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Tokamak machine monitoring and control system for JT-60

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Abstract

The tokamak machine monitoring and control system has been developed to avoid machine damages in JT-60 safety operation. It monitors the JT-60 mechanical structures and other sub-components to maintain their conditions. The system adopts the CAMAC digitizers, the Signal Transfer Unit (STU), and the hard-wired interlocks. Over 20 year, it has never been affected by any major troubles except a water leakage in toroidal field coil (TFC). The TFC monitoring system has been developed for the TFC safety with the water leakage from a cooling water channel. It has improved the reliability and efficiency of the TFC operation.
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Keywords: JT-60; CAMAC; PIO; Water leakage; Toroidal field coil (TFC)

1. Function of tokamak machine monitoring and control system

A tokamak machine monitoring and control system for JT-60 safety operation has been developed [1]. The system is consist of the CAMAC, the hard-wired and the Signal Transfer Unit (STU). It is monitoring the conditions of the JT-60 main structures, the components and the local equipments. For instance, the condition is monitoring the displacement of the support structures, the pressure of the vacuum vessel (VV) and the displacement of the toroidal field coil (TFC) and the poloidal field coil (PFC). If the system detects the abnormal values, the coil excitation and neutral beam injection (NBI)/radio frequency (RF) heating systems are stopped, and gas puff is shut off and then the JT-60 operational sequence is cancelled or aborted [2,3]. The system is also monitoring the temperature, the pressure, the flow rate of cooling water of the TFC and the PFC, the amount of the water in the tank and the status of the cooling water pumps. If the conditions for JT-60 operation are satisfied, the operational sequence can start. On the other hand, if the conditions are not satisfied before the TFC excitation, the operational sequence is cancelled. When trouble erupts about a pump in the cooling water system, the spare pump is started to operate as backup. So, the cooling water system for TFC has the protective function. The other spare pump works as the emergency backup in the case of electricity failure, and provides enough water flow to the coils. The baking system controls electrical heaters and temperature of gas. When the temperature of VV increase or decrease from the target temperature (max 300 °C or room temperature), the temperature difference between several sections of the VV is controlled within 80 °C to avoid strong thermal stress at the local positions. In steady state, the temperature difference is also locally controlled within 80 °C.

2. Composition of the monitoring and control system

The tokamak machine monitoring and control system consist of the CAMAC [2], the hard-wired and the STU systems. The equipments are monitored by the system. The several components are controlled by the hard-wired system. The important analog data are monitored by STU.

2.1. CAMAC system

The almost equipments are monitored by the CAMAC system with microcomputers. The CAMAC system transmits the many data using CAMAC standards serial-highway. The data are standardized in transmitting and receiving data formats. The system is built to be a hierarchical system by the CAMAC modules for digital optical transmission and external IO in local equipments. Fig. 1 shows the schematic diagram of the CAMAC system for the cooling water system, the baking system and the

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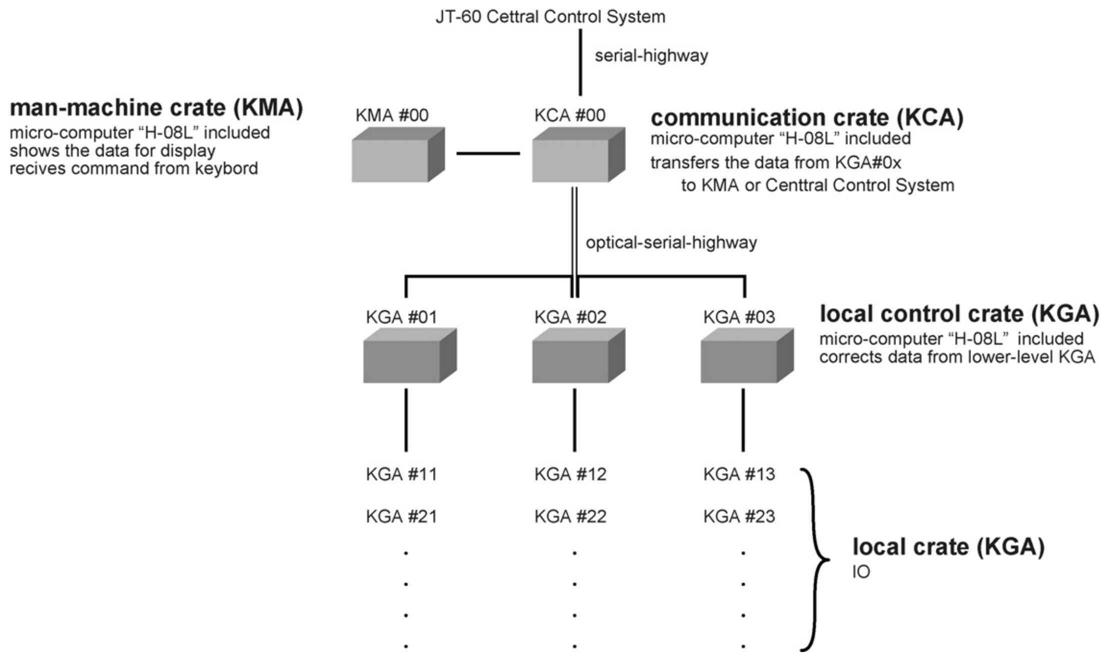

Fig. 1. Schematic diagram of the CAMAC system for JT-60.

exhaust system etc. The communication crate (KCA) is main crate connected via the serial-highway to the JT-60 central control system and the man-machine crate (KMA), and the local control crates (KGA) via the optical-fibered serial-highway. The optical-fibered serial-highway is used for isolation of noise reduce of EM and potential difference between two buildings, and it extend the serial-highway up to 1 km. The KCA, the KMA and the KGA have a microcomputer. Through the IO modules, operators have a good grasp of the several current information of plants with the KMA. The KGA corrects and checks the data from lower level KGA IOs and send the reconstituted data to KCA. The KCA transfers the reconstituted data to the central control system and the displayed data to KMA by operator's request.

The various and massive data are acquired by the CAMAC system. Most data are checked whether it is normal or not. There were about 1600 chromel–alumel thermocouples for baking of VV, about 200 stress sensors for main structures and about 1700 digital inputs for apparatus in 1985. The operating methods were modified on the basis of the operating experience when JT-60 modified to be JT-60U in 1991 [4]. At present, number of input data reduced to be about 570 analog inputs and about 900 digital inputs. The multiplexers of commercial CAMAC module do not have an extrinsic noise filtering. However, it is necessary to cut off extrinsic noises that are produced in the Torus hall. The PIOs are used for input data of many thermocouples in the tokamak instrumentation and the baking system since those have filtering function. These PIOs are directly connected to the memory-bus of Auxiliary Controller with Micro Computer (ACM) through the interface module (IPIO) and directly controlled by the application program of the ACM. Table 1 shows summary of the data acquisition module for the plant data. The monitoring data of the JT-60 main structures and the components are collected by the PIOs with noise cut function. Then the monitoring data of local equipments like auxiliary machinery are collected by the MPX + ADC.

2.2. Hard-wired system

The damage of tokamak machine is avoided by the interlock of a hard-wired system. The hard-wired system controls the equipments that the higher reliability is needed. In order to prevent a wrong operation, the graphic panels are set in the each equipment. The system controls flow rate, gas pressure and water by the set point. In order to restart JT-60 operation quickly and avoid the equipment breakdown, the system has interlock not to receive the influence of other equipment abnormal conditions. It has interlock for the local equipments to stop the equipment safely when the equipment fails as loss of power or failure of circuit.

Table 1
Summary of the data acquisition module

Signal type	Name	Number of channels	Scan rate	Noise cut function
Analog input	PIO (H-7600)	256ch	5000 points/s	Installed
	MPX + ADC (CAMAC)	15ch	2 ms (change over time)	None
Digital input	DI (CAMAC)	24ch	100 ms	–

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