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Hard- and Software for Measurement and Control of the Pulse Thermonuclear Installation

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Abstract

This paper describes control and measuring systems of the pulse thermonuclear installation "Angara-5". The "Angara-5" operates in a monopulse mode. It takes a long time to prepare the installation to the work shot . The main information flow about the installation output parameters and the target processes comes for 10^{-7}-10^{-8} sec. The measuring-control equipment has a multi-level hierarchy structure where the lower level is local systems controlled by own computers. Measuring systems contain waveform digitizers different types. The supervisor console system realizes the communications with the local systems, as well as the data acquisition, processing and storage. Hardware and software structures are given. Careful equipment shielding and grounding have provided level of noise 30 mV. Fast signals processing features are discussed.

I. INTRODUCTION

High power pulse generators had been using at first as accelerators of high current electron beams [1], lately have founded use as a driver technology for inertial confinement fusion experiments. Such generator can produce electromagnetic pulses with power 10^{13} - 10^{14} W and duration $< 10^{-7}$sec on load. Type of load is determined by experimentally program taken place at the installation. High voltage diodes producing intense ion beams are used as load at some experiments. Beams energy has been transporting on thermonuclear target [2]. Gas jets or liners different types are used as load at other experiments. In this case ions of load are accelerated to axis by means magnetic field of current through load [3]. It's necessary to note next features of such installations that determine structure of control and measuring systems:

-small duration of processes in installation after start (~10^{-6} sec). It excepts possibility of control at regime "on line" and requires application of fast analog-to-digital converters with buffer memory,

-seldom work starts of installation (few starts in day) make easier requires to systems of before-starting preparation and to data processing rate after shot. It's allows to design systems on base interfaces like CAMAC,

-high risetime of currents and voltages (~10^{14} V/sec, A/sec) provoke high level electromagnetic noise and requires the special design on electromagnetic compatibility of equipment.

Such installations are specific systems and requires design the special hard-software for effective working.

This paper describes the realization experience of control and measuring systems on the pulse thermonuclear installation "ANGARA-5" [4]. The installation consists of 8 modules worked synchronously on common load. Parameters of installation ($U=1.5$MV, $I=4$MA, $T=10^{-7}$ sec) allow to provide a different experiments on thermonuclear targets heating.

II. HARDWARE

Hardware consists of separate local systems and has multilevel structure. Local system fragment is shown in fig.1. The CAMAC crate blocks or their VECTOR [5] analogs are placed at the low level and are controlled by means of CC. The CAMAC crates are connected in systems by help UNIBUS and controlled by means of PC computer through adapter. Local systems are united in complex and connected with host computer center by ETHERNET.

The technological parameters system ST (realizes control before-starting preparation) and the synchronization system SS (determines moments of switching on installation parts and measuring systems) are control systems in the usual sense. Let's consider of structure (fig.2) and functions of local systems.

Supervisor system SD produces local systems control and provides date acquisition, archiving, processing and display imaging of information from all local systems.

Technological preparation system ST realizes all necessary operations before installation shot. A main operations are measurement of slow changing parameters (distilled water resistance, gases pressure in switches, voltage on condensers etc.) and control of gases pressure and condenser charges processes.

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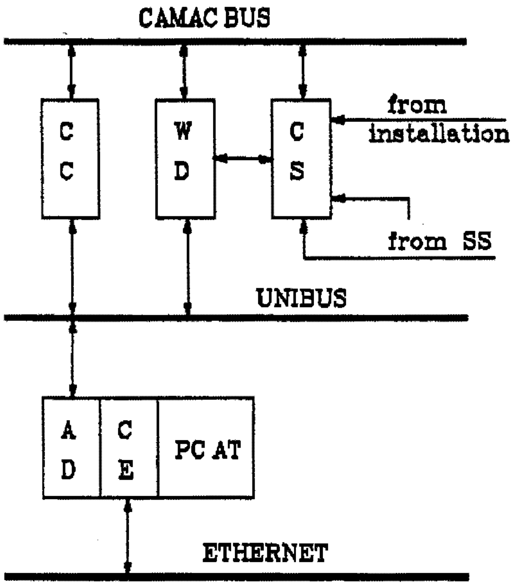

CC : crate controller

WD : waveform digitizer

CS : commutator

AD : adapter PC–UNIBUS

CE : controller ethernet

Figure 1. Typical schema of local system.

It's possible to measure technological parameters on 256 channels and to regulate pressure in 128 volumes. Technological parameters slow change allows to use CAMAC blocks commercial set.

Synchronization system SS organizes work of all measuring systems in the same time scales "attached" to installation work cycle. The set of VECTOR blocks allows to generate starting signals at different moments of cycle. Time scales is determined by 100 MHz frequency generator. Timeseting blocks "attachs" synchronization pulses to cycle with accuracy 2,5 nsec. With purpose of universality the system is equipped of blocks for multiplication and amplification of synchronization signals.

Fast processes measuring are produced by systems SW1,SW2,SG. These systems contains fast analog-to-digital converters different types and includes both commercial CAMAC or VECTOR blocks and special developed devices. It's necessary to have the information about parameters of 200 signals in each shot . Main installation processes have the duration 10^{-6}-10^{-8} sec and contain ~100 Kbyte (without video image information). The systems architecture are designed according to types of devices. Signals sorting according to users requires is provided on software level in the supervisor system.

System SW1 contains 32 scale-time digitizers UPN-92 producing signal waveform measuring with time step 1 nsec. Fragment of SW1 system is shown in fig.3.

System SW2 includes 32 measuring channels with a different types of real-time waveform digitizers. Measuring step on time is from 10 nsec to 50 nsec.

Characteristics of digitizers basis types are shown in table 1.

Table 1

Characteristics of digitizers basis types

Types	Bits	Time step	Steps number
UPN-92	8	1 nsec	256
BPN-93	7	15 nsec	128
F-4226	8	50 nsec	1024

System SG contains less expensive digital devices for pulse general parameters measuring and includes 64 channels of pulse start time measuring, 64 channels of gated time integrals measuring and 16 channels of peak amplitudes measuring.

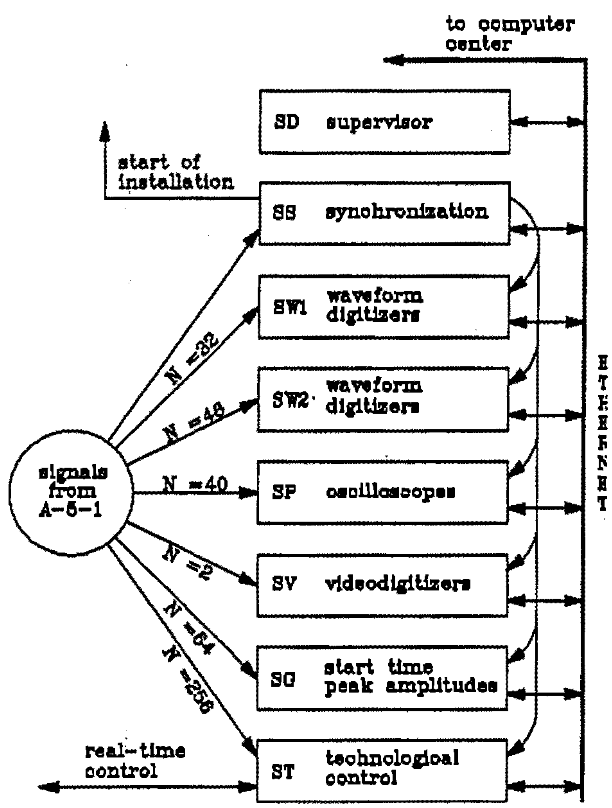

Figure 2. Hardware composition.

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Video image processing system SV is intended for reception of data arrays about load radiation image. There are used as coding devices:

- mechanical density measurement device (AMD) scanning image on photographic film (step = 5 Mkm) and transferring blacken density to digital code,
- image digitizer on base of charge transfer devices.These devices application as positional sensible detectors allows to receive information about allocation of intensity of plasma radiation in different range of waves lengths (X-ray too). In this case distribution of intensity are registered without film processing.

Physical diagnostics system SP serves of devices complex intended for registration of load radiation (neutron, optical, X-ray and etc.) and includes oscilloscopes different types. Highest band width is 1.5 GHz. System functions are preparatory operations (service of cameras, oscilloscopes, generation of a test signals), registration and processing of signals from neutron activating analysis detectors. Commercial CAMAC blocks are used as control hardware.

All pulse measurements systems contains necessary equipment for automatic amplitude-time calibration. Vertical deflection factors, time base sweep curves and time start reaction are determined and stored on disk for each digitizer. The special electrical supple, careful shielding and grounding of all measuring and control systems, galvanic isolation by optic devices are used for electromagnetic compatibility. As result, a peak-to peak noise level of 30 mV has been measured from cables located in the noisiest region [6].

Figure 3. Fragment of SW1 system.

III.SOFTWARE.

The hardware specific and installation ANGARA-5 peculiarities have required specific software design. All software blocks are "canned" for users. Special menus provide users interaction with hard-software. Main blocks of software structure is shown in fig.4.

Dispatcher program occupies the central place in the structure. Program supports next tasks:

-data reading of experiment description program (DSR), preparation them for transmission to local systems,

-definition of equipment work regime (calibration, work shot),

-initialization of connection with local systems, preparation of local systems to work,

-start of the synchronization system, data reading from local systems and transmission them to data base,

-graphic data presentation.

Hardware adaptation to concrete experiments is executed by means of DSR program. The program provides:

-holding and editing of installation sensors parameters,

-holding and editing of synchronization channels parameters,

description of signals transmission lines including coefficient of signal fading in cable,

-schema of registrars switching.

The information is transmitted from DSR to signals file of data base by means of D-program in each shot.

Object specificity have required development of the object-oriented data base DB with program interface and developing possibilities of graphic presentation. Data base knows 3 type of object: signals, amplitudes, times. Every signal saved in DB consist of fixed and variable parts. Fixed part contains ancillary information about sensor type, measuring schema etc. Variable part contains signal itself. Length of the part depends of digitizer type. Manager of data base allows to look through data base on different indication, to extract and edit a data.

Local systems during exploitation are the most evolution part in respect of its composition, because necessity in substitution of coding device type arises constantly. That's why programs LS was built so, that they could be easy adapted to change of there compositionally. Local system is divided on subsystems for which was built files of schemas description. External file describes connections between subsystems. One can make out next elements in software structure of local systems :

-the set of system control functions,

-the set of subsystems control functions,

-the set of blocks control functions.

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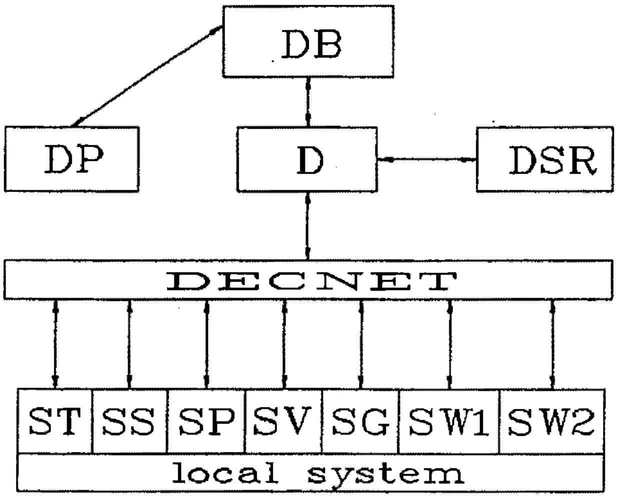

Figure 4. Software composition.

-the set of blocks control functions.

This elements are basis for local systems software. Graphic package is used for subsystems description special program. Changes of subsystems structures are made by means of screen picture editing. Special program transmits these changes to local system description file. Documentation about a system structure is printed at the same time.

Processing programs DP are intended for correction of errors arising on each element of a measuring line (censor-cable-registrator) and for realizing of users different algorithms. Correction programs include of "false" points liquidation, low and high frequency compensation. The example of distortion high frequency compensation arising in cable (length is 80m) is shown in fig.5.

User programs library contains arithmetic operations with signals including addition, subtraction, multiplication, Fourier transform etc. The software interface provides interaction of processing programs and data base.

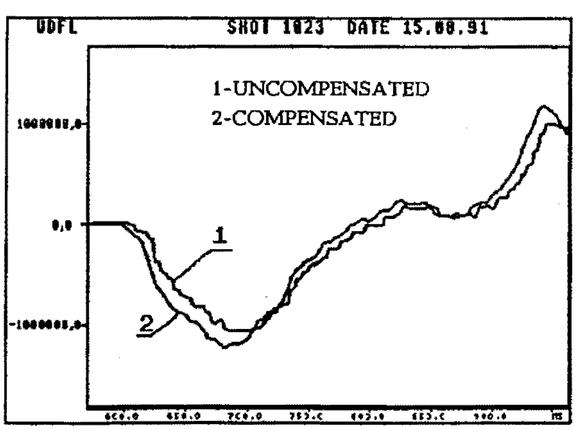

Figure 5. Example of high frequency compensation.

IV. CONCLUSION.

The tests of the hard- and software complex described in this paper have shown satisfactory correspondence to the principal installation performances. The insertion into hardware fast analog-to digital convertors is necessary for investigation of installation processes. It's desirable to realize the special corrective algorithms for the increasing of the measurement accuracy. The duration of data processing is a few minutes after each shot. The users can observe and process data at their working places by means of the ETHERNET. The structure of software let to adapt the complex for various experiments quite easy.

V. ACKNOWLEDGMENT.

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