

A Pulse Generation Technique for PFC Half-bridge Boost Converters used in PMBLDCM through C-Programming in PSIM

Prof. Richa Dubey,

Assistant Professor, Department of Electrical Engineering Department,
Shroff S R Rotary Institute of Chemical Technology, Ankleshwar ,India, richa.dubey@sriect.in

Prof. K.B Shah,

Associate Professor, Department of Electrical Engineering Department,
SankalChand Patel University, Visnagar, Mehsana, India, kbshah.ee@spcevnng.ac.in

Abstract— This paper deals with the pulse generation technique of PFC converter using C program. Generally this technique is used for switching in the half bridge boost converters which are used in PMBLDC motor drive. Half bridge boost converter is used for power factor correction (PFC) in the PMBLDC motor drive. The ON-OFF control of power switches (IGBT’s or MOSFET’s) of the half bridge converter can be done by this novel technique of pulse generation. Digital control for BLDC motor drives will help to reduce the cost and complexity of the motor control hardware; this, in turn, can boost the acceptance level of BLDC motors for commercial mass production applications, successfully fulfill the promises of energy savings associated with adjustable speed drives.

Keywords—Logic gate, Boost converter, PMBLDC Motor, PWM technique, Triangular wave, Square wave, PFC, C-Program, PSIM.

I. INTRODUCTION

In many aspects of our daily life, electric motors play an important role. PMBLDC motors find their uses 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. At present, the air conditioning system mostly uses a single phase induction motor to drive the compressor. The single phase induction motor achieves maximum efficiency near rated load only; therefore, it is operated at either full load (compressor ‘on’) or not at all (compressor ‘off’) to regulate the temperature of the air conditioned zone in a hysteresis band. The frequent ‘on/off’ operation results in increased losses and wear-tear of the motor, thereby poor efficiency and reduced life of the motor. Alternately, the temperature is maintained constant at the set reference by using a PMBLDCM with the speed control to drive the compressor of the air conditioner. It results in reduced electrical energy consumption and efficiently maintains the room temperature at set reference while delivering desired cooling capacity [1]. To replace the function of commutator and brushes, the commutation of the BLDC motor drive is controlled electronically. This whole electronic control circuit involves half bridge boost converter. Half bridge boost converter requires gate pulses to ON-OFF the switches. This pulse generation technique is having an additional to conventional PWM schemes [2].

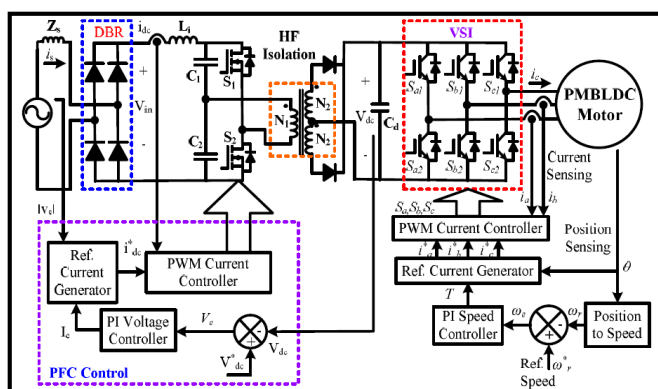


Fig 1: Control scheme of Proposed Half-bridge PFC converter

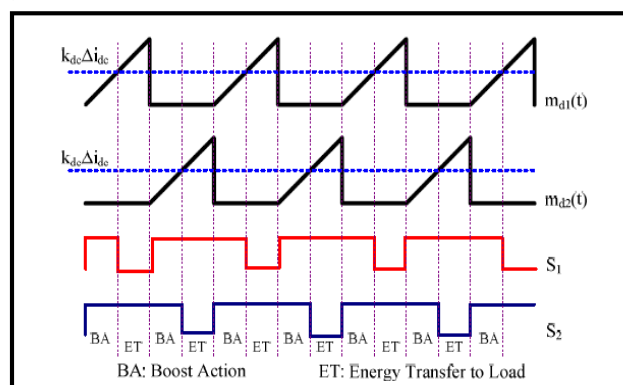


Fig. 2: PWM control of the boost converter.[1]

The power quality standards for low power equipment require a sinusoidal current to be drawn from AC mains by this equipment. Therefore a power factor correction (PFC) circuit is almost required at the utility interface of any equipment generating harmonics. The half bridge boost converter which is used for PFC is

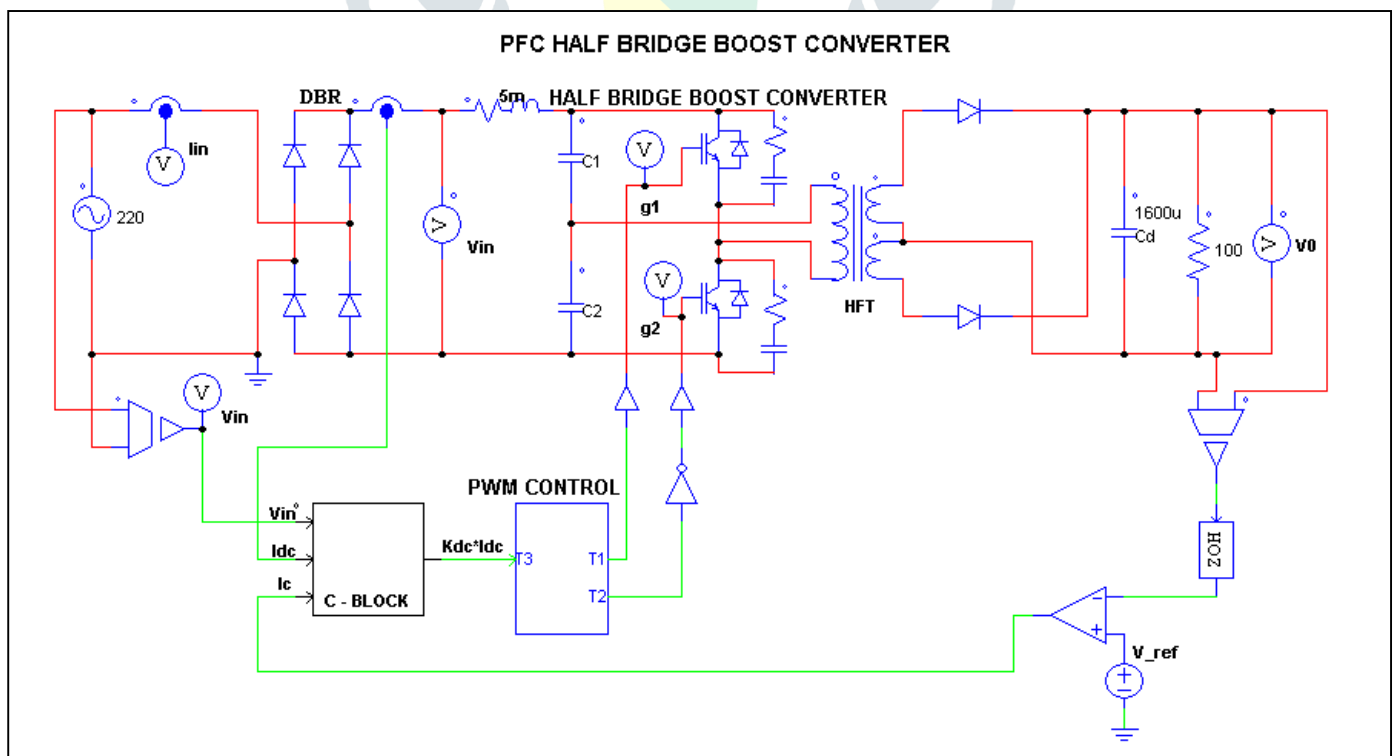
connected between DBR and VSI of PMBLDCM drive circuit. There are many DC-DC converter topologies available amongst which half-bridge boost converter topology is selected for PFC due to its features of high-voltage conversion ratio, low input current ripple and low conduction loss of switches [2].

II. HALF BRIDGE BOOST PFC CONVERTER BASED PMBLDCM DRIVE FOR AIR CONDITIONER [1]

The design values of the PFC half-bridge boost converter for a DC link voltage (V_{dc}) of 400 V, with $V_{in} = 198$ V for $V_s = 220$ V, the turns ratio (N_2/N_1)=1, $f_s = 40$ kHz, $\Delta I_{Li} = 0.12$ A (3% of I_{av}), $\Delta V_{Cd} = 4$ V (1% of V_{dc}), $I_{av} = 4$ A are calculated as $L_i = 5$ mH and $C_d = 1600$ μ F.

- The output voltage (V_{dc}) of the PFC half-bridge boost converter is given as,
$$V_{dc} = 0.5 V_{in} (N_2/N_1)/(1-D) \tag{1}$$
- where N_1, N_2 are the number of turns in primary and secondary windings of the high frequency (HF) transformer, respectively and V_{in} is the average output DC voltage of a DBR connected to a single-phase AC mains voltage (V_s) given as,
$$V_{in} = 2\sqrt{2}V_s/\pi \tag{2}$$
- The boost inductor (L_i) provides necessary voltage boost for a given peak to peak current ripple (ΔI_{Li}) in the inductor for the given switching frequency (f_s), given as
$$L_i = DV_{in}/\{4f_s(\Delta I_{Li})\} \tag{3}$$
- For a constant output voltage of the half-bridge boost converter, a capacitor (C_d) is used to minimize the ripples introduced due to high switching frequency of the converter. Its value is calculated for a specified ripple in output voltage (ΔV_{Cd}) given as,
$$C_d = I_{av}/(2\omega\Delta V_{Cd}) \tag{4}$$
- The design values of the PFC half-bridge boost converter for a DC link voltage (V_{dc}) of 400 V, with $V_{in} = 198$ V for $V_s = 220$ V, the turns ratio (N_2/N_1)=1, $f_s = 40$ kHz, $\Delta I_{Li} = 0.12$ A (3% of I_{av}), $\Delta V_{Cd} = 4$ V (1% of V_{dc}), $I_{av} = 4$ A are calculated as
- $L_i = 5$ mH and $C_d = 1600$ μ F.

The fig.3 below is the Simulation of PFC Half bridge boost converter used in air conditioning system where gate pulses for Half bridge is generated through C-programming using C-block in PSIM-9



III PFC MODELLING [1]

PFC Converter

The PFC converter using average current control is constituted by a DC link voltage controller, a reference input current generator and a PWM current controller as given below.

- 1) **DC LINK VOLTAGE CONTROLLER:** The DC link voltage controller is a PI controller which closely tracks the reference voltage and gives control signal (I_c) to minimize voltage error. At k th instant of time, the voltage error $V_e(k)$ is calculated from reference DC link voltage $V^*_{dc}(k)$ and sensed DC link voltage $V_{dc}(k)$ as,

$$V_e(k) = V^*_{dc}(k) - V_{dc}(k) \quad (5)$$

The output of the controller $I_c(k)$ at k th instant is given as,

$$I_c(k) = I_c(k-1) + K_{pv}\{V_e(k) - V_e(k-1)\} + K_{iv}V_e(k) \quad (6)$$

where K_{pv} and K_{iv} are the proportional and integral gains of the voltage controller.

- 1) **REFERENCE INPUT CURRENT GENERATOR:** The reference input current of the half-bridge boost converter (i^*_{dc}) is given as,

$$i^*_{dc} = I_c(k) u_{Vs} \quad (7)$$

where u_{Vs} is the unit template of the voltage at input AC mains, calculated as,

$$u_{Vs} = v_d/V_{sm}; v_d = |v_s|; v_s = V_{sm} \sin \omega t \quad (8)$$

where ω is frequency in rad/sec at AC mains.

- 1) **PWM CURRENT CONTROLLER:** The reference input current of the half-bridge boost converter (i^*_{dc}) is compared with the current (i_{dc}) sensed after the DBR which results in a current error $\Delta i_{dc} = (i^*_{dc} - i_{dc})$. This current error is amplified by gain k_{dc} and compared with fixed frequency (f_s) carrier waveforms $md1(t)$ and $md2(t)$ as shown in Fig. 4.3 to get the switching signals for the MOSFETs of the PFC half-bridge boost converter as,

$$\text{If } k_{dc} \Delta i_{dc} > md1(t) \text{ then } S1 = 1 \text{ else } 0 \quad (9)$$

$$\text{If } k_{dc} \Delta i_{dc} > md2(t) \text{ then } S2 = 1 \text{ else } 0 \quad (10)$$

where $S1, S2$ are upper and lower switches of the half-bridge converter as shown in Fig.5.1 and the values '1' and '0' represent their 'on' and 'off' position.

IV PFC CONVERTER USING C-BLOCK.

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 (L_i) control its DC link voltage. A high switching frequency (f_s) 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. Metal oxide field effect transistors (MOSFETs) are used as the switching device for high switching frequency in the proposed converter. The Algorithm for C-programming and step by step procedure is given below.

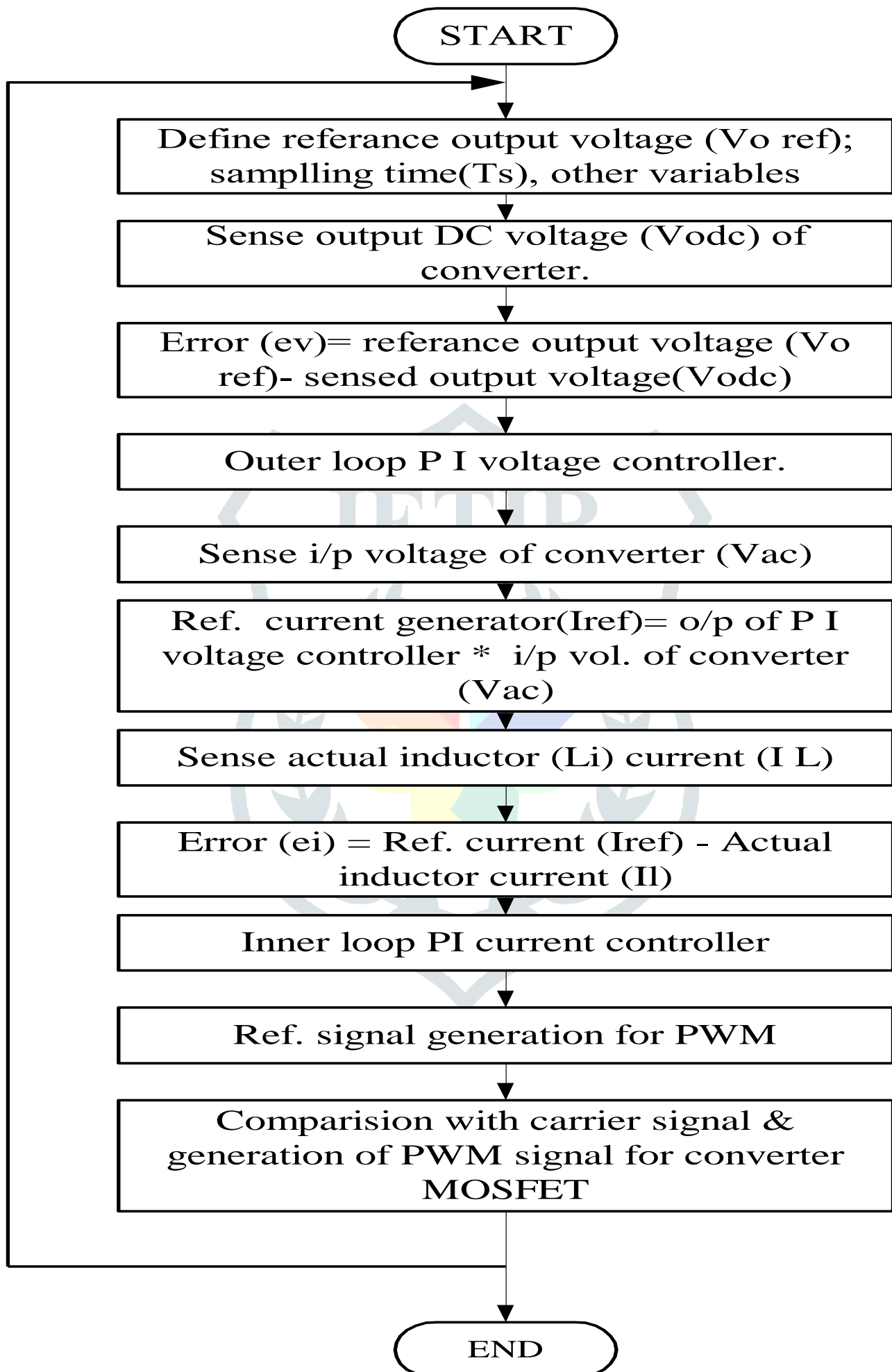


Fig. 4: Algorithm for pulse generation

V ALGORITHM TO GENERATE GATE PULSES

Step1:- Start

Step2:-Two signals are selected. 1) Triangular Wave (1) 2) DC Signal (1)

Step3:- Triangular wave (1) is connected to Proportional (Gain) block.

Step4:- One Summer block (+/-) is taken.

Step5:- Triangular Wave (1) is connected to Summer block through proportional block at positive terminal.

Step6:- DC Signal (1) is connected to the negative terminal of the summer block directly.

Step7:- Select the Comparator (1).

Step8:- Output of the summer block is given to the non-inverting (positive) terminal of the Comparator (1).

Step9:- DC Signal (2) is taken which is connected to the inverting terminal (Negative) of the comparator (1).

Step10:- NAND gate (1) is selected.

Step11:- One input terminal of the NAND gate is connected to the output of the comparator (1).

Step12:- Now select Square Wave (1) which is connected to another input terminal of the NAND gate (1) through NOT gate.

Step13:- Output signals of NAND gate (1) are the switching pulses which are given to the one MOSFET of the half bridge boost converter.

Step14:- Now Select the Comparator (2) and Triangular Wave (2).

Step15:- Triangular Wave (2) is connected to the non-inverting (positive) terminal of the Comparator (2).

Step16:- DC Signal (2) is connected with the inverting terminal (Negative) of Comparator (2).

Step17:- Now select NAND gate (2).

Step18:- Output of the comparator (2) is connected with the one input terminal of the NAND gate (2).

Step19:- Square Wave (2) is taken which is directly connected to the another input terminal of the NAND gate (2).

Step20:- Output signals of the NAND gate (2) are switching pulses which connected with another MOSFET of the half bridge boost converter.

Step21:- End.

The Whole algorithm can be Understand by the fig.4

However, insulated gate bipolar transistors (IGBTs) are used in VSI bridge feeding PMBLDCM, as it operates at lower frequency compared to PFC switches thereby the switching stresses are reduced.

VI RESULTS

Simulation Results of Generated gate pulses ,output Voltage ,input current and input Voltage for PFC converter using C Programming in PSIM-9 are shown below. Satisfactory results of Power factor (0.996),THD and Crest factor is obtained using above mentioned technique which are same as obtained through conventional PWM techniques.

This concept of pulse generation is more controlled and suitable for PMBLDC drives and it is giving the same results as proposed in PFC Modelling. The following fig.3 shows the circuit diagram of the pulse generation circuit .

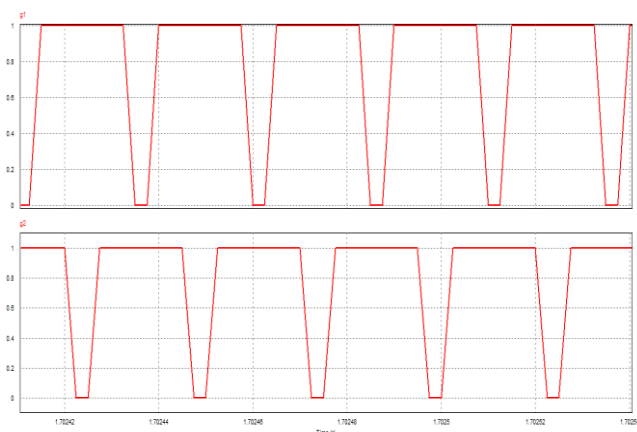


Fig. 5: PWM Pulses (g1& g2)

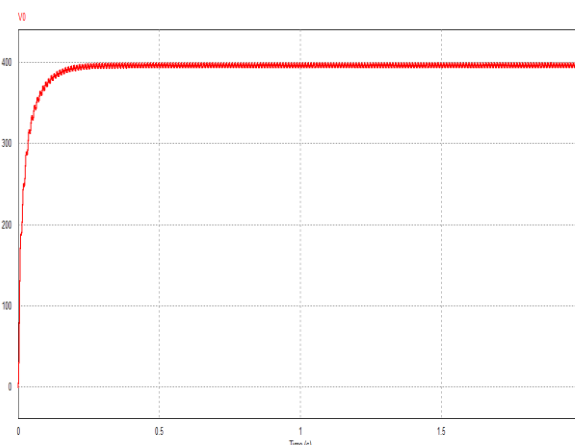


Fig.6: Output voltage (400V) (y axis-1 div. = 100V)

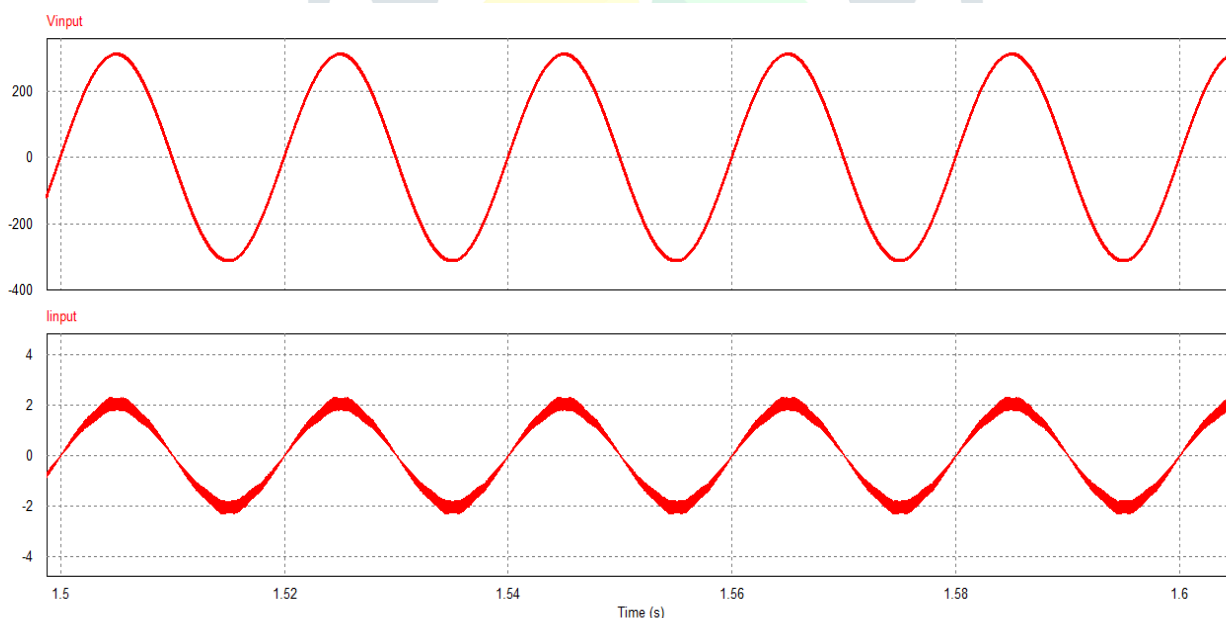


Fig.7: Input voltage(220V rms) & input current (1.49A rms) PF(0.996)

VI Conclusion

This technique gives the satisfactory results as that of conventional PWM techniques such as Power Factor, THD, Crest Factor. Further more , PWM generation through C-programming can be used with different family of microcontrollers for PMBLDC drive and commercially mass produced appliances like fans, blowers, washers, dryers vacuum cleaners, etc, Therefore, it is expected that the digital control for BLDC motor drives will help reduce the cost and complexity of the motor control hardware; this, in turn, can boost the acceptance level of BLDC motors for commercial mass production applications, successfully fulfill the promises of energy savings associated with adjustable speed drives.

Table 1: Simulation Results using C-programming

Results	V_{input}	I_{input}
Power Factor (P.F)	0.996	
Total Harmonic Distortion(T.H.D)	0.992%	1.88%
Crest Factor (C.F)	1.44	1.4

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