Sensors & Transducers, Vol. 178, Issue 9, September 2014, pp. 161-166

Sensors & Transducers

A Universal Motor Performance Test System Based on Virtual Instrument

Wei Li, Mengzhu Li, Qiang Xiao
School of Instrument Science and Engineering, Southeast University,
Nanjing, Jiang Su, 210096, China
Tel.: 18015506900
E-mail: liwei@seu.edu.cn

Received: 25 June 2014 /Accepted: 29 August 2014 /Published: 30 September 2014

Abstract: With the development of technology universal motors play a more and more important role in daily life and production, they have been used in increasingly wide field and the requirements increase gradually. How to control the speed and monitor the real-time temperature of motors are key issues. The cost of motor testing system based on traditional technology platform is very high in many reasons. In the paper a universal motor performance test system which based on virtual instrument is provided. The system achieves the precise control of the current motor speed and completes the measurement of real-time temperature of motor bearing support in order to realize the testing of general-purpose motor property. Experimental result shows that the system can work stability in controlling the speed and monitoring the real-time temperature. It has advantages that traditional using of SCM cannot match in speed, stability, cost and accuracy aspects. Besides it is easy to expand and reconfigure. *Copyright © 2014 IFSA Publishing, S. L.*

Keywords: Virtual Instrument, CompactRIO, Motor Performance Test, Phase Angle Control Mode.

1. Introduction

Universal motors are widely used in every field of daily life and production. With development of technology, relationship between motor and industrial production become more and more closely, and motor performance requirements are increasing gradually (Pan et al., 2012). Different environments have different performance requirements for general motors, so properties of its detection have a very important practical significance (Wu and Li, 2005). Through controlling the speed of the motor, the equipment can implement the test of the stability and life of the motor.

Motor testing system based on traditional technology platform, which has been a long development period, high cost, low degree of automation, poor lack of portability and some other shortages. The control of the traditional universal motors is achieved by using chip microcomputer system (Bruno, 1998). Due to the small capacity of chip microcomputer, the requirement of control algorithm is very high. Besides, the requirement of the peripheral circuit is also high. The instability of peripheral circuit may cause instability of the whole control. Furthermore the cost is very high. At present, NI company introduced a powerful virtual instrument software — LabVIEW for automatic detection and control of complex systems. Compared with other computer software, LabVIEW is a perfect simulation, debugging tools, such as setting breakpoints, single step and so on (Li and Hu, 2010). It can quickly collect data, realize data analysis and processing (Ling et al., 2010). It achieves hardware simulation through software.

2. Platform

In this paper, NI cRIO is used to build the system. The system has many advantages compared with traditional chip computer system.

- Low-cost architecture with open access to low-level hardware resources.
- Real-time processor and reconfigurable FPGA for reliable stand-alone embedded or distributed applications.
- Powered by reconfigurable I/O (RIO) FPGA technology for ultrahigh performance and customization.
- Good encapsulation of FPGA, good anti-interference and more stable.

This system can control the speed of 20 type motors at the same time and every type consist 32 motors. Operation interface is very friendly.

3. System Principle and Hardware Design

3.1. System Principle

This system can be divided into two main parts: velocity measurement of Universal motors part and real-time temperature measuring of bearing part. Velocity measurement of universal motors part uses phase angle to control the speed of universal motors. First, zero crossing detection function of the LabVIEW development kit is used to detect zero crossing point. Second, changing conduction angle of triode ac switch (TRIAC) to adjust motor power to control the speed of the motor. The diagram of phase angle control is shown in Fig. 1.

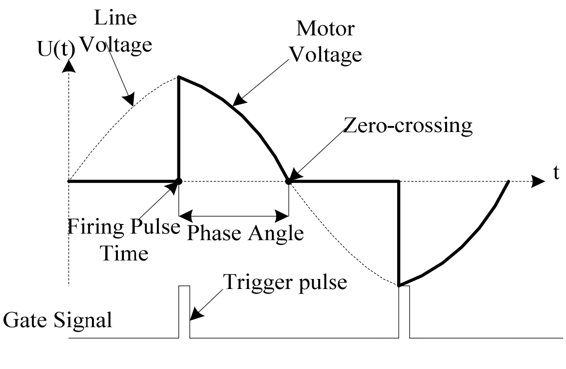

Fig. 1. Diagram of phase angle control.

The change of thyristor operating angle is realized by software PID. The traditional PID control is made of proportion (P) control, integral (I) control and differential (D) control (Brian, 2008). Continuous form of the algorithm is shown as follows (1):

$$U(t) = K_p\left(e(t) + \frac{1}{T_i}\int_0^t e(t)dt + T_d\frac{de(t)}{dt}\right)$$

Writing in the form of transfer function is shown as follows:

It is generally used in the form of transfer function as:

$$G(s) = \frac{U(s)}{E(S)} = kp(1 + \frac{1}{T_i s} + T_d s)$$

where K_p is the proportional gain, $e(t)$ is the deviation between the time output and a given value, T_i is the integral time constant. T_d is the differentiating time constant. The PID control of this system is achieved by the PID control digital position type algorithm and implemented by software (Brian, 2008). The given speed is set to SP, the actual speed output value is set to PV value, and the deviation is:

$$e(k) = \left(SP - PV_f\right)$$

The corresponding proportion, differential and integral controls are:

$$U_P(k) = K_c \times e(k)$$

$$U_I(k) = \frac{K_c}{T_i}\sum_{i=1}^{k}\left[\frac{e(i)+e(i-1)}{2}\right]\Delta t$$

$$U_D(k) = K_c\frac{T_d}{\Delta t}\left(PV_f(k) - PV_f(k-1)\right)$$

The actual expressions of PID control:

$$U(k) = K_c(SP - PV_f) + \frac{K_c}{T_i}\sum_{i=1}^{k}\left[\frac{e(i)+e(i-1)}{2}\right]\Delta t$$
$$+K_c\frac{T_d}{\Delta t}\left(PV_f(k) - PV_f(k-1)\right)$$

Its closed loop structure is shown in Fig. 2.

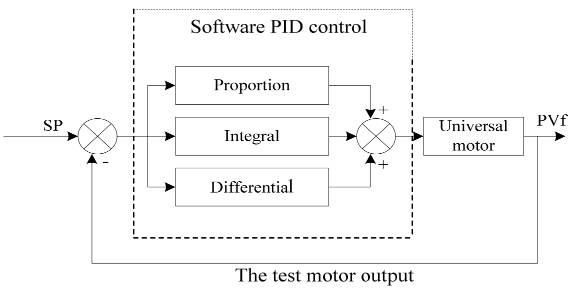

Fig. 2. Closed-loop PID structure diagram.

The speed control mode has many advantages, such as low cost, high control precision high stability and simple structure. Besides, this system not only controls the speed of motor, but also uses thermocouple to measure the real-time temperature of the bearing pedestal. This system can also evaluate the performance of the motor (Fig. 3).

3.2. Hardware Design

This system takes advantage of NI acquisition system CompactRIO and is re-configuration and embedded control system. In this system, 20 different types of motors are used to test and every type consist 32 motors. It is made of cRIO -9014 controller, 9104 FPGA case, cRIO-9477, cRIO-9211, cRIO-9205, motor driver and user interface based on virtual instrument.

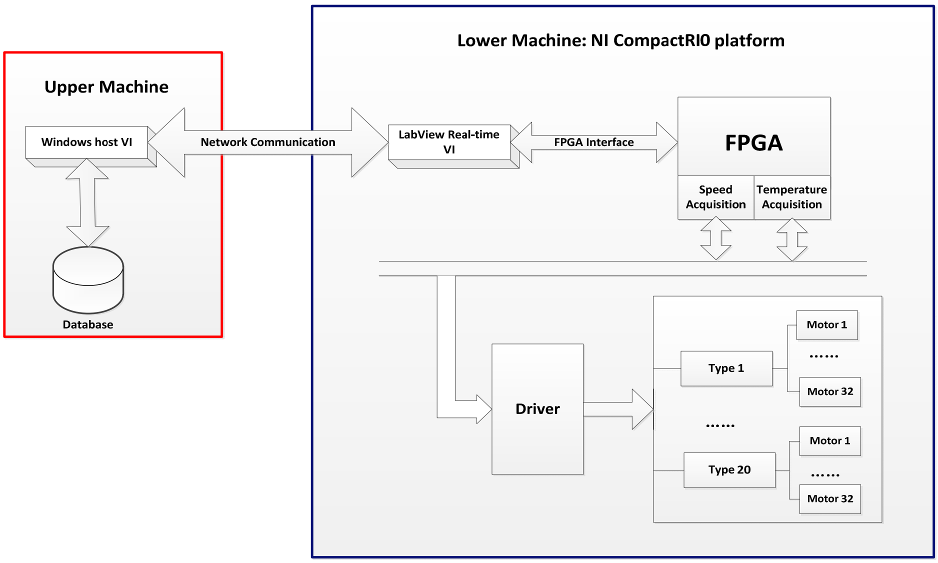

Fig. 3. Universal motor performance test block diagram.

First, the setting in the host decides which type of motor to test. Then the host communicates with the CRIO and the analog input module CRIO – 9205 collect the partial pressure signal, then Call Zero-crossing function of LabVIEW development kit to extract zero crossing point of the motor power signal. Through the software PID function, CRIO – 9477 outputs window signal to control the angle of flow of triode ac switch BTA16-600BW. Through controlling the angle, then the system can control the speed of the motor. The hardware principle diagram is shown in Fig. 4.

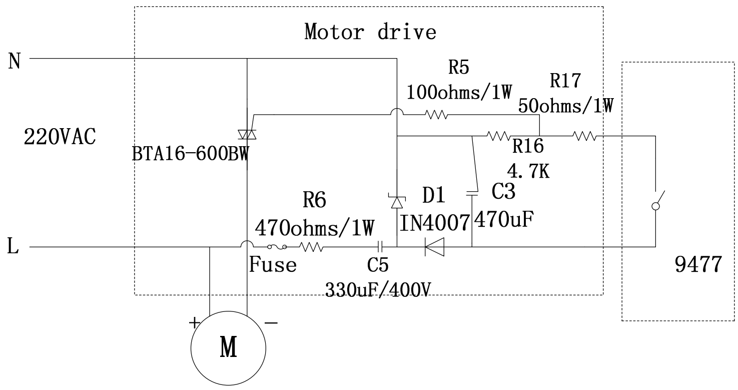

Fig. 4. Motor speed control principle diagram.

Second, the feedback from the output of the speed measuring motor enables cRIO-9205 to record the real-time speed of the machine. The temperature of bearing pedestal is measured through the thermocouple. Analog input module cRIO-9211 collects the thermocouple output signal to get the real-time temperature of the bearing pedestal. All of these actions above are completed in CompactRIO platform. Then these data is sent to the host and saved in the database.

4. System Software Design

4.1. Software Structure

The whole system software is completed under the environment of LabVIEW 8.5 which is a graphical software belong to National Instruments. Extremely high-performance control and acquisition system can be achieved by CompactRIO through the use of LabVIEW FPGA software and reconfigurable technology (Qian et al., 2010). The software flow chart is shown in Fig. 5.

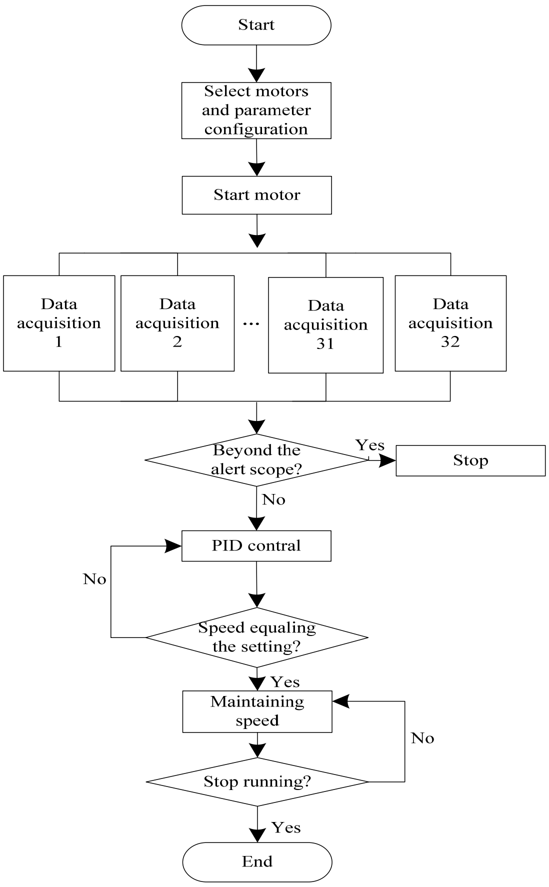

Fig. 5. Software flow chart.

The software part of the system is divided into PID speed control section and real-time temperature measurement section. PID control part mainly use software PID control mode to control angle of triode ac switch (TRIAC) α and then adjust the motor power signal to control the motor speed. Temperature measurement part mainly change the thermoelectric potential signal generated by thermocouple to temperature signal by using algorithm. The thermoelectric potential signal is collected by cRIO-9211.

4.2. Software PID Control Module

PID control portion is the core part of the whole software part, using PID to control the start time of the SCR trigger pulse. The software can control the speed of the motor through setting the angle of triode ac switch (TRIAC) α. The difference between the speed setting by the motor and the actual output speed is the PID control deviation. Then start time of the trigger pulse can be gotten. The main block diagram is shown in Fig. 6.

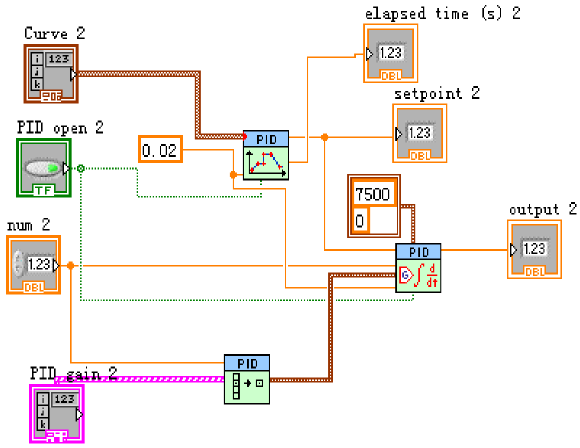

Fig. 6. PID control module block diagram.

The PID control can set the maximum and minimum speed: U_{max} and U_{min}

When U(k) $\geq U_{max}$, U(K) = U_{max}

When U(k) $\leq U_{min}$, U (K) = U_{min}

K_p, T_i, T_d can be obtained by experiments in debugging stage. In order to get control the motor speed more accurately, the motor is set at different speed in different stage. When the maximum speed is 600 r/min, 700 r/min and 2500 r/min, the gain is shown in the Fig. 7 respectively.

4.3. Temperature Measurement Module

The temperature measurement module is used to measure the temperature of the motor shaft in real-time, when the motor is running. This module is used to implement two main functions: The first one is to observe the temperature of the motor shaft when the motor running at a specific speed; the second one is to prevent the temperature of the running motor is higher than a predetermined temperature. When the real-time temperature of the motor is higher than a predetermined temperature, the motor will alarm and stop. Temperature measurement module block diagram is shown in Fig. 8.

The voltage of the thermocouple channel which is gathered by CRIO-9211 cannot be directly converted to a temperature value. It must perform arithmetic operations with the value of the cold junction compensation channel and the auto-zero channel before it is converted to temperature, this temperature is the actual temperature of the motor shaft seat. The temperature conversion program is shown in Fig. 9.

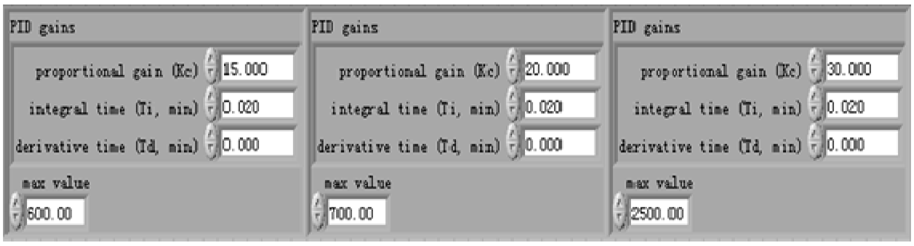

Fig. 7. PID motor speed control gain table.

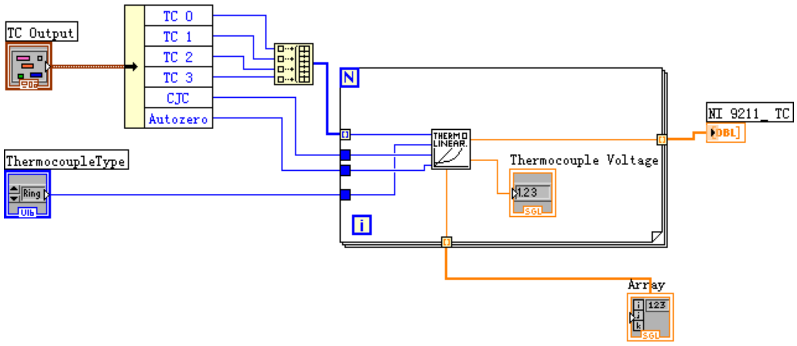

Fig. 8. Temperature measurement module block diagram.

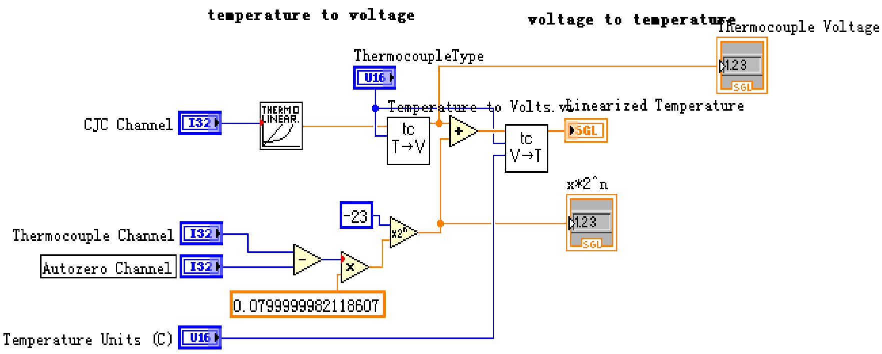

Fig. 9. Temperature conversion module block diagram.

5. Experimental Results and Analysis

First, the temperature of the motor speed alarm parameters and operation cycle are set in the motor parameter setting area which are shown in Fig. 10.

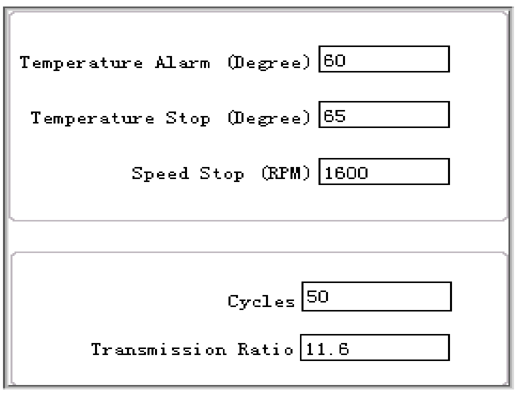

Fig. 10. Motor running and alarm parameters Figure.

Alarm parameter is a value which normal operation of the motor cannot be achieved. Abnormal factors must exist if alarm occurred, then the motor is required to stop automatically to remove the fault (Wei and Song, 2009). In addition, different motor model have different transfer ratio. Then the operation curve of the motor is set, after starting the motor, the running status of the motor is shown in Fig. 11.

The Fig. 11 is shown the performance of one motor. The subgraph which is on the right in Fig. 11 has two subgraphs. The red line figure is the diagram of the motor speed, the blue one is the actual motor speed curve. From the figure, it can be seen that the system can achieve the precise control of motor speed and display real-time speed. The left area of the figure shows the operation cycle of the motor, current running speed and temperature. It can be seen from Fig. 11 that this system has advantages that conventional single-chip systems cannot match: First, the real-time speed of the motor, real-time temperature of the motor bearing the operation cycle of the motor to be observed in the interface. Second, the burr will occurred when traditional chip microcomputer use hardware to control the motor speed. In this system, the speed of the motor is set by software, it can avoid burr. Finally, operational data can be saved and converted to Excel spreadsheet by using LabVIEW, and then it is easy to understand overall performance of the universal motor.

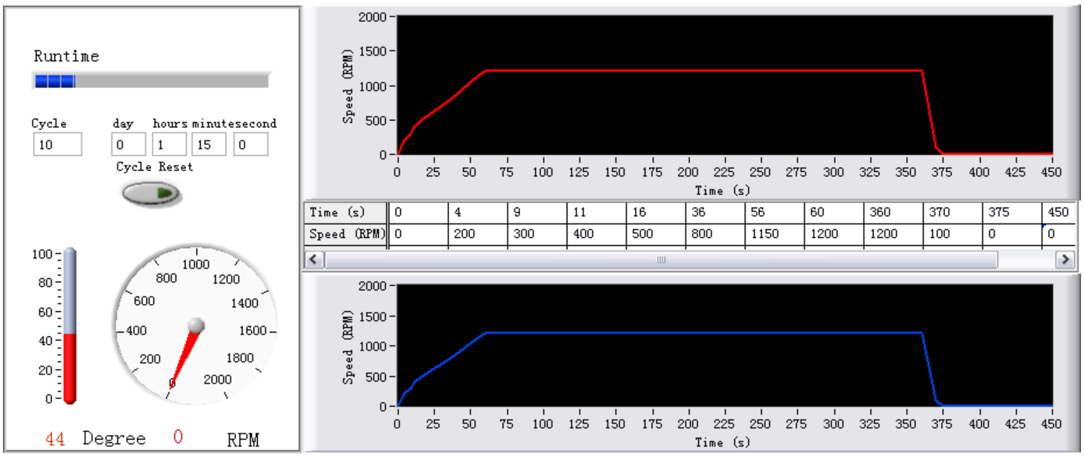

Fig. 11. Motor running status display.

6. Conclusions

The test system realize the universal motor performance test based on virtual instrument, which has advantages that traditional using of SCM cannot match in speed, stability, and accuracy aspects. In the system design process we should pay attention to the rational use of resources, the strength of electrical separation FPGA and system wiring at issue. As the virtual instrument has characters of simple structure, low cost, high accuracy, users can develop their own software testing system by using virtual instrumentation to improve the measurement accuracy and measurement speed, these systems has advantages of small, flexible, low cost, and high efficiency in addition, besides it is easy to expand and reconfigure, it is all for these, virtual instrument become the development direction of modern measurement and control systems.

References

[1]. Bruno, M., ST62 Microcontrollers Drive Home Appliance Motor Technology, *Roznov System Application Laboratory*, 2008.

[2]. Brian, R., C., The Design of PID Controllers using *Ziegler Nichols Tuning*, 2008.

[3]. Ling, J., Li, Z. Y., & Zheng, F. R., LabVIEW Virtual Instrument Programming from Entry to Master, *Posts & Telecom Press*, 2010.

[4]. Li, Q. X., & Hu, J. T., Simulation model of Induction motor based on LabVIEW, in *Proceedings of the 3rd International Conference on Intelligent Networks and Intelligent Systems*, 2010, pp. 273 – 276.

[5]. Pan, P. H., Yao, J., & Gu, M. M., Motor Parameter Measurement and Testing System Based on LabView, *Advances in Intelligent Systems Research*, 2012, pp. 1349-1351.

[6]. Wu, J. W., Li, D. C., Modern Motor Testing, *China Machine Press*, 2005.

[7]. Qian, Z. B., Huang, C. H., Li, K., A Data Acquisition and Monitor System Based on LabVIEW and Linux, *Measurement & Control Technology*, Vol. 29, Issue 11, 2010, pp. 41-43.

[8]. Wei, X. W., Song, A. G., Design of Multi-Motor Control System Based on C8051F340, *Measurement & Control Technology*, Vol. *28*, *Issue* 1, 2009, pp. 38-40.

[9]. Zhang, H. D., & Ji, W. Z., Database Access Technology Based on LabVIEW in Data Acquisition System, *Industrial Instrumentation & Automation*, 2009, pp. 63-66.