NEW DEVELOPMENT OF EPICS BASED DATA ACQUISITION SYSTEM FOR ELECTRON CYCLOTRON EMISSION DIAGNOSTICS IN KSTAR TOKAMAK

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Abstract

Korea Superconducting Tokamak Advanced Research (KSTAR) has operated in the 6th campaign in 2013 after achievement of first plasma in 2008. Many diagnostic devices have been installed for measuring the various plasma properties in the KSTAR tokamak during the campaigns. From the first campaign, a data acquisition system of Electron Cyclotron Emission (ECE) Heterodyne Radiometer (HR) has been operated to measure the radial profile of electron temperature. The DAQ system for ECE diagnostics at the beginning was developed with a VME-form factor digitizer in Linux OS platform. However, this configuration had some limitations that it could not acquire over 100,000 samples per second due to its unstable operation during the campaigns. In order to overcome these weak points, a new ECE HR DAQ system is under development with a cPCI-form factor in Linux OS platform and the main control application is going to be developed based on EPICS framework like other control systems installed in KSTAR. It also includes MDSplus interface for the pulse-based archiving of experimental data. Besides solving the described problems main advantages of the new ECE HR DAQ system are capabilities of calculating plasma electron temperature during plasma shot and displaying it in run-time.

INTRODUCTION

Korea Superconducting Tokamak Advanced Research has operated and installed various diagnostic devices from the first campaign, and has executed to add, change and upgrade the devices according to KSTAR upgrade and installation plan every year. A data acquisition system of Electron Cyclotron Emission (ECE) Heterodyne Radiometer (HR) has been operated to measure the radial profile of electron temperature in KSTAR tokamak [1]. At first, Linux OS platform was set up to VME-form factor with DAQ unit to measure ECE diagnostics. At the first campaign, 8 channels were measured and stored, DAQ system was developed as EPICS [2] middleware in the Linux OS platform like other diagnostic and control devices of KSTAR. To store data, MDSplus [3] DB was used, and Qt [4] was used with DAQ Control UI. This system measured 2 other diagnostic devices as well as ECE at the same time (H-Alpha, millimetre-wave interferometer). ECE was increased to total 40 channels at the second campaign and 48 channels at the third campaign, and VME unit as the same farm-factor was newly set up to operate. At the fourth campaign, 76 channels were extended to operate. But, there were some limitations in the new VME DAQ. First, sample rate was limited to 100 kHz, and loss of test data was increased every year due to the instability of embedded DAQ system. For ECE electron temperature diagnostic data, over 100 kHz was required to measure and store, so cPCI-form factor was newly set up to operate the unit stably in 2012. And there's, in the existing system, disadvantages that data was stored to local HDD, and could be identified after long time with shot-off. DAQ system was newly set up to compensate the disadvantages. It was realized with a function to measure and store data to MDSplus and to display raw data in real-time in 2012, and in 2013, the other function to display and calculate electron temperature according to each position by channels depending on change of TF magnetic field in run-time and another function to calibrate a factor of radial profile with Electron Cyclotron Emission Heterodyne Radiometer prior to testing were set up. As a result of operating the device in 2012 and 2013, it was stably operated and increased the availability of system. Also, by using ECE real-time data, the real-time plasma control was successfully tested through Ethernet.

UPGRADE OF ECE DATA ACQUISITION SYSTEM

To remove problems and to improve performances in the existing KSTAR radial profile of electron temperature measurement system, the new ECE DAQ system was set up with ACQ196 compact PCI form-factor digitizers of D-TACQ [5] in the 64 bit Linux OS platform. D-TACQ ACQ196 cPCI provides embedded web service interface with remote control.

H/W Upgrade for ECE HR DAQ System

ECE data acquisition system to measure electron temperature in KSTAR is composed of a home-made Local Timing Unit (LTU), Analog-to-Digital Convertor module and RTM-T (Rear Transition Module) in 4U industrial PC installed SSD (Solid State Disk) to store the high speed data for a long time and 3.1 GHz cores CPU [6]. The D-TACQ ACQ196 ADC digitizer has 96 analog input channels, 16 bit resolution, 1GB DDR memory on board and ±10 volt input ranges (default). The bit-resolution of the new ECE HR DAQ system was downgraded from 24 bit to 16 bit but the sampling rate was upgraded from 216 kS/s to 500 kS/s. RTM-T provides a fast data path direct to gigabit serial links (PCI-Express on Cable, Optical fibre SFP, Gigabit

ISBN 978-3-95450-139-7

Ethernet). In the new DAQ system, PCI-Express on Cable was used to transfer the data directly to the host PC adapter. This minimize overheard on the host computer and transfers streaming data of over 200 MByte/sec efficiently.

The ECE HR data acquisition sequence is synchronized with KSTAR experimental cycle using the LTU [7]. The LTU is configured with a pre-programmed scenario before plasma shot, and generates triggers and clock signals according to the scenario it receives a shot start signal from a Central Timing unit (CTU) and is under control of a CTU in TSS [8].

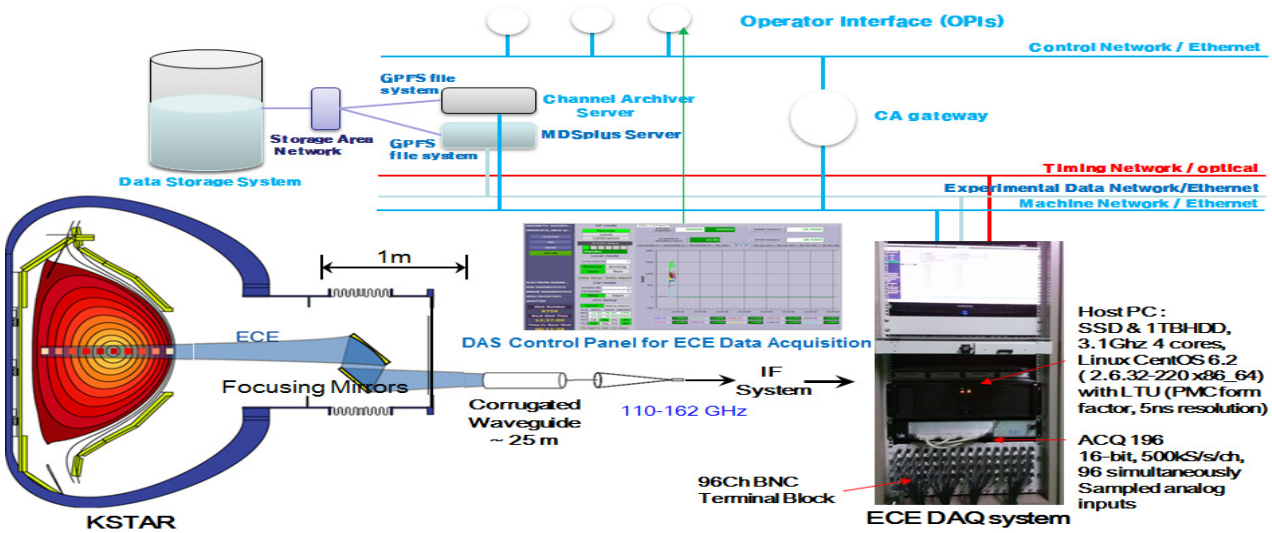

Figure 1: Network connections to the infrastructure of the KSTAR control system and Configuration of ECE DAQ System.

Table 1: Specifications of the New ECE DAQ System

Item	Specifications
Host PC	Intel® Xeon CPU E31220 @ 3.1 GHz 4 cores, RAM 8 GByte, SSD 160 G, HDD 1 TB
ACQ196	96 simultaneously sampled analog inputs, 16 bit, 500 kS/s per channel, ±10 V input range
RTM-T	PCI-Express on Cable 1x Streaming data transfers over 200 Mbytes/sec to a host PC
BNCPANEL	2U rack-mount steel panel 32 isolated BNC connectors Differential wiring to S68 connector on rear side 100V zener diode transient protection
LTU	Bespoke. Local Timing Unit Max 5ns accuracy Output clock : 1 Hz ~ 100 MHz Max 50 multi triggering sections 2 Gbps Optical Communication speed Extension : Configurable 8 channels (Trigger or Clock)

S/W Development for ECE DAQ System

Like the other DAQ systems of KSTAR, ECE DAQ system was set up with (Cent OS 6.2 – kernel 2.6.32-220.17.1.e16.x86_64) EPICS middleware based on Linux O/S as well. Just as most of data acquisition systems used in KSTAR, device/driver was also developed in ECE DAQ system with SFW (Standard Frame-Work) utilized the IOC core software provided for EPICS.

The SFW [9] is a development package for KSTAR control system. It is configured with EPICS library, template files, record instance file, and database definition files. It supports synchronized operation with KSTAR discharge experiment by using internal sequence handler. It provides MDSplus interface and system status manipulator. We can make shorten of system development time and increase the system reliability by using the SFW. GUI to control DAQ system was developed to use KSTAR Widget Toolkit (KWT) based on Qt library. ECE OPI panel is composed of some sub-panels. Those are 3 sub-panels to identify Operate data acquisition and raw data by each channel in real-time, 5 sub-panels to identify electron temperature trend by each channel in real-time and 1 sub-panel to display electron temperature of positions by each channel in real-time according to TF current. In the data update rate in real-time, the data in 500 kHz sample rate is updated at about 100 Hz, and in 100 kHz sample rate, it is done at about 20 Hz. EPICS device/driver in the ECE DAQ system was developed by

ISBN 978-3-95450-139-7

using ACQ2XX_API and RTM-T-Hostdrive provided by D-TACQ [5]. In addition, ECE DAQ system was used with common libraries in the other control system of KSTAR; timestampRecordLib to provide information system time, sysMonLib to provide health status in the system and kutilLib to store log information for debugging of device/driver. Figure 2 shows the function blocks of ECE DAQ system EPICS IOC.

Table 2: Environment for Development

Program	Version	Site
EPICS	3.14.12	http://epics.aps.anl.gov/epics
MDSplus	2.3-0	http://www.mdsplus.org
Qt	4.3.2	http://www.trolltech.com
ACQ2XX_API RTM-T	1.11 hostdrive	http://www.d-tacq.com

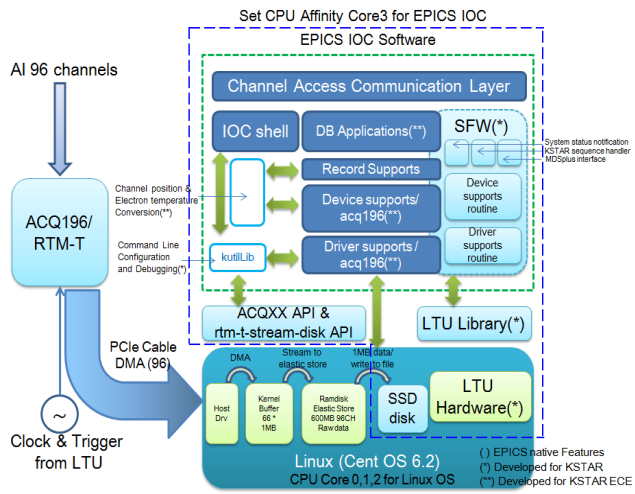

Figure 2: Function blocks for ECE IOC.

Calibration with New Digitizer

ECE system should be performed to calibrate accurately as it's a device to measure electron temperature and its distribution of Plasma. For this, ECE system in the KSTAR has adopted the absolute calibration to find out a calibration factor through comparison with more than two radial temperatures by using blackbody emission source [10]

To measure ECE calibration factor Oscilloscope was first used in 2008. As channels are increased, the digitizer was used to measure and calculate data for calibration factor. The existing VME form-factor 24 bit digitizer had measured for one second per a shot in 100 kHz sample rate, and values of calibration data for 4 (250°C, 350°C, 450°C and 550°C) temperatures per 1000 shots in each temperature had been measured. The newly upgraded cPCI form-factor, 16bit DAQ system to measure calibration data measured for 15 seconds per a shot in 500 kHz sample rate, performed 1000 shots for 5 (150°C, 250°C, 350°C, 450°C and 550°C) temperatures per 200 shots in each temperature, and measured calibration data value of about 490 GByte.

The existing DAQ equipment was unstable, so it took long time to perform total calibration as it's short time to measure calibration data per a shot. But, the new DAQ system made to shorten the calibration as the number of shots was decreased because it's possible to measure for a long time per a shot. And there were the data missing in only 2 shots in the progress of 1000 shots for the new DAQ system. These were caused by delay of deleting buffer space in the intermittent ramdisk due to overuse of CPU and memory. To solve these, Linux OS run level was performed at 3 from 5, and 1 CPU among 4 host computer CPU isolated from linux kernel scheduler was performed to designate CPU affinity in EPICS IOC.

In the Figure 3, it's identified that there's no problems to use ECE DAQ system in the digitizer as 24 bit calibration data was divided into 16 bit calibration and compared and analysed by log scale, as a result of performing calibration with the existing 24bit digitizer and new 16 bit digitizer equipment.

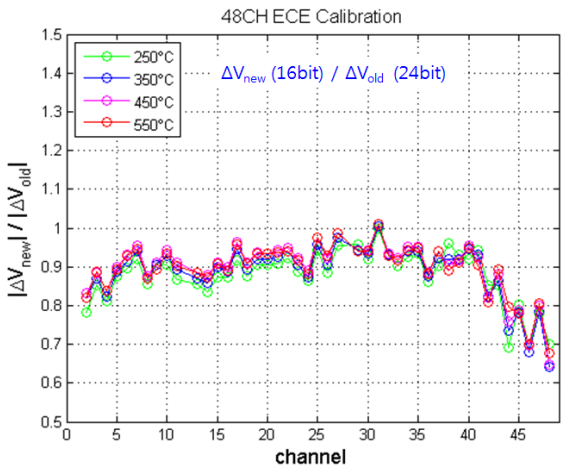

Figure 3: Comparison of calibration factor between new and old DAQ.

RESULT OF OPERATION

After ECE DAQ system was upgraded, its stability and usability were improved. As seen in the table 3, no fault has been found in the ECE DAQ system since the system was upgraded. Data loss is caused by users' mistaking a mistake while controlling LTU and due to KSTAR shot sequence fault.

In the campaign in 2013, CA (Channel Access) in 1G Ethernet was used in the real-time ECH power control with ECE real-time data. In the Figure 4, it's shown to control plasma successfully with ECE data and to display ECE data in real-time in accordance with KSTAR tokamak on sub-panel and ECH DAQ system control panel. After the upgrade of ECE DAQ system, all was functioned with success.

ISBN 978-3-95450-139-7

Table 3: ECE DAQ System Fault Rate

Campaign	DAQ fault counts	Lost shot	Total shot
1st 2008	23 (VME)	23	1283
2nd 2009	4 (VME)	2	1059
3rd 2010	14 (VME)	17	2126
4th 2011	1 (VME)	2	2002
5th 2012	0 (cPCI)	3	1822
6th 2013	0 (cPCI)	5	1071

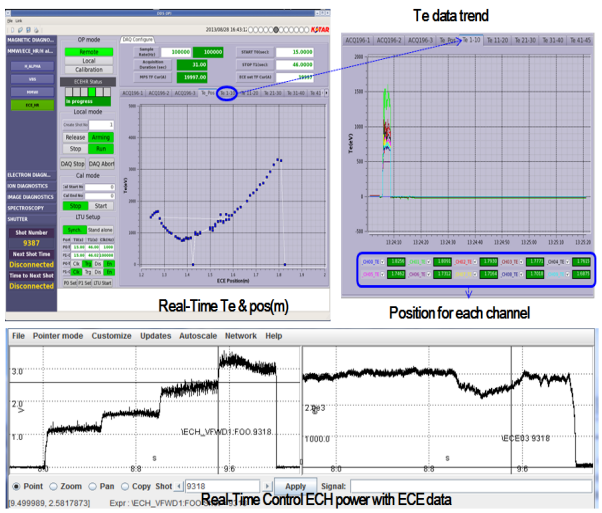

Figure 4: OPI panels to operate DAQ system and display electron temperature data in run-time, result of ECH power control on real-time with ECE.

SUMMARY AND FUTURE PLAN

ECE DAQ system was newly set up in KSTAR operation in 2012, so the new system was built to operate with improvement of its performance and function in 2013. Compared to the previous DAQ system, the new DAQ system has a lot of advantages in its hardware and software; improved performance in measuring data, stable motion, more accurately synchronized operation with clock/trigger on timing board, calculation of real-time electron temperature and electron temperature data display according to position. In future, ECE diagnostic DAQ system will be modified to achieve data so that raw data can be stored to MDSplus DB without delay.

REFERENCES

[1] S.H.Jeong, K.D.LEE, et.al.., Rev. Sci. Instrum. 81, 10D922 (2010).
[2] http://www.aps.anl.gov/epics
[3] http://www.MDSplus.org
[4] S.Baek, et.al.., "KSTAR widget toolkit using Qt library for the EPICS-based control system" Proceedings of ICALEPCS (2009).
[5] http://www.d-tacq.com
[6] Mikyung Park, et al.., "Development of a Prototype Time Synchronization System for KSTAR with a VME-bus System", Fusion Eng. Des. 81 (2006) 1817-1821.
[7] Mikyung Park. Other, "The Upgrade of KSTAR Timing System to Support Long Pulse Operation and High speed Data Acquisition", Proceedings of IAEA TM (2011).
[8] Mikyung Park, et.al.., "Data acquisition system implemented with various platform for KSAR diagnostic systems", Fusion Eng.Des. 85 (2010) 350-355.
[9] Woongryol Lee, Other, "Design and implementation of a standard framework for KSTAR control system", 9th IAEA TM on Control., (2013).
[10] Y.Kogi, S.H.Jeong, et.al.., Rev. Sci. Instrum. 81, 10D916 (2010).

ISBN 978-3-95450-139-7