DESIGN AND TEST OF A GIRDER CONTROL SYSTEM AT NSRRC

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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 [1][2]. A tiltmeter monitors the pitch and roll of each girder; several touch sensors measure the relative displacement between consecutive girders. Moreover, a laser position sensitive detector (PSD) system [3] measuring the relative displacement between straight-section girders is included in this girder control system. Operator can use subroutines developed by MATLAB [4] to control every local girder control system via intranet. This paper presents details of design and tests of the girder control system.

INTRODUCTION

TPS girder control system consists of twenty four girder control systems and a girder-position computer. A girder-position computer grabs each girder's observation values indicating six degree of freedom, three degrees of freedom come from touch sensors; two degrees of freedom are from a tiltmeter and one degree of freedom from a PSD system. The system calculates all girder best positions by minimizing global girder position errors and the algorithm [5] is developing. Each girder control system receives six motorized cam mover angles determined by a girder adjustment algorithm from the girder-position computer via intranet. A girder control system driver drives a girder with six motors to adjust quickly and precisely the displacement and rotating angle of the girder. An adjustment cycle is finish. Locking systems are applied to fix all girders after the global girder position error achieves a good required precision for the whole storage ring. One twenty-fourth of the whole ring is shown as figure 1.

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

A GIRDER CONTROL SYSTEM

In order to achieve one micrometer-level displacement [6] 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 control system synchronously controls three girders and each girder with six motors is driven co-ordinately to keep each girder's movement at minimum rotating variations.

The whole controller systems are adopted PXI platform and Microsoft Windows 7. PXI architecture is PC-based platform for control and measurement. The advantage of PXI is easy to design control system without other extra learning. The disadvantage is that the control system is unstable without good programming techniques and schemes. A girder control system is shown in figure 2. Eighteen motor drivers are arranged in the upper cabinet, PXI controller in the middle and custom electronic circuits for motors and encoders system in the bottom of the cabinet.

Figure 2: A girder control system.

A Cam Mover Control System

In order to provide good support of magnets and align the girder precisely and quickly, each girder is constructed with six cam movers on three pedestals to realize six-axis adjustments with automation. In addition to eighteen automatic motor baker control channels, each cam mover control system possesses eighteen stepper motor control channels and twelve critical signal stops. Those stops' quantity is adjusted channels depended by practical requirements. The control system provides driving eighteen motor synchronously with three girders coordinate movements.

In order to achieve the requirements, NI PXI-7813R [7] with Xilinx Virtex-2 is chosen as a customized motion card of the cam mover control system for the girder control system. The algorithm of a motion card is programmed by VHDL in addition to NI CLIP 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 includes eighteen motor control channels, eighteen automatic motor baker control channels and thirty-two critical signal stops as figure 3.

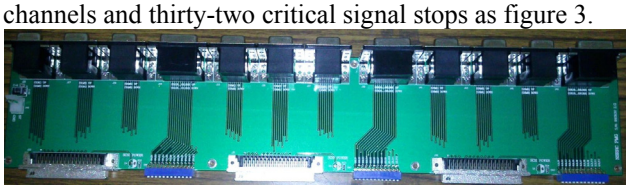


Figure 3: Eighteen motor control circuits for a cam mover system.

A 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 protocol provided by Heidenhein as an interface to transit position data to sequential equipments.

In order to provide PXI encoder cards with higher channel quantity of Endat 2.2 protocol, NI PXI-7811R with Xilinx Virtex-2 is chosen as a customized encoder card. PXI-7811R 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 PXI-7811R grabs 18 rotational encoders and 18 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 4) reduces installation time and human errors.

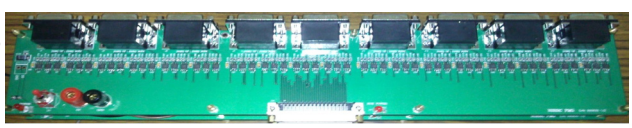


Figure 4: Eighteen differential circuits for encoders and touch sensors.

A Tiltmeter System

To measure the pitch and roll direction of a girder with one microradian resolution, Nivel 220 [8] is chosen as a tiltmeter. One twenty-fourth of the whole ring consists of three tiltmeters and those sensors connect together by RS-485 protocol. Before the installation or after any slight impact, a tiltmeter has to be calibrated.

A PSD System

The laser positioning system, a part of a girder auto-alignment scheme, will be installed on the girders located at both sides of each straight section of the storage ring. The system (figure 5) is composed of a laser and four sets of a position sensing device (PSD). The laser propagates thirteen meters along the girder and plays the role of a reference line of girders of the straight section. Based on the laser linear characteristics, the other girder can be adjusted and aligned by a cam mover according to PSD data. To achieve superior precision, the whole laser positioning system should be constructed stably. The precision of the laser positioning system can achieve two micrometer at thirteen meters propagating distance every four hours.

Each PSD provides a PCI DAQ card to detect laser position and power.

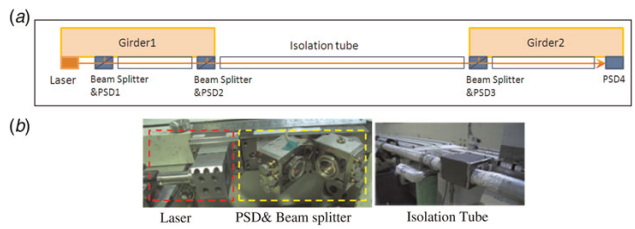


Figure 5: (a) Architecture of the laser positioning system. (b) Main portions of the laser positioning system.

A Locking System

After the global 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 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 PWM 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 motion card with PXI interface is programmed by VHDL with FPAG chip and also provides critical signal stops.

The locking system can provide 2000 kg of the maximum force at the condition that motor runs at 24V and 2A.

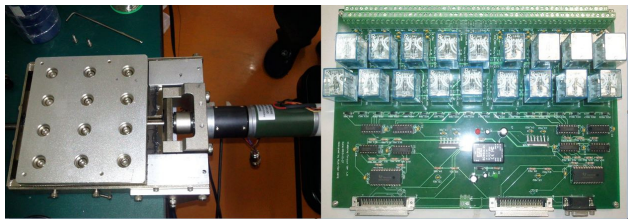


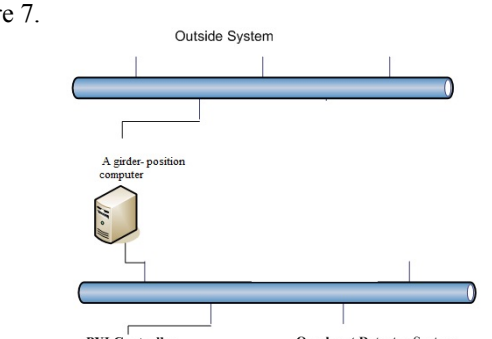
Figure 6: A wedge mechanism and electronic circuits.

Network and System Architectures

TPS girder control system consists of 24 girder control systems and a girder-position computer. To avoid virus risks, all control systems are in the individual network except a girder-position computer connecting internet for transiting sensors massage to Archive system.

Each girder control system receives six motorized cam mover rotating angles from the girder-position 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 tiltmeters. 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. The network and system architecture is shown as figure 7.



Name	Quantity	Desciption
PXI Computer	1	Compute the argrthm of girders
RS232 Port	1	Read data from Nivel 220
Encoder Card	4	Read Endata 2.2 signals of rotary and linear encoders
Digital I/O Card	2	For limit switches
Motion Card	1	Control Stepping Motor

Name	Quantity	Desciption
Sever	2	Operation System
Quadrant Detector card	2	Read the voltage of a quadrant detector

Total quantity of local side computers is 24

Figure 7: Network and system architectures.

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 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.

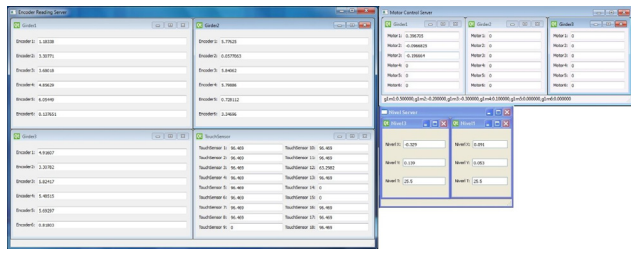


Figure 8: The graphical user interface of a girder control system.

Table 1: The Deviation of a Locked Girder

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

CONCLUSION

A six-axis adjustments of a girder are developed automatically to adjust the displacement and rotating angle of all girders in the storage ring quickly and precisely with little manpower. The test results show that a girder control system adjusts girders quickly, precisely and stably. However, EPICS system will be adopted in Taiwan Photon Source. Therefore, our next step is to change the current system with EPICS.

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