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Machine Control System of Steady State Superconducting Tokamak-1

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ABSTRACT

Central Control System (CCS) of the Steady State Superconducting Tokamak-1 (SST-1) controls and monitors around 25 plant and experiment subsystems of SST-1 located remotely from the Central-Control room. Machine Control System (MCS) is a supervisory system that sits on the top of the CCS hierarchy and implements the CCS state diagram. MCS ensures the software interlock between the SST-1 subsystems with the CCS, any subsystem communication failure or its local error does not prohibit the execution of the MCS and in-turn the CCS operation. MCS also periodically monitors the subsystem's status and their vital process parameters throughout the campaign. It also provides the platform for the Central Control operator to visualize and exchange remotely the operational and experimental configuration parameters with the sub-systems. MCS remains operational 24 × 7 from the commencement to the termination of the SST-1 campaign. The developed MCS has performed robustly and flawlessly during all the last campaigns of SST-1 carried out so far. This paper will describe various aspects of the development of MCS.

1. Introduction

Steady State Superconducting Tokamak, (SST-1) at Institute for Plasma Research (IPR) has been designed for a long pulse steady state operation and was commissioned successfully in mid-2013 [1–3]. The Central Control System (CCS) of SST-1 is inherently designed as a distributed and a hierarchical control system, it includes several subsystems that provides various functions of supervision, real-time monitoring and control, data acquisition, time synchronization, data handling and analysis etc [4,5]. CCS controls and monitors around 25 plant and experiment subsystems of SST-1 located remotely from the Central-Control room. Usually any physical system like CCS, that comprising of handling several sub-systems can be modeled through a state diagram. In CCS, a state diagram was also devised so that to make the SST-1 subsystems ready for the operation and subsequently executes the experiments. Machine Control System (MCS) is a supervisory system that sits on the top of the CCS hierarchy and implements the CCS state diagram.

The core of SST-1 control system MCS, which is the heterogeneous process communication software. It is the hinge of the whole control system, with the responsibility for controlling and harmonizing the complete system, and sends the control commands to the subsystems. Hence the major part of development is done at the MCS front.

The SST-1 Central Control System is a distributed and heterogeneous system, based on network programming. The Server locations, data marshalling and network boundaries have been taken care by MCS. CCS is essentially designed as a modular, flexible and a scalable system. Any subsystem communication failure or its local error does not prohibit the execution of the MCS and in-turn the CCS operation. MCS ensures the software interlock between the subsystems and the CCS and also periodically monitors the subsystem's status and their vital process parameters, before, during, and between the experiments. It also provides the platform for the Central Control operator to visualize and exchange operational

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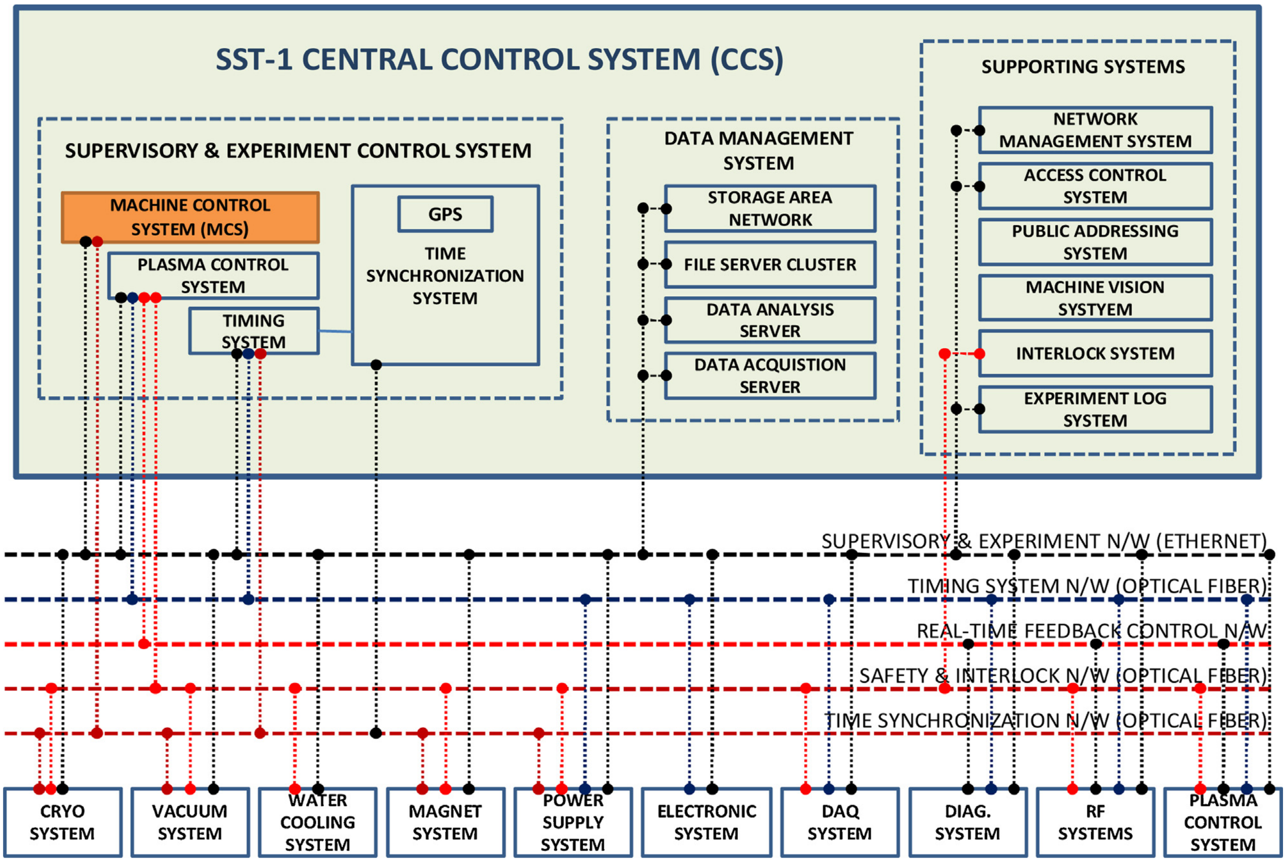

Fig. 1. SST-1 Central Control System its components and communication network diagram.

and experimental configuration parameters with the sub-systems. MCS remains operational 24 × 7 from the commencement to the termination of the SST-1 campaign.

2. Objectives of MCS

The one of the main objective of MCS for its design was to take care of proper sequencing of various subsystems of SST-1 from session commencement to readiness of the machine i.e., implementing the SST-1 state machine devised for the operation of SST-1. Apart from that, remote control and remote continuous monitoring, for 24 h a day and night, of subsystem parameters and status were also required. It should able to detect any anomalous condition arising with the subsystems status and alert the experiment operator of such situations. Also to preset or configure the control parameters of various subsystem like power-supply parameters of Toriadal Field Magnets, Ohmic Coils etc. In addition to that it should provide an easy to use graphical interface for the experiment operator. The architecture of MCS should allow to expand it easily in case of an induction of a new subsystem in SST-1. MCS will also be used to exchange and transfer data/messages between the interfaced systems operators using experiment network and also will log them for future reference. MCS should also acquire the experiment and plant supervisory data.

3. Architecture, design and development

3.1. Architecture

The basic unit of MCS is the server computer and all the subsystems are prioritized for the logic position, each subsystem completes the process with its control task. Using this structure, a complicated task is divided into many subtasks, which are parallel running process, and are controlled independently.

During operations, the data in the MCS is monitored in the control room. User monitoring of data and automated monitoring of real-time data via the control computer is also provided. These considerations clearly dictated a multi-tasking environment.

Linux is used as the Operating System which possesses the standard IPC resources such as signals, pipes, etc. and communications on the network is based on Socket APIs. C as the basic programming language is used for the applications with front-end graphics using Tcl/Tk. MCS is a group of scalable, modular, fail safe and multithreaded applications with mutual collaboration.

3.2. Design and development

The control system of SST-1 Tokamak (Fig. 1) is composed of separated local subsystems communicating each other on various SST-1 communication networks. MCS of the control system is designed as 2-tier (Client-Server) architecture that communicates with local subsystems over Ethernet. Following are the rules considered for the design of MCS: (1) Fault free data transfer. (2) A robust protocol over network to handle all possible communications. (3) Reliable and safe operation over months of time. (4) Modular and easily extensible.

Communication between the heterogeneous entities of a distributed system and the Machine Control System plays a crucial role here. There are different approaches used here to communications abstracting in the heterogeneous distributed system. MCS is based on the approach in which all the underlying low level methods are written and all the anomalies have been taken care off. It requires being concerned with many details of interaction between com-