Fusion Engineering and Design 129 (2018) 83–87

Contents lists available at ScienceDirect

Fusion Engineering and Design

journal homepage: www.elsevier.com/locate/fusengdes

Design of real-time data acquisition system for POlarimeter- INTerferometer diagnostic

Y. Chen[a,*], S. Li[a], Z.P. Luo[a], Y. Huang[a], Q.P. Yuan[a], B.J. Xiao[a,b]

[a] Institute of Plasma Physics, Chinese Academy of Sciences, Hefei, Anhui, China
[b] School of Nuclear Science and Technology, University of Science and Technology of China, Hefei, Anhui, China

ARTICLE INFO

Keywords:
Data acquisition
Real-time
RFM
Point
P-EFIT

ABSTRACT

The real-time data acquisition system is designed for providing POlarimeter-INTerferometer (POINT) diagnostic data to P-EFIT in real-time. The digital phase detector of POINT can provide real-time Faraday rotation angle data and density phase shift output which can be used in plasma control. P-EFIT, a code based on parallel computation in Graphic Processing Unit and the EFIT framework, is developed for EAST plasma control. Now P-EFIT includes a new algorithm for real-time plasma current profile reconstruction with POINT diagnostic data. The new real-time data acquisition system has been designed based on a reflective memory (RFM) network and the LabVIEW real-time operating system. It can be divided into three modules: data acquisition, data pre-processing and real-time data transmission. The data acquisition module receives a message containing the plasma shot information from the data acquisition console (according to the rules of the EAST data acquisition system) and then acquires the POINT diagnostic data after signal conditioning. The data pre-processing module primarily converts the raw data into a valid physical signal thus reducing the workload of P-EFIT. The EAST Plasma Control System has a well-established RFM network from which P-EFIT is able to get all the data it needs. This means that the data transmission module must first choose the RFM network to transfer processed data in real-time, and then P-EFIT can perform a new equilibrium reconstruction iteration with the most recent data from the data transmission module and the last equilibrium result. The data transmission frequency is 20 kHz, which satisfies the requirements of the P-EFIT real-time plasma current profile reconstruction.

1. Introduction

EAST (Experimental Advanced Superconducting Tokamak) aims at long pulse and high performance operation [1]. EFIT is a framework used in equilibrium reconstruction, which can provide plasma boundary, current density and safety factor profiles for tokamak operation and research [2]. It has been widely used in many tokamaks worldwide. P-EFIT is a parallelized version of EFIT. It is based on Graphic Processing Unit (GPU) parallel computation and the EFIT framework, and developed for EAST plasma control. It is built with the CUDA™ architecture to take advantage of massively paralleled GPU cores to significantly accelerate the computation [3]. P-EFIT has been successfully used on EAST.

Now P-EFIT includes a new algorithm for real-time plasma current profile reconstruction with the POlarimeter-INTerferometer (POINT) data. The POINT diagnostic is used for measuring the current and electron density profiles on EAST. The digital phase detector (DPD) of the POINT can provide real-time Faraday rotation angle data and density phase shift output which can then be used in plasma control [4,5]. This method of plasma current profile reconstruction using the POINT data from a simulated equilibrium has been validated [6,7]. The details of the real-time plasma current profile reconstruction with POINT diagnostic have been described by Y. Huang et al. [8].

In this paper, it is presented a real-time data acqusition system developed to acquire the data of the POINT diagnostic on EAST and provide the data to P-EFIT in real time. Hereafter the system will be abbreviated as POINT-RTDAQ. The key requirements are described as follows:

- EAST aims at long pulse and high performance operation. The system must support continuous and autonomous data acquisition and transmission even during long-pulse operation.
- The POINT diagnostic provides 22 signals: Faraday rotation angle signals and density phase shift signals. P-EFIT uses these signals to do real-time plasma current profile reconstruction. So the system should provide multiple channels.
- The new algorithm of P-EFIT is used in real-time plasma control, and the computing cycle of P-EFIT using the POINT data is about 350 us.

* Corresponding author.
E-mail address: cheny@ipp.ac.cn (Y. Chen).

https://doi.org/10.1016/j.fusengdes.2018.02.080
Received 15 June 2017; Received in revised form 16 January 2018; Accepted 20 February 2018
Available online 24 February 2018

So the cycle of POINT-RTDAQ providing the POINT data to P-EFIT should be less than 350us, in order to meet the real-time requirement of the new algorithm.

- The EAST Plasma Control System (PCS) has a well-established reflective memory (RFM) network that can also be used by P-EFIT to exchange data with other systems. The data transmission frequency of the EAST RFM network is 20 kHz. Considering the cycle of P-EFIT to using POINT data is 350 us, the data transmission frequency is adaptive.

In Section 2, the architecture of the whole system, including the relevant auxiliary systems, is summarized. In Section 3, the details of the system implementation are described. In Section 4, the results of the transmission delay test and the experimental simulation benchmark test are presented. Finally, a conclusion is given in Section 5.

2. System design

POINT-RTDAQ is a subsystem of the EAST data acquisition system (DAQS) which integrates the data acquisition of the various diagnostics with long-term data storage. This modular architecture makes adding a new diagnostic data acquisition subsystem relatively easy. However, there is one major difference between POINT-RTDAQ and the rest of the EAST data acquisition subsystems. The primary objective of POINT-RTDAQ is to acquire the POINT data and provide it to P-EFIT in real-time, while the general data acquisition is not meant to be done in real-time.

Fig. 1 shows the overview of the whole system. There are three related systems: the POINT diagnostic, P-EFIT, and data acquisition console. The data acquisition console is the control module of the EAST DAQS, which controls and manages all data acquisition flow. POINT-RTDAQ is also controlled by the data acquisition console and receives analog signals from POINT diagnostics. The amplitude of the analog signals can exceed the range that the data acquisition hardware can receive which is solved with the signal conditioning module. The signal conditioning module is an amplifier developed by EAST team. The amplifier is for the signal outing of acquisition device's voltage range, and its parameters are: (1) Gains: 0.1, 0.5, 1, 2, 5, 10, 20, 50; (2) −3 dB bandwidth: 500 kHz when gain = 1; (3) Noise: less than 10 mV when gain = 1; (4) Output range: −10 V ∼ + 10 V [9]. Then P-EFIT is able to perform a new equilibrium reconstruction iteration with the most recent POINT data.

The following is a list of the hardware of POINT-RTDAQ.

- Chassis: NI PXIe-1082
- Controller: NI PXIe-8840 (Previous: NI PXIe-8135)
- DAQ card: NI PXIe-6358
- RFM card: GE PCI-5565PIORC
- Signal conditioning: Amplifier developed by EAST team [9].

The system is based on the RFM network and LabVIEW real-time operation system, developed in LabVIEW 2014. The system can be divided into three modules in terms of their respective function: data acquisition module, data pre-processing module, and data transmission module.

The data acquisition module acquires data after signal conditioning. The data pre-processing module converts the received data into a valid physical signal before the transmission. The data transmission module is then utilized to transfer data to P-EFIT via the RFM network.

POINT-RTDAQ achieves completely autonomous operation without the need for any manual adjustments or inputs. An EAST campaign usually lasts several months. This fully automated system frees personnel from this heavy workload giving them time to focus on other research.

3. System implementation

3.1. Data acquisition module

The data acquisition module can acquire the POINT data in real-time. Then the data pre-processing module and the data transmission module can work in succession. The data acquisition is seen as a DAQ node of the EAST DAQS which includes the data acquisition console, DAQ nodes, and data server. There are dozens of DAQ nodes distributed throughout the EAST data acquisition system, all of which communicate with the data acquisition console and data server through the LAN. While most of the DAQ nodes are universal, some nodes, like this POINT-PEFIT system, need to be customized. The workflow of the data acquisition module is as shown in Fig. 2. Each time a shot message is received it goes through the following three sequential stages.

1. Get shot message: When a new pulse is coming, the data acquisition console will distribute the shot message to the DAQ nodes. After receiving the shot message, the data acquisition module extracts the shot number, data acquisition time, and other information from the message.
2. Real-time acquisition: In order to stay in sync with other systems, it will not acquire data until receiving the trigger. It synchronously acquires 22 POINT signals at a 20 kHz sampling rate. These 22 signals then form a set of data. As soon as obtaining each set of data, it provides the data to the data pre-processing module.
3. Finish acquisition: The data acquisition will not finish before the predetermined data acquisition time interval (known from the shot message) is complete. After finish the data acquisition, it will wait for the next shot message.

3.2. Data pre-processing module

As seen in Fig. 3, the raw data is first converted into a valid physical signal through a data conversion process. Then the background noise is detected, and removed. Removing the background noise is crucial for reducing the workload, and consequently the processing time, of P-EFIT. Furthermore, it allows the output data from the pre-processing module to be used by P-EFIT directly without any further processing.

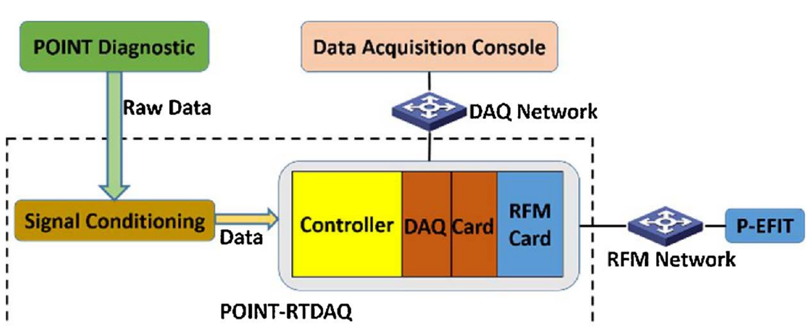

Fig. 1. System architecture.