CONF-870552--3

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THE ATF STATUS AND CONTROL SYSTEM*

CONF-870552--3

DE87 009664

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Abstract: The Advanced Toroidal Facility (ATF) Status and Control System (SCS) is a programmable controller-based state monitoring and supervisory control system. This paper describes the SCS implementation and its use of a host computer to run a commercially available software package that provides color graphic interactive displays, alarm logging, and archiving of state data.

1. Introduction

The ATF is a plasma confinement experiment at Oak Ridge National Laboratory (ORNL) scheduled to begin operation in mid-1987. The ATF is a stellarator device ($\ell = 2$ torsatron configuration) used to study a number of general toroidal plasma confinement issues, including high-beta plasmas, impurity behavior, and steady-state plasma operation [1].

The ATF has replaced the Impurity Study Experiment (ISX-B) tokamak at ORNL and uses the facility and diagnostic subsystems from ISX-B. These subsystems include power supplies (up to 125 kA at 1000 V), vacuum system, rf and neutral beam heating systems, cooling water, and personnel protection. All of these subsystems require protective interlocks and careful monitoring of their operation. In order to effectively operate ATF and its facility systems, a carefully designed SCS has been developed that monitors the state of all controlled devices, provides personnel safety and equipment protection interlocks, and provides supervisory control capabilities. The SCS, in conjunction with the ATF data acquisition system [2], makes up the operator and user interfaces to the ATF experiment. All time-critical processes that need high-speed control are handled by specialized controllers.

The ATF poses a number of problems associated with the design of the SCS. Since ATF is an experimental facility, there is a strong need for the SCS to be flexible in response to changes in equipment and operations. Also, the ATF is a source of strong magnetic fields and electromagnetic interference, so the SCS must work reliably in this environment. The reliability of the SCS is a major concern, since lost operating time will have an impact on the research program. The cost of the SCS, for both installation and operation, must be minimized so that limited resources can be reserved for experimentation rather than for providing a utility such as a control system.

*Research sponsored by the Office of Fusion Energy, under Contract No. DE-AC05-84OR21400 with Martin Marietta Energy Systems, Inc.

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2. System Configuration

The ATF SCS hardware configuration is shown in Fig. 1. The SCS is based on commercially available Gould Modicon 584A programmable logic controllers (PLCs) [3]. PLCs were selected for the SCS based on their ability to meet the control requirements of the various systems. In particular, the reliability, ease of programming, and working environment of PLCs were found to be better suited to ATF than any other control scheme. The choice of Modicon PLCs was motivated primarily by availability and experience.

The SCS uses four PLCs; each performs different functions. A typical installation of one PLC is shown in Fig. 2. Most of the I/O for the PLCs is located in the machine enclosure as close to the field devices as practical. These remotely located I/O channels are connected to the PLC processor with a single coaxial cable. This arrangement reduces the amount of field wiring needed and therefore lowers the installation cost. All I/O connections are isolated within the I/O modules, and the ac power for the I/O channels and processor comes from an isolation transformer and is filtered. The ground for each PLC system, including its remote I/O, is run to a single point on the ATF ground bus to minimize potential ground loops.

The VAXcluster served as a design tool in the design of all wiring required for the SCS PLCs. The wiring information for each PLC was generated from a System 1032 [4] database built and maintained on the VAXcluster. Procedures written in 1032's query language generated formatted output that resembles wiring drawings. This was used by electricians for the actual wiring hookup.

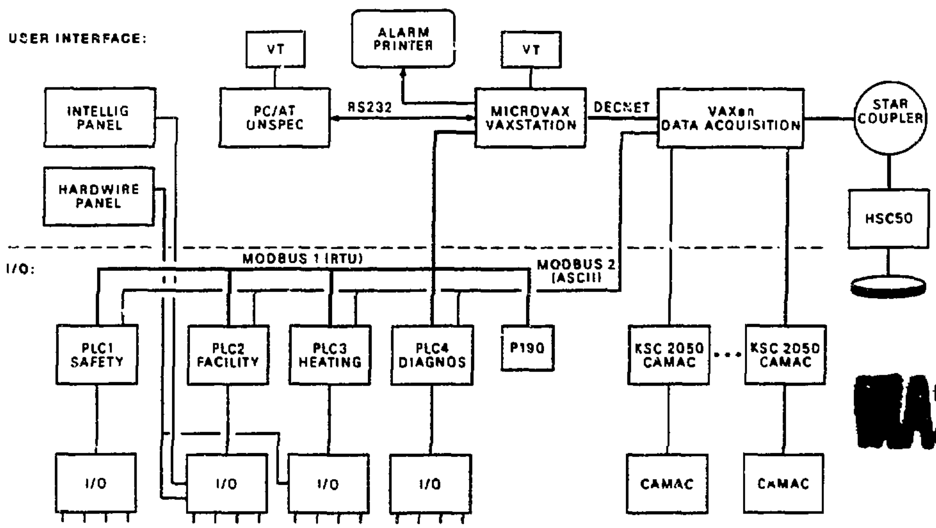

Fig. 1. ATF SCS configuration.

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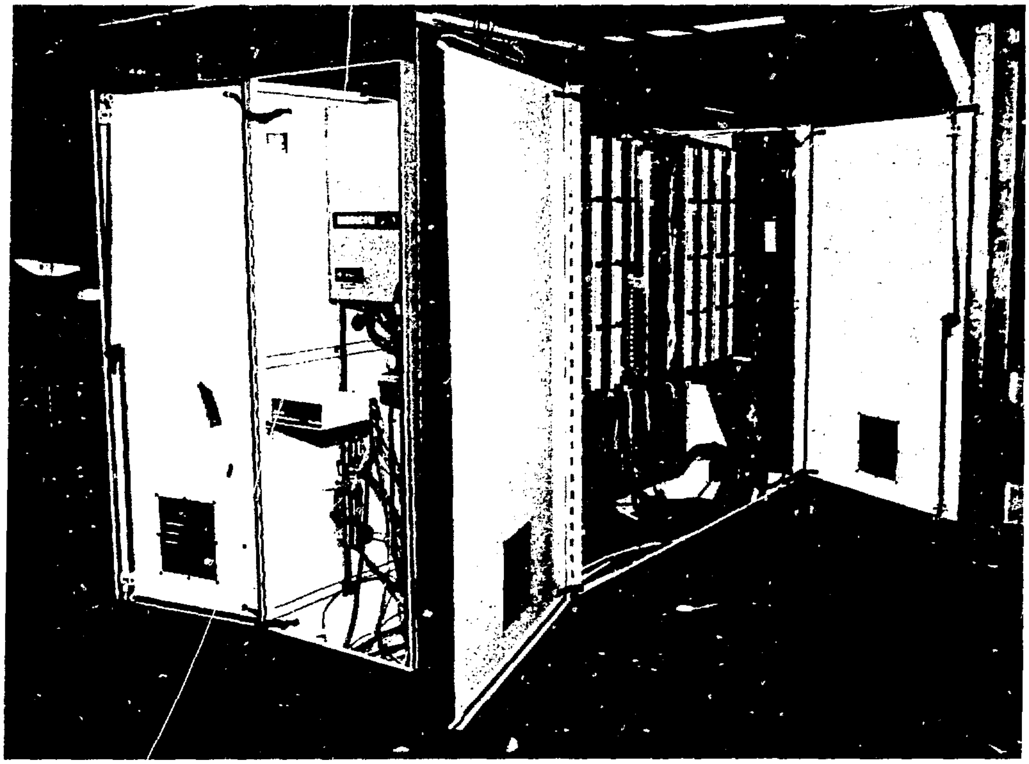

Fig. 2. Typical SCS PLC installation.

The four PLCs used in the ATF SCS are designated PLC 1 (safety interlock PLC), PLC 2 (facility PLC), PLC 3 (plasma heating PLC), and PLC 4 (diagnostic systems PLC). The safety interlock PLC (PLC 1) is used strictly to monitor safety-related systems and provide safety interlocks. The control of the ATF vacuum system is split between the facility PLC (PLC 2) and the plasma heating PLC (PLC 3) to provide a level of redundancy. PLC 2 is also used to control the cooling water, power supply, and discharge cleaning systems. PLC 3 monitors the electron cyclotron heating (ECH), rf, and other plasma heating–related systems. The diagnostic systems PLC controls and monitors individual diagnostic systems on ATF.

Each Modicon 584 PLC has two MODBUS ports, which are serial (RS-232) interfaces to the PLC processor. The MODBUS ports can be configured for one of two protocols known as ASCII and RTU. The PLCs are programmed through a P190 programming terminal that is connected to one of the MODBUS ports configured for RTU communications. The other MODBUS port, configured for ASCII, is interfaced to a VAX host computer running a software package from Modicon for PLC program documentation and verification. In addition, connections to the RTU MODBUS port are distributed throughout the facility. This allows the use of a P190 programming terminal in the field to troubleshoot equipment problems.

The PLCs in the SCS are also interfaced via MODBUS (RTU protocol) to a MicroVAX computer running a commercially available software package called ONSPEC [5]. This package provides color graphic interactive displays for monitoring and operating the system, alarm logging, and archiving of state data. The MODBUS port on the PLC is the slave in the MODBUS communications master-slave protocol; therefore, all of the PLCs are tied in parallel to the MicroVAX and communicate one at a time. The actual MODBUS connection is through RS-485 to RS-232 convertors that allow multiple drops from a dual twisted pair cable. The ONSPEC package has a driver for MODBUS RTU communications to the Modicon PLCs and uses IBM Personal Computers (PCs) as graphic display terminals. The PCs run a terminal emulation program, log into the MicroVAX, and run a program on the MicroVAX that attaches to the ONSPEC real-time database and displays current data on the PC's monitor. Up to 96 screens can be created and used by any of the PCs logged into the MicroVAX. A serial printer on the MicroVAX logs any alarm messages generated by ONSPEC from alarm conditions in the PLCs. A functional diagram of the ONSPEC system is shown in Fig. 3.

3. System Operation

A set of operator control panels and the supervisory ONSPEC system are the two primary operator interfaces to the SCS. The control panel system consists of hardwired panels that interface directly to the PLC I/O modules and intelligent panels. The intelligent panels house programmable backlit push buttons whose inputs and outputs to the PLC are multiplexed and connected to a PLC ASCII port with an RS-232 serial line. These panels reduce the cost of wiring and allow future changes to be made in software rather than in wiring. The panel system is being used for initial operation of ATF and may eventually serve as a backup should the supervisory system be off-line.

The supervisory ONSPEC system displays on the PC monitors allow the operators to monitor and control all of the facility systems interfaced to the SCS, such as the vacuum, power supply, plasma heating, cooling water, and diagnostic systems. Individual diagnostic subsystems can use the SCS for control of their systems and may have their own supervisory ONSPEC displays. The alarm logging feature of ONSPEC is used by the

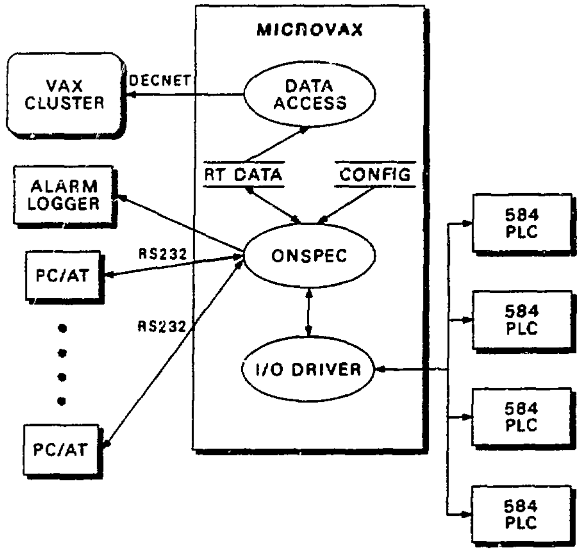

Fig. 3. ONSPEC functional diagram.

operators to maintain a log of events for reconstruction of any problems that occur.

The Modicon PLC documentor software package is used for PLC program documentation and provides annotated program listings. This system also allows the host VAX computer to upload and download a copy of the PLC program. The rung and variable comments for the documentation are kept in a text file, which can be easily modified as the PLC program changes. Periodic uploads and comparisons of the PLC programs are made to ensure program integrity. Documented PLC program listings, which are generated from the comment file and uploaded PLC program, are kept online on the VAXcluster for easy reference.

4. Integration to Data Acquisition System

The SCS is integrated with the VAX-based ATF data acquisition and management system through the MicroVAX running ONSPEC. As shown in Fig. 1, the MicroVAX has an ETHERnet connection to the VAXcluster computers that are used for data acquisition and analysis. The ONSPEC software running on the MicroVAX uses an installed shareable image to hold the real-time database. Access mechanisms to the database are provided for locally developed applications. One such application periodically dumps data from ONSPEC to a disk file that is copied to the VAXcluster for archiving with the experimental data. Another application being developed will make state data from the SCS PLCs available throughout the ATF data system VAXcluster via DECnet interprocess communications from the MicroVAX running ONSPEC. This will allow users on any ATF VAX to see the current state of any points in the ONSPEC real-time database.

5. Conclusions

The ATF SCS provides the experimental facility with a flexible, programmable state control system at relatively low cost. Despite budgetary constraints and manpower limits, a highly functional system has been implemented. The capability to add additional display terminals and modify the logic and I/O capabilities of the system at any time makes the SCS very effective for the ATF experimental environment. The use of computers in the design, operation, and maintenance of the SCS has proven to be an example of how useful computers can be in the control of large-scale fusion experiments.

6. Acknowledgments

The authors wish to acknowledge the contributions of W. R. Wing, R. D. Foskett, P. H. Edmonds, and others in the ATF SCS development.

Reference to a company or product name herein does not imply approval or recommendation of the product by ORNL, Martin Marietta Energy Systems, Inc., or the U.S. DOE to the exclusion of others that may be suitable.

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