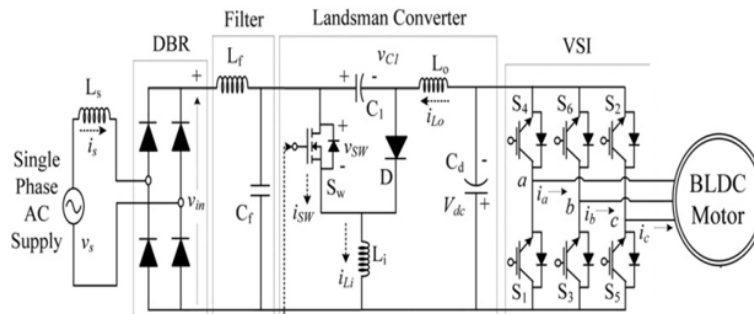


Fig.1 Landsman converter
MODES OF OPERATION

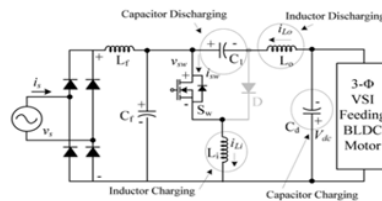


Fig. 2 Modes of operation in mode-1

In Fig 2, when switch (Sw) is on, an energy from the supply and stored energy in the intermediate capacitor (C_1) are transferred to input inductor (L_i). The output inductor (L_o) starts discharging and the voltage of intermediate capacitor (v_{C1}) starts reducing while DC-link voltage (V_{dc}) starts increasing. The value of intermediate capacitor is large enough to store required energy such that the voltage across the capacitor does not become discontinuous.

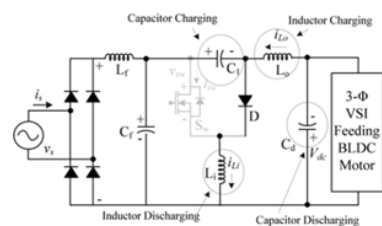


Fig.3 Modes of operation in mode-2

In Fig 3, switch is turned-off. An intermediate capacitor (C_1) and DC-link side inductor (L_o) are charging through the supply

current while output inductor (L_i) starts discharging. Hence, v_{C1} starts increasing in this mode. Moreover, the voltage across the DC capacitor (V_{dc}) decreases.

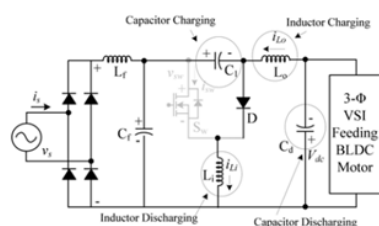


Fig.4 .Modes of operation in mode-4

Fig.4 .shows the DCM for converter operation as the input inductor (L_i) is discharged completely and current i_{Li} becomes zero. The current of DC bus side inductor (i_{Lo}) starts increasing and the voltage of intermediary capacitor (v_{C1}) continues to decrease in this mode.

2 Simulation

The system shown in fig 5 is used to implement the power factor correction in BLDC motor using Landsman converter. The AC source will be rectified by bridge rectifier and filtered by LC filter. The landsman converter converts the voltage level. The six pulse inverter converts the DC voltage to AC voltage. The PI controller controls the output voltage of the converter according to the speed. For the 180° mode VSI, each MOSFET conducts for 180° of a cycle. Like a 180° mode, 120° mode inverter also requires six steps, each of 60° duration, for completing one cycle of the output ac voltage. Where, S1 to S6 are the MOSFETs and the three phase load is assumed to be star connected. The MOSFETs are numbered in the sequence in which they are triggered to obtain voltages v_{ab}, v_{bc}, v_{ca} at the output terminals a, b and c of the inverter. The power circuit diagram of this inverter is shown in the Fig.6

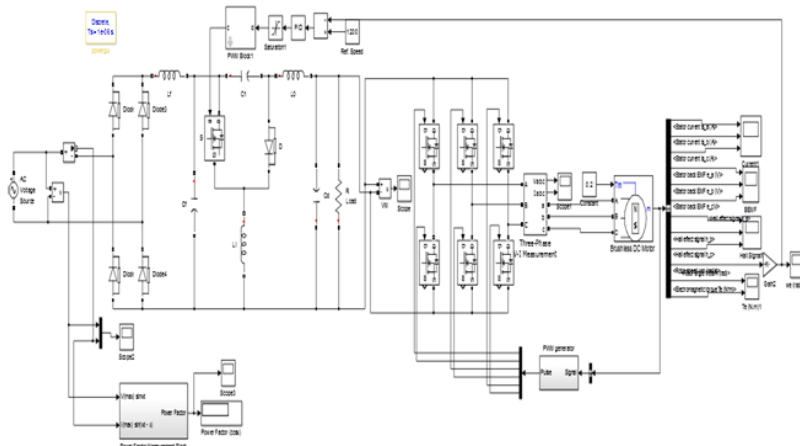


Fig.5 Power factor correction using Landsman converter

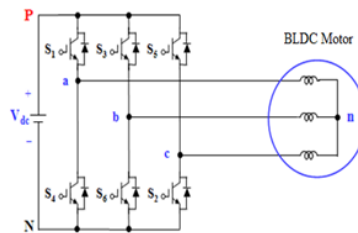


Fig.6 Three-Phase Voltage Source Inverter.

It means that S1 conducts for 180° of a cycle. MOSFETs in the upper group, i.e. S1, S3, S5 conduct at an interval of 120° . It implies that if S1 is fired at 0° then S3 must be fired at 120° and S5 at 240° . Same is true for lower group of MOSFETs. Thus as seen from the Fig.3.2 only three MOSFETs are conducting one from upper group and two from lower group or two from upper group and one from lower group. The switching sequence for the six step voltage source inverter is :561 (V1) 612 (V2) 123 (V3) 234 (V4) 345 (V5) 456 (V6) 561 (V1), Where, 561 means that S5, S6 and S1 are switched on similarly the other sequences. The phase voltages have six steps per cycle and line voltages have one positive pulse and one negative pulse (each of 120° duration) per cycle. The phase as well as line voltages are out of phase by 120° so, the function

of the diodes is to allow the flow of currents through them when the load is reactive in nature. In fig 7 and 8, the waveforms for input voltage , current and output voltage are given. The phase difference between voltage and current is observed from the fig.9.

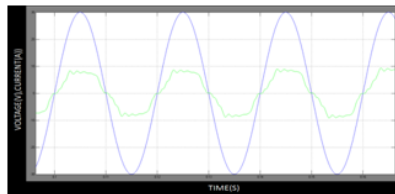


Fig.7 Input voltage and current

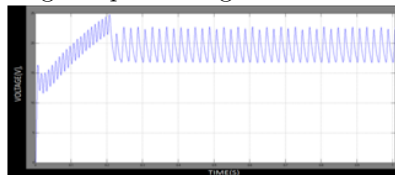


Fig.8 converter output voltage

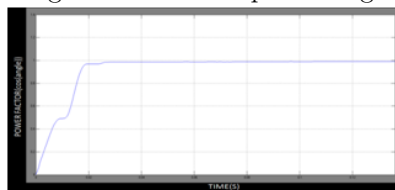


Fig .9 shows the power factor of this system.

Figure 10 shows the BLDC motor. It is a permanent magnet 24V BLDC motor. The specification of this motor is given below
Landsman converter is shown in fig.11.

Specification:

Power : 200 W

Voltage : 24 V

Speed : 1500 rpm

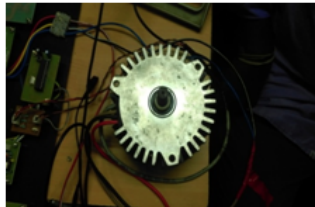


Fig.10. BLDC motor



Fig.11. Landsman converter

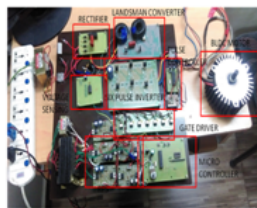


Fig.12. Hardware Implementation

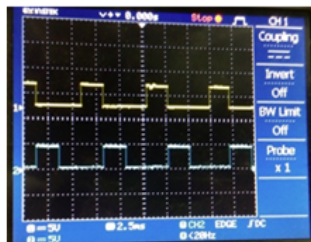


Fig. 13 shows the waveform for Input voltage and current. The yellow line indicates the voltage and blue line indicate current.

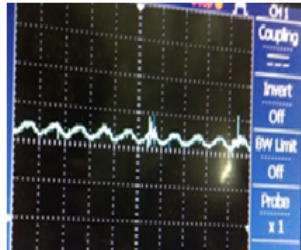


Fig.14 Input Voltage and current

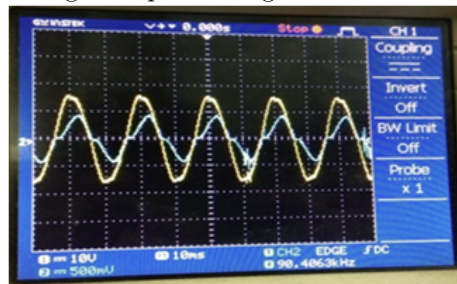


Fig.15 Output Voltage

The converter output voltage is shown in fig.18 whose value is found to be 12v

3 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 converter removes or smooth out the dc output from ripples. 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 its enhanced reliability. This is further enhanced by the usage of PFC converters. It is found that the Landsman Converter is found to provide better power quality.

References

- [1] Baszynski, M., Pirog, S.: A novel speed measurement method for a high-speed BLDC motor based on the signals from the rotor position sensor, *IEEE Trans. Ind. Inf.*, 2014, 10, (1), pp. 8491
- [2] 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. 43694375
- [3] 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. 124133
- [4] Emrani, A., Amini, M.R., Farzaneh-Fard, H.: Soft single switch resonant buck converters with inherent PFC feature, *IET Power Electron.*, 2013, 6, (3), pp. 516522
- [5] Gieras, J.F., Wing, M.: Permanent magnet motor technology-design and application (Marcel Dekker Inc., New York, 2011)
- [6] Gopalarathnam, T., Toliyat, H.A.: A new topology for unipolar brushless DC motor drive with high power factor, *IEEE Trans. Power Electron.*, 2003, 18, (6), pp. 13971404 26 Bist, V., Singh, B.:
- [7] Ho, T.Y., Chen, M.S., Yang, L.H., et al.: The design of a high power factor brushless DC motor drive. 2012 Int. Symp. Computer, Consumer and Control, 46 June 2012, pp. 345348
- [8] Huber, L., Zhang, J., Jovanovic, M.M., et al.: Generalized topologies of single-stage input-current-shaping circuits, *IEEE Trans. Power Electron.*, 2001, 6, pp. 508513
- [9] 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. 28462852

- [10] 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), pp. 385389
- [11] 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. 974982
- [12] Liang, T.J., Yang, L.S., Chen, J.F.: Analysis and design of a single-phase AC/DC step-down converter for universal input voltage, IET Electric Power Appl., 2007, 1, (5), pp. 778784
- [13] Baszynski, M., Pirog, S.: A novel speed measurement method for a high-speed BLDC motor based on the signals from the rotor position sensor, IEEE Trans. Ind. Inf., 2014, 10, (1), pp. 8491
- [14] 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. 43694375
- [15] 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. 124133
- [16] Emrani, A., Amini, M.R., Farzaneh-Fard, H.: Soft single switch resonant buck converters with inherent PFC feature, IET Power Electron., 2013, 6, (3), pp. 516522
- [17] Gieras, J.F., Wing, M.: Permanent magnet motor technology-design and application (Marcel Dekker Inc., New York, 2011)
- [18] Gopalarathnam, T., Toliyat, H.A.: A new topology for unipolar brushless DC motor drive with high power factor, IEEE Trans. Power Electron., 2003, 18, (6), pp. 13971404 26 Bist, V., Singh, B.:
- [19] Ho, T.Y., Chen, M.S., Yang, L.H., et al.: The design of a high power factor brushless DC motor drive. 2012 Int. Symp. Computer, Consumer and Control, 46 June 2012, pp. 345348

- [20] Huber, L., Zhang, J., Jovanovic, M.M., et al.: Generalized topologies of single-stage input-current-shaping circuits, IEEE Trans. Power Electron., 2001, 6, pp. 508513
- [21] 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. 28462852
- [22] 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), pp. 385389
- [23] 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. 974982
- [24] Liang, T.J., Yang, L.S., Chen, J.F.: Analysis and design of a single-phase AC/DC step-down converter for universal input voltage, IET Electric Power Appl., 2007, 1, (5), pp. 778784.

