STUDY OF THE COMBINED CONTROLLER FOR ADJUSTING AND LOCKING A GRIDER WITH MICROMETER-LEVEL AT NSRRC

H.S. Wang, Y.L. Tsai, S.Y. Perng, W. Y. Lai, M.L. Chen, T.C. Tseng, J.R. Chen
National Synchrotron Radiation Research Center, No. 101, Hsin-Ann Road, Hsinchu 30076, Taiwan, R.O.C.

Abstract

A girder control system is proposed to quickly and precisely adjust the displacement and rotating angle of all girders in the storage ring with little manpower at the Taiwan Photon Source (TPS) project at National Synchrotron Research Center (NSRRC). In this control girder system, six motorized cam movers supporting a girder are driven on three pedestals to perform six-axis adjustments of a girder. To increase the nature frequency of a girder, the locking system is applied to promote the stiffness of a girder structure. The locking system consists of six locking mechanisms attached to three inboard pedestals and a locking controller. The study of the girder control system and the locking system control combined are achieving to the positioning with micrometre-level. This paper presents details of the study and tests of the combined controller.

INTRODUCTION

In order to provide quick and precise adjustment, a motorize girder sets (Figure 1) combined with sensors feedback control system is designed for the TPS storage ring at NSRRC. Each girder can be automatically adjusted in six degree of freedom with six movers controlled by an industrial computer. The computer receives variation values from sensors indicating six degree of freedom, three degrees of freedom come from touch sensors; two degrees of freedom are from an inclination sensor and one degree of freedom from a laser position sensitive detector (PSD) system [1]. These sensor data from all girder transfer to the girder-position calculating center computer to determine the mover adjusting angles with a girder adjustment algorithm [2][3] via intranet. Then, the local computers can adjust girders according to the calculated data transferred back.

This feedback control system can adjusted girders the desired position with one μm resolution. However, the girder supported on six movers is kinetic mounted and floating design. The first natural resonant frequency is not enough and also easily moved by extra force. A girder locking system is designed to increase the natural frequency of a girder system and to decrease the movement by extra force. Three couples of locking system mechanisms installed between one girder and three pedestals. The locking mechanism is of wedge type driven by DC motors and also controllable.

The whole controller systems adopt PXI platform and Microsoft Windows 7. PXI architecture is a PC-based platform for control and measurement. The advantage of PXI is easy to design control system without other extra learning.

This paper includes several parts about the girder control system. The first shows the design of the motor control to meet the request of controlling eighteen motors simultaneously and adjusting girders with small angle deviation. Second part shows the design procedure of a reading card with PCI extension for instrument (PXI) interface to grab the data from thirty-four sensors with ENDAT 2.2 interface simultaneously. The third introduces the vibration system monitoring for TPS ground vibration and girder vibration. This vibration monitoring system includes three-axis velocity sensors and accelerometers. The four shows control system network. The girder control system adopts EPICS as the main communication protocol between hardware and software. Users operate hardware via intranet by MATLAB [4]. The fifth shows locking system hardware and software. And the last is the testing result.

Figure 1: One twenty-fourth of the whole ring consists of three girders.

GIRDER MOTOR CONTROL SYSTEM

In order to achieve one micrometer-level displacement and one microradian-level revolution of the rotation of a girder, a girder control system includes touch sensors provides resolution of thirty nanometers and two micrometer of accuracy, a tiltmeter provides resolution of one microradian and a PSD system has resolution of two micrometers at thirteen meters propagating distance every four hours. A girder motor control system synchronously controls three girders. Six motors of each girder are modulated the rotating speed in proportion of the rotating angle to make six motors is driven co-ordinately to keep each girder's movement at minimum rotating variations. The motors of each girder are assembled brakes. The motor power is off to generate the small uncontrolled rotating angle of a motor. And it reduces the positioning precision of a girder. To avoid this risk, the motor control signals are customized to solve this problem. These signals are shows Figure 2. The yellow, the green and the red line represent the clockwise signal, the counter clockwise signal and the brake control signal respectively.

ISBN 978-3-95450-115-1

First the pulses of the clockwise and counter clockwise sent to the motor driver are fictitious and make the motor driver boosts the reduced current at standstill to the motor running current. The brake release signal sends to the motor driver after meanwhile. The motion card precisely control the rotating angle of a motor with the motor running current after releasing motor completely. After finishing the rotation of a motor, the brake signal changes the status from 0 Voltage to 5 Voltage.

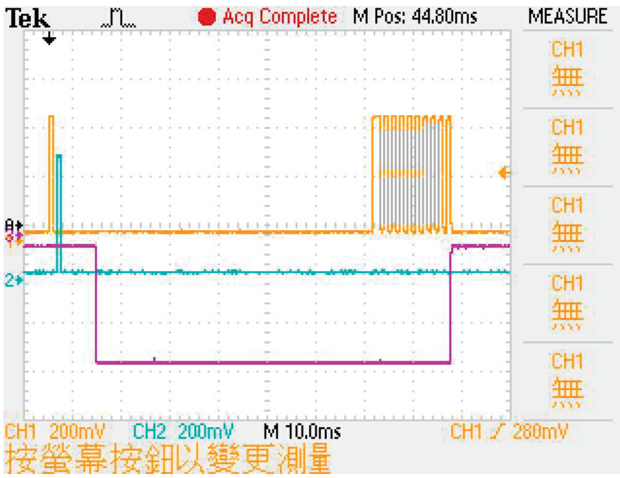

Figure 2: A motor control signal.

In order to limit the gap between the vacuum chamber and the magnets, each girder motor control system possesses the twelve limit sensor circuits, in addition to eighteen motors control. The quantity of those limit sensor circuits is adjusted channels depended by practical requirements with twelve switches.

In order to achieve the requirements, The FPGA card with Xilinx Virtex-2 is chosen as a customized motion card of the cam mover control system for the girder motor control system. The algorithm of a motion card is programmed by VHDL in addition to NI CLIP [5] method. Applied to NI library, the girder controller handles the rotating angle of each motor in Microsoft Window 7 environment.

To reduce the entire installation time and human errors, customized circuits are designed for wiring installation. The customized circuits include eighteen motor control circuits and thirty-six limit sensor circuits as Figure 3.

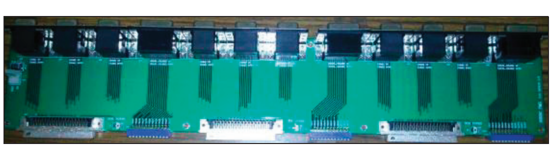

Figure 3: Eighteen motor control circuits for a cam mover system.

ROTATIONAL ENCODER AND TOUCH SENSOR READING SYSTEM

Rotational encoders and touch sensors provide absolute position with resolutions of 25-bit counts per rotation and 32-bis counts in twelve mm respectively. Sensors adopt ENDAT 2.2 [6] provided by Heidenhein as an interface to transit position data to sequential equipment.

The signals of ENDAT 2.2 are measured as Figure 4. The yellow, the pink and the green line represent the clock signal, the mode signal and the position signal respectively. The data according to the mode signal are transmitted in synchronism with the clock signal from a customized card.

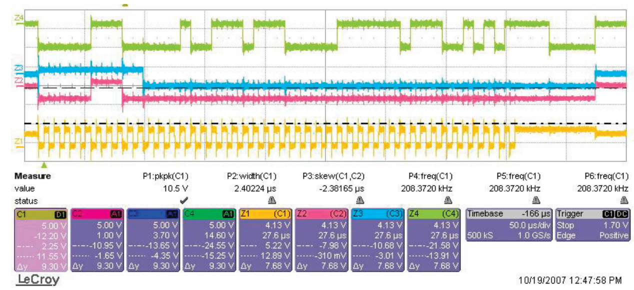

Figure 4: ENDAT 2.2 signals.

In order to provide PXI encoder cards with higher channel quantity of ENDAT 2.2 , The FPAG card with the PXI interface is chosen as a customized encoder card. The FPGA card does not possess differential circuits to be compatible to rotational encoders and touch sensors with ENDAT 2.2. The extra circuit is designed to be compatible to ENDAT 2.2 specs. A FPGA card grabs 18 rotational encoders and 16 touch sensors synchronously and the update rate achieves 10 kHz. It is similar to motion card of the cam mover system. The extra circuit board (Figure 5) reduces installation time and human errors.

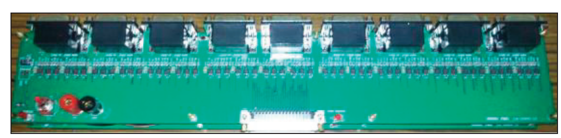

Figure 5: Eighteen differential circuits for encoders and touch sensors.

VIBRATION MONITORING SYSTEM

A vibration monitoring system includes a tri-axial velocity sensor, three accelerometers and a dynamic signal analyser. The velocity sensor located at the middle between straight-section girders monitors the tri-axial ground vibration. The accelerometers assembled to the girder monitor the mechanical vibration. In TPS project, twenty four vibration monitoring systems will measure the vibration simultaneously.

CONTROL SYSTEM NETWORK

To avoid virus risks, all control systems are in the individual network except an operator computer connecting internet for transiting sensors massage to Archive system.

Each girder control system receives six motorized cam mover rotating angles from an operator computer in the individual network. To increase the facility of control hardware, the basic subroutines developed by Matlab communicates to girder control systems. Users just study the algorithm for the adjustment without understanding hardware.

The girder control system provides the control of cam movers and the reading of encoders, touch sensors and inclination sensor. To increase system stability, all functions are developed to a small program with TCP/IP. Users read the sensors' data or control actuators via the individual network.

In addition to the interface of TCP/IP, an individual computer is established with EPICS. In this individual computer Input/Output Controllers (IOCs) of all girder control systems are built with Stream Device method providing TCP/IP to communicate to the origin TCP/IP programs without any modification.

LOCKING SYSTEM

After the girder position error achieves to required precision for the whole storage ring, locking systems (Figure 6) are applied to fix all girders. Three couples of locking systems installed on three pedestals between a girder and pedestals improve the resonance frequency. A locking system includes a wedge mechanism and electronic circuits. A couple of wedge mechanisms driven by direct current (DC) motors push the wedges to reduce gaps between wedges and the girder to cause a clamping effort.

In order to control the wedge mechanism, a locking electronic circuit is designed to drive a couple of the wedge mechanisms synchronously. A DC motor is driven by pules-width modulation method and the motor rotating angle is monitored by the encoder installed at the end of the motor. The locking electronic circuit provides eighteen driven channels. Two channels can be controlled at once, and switching techniques help us to actuate eighteen DC motors.

The torque of a motor is proportional to the current of a motor wire from Lorentz's Law and is transferred to the clamping force of the wedge mechanism. The relation between the clamping force and the voltage transferred from the current of a motor is shown as Figure 7. The pulse width is proportional to the time the current flowing motor wires and is used to control the clamping force.

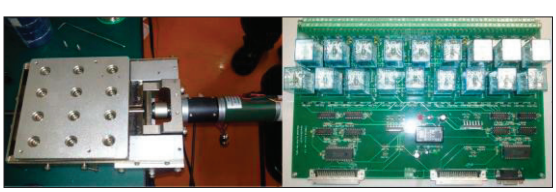

Figure 6: A wedge mechanism and electronic circuits.

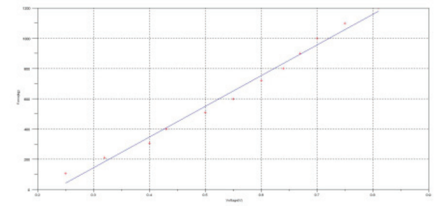

Figure 7 The relation bewteen clamping force and the the volotage.

TEST RESULTS

After stability tests, a girder system runs normally for more six months. Many Experiments are processing by girder control systems and the statuses of the systems are stable. The graphical user interface is shown as Figure 8.

The locking system is applied to lock girders with 1500 kg and the test results are presented as table 1. The deviation of a locked girder is less than 10 micrometers in the transverse. It is not controllable in other two directions and the deviation is larger than the transverse. The vertical and longitudinal movements of the girder are due to the locking force.

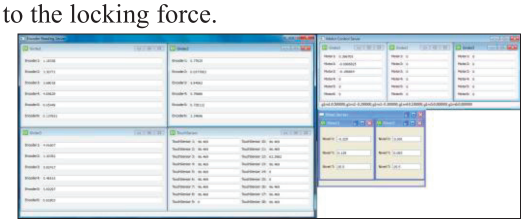

Figure 8: The graphical user interface of a girder control system.

Table 1: The Deviation of a Locked Girder

Deviation	Transverse	Vertical	Longitudinal
First	-3 μm	8μm	6μm
Second	-9μm	20μm	-17μm

CONCLUSION

A combined controller was developed and tested successfully. This controller can adjust 3 girders with 18 motorized movers simultaneously. Also 18 locking systems and vibration monitoring sensors can be included. After TPS storage ring finished installation, the girders auto-alignment procedure will be performed with these controllers and thought test will be carried out.

REFERENCES

[1] M.L. Chen and others, "Design Improvements and Tests of a Laser Positioning System for TPS Girder System", MEDSI, 2010.
[2] T.C. Tseng and others, "A Precise 6-axis Girder System with Can Mover Mechanism," MEDSI, 2006.
[3] T.C. Tseng and others, "Design and Prototype Testing of the Girder System for TPS," SRI, 2008.
[4] http://www.mathworks.com
[5] http://www.ni.com
[6] http://www.heidenhein.com

ISBN 978-3-95450-115-1