Fusion Engineering and Design 128 (2018) 86–89

Contents lists available at ScienceDirect

Fusion Engineering and Design

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

ITER Control System Model: A full-scale simulation platform for the CODAC infrastructure

Martynas Prokopas[a,b,*], Anders Wallander[a], Bertrand Bauvir[a], Jorge Sousa[b]

[a] ITER Organization, Route de Vinon-sur-Verdon, CS 90 046, St. Paul Lez Durance Cedex 13067, France
[b] IST-IPFN, Av. Rovisco Pais 1, Lisbon 1049-001, Portugal

ARTICLE INFO

Keywords:
ITER
CODAC
Control
Simulation
Testing
Integration
Validation

ABSTRACT

ITER Control System Model (ICM) is a simulation platform for CODAC that is currently being developed at ITER. CODAC is the conventional control system responsible for operating all plant systems from the 35 member states that are contributing to the ITER development. ICM is a full-scale implementation of CODAC that follows all ITER hardware and software conventions, but does not have any signal interfaces to other components of ITER nor any simulation of physical processes. Instead, it relies on state-based simulators that are used to verify CODAC operation at different stages of ITER execution. ICM currently consists of a single server cubicle that houses all hardware and software required to run a full-scale control system configuration without any dependencies on external servers. With its self-sustaining and isolated nature, ICM is capable of simulating the production stage of ITER. It provides an excellent test environment for various CODAC technologies and validating the interoperability of all the different plant systems across the infrastructure, which will contribute to minimizing the downtime of ITER due to avoidable errors. ICM is also being considered as a potential operator training facility.

1. Introduction

ITER is the upcoming world's largest tokamak fusion device [1]. It is the first device of its kind that is expected to produce a positive ten-fold return on energy input and demonstrate that nuclear fusion is a viable source for commercial electrical energy applications. A project of this scale poses many difficult scientific and engineering challenges, which requires a global collaboration currently consisting of 35 member states from all over the world.

CODAC is the conventional control system that is responsible for controlling all plant systems of ITER [2]. In order to manage an infrastructure that is simultaneously developed by so many different members, CODAC includes strict hardware and software standards that are specified in a publicly available Plant Control Design Handbook [3]. In addition, developers are required to use the CODAC Core System software suite for plant system integration [4]. Although CODAC includes clearly defined conventions, concerns were raised over control system scalability and an additional test platform was required to validate various CODAC technologies that will be used for operating the project.

ITER Control System Model (ICM) is a test platform that was proposed in order to address the scalability concerns of CODAC. The following principal goals have been identified that should be addressed by the platform:

- Validate CODAC control system scalability:
  CODAC is expected to be composed of many different functional control groups, each consisting of hundreds of computers operating with millions of process variables simultaneously. A separate full-scale testing environment is required in order to assure interoperability of all the different components across the infrastructure.

- Provide an isolated test environment to minimize ITER downtime during commissioning and operation:
  ITER project is one of the most ambitious and expensive scientific projects on the planet. Once it goes into full operation, it cannot afford to have any downtime due to avoidable errors. In order to avoid this, all systems need to undergo rigorous testing procedures before they are integrated into the project.

- Provide state-based simulators for testing CODAC technologies and individual plant system modules:
  A state-based architecture without any physical process simulation is chosen in order to test the operation of CODAC and individual plant system modules. This architecture allows running large-scale

---

[*] Corresponding author at: ITER Organization, Route de Vinon-sur-Verdon, CS 90 046, St. Paul Lez Durance Cedex 13067, France.
E-mail address: Martynas.Prokopas@iter.org (M. Prokopas).

https://doi.org/10.1016/j.fusengdes.2018.01.060
Received 7 June 2017; Received in revised form 23 January 2018; Accepted 24 January 2018

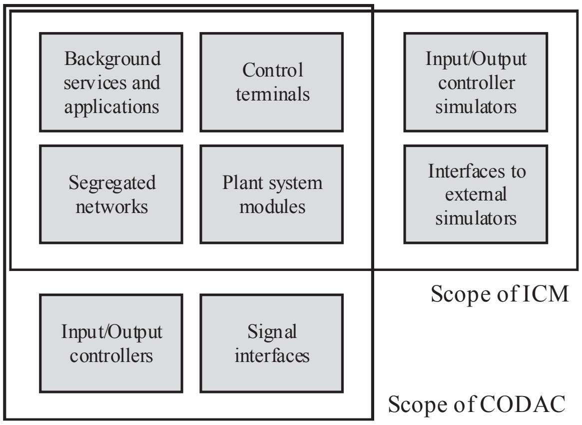

Fig. 1. Scope of ICM with respect to CODAC. ICM mimics the infrastructure of CODAC, but simulates signal interfaces to other physical components of ITER.

simulations and validating operation of the control system with relatively modest hardware resources. However, the platform will also include high-performance computers and physical networks in order to simulate real-world performance. Interfaces to external real-time process simulators should also be considered.

- Provide an operator training environment:
  Since the test platform is intended to closely mirror all CODAC technologies with the same conventions and human interfaces, it is also being considered as a potential operator training facility.

2. Implementation

The following architecture of ICM has been proposed in order to accomplish the goals regarding the scalability concerns of CODAC (Fig. 1). ICM is being developed with the same central servers, applications and naming conventions [5] as CODAC, but it does not have any signal interfaces to other components of ITER. Instead, interfaces are replaced with controller simulators on the platform itself, but the platform may also include interfaces to external simulators in order to provide a more powerful testing environment.

2.1. Hardware

All physical components of ICM are currently contained within a single server cubicle in one of the ITER server rooms. Unlike other cubicles in the server room, ICM needs to be completely self-sustaining without any reliance on external interfaces (except for power).

Network is provided by 4 dedicated switches for simulating different networks across the CODAC infrastructure. These are PON (conventional network), TCN (time synchronization) [6], DAN (archiving) [7] and SDN (real-time feedback) [8]. TCN switch is also accompanied by a grandmaster clock (synchronized to GPS) in order to provide a time reference for all components in ICM. All servers are interconnected using standard physical connections in order to simulate real-world performance. Note that CODAC configuration also has interfaces to interlock and safety systems [9] (implemented separately from CODAC), but in ICM these are replaced by simple process variable simulators in order to provide an isolated environment.

CODAC servers are running on two dedicated virtualization servers (hypervisors) managed by Red Hat Virtualization [10], which simulate various different servers across the CODAC infrastructure (~100 simultaneously running servers have been tested). These include bespoke CODAC servers such as archiving, alarm, gateway and consoles and background support servers (see 2.2) in order to provide a completely self-sustaining environment. In addition to virtual servers, 2 PICMG 1.3 [11] casings with 8 high-performance computers are included as well in order to test demanding applications that take advantage of DAN and SDN networks.

For development reasons, ICM still contains a single interface for external access, but it is made to be completely self-sustaining, and this interface may be removed at any time in order to simulate an isolated nuclear perimeter. In addition, the platform is being designed to be completely expendable. Additional virtualization servers and high-performance computers may be added for extra performance and the platform may even be extended to multiple cubicles if required. As mentioned previously, some isolated interfaces to external simulators may be incorporated in the future, but no such extensions have been implemented at the time of writing.

2.2. Software

The base operating system for servers across the infrastructure (both for ICM and CODAC) is Red Hat Enterprise Linux [12]. All servers across the infrastructure come with the same base Red Hat operating system (with different resource allocations), with an exception of high-performance computers that are running on Red Hat MRG replacement kernel for real-time applications [13]. CODAC central servers and plant system modules are based on EPICS [14], which provides a framework for fundamental control system functionality including communication, archiving, alarms, Human-Machine Interface (HMI) and many others.

Servers used for managing the infrastructure contain a limited number of commercial solutions as well. Some of these include Red Hat Satellite [15] for software provisioning, LDAP and NFS services for user management and access control, SubVersion for software repository (all from Red Hat channels), SOLIDserver [16] for address management and Splunk [17] for archiving and monitoring. Ansible [18] is currently being investigated as well as a tool for automatic server configuration.

All these open-source and commercial applications in combination with the hardware detailed in the previous section provide a completely self-sustaining environment without any dependencies from external servers. This configuration can be used to test and validate various CODAC technologies and individual plant system modules prior to integration.

3. Use cases

Although ICM is still under development and plasma stage of ITER is still a few years into the future, it is already heavily involved in testing of various CODAC technologies. This section will summarize some of the key examples of how ICM is currently being used to advance the overall control system development.

3.1. Automatization of server deployment

The production stage of ITER is expected to contain hundreds of servers running simultaneously. Configuring such a large number of servers manually would be completely impractical and thus an automatic configuration procedure is required in order to manage the infrastructure. ICM can currently run a few hundred virtual servers (depending on hardware requirements) and is being investigated for large-scale server configuration.

The deployment of servers consists of the following steps: first, the CODAC and plant system developers upload their software modules to the central CODAC repository. These modules are developed using the SDD (Self-Description Data) toolkit, which contains various editors, libraries and automatically-imposed naming conventions to facilitate the plant system module development [4] and is synchronized directly with the CODAC software repository. After the modules are uploaded, they need to be converted into functional servers fulfilling different roles across the infrastructure. A deployment procedure summarizes all steps that are required to convert these software modules from the central repository into operational servers.