Application of MDSplus for the Management of the Pulsed-based Experimental data in KSTAR Tokamak
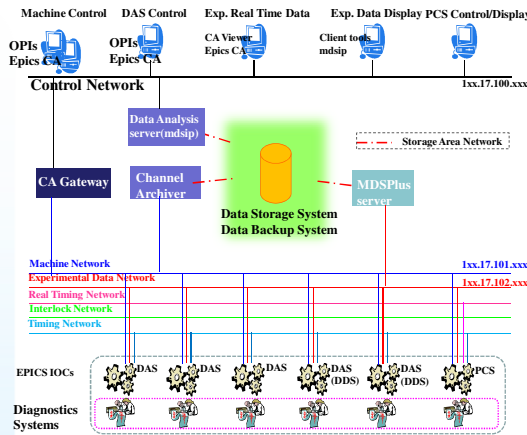
Taegu Lee *, Sangil Lee, Sulhee Baek and Mikyung Park
National Fusion Research Institute (NFRI), Daejeon, Republic of Korea

Introduction

❖ The KSTAR Control System has been developed using **EPICS** (Experimental Physics and Industrial Control System) as a middleware of control system
❖ **Five different optical networks named as MERIT** connected between central and local control systems according to the applications
❖ Using two types of database :
- **EPICS Channel Archiver** : continuously produced machine operational data at a low rate
- **MDSplus** : shot-based experimental pulse data with a large volume
❖ Development & Operating software : EPICS (R3.14.8.2 & R3.14.10), MDSplus (v.2.0.1 Sep.2008), Qt (R4.3.2), Linux (Kernel 2.6), Vxworks (Tornado2.2)
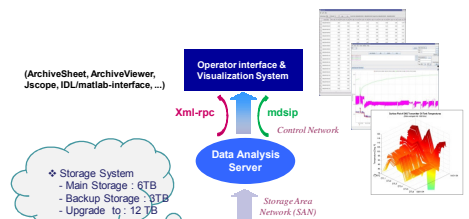❖ Experiment data structure upgraded for more flexible management

KSTAR Control System

- **Integrated the heterogeneous local systems** such as VME, cPCI, PXI, PLC(AB, Siemens), VXI, cFP with EPICS

- **Basically, Linux-based system** except some diagnostic systems

- **Five Different Networks**
  - **Machine network** : Machine control data/event, EPICS Channel Access , General Plant Control/Monitoring (Ethernet)
  - **Experimental data network** : Diagnostic data, MDSip protocol (Ethernet)
  - **Real-time network** : Real-time Information, CCS/PCS/MPS, True-put > 175MB/sec, Latency ~ 0.7usec/node (Reflective memory (RFM) network (Optical))
  - **Interlock network** : Interlock information, Redundant optical network, ControlNET (ControlNET,(Optical/Redundant))
  - **Timing network** : GPS Time,100MHz Master Clock, Trig/Clock Information (In-house development (Optical))

- **Two Databases**
  EPICS ChannelArchiver : operation data management
  MDSplus : experimental pulse data management
  MySQL : signal information data management

- **Development software**
  EPICS r3.14.8.2,
  MDSplus v.2.0.1-.2008,
  MySQL,
  Qt R4.2.1,
  Linux Kernel 2.6.9, & 2.4.x(some of system)
  Vxworks-5.5
  Window.
  Cygwin.

MDSplus DB Structure for the 1st Plasma

No	Tree Name	1st Plasma - Data Size	Node	Remark
1	XDATA	199G	~1000	All DAQ acquired data stored
2	RDATA	3.8G	~ 4000	Calculation Expressions & parameters
3	ADTAT	4.7G	~ 300	Result of Calculated data
4	PCS_KSTAR	53G	~ 5000	PCS data
	Total Size	206.5 G	~ 10300	

Changed DB Structure

New Tree Name		
Flux_loop	1	Flux loop
Dia_loop	2	Diamagnetic Loop
Mag_FP	3	Magnetic Field Probe
Rog_Coil	4	Rogowski coil
Vessel_CM	5	Vessel Current Monitor
Halo_CM	6	Halo Current Monitor
Locked_Mode	7	Locked Mode
Mirnov_Coil	8	Mirnov Coil
Saddle_Loop	9	Saddle Loop
ECE_HR	1	Fast Reciprocating Langmuir Probe Assembly
MMWI	2	Millimeter Wave Interferometer
FRL_Probe	3	Electron Cyclotron Emission Heterodyne Radiometer
VS_SPEC	1	Visible Survey Spectrometer
Ha_Monitor	2	H_alpha Monitor
VBA	3	Visible Bremsstrahlung Array
FILTER_S01	1	Visible Filterscope
FILTER_S02		
EFIT01		
EFIT02		
ELECTRON	INTERFERO	1	MMW Intrferometer
	ECERADIO	2	ECE radiometer
STRUCTURE		
VACUUM		
SET_TIME		
SET_DAQ		
ECH		
ICRF		
NBI01		
NBI02		
LHCD		
ECCD		

Changes in DB Structure of KSTAR Experimental Data

- **Previous issues of data structure**
  - Mistakes of developer
  - Poor in conceptual structure
  - Difficulties of administrative control (Categorized data access)
  - Difficulties of flexible data management
- **Advantage of the new structure**
  - More flexible data access control
  - Increase data volume due to fluid handling

❖ Modification lists from the changed tree
  - Reducing data size of raw data
  - All data synchronization with pcs data.
  - Some of data delays recovered in DDS1 DAQ

● Example of error in data acquisition
: Time Delay in DDS1 DAQ System for Magnetic Diag.
  ➢ Cause : Internal clock malfunctioned in a digitizer
  -> Sampling clock was estimated to be 200.699kHz (Not 200kHz).

Aliasing Interval   200kHz Sampling Clock error

$$\Delta T = 1.43msec \rightarrow \Delta f^{\pm} = \pm 699.3Hz$$

$$DelayTimePerSecond = \frac{1}{SampleCountsPerSecond} \times$$
$$(RealSampleCountsPerSecond - SampleCountsPerSecond)$$
$$= \frac{\Delta f^{\pm}}{f_0} = 3.495msec/sec$$

❖ Compare PCS data and the calibrated data
➢ Range of delay-time : dx = 3.973689e-4
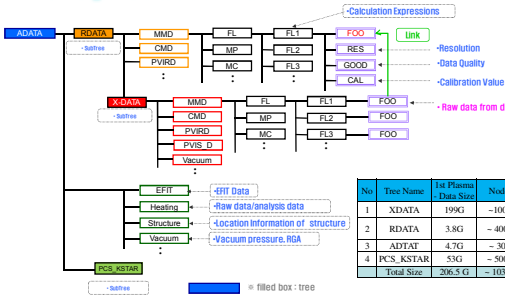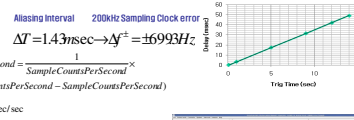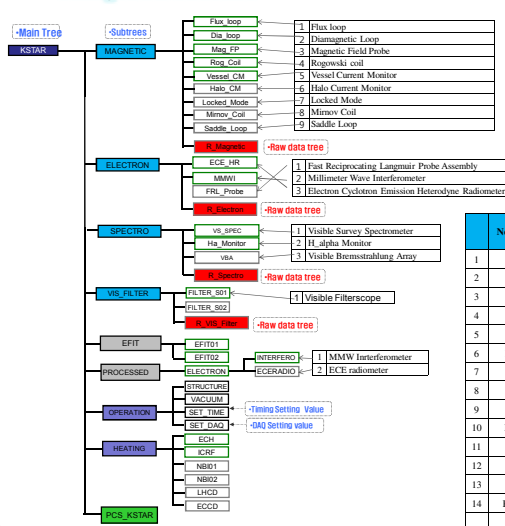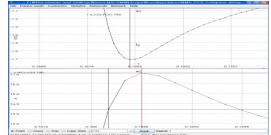
1.43msec

Data Management

❖ Data of configuration & system status : archived by **EPICS channel archiver** using CA/Machine network
❖ **Shot-based diagnostic data** : archived by **a MDSplus using MDSip/Experimental network**
❖ **Some diagnostic data** (slow sample) service in real-time by **EPICS Channel access**
❖ 4 MDSplus data tree were used for the 1st campaign
❖ Data tree modification after the 1st campaign for more flexibility and adaptability to prepare for the increasing of diagnostics
❖ 3 data servers operate in accordance with operation modes.

(ArchiveSheet, ArchiveViewer, Jscope, IDL/matlab-interface, ...)

Operator interface & Visualization System
Xml-rpc   mdsip
Data Analysis Server
Control Network

❖ Storage System
  - Main Storage : 6TB
  - Backup Storage : 6TB
  - Upgrade to : 12 TB

Storage Area Network (SAN)

Channel Archiver Server — Centralized Storage System — MDSplus Server

●Continuous operation data
●Plant monitoring data

Machine Network — Control Parameter & Down Sampling Data

Experimental Data Network — ●Pulse-related data

Local Control Systems

Diagnostics, PCS, Heatings, MPS,…

● **Configuration/EPICS CA**
  - Enable/disable channels of digitizers
  - Set trigger start time/period
  - Set sampling clock and DAQ ready
  - Lock-out
● **Issue 'Shot start'**

Pre-processing

● **Shot sequence**
  - 'Shot start' transferred from CTU to all LTUs via Timing network
  - LTU generates trigger/clock referring to the configured parameters
  - Data acquisition executed (store Local system and real-time transport)

Plasma Discharge

● Data transferred automatically to the main storage
● Calculation executed automatically after a flag to indicate the completion of data transfer
● Processed shot result displayed automatically

Post-processing

Results and Future Work

	New Tree Name	Data stored during 1st Plasma	Remark
1	KSTAR	41M	KSTAR tree have all the tree of subtree. (Main Tree)
2	EFIT	41M	EFIT Data
3	Electron	202M	Calculation Expressions and parameters of MMWI & ECE
4	R_Electron	2.4G	Raw data of Electron data
5	Magnetic	3.5G	Calculation Expressions and parameters of MD data
6	R_Magnetic	143G	Raw data of Magnetic data
7	Spectro	121M	Calculation Expressions and parameters of H-Alpha & VSS
8	R_Spectro	7.4G	Raw data of Spectro tree data
9	Vis_Filter	101M	Calculation Expressions and parameters of Filter Scope
10	R_Vis_Filter	528M	Raw data of Filter Scope
11	Heating	355M	Heating Device Data(ECH, ICRF)
12	Operation	657M	Time, Structure info ,Vacuum RGA…
13	Processed	558M	Result of Calculated data(Interferometer)
14	PCS_KSTAR	53G	Occured data at Plasma Control
	Total Size	211.904 GB	

- **Experiment data management for 1st campaign was successfully performed to provide services and store the experiment data .**
  - Total 233 channels of experiment data were stored.
  - About 134 users registered for the data service.
  - Data stored for 55 days by conducting 1283 shots
- **Many diagnostics systems will be installed step by step for the next campaign operation.**
  - New diagnostics and channel expansion are going on
  - Add new MDSplus tree nodes for the texpansion of diagnostics.
  - Improvement in Performance of Data service.
  - To provide more secure data service in case of remote access