http://ansinet.com/itj

ITJ

ISSN 1812-5638

INFORMATION TECHNOLOGY JOURNAL

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Information Technology Journal 12 (15): 3075-3081, 2013
ISSN 1812-5638 / DOI: 10.3923/itj.2013.3075.3081

Development System of Pmsm Based on Labwindows/cvi

Song Wang
School of Mechanical, Electrical and Information Engineering, Shandong University, Weihai, China

Abstract: Control algorithm and driver development of PMSM is a hard work in embedded development environment due to the limited resources. PC host has abundant hardware and software for engineers. In this paper, we provide a development platform based on PC host installing LabWindows/CVI. LabWindows/CVI programming environment from National Instruments is designed for instrumentation control, data acquisition and visualization of processes. In addition, the complier is based on C language. Therefore, the algorithm can be transplanted to embed processors easily. We use the platform to realize a SVPWM algorithm and design a PID control algorithm. The results indicate that the SVPWM algorithm is valid to drive the PMSM and the control algorithm is valid to realize closed loop control and against load disturbances.

Key words: SPWM PMSM, lab windows/CVI, SVPWM, data acquisition

INTRODUCTION

AC servo system plays an important role as an industrial device driver source in modern industrial automation field and widely used in social production and daily life. It is very suitable for some high-performance requirement applications, e.g. robotics, aerospace, electric ship propulsion systems, wind power generation systems (Liu *et al.*, 2012). It has been shown that PMSM can provide significant performance improvement in many variable speed applications (Caricchi *et al.*, 1998). Motor speed control method is numerous. The commonly used one is vector control. The control algorithm development procedure of PMSM is: firstly we use mathematical model and simulation software to evaluate the performance of the algorithm on the computer. If the simulation result is perfect, the simulation code will be converted to a transplantable code and then the code will be transplanted into DSP, FPGA or other embedded processors (Rodriguez-Resendiz *et al.*, 2012). Finally, the developers debug the algorithm on actual motor. However, due to the complexity of development and testing of the embedded processor, together with the difference between the simulation model and actual motor, the development of control algorithm often meet with unexpected problems and the development cycle will grow long. In order to reduce development cycle, using mature hardware and software technology under Windows (Kong *et al.*, 2010) it is a valid method to realize reliable control of PMSM. LabWindows CVI is based on C language environment under Windows. It has friendly user interface, rich library function and variety of simple debugging methods (Metzger, 1999). These characters make designers to design and debug algorithm rapidly.

In this study, PMSM is the research object. In the LabWindows/CVI platform, we write and debug the SVPWM program and PID control algorithm. We can obtain the test result conveniently and the result can be analyzed deeply. Through this, we can determine the improvement plan of the algorithm. And also, C language is easy to write and it is easy to transplant to DSP and ARM etc. directly. The platform can reduce the development cycle.

MATHEMATIC MODEL OF PMSM

Accurate mathematical model of motor is the foundation of vector control technology. Supposed that, there is no iron saturation, no rotor damping winding, no eddy current and no hysteresis loss. We use the d-q rotating coordinate to analyze PMSM's steady and dynamic performance it is more convenient than other coordinates. In d-q rotating coordinate, the voltage equations are as follows (Wang *et al.*, 2012):

$$\begin{cases} u_q = R_s i_q + p\psi_q + w_e \psi_d \\ u_d = R_s i_d + p\psi_d - w_e \psi_q \end{cases} \tag{1}$$

Flux equations can be described as equation:

$$\begin{cases} \psi_d = L_q i_q \\ \psi_d = L_d i_d + \psi_f \end{cases} \tag{2}$$

Flux equations can be described as:

$$T_e = p_n(\psi_d i_q - \psi_q i_d) \tag{3}$$

For PMSM, we use id = 0 control method. Therefore, the flux equation (3) is described as:

$$T_e = p_n \psi_d i_q \quad (4)$$

where, u_d, u_q, i_d, i_q, L_d, L_q, Ψ_d and Ψ_q are voltage, current, inductance and flux on d, q axis. Rs is the phase stator resistance. W_e is electric angular speed of rotor. Ψ_f is rotor flux generated by permanent magnet. P_n is number of pole pairs. T_e is electro-magnetic torque.

From above equations, we can see torque output of PMSM can be controlled by the value of i_q.

REALIZATION OF SOFTWARE AND HARDWARE

Design of overall system: We use the ST110-series motor in this study. The three phases winding of stator is the star connection mode and the back electromotive force is sinusoidal waveform. NI PCI-6221 data acquisition (DAQ) card is the signal acquisition and output equipment, the host computer is the main controller. Intelligent power module IPM PS21267 is the power conversion device. Using Space Vector Pulse Width Modulation Technology (SVPWM) realizes the PMSM ac servo system control. Figure 1 shows the diagram of whole system.

The main structure of the system is a voltage type converter of ac to dc to ac and composes of the rectifier circuit, filter circuit and the inverter circuit. Rectifier circuit adopts three-phase uncontrolled rectifier bridge with high power factor. Capacitance is used in filtering part. Inverter circuit adopts intelligent power module IPM PS21267. LabWindows/CVI 2009 software is installed on PC host. LabWindows/CVI 2009 provides a wealth graphical user interface elements and integration of a variety of interface function library and it is convenient to debug and maintain the system (Song *et al*., 2009). LabWindows/CVI (each pulse is 0.036° mechanical angle). The encoder can adopts PCI-6221 Data Acquisition Card (DAQ Card) to acquire data. The DAQ card have 16 analog input ports with the resolution of 16, two analog output ports with the high speed of 833 k $\sec^{-1}$, 24 digital I/O, two timer with 32bit and 8 DIO with the clock of 1MHZ. The resource of PCI-6221 Data Acquisition Card is enough to develop the driver of the servo system.

Vector control technology has a requirement of stator current collection. PCI-6221 data acquisition card can realize acquisition of phase current, rotor speed and voltage signal. These signals will transfer to PC host, the software of PC uses the current for current close loop adjustment and it is converted to SVPWM input voltage after coordinate transformation and then SVPWM pulse signal will be generated. The output of SVPWM pulse needs the digital pulse generating function of data acquisition card. The SVPWN pulse is transferred to light coupling isolation circuit and driver circuit and then added to the IGBT of intelligent power module IPM. Three phase Alternating Current (AC) is output. The start of synchronous motor needs the position of the rotor (Bolognani *et al*., 1999). We can determine it through counting the encoder pulse signals. Motor speed is detected by measuring encoder pulse signal. These parts will be introduced in the following part.

ROTOR SPEED AND POSITION DETECTION

Photoelectric encoder and counter: Currently, the methods of detecting rotor position mainly are photoelectric coding plate method, rotating transformer method and motor internal position sensor method etc. (Zhou *et al*., 2008). ST110-series motor has an incremental photoelectric encoder internal. The encoder is connected to the DAQ card. The zero offset of ST series servo motor has 2650 pulses. Every cycle of motor has 10000 pulses output two types of signal, ABZ signal and UVW signal.

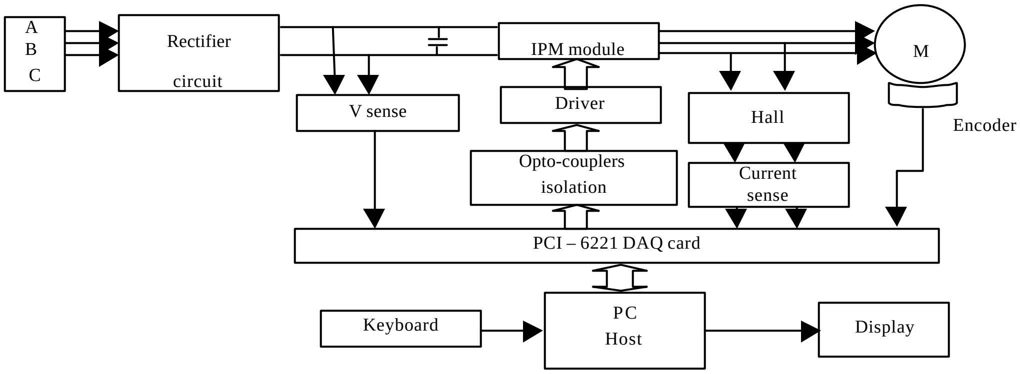

Fig. 1: Structure of the whole system

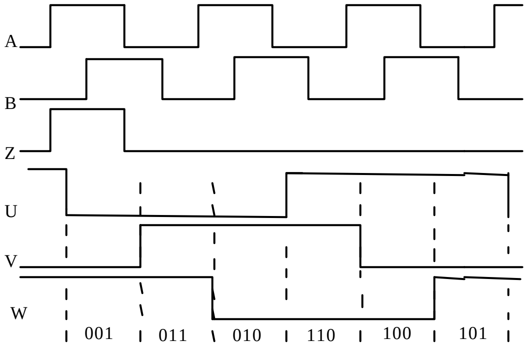

Fig. 2: Pulse output of encoder

A and B pulses are used to judge the steering and speed of rotor. Z pulse is released every cycle of motor. U, V and W pulses number are the same as motor pole. It can be used to judge the position of pole sketchy. Fig. 2 is the pulse waveform of encoder. The rotor position is important parameter in the PMSM control. Before the start of the motor, the rotor position is unknown. Therefore, we need to detect the rotor initial position (Morimoto *et al.*, 2006). After the start, we need to use the electrical angle in the process of coordinate transformation. In order to detect the position of electrical angle, the rotor position is required (De Belie *et al.*, 2010). In the process of working, we need to get the current motor speed feedback value in order to realize speed closed loop control, so we must test motor speed through the encoder. The rotor mechanical angular displacement can be detected by pulse number. PCI-6221 DAQ card have two 32bit counters. The pulse can be measured by the counter. The counter can be configured according to our requirement.

Realization of rotor speed and position detection under LabWindows: In the speed detection, DAQmxCreateTask function of DAQ card is used to build the task. DAQmxCreateCIFreqChan function is used to build the detection channel. DAQmxReadCounterF64 function is used to read the frequency value, the detection frequency can be configured and the DAQ card can select the reference clock automatically. The sample time is 1s. In the initial position detection of rotor, the relations of UVW pulse are requirement. DAQmxCreateDIChan function is used to build a digital channel and DAQmxReadDigitalScalarU32 function is used to read the digital value. The UVW pulse output of encoder is divided into six sectors. Every sector is corresponding to 60°electrical angle. The initial program of rotor position is shown as follows.

SVPWM pulse generation: Inverter system and motor are considered as a whole system in SVPWM technology. Fig. 3 is a typical three phase voltage inverter circuit, where Udc is the DC bus voltage.

In Fig. 4, there are six switching devices. The turn-on of upper bridge is defined as 1 and turn-off is 0. Therefore, there are eight statuses for six switching devices. The status of upper and lower switching devices are inverse. There is no current in motor for status V0 (000) and V1 (111), they are zero vectors. Other six status of switching devices are valid vector, the amplitude of the vector is 2Udc/3. The 360 degree is divided into six sectors by the six statuses. The six valid vectors and zero vectors compose of any space voltage vector (Reza and Ali, 2010).

The SVPWM can be realized by table-look-up method in open loop. In this paper, we adopt a sine table to simulate the component of stator current on two phase rotary coordinate. The sine table is even-distributed. The amplitude is decided by the component of stator current on α and β coordinate axis. The PWM pulse is calculated in timing program. In LabWindows/CVI, the highest frequency of timer is 1KHZ. Therefore, the cycle of timer is 1 m sec.

The frequency of sine wave has a relationship with sine table as following:

$$\frac{1K}{f}=\frac{M}{i} \tag{9}$$

Namely:

$$f=\frac{1000i}{M} \tag{10}$$

where, the timer frequency is 1000, the sine wave frequency is f, the data number of sine table is M and i is the increment of indexing value for sine table which is a integer value. From the equation we can see bigger M can create a high accuracy sine wave. Therefore, the corresponding speed regulation accuracy is higher. For example, if we want a sine wave of 50HZ, due to the timer frequency is 1 KHz, every period of sine wave can sample 20 data corresponding to the sine table. Therefore, if M is 400, the indexing value will be 20 in the timer callback function. In the same way, if we want a sine wave of 10Hz and the increment of indexing value is 4. The frequency accuracy of sine wave is 0.02HZ when M is 50000. The speed regulation accuracy is 0.57 r mim^{-1} in theory according to the equation n = 60f/p of PMSM (n is speed, f is power frequency, p is pole pair number). The regulation accuracy can meet the requirement. Therefore, the number of sine table is 50000. The á and â coordinates

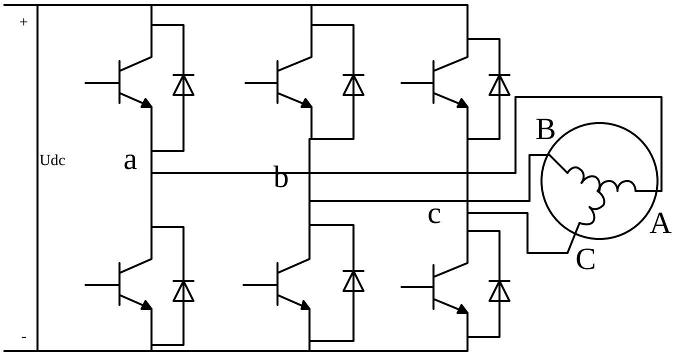

Fig. 3: Inverter circuit of three phase voltage

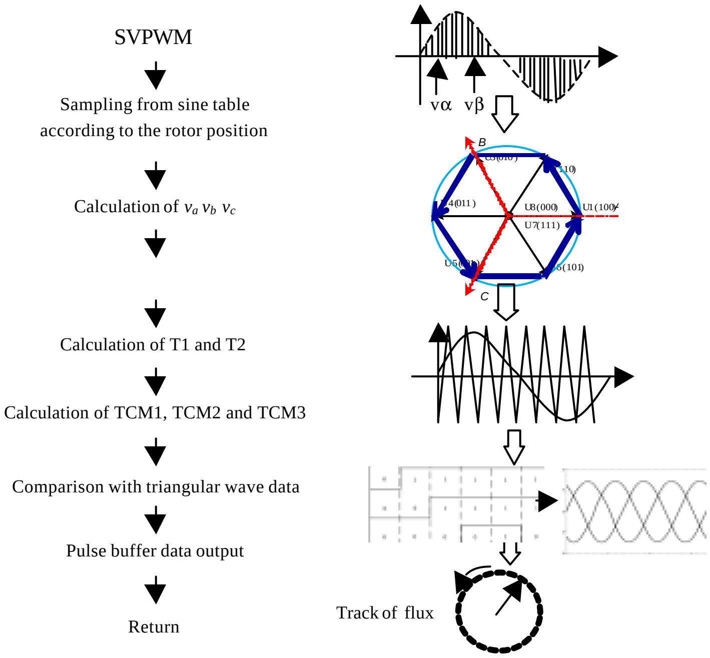

Fig. 4: Realization diagram of SVPWM program

have a difference of 90 degree electrical angle. The indexing of the two signals has a difference of 12500 in sine table when the sine table has 50000 data. The initial position of rotor can be obtained by encoder, determining the corresponding position in sine table according to the encoder value and then the indexing value of anther signal has an offset of 12500. Finally, the SVPWM pulse was output. The carrier function is triangle function. The triangle function is realized through table. The table is even-distributed. The number of the triangle function table affects the pulse accuracy and motor speed. In this paper, the number is 101. The amplitude of triangle function is 0.5.

In the calculation of pulse duration, in order to avoid frequent table-look-up operation and improve the execution speed of the program, we need to calculation the pulse indexing value of every channel in the triangle function table. The conversion of switch point and the indexing value are shown as follows:

$$\text{com1} = (\text{int})(\text{Tcm}(1)/0.5*100) \tag{11}$$

$$\text{com2} = (\text{int})(\text{Tcm}(2)/0.5*100) \tag{12}$$

$$\text{com3} = (\text{int})(\text{Tcm}(3)/0.5*100) \tag{13}$$

where, Tcm(i) is the switch point by calculation, comN is the indexing value in triangle function table.

In LabWindows/CVI, we should write the SVPWM program correspondingly. Fig. 4 is realization diagram of

SVPWM program. In open loop SVPWM program, uá and uβ can be obtained by sine table which have a difference of 90° electrical angle, namely the indexing value has a offset of 12500. According to uá and uâ, we can judge the sector of the vector. And then the switch point and indexing value of triangle are calculated. Finally, the pulse is obtained. The DAQ card outputs the pulse in timer callback function to control the PMSM.

SOFTWARE DESIGN

The LabWindows/CVI is based on the event, like user action etc. LabWindows/CVI call event callback function and carry out the program of callback function. In this paper, the timer button and display box are used. The mainly program is realized in the timer function, the timing setting value is 1k. The button is used to input the parameters. The display box is used to display the real-time speed. The flow of main program is shown in Fig. 5.

In the program, the variables are mainly used to preserve detection information data external and output signal data. The initialization tasks include analog quantity acquisition task, digital pulse output task and external pulse counting and frequency detection task. In addition, there are some global variables and sine table, triangular wave table data, etc. out of the main program.

In the process of pulse generation, all of the pulses are stored in a buffer of data [600]. Every channel has 100 data. A 100KHZ clock internal is adopted as the output sample clock. The pulse generation will occur in timer callback function every millisecond.

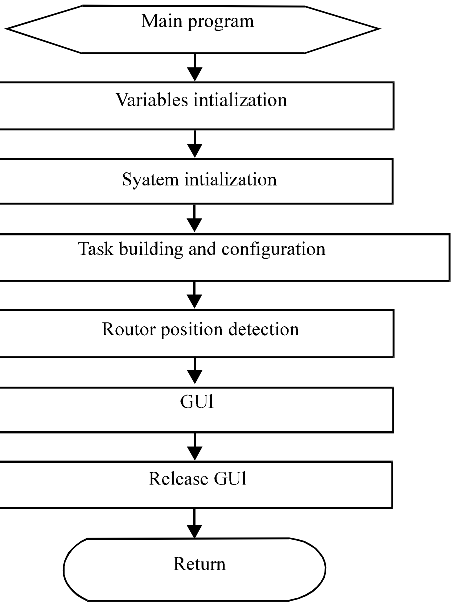

Fig. 5: Flow of main program

EXPERIMENTS

In the experiment, we use ST110-series motor to test the system in our lab. The test platform includes a motor platform, a rectifier device supplying the DC power, an IPM board providing an interface of DAQ card and three phases AC power source, PCI-6221 DAQ card for data input/output and a PC host installing LabWindows/CVI as controller.

FLUKE43B power quality analysis instrument is used to detect the voltage and current of stator and its harmonic analysis. Fig. 6 is the voltage wave form of stator, Fig. 7 and 8 is the harmonic analysis of voltage and current.

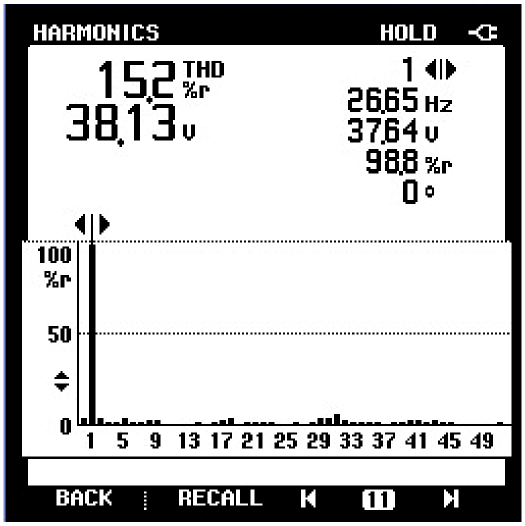

Fig. 6: Voltage and current

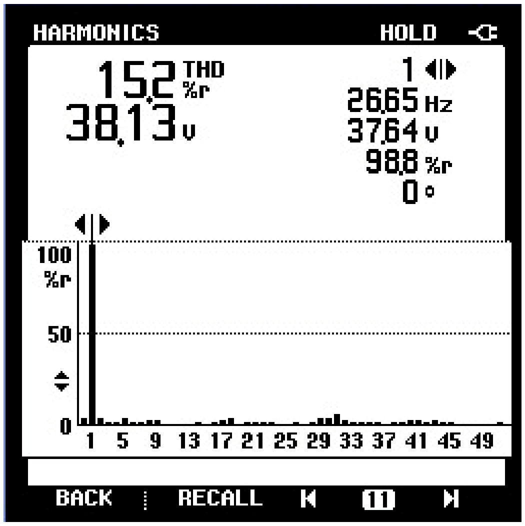

Fig. 7: Voltage harmonic

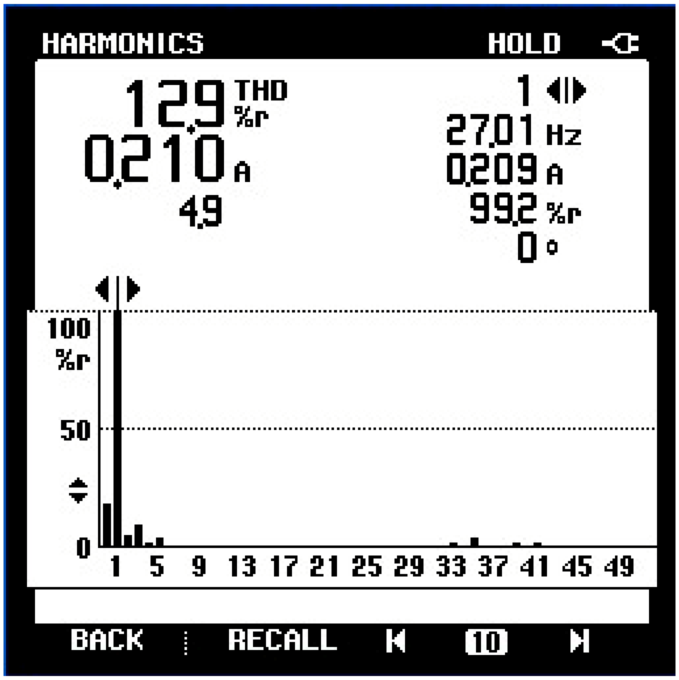

Fig. 8: Current Harmonic

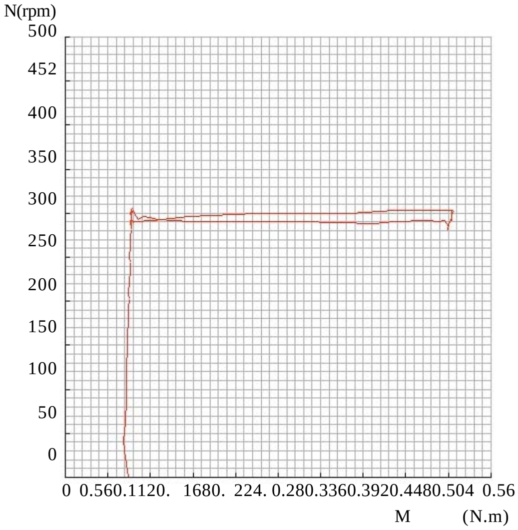

Fig. 9: Motor test report after adding 0.5N.m load

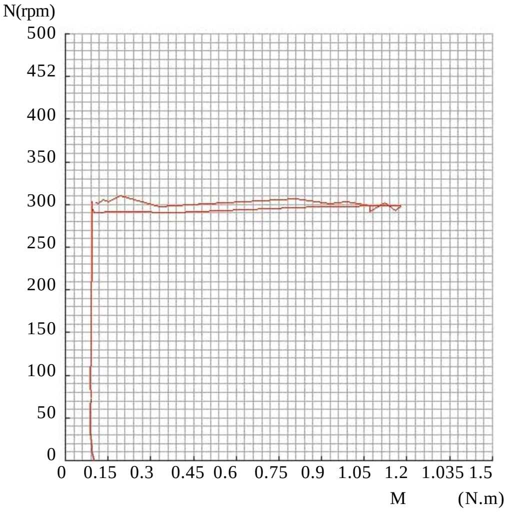

Fig. 10: Motor test report after adding 0.5N.m load

The speed set point is 300r/min. we use the dynamometer to test the control system. Two types of load 0.5 N.m and 1N.m were added to the motor whenmotor is stable. Fig. 9 and 10 is the motor test report. From Fig. 9 and 10, we can see the PID is valid and the capacity of resisting disturbance of the system is strong.

CONCLUSIONS

In the software design of servo driver, the CCS and simulator of DSP are commonly used to debug the control algorithm. However, CCS has some limitation in parameter configuration, result display and analysis. This study provides a better way to design the control algorithm of

PMSM. The platform is based on the windows and also, LabWindows/CVI provides a lot of functions for result analysis. Therefore, this will help designer to analyze the algorithm deeply and determine the improvement plan quickly and easily. This is the prototype of the platform. We have a lot of works to perfect the function of the platform. We will use the platform to design some useful and practical algorithm form PMSM control.

ACKNOWLEDGEMENT

This study is supported by the Shandong Province Science and Technology Development Plan of China (Grant No. 2011GGE27053).

REFERENCES

Bolognani, S., R. Oboe and M. Zigliotto, 1999. Sensorless full-digital pmsm drive with ekf estimation of speed and rotor position. IEEE Trans. Ind. Electron., 46: 184-191.

Caricchi, F., F. Crescimbini and O. Honorati, 1998. Low-cost compact permanent magnet machine for adjustable-speed pump application. IEEE Trans. Ind. Appl., 34: 109-116.

De Belie, F.M., P. Sergeant and J.A. Melkebeek, 2010. A sensorless pmsm drive using modified high-frequency test pulse sequences for the purpose of a discrete-time current controller with fixed sampling frequency. Math. Comput. Simul., 81: 367-381.

Kong, J., H. Su, Z.Q. Chen, C.F. Dong and Y. Qian *et al*., 2010. Development of multi-channel gated integrator and pxi-daq system for nuclear detector arrays. Nucl. Instrum. Methods Phys. Res. Sect. A, 622: 215-218.

Liu, K., Z.Q. Zhu, Q. Zhang and J. Zhang, 2012. Influence of nonideal voltage measurement on parameter estimation in permanent-magnet synchronous machines. IEEE Trans. Ind. Electron., 59: 2438-2447.

Metzger, M., 1999. Design of freely programmable labwindows/cvi-based real-time simulators for testing industrial controllers. J. Syst. Anal. Modell. Simul., 30: 153-165.

Morimoto, S., M. Sanada and Y. Takeda, 2006. Mechanical sensorless drives of IPMSM with online parameter identification. IEEE Trans. Ind. Appl., 42: 1241-1248.

Reza, A.P.M. and M.H. Ali, 2010. An optimized svpwm switching strategy for three-level npc vsi and a novel switching strategy for three-level two-quadrant chopper to stabilize the voltage of capacitors. Energy, 35: 4917-4931.

Rodriguez-Resendiz, J., J.M. Gutierrez-Villalobos, D. Duarte-Correa, J.D. Mendiola-Santibanez and I.M. Santillan-Mendez, 2012. Design and implementation of an adjustable speed drive for motion control applications. J. Applied Res. Technol., 10: 180-194.

Song, J.H., C.Z. Fan and Y.Y. Ye, 2009. Testing system of new three-dimensional permanent magnet motor based on LabVIEW. Mech. Electr. Eng. Mag., 26: 52-55.

Wang, S., R.J. Zhao, W.M. Chen, G.D. Li and C. Liu, 2012. Parameter identification of pmsm based on windowed least square algorithm. Proceedings of the International Conference on Manufacturing Science and Technology, November, 2011, Singapore, pp: 5940-5944.

Zhou, X., C. Wang, X. Qi and T. Zhong, 2008. Rotor position self-sensing of sensorless permanent synchronous motor based on fluctuating high-frequency voltage signal injection. Micromotors, 41: 13-16.