HIGH POWER FUSION FACILITIES AS CONTROL OBJECT

V.I. Zaitsev
State Research Center of Russia Troitsk Institute for Innovation and Fusion Research 142190, TRINITI, Moscow region, Russia

Abstract
The areas of high power ($10^{12} \div 10^{14}$ Wt) facility (HPF) main application are production of megaamper-level particle beams, high power sources of x-ray radiation and inertial thermonuclear fusion. In spite of designs and experiment tasks differences the HPF have the same operation algorithm features such as short duration of processes, low operation rate - several shots per day, a lot of parameters of control. According to operation specific the HPF control must be contain the some necessary parts:

- System of HPF preparation to shot must provide check-up and adjusting technological parameters (gas switch pressure, capacitor battery voltage and so on).
- Timing system must provide the operation synchronization of all facility parts with nanosecond range accuracy.
- HPF processes monitoring system requires the application of data acquisition devices with different sampling time ($10^{-7} \div 10^{-10}$ sec). Special signal transmission lines are necessary.

As example of this problems solution the control structure of HPF ANGARA-5 are presented.

INTRODUCTION
The large physical facilities are the unique installations. Control systems of ones are different and depend on facility specifics. However, the facility of the same research direction have similar operation algorithms and control systems. In this paper the facilities for producing related to inertial fusion experiments are considered. For this experimental researches heavy ions accelerators, high power lasers and megaamper z-pinches are used. The final stage of this facilities operation cycle is producing of high power on the thermonuclear target. For example, the pulse electrical power of Z facility (Sandia National Laboratory, USA) is $6 \cdot 10^{13}$ Wt. For control system of heavy ions accelerators the wide experience of accelerator’s technique is used. The main operation specifics of laser and z-pinch facilities that determine the control system structure are the following:

- there are two very distinguished temporal stage of facility operation: the stage of technological preparation and the stage of pulsed power producing and processes in target;
- wide range processes duration : from seconds at the working cycle (shots) preparation stage up to $10^{-9}$ sec at final stage of shot;
- low repetition of working cycles (the shots) per day.

The typical features of inertial fusion facility working cycle are shown in the Table 1.

It is possible to see that control tasks are very different on the stages of working cycle. The realization of control requires the set of different systems. According to analysis of control tasks the PC is the base for any systems of control.

<table>
<thead>
<tr>
<th>Cycle parts</th>
<th>Technological preparation</th>
<th>Energy storage</th>
<th>Shot</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stage duration</td>
<td>hours</td>
<td>minutes</td>
<td>micro-seconds</td>
</tr>
<tr>
<td>Procedures</td>
<td>mechanical adjusting, target installation and so on.</td>
<td>capacitor battery charging</td>
<td>energy transport, processes in target</td>
</tr>
<tr>
<td>Feed-backs</td>
<td>yes</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>Parameters number</td>
<td>up to $10^3$</td>
<td>up to $10^2$</td>
<td>up to $10^7$</td>
</tr>
<tr>
<td>Information producing rate per parameter</td>
<td>$10^3$ bit/sec</td>
<td>$10^4$ bit/sec</td>
<td>$10^{13} \div 10^1$ 4 bit/sec</td>
</tr>
</tbody>
</table>

CONTROL SYSTEMS STRUTURE
Fig.1 shows the typical structure of the inertial fusion facility control [1,2]. The technological preparation system operates before the start of the working cycle. There are a lot of parameters of control but ones change slowly. The rate of information processing is not more $10^6$ bit/sec and PC is quite suitable as the element of feedback control. For PC connection to facility equipment the interfaces similar to VME or CAMAC are used. When technological parameters (vacuum, mechanical elements, gas pressure and so on) are ready the charging of the energy storage systems (usually capacitor battery) are started. After charging the PC records the all technological parameters and permits the start of shot. Technological Preparation Systems are conservative parts of facility control and practically don’t change during facility life.
Fig. 1. Typical structure of fusion facility control.

The main task of Timing System is synchronization of different facility parts operation. Usually this systems contain $10^2 - 10^3$ output channels for control. In the some case these systems have time measurement task also [3]. For fusion facilities the precision of timing and adjusting are in range $\sim 10^{-9}$ sec. The communication operations (channels time setting, channels operation testing) are executed during intermission between shots and by means of PC of the local systems.

The Fast Data Acquisition Systems provides the waveform parameters recording during the shot and preprocessing of this information flux. The range of signals duration is $10^{-5} - 10^{-9}$ sec. There are a lot of ADC types for measurement in time range $10^{-5} - 10^{-7}$ sec. The different interfaces (as example, CAMAC, VME) can be used. For recording more fast signals the devices of TEKTRONIX type are used. Usually this devices have GPIB or RS-232 interfaces. Information about waveform of processes during the shot time accumulates in the fast ADC memory. PC function of this system are:

- preparation of channels for pulse recording;
- data preprocessing for correction of different distortions;
- data transfer from ADC memory to supervisor data base.

These procedures are produced during intermission between shots. As rule for these procedures execution the PC possibility is enough. The detail processing of experimental data is produced out the control systems on the user’s computer usually.

According to experience of exploitation the such structure can be the ground of the HPF control.

ACKNOWLEDGEMENTS

The author is grateful to Dr. V. Murugov for discussing of this problem and my colleagues A. Kartashov, N. Lachtushko, V. Savochkin, E. Dudorova which solved a lot of problems of ANGARA-5 control design.

REFERENCES