CONTROL ROOM INTERFACE UPGRADE OF AN OPERATING FULL-SCOPE TRAINING SIMULATOR

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KEYWORDS

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ABSTRACT

The Full-scope Block Simulator of the Paks Nuclear Power Plant has been operating since 1988. In 2001 the whole Control Room Interface of the Simulator was replaced by a new one. The upgrade was executed in a very tight time schedule, because the training on the simulator had to be maintained during the installation of the interface. This paper describes the operation of the new interface and the main organization aspects of the installation.

INTRODUCTION

The full-scope training simulator of Paks Nuclear Power Plant (Hungary) has been operating since 1988. Six years ago the original VAX computer of the simulator was replaced by a DEC AlphaServer 2000 - 4/275, and – with this new hardware - the simulation cycle time was reduced from 1 second to 0.2 second. However, this simulation speed-up could not be seen in the Control Room, because its interface could operate only with 1 second refreshing time. The Control Room Interface (CRI) was designed in the mid-eighties and was built from CAMAC modules. Thus the interface became obsolete because

- its speed was not sufficient for the new requirements,
- spare parts for the electronics were hardly available,
- all of its reserve channels were practically spent.

For the above reasons a completely new interface was designed and installed in 2001. For the installations the following constrains had to be met:

- the cabling between the interface and the Control Room had to remain intact,
- the installation had to be performed in very short time steps, because the training on the simulator had to be maintained during the interface upgrade.

In the new interface VME electronics has been used, because of its reliability and we have had a proper development background.

GENERAL CRI CONSIDERATIONS

In a Control Room there are several different instruments and their implementation in a simulator can be different: from the use of the very same devices, to the use of their graphical representations. In our simulator the faces of the instruments are the same as the real ones, but their operation is simulated. In this case again several approaches are possible. In our approach the instruments are divided into devices. A device is a simple entity in the Control Room having identical connections to the CRI, e.g.: digital input devices are pushbuttons, selector switches, relay contacts, etc. Thus every device has one or more input/output lines in the CRI and a value associated with the actual states of the lines (e.g.: a logical value in the case of a pushbutton, or an integer in the case of a thumbwheel switch). Most devices have very simple logic, but there are also some exceptions, e.g.: the synchronoscope, used to connect the electrical generator to the grid. In our approach the devices are handled in the CRI electronics, i.e. the input system calculates the values of the input devices, the output system drives the output lines associated to the values of the output devices.

The instruments are handled in the simulation server. Most instruments are modeled in the Control Room Communication System (CRCS), but the most complicated controllers (as e.g.: turbine controller, reactor power controller) are realized by independent model programs.

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HARDWARE CONFIGURATION

The Control Room Interface can be divided into five units, as digital input (DI), two identical digital outputs (DO1, DO2), analogue output (AO) and special output (SP). The SP subsystem drives the special devices, e.g. synchronoscope. The units are connected to the simulation server by a dedicated Ethernet network (See Fig.1.).

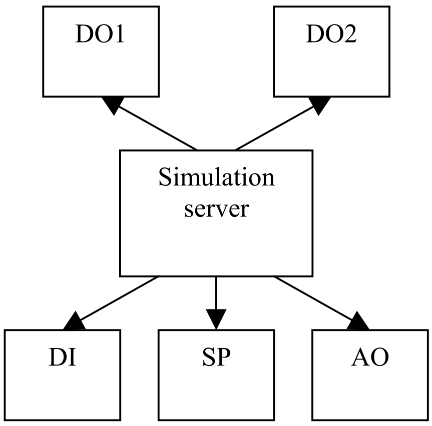

Figure 1: Basic hardware structure

Each unit has an identical structure: it contains a processor and identical peripheral cards arranged in crates. Because the peripheral cards need more than one crate, the crates are connected to each other by a transparent bus. The processor is a BVME4500 single board computer produced by BVM Ltd, Southampton, England. This board contains a 32-bit Motorola processor running at 33 MHz, a 10baseT Ethernet interface, a VMEbus system controller, 16 Mbytes RAM and 2 Mbytes Flash memory. The peripheral cards were developed and manufactured in the MTA-ITA-LAI. There are five different peripheral cards:

1. DI-64 receives 64 active low level TTL signals,
2. DO-64 provides 64 open collector Darlington drivers,
3. DR-64 contains 64 reed relays to convert logical signals to ground independent relay contacts,
4. DA-32 generates 32 current type (0÷5 mA, or 4÷20 mA, jumper selectable) analogue outputs with 8-bit resolution,
5. STP4 drives four stepping motors.

There is an additional analogue output board in the SP system (MVME 512-051) generating 12-bit resolution setpoint signals for controllers. The total number of input/output lines can be seen in the following table:

Unit	Line
Digital input	2880
Digital output	6912
Analogue output	768
Stepping motor drive	8

At present all lines are not used, but 10÷15% are reserve lines.

SOFTWARE STRUCTURE

The basic software structure of each interface unit is identical:

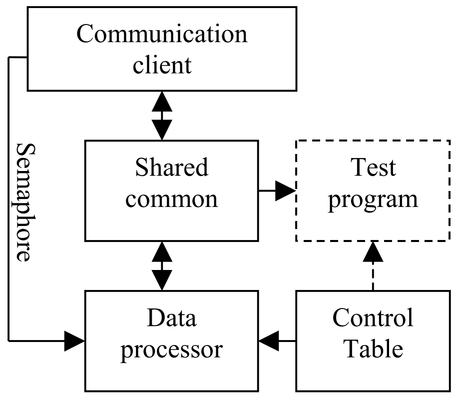

Figure 2: Basic software structure

An interface unit always replies to a command received from the server. The data processing is table controlled, i.e. a control table determines which lines form a device and how the lines have to be treated. The control tables are downloaded from the simulator server at the beginning of a simulation session. This solution is very versatile, since a new device can be added to the system without modifying the interface program.

The execution of the test program is optional, it is executed from a remote terminal connected to the network.

In the DI system there is an additional program running with its own 40 milliseconds timing. This program measures the input lines and detects the lines changed since the last data request.

All of the interface programs are developed in C language and they are executed in a diskless OS9 operating system.

INTERFACE STATES

Every interface unit has the following system states:

- initial,
- downloading,
- downloading completed,

- setup,
- setup completed,
- normal.

When an interface is switched on, the unit goes to **initial** state. Downloading can be executed only from this state.

In course of **downloading** the control table is loaded from the simulator server. When the downloading is successful, the unit goes into the **downloading completed** state. Setup may be executed only from this state.

Setup exists when an initial condition is loaded into the simulator server. During setup the output image of the Control Room is sent to the interface, moreover, the state of the input lines are measured and compared to the input image stored in the initial condition file. So called lineup reports are generated until the measured and the stored input images are different. When the setup successfully terminates, the interface goes to the **setup completed** state. The unit may be controlled into **normal** state only from this state. The permitted state transitions can be seen in Fig. 3.

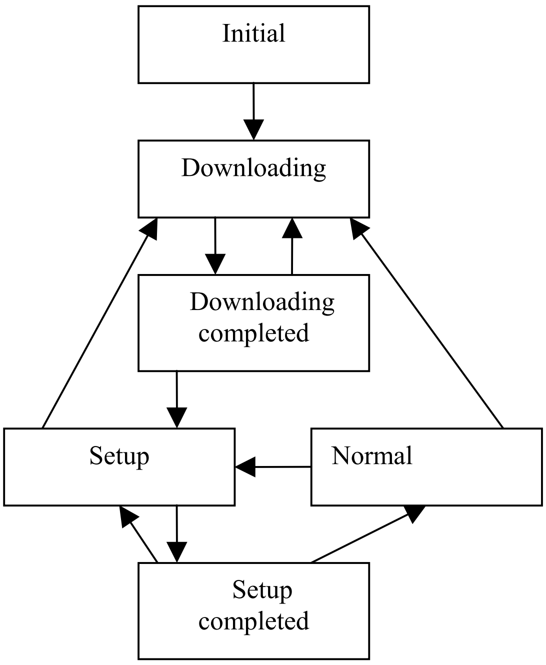

Figure 3: Permitted system state transitions

All of the state transitions are controlled by commands generated by the Control Room Communication System of the simulator server.

CRCS SOFTWARE STRUCTURE

The Control Room Communication System (CRCS) is a subsystem in the simulator server. It contains several programs realizing the models of the Control Room and driving the different event-driven actuator handlers of the simulator (pump handler, valve handler, etc.). This system can be divided into two parts as logical- and physical ones. The Control Room Data Processor (CRDP) forms the logical level and it is connected to the actuator handlers. The physical level contains different Control Room Interprocess (CRIP) drivers. Each interface unit has its own CRIP driver. Each CRIP driver is connected to the VMESRV server program realizing TCP/IP data transfer among the clients and the server.

The basic CRCS program structure can be seen in Fig. 4.

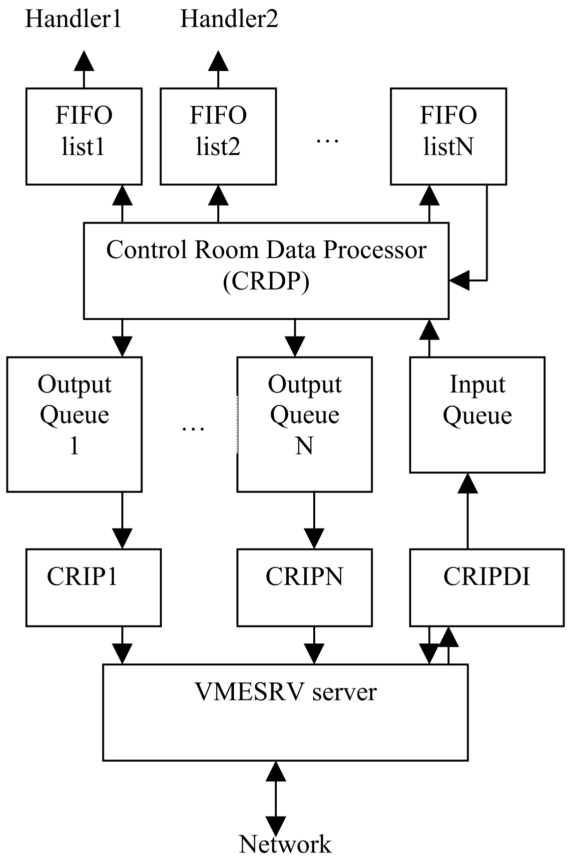

Figure 4

CRDP drives the whole interface system. This program is started every 0.2 second by its own timing.

CRDP has FIFO organized circular input/output buffers, namely 32 input- and 2 output buffers. From the 32 input buffers 24 are connected to different actuator handlers and 8 are used within the CRDP itself. This CRDP feedback is used for the modeling of complex instruments.

CRDP drives the CRIP processes via output queues. Each CRIP has its own queue for storing both data and commands. The DI and the SP units have additional queues for transmitting to the CRDP level the input changes received from the CRI electronics. Each CRIP process has its own flag and they are awakened by CRDP every 0.2 sec.

OPERATION MONITORING

Since the simulator is continuously used and consequently the Control Room Interface is permanently switched on, monitoring of its correct operation has utmost importance. Three different kinds of monitoring are needed, as

- monitoring the operation of the CRI units,
- monitoring the operation of the CRCS system,
- monitoring the data transfer in the network.

For monitoring the operation of the CRI electronics, each interface unit has a test card and a test program. The test card listens to the VMEbus and it generates an error signal if a peripheral board doesn't answer to the VMEbus system controller. In this way the erroneous cards are detected.

When an error is detected a test program can be started from a remote terminal. This menu driven program displays the following types of information on the terminal:

- the content of the last input/output data block,
- the content of the control table, which determines the operation of the given interface unit,
- the number of the communication errors registered since switching on,
- the actual values of the different control variables of the given unit.

Moreover, by means of the test program the value of any device can be overwritten.

Each unit checks the execution of the received commands and if an intolerable error occurs, a fatal error is reported to the CRCS system. In the CRCS a fatal error reception causes a break in the operation of the simulator and an error message is sent to the instructor.

In the CRCS there is also a monitor program. This monitor program can be started from any terminal of the simulator server. The monitor displays the following data:

- the content of any circular buffer of the CRDP program,
- the content of the input/output queues,
- states and error diagnostics of the CRIP processes.

A third program monitors the data transfer of the network. This program is executed in the simulator server and it has the following services:

- listing of the last data block of any interface unit,
- preparing input data blocks for testing purposes,
- displaying error counters of the different clients.

UPGRADE ORGANIZATION

The CRI upgrade was complicated enough not to start the project without any experience. For this reason first a pilot project had been started, in which only the SP part of the interface was built and installed in the simulator. This subsystem was selected for pilot installation, because few cabling was affected, but at the same time the most complicated devices had to be programmed. During this project the communication server-client program pair and the main programming structure of the interface were worked out. The real upgrade project has started only after the successful completion of the pilot project.

The upgrade was executed in a very tight time schedule, because the simulator is practically permanently used. The whole CRI electronics was manufactured in our institute and first it was installed at us. In the Simulator Department we have a simulation server identical to the one operating in the power plant, and the new interface was connected to it. One piece from each Control Room devices was connected to the interface and the operation of the new interface was tested in detail. However, only the device treatment was tested in this way, some controllers could not be tested without the Control Room. When the development and testing was completed, an in-house testing was organized with the representatives of the Buyer. The interface was delivered to the final site after the successful in-house testing.

At the final site the new interface was installed beside the operating old CAMAC interface. The testing was organized during prolonged weekends in steps. First the analogue cables were connected to the AO unit and the digital input/output cables remained on the old interface. In the CRCS system the CRIP driver of the analogue subsystem was replaced by the new one. All analogue signals were individually tested before the next installation phase has started.

In the second phase the digital input part was replaced, because it needed less cabling work than the digital output subsystem. Again every input device was individually tested.

In the third phase the digital output cables were also connected to the new interface and every output line was tested seriously.

The last testing phase has started when the whole Control Room was driven by the new interface. During this one-week long testing experienced instructors performed different transients in the simulator. During this phase some fine tunings were done, because in the mixed operation – when both old and new interfaces operate – the CRDP timings were determined by the slower old one.

After completion of the installation the old interface remained at its original place for about half year, in order to use it again if a serious failure occurs. Fortunately, it was not the case and finally the old interface was removed from the computer room and the cabling was finalized. Since this time the new VME interface has been operating continuously.

AUTHOR BIOGRAPHIES

JÁNOS BIRI received his M.Sc.E.E. degree at the Technical University of Budapest in 1960. He is member of ESONE, member of IEEE, member of the New York Academy of Sciences. Since 1970 he is the leader of the department for laboratory automation in KFKI-MSZKI. For his leading role in the development of the CAMAC modular real-time system, he was awarded with the National Prize of Hungary in 1980. His research fields include modular instrumentation for experimental physics, special analogue devices (e.g. analog - to - digital converters), real-time systems for laboratory measurement and automation.

LAURA BÜRGER received her M.Sc.E.E. degree at the Technical University of Budapest in 1958. She is member of the European Nuclear Society. Her research field is the application of computer technique in the nuclear industry. Previously she was interested in computerized methods of disturbance analysis. She took part in the Jánossy price awarded team realizing a computer based closed loop reactor control system on the Budapest Research Reactor. Presently her main interests are: real time data collecting and processing systems, simulators, etc.

GÁBOR HÁZI received his B.Sc.E.E. degree at the Kando Kalman College in 1992, M.Sc.E.E. degree in 1995 and Ph.D. degree in 2000 at the Technical University of Budapest. He is member of the Hungarian Nuclear Society. For his research activity, he was awarded with the Prize for Young Researchers of the Hungarian Academy of Sciences in 2001. His research fields include noise diagnostics in nuclear power plants and different aspects of thermohydraulic modeling.

LÁSZLÓ VARGA received his M.Sc.E.E degree at the Technical University of Budapest in 1980. In the early 80'ies he was the developer of the CPU module and programmer of a PLC called EV-01. Later he became a research fellow-worker at MTA-SZTAKI and participated in the software development for the Central Control Room of the Nuclear Power Plant, Paks. In 1998 he together with some of his colleges departed the institute and first founded a private company, called AKRIBIA which was mainly devoted to the development of a special data acquisition and archiving software also for NPP Paks. He is now responsible for software quality assurance at a successor company, called EASTRON. His main areas of interest are process control and data acquisition, microprocessors and microcontrollers, real-time operating systems, distributed systems and communication.

ENDRE VÉGH received his M.Sc.E.E. degree at the Technical University of Budapest in 1961. At that time he joined the Central Research Institute for Physics (KFKI), where he was engaged in the construction of nuclear instruments and in the development of different computer systems for the nuclear industry (reactor information systems, power plant simulators). In the period of 1980-1995 he was the head of the Simulation and Reactor Control Department. He is a member of the Hungarian Nuclear Society. His research fields include reactor core surveillance, plant computers, simulation of nuclear power plants.