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Research paper

Realization and Encompassment of Torque and Speed Pulsations Depriciation in Permanent Magnet Synchronous Motor Employing ILC-Sine PWM

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Abstract

The rotor of PMSM is made of permanent magnet and thus it does not rely on an external source to generate the rotor flux. The major drawback of Permanent Magnet Synchronous Motor is torque ripple, where speed oscillations are generated and weaken the function of drive which operates at low speed. This paper propose the Iterative Learning Controller (ILC) with SPWM to extinguish the speed and torque ripple in PMSM driven by field oriented control. The reference motor speed is compared with actual motor speed by the speed controller, and generates the reference current i_{qref} value where the speed error is reduced. Depending on i_{qref} value SPWM pulses are generated. These generated pulses are sent to the three phase inverter. The major merit and effeciency of the proposed method for speed ripple and torque suppression are designed, analysed, simulated and implemented in hardware using TMS320F2812. The outcomes obtained show the significant minimisation of speed ripples using PI plugged in ILC with SPWM. Thus reduction of speed ripple is done by this proposed method.

Keywords: *Permanent Magnet Synchronous motor (PMSM), Torque ripple, Speed pulsation reduction, Field oriented Control (FOC), Proportional plus Integral Controller (PI), Iterative Learning Controller (ILC), Sine Pulse Width modulation (SPWM).*

1. Introduction

Permanent magnet synchronous motors (PMSM) are widely employed in low power utilizations for regulating speed drives and electric vehicles. PMSMs are yet featured for their extreme efficiency, energy concentration, where is best suitable alternative for different speed varying applications. Production of torque ripple is the major disadvantage in several application. Occurrence of the torque ripples results in instant torque that pulsate regularly with position of rotor. The periodic pulsation in the motor speed occurs as the reflection of these oscillations, particularly for lowerspeed application.

But in the high speed operation these ripples are filtered naturally by the rotor and load inertia and will not affect the motor speed. But in the absence of mechanical gears the motor needed to be operated at lower speed. The different causes for torque ripples in a PMSM are as follows:

1. the cogging, flux harmonics, errors in current measurements, and phase unbalancing.

2. Many techniques have been opted for reduction of torque ripple in both the design of motor and soft computing controlling techniques have been proposed in literature.[4]

An iterative learning controlling technique is dealt in this paper to minimise the speed ripple associated with the field oriented control when used in control of a PMSM. Smooth torque performance in both steady state and transient operation of motor is obtained by the SPWM -ILC. Also, main advantage of FOC is that it increases efficiency, by making the performance of AC machines is driven as DC machines. The ILC is best known for its preventative iteration that it has ability to compensate the regular dicturbances by repetitive error correction on previous iterations.[5]

2. Overview of Vector control

The vector control is also called as FOC control where the PMSM is controlled by a proficient method for variable speed drive application with fast changing load in a open series of speeds. Stator currents are controlled by the FOC represented by a vector. In this technique three phase axis is converted to two phase axis such as d axis and q axis. This is similar to Dc machines and the control calculation are done as a DC machine. FOC technique need two constants as input references coordinating the torque aligned along q axis and flux aligned along X axis. Thus the performance is viewed in terms of steady state and transient state. The flow chart of speed control of PMSM is shown in Fig.1.

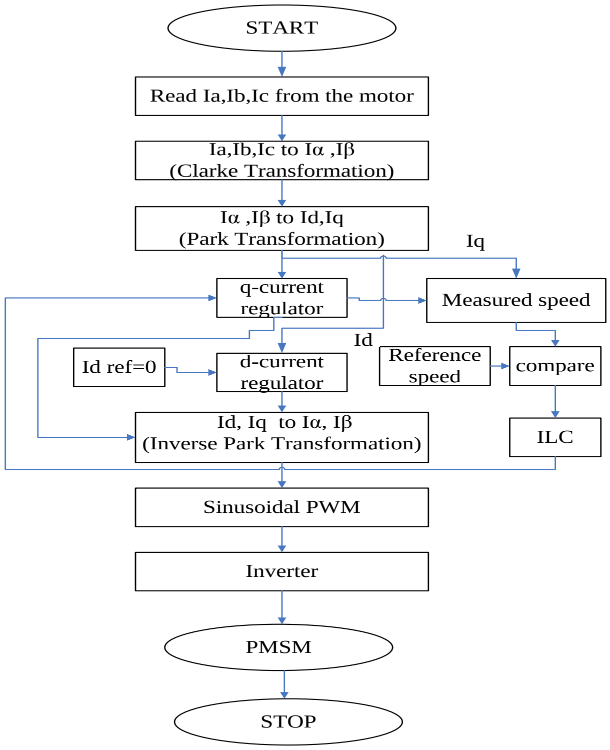

Fig.1: Flowchart for speed control of PMSM.

3. Proposed System

The proposed system contains the PI controller in the speed controller part is replaced by the Iterative Learning controller. The input to the Iterative Learning controller will be the speed error and the output will be the reference current iq. The proposed Hardware block diagram of PMSM with FOC and ILC is shown in the figure b. The ILC is an approach where the tracking of system is carried out repetitively and improve the results over a fixed time interval. The memory stores the previous result and computes the new result based on the error corrective algorithm. The main advantage is no tedious calculation is needed for this approach. [1, 8, 9]

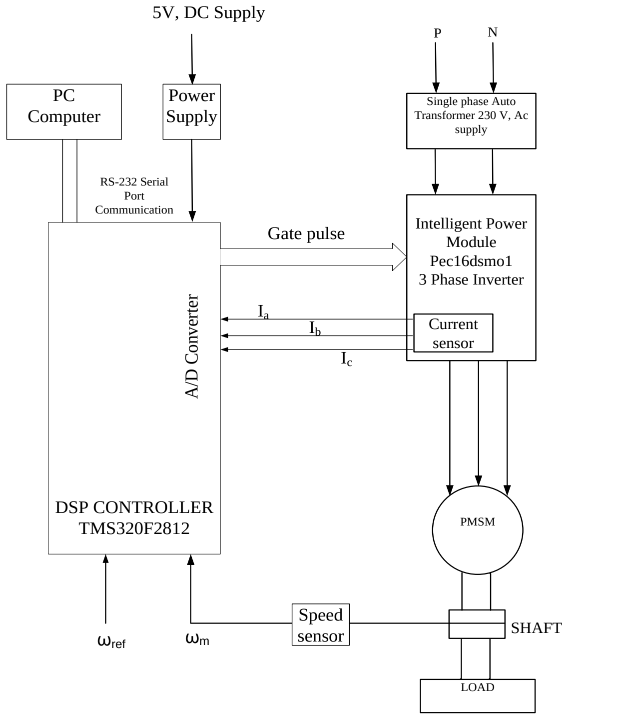

Fig.2: Proposed Hardware Block diagram of PMSM-ILC-SVM

3.1. Sinusoidal Pulse Width Modulation

The sinusoidal pulse width modulation produces the gate pulse by comparing it with the reference and carrier frequency.the pulses produced from the controller is fed to inverter.

3.2. Iterative Learning Control

The ILC is an approach where the tracking of system is carried out repetitively and improve the results over a fixed time interval. the error corrective algorithm is used to generate improved result by storing the previous result in the memory. The main advantage is no tedious calculation is needed for this approach. [1,8,9].The equation used for ILC is formulated in below equation (1) and the respective flow chart is represented in fig c.

$$u_{i+1}(t) = (1-\propto)u_i(t) + \emptyset e_i(t) + \Gamma e_{i+1}(t) \qquad (1)$$

Where i= number of iterations;
$u_i(t)$ = signal of control
$e_i(t)$ = signal of speed error
$\propto$= forgetting factor
$\emptyset$ = feed back from previous cycle
Γ = feedback during current cycle

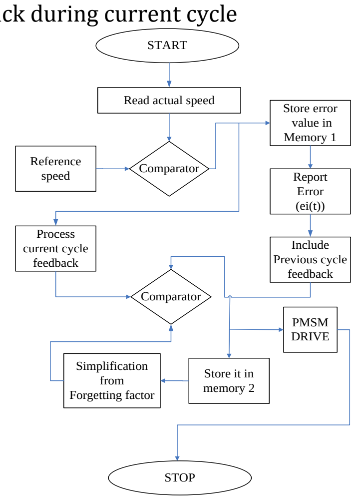

Fig.3: Flowchart for ILC control

3.3. Tuning of PI Controller

The reference current which is produced by the PI controller by comparing actual speed with reference speed thus tuning of PI controller is done. The current loop is used to compare actual current and reference current.

4. Simulation Results and Discussions

Initially motor is controlled by using the PI controller and speed outputs are recorded and analysed. The waveforms of the PI controller based PMSM drive is shown in the Fig.4.

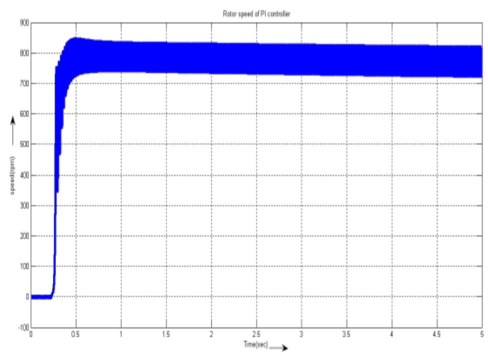

Fig.4: Speed output of PI-SPWM controller (speed=750rpm)

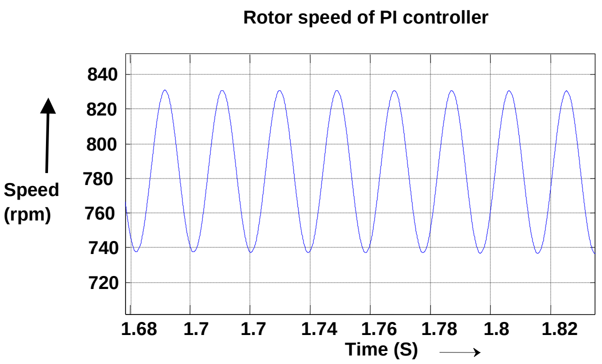

Fig.5: PMSM Speed ripples using FOC-PI-SPWM

5. Hardware Results and Discussions

5.1. Output Current Waveform For 50%Loading

The figure g shows the output current waveform at 50%loading.The current value is 3.3A at 2300 rpm. The parameters are

X-Axis –Time in ms,(1 div=5ms)

Y axis-(I1, I2, I3) - current in Amps, (1div = 2A)

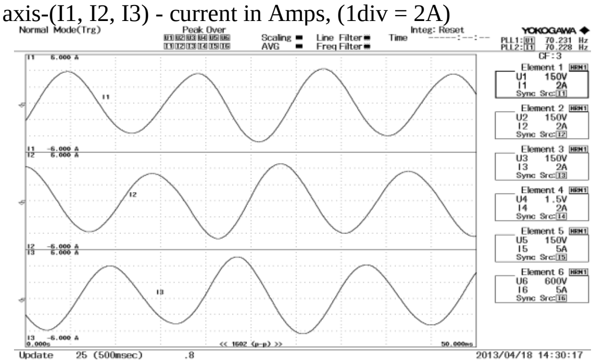

Fig.7: Waveform of Output currents (Ia,Ib,Ic =3.3A) at speed 2300rpm

5.2. Output Voltage Waveform For 50%Loading

The figure h shows the output voltage waveform at 50%loading.The voltage value is 100V at 2300 rpm. The parameters are

X-Axis –Time in ms, (1 div=5ms)

Y axis-(U1, U2, U3) - Voltage in volt,(1div = 150V).

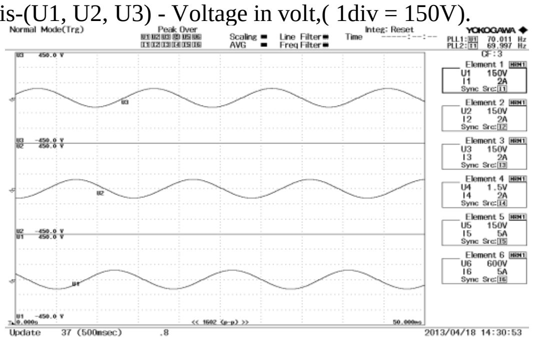

Fig.8: Waveform of Output Voltage (Va,Vb,Vc =100V)

5.3. Torque Waveform of Pi-Spwm

The figure i shows the torque response of PI-SPWM at the 50%loading at speed 2000rpm

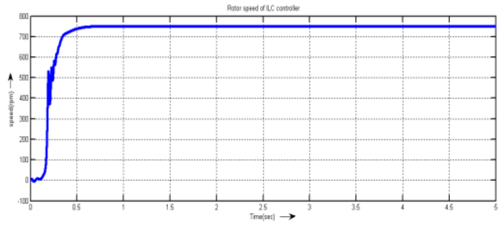

Fig.6: PMSM Speed output using FOC–ILC-SPWM

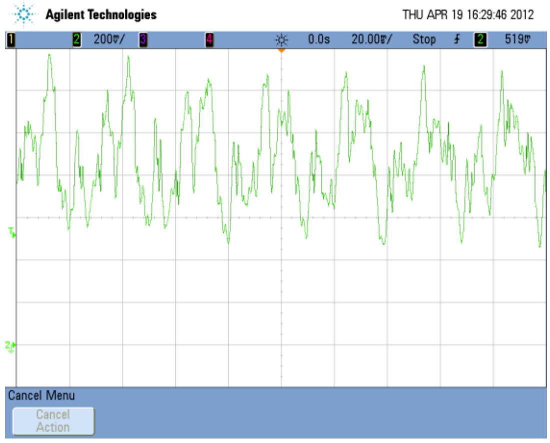

Fig.9: Torque waveform of PI-SPWM at 50% loading

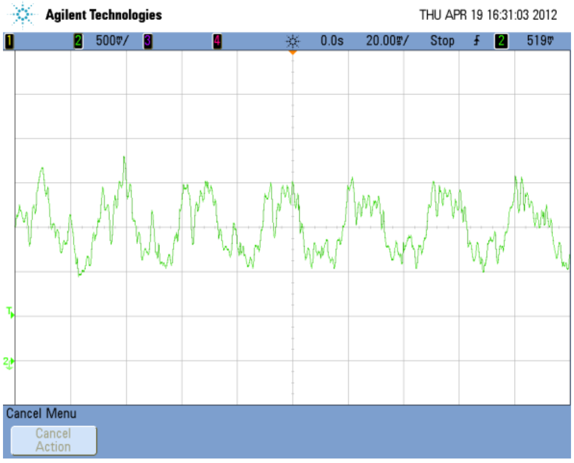

Fig.10: Torque waveform of PI-SPWM at 100% loading

5.4. Waveform of Svpwm, Lineto Line Voltage Without Filtering and With Filtering

The figure k shows the SPWM pulses, inverter output voltage for each phase without filtering and with filtering. The voltage value is 220V at 4000 rpm. The parameters are

X-Axis –Time in ms,(1 div=5ms)

Y axis-(U1, U4, U5) - Voltage in volt, (1div = 150V).

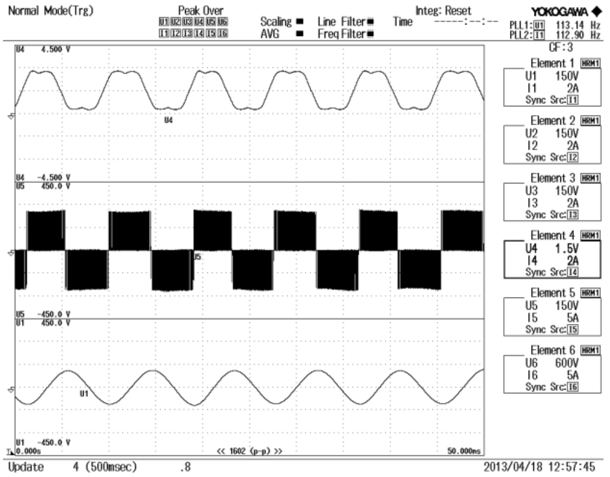

Fig.11: Waveform of SPWM, line to line voltage without filtering and line to line voltage with filtering.

5.5. Waveform of Pi-Ilc-Spwm

The figure 1 shows the dynamic speed response of PI-ILC-SPWM at the speed range of 300 rpm to 2000rpm

Fig.12: Dynamic speed waveform of PI-ILC-SPWM

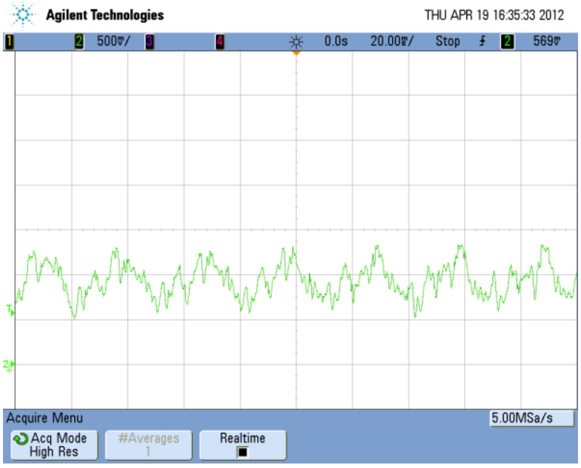

Fig.13: Torque waveform of PI-ILC-SPWM at 50% loading

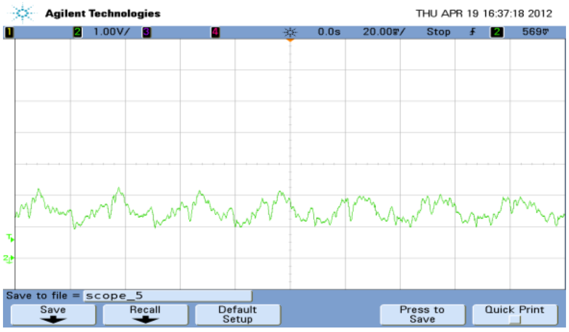

Fig.14: Torque waveform of PI-ILC-SPWM at 100% loading at 2000rpm.

The table I depicts the comparative analysed result of field oriented control of PMSM using PI-SPWM and PI-ILC-SPWM.

Table 1. Comparitive results of field oriented control in PMSM

FOC	SRF (%)
PI-SPWM	12.3
PI-ILC-SPWM	10.06

The result clearly explains the comparitive results of depreciation of speed ripple from 12.3% to 10.06%.thus the ripples are reduced upto 1.7% using ILC technique.

6. Conclusion

Thus the comparative results shows that the ripples is reduced using ILC technique and the results of hardware is also discussed in this paper depicting the improved performance.

Table. 2. Block values

PI BLOCKS	K_p	K_i
Speed controller	2	20
Current controller1 &2	5	50

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