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ORIGINAL RESEARCH

Design of Timing System Software on EAST–NBI

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Abstract Neutral Beam Injector (NBI) is one of the main plasma heating and plasma current driving methods for Experimental Advanced Superconducting Tokomaks. In order to monitor the NBI experiment, control all the power supply, realize data acquisition and network, the control system is designed. As an important part of NBI control system, timing system (TS) provides a unified clock for all subsystems of NBI. TS controls the input/output services of digital signals and analog signals. It sends feedback message to the control server which is the function of alarm and interlock protection. The TS software runs on a Windows system and uses Labview language code while using client/server mode, multithreading and cyclic redundancy check technology. The experimental results have proved that TS provides a stability and reliability clock to the subsystems of NBI and contributed to the safety of the whole NBI system.

Keywords NBI · TS · Unified clock · Labview · CRC

Introduction

The EAST NBI system comprises two neutral beam injectors. Each beam line consists of two ion sources and two timing systems which are used to send and receive input/output signals of the two ion sources respectively. According to the schedule, the whole system will be constructed in two phase. The first phase of NBI system is currently under development at the Institute of Plasma Physics, Chinese Academy of Sciences (ASIPP). The designed power is 2 MW at 50 keV and 4 MW at 80 keV [1–3].

In this paper design and implementation of TS for NBICS is presented. TS implements synchronous digital signal and analog signal output of all power systems which is also able to receive signal from site measurement level to alarm and protect the NBI system. A custom algorithm of cyclic redundancy check is used in the digital network to detect accidental changes to the raw data when TS communicates with main control server (MCS). It is shown through application that TS is with good accuracy and reliability.

Analysis of TS Hardware

The hardware system of TS consists of PXIe-8135 controller with Win7 (64-bit) system, PXI-6733 card and PXI-7842R FPGA card from NI company. PXI-6733 realizes 8 waveform analog outputs, 8 digital I/O lines and 2counter/timers. PXI-7842R with virtex-5 lx50 series multifunction RIO module includes 8 analog inputs, 8 analog outputs, 96 digital inputs/outputs. The sampling rate of the hardware using in NBI experiment is 100 k.

Requirement and Analysis of TS Software

NBICS consists of four levels that are shown in Fig. 1: the remote monitoring level, main control level, site measurement level and video monitoring level [4, 5]. TS is the one of the most important part of the site measurement level, whose major function is to provide a unified clock to

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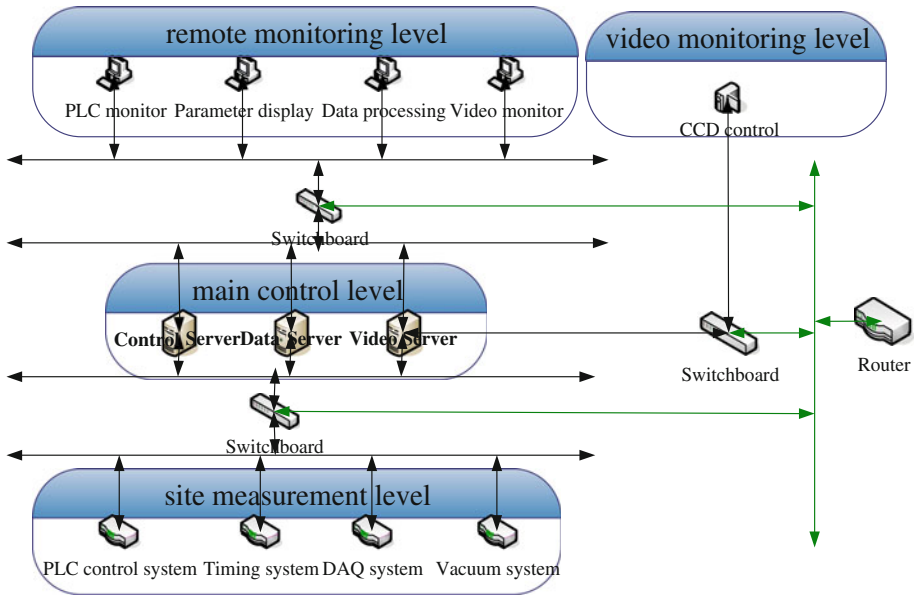

Fig. 1 Structure of NBI control system

all subsystems of NBI. TS should be furnished with the following specific functions:

(a) Providing a unified clock. This clock signal will be send to gas power system, arc power system, filament power system, high voltage system, suppressor power system, snubber power system and magnet power system. The accuracy of this clock is 10 microseconds.
(b) Providing 16 analog signal output. The waveforms of this 16 analog output include square wave, square wave of two steps and square wave with rise slope and fall slope.
(c) Receiving status of the power systems of the site measurement level. When the received digital signal equals to false, timing system will block off different power supply according to different fault level and send the status to the main control server at the same time.
(d) Getting the real-time feedback of analog data of power systems. Some key equipment's value will be got back in real time to TS, such as high voltage value. All these will provide reference to the experiment operator and make it easy to alarm and interlock protection.
(e) Realizing the cycle output of high voltage supply. In this way, we can ignore some small breaks of the NBI experiment and get longer pulse length.

Implementation of TS Software

Timing system software develops under Win7 operating system, using labview language. The communication between TS and MCS bases on TCP protocol, using the client/server model. As the client-side, once the TS software runs, it will connect to control server actively. It uses different threads to deal with different requests of MCS.

The Flow of Timing System Software

For the security of network communication, all terminals of NBICS (expect for MCS) takes steps of registering to MCS as one of its client when the terminal starts and applying for logout when it exits [4]. As the client-side, TS will register to MCS when it starts running and logout when it exits. Fig. 2 is the flow of timing system software, if username, password and CRC message of TS are correct, MCS will send OK message to TS and then they can communicate other message, else MCS will send user information error to TS and TS should register to MCS again. After successful registration, TS will create four threads to transmit different message with MCS. Thread A is used to monitor status of all power system which is from site measurement level transferred through DIO channels of PXI-7842R. Normally, the status equals to true. If the status equals to false, Thread A will block off some power supply according to the failure type and send this status to MCS. Thread B is used to receive emergency stop command from MCS. When thread B receives this command, it will stop all digital and analog output and protect the whole NBI system. Thread C is used to send the value of the key power system to MCS after an experiment starts. Then MCS will send this feedback values to main control console and provide a reference for operators. Thread D is the main thread. It is used to receive commands from MCS. If the command is Reset, it will reset the hardware and software of the timing system. If the command is

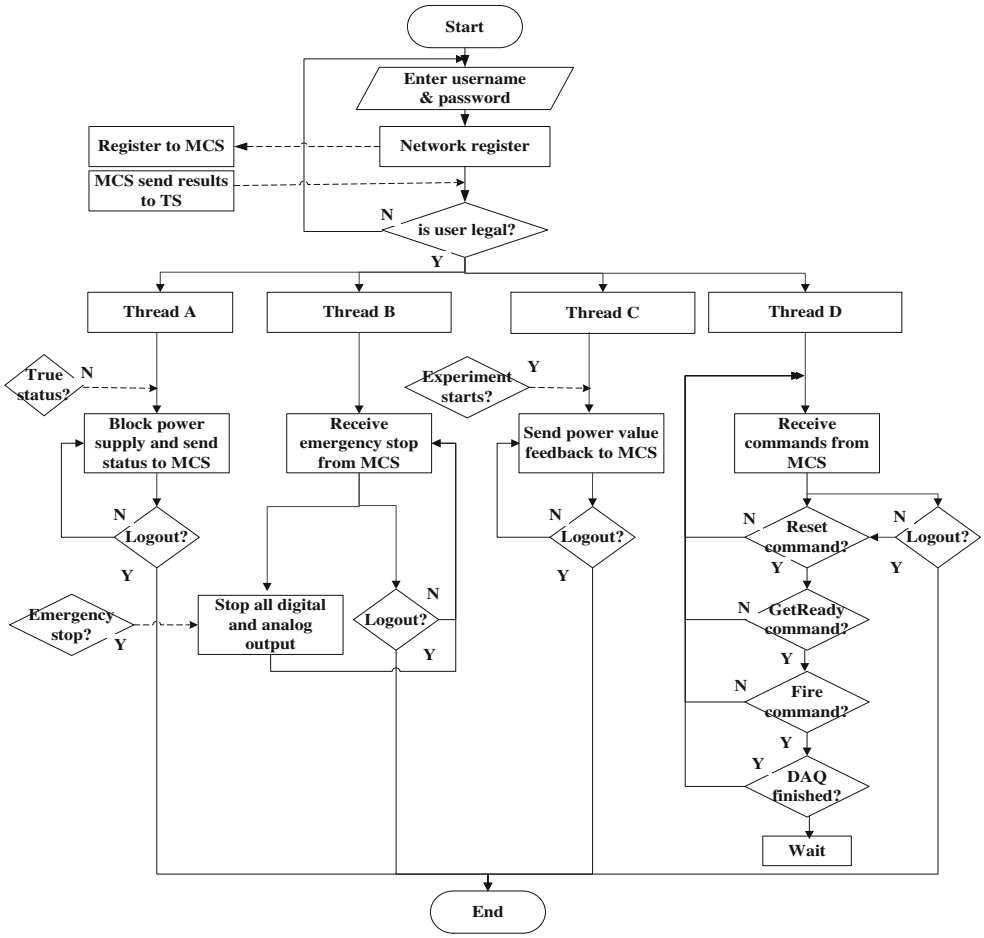

Fig. 2 Flow of timing system software

GetReady, it will get configuration to MCS and change data to the required format of the hardware. If the command is Fire, it will output the signals to the power systems. Once DAQ terminal finishes the data acquisition, thread D will wait for receiving the next experiment commands. If the operator send logout command, thread A, B, C and D will end and the timing system software will exit.

TCP Data Structure Uniform

The work model of TS is based on Client/Server model and communicates with MCS through TCP/IP protocols. In view of the processing data between TS and MCS, the unified data structure must be harmonized, which is also used between other terminals of NBICS. The NBI TCP communication data structure is defined as follows, shown in Fig. 3.

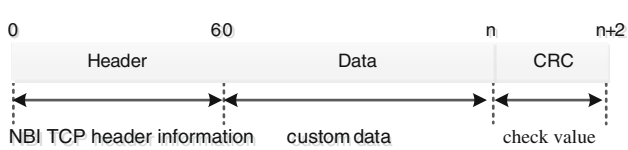

Fig. 3 Definition of the NBI TCP communication data structure

The part of NBI TCP header information occupies 60 bytes, which contains information that is necessary to a reliable and effective communication between equipment of NBICS [6]. The CRC is the check value (or data verification), the value of it is based on custom cyclic redundancy check algorithm. CRC can verify the legality of the custom data and find the wrong data due to network failure. The numbers at the top of figure express the size of bytes in different fields.

Data Structure of TS Configure

TS gets experiment commands and experiment configures from control server. TS can differentiate different commands through the different TCP header information. If TS receives configure information, it will storage these configures into different arrays in order. The messages sent to PXI-7842R and PXI-6733 are in different styles.

Configuration of PXI-7842R consists of digital configuration and analog configuration. The configurations of 48 digital output channels form a one-dimensional array of 96

seats and 8 analog output channels form another one-dimensional array of 32 seats. In the digital array, each channel's information owns two seats of the array and the first seat is the beginning time of the pulse and the second seat is the end time of the pulse. In the analog array, each channel's information owns four seats of the array and the first seat is the beginning time of the pulse, the second is the output value of the beginning time, the third seat is the end time of the pulse and the fourth seat is the output value of the end time. PXI-7842R output a point every 10 microseconds.

PXI-6733 gets configuration with a one-dimensional array through calculation. The size is changed according to parameters from MCS. Each seat of the array is the output value of every sampling point and the sample rate of PXI-6733 card is 100 k.

Conclusion

The design and implementation of TS for NBICS on the first neutral beam line is described in this paper. Experimental results show that TS can perform well as a unified clock transmission device, with the characteristics of accuracy and stability. The accuracy of timing system software is 10 microsecond. TS has been successfully applied in the NBI experiments. The results have proved that TS could meet the requirements of the experimental process of NBICS very well.

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References

1. C.-D. Hu, NBI Team, The development of a megawatt-level high current ion source. Plasma Sci. Technol. **14**, 75 (2012)
2. C.-D. Hu, NBI Team, Conceptual design of neutral beam injection system for EAST. Plasma Sci. Technol. **14**, 567 (2012)
3. C.-D. Hu, NBI Team, Preliminary results of ion beam extraction tests on EAST neutral beam injector. Plasma Sci. Technol. **14**, 871 (2012)
4. Y.-Z. Zhao, C.-D. Hu, P. Sheng, X.-D. Zhang, Study of mechanics control server application software on EAST–NBI. Appl. Mech. Mater. **214**, 562 (2012)
5. P. Sheng, C.-D. Hu, S.-H. Song et al., *Control plan of EAST–NBI ion source test, presented at Asia Pacific conference on plasma science and technology* (Jeju Island, Korea, 2010)
6. X.-D. Zhang, Z.-M. Liu, P. Sheng, C.-D. Hu, Y.-Z. Zhao, Research of data server application software for NBI mechanicalcontrol on EAST. Appl. Mech. Mater. **214**, 538 (2012)