CONTROL SYSTEM FOR THE EXPERIMENT PREPARATION OF THE THERMONUCLEAR FUSION DEVICE

V.I.Zaitsev, V.V.Bulan, V.M.Chikovsky,
Troitsk Institute for Innovation and Fusion Research
TRINITI, Troitsk, 142092, Moscow region Russia

Abstract

The architecture of thermonuclear fusion device Angara-5 control system was described in [1]. In present paper the description of the control system for shot preparation of Angara-5 is given. This stage of working cycle precedes the experiment and includes a lot of control and monitoring operations. The control system hardware consists of the CAMAC blocks (ADC, multiplexers, I/O blocks, PC-connected controllers) and IBM PC. The design of the control system permits us to maintain the self-testing operations. The main part of the software is the polling program that gives the possibility to fulfill the preparation of the gas pressure means and starting the procedure of capacitor bank charging. The program users are technical personnel and the program has reporting and archiving capabilities. Special tools for the supervision of preparation process in the real time are designed. There are some instruments for the system test and maintenance also. The hardware and software charts of control system are given.

1 INTRODUCTION

The devices of Angara-5 type are named pulsed power technology. The areas of such device's applications are inertial confined fusion [3], production of high current electron and ion beams [4], and intensive x-ray flows generation [5]. The seldom repetition working cycles (shots) is the operational feature of high power devices. The output parameters of the installation are produced by means of a very high power voltage generator (voltage~MV, current~MA). The duration of energy delivery process is about $10^{-6} \div 10^{-7}$ sec, but the preparation takes some hours. The main part of the procedure is the preparation of the object under investigation and appropriate measurements. Nevertheless, there are the stages of the preparing and testing of the technological parameters. This last includes:

-Tests of the insulator quality (resistance of the deionized water);
-Control of vacuum volumes pumping out;
-Control of pressure in the gas switches;
-Control of capacitance's charging.

This procedures are carried out by means the system of technological device preparation to experiment.

When all technological parameters correspond to experiment requirements and all control operations have been carried out the command for the shot is given.

2 THE SYSTEM HARDWARE

The main part of device preparation is control of the gas pressures in the switches. As the time between shots is not defined and can equal several hours, the duration of this operation is undefined too. Therefore it is possible to use CAMAC hardware for this operation. The gas parameters in the switches determine the synchronization of the pulse generation. Angara-5 device contains several hundred gas switches of different kinds. Two sorts of gases are used (N_2 and SF_6). The preparation system provides measurements of gas pressure in 256 volumes and controls gas pressure in the 128 volumes. Value of gas pressure has been changed by means of the two valve's operation (at input and at the output of the switch volume) that are connected with gas distribution system . The fragment of gas the control system for two directions is shown on the fig.1.

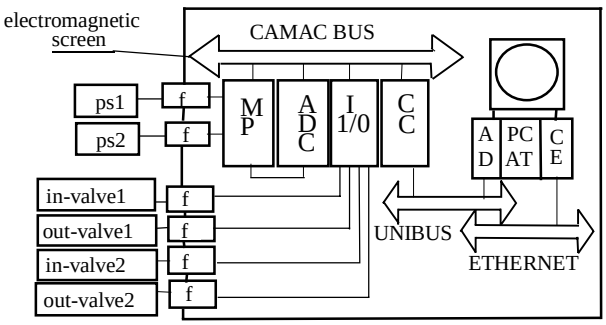

Figure 1. Fragment of hardware control system: MP-multiplexer; ADC-analog-to-digital converter; I-register; AD, CE-adapters; ps-pressure sensors; f-filters.

The signals of all pressure sensors get to IBM PC through CAMAC blocs (multiplexers, analog-to-digital converters). These signals are compared with intended pressure values. In accordance with the real pressures at the input and at the output of the volume to the desired value the signal for opening of input or output

valve is produced. At the same time the other technological parameters are being measured. When all parameters are OK and measurement systems are ready the command to charge capacitance banks is given. The duration of the charge procedure is several minutes. When the charging is finished the command to shot follows.

The hardware includes some equipment (generators, precise voltmeter, and multiplexers) for checking of system measuring circuits.

As the devices of ANGARA-5 types produce high electromagnetic noise level some remedies for electromagnetic compatibility had been provided. As example, the control room is screened with steel walls, CAMAC is connected with device equipment (sensors, valves) through high frequency filters.

3 THE SYSTEM SOFTWARE

The system software has several components:

-The programs for the circuit tests;

-The programs for the measuring and multiplexing device tests;

-The editors for the pressure and voltage settings;

-The measuring devices polling program; this program can change the operation mode (control/measurement), save and/or print reports and so on;

-The programs for the converting of the binary reports on the charge processes to the ASCII format. The system operates under MSDOS operating system. The requirements to hardware are not excessive: the PC with 286 Intel processor in use now.

The main part of the system is the program for the polling of the measuring devices and for the control of the pressures. The program consists of the several modules:

- The polling and control module;
- The hardware I/O module;
- The command interface module (keyboard input processing);
- The report saving;
- The report output to the screen and to the printer;
- The communication module for printing reports to additional terminal (through RS232).

The polling module contains the infinite loop. The loop exits after the appropriate command of the operator.

At entry point to the loop the keyboard buffer is tested for ready to run commands. The buffer is filled by the interrupt service routine.

The switch construction with command as argument serves to choose between change of the operation mode, control mode or output services. If the command is not available the output to the screen (direct access to symbol buffer of the VRAM), control and measuring operations are performed due to the established mode of the operation.

The measuring polling and the control operations are performed at the end of the loop body.

The commands give the possibility to output reports to the printer, change the screen form, to start and to stop the control of the pressures, to start the recording of the charging voltages and currents ("oscilloscope" mode), etc..

The usage of the simple software structure is based on the strict definition of the experiment's preparation stages and the long enough time periods for the switches pressures preparation. For mode demands on the duration of the stage, the more complex algorithm of the control is required. For example, it may be necessary to take into account the laws for the gas pressure dynamics and to save the individual properties of the volumes. Those properties can be calculated from the measurement. The program has some features that takes into account the requirements to the work procedure in the different modes of the operation.

1. The ADC polling is performed in two modes: the polling of the pressure measurements and the polling of the voltage/current gauges. Usually these modes are used separately. On the stage of pressures preparation the polling of the pressures only is performed. On the charge stage the voltages and currents are measured only. The full polling cycle takes 3-4 seconds (for 250 channels), while the charge parameters polling taking less than 1 second. The distribution of the circuits to the multiplexers is optimized from the viewpoint of the number of switching operations.

2. To compensate the regular noises of 50 Hz frequency the connection of the measuring gauge to ADC is made for 20 ms. There are several measurements are made during this period, the results being averaged by the software. The number of the measurements and the calculation procedure is constructed to eliminate the sinus-like noises.

3. The control procedure for the pressures take into account the measurements from two gauges located near the input and the output valves. The valves are connected to the work volumes by means of the long 6 mm internal diameter plastic tubes. The length of the tubes can be from 10 to 30 meters. For the operations with large volumes filled with SF_6 - N_2 mixture the pressure change rate is not very fast and the opening or closing of the valve can be made after polling cycle.

For the operations with small volumes filled with nitrogen the change rate is very big. For this case the valves are opening and closing, by appropriate command, after 100 ms from opening event.

The feedback rate can be changed by means of the narrowing of the feeding tube near the valve.

The time of the valve reaction is comparable with the software delay.

4. The system software human interfaces are oriented to the technical personnel that have limited experience with PC's. The full number of commands is about 50. The number of the main commands is less than 10. Usually operator use one command with hand entered parameters - the command for input of the experiment id-number.

The example the screen-table of process preparation of installation to shot is shown at the figure 2.

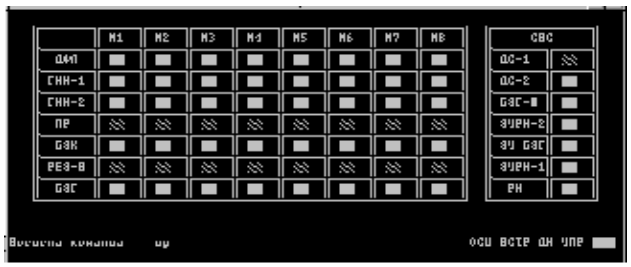

Figure 2. Screen picture of preparation device process.

The technological systems situation of each modules of installation is shown (the installation contain 8 modules).

The main screen looks like a set of square shapes, each shape reporting, by color, the state of the volumes. The possible states are: pressure ready, too small, too big, the control started, the control stopped.

Qualified personnel intend the programs for the equipment testing for the usage.

Those utilities are dialogue oriented. The dialogue requires input of the circuit numbers and appropriate precise values measured by the independent devices.

The setting editor is used by the technical personnel and can be called from the main program.

The interface is similar to the interface of the electronic tables. The editor gives the possibility to enter the pressure setting and possible discrepancy.

For small volumes, like the synchronization system, the ordinary discrepancy settings are 0.05 ATM.

To exclude the volume from the control, the operator should set a large possible discrepancy.

The other function of the main program is the start of the recording of the voltages and currents during the charge operation. These results are used for the tests of the high power generators.

These results are written in binary form. The special utilities intended for usage by engineering personnel can translate these data to ASCII format, acceptable by the standard data processing programs.

4 SUMMARY

The algorithm of pulse power device for experiment preparation can be realized by means of the simple CAMAC hardware. The special object oriented software contains both the working program and the user's interface. The number of user's commands is small enough allow use of technical personnel for these procedures. During several years, exploitation was successful and showed the conformity of the system to the main experimental requirements.

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