Fusion Engineering and Design 85 (2010) 515–519

Contents lists available at ScienceDirect

Fusion Engineering and Design

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

The EPICS based plant control system for KSTAR—First operation period implementations and experiences

Myungkyu Kim*, S.H. Baek, T.G. Lee, S.I. Lee, M.K. Park, M. Kwon

National Fusion Research Institute (NFRI), 113 Gwahangno, Yuseong-gu, Daejeon 305-333, Republic of Korea

A R T I C L E I N F O

Article history:
Available online 16 June 2010

Keywords:
KSATR
Plant control system
EPICS

A B S T R A C T

After successful achieving first plasma, Korea Superconducting Tokamak Advanced Research (KSTAR) is now preparing second operation that includes power supplies with full power operation and more diagnostic systems. During first campaign the Experimental Physics and Industrial Control System (EPICS) was adopted as a control middleware of the KSTAR control system showed stable and reliable results and did not reveal any significant system failures.

The EPICS based plant control system is used for data acquisition, data archiving and data visualization and is interfaced with Central Control System (CCS). A plant control system requires an EPICS Input Output Controller (IOC) and its own DAQ system. During the first operation the EPICS based control systems were mainly used slow data acquisition at a rate less than 10 Hz. The hardware platforms were Programmable Logic Controller (PLC) and PCI eXtensions for Instrumentation (PXI). In this paper we will describe following items: the details of control function, implementation of each plant control system, operation results and analysis, focusing on the Tokamak Monitoring System (TMS), the Vacuum Monitoring System (VMS), the Current Lead System (CLS), the Helium Distribution System (HDS), and the Heating Systems.

1. Introduction

Recently ITER officially announced its selection of EPICS for control middleware. Originally the EPICS was developed for the control of large scale accelerators having many and widely spread control points [1]. The network based distributed system has advantages in scalability, maintainability, reliability; also it could handle or accept the new technologies. The large EPICS open source community will facilitate worldwide collaborations.

To find a suitable control system for KSTAR, we focused on several areas: complexity and ease of use, error tracking, spontaneous response to problems or errors, and optimizing with respect to individual application requirements. To meet these requirements, open source software that is freely modifiable, derivable, and redistributable was considered. In particular we looked at robustness, code clarity, and cost. With this in mind, KSTAR has kept an eye on the EPICS since 1998.

The first use of the EPICS in tokamak was National Spherical Torus eXperiment (NSTX), PPPL, US. Mainly they have used the EPICS for the purpose of plant or process control [2].

Because the superconducting coil structures KSTAR are under 24 h continuous operation, we required very high reliability and stability. In 2003, KSTAR had announced the choice of EPICS as its control system middleware [3]. And one year later in 2004, the first demonstration of an EPICS based plant control system for the Vacuum Monitoring System (VMS) was successful [4]. Since the KSTAR uses the EPICS in all tokamak control domains, like plant control, plasma control, diagnostics, and time synchronization part it is a more comprehensive use of the software than was done at NSTX.

2. Implementation

2.1. KSTAR control system

The control system for KSTAR device is based on a distributed network that integrates central and local function and is widely scattered around KSTAR building. Through the network, an individual system performs its dedicated mission and is tightly coupled with the other systems. This is the key design factor for KSTAR.

The KSTAR control system nodes, use up to 5 separate networks for communication, depending on which features and applications are needed. According to its assigned mission, the local node is designed to use these 5 mentioned networks, it is essential that most of them use the interlock network and the machine network [5]. Fig. 1 shows the overall structure of KSTAR integrated control

* Corresponding author. Tel.: +82 42 870 1617.
E-mail addresses: mkkim@nfri.re.kr, myungkyu.kim@gmail.com (M. Kim).

0920-3796/$ – see front matter
doi:10.1016/j.fusengdes.2010.05.028

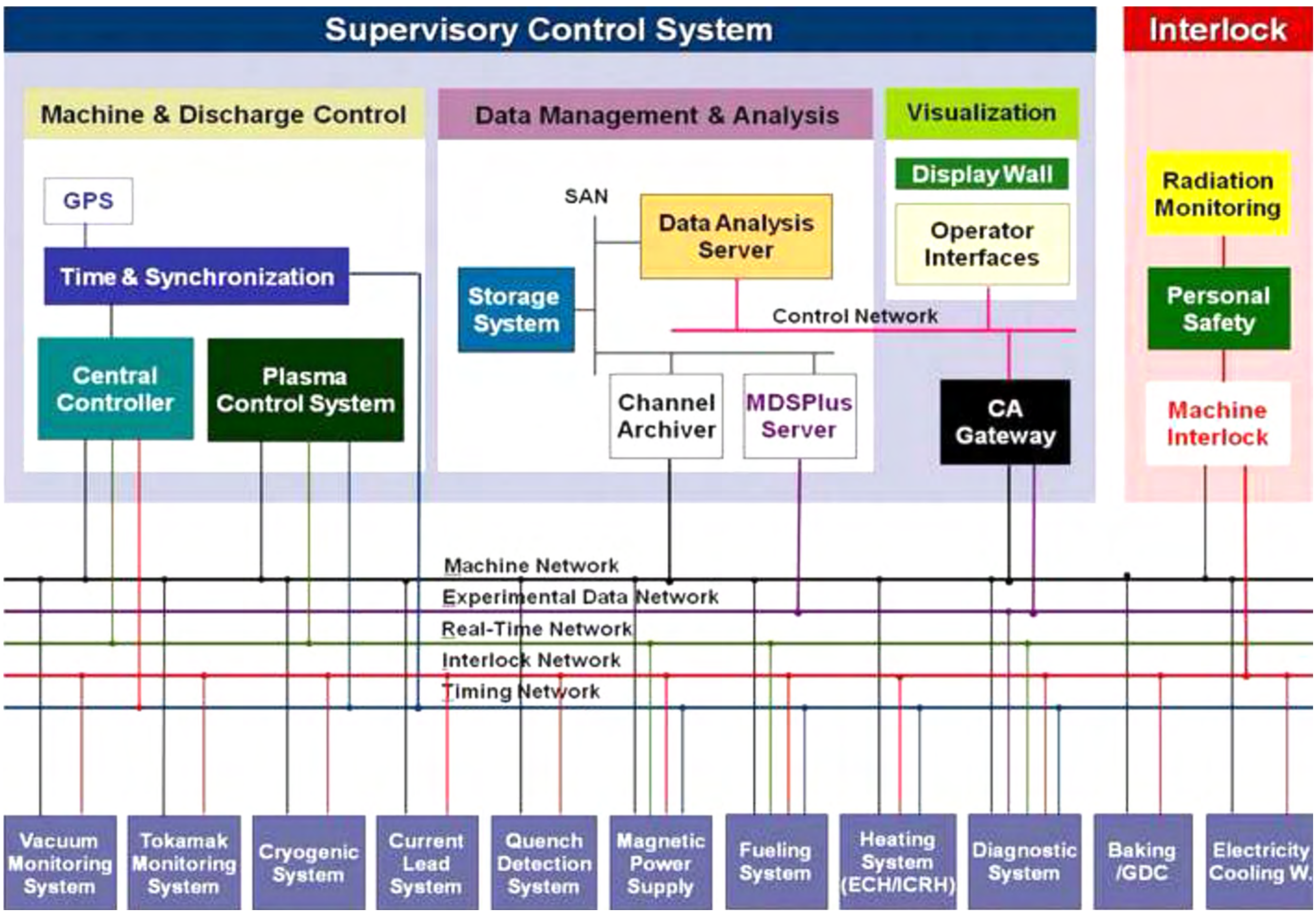

Fig. 1. Overall structure of KSTAR control system.

system with its 5 networks. Each KSTAR control system uses Linux as an operating system and the EPICS as a control middleware. Fig. 2 shows all of the local plant control systems and their respective locations.

2.2. Plant control system

A PLC is a typical device for process control and widely used in the plant control systems. The PLCs usually enables stable and efficient control system implementation for slow speed operation (~100 ms) and ON/OFF control. They can be used in situations requiring small calculations. In KSTAR local control systems such as Vacuum Monitoring System (VMS), Current Lead System (CLS), Helium Refrigeration System (HRS), Helium Distribution System (HDS) and Electron Cyclotron Heating (ECH) System have been developed based on PLCs because these fit within the previously mentioned constraints. In selection of models and vendors of PLC, we gave highest priority in communication with EPICS. Therefore we chose Control Logics (or Compact Logics) PLC using ether-ip by Allen Bradley and S7 PLC using TCP communication by Siemens those device drivers already available in EPICS community. The general type of PLC based plant control system is shown in Fig. 3 more details on the configuration for each control system is described in Table 1, where I/O is the real signal from sensors or instrument, PV is the virtual sensors or signals made by EPICS, OPI stands for the operator interface and Qt is the cross-platform application and user-interface framework by nokia.

On the other hand, the Tokamak Monitoring System (TMS) which measures temperature, strain, displacement, and field strength of the tokamak and structures does not need fast read out (~1 Hz) but doe require the handling of numerous sensors and rather complex calculation to convert engineering values. The National Instruments PXI and cFP were selected as the main DAQ controllers [6].

The basic operation mode and functional requirements of the plant control system of KSTAR can be summarized as follows.

- 24 h uninterrupted operation
- Local operation and remote operation in the main control room
- Live (run-time) operation monitoring and archiving of operation data
- Self interlock for its own protection and interfacing with a central interlock system to share alarms and warnings for global system protection
- Network: machine network, interlock network
- Time synchronization with central timing system using local timing unit (ECH case)

3. Operation result

The operation of the KSTAR was carried out in 6 operation phases: vacuum pumping, cool down, coil charge, plasma experiment, warm-up and maintenance. We started the vacuum pumping March 2008 and reached the base pressure of vacuum vessel below 2.5×10^{-8} mbar and cryostat below 2.5×10^{-6} mbar, respectively. After the completion of the vacuum commissioning, the cooling of 30 superconducting coils down to 4.5 K was conducted which took about a month. When the coil temperature reaches near 20 K,