INTEGRATED ACQUISION SYSTEM OF EXPERIMENTAL DATA FOR URAGAN-2M AND URAGAN-3M

S.P. Gubarev, A.A. Kasilov, G.P. Opaleva, R.O. Pavlichenko, V.S. Taran, M.I. Zolototrubova

Institute of Plasma Physics NSC KIPT, Kharkov, Ukraine

The paper describes the integrated data acquisition system representing in real time the parameters of plasma confined in stellarator-type fusion devices Uragan-2M and Uragan-3M, which are under operation in the Institute of Plasma Physics of NSC KIPT. This system provides the synchronous multichannel high-speed measurements of electric signals coming from the sensors of the device equipment and plasma diagnostic equipment, data acquisition, transportation and graphical display of information, archiving it in the server and in the electronic data repository. The system gives to the users the possibility of access to the files with the registered diagnostic information.

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INTRODUCTION

At present time the experiments devoting to solution of the problem of controlled fusion are being provided throughout the world. As the rule, such experiments require an availability to control conditions of the experiment and to measure many plasma parameters. All obtained information has to be saved in the form convenient for further use. Because of big difference in the scale of experiments for every concrete fusion device there is a need to develop an automatic data acquisition and storage system optimized for the given equipment.

DATA ACQUISITION SYSTEM

In the IPP NSC KIPT the works on automation of experiments at fusion devices URAGAN-2M and URAGAN-3M [1] were started long time ago. With that, each of the data acquisition systems was autonomic.

Historically, automation methods were started to design and to fabricate already at the stage of each installation assembling, with an aim to put them into operation simultaneously with plasma experiments to begin. Taking into account the features of the installations' operation, the conduction of physical researches would be hindered without these methods or would be not enough complete and even impossible in some cases. The task of data acquisition is complicated by such factors as short plasma lifetime (tens of milliseconds), the necessity for multi-channel recording of fast processes (starting with microseconds) and high-speed transport of electrical signals from sensors of experimental installation to the converter equipment and computers under conditions of a quite high level of electromagnetic fields.

At a point in time of start of stellarator U-3 there was no possibility to purchase a multi-channel recording equipment with the required characteristics (the home made components with satisfying parameters were absent, and the foreign equipment was over-expensive). It was made a decision about independent creation of necessary hardware and software. Such hardware and software complex has been designed and manufactured by the employees of the laboratory of automation in the plasma physics department. All electronics consisted of home components. Structurally, the apparatus was made in the international standard CAMAC with the use of crates and modular cassettes.

The following modules were developed:

- high speed analog-digital converter with buffer memory;
- a three-channel programmable timer-synchronizer;
- multichannel device of selection and storage;
- a digital to analog converter with a buffer memory;
- serial controller CAMAC-PC.

Using different number of the enumerated modules and different configurations of their connection, the complete set of equipment with the required parameters (the number of channels, the speed of operation, etc.) was constructed. For support of apparatus operation, original software was developed. Possibility of operational settings of required configuration and parameters of system was implemented, as well as realization of the possibility to visualize of the registered information, its archiving and self-test system.

As a result of successful implementation in KIPT of an inexpensive hardware and software solutions of basic problems connected with automation of plasma diagnostics complex, it has become popular in some other domestic research centers involved in controlled fusion researches. Significant result of these studies was the implementation of the developed and manufactured hardware and software systems of various configurations in such renowned research institutions as the Kurchatov Institute (Moscow, Tokamak TM-4), Institute for Innovation and Fusion Research (Troitsk, Moscow region, tokamak TSP with strong magnetic field), Leningrad Physico-Technical Institute (tokamak "Tuman-3"), stellarator-type device in Sukhumi physical-technical institute, and others. After appearance in IPP NSC KIPT of modern computers with the corresponding operating systems, it became possible equipping them by multifunction cards or external modules of multichannel analog input signals produced by L-Card with supporting software package Lgraph. For the present time, such a solution looks most acceptable both from a commercial and technical side,

and provides a solution of main problems as for automation of plasma diagnostics. Thus, on the stellarator U-3M either earlier created facilities for registration of plasma parameters or modern equipment are exploited. It should be noted that this equipment is based on the computers of different generations furnished by the different operating systems. With that, the workplaces are located in different rooms and even in the experimental hall and are not connected to a single network. Naturally, there is no possibility for coordinated simultaneous interaction of the participants of experiments and operational analysis of the obtained information.

Principally different situation is with automation of stellarator URAGAN-2M. Due to much later time of its putting into operation, this machine was equipped with modern hardware and software in several stages according to the plan. Special attention was paid to solving the questions of functioning of the equipment and personnel in the conditions of large electromagnetic fields [1].

The automation system is built as a distributed local area network (LAN), based hardware-software complex, consisting of a series of personal computers. Computers are equipped with multi-function input-output devices of analogue and digital signals. Geographically the components of the data collection systems are located at different floors of the main IPP building, and includes the experimental hall, diagnostics room, and rooms for server and repository.

The hardware part of the complex consists of devices L-783 (3 MHz, 32-channel, PCI), modules E20-10 (10 MHz, 4 channels, USB), E14-140 (100 kHz, 32 channels, USB) and microcontroller modules [2] integrated into the overall system via interfaces USB and RS-485.

A multifunction board L-783 allows also to realize some control functions by providing multiple output digital and analog signals in accordance with the laid down program.

The system of the local area network Diagnostic U-2M includes computers and monitors that give possibility to provide an operative graphical representation of the experimental data, the remote manager workstation (located in the experimental hall), the rack-concentrator, and the data storage. The latter allows the users of the network IPP-1 ("Institute of Plasma Physics") to provide access to archive of registered experimental data.

Removed to the experimental hall rack-concentrator includes a computer equipped with circuit boards and modules for converting input-output signals. It is possible to increase the number of connected channels.

All electrical signals from the U-2M sensors are pre-amplified and normalized in the standard CAMAC modules that have been developed. The task of high-frequency galvanic isolation between electrical signals from U-2M and the input circuits of the recording equipment of the data acquisition system is solved by the use of fiber-optic communication lines (FOCL), the optical converters and individual opto-coupler devices. This ensures a high level of accuracy and noise immunity, what is particularly important when working with equipment for remote transmitter and long lines of communication. A synchronization module provides simultaneous launch of analog-to-digital converters for all diagnostic computers on arrival of sync pulse of the U-2M synchronization system.

Experimental samples microprocessor modules were developed and tested for the registration of analog signals. Small size of modules and small power consumption made it possible to integrate them into the diagnostic subsystem or to place in immediate vicinity of experimental installation sensors.

Under the conditions of high electromagnetic fields, it is possible to reduce strongly a spurious signal and to increase the signal/noise ratio. As a rule, the modules include such components as software-controlled instrumentation amplifier, switch inputs, analog-to-digital converter, a memory, a galvanically separated circuits, trigger and interfaces.

Depending on the tasks, specific microcontrollers with the required parameters were used. Given the availability of programming and debugging tools, the modules based on Microchip microcontrollers were mainly developed. For registration process with a conversion time of the order of several microseconds per channel the microcontrollers PIC18F2550, PIC18F2620, PIC18F25K80 were used, and similar to them, and for faster processes (less than 1 microsecond) – signal processor dsPIC33. Lately, work is underway on the development of devices based on modern microcontrollers of STM32 series. It should be noted that all these microcontrollers are cheap (from one to several dollars) and low power (a few milliamps in operation or several microamperes in the SLEEP mode). This allows to use them one by one for each diagnostic channel with independent power supplies. Of the disadvantages of using these modules one should note the necessity for individual development and production of modules and software.

It is worthy of note that, in contrast to the possibilities of service of U-3M the infrastructure of automation system of the U-2M stellarator has a large diagnostic room equipped with a large screen monitor, and several computerized working places for diagnosticians. Also it was difficult to provide at the U-3M the joint experiments in cooperation with colleagues from other organizations. In this regard, the task on combining resources of two automated data collection systems became actual.

The ability to respond rapidly to changes of the basic plasma parameters after the main pulse for further correction is one of the main criteria for a successful and effective experiment. For the purpose of improving management efficiency of the experiment, in the IPP NSC KIPT an integrated data acquisition system (DAS) was developed and implemented, which consists of hardware and software. The structural scheme of the DAS is shown in Fig. 1.

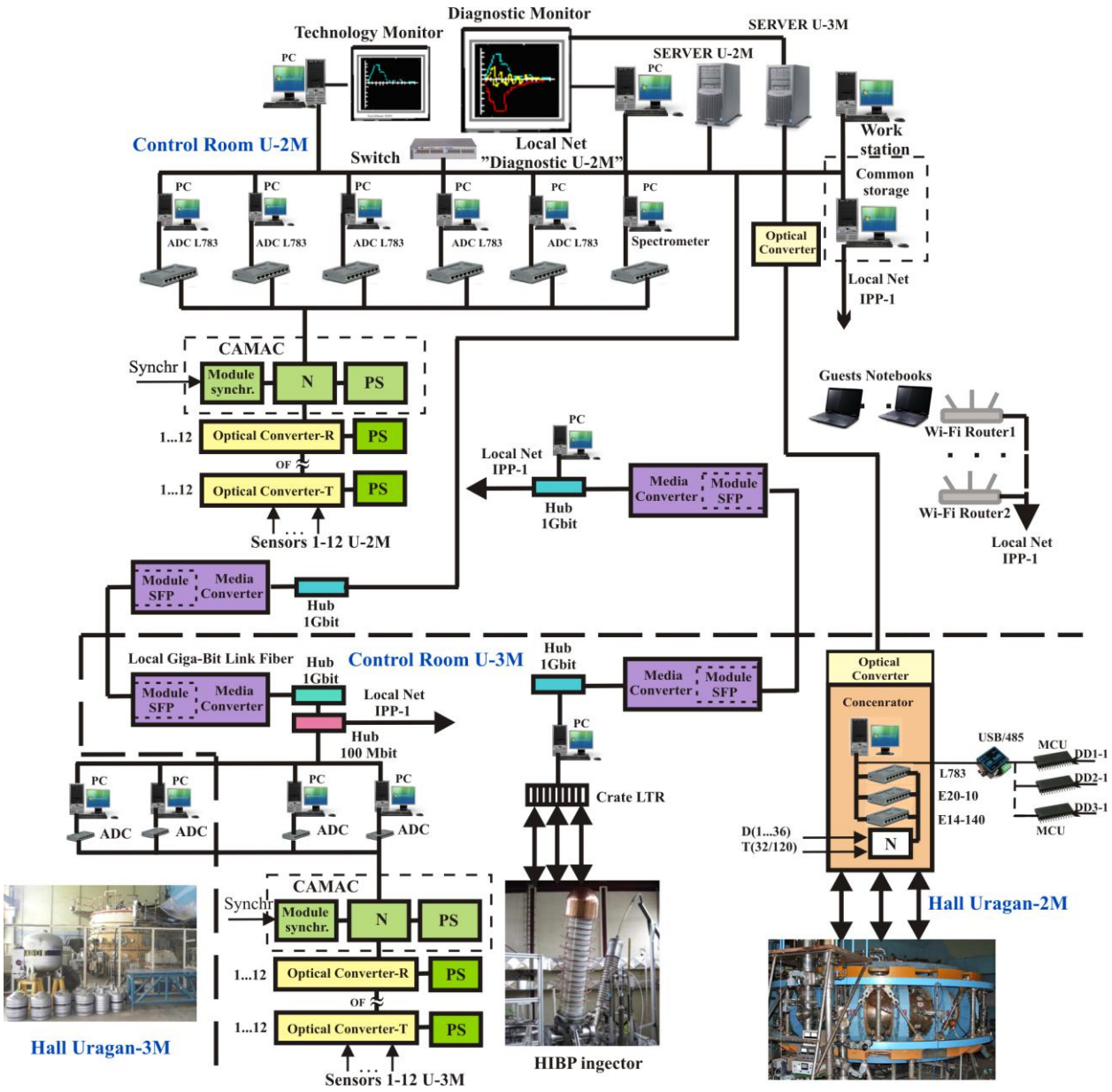

Fig. 1. DAS Structural Scheme. PC – Personal Computer; ADC – analog-to-digital converter; Synchr-synchronization signal; N – normalization module; PS – power source; D (1 ... 32) – diagnostic signals; T (32/120) – technological signals; MCU – microcontroller; DD1-3 – normalized signals

The data acquisition system of "URAGAN" devices represents a set of diagnostics, that sends the data to computers with boards and modules for analog-to-digital conversion (ADC). Because of high level of electromagnetic fields in the experimental hall, all communications to join the recording equipment were performed by the use of fiber and media converters.

SOFTWARE

To create the integrated data acquisition system it was suggested to develop a completely new software that would create a database with entering into it previously obtained experimental data, and automatic filling by data during the subsequent operation of the device. This software was developed and created with the use of a high-level programming language. The basis of the software is the program U-3M Control, providing the opportunity to work with the equipment U-2M and U-3M.

The main features of the program U-3MControl are: the automatic diagnostic data acquisition from the PC to create a database on the server, displaying the received signals and logging of experimental data. The software U3MControl consists of two parts: server and client. Automatic data acquisition is realized as follows: the diagnostic PC with ADC board receives multichannel analogous signal. Then, in a fixed time, after digitizing the signal and a data file creation, the software U3MControl installed in the server, reads this data file through a local network and creates a new hdf5-type file (Hierarchical Data Format) in the server.

After file creation in the database, the program outputs signals to the monitor.

The software U3MControl is able to interact with unlimited number of diagnostics. In experiments at U3-M

there are several non-digitized parameters, like working gas pressure in the system, voltage applying to RF oscillators, number of shot, and others. The SW U-3MControl allows the operator to write these parameters directly into the database, binding to a specific shot during the experiment. This function allows to search shots in accordance to specified parameters. For controlling and monitoring plasma parameters, the SW U-3MControl has ability to plot and display graphs in a graphical environment and in a separate window displaying on the monitor (Fig. 2).

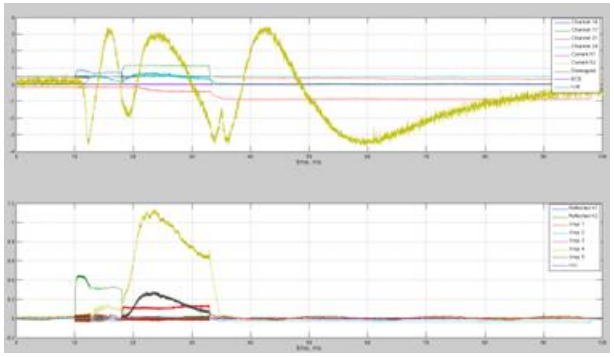

Fig. 2. Graphics displayed on external monitor

Fig. 2 shows an example of main signals plotting. Simultaneous displaying of such signals as currents in RF antennae of Kaskad-1 and Kaskad-2 generators, signals of electron cyclotron emission (ECE), X-rays, and many others, allows to perform quick visual comparison and evaluation of various plasma parameters. The operator is able to select the number of graphs and signals that will be displayed. For programming of microcontroller the language C18 is used. It is a special version of the C language for programming microcontrollers series PIC18. Software is a set of independent modules connected by the supervisor and the overall data files. Such a structure package provides a complete separation of functions between the modules that is convenient for editing and replacement of individual modules. Software modules run under control of operating systems Windows XP, Windows Server 2003, Linux. The implementation of multi-user mode is achieved by the use of parallel processes with full synchronization of all client workstations and servers. Parallel processing of multiple streams of information allows survey equipment to view sensor readings and record of measurement information to the hard drive in real-time.

CONCLUSIONS

The expediency of integration of the two data acquisition systems was substantiated. Integrated system allows mutually to enrich separate systems by missing technical and programmatic equipments, to deploy additional works for experimenters and to improve the usability and quality of experimental studies.

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ОБЪЕДИНЕННАЯ СИСТЕМА СБОРА ЭКСПЕРИМЕНТАЛЬНЫХ ДАННЫХ НА УРАГАН-2М И УРАГАН-3М

С.П. Губарев, А.А. Касилов, Г.П. Опалева, Р.О. Павличенко, В.С. Таран, М.И. Золототрубова

Описана созданная в Институте физики плазмы ННЦ ХФТИ объединенная система автоматизированного сбора диагностической информации, отображающей в режиме реального времени параметры плазмы на установках управляемого термоядерного синтеза стеллараторного типа Ураган-2М и Ураган-3М. Эта система обеспечивает синхронные многоканальные измерения высокоскоростных электрических сигналов, поступающих от датчиков установки и диагностического оборудования; сбор данных; транспортировку и графическое отображение информации; архивирование данных на сервере и в электронном хранилище. Система обеспечивает пользователям возможность доступа к файлам с зарегистрированной диагностической информацией.

ОБ'ЄДНАНА СИСТЕМА ЗБОРУ ЕКСПЕРИМЕНТАЛЬНИХ ДАНИХ НА УРАГАН-2М І УРАГАН-3М

С.П. Губарєв, А.А. Касілов, Г.П. Опалєва, Р.О. Павліченко, В.С. Таран, М.І. Золототрубова

Описана створена в Інституті фізики плазми ННЦ ХФТІ об'єднана система автоматизованого збору діагностичної інформації, що відображає в режимі реального часу параметри плазми на установках керованого термоядерного синтезу стелараторного типу Ураган-2М та Ураган-3М. Ця система забезпечує синхронні багатоканальні виміри високошвидкісних електричних сигналів від датчиків установки та діагностичного обладнання; збір даних; транспортування і графічне відображення інформації; архівування даних на сервері та в електронному сховищі. Система забезпечує користувачам можливість доступу до файлів із зареєстрованою діагностичною інформацією.