



New control systems at KSTAR compatible with ITER standard technologies

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ABSTRACT

Through the lessons learned during the ITER control, data access and communication (CODAC) tasks and the interaction with various domestic and overseas communities, the KSTAR control system is being improved with new functions. We have adopted ITER synchronous data bus network (SDN) and time communication network (TCN) to increase the flexibility of control system design and improve system performance. Absolute time-based discharge operations and high-speed data communication interfaces are standardized as KSTAR standard software components. We used the reconfigurable I/O (RIO) library provided by CODAC for the renovation of a fast interlock system, and effectively implemented a real-time core structure through ITER for the next generation real-time control systems. A new hardware platform standard has been adopted for system standardization and convenience of maintenance international collaboration.

1. Introduction

The KSTAR control team is responsible for developing not only the ordinary machine control systems but also the data acquisition system for diagnostics and real-time control. Our development efforts are naturally concentrated on the system automation and standardization. More than 20 control systems have been implemented based on standard custom libraries [1]. However, the KSTAR control team is constantly facing new challenges such as the necessity to reflect the latest systems and requirements added each year, system instability owing to aging, and long-term experimental planning.

Fortunately, we have been continuously improving system performance through active exchanges with various control communities including the ITER control team, and we were able to cope with future problems in advance. This paper briefly describes the CODAC standard system installed in KSTAR. Subsequently, we introduce several newly constituted elements at KSTAR.

2. Overview of the CODAC control system at KSTAR

Since KSTAR and ITER have similar engineering characteristics and the KSTAR control system also uses the experimental physics and industrial control system (EPICS) as a middleware, it is close to the standard model of the ITER control system. Therefore, we have been performing functional and performance evaluation tasks of CODAC standard technologies for the past several years. Consequently, we have

developed a feedback control system that complies with the CODAC standards and have used plasma density control experiments. In addition to building regional control systems, the installation, analysis and evaluation tasks of the operation applications of ITER are ongoing. Fig. 1 shows the overall CODAC system configuration at KSTAR. The system typically consists of two diagnostic systems, two fuel injection systems, and a plasma controller, which includes all the high performance network interfaces and the data archiving system. In addition, a standard operation interface (OPI) was developed based on a 4K-human-machine interface (HMI) system, and the ITER operation applications showed stable synchronous operation ability through the KSTAR experiment.

Lessons learnt from the CODAC task were utilized in the maintenance and long-term improvement plans at KSTAR. Some components and schemes were evaluated and subsequently incorporated into the KSTAR control system. World-time-based operation methods using TCN and high-bandwidth real-time interfaces were reflected in KSTAR system upgrades. The design philosophy for next-generation hardware platforms and real-time control applications has been inspired by CODAC system evaluation.

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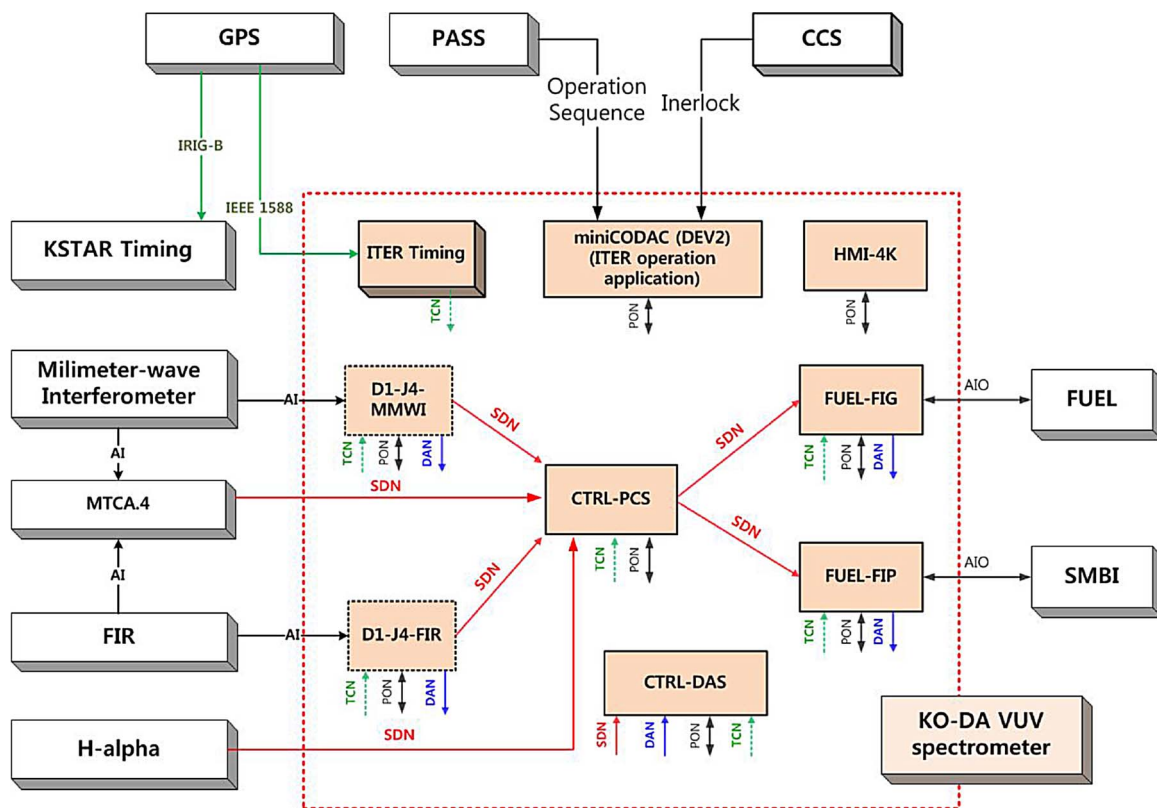


Fig. 1. Entire CODAC control system interconnection at KSTAR for real-time density feedback control.

3. Expansion of KSTAR control system by using CODAC technologies

3.1. Improvement of network infrastructure

The native KSTAR time synchronization system is primarily aimed at synchronizing clocks/triggers with a single clock source and supplying them directly to the controller. It has a star topology connection and provides a high-precision time protocol. It has a resolution of up to 5 ns, provides more than 50 programmable multi-trigger chains, and a 1–100 MHz output clock. The EPICS input output controller (IOC) built into the ARM[®] processor provides an efficient operating environment [2].

Most installed data acquisition (DAQ) control systems were designed and developed through an in-house manufacturing process. However, some DAQ systems are far from standard because they are installed independently. In order to provide the correct time stamp to a non-standard system, the pulse automation system adopts global positioning system (GPS) time protocol for the discharge start event instead of a software timer.

Moreover, system time synchronization is set up based on the ITER TCN interface, which provides a more precise time resolution for a control application. Fig. 2 shows the finalized KSTAR timing system interconnection.

In order to achieve real-time data communication performance, KSTAR uses a hardware-driven communication device, i.e. a reflective memory (RFM) card. It has benefited from the low communication latency on dissimilar hardware platforms running different operating systems, and the lack of software overhead. However, higher data rate and faster response time are required. The lack of diagnostic tools motivates us to seek an alternate solution.

ITER SDN is based on UDP/IPv4 multicast over 10 Gb Ethernet. SDN software supports for the publish/subscribe paradigm for its data communication. During previous plasma experiments which are

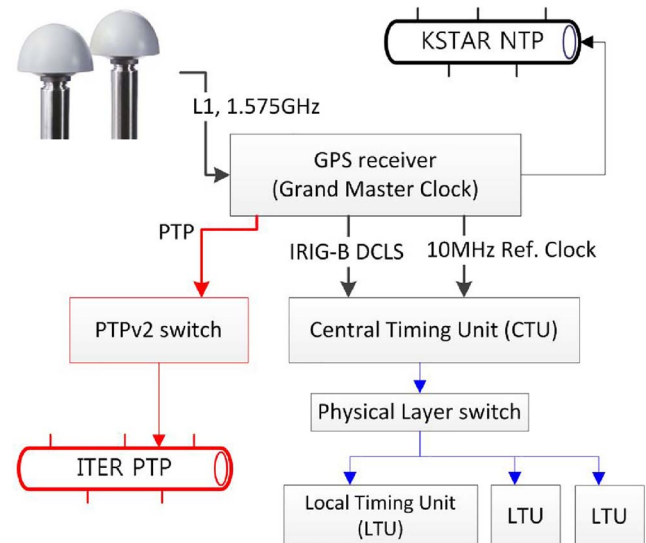


Fig. 2. KSTAR time distribution diagram with ITER TCN.

performed at KSTAR, it was confirmed highly available and deterministic transport performance for real time feedback control. There are advantages of using various diagnostic tools, i.e. WhatsUP gold, PRTG, ping, ipuf, ipscan etc. We decided to use the SDN for the high-speed control network interface, and developed a real-time gateway between the RFM and SDN, i.e. SDN-gateway, for gradually migrate from RFM to SDN [3]. Fig. 3 shows the current design and progress of SDN infrastructure. There are three categorized control systems that are intended to use the SDN interface. The second neutron beam injection (NBI) system, high-speed control cluster nodes, and real-time diagnostics are intended to use the SDN interface.

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