RECENT DEVELOPMENTS IN THE FIELD OF NUCLEAR POWER PLANT CONTROL AND INSTRUMENTATION IN HUNGARY

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Abstract

A considerable percentage (32.8% in 1989) of electric energy in Hungary is produced by nuclear power plant Paks.

The paper presents an overview of activities on control and instrumentation in the following areas:

- **control and instrumentation upgrading,**
- **training simulators,**
- **diagnostic systems.**

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1. NUCLEAR REACTORS

A considerable percentage of electric energy is produced in Hungary by nuclear power plants as Table 1 shows:

Table 1
Share of electrical energy in Hungary in 1989.

Electric energy part	million kWh	percentage %
Conventional power plants	15 547	36.6
Nuclear power plants	13 891	32.8
Electric energy import	12 959	30.6
Total	42 397	100.0

Hungary's only nuclear power plant is situated in Paks (110 km south from Budapest, at the Danube). It is equipped with four PWR reactors of type WWER-440/213 put in operation between 1983 and 1986. They have improved design, components and systems compared to similar units in the neighbouring countries, and they are provided with additonal safety increasing facilities like containments, improved monitoring systems, etc. Most important activity in nuclear C-I developments in Hungary is directed to maintain and further increase the reliability and good operation records of this power plant.

A considerable part of these developments is done in the Central Research Institute for Physics, Budapest (CRIP), where reconstruction works of the institute's research reactor (formerly 5 MW, after reconstruction 20 MW) have recently been finished. In Budapest, there is an other, small nuclear reactor at the Technical University, mostly for educational purposes. Its staff, however, also takes part in development works oriented for NPPC-I.

2. UPGRADING CONTROL AND INSTRUMENTATION

At Paks, continuous work is done for modifying, developing, upgrading and replacing the existing control and instrumentation systems originally delivered by the URSS.

2.1. New computers

In the framework of the renewal, at Units 1 and 2 different parts of the process computer system have been modernized several years ago: data logging systems, display systems, semiconductor memories introduced instead of disks. This year the computers type M60 of Soviet origin, processing 2048 analog and 3072 digital input signals, will be replaced at Unit 1-2. The new computer has a modular structure, up-to-date component base, higher reliability figures. Actually, plans are being prepared for a global reconstruction of all the computer systems of the plant. The new systems to be applied must not become obsolete in short time, must permit the introduction of up-to-date methods, like computer aided operator adviceing and enable the creation of a complex network system.

2.2. Process control instrumentation

The replacement of aged computers is accompanied by the introduction of new process control elements (transducers, signal conditioners and processor units). The Analcont instrument family developed and manufactured in Gamma Müvek Budapest has a wide choice of such elements. It is also worth to mention the set of process control elements developed by the Instruments and Measuring Technique Service of the Hungarian Academy (MTA-MMSZ) proven in several applications, as well as

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the transducers and process control elements of the factory MMG Automatika Müvek (flow-meters, fire security systems, pneumatic components, process interface microcomputers).

2.3. Experiment "ZÜRH"

There are experiments in progress by PLC-components for establishing a new Emergency Cooling System Logic, which - for an experimental period - should be installed in parallel with the operating ones, but instead of driving the actuator elements, results are displayed only ("shadow" system). Experiments wit control systems built-up by these components have been performed in conventional power plants.

The system "ZÜHR" should be provided with hardware and software means to assure maximum safety, e.g. three isolated, independent buses, self-checking, independent power inputs, special system program, etc. The system should be suitable for locating faults in the protection system and informing the operator on them.

2.4. Improvements in dosimetry

Continuous development is also made in the dosimetry systems of the plant. These systems will be interconnected to the control room computers enabling to see radiation levels, radiation maps at different places, to process dosimetry data together with technological values. Display systems will be modernized, and located at all important centres. New programs will assist the operator in analyzing the common data base. The external dosimetry system, monitoring the environment in the neighbourhood of the plant will transmit data by USW communication rather than by cabling.

New software is being developed for calculating the spread of radioactivity in the athmosphere under accidental conditions. Computers at the National Meteorology Services will be able to communicate with the plants's dosimetry systems in the future.

3. SURVEILLANCE AND MONITORING

The original core monitoring systems HINDUKUS of Soviet origin has been replaced several years ago by new ones (VERONA) elaborated in the Central Research Institute for Physics, Budapest, in order to increase reliability.

3.1. System VERONA

The installation of the VERONA system at all four units of the Hungarian Paks NPP has considerably improved the safety and economics of power production in these VVER-440 type PWRs.

In order to facilitate the operators' comprehension of the actual core status, color display monitors are applied for data presentation in the unit control room. All the necessary information are at the operator's disposal in any particular operational situation.

The in-core instrumentation is based primarily on SPNDs and assembly outlet thermocouples.

In addition to in-core measurements, ex-core neutron detector signals, boron concentration, loop inlet/outlet temperature, pressure, coolant flow measurements are also available. The actual status of the reactor system is further characterized by a number of discrete parameters corresponding to valve and pump states, control rod group positions.

The scanning of measurements is performed by an intelligent data acquisition system, consisting of analog multiplexers and A/D converters. A complete set of measured data is transmitted to VERONA through a CAMAC interface system in every 16 seconds.

VERONA SERVICES:

- The 3D power distribution, assemblywise coolant heat-up, power and burnup distributions.
- Collection and storage of all necessary information required for the subsequent re-evaluation of the core state preceding emergency situations (archivation).
- Interactive play-back facitity for detailed analysis of archived data.
- Isothermic calibration of thermocouples during the reactor heat-up period preceding nuclear startup.
- Periodical calibration of SPNDs.
- Accumulation of assembly burnups and SPND delivered currents.
- Xenon transient trace-back and prediction in case of scheduled load changes. Determination of optimal boron control and of control rod movement strategies.
- Storing of the whole planned fuel-cycle history.
- Convenient touch-panels.

Actually, reconstruction of the VERONA systems installed in Units 1 and 2 is planned. In the new system the data acquisition will be implemented by VME-units, the reactor physical computations will be made by a double MicroVAX configuration. The first part will be operated October 1991, and the complex tests of the whole system are scheduled to March 1992.

3.2. Materials Testing Reactor

By the Central Research Institute for Physics, a three level multi-channel computerized monitoring and surveillance system has been developed and installed at a materials testing reactor in Moscow, USSR. The system is based on a network of various computers with distributed tasks and is meant for the acquisition, processing and presentation of all the measured

data and related quantities relevant to the operation of the reactor and the experimental loops. A disturbance analysis subsystem is a part of the system, which, in a real-time regime, determines the possible reasons leading to the malfunction.

4.2. Compact simulators for WWER-440 plants

Researchers of the Central Research Institute for Physics - in addition to their participation in the full-scope simulator project for Paks NPP - developed and exported two simulator data and related quantities relevant to the operation of the reactor and the experimental loops. A disturbance analysis subsystem is a part of the system, which, in a real-time regime, determines the possible reasons leading to the malfunction.

A versatile modular monitoring and surveillance system is under development to be offered for various research reactors.

4. TRAINING SIMULATORS

4.1. Full-scope training simulator in Paks

Training of the operational staff is an important part of the measures to maintain safe and reliable operation of nuclear power plants: this task can be highly facilitated by using full-scope training simulators.

For Paks a plant-specific simulator project was started in 1984 with Finnish - Hungarian cooperation and based on Loviisa simulator know-how. The hardware components (control room, interface units, computers) were provided by the Hungarian party.

The software for the simulator was prepared with the assistance of Hungarian experts under the guidance given by NOKIA electronics experts. After installing the hardware and software elements on the final site a full scope acceptance test was done in 1988. During the acceptance tests the fidelity of the simulator was checked by qualified control room staff.

The experience gained with the simulator during one and a half year has proved that it can effectively be used for a number of purposes:

- Basic training for control room staff.
- Refreshing training for control room staff.
- Shortened training programs for technical staff.
- Checking operational instructions and emergency procedures.
- Testing effects of plant modifications and improvements.

Demands concerning simulator services in the field of training scope are constantly growing. In order to increase the capabilities, several developments have been additonally performed:

- LOCA: As a result of a program development done by CRIP the simulator became suitable to fully simulate loss of coolant in the primary circuit. It can follow the ruptures of feedwater pipes inside the containment and other malfunctions.
- Modernizing instructor's workplace.
- Maintaining and improving simulator's fidelity.
- Introducing simulation of the reserve control room.
- Hardware improvements, new computers.

4.2. Compact simulators for WWER-440 plants

Researchers of the Central Research Institute for Physics - in addition to their participation in the full-scope simulator project for Paks NPP - developed and exported two simulator systems to Kola NPP and Rovno NPP, URSS, and further developments are also in progress.

The range of operation extends from subcritical conditions to full power; cooling back also included. A great ammount of malfunctions can also be simulated to help different accident scenario trainings.

The simulator can be used in normal-, fast- and slow time modes. In fast time mode the Xenon-Iodine behaviour of the plant can be accelerated by 10, 60, and 120 times, respectively. In slow time mode the simulation is slowed down by a factor of 5. In addition, the simulation can be freezed at any time, then the simulation can be continued.

All of the main controllers and safety related alarm and interlocking systems are simulated. Every controller can be taken into manual mode to help the detailed understanding of the operation.

The Compact Simulator comprises a control desk, four colour displays and an instructor's display terminal.

The control desk is composed of two main parts: a mimic diagram and a controller station. The mimic diagram is built from a mosaic tile system allowing easy changes. Analog indicators and LED diodes indicate the actual state of the most important process components. Alarm windows signalize abnormal situations. A great number of switches, pushbuttons and thumbwheel switches form the control station of the control desk. A special microcomputer based electronics of the desk simulates the operation of the controllers, so that the impression of continuous operation is retained.

The four colour display terminals are used for different purposes. Two terminals are used as plant computer CRTs, thus a very detailed presentation of the technology is provided. One terminal simulates the operation of the so called Neutron Flux Monitoring System which is one of the most important safety related equipment of the plant. The last terminal is used to display the time functions of the monitored variables.

The instructor's terminal is an alphanumeric display unit and the whole simulation process and trainee's evaluation can be controlled by a cursor selected menu system.

5. DIAGNOSTIC SYSTEMS

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Research and development on noise diagnostics of nuclear reactors have been performed in the Central Research Institute for Physics since long. The first applied result of them, a diagnostic system developed together with the researchers of the Institute for Electrical Power Research (VEIKI) has been put into operation at Unit 1-2 of Paks NPP, several years ago. The system based on in-core and ex-core neutron detectors, thermocouples, pressure transducers, vibration sensors was built-up mostly by CAMAC units. The system monitors the turbines and the reactor.

5.1. Complex diagnostic systems

Following the first application, an extended and improved diagnostic system has been put into operation at Unit 3-4 of Paks NPP comprising a core monitoring system (CRIP, named: PDR), a vibration monitoring system for the pumps and turbines (VEIKI, named: ARGUS-II), and a leakage detection system in the primary circuit analyzing acoustic emission activities (CRIP, named: ALMOS). The complex system operating since 1989 works with IBM-PC-s, includes software controlled signal conditioning and processing units. Its different, menu-based comprehensive software packages running simultaneously monitor normal operation, automatically detect anomalies and facilitate detailed analysis.

A similar, complex diagnostic system has been ordered in 1989 by URSS for a WWER-1000 PWR reactor in Kalinin.This system put into operation in 1991 has improved specifications comparing to that of the former one. The vibration diagnostic system ARGUS III handles 36 measuring channels in the primary circuit and 54 channels in the secondary. The rotating speed signals of the 4 main circulating pumps, the turbogenerator and the 2 filling pumps are included. The general features of the system, e.g. the built-in postprocedures performing trend functions, and the turbogenerator vibration diagnostics expect system, which is an integrated part of the ARGUS III., perfectly help the users in solving vibration problems.

The core monitoring subsystem (PDR) has also an extended set of observed sensors and improved techniques. It can detect anomalies or situations which may become later dangerous and provides several modes of analysis.

The acoustic emission leakage detection system ALMOS has 20 acoustic emission sensors located at potentially dangerous zones of the primary circuits, pumps and pressure vessel. Signal conditioning and processing is made by software-controlled units located near to the sensors. Central data processing, evaluation and alarming takes place in the diagnostic control room.

Development works are also carried out at the MMSZ (Instrument and Measuring Technique Services of the Academy). The Diagnostical Information System (DIR-90) under development will comprise several subsystems covering nearly all the major diagnostic fields (reactor core, primary circuit, main coolant pumps, leakage detection, loose part monitoring, technological parameters, etc.). Several units of the data conditioning and processing electronics are already tested in different, non-nuclear applications, and the software structure is elaborated.

5.2. Expert systems for diagnostics

Research and development on expert systems applied in diagnostics is carried out at several institutes in Hungary.

Expert system for turbogenerator vibration diagnostics was developed by the Institute for Electrical Power Research (VEIKI) and installed at Paks NPP in 1990. The system is based on the modified Genesys 2.1. shell (developed by SZAMALK, Hungary), and is strongly coupled to the ARGUS II. vibration diagnostics system of the units. The system is able to identify 13 different faults of the parts of a turbogenerator. The evaluation is based on the measured vibration data (ARGUS II.) and on the data which are stored in maintenance files. Now the knowledge base consists of 200 rules. The system runs on an IBM-PC/AT.

Researchers of the SZTAKI (Computer and Automation Institute, Budapest), in cooperation with Paks NPP experts work on the prototype of a noise diagnostic expert system tested on Units 3-4. The sensors used in the prototype system are accelerometers located on the control rod driving mechanisms, the reactor pressure vessel head and on the housing of the main coolant pumps, steam generators and hot leg main valves (altogether 28 detectors/unit), pressure fluctuation sensors located in each loop, at the reactor inlet and outlet and at the pressurizer (14 sensors/unit) ex-core ionization chambers of the safety instrumentation (6 chambers arround the core), 3 additional ionization chambers, in-core SPN detectors (6 strings/unit, each consisting of 7 detectors placed at different core high) and 3 core outlet coolant temperature fluctuation sensors. The prototype system under development is able to reach on-line 2x96 noise signals independently, and without disturbing the operation of the standard noise diagnostics systems. The principles and realization outlined are being tested in the diagnostics of failures of the primary circuit.

that ENEL will have to make for future Italian reactors, also