

POWER FACTOR IMPROVEMENT IN SINGLE PHASE DC MOTOR DRIVE USING DOUBLE SIDED PWM SWITCHING

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ABSTRACT

This paper presents power factor correction by interleaved dual boost converter fed DC Motor through full bridge DC-DC converter with unipolar voltage switching technique. The proposed topologies are designed to achieve unity power factor with average current mode controller PID based double sided PWM switching(DSPWMS) and it is a simple and effective manner which creates reduced total harmonic distortion in AC input line current. Simulation results with dual boost converter there is shows an improvement in power factor and THD and also improvement in DC motor performance. The entire system simulation work is carried out using MATLAB/SIMULINK environment.

Keywords: *Interleaved Dual Boost Converter, PID Controller, Average Current Mode Control, Double Sided PWM Latched Switching, THD.*

1. INTRODUCTION

DC motor drives are very essential for industrial applications due to high performance. A high performance DC motor drive system must have good load regulating response and dynamic speed command tracking, excellent speed control for both acceleration and deceleration. Separately excited DC motor allows for precise voltage control, and is necessary for torque and speed control applications. DC motors have long been a backbone of industrial applications because of favorable cost, reliability and their simplicity and ease of application. Generally DC drives are less complex and expensive as compared to AC drives system.[1]

The conventional phase controlled DC drive systems, though are simple to control and to design but end up in demand of larger Power Quality Improvement devices to manage power factor and harmonics generated and EMI. Especially in four quadrant drives and higher powered drives these are mandatory and results in cost escalation. So they are being replaced by the present days Power Electronics Hi-Powered Switching Devices such as MOSFETs, IGBTs, MCTs and the PWM control techniques which made the system simple and reliable in view of EMI reduction, Power factor correction(PFC) and Total harmonic Distortion (THD) etc.[2]-[3]

In the literature survey, the single phase DC drive have successfully proved better performance characteristics by PID controller whose gains values has been developed by using Zeigler-Nichols tuning method.[5]-[12] This paper discusses about new four quadrant closed loop controlled single phase drive by PID-PWM full bridge DC-DC converter with bipolar voltage switching technique.[13] In this method, the speed response for four quadrant of the DC Motor is improved by implementation of PID controller and closed loop system. Only drawback of this method is high R.M.S ripple content in output voltage of DC motor and low power factor in the utility side.

Various power factor correction techniques are implemented to overcome power quality issues out of which boost converter with average current mode control topology has been extensively used in AC-DC and DC-DC applications.[14]-[27]

In this paper PID based full bridge DC-DC converter fed DC motor followed by single phase diode bridge and power factor correction input AC side by interleaved dual boost converter with double sided PWM switching is proposed.[28]-[29]

This paper is organized as follows: Section II gives an operation of proposed Double sided PWM latched switching. Section III describe the modeling

of DC motor equivalent circuit and its parameters. In the section IV describe. The Proposed PFC Dual boost Converter Fed PID-PWM Based Four Quadrant Operation Of DC Motor With Average Current Mode Control by double sided PWM switching. Section V presents simulation results and discussion. Finally concluded in section VI.

2. OPERATION OF DOUBLE SIDED PWM CONTROL.

In the current mode control of double sided active PFC AC – DC boost converter with sensor less current mode control is implemented. Here in this method modulation of booth edges has been achieved maintaining full latched operation. Double sided PWM scheme two comparators are used instead of one to set switch and other one to reset. From this one comparator is used for the comparison between the signal of feed back and ramp to set while second comparator is used for the comparison between the signal of offset feedback and ramp to reset switch. With the help of triangular wave equal raising and falling slops to set the switching frequency and to stabilize the duty ratio of the switch. Fig. 1 and 2 shows the proposed double sided PWM scheme for active PFC AC – DC converter with PID based and timing diagram of DSPWM. The generator PWM signal is shown at the bottom of the figure. Note that T is the delay between raising and falling edges. The slope of the ramp is chosen to be equal to the feedback signal at the half of a duty ratio.

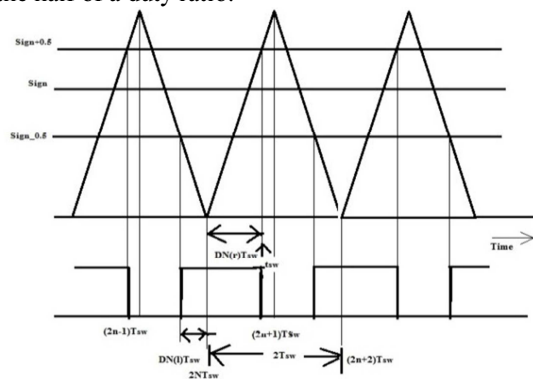


Figure 1: Timing Diagram

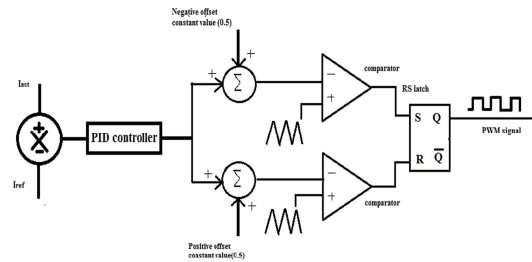


Figure 2: Double Sided PWM Latched switching

3. EQUIVALENT CIRCUIT OF DC MOTOR.

The separately excited DC Motor equivalent circuit is shown in fig.3. The current in the field coil and the armature is independent of each other.. The equations describing the dynamic behavior of the DC motor are as follows.

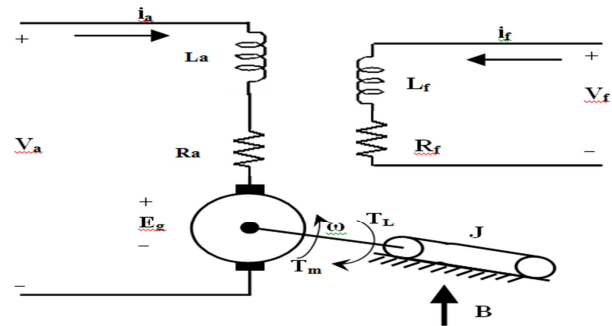


Figure 3: Equivalent Circuit of Separately excited DC motor

$$V = R_a i_a + L_a \frac{di_a}{dt} + e_b \quad (1)$$

$$T_m = K_t i_a(t) \quad (2)$$

$$T_m = J \frac{d^2 \omega(t)}{dt^2} + B \frac{d\omega(t)}{dt} \quad (3)$$

$$e_b = e_b(t) = K_b \frac{d\omega(t)}{dt} \quad (4)$$

Simplification and taking the ratio of $\omega(s)/v(s)$ we will get the transfer function as below

$$\frac{\omega(s)}{V_a(s)} = \frac{K_b}{[JL_a s^2 + (R_a J + BL_a)s + (K_b^2 + R_a)]} \quad (5)$$

Where,

R_a =Armature resistance (ohm)

L_a =Armature inductance(henry)

I_a =Armature i(ampere)

V_a =Armature voltage (volts)

$e_b=e_b(t)$ =back emf in voltage(volts)

K_b =back emf constant(volt/(rad/sec))

K_t =torque constant(N-m/Ampere)

T_m =Torque developed by the motor(N-m)

$\omega(t)$ =angular speed of shaft (radians/seconds)

J =moment of inertia of motor and load,

B=frictional constant of motor and load (Nm/(rad/sec))

4. THE PROPOSED PFC DUAL BOOST CONVERTER FED PID BASED FOUR QUADRANT OPERATION OF DC MOTOR WITH AVERAGE CURRENT MODE CONTROL BY DOUBLE SIDED PWM SWITCHING.

A single phase AC supply is applied to diode bridge rectifier with DC link capacitor fed to the DC motor through full bridge DC to DC converter, its output voltage controlled by speed PID controller. The draw back of conventional single phase DC motor has such as poor power factor, high value of total harmonics distortion in AC main input current due to controlled charged DC link capacitor. Various power factor converter topologies are used for such DC drive but boost power factor correction with average current controller is very simple.

The proposed power factor correction PID based full bridge DC to DC converter fed DC motor by interleaved boost converter with double sided PWM switching system is shown in the figure 4.

A single phase AC supply is applied to diode bridge rectifier with filtered capacitance whose output is given to full bridge DC to DC converter fed DC motor followed by double sided PWM double sided switching interleaved boost converter. The output of boost voltage multiplied with rectified input voltage by using multiplier, whose output is taken as reference current of input current of inductance. After comparing high reference

current (I_{ref}) and actual current of inductance (I_{act}) whose error is fed to current PID controller. The output of PID controller is compared with triangular wave and generate the pulses to turn on the interleaved boost converter switches by double sided PWM switching.

In the full bridge DC –DC converter, MOSFET switches(M_1, M_2, M_3 & M_4) are controlled by PID – PWM with unipolar voltage switching technique, In this control technique the motor speed is sensed and compared with a reference speed, whose speed error is given through current PID controller then output is compared with high frequency whose triangular wave signal then generate the pulses on the MOSFET switches. The proportional integral and derivative controller is used to reduced the maximum overshoot and steady state error of the speed response. The transfer function of PID controller is given by

$$G_c(s) = K_p + \frac{K_i}{s} + K_d s \quad (7)$$

Where K_p , K_i and K_d of proportional, integral and derivative gains the values of K_p, K_i, K_d are calculated by Zeigler – Nichols tuning method.

5. SIMULATION RESULTS AND DISCUSSION

The interleaved boost converter fed DC motor followed by full bridge DC-DC converter were simulated using MATLAB/SIMULINK which is shown in fig.5 and subsystem of DSPWM is illustrated in fig.6. The simulated resulting waveforms are shown in figures from (7-10)

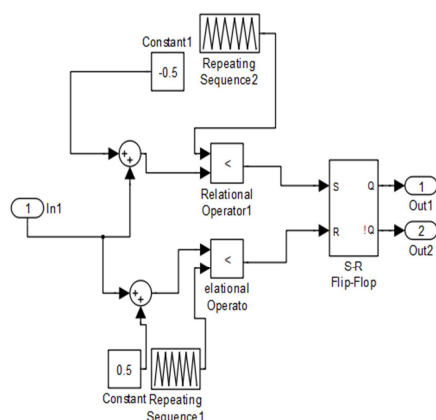


Figure 6: Subsystem of the Double sided PWM switching

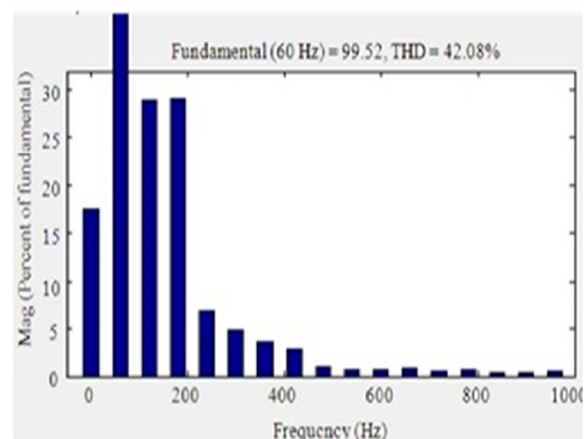


Figure 7(a). FFT analysis of without PFC converter

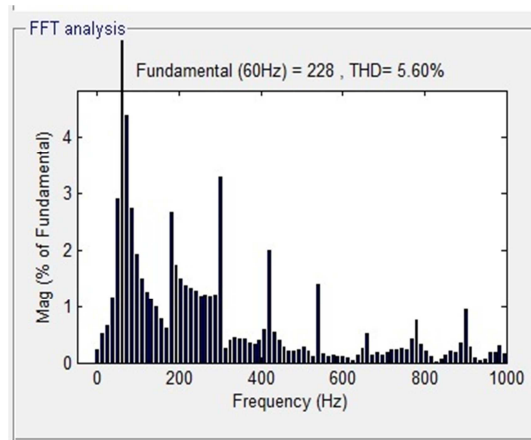


Figure.7(b):.FFT analysis of with Boost PFC converter

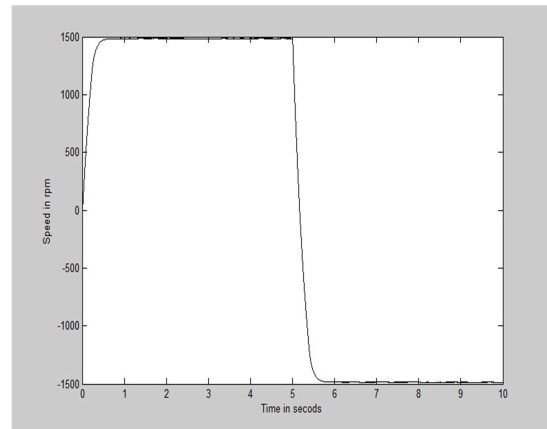


Figure.8: .Speed Response waveform of double boost converter fed dc motor drives(DSPWMS)

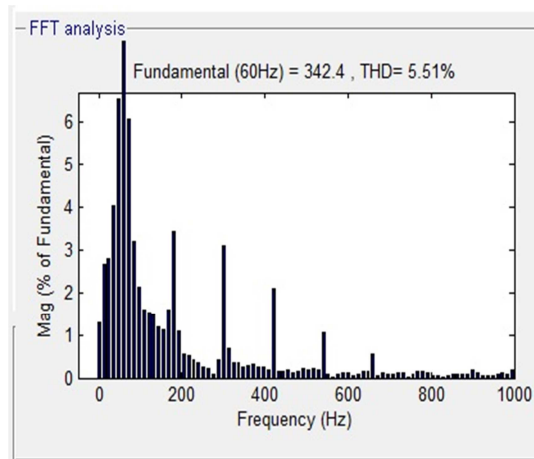


Figure.7(c): FFT analysis with interleaved boost PFC converter (Normal PWM s)

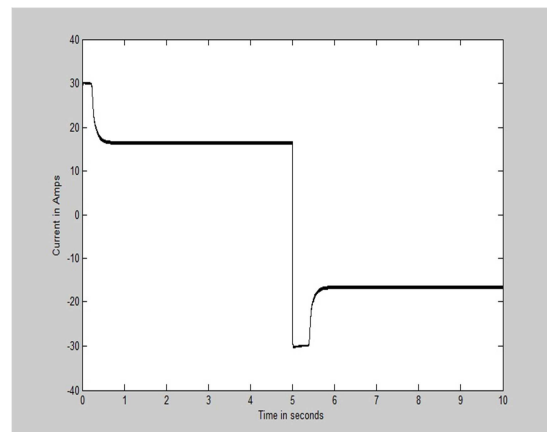


Figure.9: Current Response waveform of dual boost converter fed dc motor drive(DSPWMS)

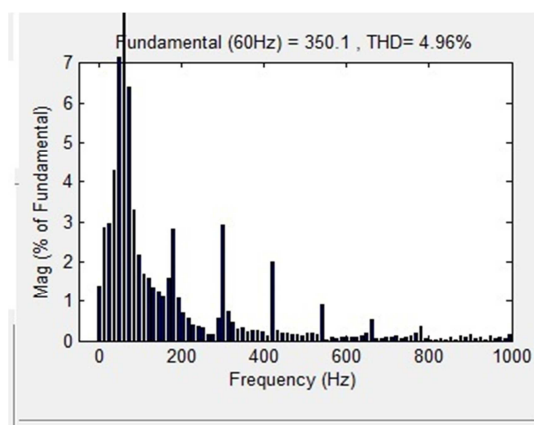


Figure 7(d): FFT analysis with interleaved boost PFC converter (Double sided PWM latched Switching)

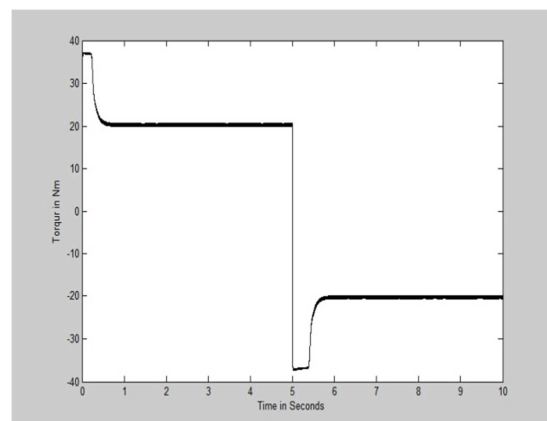


Figure.10: Toque Response waveform of dual boost converter fed dc motor drive(DSPWMS)

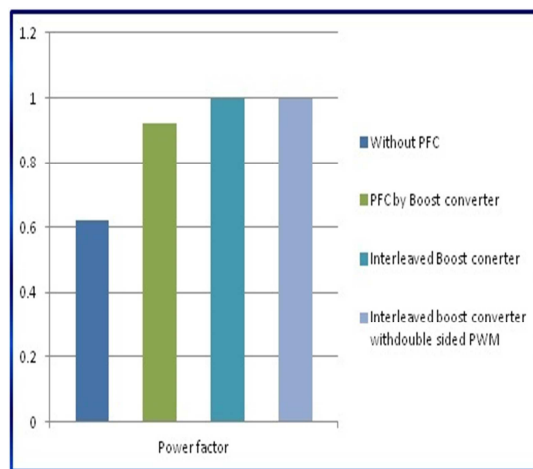


Figure 11 :Comparison of THD

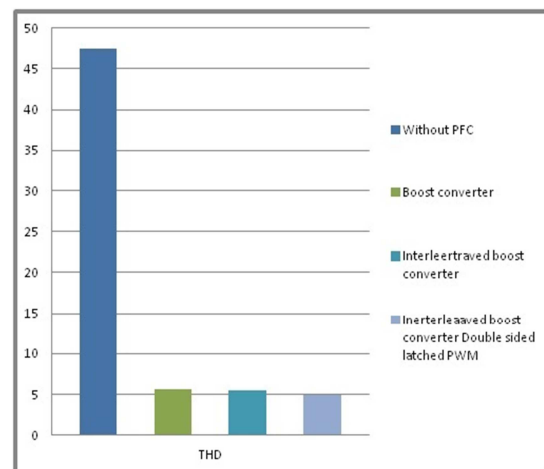


Figure 12: Comparison of Power factor

From the table 1 it is observed that the total harmonic distortion value reduced from 5.51% to 4.96% and the overall performance characteristics of DC motor has improved by this method.

6. CONCLUSION

A PID based interleaved dual boost converter with double sided PWM in active power factor correction AC-DC converter fed DC motor through full bridge has been described. This proposed method improves the performance characteristics of DC motor and dynamic response of input AC line current, THD value reduction by this method compared to the normal PWM method. The whole system has been tested by means of simulation using MATLAB/Simulink software. In addition to the torque ripples have been reduced.

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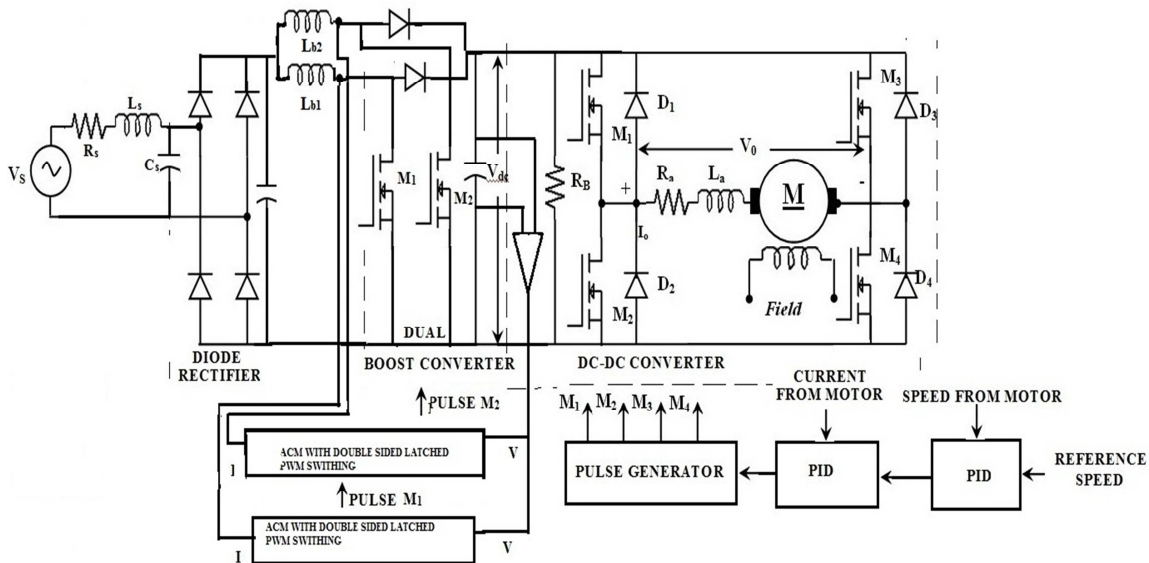


Figure 4: Block diagram of Proposed dual boost converter fed D.C Motor with DSPWMS

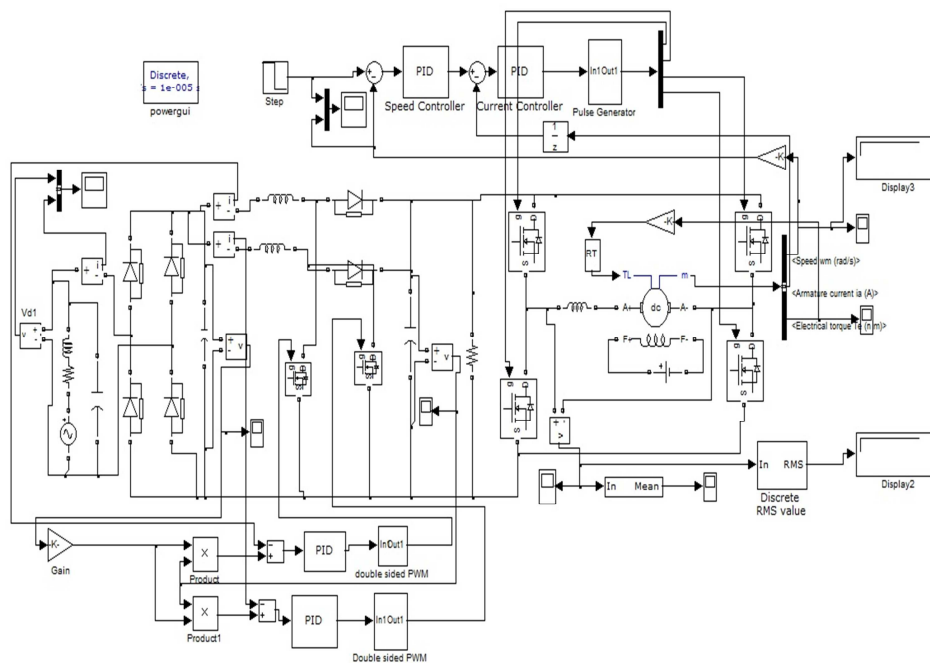


Figure 5: Simulink model of PID based Four quadrant operation of Single phase DC motor with DSPWMLS

Table 1: Comparison of THD ,PF and Motor performance

ITEM	A.C Input voltage	D.C link Voltage	THD	PF	V _O in volts	Speed in rpm
Without power factor correction	300V	200V	42.08	0.635	200V	1469
With boost power factor correction	110V	215V	5.60	0.993	202V	1478
With interleaved boost power factor correction.	85V	220V	5.51	0.998	203V	1482
Interleaved Boost converter with double sided PWM switching.	85V	220V	4.96	0.999	204V	1486