# EXPERIENCE IN RENOVATION OF THE CONTROL AND INSTRUMENTATION SYSTEM OF THE DALAT NUCLEAR RESEARCH REACTOR

**T. H. Anh, N. N. Dien, T. D. Hai**
Nuclear Research Institute, Vietnam

## ABSTRACT

The Control and Instrumentation System (CIS) of the Dalat Nuclear Research Reactor (DNRR) was designed and manufactured by the former Soviet Union and put into operation in November 1983. In general, the system has had good reliability and proved its ability to ensure reactor safety operation. However, spare part procurement problems were expected and, due to using technology of the 1970s with discrete and low-level integrated electronic components, the system technology became obsolete and unsuited to a tropical climate. After ten years of reactor operation, the CIS's reliability was degraded because of aging of equipment and electronic components. Those were the main reasons for the system renovation and modernization.

## 1 INTRODUCTION

Under the assistance of the International Atomic Energy Agency (IAEA), a Technical Co-operation Project entitled "Renovation of the Dalat Reactor Control System" was implemented. The renovation work was carried out by Nuclear Research Institute (NRI) staff during the 1992-1993 period and, since October 1993, the reactor has been operating with the renovated control and instrumentation system.

The most important renovation task was to re-design and construct a number of electronic systems/blocks that play the key role in enhancing the reliability of the system. In the new design, the operating principle of the old system had to be kept unchanged. It should make use of high quality and modern components and equipment in order to ensure long-term reliability and ease maintenance work. In addition, the new design had to meet strict technical and safety requirements.

The main results obtained from the renovation work are as follows:

1) Redesign and rearrangement of the control panels and reactor control console in the reactor control room. The size and number of control panels have been reduced. Four of seven control panels were removed but all the control and monitoring functions of the old system were retained.

2) Replacement of the reactor operation parameter's monitoring system. The new system was built using an industrial grade PC-AT and advanced data acquisition add-on cards.

3) Design and construction of a position indication block and a dropping time measuring block for the control rods.

4) Design and construction of a new PC-based 12-channel dosimetry system. The electronic blocks of this system were built in Eurocard standard with an interface to a PC. The information on radioactivity level is displayed digitally and graphically on the PC monitor. Data can be saved on PC hard disk.

5) Replacement of some equipment of the reactor Process and Instrumentation System (PIS). Main reactor technological parameters are measured, recorded and displayed on the reactor control console -

flow rates of primary and secondary cooling water loops, water levels in the reactor and supplement tanks, temperatures at various locations in the reactor tanks, etc.

This paper overviews the main experiences obtained from renovation and modernization of the DNRR's control and instrumentation system.

## 2 DESCRIPTION OF THE REACTOR CONTROL SYSTEM

The control and instrumentation system of the DNNR can be divided into four main parts:

1) Neutron Flux Control System (NFCS)
2) Reactor Data Display System (RDDS)
3) Control Logic System (CLS)
4) Process and Instrumentation System (PIS).

### *2.1 Neutron Flux Control System - NFCS*

The NFCS system has the function of measuring reactor power and period; generating an analog signal proportional to the unbalance between reactor and setting powers, alarm and scram signals on power and period for each measuring channel. All these signals are led to the CLS to be processed and to produce acting alarm and scram signals).

The NFCS system consists of three identical and independent electronic units namely the Information Acquisition and Processing Unit (IAPU). The wide range in reactor power generally makes it impossible to use a single detector channel. In our case, neutron-flux density in ten decades ($10^{-8}$ - $1.2 \times 10^{2}$ %Pn, Pn = 500 kW) is covered by three overlapping measuring ranges by nine individual measuring channels (three channels in each IAPU): source range (SR) - $10^{-8}$ - $10^{-2}$ %Pn, intermediate range (IR) - $10^{-3}$ - 10 %Pn and power range (PR) - 1 - 120 %Pn. To control the reactor neutron flux, 9 neutron detectors with gamma compensation have been used (6 type KNK-15 fission chambers and 3 type KNK-3 ionization chambers). The KNK-15 chambers, operating in pulse mode, are used for SR and IR ranges and the KNK-3 chambers in current mode are used for PR range.

### *2.2 Reactor Data Display System - RDDS*

The designed system has been used for 1) presenting on a monitor screen, by digit and line modes, reactor important parameters, such as power and period values of nine measuring channels in three ranges, the averaged values of reactor power and period in each range, beginning and ending values of each range, safety threshold values of reactor power and period, reactor negative period etc.; 2) recording reactor power and period on a 2-pen recorder; 3) emitting alarm signal if any parameter is abnormal; 4) managing and saving data in PC hard-disk.

Because of low reliability and low quality of indication, the RDDS system was totally re-designed and constructed according to the VIE/4/010 project program.

### *2.3 Control Logic System - CLS*

The system has the functions of controlling the reactor in manual and automatic modes; shutting down the reactor at power or period scram signals, scram signal from the PIS system or failure of the city electricity network; indicating on control console status information of the whole reactor control and instrumentation system.

To control the reactor, 7 control rods have been used (2 safety rods - SR, 4 compensation rods - CS and one automatic regulation rod - AR).

In order to increase accuracy and reliability of rod position indication and rod dropping time measurement in the framework of the renovation project, the rod position indicators and related electronic boards have been re-designed and replaced. The indicators are of a digit and bar-graph. Besides, all relays in the intermediate relay boards and all transistors in the amplifier boards have been replaced by items with a higher quality and reliability. Decreasing currents to LED indication and consequent decrease in power consumption in all electronic boards has an important meaning in the reliability improvement of the CLS system.

### *2.4 Process and Instrumentation System - PIS*

The PIS of the Dalat reactor has the following functions:

1) Measuring and recording/indicating the reactor technical parameters such as temperatures in various locations in the reactor tank, inlet and outlet temperatures of the primary and secondary cooling loops at the heat exchanger; lost water levels in the reactor and other tanks and in the reactor hall sump; water flow-rates of the primary and secondary loops; air flow-rate from the reactor tank space and in the reactor stack; pressure at some points on the primary and secondary loops; conductivity of reactor water before and after passing the water purification system of the primary loop.

2) Creating alarm and scram signals on water level of the reactor tank and water flow-rates of the primary and secondary loops and sending these signals to the CLS system to shut down the reactor. The PIS system has been totally renovated in the framework of the VIE/4/010 project.

## 3 MAIN RESULTS FROM THE RENOVATION AND MODERNIZATION WORK

### *3.1 Reactor Data Display System*

The PC-based system for monitoring reactor operation parameters received from the NFCS system was designed and installed in the reactor control room. The system has the function of acquiring, displaying and saving information on reactor power and period of each measuring channel; alarm and warning setting thresholds for reactor power and period of each channel; working range values of the reactor, etc. The system was built upon the electronic modules in Eurocard standard and interfaced to a PC through an advanced data acquisition add-on card.

The block diagram of the display system is illustrated in Figure 1. The hardware of the system consists of two parts: an Eurocard crate with the functional electronic modules and the central unit with a PC and the add-on cards. The first part contains the chopper isolation amplifier boards on analog devices AD204, a 64 to 16 multiplexer board and a 16-channel active filtering board. The second part consists of a PC-AT, an ADC/DAC industrial multifunction card (PCL-812), an interfacing board to LED indication block located on the reactor control console. The parameters are presented in digital and graphic types on the PC monitor.

One of the essential requirements of interfacing of reactor signals with the computer is that any malfunction in the computer must not be transmitted to the reactor control system. This is achieved by providing proper isolation between the reactor signals and the computer interface. Each input channel of the data display system is galvanically isolated from the signal source for maximum instrumentation isolation and protection.

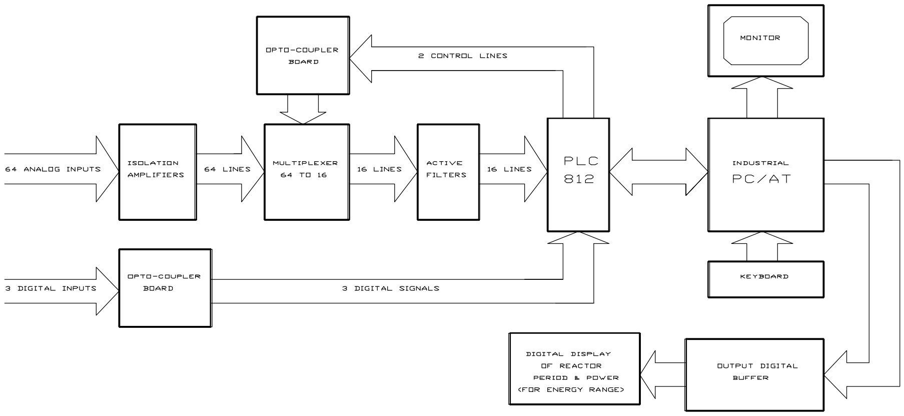


**Figure 1  Block diagram of the PC-based reactor data display system**

### *3.2 Reactor Data Logging System*

When the DNRR is in operation, many technological parameters have to be monitored continuously. They include the signals of reactor power  and period in different power ranges, position of control rods in the reactor core, flow rates of primary and secondary cooling water loops, temperatures at various locations in the reactor tank, temperatures at the inlets and outlets of the heat exchanger, water level in the reactor tank, water conductivity at the inlet and outlet of the filter system, etc. Totally there are 36 analog signals to be monitored. Besides, more than 10 digital signals are used to indicate the status of the different facilities. In order to automate the task of monitoring and processing of the important technological signals, storing them, as well as presenting instant warning to the operating personnel about the abnormal variation of the parameters, an automatic data logging system has been designed and constructed, built upon Eurocard standard and interfaced to the PC.

Values of the process parameters are converted into electric signals by sensor-transducer blocks. These converted signals are usually in the industrial standard form of current  (4 to 20 mA) or voltage (0 to 100 mV). The multichannel electronic boards including the DC amplifiers for small signals and the large range V to F or I to F converters with high linearity have been designed to convert the measuring signals to frequency, which makes it easy to isolate the front-end electronic signals to the acquisition and processing central unit. A multi-functional interface board consisting of a programmable timer, 32 channels of 16-bit counters, 24-bit digital input/output port, etc. has been made and plugged into one of the 8-bit extension slots of  PC. The block diagram of the system is shown in Figure 2.

The system also enables saving the measured parameters in hard disk periodically. The time interval between two successive recordings can be changed via the keyboard. The system also gives warning signals in the forms of sound or different colors flashing message on the computer screen immediately whenever the value of any parameter exceeds or falls below the set limit.

The system user-friendly designed provides the operator and reactor users a quick overview of the status of the reactor and its control system. Based on the information collected by this system and its software program in Turbo Pascal language, the on-line calculation and display of several reactor physics parameters can be performed and reactor physics experiments can be carried out conveniently.

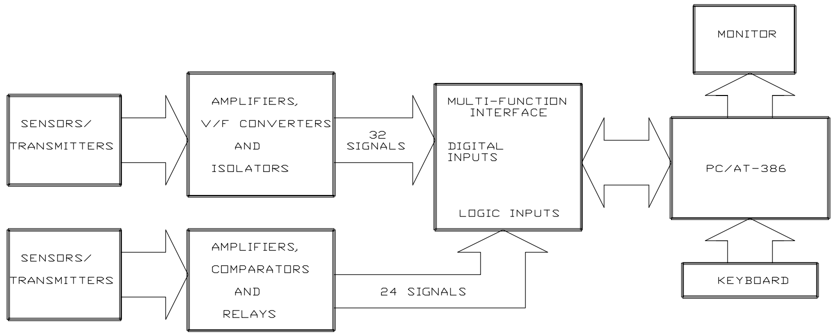


**Figure 2** Block diagram of the reactor data logging system

### *3.3 Area Monitoring System*

The multi-channel dosimetry system for area monitoring at the Dalat reactor is based on a set of individual measuring probes. The system is used for detection and measurement of ambient gamma radiation as well as for processing, displaying and storing information on radioactivity levels at 12 different positions in the reactor building, reactor control room and in the rooms where technological equipment is installed. System hardware consists of three essential parts: probes, central unit and alarm devices. As sensing elements, 12 GM type gamma counters tubes with shaping circuits are used. The electronic blocks of the central unit have been built in Eurocard standard with an interface to the PC. An intermediate relay board to control the alarm devices is located in the same crate with the central electronic modules. The block diagram of the dosimetry system is shown in Figure 3. The system has the following functions:

1) Continuously measuring radioactive level at 12 points.
2) Displaying count rate/dose rate in digital and graphic form on the PC's monitor.
3) Giving light and sound warning signals whenever the radioactive level exceeds the setting value.
4) Recording information on count rate/dose rate into the PC's hard disk.

In the counter/timer board of the central unit, four IC Intel 8253 are used to set up 12 counting channels and one IC 8253 is used as a programmable timer. 12 channels are simultaneously counting by the "Start" command sent from the computer and stopped counting by the timer interruption. The counter/timer board is connected to the computer via add-on interface card using either interrupt function (IRQ3) or flag setting (DB0 on data bus of the PC).

Whenever radioactive level at any monitoring place exceeds a set level, the control program from the PC gives out a signal to the intermediate relay board to warn by lamp and buzzer at the detector place as well as at the reactor control room.

Application software permits display both in the graphic and digital modes. For this purpose, the screen of the PC is divided into four windows where each window can display three channels but only one channel is visual. It means that, at the time on the screen, only four channels are visualized, but the operator can see any channel by pressing a pre-assigned function key. In case the signal value of any of the radiological channels exceeds the preset level, a visual alarm indication appears on the corresponding window. The alarm can be reset by the operator but the visual indication remains as long as the alarm condition persists.

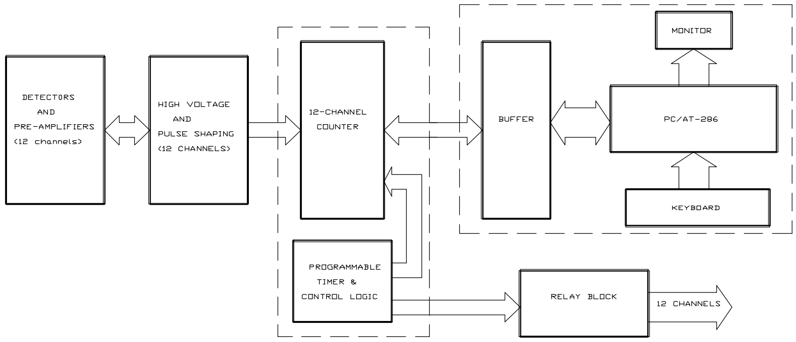


**Figure 3.** Block diagram of the reactor dosimetry system

### *3.4. Effluent Monitoring System*

The effluent monitoring system is a computer-based, cart-mounted system designed to monitor gaseous effluent samples of radioactive particulate, iodine, and noble gases released from the reactor stack. The system consists of a particulate detector and an iodine detector in a compact shielding sampling chamber, a noble gas detector that is mounted inside of the chimney for greater sensitivity, a vacuum pump, an air flow meter, control valves, a programmable logic control (PLC), amplifiers, timing single channel analyzer and high voltages for NI(Tl) scintillator detectors. All of this is located at the bottom of the reactor stack. The computer and printer located in the reactor control room 100 m away from the chimney (Figure 4).

The amplifiers, timing single channel analyzer and the high voltages are modular and self-contained units in a standard Eurocard system designed for ease of operation, maintenance and replacement or repair. The PLC at the front end is used to control the elevator and the vacuum-pump, as well as to sense the valve positions. The PLC displays the actual status of the system on a front-plate and reports the status on request to the computer via an RS-232 link.

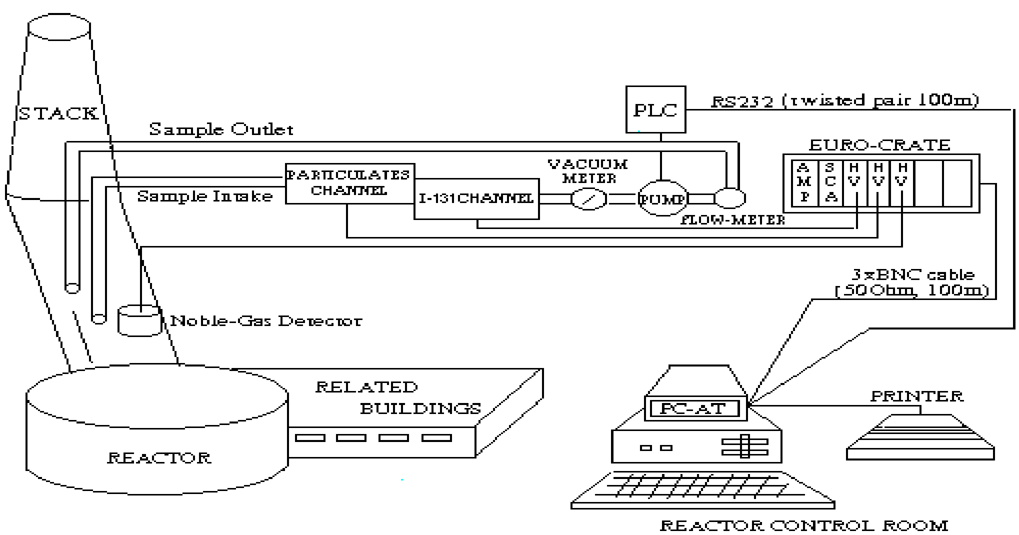


**Figure 4** Functional block diagram of the effluent monitoring system

The PC-AT computer is used for counting, data acquisition, computation and evaluation, presentation in straight understandable way, warning and alarm setting, and data recording and reporting to the relevant authority. Data are periodically recorded on the PC's hard disk. The printer prints out results in case of alarm or upon request. Air flow rate, radioactivity concentration on the filters of particulate and iodine, and emission rates of radioactive particulate, iodine and noble gas are presented on the PC's monitor.

The software program is written in Turbo Basic and Assembler languages with the main features of:
a) visual access to all incoming data; b) pre-adjustable alarm levels which are continuously displayed;
c) data are being recorded under working conditions and in case of an alarm and can be printed at any time upon request; and d) all changes of the normal working conditions like taking Grab-sample or making a Purge are recorded on the PC's hard disk.

## 3.5 Renovation of the Process and Instrumentation System

In the framework of the VIE/4/010 project, the PIS system has been totally re-designed and replaced. Most industrial equipment used in the renovated system was ordered from H&B company, but electronic modules and cards have been in-house made by the Dalat NRI's staff.

### 3.5.1 Temperature Measurement

In order to measure temperatures at various locations in the reactor tank, at the inlet and outlet of the primary and secondary loops at heat exchanger, etc., resistance temperature detectors (RTD) of the Pt 100 type have been used. These RTDs are connected to type TEU-7 transmitters. The output current of transmitters is in industrial standard with range of 4-20mA.  This current is used for driving type SK12 2-pen recorders and for display on 3½ digit LED DMP digital indicators. The temperature measuring range is of 0-50$^{o}$C or 0-100$^{o}$C. The recorders have alarm functions with adjustable setting.

### 3.5.2 Flow Rate Measurement

The measuring loops for water flow-rates of the primary and secondary cooling loops consist of diaphragm sensors, type ARK 500 differential pressure transmitters and 2-pen recorder with alarm value monitoring function. The water flow-rate measuring ranges are 0-63 $m^3$/h and 0-100 $m^3$/h. Whenever water flow-rate becomes lower than a set value, the recorder emits a scram signal. This signal is transmitted to the CLS system to shut down the reactor. One switch will lock the 48 V DC power supply for feeding the control rod servo-drives, then raising the reactor power is prohibited.

The measuring loop for water flow-rate in the water filtering system has a sensor/transmitter supplied by RS company with the range of 0-2.5 $m^3$/hr, current to voltage converter and digit indicator type 3½ digit LED DMP digital indicators.

The measuring loops for air flow-rate exhausted from the reactor tank space and of the reactor stack consist of Venturi sensors, differential pressure transmitters, amplifiers and digital indicators. The air flow-rate measuring ranges from the reactor tank space and the reactor stack are 0-32,000 $m^3$/h  and 0-3,200 $m^3$/h respectively.

### 3.5.3 Water Level Measurement

The gross measuring loop for lost water level in the reactor tank contains a pressure sensor pipe sank in the reactor tank with depth of 4 m (measuring range 0 - 4 m), type ARK 200pressure differential transmitter, electronic circuit for emitting alarm (water level lower than 30 cm from full level) and scram (water level lower than 60 cm from full level) signals and 3½ digit LED DMP digital indicators. The alarm and scram signals are transmitted to the CLS and to the indication circuit to emit flashing light and bell sound. In order to prohibit starting the reactor one switch locks the 48 V DC power supply when the loop is in checking mode.

The fine measuring loop was installed to strictly and accurately control reactor water level. The loop has a pressure sensor pipe sunk into the reactor tank to a depth of 20 cm (i.e. the measuring range is 0 - 20 cm), type ARK 200 pressure differential transmitter and 3½ digit LED DMP digital indicators.

The measuring loop for water level in the reactor back-up tank contains a pressure sensor pipe sunk in the tank to a depth of 1 m (measuring range is 0 - 1 m), type ARK 250 pressure differential transmitter and 3½ digit LED DMP digital indicators.

### 3.5.4 Pressure measurement

In order to control the operation status of pumps, valves, mechanical and ion filters in the primary and secondary loops, pressure meters have been installed at some measuring points and at places easy for operator reading. The pressure meter at outlet of the primary loop pump has an alarm contact to emit signals when the pressure at outlet is lower than a preset value. The signal switch on a *"No cooling water for pump"* lamp.

## 4 CONCLUSION

Under the VIE/4/010 project, besides activities related directly to the renovation of the reactor control and instrumentation system, the radiation protection problem was more stringently resolved. A number of computer-based systems have been designed and developed. The main configuration of each system is to contain sensing elements; functional electronic modules, each having specific application; central computer or microprocessor units and output devices. These systems are now working on their separate hardware and software features. In the near future, for their development, improvement and effective utilization, these systems would be linked through the local computer network system. The use of PCs as an operator aid has been found to be highly beneficial for operation and maintenance related tasks and has a potential for applications in many different areas.

During the last three years, the renovated control system has been operating with high reliability and has given higher confidence on reactor safety.

## 5 REFERENCES


[1] Nguyen Nhi Dien. The Dalat reactor instrumentation and control system after renovation. IAEA Technical Committee Meeting on Technology and Trends for Research Reactor Instrumentation and Controls. JSI, Ljubljana, Slovenia, 4-8 December 1995.

[2] Nguyen Nhi Dien et al. Application of personal computers to the control system of the Dalat Nuclear Research Reactor. International Workshop on Control Systems for Small- and Medium-Scale Accelerators. Tsukuba, Japan, 11-15 November 1996.