EXPERIMENTAL STUDIO—NEW DATA ACQUISITION SYSTEM FOR EXTENDED EDUCATION AND TRAINING AT VR-1 REACTOR

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Abstract

The training reactor VR-1 was commissioned in 1990 at the Czech Technical University in Prague. It is a zero power reactor utilized mainly for education and training. Czech Technical University as a reactor licensee makes permanent effort to improve the reactor equipment, instrumentation and develop the educational and training methodologies. It is way how to provide effective education and training and keep the reactor attractive for the students and other users. The example of such improvement is new data acquisition system which has been connected to the human machine interface of the VR-1 reactor. It is based on a computer with software application called Experimental Studio. The application allows processing and easy analyzing the wide range of on-line reactor operational data (e.g. power, change of power rate, actual position of control rods or external neutron source) independently on the reactor safety and control system. Experimental Studio was designed and developed in a close cooperation between Czech Technical University and dataPartner Company. It was made as a dialog application within definable project to provide data acquisition from a human machine interface; data processing; data presentation in the form of a table or a graph; and data output.

1. INTRODUCTION

The paper presents the new data acquisition system which has been installed at the training reactor VR-1. The reactor is operated by Czech Technical University in Prague (CTU) more than 20 years. It is a pool-type light-water reactor utilizing 20% enriched uranium. Its thermal power is up to 5 kW. The neutron moderator is light demineralised water, which is also used as a reflector, biological shielding, and coolant. Heat is removed from the core by natural convection. The pool design of the reactor facilitates access to the core, setting and removing of various experimental samples and detectors, and easy and safe handling of fuel assemblies. The cadmium control rods serve the reactor control and safe shutdown. Construction of all rods is identical, they differ in their functions (safety, compensation or control) according to the connection with the control and safety system (I&C). A neutron source is used to start up the reactor. The source ensures a sufficient signal level at the output of the power measuring channels from the deepest subcriticality and thus guarantees a reliable check of the power during reactor startup. The reactor is utilized primarily for training of university students and nuclear power plant staff [1]. The training at the VR 1 reactor is oriented towards the reactor and neutron physics, dosimetry, nuclear safety, and control of nuclear installations.

The data acquisition system at VR-1 reactor was significantly improved by installation of software application called Experimental Studio in the computer for evaluation of experiments. The computer is connected to the reactor human machine interface (HMI). In order to provide the HMI and all reactor I&C security, the communication is based on a one way fiber optics line with output from the HMI. This measure provides protection of HMI and I&C against external influences. The Experimental Studio enables processing and user-
friendly analysis of on-line or off-line reactor operational and experimental data. The next significant part of VR-1 reactor data acquisition system is history server. The history server is a computer ensuring continuous storage of all operational data from the reactor I&C. It is connected to the control system and to the HMI and stores the data every 0.1 second. These data can be used either for evaluation of reactor experiments or documentation of the safe reactor operation. The storage capacity of the history server makes possible to store operational data at least for ten years. Parallel hard disc drives are used for safe data storage.

2. MAIN COMPONENTS OF DATA ACQUISITION SYSTEM AT VR-1

The data acquisition system of VR-1 reactor has currently three basic components: the history server, the HMI computer (HMI PC) and the computer for evaluation of experiments. All these components enable working with actual (on-line) or previous (off-line) reactor operational data. Figure 1 depicts location and interconnection between individual components of the reactor data acquisition system.

![FIG. 1. System for data acquisition at VR-1 reactor.](image)

The control system\(^1\) sends operational data to the HMI PC and to the history server [2]. The HMI PC communicates with the reactor control system and the history server via an Ethernet computer network. The PC for evaluation of experiments is connected to the HMI PC via one way fiber optics line. The HMI PC sends continuously all reactor operational data

\(^1\) Control system controls the VR-1 reactor operation and provides the I&C diagnostics. It also serves as an automatic power control system; it controls the movement of the reactor control rods to obtain the required reactor power. Furthermore, it calculates the average values of the important variables (e.g. power, power rate). The control system sends data to the HMI PC, receives commands and button inputs from the operator's desk and carries them out according to the reactor operation mode.
to the PC for evaluation of experiments which allows on-line data processing by the software Experimental Studio.

Finally, the reactor operational data can be sent from the PC for evaluation of experiments through the LAN network to any workstation administrated by students in the reactor laboratory.

2.1. HMI computer

The HMI computer [3] is principal part of the VR-1 reactor human-machine interface. It consists of the IBM compatible PC with enough computational performance equipped with AMD 3.11 GHz microprocessor, 4 GB RAM and 500 MB HDD. The HMI PC communicates with the reactor control system and the history server via an Ethernet 100 Mb/s computer network. The Microsoft Windows XP operating system is used in the HMI PC. The HMI PC is located in the reactor control room.

The data pack sending to the HMI PC from the control system consists of average values of the reactor power, power rate, the power and power rate values from individual operational and independent power measuring channels, control rod position, system status, etc. The HMI PC provides visualization of received data; stores them into the history server and sends them on-line to a PC for evaluation of experiments.

2.2. History server

The history server [4] stores data from the operational history of the VR-1 reactor. It is an IBM PC compatible industrial computer using two 500 GB HDDs with RAID1 (mirroring) for high reliability of stored data. The server is connected via the Ethernet network to the control system and the HMI PC and stores all operational data every 0.1 second. The history server also provides the previous data to the HMI PC upon request (off-line data). These data can be also transferred from the HMI PC to the PC for evaluation of experiments. The history server is situated in I&C room at the reactor laboratory.

2.3. Computer for evaluation of experiments

A PC for evaluation of experiments [5] is the IBM compatible PC equipped with Intel 2.33 GHz microprocessor, 4 GB RAM and 500 MB HDD. Processing and analysis of the reactor operational data enables software application called Experimental Studio which is installed in this PC.

The high speed serial card MOXA with fiber optics interface and baud rate up to 921 kb/s is used for communication with the HMI PC. The communication between the PC for evaluation of experiments and the HMI PC is, from safety reason, based on a one way fiber optics line (from HMI PC to for evaluation of experiments). This measure ensures protection of the HMI PC against external influences. The computer for evaluation of experiments is located in the reactor control room.

3. EXPERIMENTAL STUDIO

Experimental Studio is a software application [5], recently installed at the VR-1 reactor, which enables processing and user-friendly analysis of reactor operational and experimental data. It is principal software part of the reactor data acquisition system. It was designed and developed in a close cooperation between CTU and dataPartner Company as a dialog application to perform following tasks:
— Data acquisition from a HMI;
— Data processing;
— Data presentation (display) in the form of a table or a graph;
— Data output.

3.1. Description of application

Figure 2 shows main window of the application with a project example. The application window is divided into two parts. The left part contains primarily the tools for design, creation, setting and management of the project. The right part serves as project workspace. It contains the basic components of the project – the modules. The modules serve the required functionality within the project solution.

The application menu is situated in the top part of the window. The menu contains options to start new projects, open an existing project, save the project, save the project to a file and exit the application.

The application offers three basic tabs for the project development and management:

— Project manager;
— View data in graph;
— View data in grid.

First tab (Project manager) enables to develop, control, edit and view the project structure (all modules and their interconnection). The second one (View data in graph) allows to display data items of the project in a graph and the third tab (View data in grid) enables to present data items of the project in a tablet.
Another three tabs are active within the Project manager. They are called Project, Settings and Design. The tab Project shows list of individual modules in the project. The tab Settings enables setting of an individual module included in the project. The tab Design shows the list of all available modules in the application. These modules can be inserted into the project workspace. In the left part of the application, there is also situated project control by the Start/Stop buttons.

3.2. Project modules

The main components of each project are function modules (see Fig. 3). The modules inserting in the project serve to carry out the required functionality within the project solution. Every module performs a predefined function, and its behavior can be set up by configuration parameters. Individual modules can be connected one to each other. The output from one module can serve as an input for another module. It allows to utilize the data processed by the previous modules in calculations and divide calculations and functionalities between individual modules. The modules are distributed according to their type into following groups:

— Input module;
— Output module;
— Function module;
— Script module.

Each module is identified by a title which is unique within the project. Other unique module feature is its identification number. The module is identified by this number within the application. The last common character of all modules is the state. The module can be run or stop situation.

The input modules serve for data acquisition from data channels; they parse and save data to a model. Data source can be either a serial port (on line data from HMI or from other Experimental studio application), or a file (e.g. data from the history server) or a TCP server. The input modules are put on the first place in the project (see Fig. 2).

The output modules serve for data storage into data channels. The data telegram is formed prior to storage of data into a given data channel. A data builder is utilized to form a data telegram. A serial port, a file or a TCP server can be aimed for the data. The data can be stored into files in text, CSV or XML formats. The output modules are put on the last place in a project.

The function modules receive the data and process them using predefined functions. These modules should be preceded by the input module or by another function module and are usually followed by the output modules. The script modules represent programmable function modules and as such they are put in the middle of a project as well. The source code of the script module can be written in various programming languages. User can choose one of following script modules:

— C#;
— Visual Basic;
— Jscript;
— Iron Python;
— Lua.

It is necessary to choose an appropriate module to support the particular language. It is possible to combine various scripts within one project. The logging function can be used for easier debug of a script and monitoring its functionality. The module can hold a function of input, output or functional module in accordance with built-up algorithm. However, a module will act as a functional type in the majority of cases. Filters can be used within modules to
limit the data flow which are processed by a module. It is possible to choose one from five predefined filters.

A new module is added to the project from a list of available modules (see Fig. 2). The selected module is then move from the list to the project workspace. The modules connection is represented by lines between their output/input connectors. A data model and a project can be edited only if the project is stopped.

3.3. Project example

Figure 4 shows an example of graphical output from a simple project created in Experimental Studio. This by students created project can calculate and visualize the time behavior of reactor power (red line) and reactivity (blue line). The behavior shown in Fig. 4 corresponds to reactivity changes (in $\Delta$) caused by periodical control rod movement. Although it is only a simple example it shows the main strength of the Experimental Studio, which makes it attractive for the student; its interactivity and programmability.

The project consists of three modules (see Fig. 3). The first module is the input module which serves to read and process raw data from a serial port (data sending from HMI PC). The input module send selected data to script module which are: the power from individual operational power measurement channels (4 channels at the VR-1 reactor) and external neutron source position (in/out core). The output connector from input module is connected to the output module as well. The script module processes the data sending from the input
module by a script created in C# language. The script (script editor is shown in Fig. 3) can calculate the actual reactivity from the above mentioned data. The reactivity calculation is based on the inverse kinetics method. The results are the reactivity values calculated on the basis of power measured by the individual power measurement channels. The last module is output module connected to both script and input module. The module enables to write reactor operational and calculated data into the CSV file.

![Screenshot of Experimental Studio](image.png)

**FIG. 4. Screenshot of Experimental Studio - graphical output.** The blue line represents the reactivity changes caused by control rod movement (green line) and the red line represents power response to the reactivity changes.

4. CONCLUSIONS

New system for data acquisition and evaluation was installed at VR-1 reactor in 2009. The system is based on personal computer equipped with software application called Experimental Studio. The computer is connected to the HMI PC via one way fiber optics line. The HMI PC sends continuously all reactor operational data to the computer which allows on-line data processing by the mentioned software. Finally, the reactor operational data can be sent from this computer through the LAN network to any workstation administrated by students in the reactor laboratory. Such a structure of data acquisition allows students to process the reactor operational data on-line; nevertheless, without any influence on the reactor control and safety.

The Experimental Studio allows processing and easy analyzing the wide range of on-line reactor operational data. The selected data can be processed by several predefined or user programmed modules. The required functionality of a module can be defined by one of optional script languages. A user can display raw or processed data in the form of tables or
graphs. The output data can be stored into various file formats or sent through LAN to any workstation in the reactor laboratory.

More than one year reactor operation with new data acquisition system at the VR-1 reactor shows that equipment and software presented in the paper significantly enhance training at the VR-1 reactor. The data acquisition system was approved especially during the reactor physics courses performed at the VR-1 reactor.

REFERENCES


