SIMULATION AND ANALYSIS OF PFC HALF BRIDGE BOOST CONVERTER FED PMBLDCM DRIVE

Sachin Patil[1], Shehjad Hansrod[2], Priyank Patel[3], Soham Gohil[4], Richa Dubey[5]

[1,2,3,4] Student, Electrical Engineering, Department of Electrical Engineering,
Shroff S R Rotary Institute of Chemical Technology. Ankleswar-Valia Road At & Post-Vataria
[5] Assistant Professor, Department of Electrical Engineering,
Shroff S R Rotary Institute of Chemical Technology. Ankleswar-Valia Road At & Post-Vataria

ABSTRACT

This project deals with the control strategy of PMBLDC motor. Permanent Magnet Brushless DC (PMBLDC) motors are replacing DC motors in wide range of applications such as household appliances, automotive and aviation. DC motors are commutated through brushes and commutator assembly whereas BLDC motors are commutated electronically. Rotor position sensors are required to provide proper commutation sequence. This is used to turn on the power devices in the inverter bridge. The major difference between PMSM and PMBLDC motors is, PMSM produces sinusoidal back- emf and PMBLDC motor produces trapezoidal back emf. A three phase bridge inverter is used to control the BLDC motor. There are six switches and these switches should be switched based on the Hall sensor inputs. The Pulse width modulation techniques are used to switch ON or OFF the switches. Power factor correction (PFC) is achieved by using Half Bridge Boost Converter. This all work will be done with the help of "PSIM".

Keyword: - *PMBLDC (Permanent Magnet Brushless D.C.) Motor, Hall Sensors, Power Factor Correction (PFC), Boost Converters, PI Controllers, Comparators, PSIM*

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1. Introduction

From the past two decades several Asian countries such as Japan, which have been under pressure from high energy prices, have implemented variable speed PM motor drives for energy saving applications such as air conditioners and refrigerators.

On other hand, the U.S.A. has kept on using cheap induction motor drives, which have around 10% lower efficiency than adjustable PM motor drives for energy saving applications. Therefore recently, the increase in energy prices results higher demands of variable speed permanent magnet motor drives. Also, recent fast proliferation of motor drives into the industries of automobile, based on hybrid drives, generates a serious need for high efficient PM motor drives, and this was the beginning of interest in BLDC motors.

PMBLDC motors for compressor of an air conditioning system due to its features like high efficiency, wide speed range, and low maintenance requirements. The operation of the compressor with the speed control results in an improved efficiency of the system while maintaining the temperature in the air conditioned zone at the set reference consistently. Whereas, existing air conditioners mostly have a single phase induction motor to drive the compressor in “ON – OFF” control mode. This results in increased losses due to frequent “on-off” operation with increased mechanical and electrical stresses on the motor. There by poor efficiency and increased life of the motor. Moreover the temperature of the air conditioned atmosphere is regulated in a hysteresis band. Therefore improved efficiency of the air conditioning system will certainly reduce the cost of living and energy demand to cope up with ever increasing power crisis. Because of their high power density, efficiency, reliability, maintenance free nature and noise free operation, permanent magnet (PM) motors have been widely used in variable applications. [11]

Brushless DC (BLDC) motors are synchronous motors having permanent magnets on the rotor and armature windings (Electro magnets) on the stator. Hence, from a construction point of view, they are the inside-out version of DC motors in which the permanent magnets or field windings on the stator and armature windings on the rotor. The most obvious advantage of the brushless type is the removal of the brushes, which eliminates brush maintenance and the sparking which is associated with brushes. BLDC motor having the armature windings on the stator which helps the conduction of heat from the windings. There are no windings on the rotor due to it electrical losses in the rotor are less. The brushless dc motor compares with induction motors in the fractional horsepower range. The former will have better power factor and better efficiency and, therefore, a greater output power for the same frame, because the field excitation is contributed by the permanent magnets and does not have to be supplied by the armature current.

BLDC motor is a one type of synchronous motor. This means the magnetic field generated by the rotor and the magnetic field generated by the stator rotates at the same frequency. Brushless DC motors do not having the “slip” which is normally seen in induction motors. Brushless DC motor is constructed with a permanent magnet rotor and wire wound stator poles. [10]

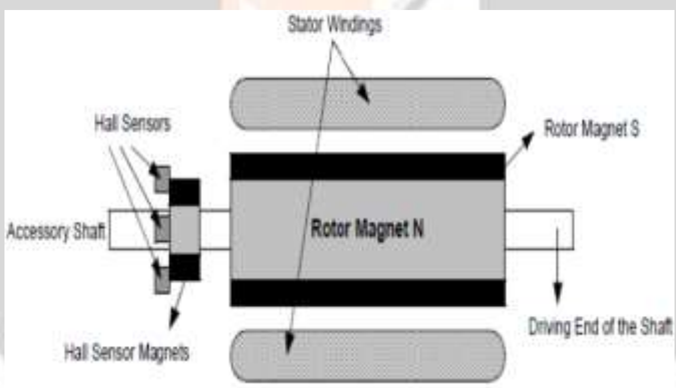

Fig -1: - Rotor and Stator of PMBLDC Motor

1.1 Major Applications and Drawback of BLDC Motor

i. Compressor (air conditioner, refrigerator).
ii. Appliances (refrigerator, vacuum cleaner, food processor).
iii. Industrial fan
iv. Automotive (fuel and water pumps, cooling fan, climate control).
v. One major drawback is Overall system cost due to cost of electronic control. [7]

1.2 Working of BLDC Motor

- In D.C motor commutation is done through brush and commutator assembly.
- In BLDC motor commutation is done with the help of electronic commutation.
- Brushless dc motor having permanents magnet on the rotor and electromagnets on the stator.

Fig -2: - DC Motor and BLDC Motor

- While apply the dc power to the electromagnetic coil, coil will get energized.
- The Operation of bldc is based on the simple force interaction between the permanent magnet and electro-magnet.
- When coil A is energized opposite poles of rotor and stator are attracted to each other.
- As rotor leaves coil A, coil B is energized.
- As rotor leaves coil B, coil C is energized.
- After that coil A energized with the opposite polarity.
- This process is repeated and rotor continues rotate.
- In the whole process the position of rotor sense by three Hall Effect sensors.[3]

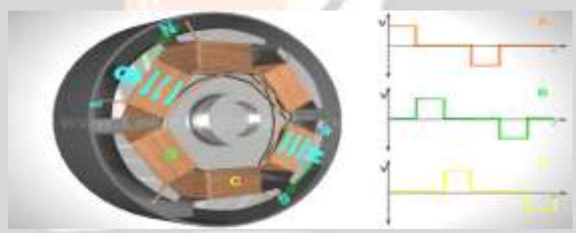

Fig -3: - Operation of BLDC Motor

2. PFC by Half Bridge Boost Converter

PFC is used as a positive method for improving the power quality. Essentially PFC can eliminate harmonic source of rectifier devices, through input current waveform automatically with input voltage waveform of the grid, and get the former waveform as sine waveform and have the same waveform with voltage waveform on phase. [1]

2.1 Power Factor Correction Techniques

There are two types of power factor correction (PFC) techniques.
a) Passive Power Factor Correction
b) Active Power Factor Correction

2.2 Passive Power Factor Correction

Harmonic current can be controlled in the simplest way by using a filter that passes the current only at line frequency (50 or 60 Hz). Harmonic currents are suppressed and the nonlinear device looks like a linear load. Power factor can be improved by using capacitors and inductors. But the disadvantage is they require large value high current inductors which are expensive and bulky. [1]

2.3 Active Power Factor Correction

An Active approach is the most effective way to correct power factor of electronic supplies. Here we place a boost converter between the bridge rectifier and the load. The converter tries to maintain a constant DC output bus voltage and draws a current that is in phase with and at the same frequency as the line voltage. [1]

2.4 Advantages of Half Bridge Boost Converter

1. Active wave shaping of input current
2. Filtering of the High frequency switching
3. Feedback sensing of the source current for waveform control
4. Feedback control to regulate output voltage

2.5 Working of PFC Half Bridge Boost Converter

In a half-bridge boost converter, the switches are operated alternatively with shorting of inductor in between through both switches for boost action. The duty ratio (D) and the value of boost inductor (Li) control its DC link voltage. A high switching frequency (fs) is used for fast control and reduced size of inductors and transformers; however, the switching frequency is limited by the factors such as switching devices used, switching losses of the device, operating voltage and power level. Insulated gate bipolar transistors (IGBTs) for high switching frequency in the half bridge boost converter.

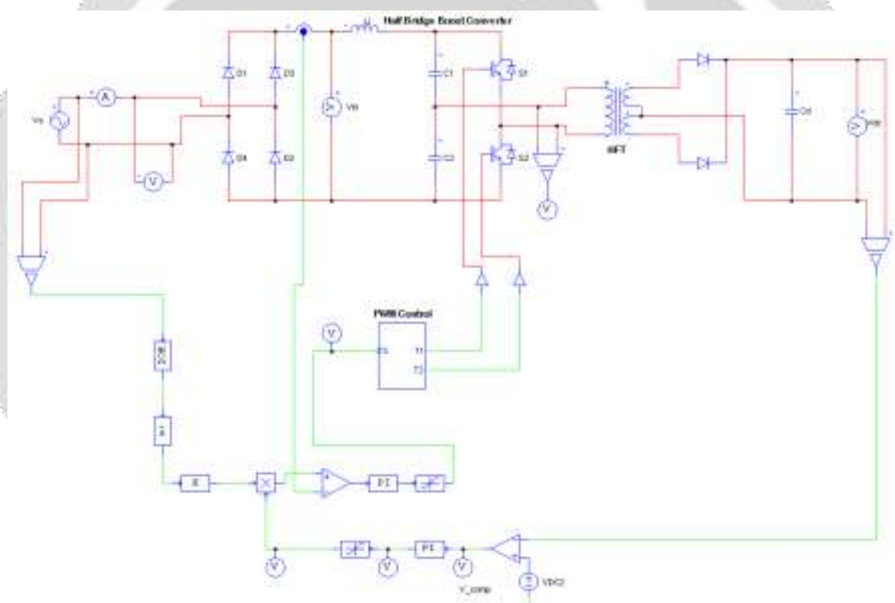

Fig - 4: - Simulation of PFC half Bridge Boost Converter

The voltage control loop uses an inner loop for current control employing current multiplier approach. The half bridge boost converter is operated in CCM with an average current control scheme to maintain a constant DC link voltage (Vdc) with PFC action. The voltage controller is a PI controller which processes the voltage error generated after comparison of the sensed DC link voltage (V_{dc}) with a reference voltage (V^*_{dc}). The resultant modulating current signal from voltage controller is multiplied with a unit template of input AC voltage and compared with DC current sensed after the DBR resulting in a current error. This current error is amplified and compared with saw tooth carrier wave of fixed frequency (F_S) to generate the PWM pulse for the devices of the half-bridge boost DC-DC converter. [4]

2.6 Pulse Generation Technique by PWM Control

The figure 5 shows the pulse generator circuit for the switching for the half bridge boost converter. The pulses generate the two actions:-

1. Boost Action
2. Energy Transfer to Load [4]

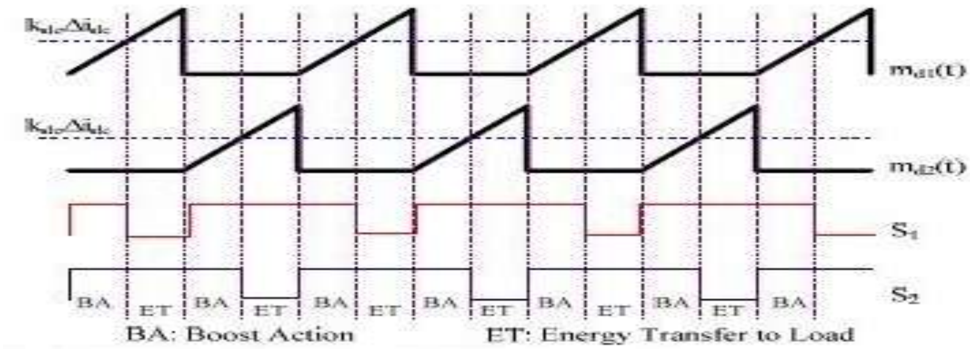

Fig - 5: - Pulse Generations through Conventional PWM Techniques

The following figure shows that how the pulses of PWM control block are connected with half bridge boost Converter.

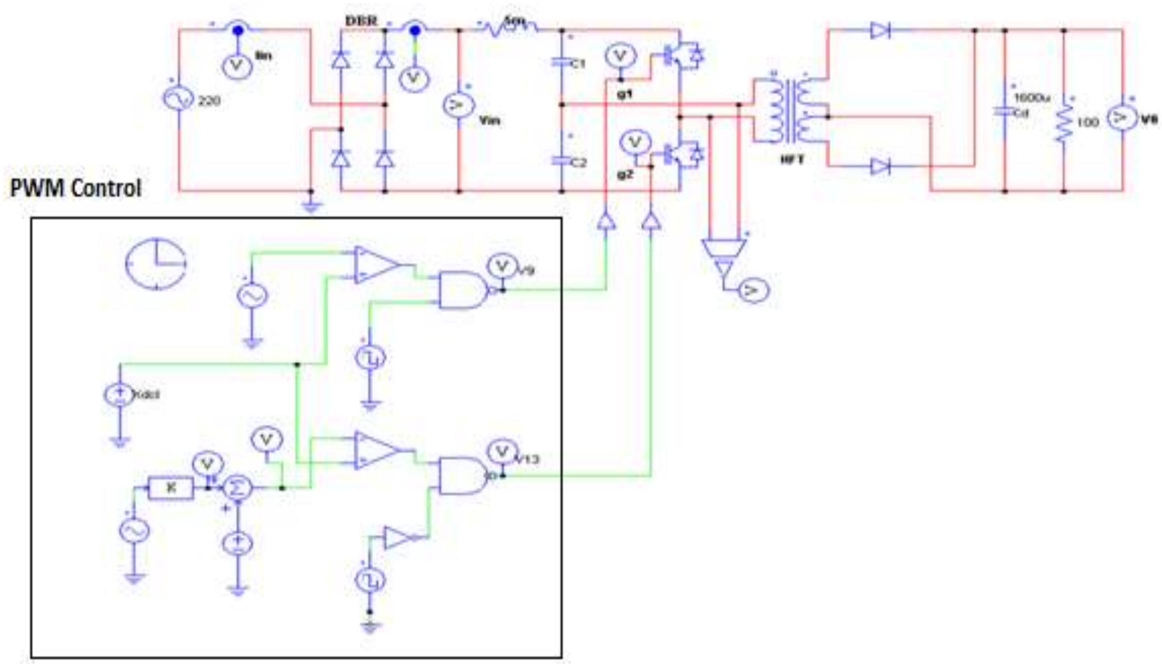

Fig - 6: - PWM Control Block with Half Bridge Converter

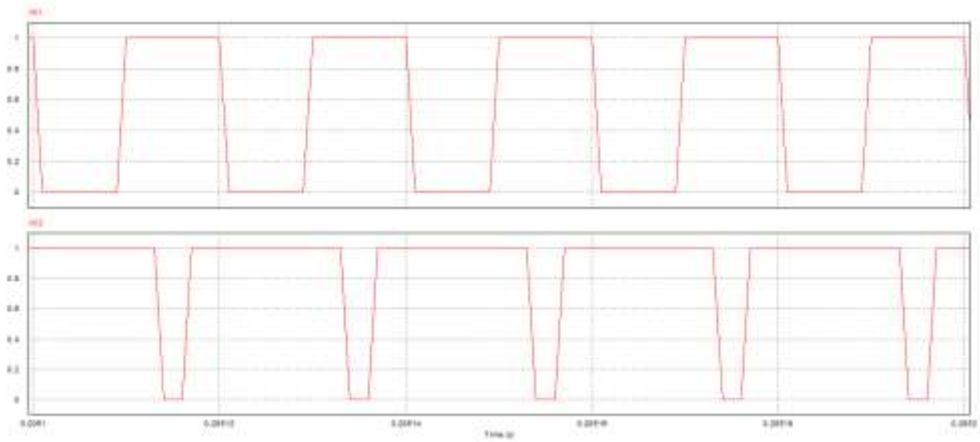

Fig - 7: - Switching Signals for the IGBTs of the PFC Half-Bridge

In every cycle of pulse, boosting as well as energy transfer action takes place necessary for different applications.

3. Speed Control of VSI Fed PMBLDC Motor Drive

In this section, we discussed a digital control of BLDC motor, which is simple to implement at low cost. Simulation results show its performance and practical usefulness. The proposed digital control can be implemented with few logic gates and comparators, which demonstrates ease of developing a low cost ASIC for digital control of BLDC motor drives. This will help reduce the cost and complexity of motor control hardware; this, in turn, can boost the acceptance level of BLDC motors for commercial mass production applications and successfully fulfill the promises of energy savings associated with adjustable speed drives.

This novel digital control, the BLDC motor act as a digital system and regulates speed with the help of two predefined state variables or conditions, condition-1 applied for high-speed operation and condition-2 defined for low-speed operation. The comparator compares actual speed with set (reference) speed and then switches between appropriate states. Thus, task of this digital control technique is to deliver right amount of power to the motor by right numbers of state-1 and state-2 operations so that power delivery matches required power. It needs few comparators and logic gates to implement this digital control, for control the speed of BLDC motor drives. [13]

3.1 Current Mode Digital Control

State-1 designed for high speed (ω_h) operation and state-2 designed for low speed (ω_l) operation. Phase current is chosen as the state variable and hysteresis switching is used for current control. Current I_h is state-1 and is of relatively higher magnitude to deliver more power to the motor. Current I_l is state-2 and is of relatively lower magnitude to deliver less power to the motor. Actual motor speed ω is compared to the set speed ω* ($\omega_l < \omega^* < \omega_h$) and then digital controller decides to:

Switch to or stay at ω_h if $\omega^* > \omega$
Switch to or stay at ω_l if $\omega^* < \omega$

Fig.8 illustrates this concept. A comparator compares actual speed with set speed and then switches appropriate current values to the hysteresis current regulator.

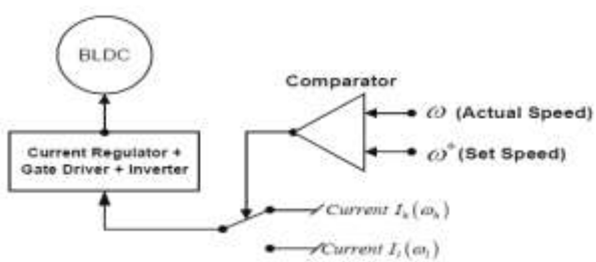

Fig - 8: - Schematic of the current-mode digital control

Fig. 9 shows corresponding waveform of a phase current for digital control technique with hysteresis switching scheme. Currents for other phases would be similar with appropriate phase delay. [13]

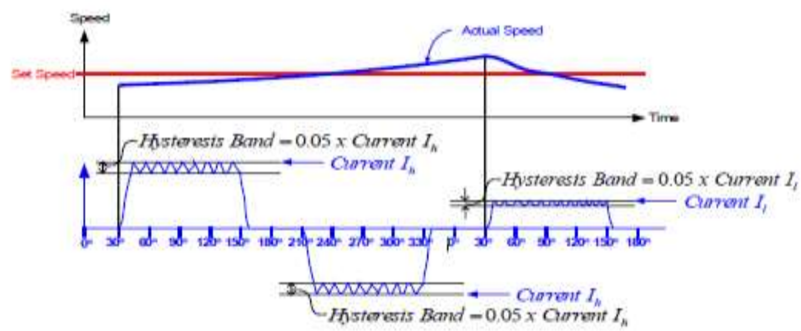

Fig - 9: - Phase current waveform for current-mode digital control

As shown in above Figure 9, when actual speed is lower than set speed, digital controller choose to provide high current I_h to the motor; this in turn, will increase the motor speed. Current is regulated within band of 5% by the hysteresis current regulator. If actual speed is higher than set speed, digital controller chooses to provide low current I_l to the motor, which will decrease the speed. Obviously, state-1 (high current I_h) is designed to deliver more power to the motor, while state-2 (low current I_l) is designed to deliver less power to the motor. Thus, the task of the digital control is to deliver right amount of power to the motor by applying right numbers of state-1 operations and state-2 operations so that average power delivery matches to that of required power.

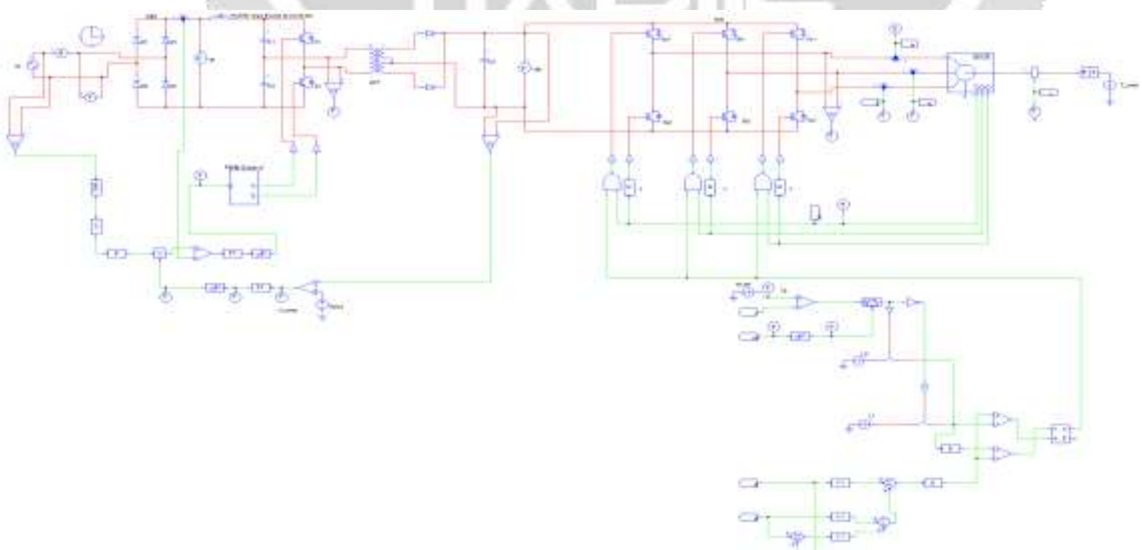

Fig - 10: - Digital Control for PMBLDC Motor Drive System

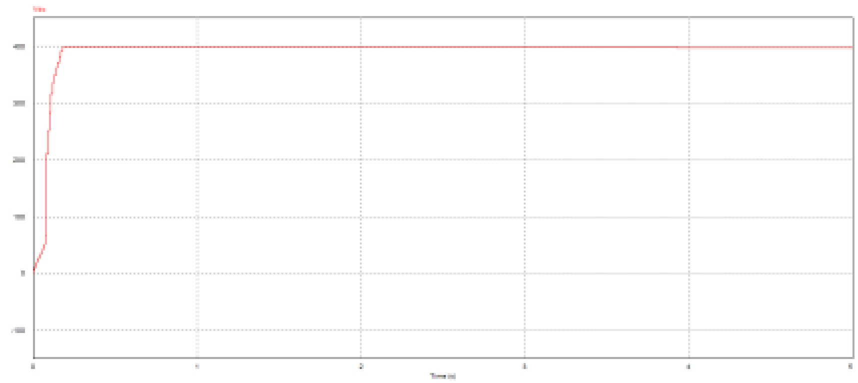

Fig - 11: - Constant Output Voltage of the Half Bridge Boost Converter

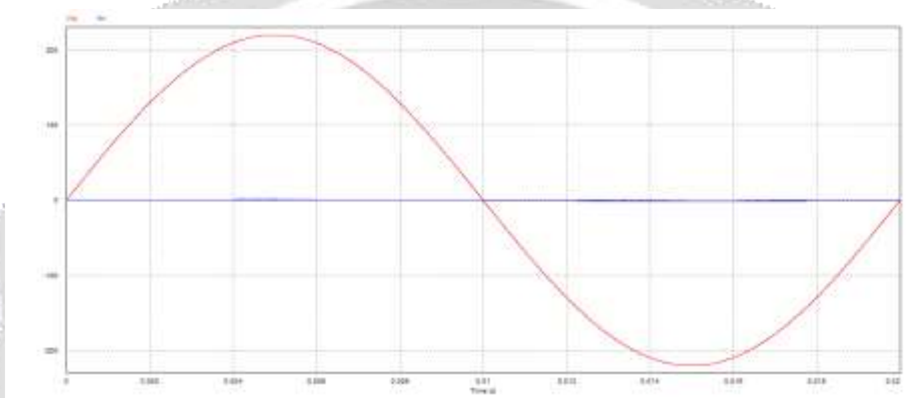

Fig - 12: - High Power factor due to PFC Half Bridge Boost Converter

From the simulation it is clear that the power factor can be corrected through half bridge boost topology is simple and effective. Here we get the power factor (PF) is about 0.95. So the power quality issues can be minimizing by it.

3.2 Simulation Results of Digital Control Technique of PMBLDCM Drive

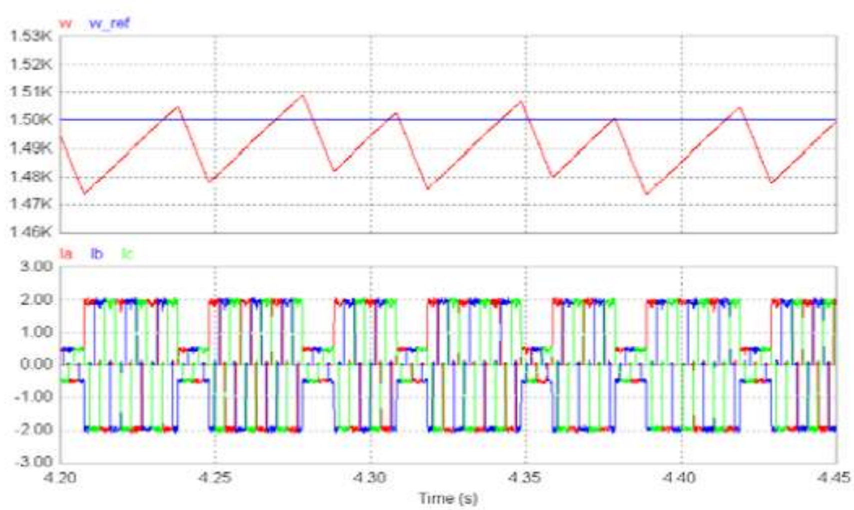

Fig - 13: - Variation in Output Speed at 1500 RPM Set Speed, 0.8 Nm Load

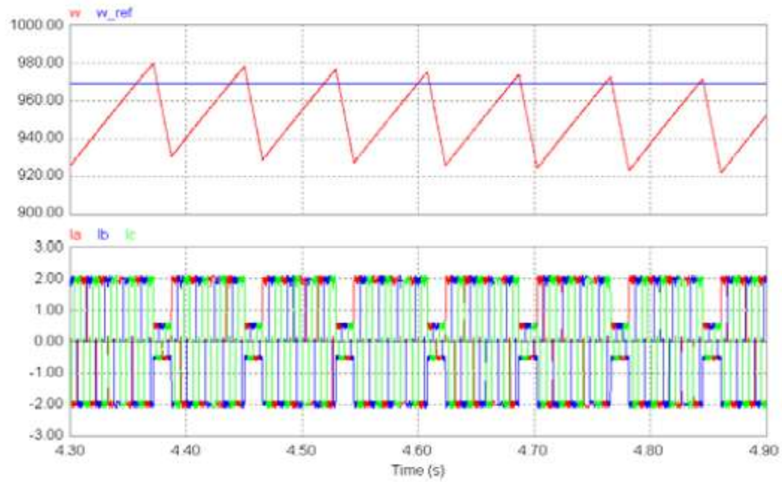

Fig - 14: - Variation in Output Speed at 970 RPM Set Speed, 1 Nm Load

4. CONCLUSIONS

The Aim of this project is to control PMBLDC motor by using effective control strategy and supply clean energy with the help of PFC (Power Factor Correction) using Half Bridge Boost Converter.

We have concluded that the power quality of supply can be improved by PFC half bridge boost converter and the PMBLDC Motor can be control using digital current control method which is cost effective and simple control strategy. So this project fulfills both the requirements of the user or customer that are effective control and energy saving application.

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