

TMS320F2812 BASED IMPLEMENTATION OF SENSORLESS CONTROL FOR BLDC MOTOR

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Abstract: The paper attempts to develop a novel sensorless control scheme suitable for brushless dc permanent magnet (BLDC-PM) motor with a view to elaborate its flexible operating status. It orients its focus to detect the zero crossing instant of the back emf and there from assuage a methodology to control the speed of the motor. The state of the art technology facilitates the use of a powerful processor to realize the strategy in real time. It includes MATLAB simulation to evaluate its performance and seeks the role of DSP (Digital Signal Processor) TMS320F2812 controller to validate the same using a prototype. The results illustrate the ability of the proposed technique to improve the input power factor in addition to regulating the speed of the motor.

Keywords: *Sensorless control; DSP; Back EMF; Speed Regulation.*

I Introduction

The drive industry continues to experience a reformation in view of the elaborate automation and exhaustive sophistication. Though a large number of electric motors are available still the Brushless Direct Current (BLDC) motors appear to gain popularity on account of better speed versus torque characteristics, improved dynamic response, higher efficiency, longer operating life, noiseless operation and higher speed ranges. They are widely used in appliance, automotive, aerospace, consumer and medical industries.

The BLDC motors are electronically commutated and are usually operated with one or more position sensors. It is desirable to run the motor without position sensors and therefore prefer a sensorless operation.

A Fuzzy logic controller has been designed for a BLDC permanent magnet motor drive. The simulation and TMS320F2808 DSP based experimental results have been found to portray the superior performance of its dynamic characteristics [10]. An efficient simulation model for fuzzy logic controlled brushless direct current motor drives using Matlab/Simulink has been presented. The dynamic characteristics of the BLDC motor (i.e. speed and torque) and as well as currents and voltages of the inverter components have been analyzed using the developed model [11].

A current control mechanism for BLDC motors based on a mean DC signal (i.e., generation of quasi-square wave currents using only one current controller for three phases) has been suggested. It has been to successfully remove

excessive current and consequent back EMF present at the end of the commutation period and result in improvement in efficiency and lower acoustic noise [12].

A speed regulation scheme for a small BLDC motor with trapezoidal back-emf has been proposed. The control Strategy has been found to use the proportional controller where the proportional gain, kp , has been appropriately adjusted using a genetic algorithm. The scheme has been found to perform well in order to compensate the BLDC motor with load disturbance [13].

II Proposed Statement

The basic philosophy charters to acquire the zero crossing instant of the Back EMF (BEMF) and design a sensor less methodology to improve the input power factor in addition to regulating the speed of a Power Inverter fed BLDC-PM motor over a desired operating range. The investigative study involves MATLAB

simulation and implementation using a Digital Signal Processor (DSP) based experimental arrangement to bring out its applicability.

III Proposed Approach

Commutation in sensorless control strategy is based on indirect rotor position information. It revolves around the phenomenon of identifying the zero crossing instant of the BEMF that ideally acquires a unique position within an electrical cycle. The position dynamically varies and is monitored through an appropriate mechanism.

The sensorless control based on zero-crossing detection of BEMF claims the advantages of its suitability of use on a wide range of both Y and Δ connected 3-phase motors. It is relatively insensitive to motor manufacturing tolerance variations and found to work satisfactorily for either voltage or current control.

The Power module seen in Fig. 1 is constituted of a three phase MOSFET based PWM Inverter and involves the use of V/F algorithm to accelerate the motor regardless of its actual position. It starts with an initial hazzle because of the unknown rotor position and there after the motor proceeds using the reference voltage and frequency irrespective of the position of the rotor.

When the BLDC motor rotates, each winding generates BEMF that can be calculated using equation (1).

$$BEMF = NlrB\omega \quad - (1)$$

Where

- N= number of winding turns per phase
- l = length of the rotor
- r = internal radius of the rotor
- B = rotor magnetic field density
- ω = motor angular velocity

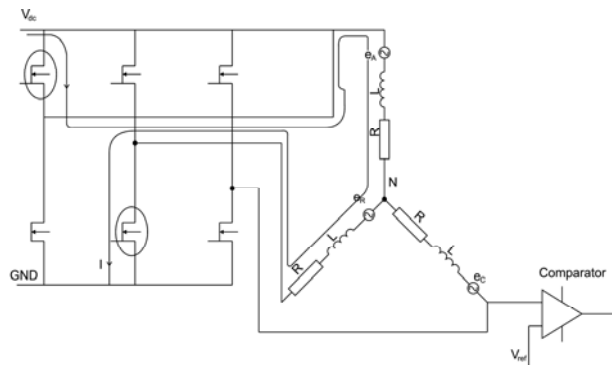


Fig.1 Power Module

It is apparent from the expression that BEMF is governed only through the angular velocity or speed of the rotor. The Sensor less control of BLDC motor calls for commutation based on the BEMF produced in the stator windings. The theory shows that only two out of three phases are excited at any instant of time. The PWM drive signal can be applied either in the high or low or on both sides.

The operating equations are written as

$$i_a = -i_b, i_c$$

$$v_{nGND} = v_{AGND} - (i_a R + L \frac{di_a}{dt}) - e_{AGND} \quad (1)$$

$$v_{nGND} = v_{BGND} + (i_a R + L \frac{di_a}{dt}) - e_{BGND} \quad (2)$$

$$v_{C_{GND}} = v_{nGND} + e_{c_{GND}} = \frac{v_{A_{GND}} + v_{B_{GND}}}{2} - \frac{e_{A_{GND}} + e_{B_{GND}}}{2} + e_{c_{GND}} \quad (3)$$

Where v_{nGND} is the neutral point voltage.

$$\text{But } e_{A_{GND}} + e_{B_{GND}} = 0 \quad (4)$$

$$\text{So } v_{C_{GND}} = \frac{v_{A_{GND}} + v_{B_{GND}}}{2} + e_{C_{GND}} \tag{5}$$

The above equations reflect the situation in Fig.1 where C is the non-energized phase. The BEMF appears to pass through zero, through a comparison of $v_{C_{GND}}$ with half Vdc and serves to devise a strategy that realizes the voltage sampling after PWM ON time. If $e_{C_{GND}}$ is equal to zero, the terminal voltage on phase C is equal to half of the sum (Vdc+0, with respect to the ground). It thus becomes necessary to monitor all the three phase terminal voltages and the DC supply voltage using potential dividers and ADCs to identify during appropriate sectors, when the phase BEMFs cross zero. However only one phase voltage is required to be monitored for a given sector.

There is a need to synchronize the rotating magnetic field in the stator with the MMF vector in the rotor, above a certain speed, when BEMF zero-crossing detection is feasible. A ZCD window is created taking into consideration the commutation period. The ZCD signal is allowed to occur “in the middle” of the commutation period and ensure that each phase is powered through the ZCD pattern. However it turns out that “secure” zero-crossing detection is assured only for minimum 20% duty-cycle.

IV Control Algorithm

The ZCD in the control circuit seen in Fig. 2 is a toggle signal that changes from 1 to 0 each time the BEMF from one phase passes through zero. The zero crossing of back emf is shown in the Fig.3.

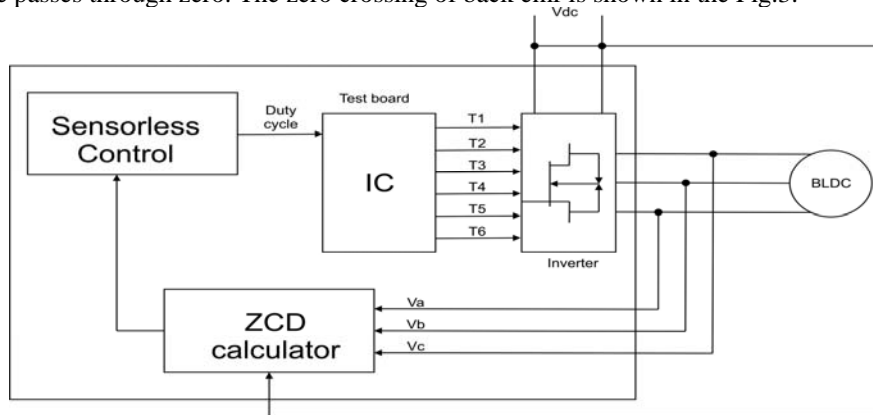


Fig. 2 Control Algorithm

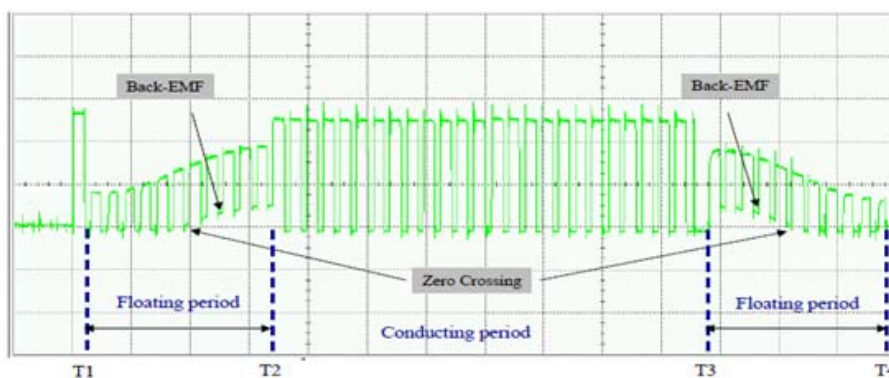


Fig.3 BEMF Waveform

The ZCD circuit detects the crossings of back emf signal and attempts to generate the PWM signals for the power switches in the inverter to the drive BLDC motor in the sensor less mode.

V Simulation

The strategy is simulated in the MATLAB/SIMULINK platform, Fig.s 4 And 5 respectively show the back EMF wave forms and the PWM pulses used in V/F control while starting the motor. The Figs. 8 and 9 display

the speed regulating characteristics of the Sensorless approach in the event of the motor being subjected to step changes in load and reference speed respectively.

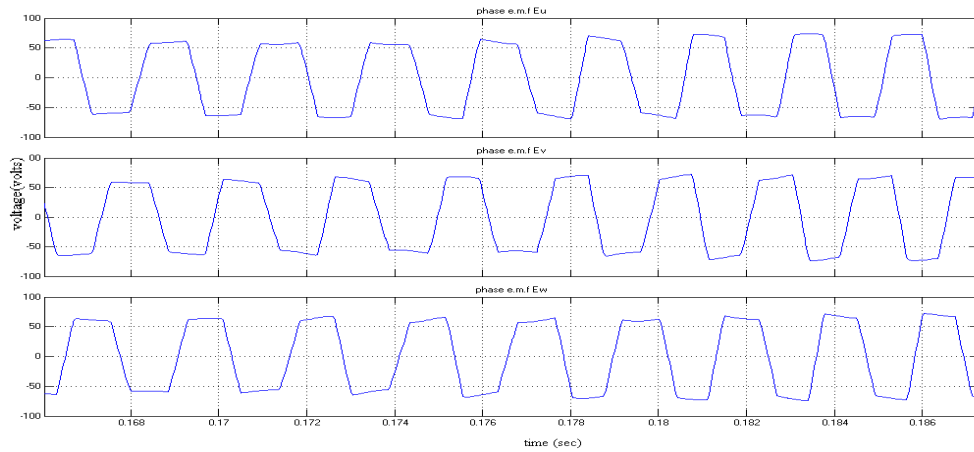


Fig. 4 Back emf in V/F control

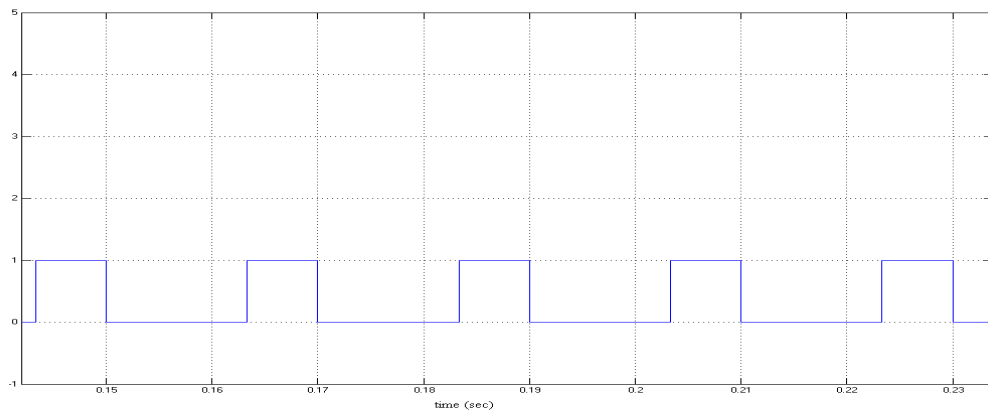


Fig. 5 PWM pulse in V/F control

The BEMF and ZCD signals obtained in the sensorless mode, with a PI corrective action to control the speed are drawn in Figs.6 and 7

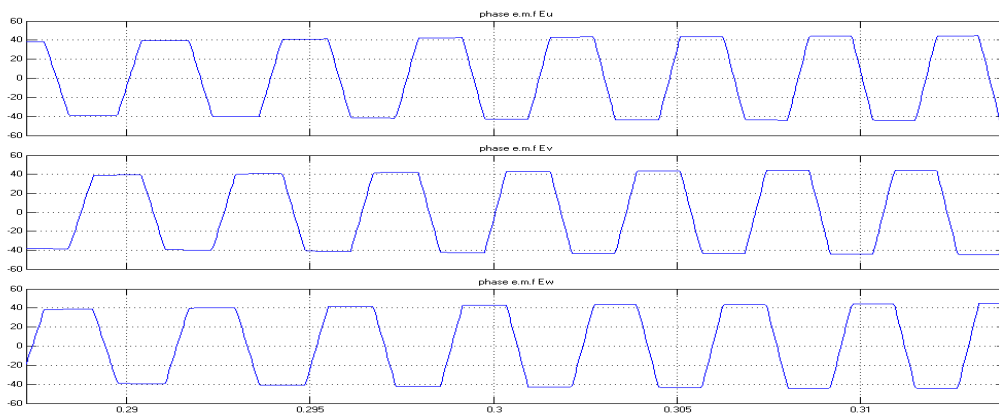


Fig. 6 Back emf in sensorless control

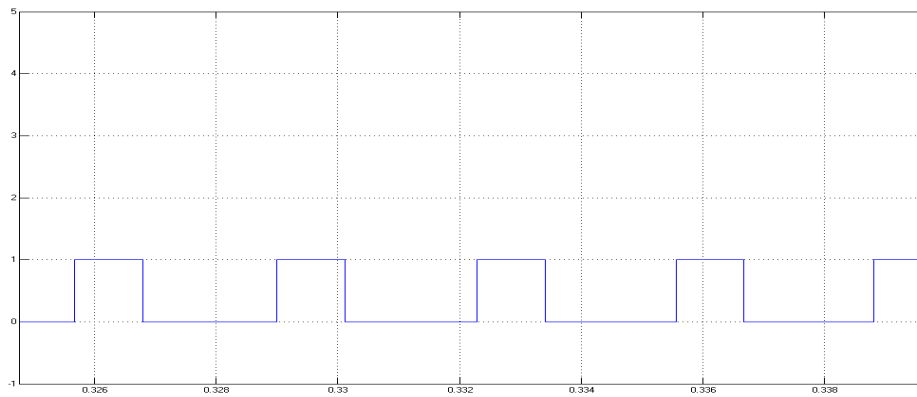


Fig. 7 PWM pulse in sensorless control

VI Real time implementation

The scheme implemented in real time using a 1.1 HP, 4600 rpm, 310 volts BLDC-PM motor is shown in Fig. 8. The back emf waveforms without filtering , with filtering and PWM pulses for both V/F control and sensorless control are shown in the Figs 9 ,10 ,11 and 12 respectively.

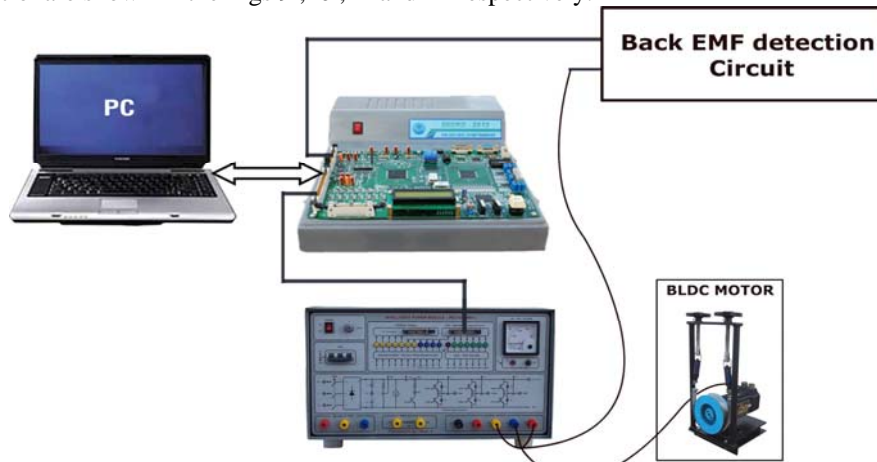
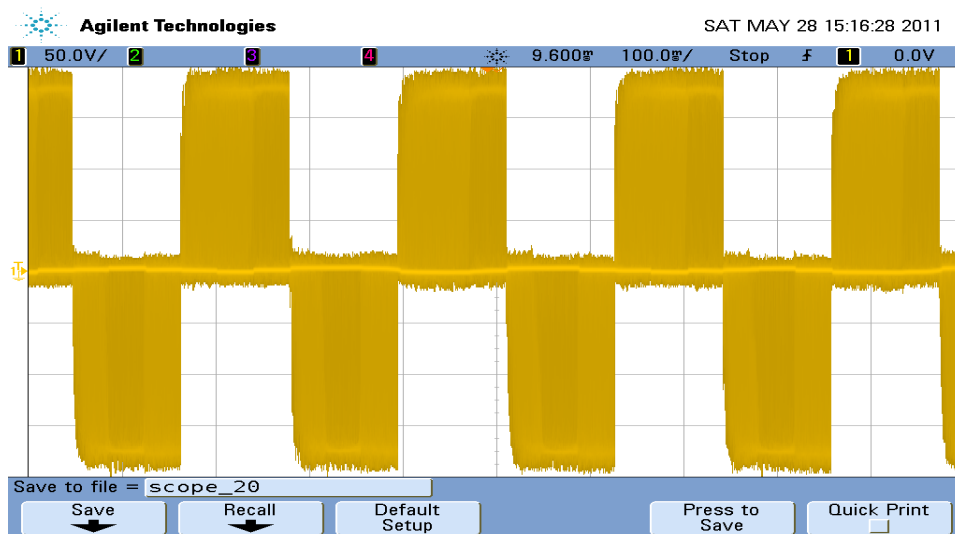
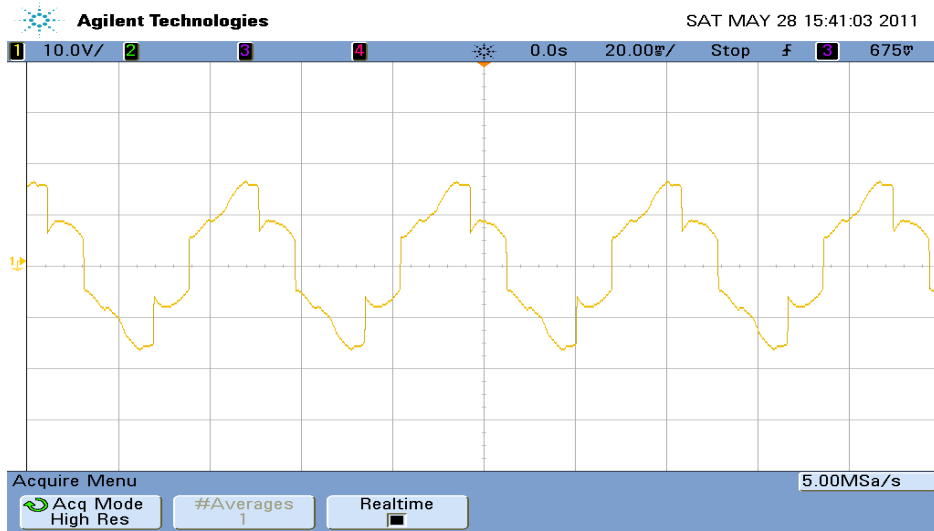


Fig. 8 Real time Implementation



(a)



(b)
Fig. 9.Back emf (a) Without filtering (b) With filtering in V/F control

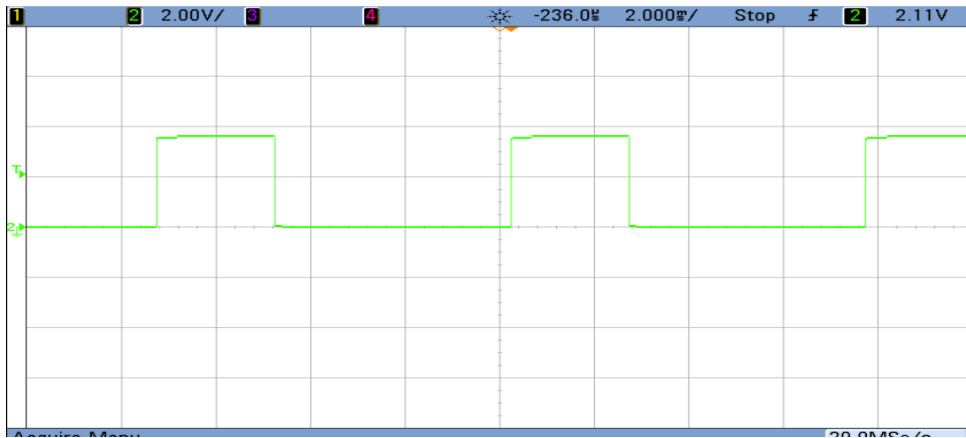
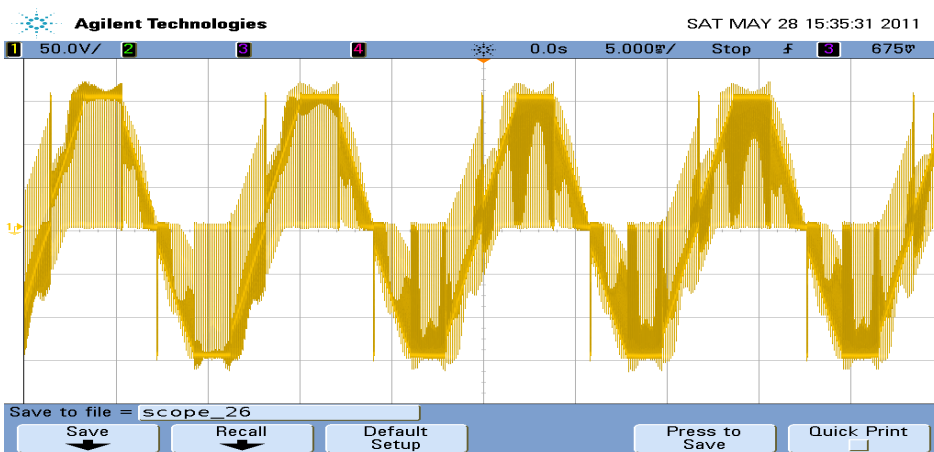
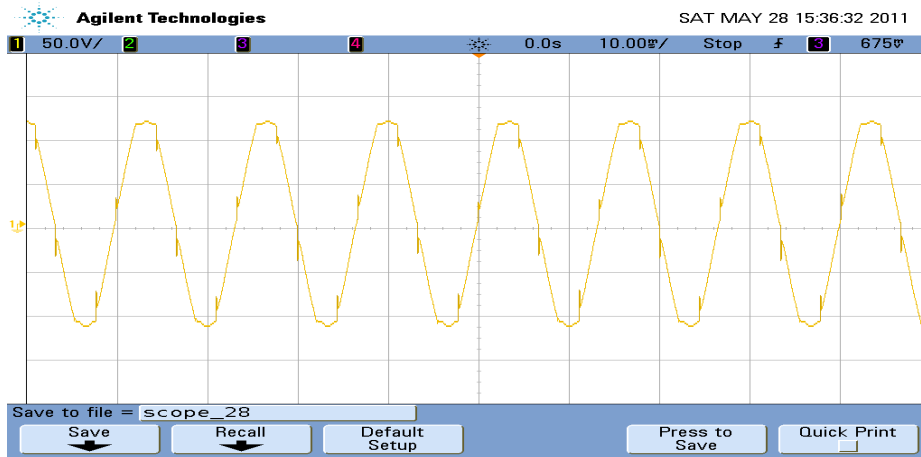


Fig. 10 Back emf and PWM pulse in V/F control



(a)



(b)

Fig. 11.Back emf without filtering and with filtering in sensorless control



Fig. 12 PWM pulse in sensorless control

The three phase current wave forms for V/F control and sensor less control are shown in the Figs.13 and 14. It is observed that the current wave forms in V/F control are not symmetrical because of switching that takes place without knowing the actual position of the rotor.

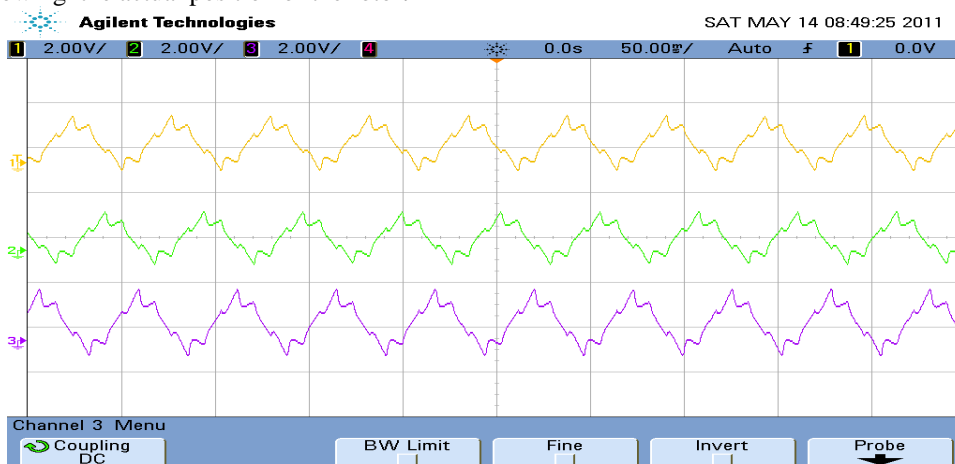


Fig.13 Current waveforms in V/F control

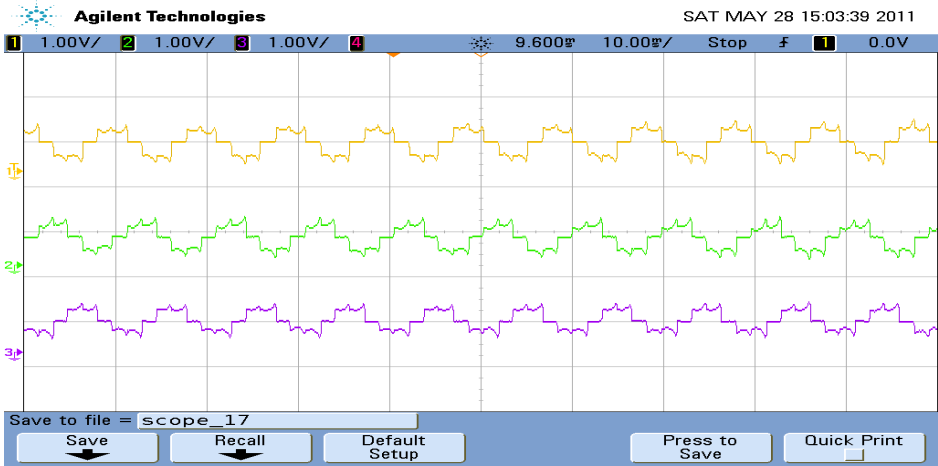


Fig. 14 Current waveforms in sensorless control

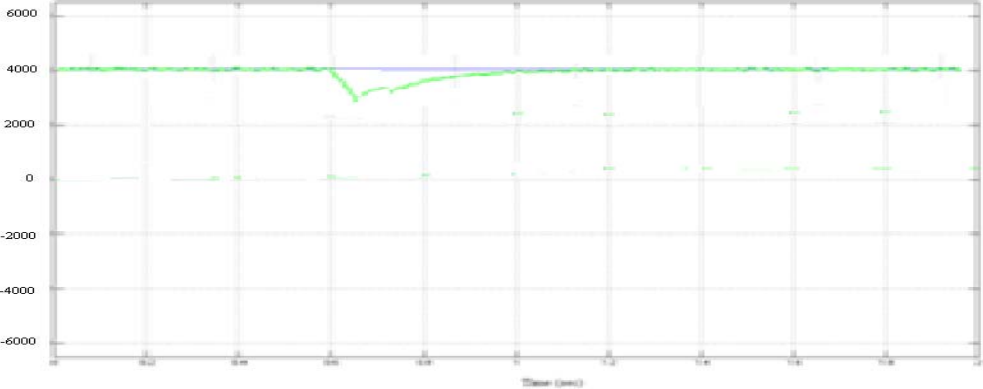


Fig. 15 Speed Vs Time waveform with a step change in load

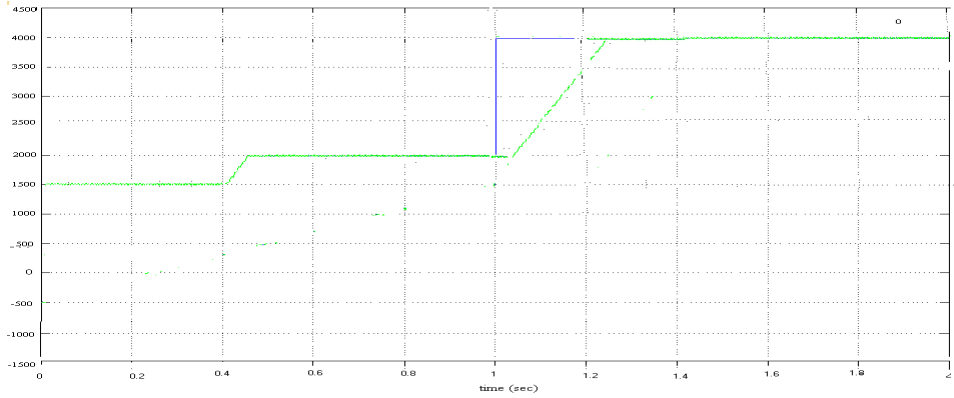


Fig. 16 Speed Vs Time waveform a step change in reference speed

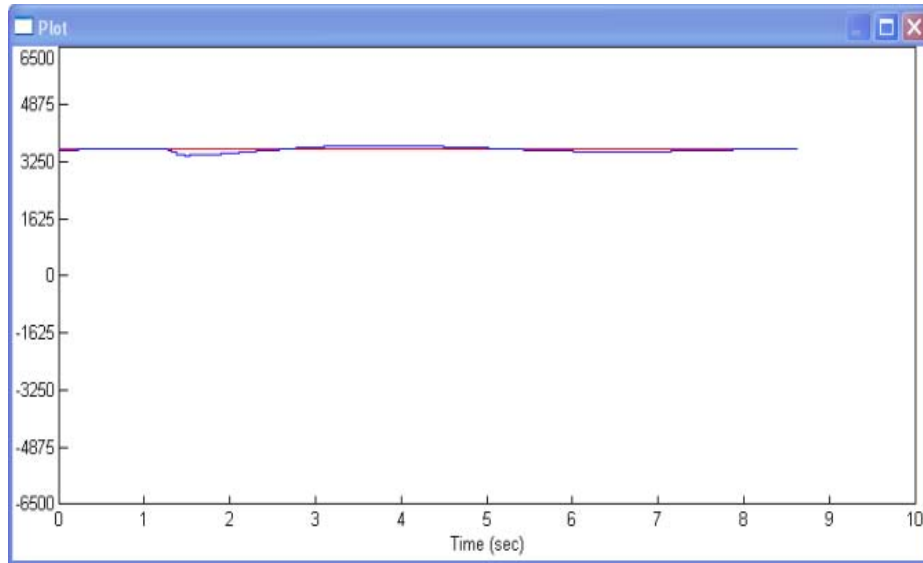


Fig. 17 Speed Vs Time waveform with a step change in load

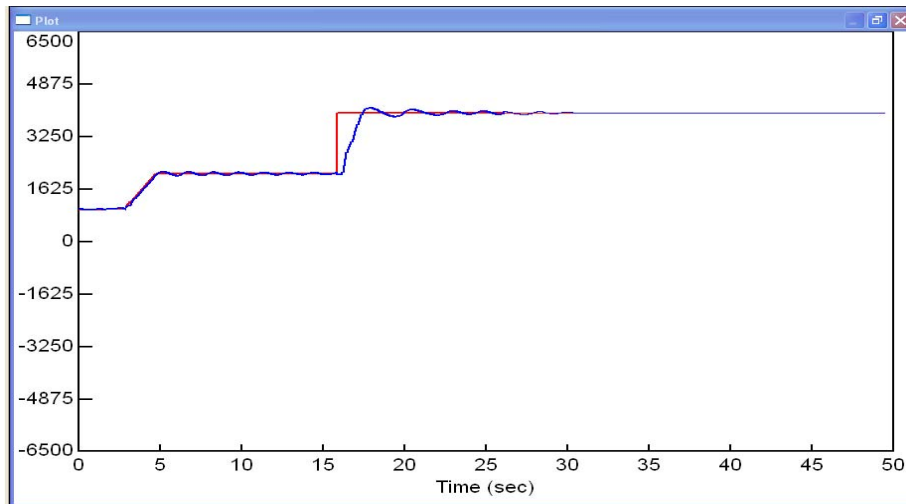


Fig.18 Speed Vs Time waveform a step change in reference speed

The speed regulating characteristics of the Sensorless approach in the event of the motor being subjected to step changes in load and reference speed respectively. The servo and regulatory responses obtained through simulation is seen in Figs.15 and 16. The same adequately valuated through experimental results in Figs 17 and 18 exhibit the ability of the scheme to allow the motor to reject the disturbances and reach steady state in reasonably quick time.

VII performance Comparison

The study further compares the input power factor for different currents in hall sensor mode and sensorless mode in Table 1 to elucidate the improvement in power factor and the effective speed regulatory action on account of the sensorless operation.

TABLE 1 . COMPARISON OF INPUT POWER FACTOR AND SPEED REGULATION

Current in amps	Power factor in				Open loop control				Closed loop control (Reference speed=4000 RPM)			
					Hall sensor mode		sensor less mode		Speed in Hall sensor mode (RPM)		Speed in sensor less mode (RPM)	
	Simulation	Real Time	Simulation	Real Time	Simulation	Real Time	Simulation	Real Time	Simulation	Real Time	Simulation	Real Time
0.8	0.65	0.65	0.73	0.71	3381	3364	3385	3369	3999	3981	4000	3985
1.5	0.67	0.67	0.75	0.74	3175	3160	3179	3165	3991	3985	3996	3988
2.2	0.68	0.71	0.78	0.76	3021	3006	3024	3008	3990	3986	3992	3986
3	0.74	0.73	0.81	0.78	2901	2890	2905	2893	3992	3984	3994	3989
4	0.77	0.75	0.84	0.81	2746	2730	2749	2735	3996	3983	3998	3988

VIII Conclusion

A novel sensorless control strategy has been developed to regulate the speed and improve the input power factor of an inverter fed BLDC-PM motor. It has been based on seamless commutation to BEMF zero-crossing detection. The TMS320F2812 controller has been found to offer an easy way of real-time implementation that does not require large computation time. The performance has been found to enhance the input power factor and thereby minimize the system VAR requirements, in addition to yielding a regulated speed over the entire operating range. It can be inferred that the proposed methodology will go a long way in exploring innovative applications in this domain.

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