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# Development of a remote monitoring system based on Grid-EPICS for tokamak experiments

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**Abstract**

We present a general approach and procedures for developing a Grid-based remote monitoring system when the local control system employs Experimental Physics and Industrial Control System (EPICS). A description is given of the prototype KSTAR remote monitoring system that has been implemented on the basis of the general concept. It is demonstrated that the Grid computing technology combined with Globus toolkit software tools, can be successfully utilized for the realization of a remote monitoring system for tokamak experiments. Discussions are made on requirements and a plan to build a complete remote participation system for future tokamak experiments.


*Keywords:* Grid; EPICS; Remote monitoring; Remote participation; KSTAR

## 1. Introduction

Tokamak fusion research is entering a new era of research by the successive construction of next-generation superconducting devices, such as KSTAR [1], EAST [2], and ITER [3]. The common trend in this research field is in the direction of putting emphasis on the international collaboration, especially the remote participation in experiments. In particular, the international nature of the ITER project strongly demands for enabling remote participation in on-site experiments from seven member countries, which has been an important design requirement for the ITER Control, Data Access, and Communication (CODAC) system [4]. In KSTAR, preparing for a remote participation system has also been an important project requirement because of its high impact on the international exploitation of the KSTAR device.

For efficient fusion collaboration, it is necessary to integrate technical services such as remote experiment monitoring, remote real-time control, security, human communication such as video and phone conferencing, a reliable network service, data access and analysis, and simulations of fusion plasmas. The complexity of scientific missions of the next-generation tokamak research will require increasing use of computational power and network availability, provoking the use of a next-generation information technology. Grid computing [5] is one of the candidate technologies meeting the requirement of the global collaboration. All of the above mentioned features could be realized by the application of the modern Grid computing technology.

The Grid computing [5] is a high performance, network application technology which is capable of providing the high throughput computational capability. In fact, one of the main driving forces that has led the development of the Grid technology is the high performance computing demands from the so-called big science sector to which the fusion research obviously belongs [6]. It is now widely accepted that the Grid computing technology will become a central part for the future remote participation system, including an e-science infrastructure [6]. So far, it has been applied to such scientific fields as high energy physics, bioinformatics, drug development, molecular simulations, as well as the fusion research.

At present, a de facto standard, the Globus toolkit 4.0 [7], has been developed by the Globus Alliance [8] to promote the development of Grid systems and Grid applications. The Globus

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toolkit is a community-based, open architecture, open-source set of services and software libraries that support Grid and Grid applications. It is packaged as a set of components that could be used either independently or together to create Grid applications [7].

In Europe, the remote participation in tokamak experiments has been centered at JET under the remote participation project [9]. Recently, the fusion Grid cooperation [10] based on the Enabling Grid for E-sciencE (EGEE) framework [11] has been undertaken to promote using Grid for fusion collaboration. So far, it has focused on modeling and simulations of fusion plasmas, as first attempts. The EGEE gLite middleware [12] has been used to build the fusion grid virtual organization (VO) [10].

In United States, the National Fusion Collabortory (NFC) [13] has been carried out as a pilot project of the DoE Science Grid [14] project. The NFC project aims at the integrated exploitation of US fusion research resources, including tokamak devices and computing resources. In this project, the Virtual Network Computing (VNC) tool, which is a desktop sharing system remotely controlling another computer over a network, has been partially utilized for the remote monitoring of tokamak experiments. Using VNC, a desktop of a local control system can be shared among remote client computers through a network. A partial use of VNC has also been made of a remote monitoring system for Tore-Supra [15].

Remote participation in tokamak experiments could be divided into the remote monitoring and the direct remote control. The remote monitoring can be implemented relatively easily without causing any serious security and/or safety problems. The major figure of merit parameter of the remote monitoring system is the delay time in the global network environment. Thus, the initial remote participation in ITER experiments is envisaged to begin with the monitoring of an experiment from remote sites. It will be shown, however, in this paper that there is no fundamental difference between the remote monitoring and the remote control in terms of software technologies to be used to construct them. Thus, the development tools and experiences gained during the construction of the remote monitoring system can be directly applied to the creation of remote control applications.

In this paper, we describe a Grid-based remote monitoring system that has been developed as a prototype remote participation system in KSTAR experiments. Since the KSTAR control system is based on Experimental Physics and Industrial Control System (EPICS) [16], Grid and EPICS constitute two major tools for the development of the KSTAR remote monitoring system. Section 2 starts with a brief introduction of the generic concept and software tools being used for the development of the remote monitoring system. We also present the generic architecture for a Grid-based remote monitoring system that is applicable to any local control system employing EPICS. Section 3 is devoted to the implementation of the general architecture to the KSTAR remote monitoring system. Discussions are made on technical details of the remote monitoring services, realizing the general concept described in Section 2. We conclude this paper in Section 4 with a brief summary and a conceptual plan toward the completion of the Grid-based KSTAR remote participation system.

## 2. A generic concept for a remote monitoring system based on Grid-EPCIS

In this section, we provide a brief description of the generic architecture for a Grid-based remote monitoring system (GRMS) when the local control system is based on Experimental Physics and Industrial Control System [16].

### 2.1. Software environment and security

We use the Globus toolkit [7], which has been developed by the Globus Alliance [8], as the major software tool for the development of Grid applications. Thus, the EPICS suite of control software and the Globus toolkit constitute two main middleware systems in the present work. In addition to EPICS and the Globus toolkit, use is made of the Java Channel Access (JCA), which is an EPICS channel access client library for Java [17]. As a main programming language, we employ the Java Development Kit (JDK) version higher than JDK1.4.1.

EPICS has been widely used in large facilities, especially in the accelerator community. It consists of a core and a set of extensions that provide a number of tools for creating a control system. In EPICS, every software component is connected through the channel access which provides network transparent access to input–output controller (IOC) databases [18]. Each control object is represented by a process variable (PV) over a network, the communication of which between distributed control systems is accomplished through the aforementioned EPICS channel access. PVs contain all the necessary information to be controlled by EPICS. Thus, the monitoring or control of an experiment in the EPICS-based control system is equivalent to the monitoring or control of PVs. We refer the readers to Ref. [18] for details of an EPICS control system.

The Globus toolkit provides services and software libraries which can be used to build Grid and Grid applications. It includes various software components such as security, information infrastructure, data management, resource management and communication [7]. The toolkit defines protocols and application programming interfaces (APIs) for each software component. In fact, the Globus toolkit is the outcome of implementing architectural principles of the Open Grid Service Architecture (OGSA) [19] which aims to define a common, standard, and open architecture for Grid and Grid applications. Practically, we used the core and the Grid security infrastructure (GSI) [20] components of the Globus toolkit 4.0 for the development of the GRMS in the present work.

One of the OGSA's requirements is that services should be stateful. Thus, Grid services are stateful Web services. Since the release of the Globus toolkit 4.0, the Web Service Resource Framework (WSRF) [21,22] has been used to make a service stateful. WSRF is a specification developed by the Organization for the Advancement of Structured Information Standards (OASIS) [23]. It specifies how one can make his/her Web service stateful. The implementation of security is of fundamental importance when developing Grid and Grid applications. Thus, security must be implemented in almost all the services constituting the GRMS for tokamak experiments. In the present work,