ELECTRON CYCLOTRON RESONANCE HEATING (ECRH) CONTROL SYSTEM

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Abstract

The ECRH Control System was installed on the Tandem Mirror Experiment-Upgrade (TMX-U) in 1980. The system provides approximately 1 MW of 28 GHz microwave power to the TMX-U plasma. The subsystems of ECRH that must be controlled include high-voltage charging supplies, series pass tubes, and magnet supplies. In addition to the devices that must be controlled, many interlocks must be continuously monitored. The previous control system used relay logic and analog controls to operate the system. This approach has many drawbacks such as lack of system flexibility and maintainability. In order to address these problems, it was decided to go with a CAMAC and Modicon based system that uses a Hewlett-Packard 9836C personal computer to replace the previous analog controls.

This paper will describe the advantages, disadvantages, and the day-to-day operations of this new computer-based control and data acquisition system.

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Introduction

The TMX-U ECRH System consists of four parts that must be controlled simultaneously in order for the system to function effectively. These four parts are magnet supplies, the series pass tube, the capacitor bank charging supply, and the gyrotron anode modulator. These control functions are accomplished through a computer driven CAMAC (IEEE-583) serial highway system. The computer used to drive the CAMAC system is a Hewlett-Packard Model 9836C color computer. In addition to the many control and diagnostic functions performed by the 9836C, many system interlocks must be continuously monitored and their status acted upon. A block diagram of the control system is shown in Figure 1.

CAMAC System

The ECRH control system makes extensive use of a fiber optic serial highway. The serial highway is tailor-made for the ECRH control system since the various system components are not all located in the same area around TMX-U. The CAMAC crates also provide a convenient place to "Plug-In" custom-designed modules that must be used to control system components. This allows the control system designer to design various controls without worrying about power supplies and connection to the control computer.

Each gyrotron in the system has six focus magnets and supplies that must be tuned for optimum gyrotron performance. A block diagram of the magnet supply control is shown in Fig. 2.

The initial magnet supply reference is set by the digital to analog converter; this reference voltage is then converted into a 4-20 mA current which programs the supplies. All supply regulation is done internally. The actual supply voltages and currents are then scaled and fed into an analog to digital converter where they can be read by the computer.

Control of the series pass regulator tube is accomplished by using digital to analog converters, programmable timing pulse generators and an in-house built module that sends a fiber optic signal to the grid control of the series-pass tube. The modulator control module integrates the signals from the pulse generators and the D/A to create a light signal that is output to the pass tube grid control board. The modulator control module also has internal fault detection to prevent such things as tube run-on, over-current, and over-voltage.

The gyrotron anode controls make extensive use of fiber optic light links. The actual waveform used to program the gyrotron anode is produced by a LeCroy Model 8601 Quad-Programmable function generator.

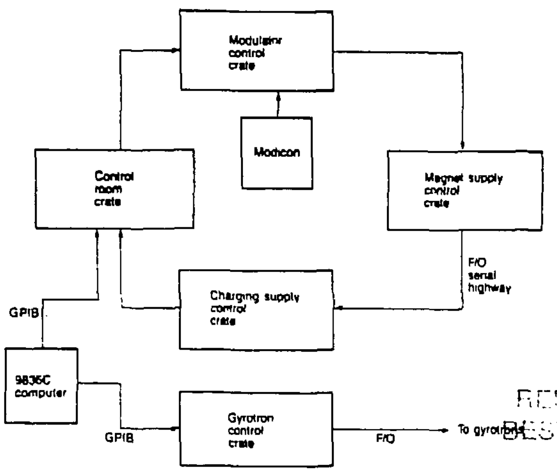

Figure 1. Computer Control System Block Diagram.

Through the use of this function generator, the operator can program any shape waveform imaginable. This waveform is then sent via fiber optic to the gyrotron anode modulation control board which in turn modulates the RF output of the gyrotron. Gyrotron RF parameters such as forward and reflected powers are then recorded by LeCroy Model 8212 Waveform Digitizers where they can be read by the control computer and viewed by the system operator.

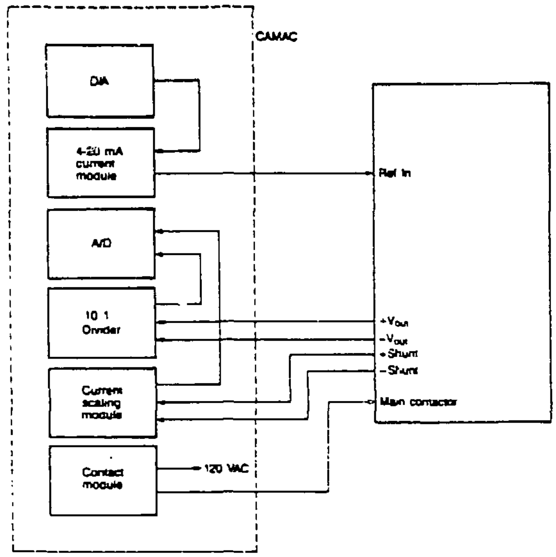

Figure 2. Magnet Supply Control Block Diagram.

Control Computer

The computer used by the ECRH control system is a Hewlett-Packard Model 9836C Color Computer. The computer comes with two internal floppy disc drives and approximately 1.5 M bytes of internal ram. The 9836C lends itself very well to control applications because of the soft keys, knob, up-down arrows, color graphics and the fact that it can be programmed in BASIC.

The soft keys, knob and up-down arrows allow the operator to quickly select the operation to be performed without having to remember a lot of "code" words. This is because the function of each key is automatically displayed on the computer screen.

The color graphics when used effectively can make it very easy for the operator to check the status of different parts of the system without having to search the screen. Abnormal system operation can be called to the attention of the operator almost immediately if the programmer chooses his colors effectively.

The entire ECRH control program is written in the BASIC computer language. The main advantage of being able to program in BASIC is that almost anyone with a minimum amount of training can maintain and update the control program. This allows everyone to become a "system expert" thus avoiding the "lone system expert syndrome" that can be disastrous to a system if the expert does not happen to be around when there is a problem.

Modicon Micro 84

The ECRH control system uses Gould Micro 84 Modicon units to look at the many system interlocks. These interlocks include such things as water flows, water pressures, and switch closures. The previous control system used extensive relay logic to accomplish this task. The modicons perform all relay logic tasks and continuously monitor the status of each interlock. The modicons also interface to the CAMAC system so that the status of each interlock can be viewed by the system operator.

Conclusion

The main advantage the new CAMAC-based control system has over the previous analog controls is the flexibility it provides. The modular design makes the system easy to maintain on a day-to-day basis and also makes the system easy to expand and upgrade. The computer also makes it easy to log operational problems and the measures taken to correct the problems. The only real disadvantage the new control system has is that the BASIC language control program requires a significant amount of computer memory.