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NEW HUMAN MACHINE INTERFACE FOR VR-1 TRAINING REACTOR

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ABSTRACT

The contribution describes a new human machine interface that was installed at the VR-1 training reactor. The human machine interface update was completed in the summer 2001. The human machine interface enables to operate the training reactor. The interface was designed with respect to functional, ergonomic and aesthetic requirements. The interface is based on a personal computer equipped with two displays. One display enables alphanumeric communication between a reactor operator and the control and safety system of the nuclear reactor. Messages appear from the control system, the operator can write commands and send them there. The second display is a graphical one. It is possible to represent there the status of the reactor, principle parameters (as power, period), control rods' positions, the course of the reactor power. Furthermore, it is possible to set parameters, to show the active core configuration, to perform reactivity calculations, etc. The software for the new human machine interface was produced in the InTouch developing environment of the WonderWare Company. It is possible to switch the language of the interface between Czech and English because of many foreign students and visitors at the reactor. The former operator's desk was completely removed and superseded with a new one. Besides of the computer and the two displays, there are control buttons, indicators and individual numerical displays of instrumentation there. Utilised components guarantee high quality of the new equipment. Microcomputer based communication units with proper software were developed to connect the contemporary control and safety system with the personal computer of the human machine interface and the individual displays. New human machine interface at the VR-1 training reactor improves the safety and comfort of the reactor utilisation, facilitates experiments and training, and provides better support of foreign visitors.

1 INTRODUCTION

This article deals with the human-machine interface upgrade at the VR-1 training reactor. This reactor is a pool-type light-water reactor based on enriched uranium (36%). The moderator of neutrons is light demineralised water that is also used as a reflector, a biological shielding, and a coolant.

The VR-1 reactor is utilised particularly for training of university students and nuclear power plant staff. The training on the VR-1 reactor is oriented to the reactor and neutron physics, dosimetry, nuclear safety and control of nuclear installations. Students not only from technical universities, but also from universities of natural science are coming to the reactor for training. Scientific research has to respect reactor parameters and requirements of the so-called clean reactor core (free from a major effect of the fission products).

The present control and safety system (I&C) of the VR-1 training reactor is digital. It utilises 8-bit microcomputers with software written in the assembly language. Even if the present control and safety system fully covers the demands that are put on it, its technical design is obsolete to a certain extent at the present time. There are also problems with maintenance because of a lack of spare parts. Furthermore, during development and production, some new internationally respected demands to ensure the quality and the qualification (e.g. the IAEA, IEC, and IEEE recommendations and standards) were not or could not be considered. Therefore, it was decided to upgrade the present control and safety system with the aim to apply the latest available techniques and technology observing the above mentioned recommendations and standards. The I&C upgrade has been carried out gradually since 2001. According to the plan, the complete upgrade will have finished by 2004. Because of the frequent utilisation of the VR-1 training reactor during the academic terms, it has been decided to carry out the upgrade during holidays so as not to affect the educational process at the reactor.

2 HUMAN-MACHINE INTERFACE AND THE REACTOR I&C

The human-machine interface enables the operation of the reactor and provides the interface between the reactor operator and the reactor I&C. A block diagram of the I&C after the complete upgrade [4] including the human-machine interface is shown in the Fig. 1.

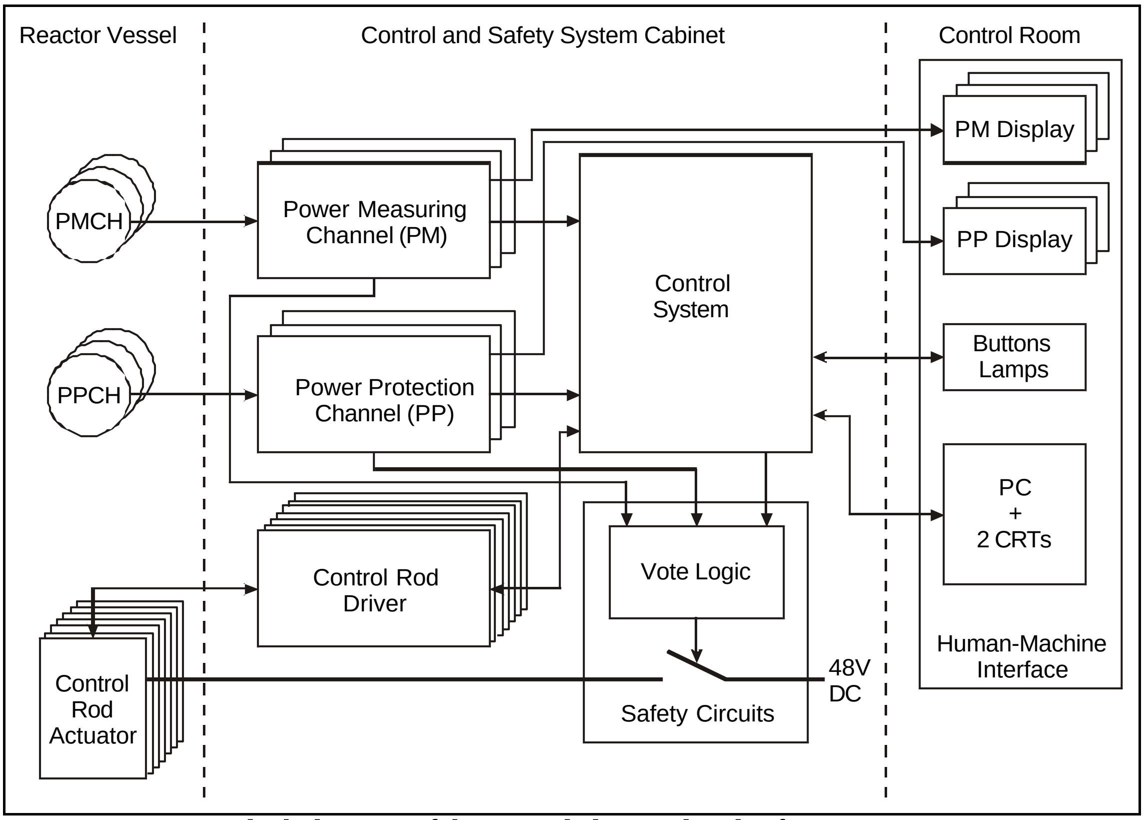

Fig. 1 Block diagram of the upgraded control and safety system

The safety part of the reactor I&C [1], [5] consists of three redundant power measuring (PM) channels with a fission chamber (PMCH) for full range neutron flux density and velocity of power change measurement and three power protection (PP) channels with boron chambers (PPCH) for independent power protection of the reactor. These channels evaluate the reactor status, and if the safety limits are exceeded, they initiate in the vote logic 2 out of 3 the safety circuits to scram the reactor because of control rod fall. These channels provide also data to adjacent individual displays that are situated on the operator's desk.

The control system receives data the from the power measuring and power protection channels, checks their values with each other and against safety limits. If either the safety limits or allowed deviations between individual channels are exceeded or there are any problems in the system, the control system requires a safety action. The control system calculates the average values of power and velocity and evaluates the deviation between the real power and the demanded power value set by the operator. If the deviation limit is exceeded, the safety action is also required. The control system sends data to a human-machine interface and receives commands from it. If the commands are permitted, it carries them out. The control system also serves as an automatic power control system and controls the movement of the control rods to achieve the required reactor power. The control rod movement is actuated by control rod drivers.

The human-machine interface serves for the communication between the control and safety system and the operator. It consists of a PC with two CRT displays, six previously mentioned individual displays, LED lamps to show the operational status of the reactor and buttons to control the reactor. The human-machine interface receives commands from the operator, evaluates them, sends them to the control system. It also receives messages from the control system and displays them and also stores data about the history of the reactor operation. The communication between the human-machine interface and the I&C is serial, utilising fibre optics.

2.1 New operator's desk and control room changes

The aim of the human-machine interface upgrade was to improve ergonomic and aesthetic properties of the operator's desk and the control room, to enhance the operator's comfort and thus to increase the utilisation of the reactor and nuclear safety [2]. The operator's desk of the training reactor has been completely changed. A new desk was installed (see Fig. 2). The desk was produced by the Reme Klášterec nad Ohří Company.

Fig. 2 New operator's desk

Old computer system based on an 8-bit microcomputer for alphanumeric communication and command recognition combined with a PC based graphical unit was replaced by a completely new one. The new PC based system is equipped with two large-scale CRT displays (19"), one for alphanumeric communication and the other one for graphical data representation. There are new control and safety buttons and indicators on the desk.

The individual displays of the power measuring and power protection channels were also upgraded. The old ones with non standard parallel data communication with proneness to a flicker and disturbance were replaced by new displays with the RS232 serial communication. On the old operator's desk were the individual displays only for the power measuring channels. Now, the individual displays for the power protection channels were added to improve their diagnostics, maintenance and calibration.

A large LED information panel was installed in the reactor laboratory. This panel provides information about the reactor status (power, velocity of power changes and deviation from the given power) or any message from the operator to the staff, experimenters or visitors. The panel communicates with the human-machine interface PC via the RS485.

2.2 Software for the human-machine interface

The human-machine interface has to receive data from the control system about the status of the reactor and equipment and to display them. It also has to receive commands from the operator, recognise and send them to the control system.

The old interface was based on the 8-bit microcomputer with software written in the assembly language. The extent of the software source code was large (about 300 Kbytes) and its maintainability low. The new interface is based on a standard PC with the operating system Windows 2000. The software for the new information system was prepared using the InTouch development tool. This development tool produced by the WonderWare Company that works in the Microsoft Windows 2000 environment is designed for industrial data acquisition and visualisation. The software was developed by ZAT Príbram Company [3]. The software recognises commands from the keyboard and sends them to the control system of the nuclear reactor. Moreover, it receives messages and data from the control system and displays them on the CRTs. Correct communication between the control system of the reactor and the PC is assured by the CRC checking.

Access to the software is permitted via username and password both for the Microsoft Windows 2000 and the application program. Users can have different rights to access the system, to set some parameters, etc.

The software utilises two CRT displays. One of them works in the alphanumeric regime; the other one is graphical. The written commands from the operator and messages from the system appear on the alphanumeric display. The 'Standard' mode of the graphical display is shown in Fig. 3. In the top middle of the picture, there are the principal parameters of the reactor operation – the power, the velocity, the deviation and the given power. The first three values are calculated as the average of the active power measuring channels; the operator sets the fourth one. At the top right, there are current positions of control rods. Bellow the control rods window, there are weights of the individual control rods. The neutron source position (NZ) and communication status (KOM) are displayed between the average values window and the control rod positions. At the top left, there is the status of the control and safety system with possible warning and safety announcements. In the centre of the figure, the power course of the reactor during the last 5 minutes is displayed with a vertical logarithmic scale. The buttons at the bottom enable the change of mode on the graphical display from 'Standard' to the other ones.

The following display mode is called 'Graphs'. In the 'Graphs' mode, it is possible to display the reactor power, velocity and deviation in different vertical (variable value) and horizontal scales (time). This mode is very helpful for experiment evaluation and study of an operational history. The next mode of the graphical display is 'Core config'. It enables to display the present configuration of the active core. The mode 'Rods' provides calculation of rod weights in different positions. The mode 'Figures' displays different pictures on the hard disc of the computer, e.g. block scheme of the control and safety system, photographs. The mode 'Tools' enables setting of parameters, users and user passwords for a user with sufficient access rights. The last 'Log' mode displays system messages.

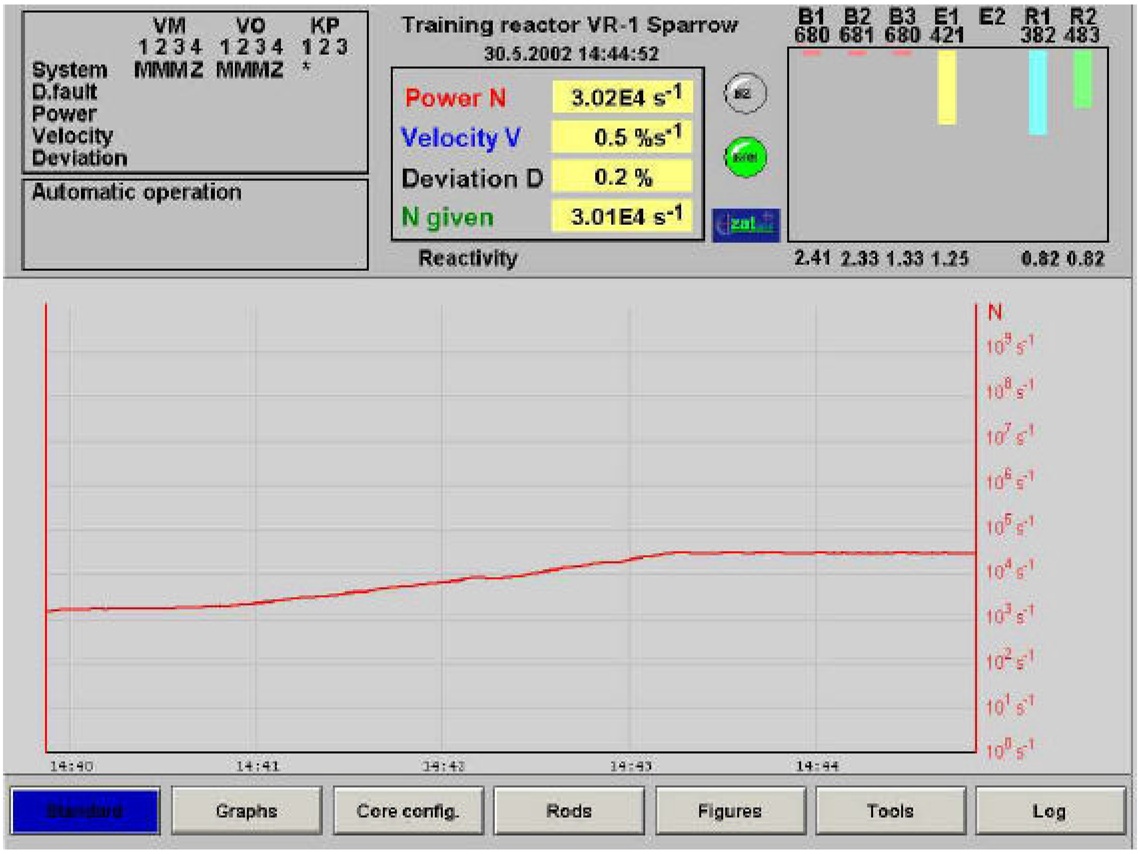

Fig. 3 Standard visualisation on the graphical CRT display

The software of the information system can be switched to operate either in Czech or English language. This is important for foreign visitors and training course participants.

The reactor operational history is stored on the PC's hard disc, and the software provides tools to study it later (e.g. the 'Graphs' mode on the graphical display). The software also enables data about the operation to be sent via a computer network. This feature will be utilised in the future for the evaluation of reactor experiments with a new data acquisition and evaluation system that is prepared with the support of an IAEA grant. Furthermore, data could also be presented on a WWW page to offer on-line information about the reactor operation for the public (this option will be put into operation during the year 2002).

2.3 Connection to the present control and safety system

According to the requirements for the gradual upgrade of the VR-1 reactor I&C, it was necessary to connect the new human-machine interface PC with the present control and safety system. It was decided that the connection will be serial, utilising either a RS232 or fibre optics line. Further, it was necessary to connect new individual displays to the present power measuring and power protection channels. The previous displays were driven by a particular hardware with parallel data communication. The new displays are based on a serial communication.

The principal requirement for the human-machine interface upgrade was that no changes of the software important to safety would be necessary. This requirement is tightly connected with the displays of the power measuring and power protection channels. It was necessary to get a communication unit that fits into the old 8-bit microcomputers utilised in the power measuring and power protection channels and is able to receive parallel data as the previous particular hardware, translate them into the proper format and send them to the new individual display via a RS232 serial line.

There was no suitable hardware available to fulfil requirements mentioned above, so it was decided to develop such a communication unit [7]. A block diagram of the communication unit is shown in the Fig. 4. The communication unit is based on the microprocessor Z80181. This microprocessor is a successor of the popular Z80 one with enhanced memory management, direct memory access and integrated peripherals. The Z80181 microprocessor provides three integrated serial lines that are utilised in the communication unit. The microprocessor is equipped with an EPROM big enough to store software, a RAM to store data and an EEPROM for unit's setting.

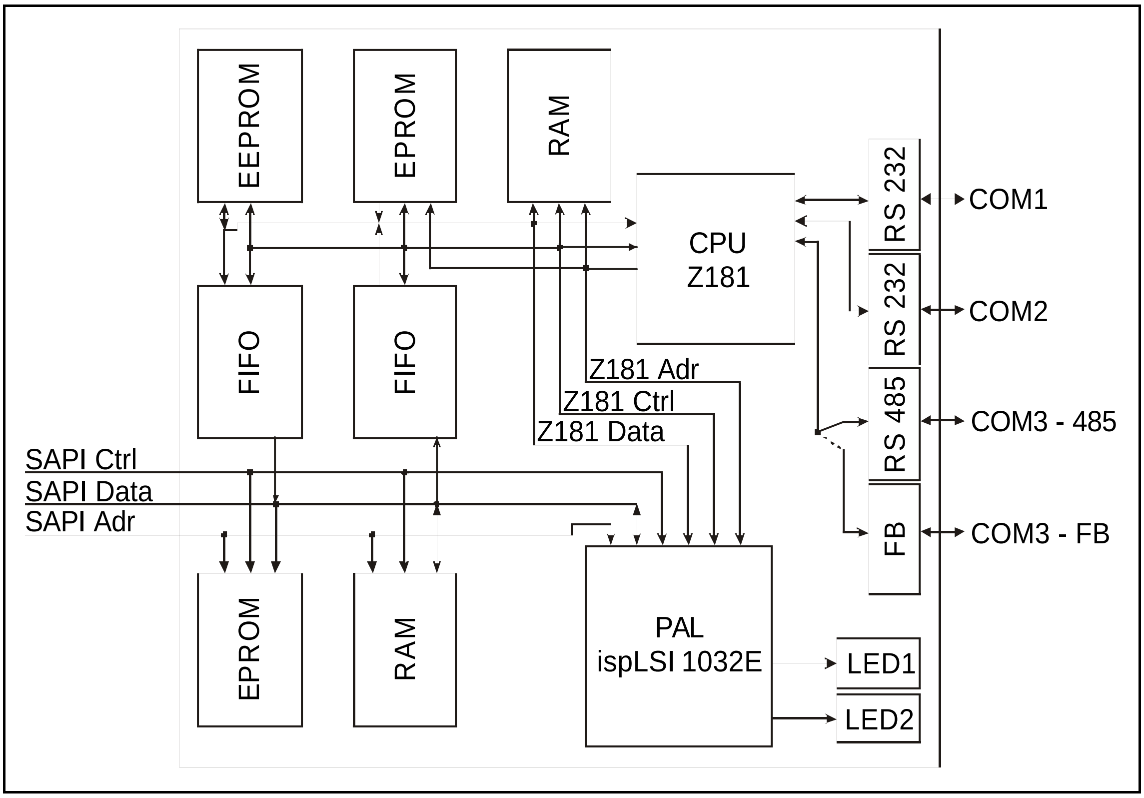

Fig. 4 Block diagram of the communication unit

FIFO (First In First Out) buffers are used for data transfer between the communication units and adjacent computers. The FIFO buffers are unavoidable because the data from the power measuring and power protection channels are sent very fast (every 3 microseconds in the worst case), and the microprocessor would not be able to receive them even in the interrupt regime. The message is then written into the FIFO and consequently read by the microprocessor. The present-day available FIFO buffers are very fast, and thus there were problems with the quality of their read and write signals. The termination of these signals was found essential.

The programmable logic array ispLSI1032 from the Lattice company is utilised as the ‚glue logic‘ of the microcomputer. The programmable logic array is responsible for addressing of individual components, driving of FIFO and data buffers, controlling of on board indicators and providing the status of the board. Furthermore, timers for delay and real-time purposes are implemented into the programmable logic array. The data for programming of the logic array were prepared in the Hardware Definition Language with the development tool Lattice ISP Expert 8.0.

The communication unit offers also the possibility to place up-to-date EPROM and RAM memories on the board for the adjacent microcomputer program and data and to substitute the old fashioned memory board REM-1 of the SAPI-1 microcomputer.

There are three serial lines on the communication unit board. Two of them are RS232 with the maximum data transfer rate up to 57600 Baud. The third one can be connected by a jumper either to the RS485 or to the fibre optics interface. Both options on the third serial line can provide a galvanic isolation if necessary.

The same communication unit was also utilised for the communication between the control system and the human-machine interface PC. This communication unit is installed in an 8-bit microcomputer that is connected to the system bus of the control system and serves as a bridge between the control system and the PC. On one hand, the bridge receives data from the system bus and sends them via the communication unit to the PC; on the other hand, it receives commands and data from the PC through the communication unit and sends them to the system bus.

The basic firmware of the communication unit is the program ‚Monitor V1.3‘. It provides the possibility to load, start and debug programs, to control communication via serial lines, etc. AREM PRO LTD granted the monitor. Two different application programs were developed for the communication unit. The first software drives the individual displays. It receives data from the power measuring and power protection channels written into the FIFO buffer, converts them from the old format and sends them via the serial line to the display. The software together with the developed hardware guarantees that no changes are necessary in the power measuring and power protection channels software, and that the new displays operate in the same way as the old ones. The second software controls communication between the control and safety system and the human-machine interface PC. It receives messages from one side, completes or checks CRC and provides data to the other side. All this software was written in the assembler. The macro assembler SASM and the linker SLINK of the Softools company were utilised for compilation and linking of the programs.

3 CONCLUSION

The aim of this article was to describe a new human-machine interface at the VR-1 training reactor. The human-machine interface and the control room were upgraded in summer 2001. This upgrade substantially improves the comfort of the reactor operation, facilitates the work of the reactor staff and thus also enhances the nuclear safety. It also provides more support for carrying out and evaluation of experiments. The interconnection of the interface with the new data acquisition and evaluation system, which is being developed with a support of IAEA, will also improve the comfort of experiments and training. The possibility to change the user interface between the Czech and English version enables better reactor utilisation for foreign visitors and users. The storage of the reactor data provided by the control PC enables more detailed evaluation of experiments and exercises that were carried out. The data serve also as the documentation of the reactor safe operation. The real data and the stored operational history will also be used for the WWW presentation of the VR-1 training reactor [6].

The training reactor VR-1 is very intensively utilised for training, and every year some 200 university students get acquainted with the reactor to a smaller or larger extent (lectures, experiments, experimental and diploma works, etc.). About 12 faculties of Czech universities use the reactor, e.g. Czech Technical University in Prague, Charles University in Prague, Technical University in Brno. International co-operation is also frequent. Worth mentioning is the co-operation with the European universities like Fachhochschule in Aachen, Technical University in Budapest, Technical University in Vienna, Slovak Technical University in Bratislava, Technical University in Delft and the involvement of the reactor in the European program ENEN for nuclear education. All users can now utilise the advantages of the new human-machine interface.

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