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DISTRIBUTED ON-LINE TEMPERATURE MEASUREMENT&CONTROL SYSTEM

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Abstract: *There is founded reasonability of implementation of measurement and control system with internet capability and proposed structure of its software in this paper. The main features of proposed structure are in its portability to system with different hardware structure. Also there is presented of investigation of dynamic characteristics of real time control system.*

Keywords: *Internet, client, server, CGI.*

1. INTRODUCTION

Nowadays the application of the distributed systems for data acquisition and control is a basic tendency in automation of the modern technological processes, which require the various equipments. Moreover, resulting of the hardware and software evolution is the concept of virtual instrumentation [1]. The virtual instruments represent a fundamental shift from traditional hardware-centred instrumentation systems towards software-centred systems that exploit the computing power, productivity, display and connectivity capabilities of popular industrial or desktop computers and workstations. Besides the intensive development of the information systems which are based on the Internet and Web- technologies with virtual instruments creates the following possibilities [2]: (i) reducing exploitation costs of existing communication channels; (ii) providing the suitable access to the equipment from any place in the world; (iii) improving the usage of remote education technologies. Therefore the development of the Web-based measurement and control system is an important and vital research issue. At present the Web-based systems are in the implementing stage in industry [3], education [4], medicine [5], homeland security [6], etc.

The typical Internet-based systems are presented by virtual laboratories giving Web-access to the equipment [7]. Thus, a user has a comfortable interface by using the Virtual instruments which emulate real devices [8, 9]. In the most cases such systems are not distributed, and they are intended for the control of one or few devices located physically in same laboratory. On other hand it is necessary to have many servers in order to combine the distributed geographically laboratories into one system.

The different programming tools like LabView, Java, C++, Php, etc are used for creation of user-oriented Web-based systems [10]. The main advantages of LabView [11] are in: convenience, availability of large volume of components and availability of versions for different platforms. However it requires a license for the developers and a license for users. Java application does not demand a license [12] in a case when the developers don't implement the commercial tools. Moreover the standard tools give less convenience for the developers.

The essential number of domain-oriented measurement and control systems was developed at the Research Institute of Intelligent Computer System and most of them were implemented in the industry. Mainly, these systems are built as distributed systems with a remote server, and a the most popular systems there was temperature measurement and control system [13-15]. So, as was indicated before, it is useful to modernize the server software for the following purpose: (i) giving access to work of the system through Internet; (ii) setting mode of equipment operation remotely.

The main goal of this paper therefore is in development the software architecture for real time control system, which has provide the Internet capability and investigate its dynamic characteristics.

2. SYSTEM ARCHITECTURE

The idea of the developed system is the software supporting of the following functions: an access through Web-browser, remote monitoring, information acquisition, dynamic updating of measurement information and reconfiguration of system's operation modes and parameters. These functions could be implemented by software and it is a way of existed computer based systems improvement. Also there are some additional requirements like: reliability, distribution, scalability, convenience and portability across different platforms, which should be implemented for such systems. The term "reconfiguration" we consider like remote control of equipment with possibility to change its operating algorithm (it's called remote reprogramming as well). Such function can lead to the possibility to test remotely the developed software and adapt it to the system hardware. In addition it is necessary to provide the connection of the unit with the remote servers, which are located in local area networks, protected by network filters (proxy-servers, firewalls, etc).

Three-tiered client-server architecture (Fig. 1) is chosen to satisfy the requirements and provide the functions mentioned above. It consists of a client (a user), an Intermediate-server (IS) and a local server (LS). Thus the IS must contain the software which allows to connect a user to the LS running appropriate commands. It also should provide the data acquisition and transfer from the LS to user

3. SYSTEM SOFTWARE

The developed software is divided into two parts: the IS and the LS software (Fig 2). The IS includes Web pages, CGI-routines and Java-applets. The CGI-routines presents the implemented Modules of Data Acquisition (MDA). Java-applets load of together with html-pages, and the user can monitor and control the system with Web-browser implementation. File and data transfer from the LS to a user, and the http-query is used for this purpose (Fig. 3)

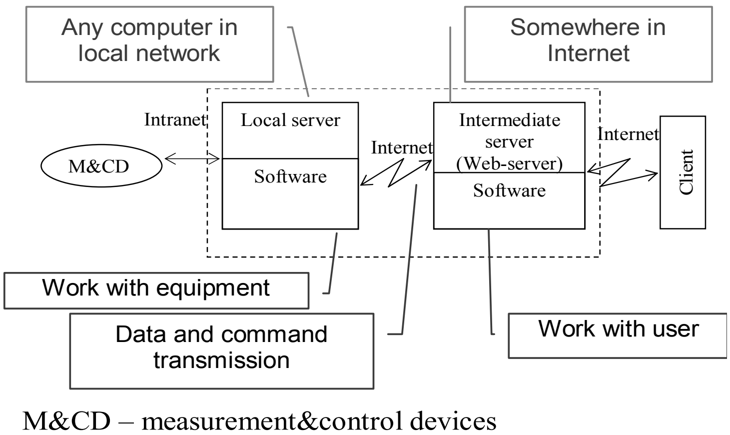

Fig.1 - Three-three-tiered client-server architecture of developed Web-based system.

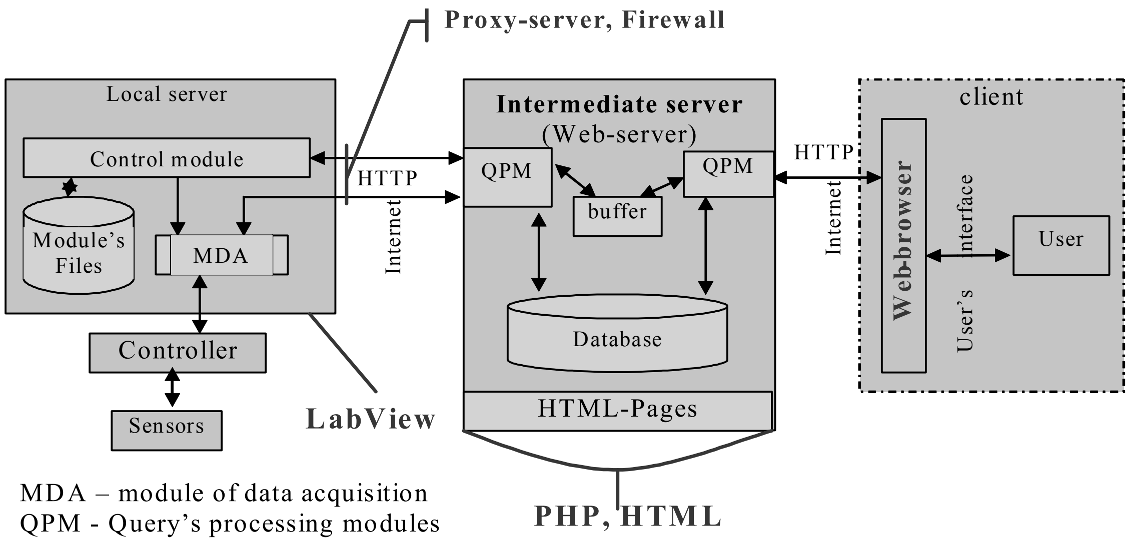

Fig.2 - System architecture with representation of software modules interaction.

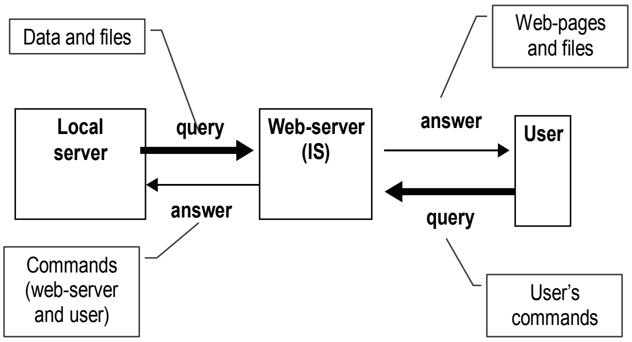

Fig.3 - System's data flows.

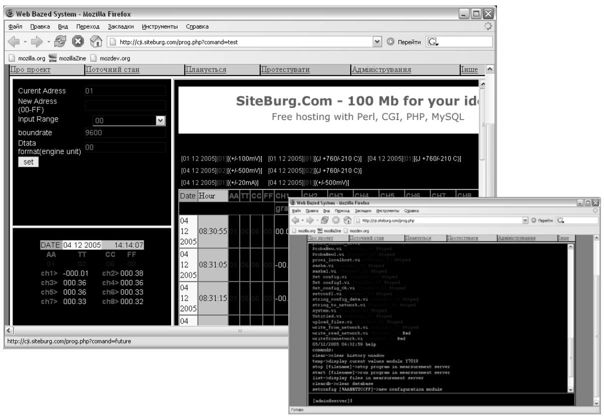

Fig.4 - Monitoring and control of module I-7018.

A PHP-technology is implemented for writing of the CGI-routines. This technology is supported by the different Web-servers, for example Apache, IIS, etc. The IS provides the information acquisition, database maintenance, online results visualization, multi-user access, compatibility and portability issues, devices control and remote administration. The IS could be geographically situated at any place in the world independently from the place of measurement devices. The LS can either have direct access to the Internet (i.e. real IP-address) or can be included in a local area network. For this purpose a possibility to have an access through Proxy-server and Firewall using HTTP protocol is implemented. It provides a protection of the LS from direct access.

The LS software could be implemented using LabView. A CGI routine processes the HTTP-requests from users and the LSs and provides them the appropriate answers. The Java-applets are used for the improvement of human-machine interface providing the interaction between the users and the Web-server an. There are presented on Fig. 4 some pages for a remote control of equipment [19].

4. EXPERIMENTAL RESEARCHES

There was developed temperature control system of airflow for testing of proposed approach (Fig. 5). The electrical heater – Heater and electrical ventilator - Fan are the actuating mechanisms of this system. Temperature sensor – T is based on semiconductor thermistor and it is situated inside airflow. This system was developed according to the requirements of IEEE-1451 Standards [17, 18], and the actuating mechanisms and sensor are connected therefore to the Smart Transducer Interfaces Modules – STIM #1, STIM #2 and STIM #3 correspondently. These modules execute the set of functions [19], which provides a unification of access to the actuating mechanisms and sensors. The STIMs are connected to Network Capable Application Processors – NCAP #1, NCAP #2, and NCAP #3 which provide the processing of data received from data source and it's transmitting to data consumer.

Meantime the NCAPs are running there the following functions:

- NCAP #3 determines the sensor's temperature of resistance measurement results and sending temperature deviation to network;
- NCAP #2 computes the heater power and sends it to STIM # 2 as well as it sends request to NCAP #1 for increasing or decreasing the rotation speed of fan in the condition of power coming out the defined limits;
- NCAP #1 computes a power of fan and sends it to STIM #1. Then an alarm signal is passed to the local server in the condition of power coming out defined limits.

In this case the NCAPs provide the dynamically reprogramming [20], and it does not have the stored operating program. Note the NCAPs are of the same type after power on local server they should provide their programming via network. Hardware and software of this control system is described generally in [21], and the additional software for local and intermediate server was developed there. As a result the remote on-line access to the temperature control system was provided.

The two main tasks of testing developed temperature control system (Fig.6) are: (i) the investigation of its dynamic characteristics which are connected with time delay of data transmission via global computer networks, and (ii) the definition of quick-action of control object in real time systems. The software structure of developed control system corresponds to Fig.2 above. This software is based on architecture with CGI and LabView implementation. The intermediate server is placed on the free hosting Internet servers. The testing was done by the users who were distributed geographically among each other, and from the intermediate server as well. The developed prototype was worked properly; a view of client monitor is presented on Fig. 7.

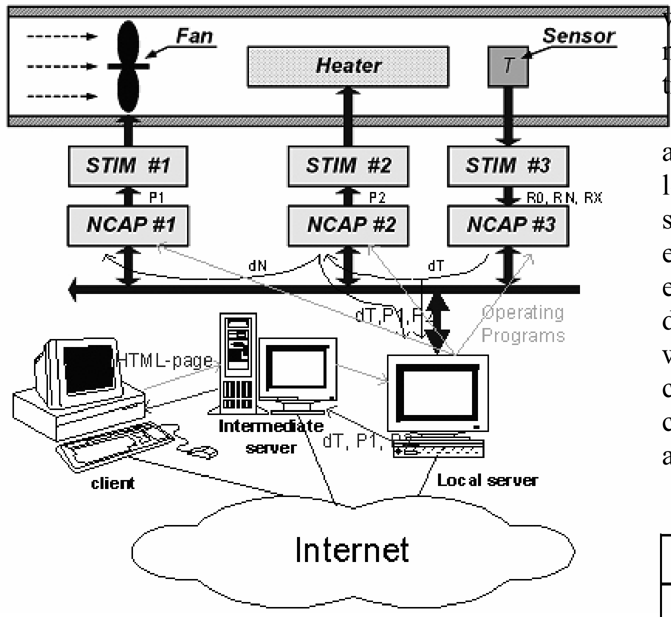

Fig.5 - Structure of on-line temperature control system.

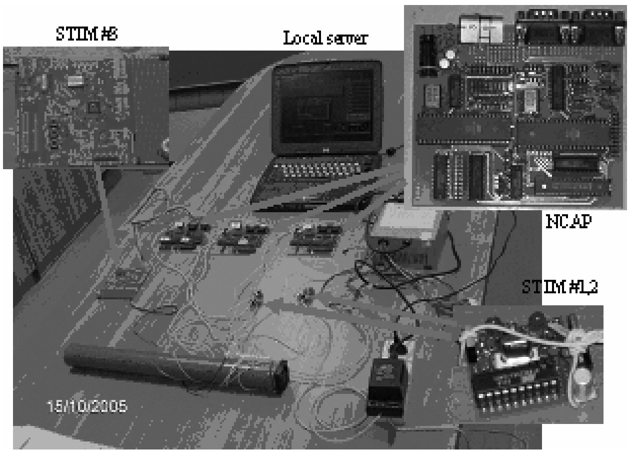

Fig.6 - Temperature control system.

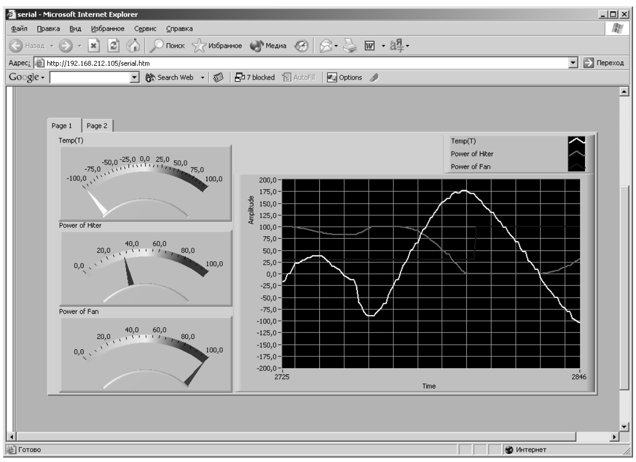

Fig.7 - Screen shot of client's monitor.

It was established the Time delay:

$$Td=Tm+Tmc+Tt+Tis,$$

where Tm - delay modules for read, Tmc –delay modules for change configuration, Tt – data's transition, Tis - intermediate server delay.

In this case the delays depend on the large amount of the influence factors like network loading, etc. Those factors are independent from the system developers and users, so the delays could be evaluated applying statistical methods. There were evaluated therefore the limits of these delays. The developed system was tested by 24-hour operation within one week. System testing was running in the condition of maximal and minimal loading of communication channel. The experimental results are showed in the Table 1.

Table 1. Time delays in the system

Delay	Time, s	Description
Tm	0,8..0.9	Working speed of the device, delay of software (bound rate of COM port 9600b/s)
Tmc	8..10 0	Working speed of the device, delay of software Without change configuration
Tt (80bytes)	0,10..0,16	Volume information for the transmission, speed of the Internet
Tws	0,01..0,02	Overload of web server

It is necessary to note, that due to the small volume of information, which is being transferred and received by the Web-server, the developed system can work at the considerable delays in the communication channels. The geographical distribution of the users and system location do not influence the system efficiency. On other side the time of the request processing grows at increasement of the number of nodes and clients, which multiply the load of the Web-server. Moreover the developed system is scalable because the new nodes can be added without additional expenses and necessity to change all software.

5. CONCLUSION

There is developed the architecture of the distributed information measurement and control system, and it's provided the remote monitoring of measurement results and remote control of its functionality. The structure of software of the proposed system was developed on the basis of data flow analysis and it enables reprogramming of system's software as well as data monitoring.

The prototype of the distributed on-line temperature control system has been developed and tested. Hardware of the prototype includes the data acquisition modules, which are connected with local server and freehosting web-server. The experimental research implemented by LabView and PHP using, it confirmed its proper functions.

The system has been tested for temperature control of airflow, and the investigation showed that there no necessity to improve speed of communication for inertial control processes like thermal, electrochemical, etc. The proposed software structure allows: (i) to add the new devices, (ii) to provide the parallel access of many users to the hardware resources of the system, and (iii) to run the remote reconfiguration of system using the software controlled modules.

The developed software isn't specified just for temperature control system, so it could be simply applied for maintenance the geographically distributed objects, like pipelines, electricity transmissions lines, railways, highways, systems of the meteorological monitoring and distance education and etc.

6. ACKNOWLEDGMENT

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