Development of a Data Acquisition Control System for the First NBI on EAST

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Abstract Neutral beam injection (NBI) heating is one of the most efficient auxiliary plasma heating methods for fusion devices. The data acquisition control system (DACS) with PXI (peripheral component interconnect extensions for instrumentation) data acquisition card for the first NBI system in the experimental advanced superconducting tokamak (EAST) is presented in this paper. As an important sub-system, DACS is designed to obtain physical measurement signals in the EAST NBI system and to deal and store these data with the Lempel-Ziv-Oberhumer (LZO) lossless data compression algorithm, as well as offer convenient data call-back and access interfaces to the user for examining and analyzing the data. Experimental results show that accurate data will ensure that researchers correctly analyze it and then properly adjust the experimental parameters or operation, so DACS should take a large step in improving experimental efficiency. The hardware and software sections are briefly presented in this paper, and now this system has been tested to be able to work reliably and steadily.

Keywords: EAST, NBI, data acquisition, TCP, LZO algorithm

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1 Introduction

International research indicates that the NBI system can provide cost-effective auxiliary plasma heating and current drive for nuclear fusion devices, such as EAST. For the sake of high-power plasma heating and non-inductive current drive for plasmas in EAST, the NBI system will be constructed at the Institute of Plasma Physics, Chinese Academy of Sciences (ASIPP), with two neutral beam injectors. Each one is designed to inject 2~4 MW of power into the EAST plasma with 50~80 keV beam energy and 10~100 s beam pulse width [1]. These two injectors have the same structure, and each one includes two ion sources, named the L ion source and the R ion source. The L source and the R source can work independently. The layout of the neutral beam injector on EAST [2] is shown in Fig. 1.

Data acquisition and control play an important role in the operation and protection of the EAST NBI system. Obtaining precise data is significant in analyzing experimental results, improving efficiency and protecting the system. So DACS is one of the most important control sub-systems for the whole neutral beam injector, and the design and implementation of DACS for the first NBI in EAST will be presented in this paper.

2 Requirements and functions

On account of the disparity of computer equipment regarding geographical positions, distributed architecture is adopted for the EAST NBI computer control system. The linking of devices on the NBI total distributed control system is achieved with the help of computer network technology. The computer network is implemented through a different flowing sub-network: a remote server main control layer, a video monitoring control layer, a local measurement and control layer, and a remote monitoring layer. The data acquisition (DAQ) system in this paper is designed to work on the local measurement and control network layer, and the data server, which manages data and offer interfaces to the user for querying data and experimental logs, will

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be designed to work on the remote server control layer. On the other hand, timing and trigger synchronization are also necessary between the various DAQ devices. Thus the main requirements and functions of DACS can be summarized as follows.

a. Measured signals must be collected accurately with a certain frequency and required time span by DACS.

b. DACS should obtain the DAQ configuration and timing control signal from the remote EAST NBI grandmaster server, including the DAQ channels, signal names, gain, frequency, time span, and so on.

c. DACS needs to work on the external hardware trigger mode and get an external synchronous clock signal for synchronization between multi-DAQ devices, for instance the 10 MHz crystal oscillator.

d. DACS should save collected data in an appropriate format on both the local computer disk and remote data server, and offer a convenient interface to experimenters for querying and analyzing data.

e. An appropriate network communication protocol and structure must be unified for interactions between the different devices in the EAST NBI.

3 Hardware implementation and overall architecture

The overall architecture of DACS for the first NBI in EAST is schematically shown in Fig. 2.

As mentioned in section 2, DACS works on the local measurement and control layer, while the data server as well as the grandmaster server, which gives the global logical control to DACS, work on the remote server control layer. For insulation between electricity and magnetism, while avoiding signal attenuation in transmission, an optical fiber is the bridge for communication between devices running on these two layers by the switcher.

The system has a DAQ upper control machine which is based on the Fedora operating system for controlling DAQ and a PXI extendible chassis for running PXI DAQ cards. The DAQ upper computer is responsible for running DAQ software, such as achieving the functions of initializing and releasing cards, the listening DAQ configurations and the external trigger signal from the NBI grandmaster server, timing synchronization from the external clock source, and so on.

The physical signals that are measured will be transported to AD connector cards by the V/F module and F/V module, mainly for the same reasons as the insulation between electricity and magnetism, and an optical fiber is used as the transmission medium too. Then, analog signals are gathered by PXI DAQ cards when these cards work.

When DAQ is ended in a time span, the DAQ upper control computer will deal with data by reading them from DAQ cards, and then save these data with the storage format in both the local disk and database. The data server also plays an important part in DACS to save data in its database instantly and offer a convenient interface to users for obtaining useful physical signals at the user’s client terminal.

According to the practical applications and taking into consideration the channel independency, accuracy and high frequency of sampling, PXI2022 DAQ cards from ADLING Company are chosen. Each PXI2022
card has 16 independent channels, with the lowest DAQ frequency of 50 K/s, so four cards are needed. Two of them are for the L ion source beam line, with the others for the R ion source beam line.

As for system extension, additional DAQ cards running on a PXI extendible chassis and external auxiliary equipment are needed to collect data signals for the second NBI in EAST.

4 Software implementation

The DACS software for the first NBI in EAST is composed of two main sections: one is the DAQ software and the other the data server software. Both of them are developed in C/C++ language, with a C/S program model based on standard TCP protocol and multi-threading technology.

The central DAQ procedure is programmed using PXI-2022S’s integrated library function, which runs on the double-buffered asynchronous operation module. The main programming scheme of the PXI DAQ card’s software is shown in Fig. 3.

When one shot DAQ is ended, data processing is important. In this work, an LZO no-losing algorithm is adopted. Based on the LZO algorithm, the original data will be compressed and saved in an LZO file with a new header structure. Then the LZO file will be uploaded to the data server and updated in the database. When a user needs to download or just examine the given signals, the data server will decompress these signals and return the original analog physical signals to the user according to the LZO header information saved on the LZO file.

Considering that different devices need network communication, an appropriate protocol and data package structure must be unified. Based on normal TCP (Transmission Control Protocol), an EAST NBI TCP protocol is applied for the interaction between terminal devices in the NBI control network. In addition, to implement the communication of the data package safely and reliably, when a terminal receives a data package from another one, the first thing that must be performed is a cyclic redundancy check (CRC). When the CRC is correct, the data package will be disposed of, or the sender will be asked to resend it. Fig. 4 shows the structure of the EAST NBI TCP header and that of the DACS TCP data package.

![Fig.3](image1.png)  
**Fig.3**  The programming scheme of the PXI DAQ software

![Fig.4](image2.png)  
**Fig.4**  EAST NBI TCP header and DACS data package structure
Based on multiple thread technology, multiple processes are run in parallel. This mechanism will evidently improve the program execution efficiency. A basic DACS control flow is shown in Fig. 5.

When the DACS software starts, the first thing to perform is initialization, including variables initialization, network environment initialization and DAQ card initialization, etc. Then, as a legal terminal in the EAST NBI control system, the DAQ device must be registered to the EAST NBI grandmaster server, and thus whenever DAQ configurations are changed, the change will be updated to the given DAQ machine.

For the DAQ software, there must be an independent thread, A, for the listening DAQ configuration from the NBI grandmaster server, and another one, B, for the listening DAQ trigger signal. Multi-thread technology is also used to transport data to the data server to improve transmission efficiency.

For the data server software, an independent thread is created for listening those requests from DAQ terminal for data transfer and another thread is created for listening requests from the NBI wave terminal for examining the actual physical signals on the current shot or historical shot.

5 Test results

DACS is mainly used for data acquisition, processing, querying and so on. Its hardware and software implementation have been described in previous sections. Now with the help of DACS, the test results for gathering data from the L ion source on the first EAST NBI are shown in Fig. 6. The graphics are obtained from the database by the data server software on the NBI wave terminal, which is a terminal in the Windows operating system running dedicated software for sending requests to the data server and displaying the signal wave of the returning results.

![Fig.5 The EAST NBI DACS control software flow diagram (color online)](image)

![Fig.6 Waveform of experimental results in shot # 26620 by DACS with a 51 keV high voltage, a 16 A high current and a 100 s pulse width (color online)](image)
6 Conclusion

Experimental test results show that DACS can work well in the practical operational environment of the EAST NBI, and can commendably satisfy the requirements mentioned in section 2. With the advantages of accuracy and stability, as well as reliability, the system will be put into operation immediately. The DACS described in this paper was designed for the first NBI in EAST, and to extend the system we only need additional PXI DAQ cards for the second EAST NBI.

References

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