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NUCLEAR POWER PLANT CONTROL AND INSTRUMENTATION ACTIVITIES IN CZECHOSLOVAKIA

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Abstract

After giving a survey of the Czechoslovak nuclear power plants a description of I and C systems of the operating plants is presented together with a brief outlook for future developments to be implemented at plants which are under construction. Special attention is paid to the adopted techniques for power distribution investigation and control in the VVER 1000 reactor core in the case of load changes. Basic futures of the in-core measurement systems are outlined. Measures implemented in the I and C systems of the operating units to improve their performance are described. Information on the country's approach to NPP personnel training and training aids usage as well as information on development work in the area of surveillance and monitoring systems completes the paper.

1. Status of nuclear power in the country and future prospects

At present, eight PWR units are operated in Czechoslovakia. All of them are aquipped with the novo-voronezh type VVER 440 MW(E) reactors. The Czech Power Company operates four units of the nuclear power plant (NPP) V3 sited at Dukovany in southern Moravia, the Slovak Power Company operates two units of the NPP V1 and two units of the NPP V2, both of them sited in southern Slovakia. The next four VVER 440 units are at advanced stage of construction at Mochovce. The pilot two VVER 1000 MW (E) units are being built at Temelin. The should go operational in early 90-ties.

The units of NPP V2, as well as all the next 440 MW units, are equipped with a reactor and primary circuit of an improved design, a confinement with pressure suppression system for coping with LOCA accidents, higher standard main circulating pumps and other components, including I and C systems /1/.

A list of all the Czechoslovak nuclear units is given in Tab. 1.

Tab. 1 Survey of NPPs and nuclear units in Czechoslovakia

Plant name	Unit No.	Site	Power /MW(E)/	First connection to the grid /year/
V1	1	Jasl. Bohunice	440	1979
V1	2	-"-	440	1981
V2	1	-"-	440	1984
V2	2	-"-	440	1985
V3	1	Dukovany	440	1985
V3	2	-"-	440	1986
V3	3	-"-	440	1987
V3	4	-"-	440	1987
V4	1	Mochovce	440	in construction
V4	2	-"-	440	-"-
V4	3	-"-	440	-"-
V4	4	-"-	440	-"-
V5	1	Temelin	1000	-"-
V5	2	-"-	1000	-"-

2. Operational experience with I and C systems and directions of further development

The basic philosophy of protection and control of the VVER units has been set by the Soviet designers. Conventional analog and relay instrumentation is being employed for controlling continuous and discrete variables of the NPP V1, V2 and V3. Data acquisition, processing and presentation to the control room staff is implemented on a Soviet computerized system KOMPLEX URAN.

Reactor and primary circuit protection and control systems are of the Soviet origin. As a rule, they are redundant systems acting either on the 2-out-of 3 or 2-out-of 4 logic. Neutron flux instrumentation systems, reactor protection systems as well as the core integral power control systems have been substantially modernized in the NPP V2 and V3 units. I and C systems of the secondary circuit of all the NPPs operated in Czechoslovakia are of domestic origin. The turbines employed in these plants have been manufactured by the ŠKODA company which equips them with its own I and C systems providing for full-range automatic operation.

The I and C systems employed at the Czechoslovakian NPPs proved to be functionally satisfactory and capable of ensuring reliable operation of the VVER 440 units both in base mode and load-follow mode. These systems are able to bring automaticaly the unit to a new stationary state in the case of anticipated operational occurrences such as an outage of the main circulating pump, load rejection, turbine trip, feedwater pumps failure, etc.; afterwards, the control is taken over by the unit's operators. Relatively limited is the application of operator support systems for failure analysis, i.e. systems for root causes and failure development evaluation. The status of the unit is monitored by the surveillance system and the information on failure of a component or system is displayed to the operator. The analysis of the failure is, however, carried out off-line on the basis of the post-mortem logs.

The I and C systems of the nowadays constructed plants are, as a rule, computerized systems based on process control computers and microcomputers. All the units of the NPP V4 at Mochovce will be equipped with the Czechoslovak decentralized microprocessor modular system DERIS 900 to control the technological processes both in the primary as well as in the secondary circuit. The data acquisition and processing system will be implemented on Soviet computers SM3 and SM4. It is believed that these advanced I and C systems will enhance both the range and reliability of the control functions. The DERIS 900 system has been thoroughly and extensively tested both in Czechoslovak and Soviet laboratories with positive results. Since the I and C system to be employed at the NPP Mochovce and Temelin have to be qualified for seismic environment specific methods and facilities for carrying out appropriate tests have been developed and constructed. The components of the NPP Mochovce units are the same as those of the standard VVER 440 units with only one exception concerning the steam generator's feedwater systems: feedwater pumps with electric drives and hydraulic clutches are to be used. Consequently, new control schemes have to be introduced.

The two 1000 MW(E) units of the NPP Temelín will be equipped with a three-level hierarchical control system. The basic level consists of protection of individual plant components and manual remote command of actuating devices; these function are implemented on a Czechoslovak relay logic system DIAMO-K. The middle level is in charge of controlling both the continuous and discrete process variables; it is implemented on a set of Czechoslovak minicomputer based systems called DASOR 600 J (one pair of DASORs controls the whole functional group: the A system being the working one, while the B system being the "hot" back-up system). The highest level consists of the information and monitoring system which is implemented on Soviet SM-type computers. Furthermore, a diagnostic system for early detection of failures and malfunctions of all important components of both the primary and secondary circuit will be installed.

3. Power spatial distribution control and in-core instrumentation of the VVER 1000 reactors

A complex simulation model of the VVER 1000 unit dynamics has been recently developed for studies of transients during normal operation as well as anticipated operational occurrences and for the unit's power control system design and analysis /2/ - /5/. The model can simulate the short-term response (i.e. the response falling into range of tens up to hundreds of seconds) of the plant controlled and monitored variables to various operational disturbances.

Simulation studies of these short-term transients, validated by data logged at the VVER 440 units, proved that reactivity feedback effects provide for the core inherent stability during the whole operating cycle. However, experience learned from operation of large units indicates that middle-term transients originating from iodine an xenon build-up and decay and absorption processes could result in power distribution oscillation in the reactor core. Therefore, development of the VVER 1000 spatial-dependent core dynamics model has been initiated last year to elaborate an efficient tool for investigation of these phenomena and to design adequate control strategies. The model is to meet the following requirements:

- to simulate the middle-term dynamics of such variables as the core integral power, power distribution in the core, fuel and coolant temperatures and some other critical parameters, as a response to disturbances in the core coolant inlet temperature and flow rate, control rods position and liquid absorber (boric acid) concentration;
- to provide information on variables which are employed as input data for control algorithms, such as the core integral power,

the mean value of the coolant temperature, the axial offset, the axial peak factor, etc.;
- to generate the initial steady-state power distribution at various time-instants during the operating cycle;
- to be tailored as a complement to the simulation model of the unit`s overall dynamics.

A simplified one-dimensional core dynamics model of the VVER 1000 reactor has been worked out last year /6/. It is based on a nodal approximation of the point-kinetics equations enlarged by additional terms representing the neutron transport from and to the neighbour nodes. The short-term dynamics of the mass and heat transfer in the core has been neglected and its quasi steady-state representation has been adopted. The middle-term dynamics has been described by the iodine and xenon built-up and burn-up processes and residual heat generation. Employing this model, investigation of the VVER 1000 core dynamics has been carried out mainly by looking for correlations between the core power oscillation magnitude and the offset values on one side and the fuel and coolant temperature reactivity feedback coefficients, the control rods position and some other parameters` values on the other side. At present, the strategy of the power distribution control as proposed by the reactor control system designer is being tested on a computer employing this simulation model. Further development of the model is aimed at working out a three-dimensional nodal model consisting of 1630 nodes, i.e. each fuel assembly will be represented by 10 nodes in the axial direction.

A prerequisite to effective power distribution control is the availability of reliable and adequately accurate in-core measurement systems. The VVER 1000 reactors are equipped with a modernized Soviet core monitoring system HINDUKUS which has been extensively tested on NPP V2 a V3 units. The input signals to this system are the in-core instrumentation signals (217[illegible] thermocouples, 252 self-powered detectors), a number of process variables of the primary circuit as well as about 280 binary signals on the operational status of some important components, e.g. the main circulating pumps, pressurizer electric heaters, valves, etc. The HINDUKUS system displays to the operator the following information in the on-line mode:

- integral heat power of the reactor,
- coolant flow rate through the reactor and through the individual cooling loops,
- mean value of the coolant temperature at the reactor inlet and at the cooling loops` inlets and the temperature increase/decrease over the reactor/cooling loop,
- pressure drop over the reactor and over the cooling loops,
- position of the control rods,
- core power calculated from data supplied by the self-powered detectors and ionization chambers,
- mean value of the fuel element linear power, maximum value of the linear power and its localization,
- pattern of power and temperature distribution in the core,
- flow rates of feeding and bleeding of the primary coolant,
- steam pressure in the steam generators.

Input data processing by the HINDUKUS system and the mode of its results presentation to the control room staff is being modified in order to make it an efficient operator support system. A thorough and detailed evaluation of the HINDUKUS functional capabilities and its reliability has been also carried out bearing in mind that this system is closely related to the operational safety of the plant.

4. Activities in the I and C area aimed at enhancement of the NPP safety

Load rejection causes in the VVER type NPPs substantial deviations from the secondary circuit saturated steam pressure nominal value. The magnitude of these deviations depends upon operational capabilities of the pressure relief facilities such as steam by-pass station the turbine condensers and steam bleeding stations to the atmosphere, upon adjustment and co-ordination of the reactor and turbine control systems and upon the relief valves characteristics. Some recommendations for the VVER 440 units` operators have been worked out concerning the way of coping with situations when simultaneous malfunctions of these facilities occur /8/.

A variety of abnormal conditions has been analyzed to look for possible ways of decreasing the number of the rapid shutdowns of the reactor per year. It has turned out that under some circumstances it is preferable that the protection actions be carried out by the control systems instead of the safety systems since it results in less depletion of the reactor life-time /7/.

Some backfitting measures have been implemented at the NPP V1 to increase the reliability of the fast acting closing valves on the main steam header. They had to be supported by specific re-arrangements of the secondary circuit control systems in order to eliminate the impacts of the non-symmetric distribution of steam pressure in the header sections caused either by non-symmetric turbines` loads or by outages of the individual primary coolant loops /9/.

5. Diagnostic systems

An automated diagnostic system for the VVER 1000 units has been conceptually designed by the Czechoslovak NPP main supplier in co-operation with the Soviet main designer. The system is open for further completions both in its hardware and software parts. Implementation of the system will be a joint undertaking by the NPP components` manufacturers and Czechoslovak research and development institutes.

The automated diagnostic system of the nuclear steam supply system will comprise the following subsystems:
- subsystem for mechanical vibrations detection,
- subsystem for loose parts detection in the primary circuit,
- subsystem for reactor coolant system integrity monitoring,
- subsystem for accoustic noise analysis aimed at detection of cracks and monitoring their further development.

The automated diagnostic system of the secondary circuit will monitor all the important components such as the turbine, electric generator, drier-superheater, feedwater pumps, reheaters, pipes, etc., by running 31 specific tests.

The efforts in the area of automated diagnostic systems are directed at extraction as much information as possible on functional status of a component and its evolution in time.

6. NPP personnel training, simulators

The operating staff of the Czechoslovak NPPs is recruited and systematically prepared and trained in compliance with the requirements and procedures set forth by the law on State Supervision of Nuclear Safety. A specialized training centre has been established in Trnava (near Jaslovské Bohunice) which provides appropriate means and applies appropriate methods for achieving by the trainees high level of professional qualifications. The centre is equipped, among the others, with full-scope simulator of the VVER 440 units (the simulators` control room layout corresponds to the V2 and V3 plant control rooms). The simulator has been designed by Czechoslovak organizations and assembled of domestic computers, components, instruments, etc.

Research and development activities on construction of a full-scope simulator of a VVER 1000 unit are at a very advanced stage.

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NUCLEAR POWER PLANT CONTROL AND INSTRUMENTATION ACTIVITIES IN FINLAND

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Abstract

Finland has achieved some remarkable achievements in nuclear power production. Existing four plants have some of the best operating records in the world - high capacity factors, low occupational doses and short refuelling outages. Although public opinion was strongly turned against nuclear power after Chernobyl accident, and no decisions for new nuclear plants can be made before next elections in 1991, the nuclear option is still open. Utility companies are maintaining readiness to start new construction immediately after a positive political decision is made. One important component of the good operation history of the Finnish nuclear power plants is connected to the continuous research, development, modification and upgrading work, which is proceeding in Finland. In the following a short description is given on recent activities related to the I&C-systems of the nuclear power plants.

STATUS AND PROSPECTS OF NUCLEAR POWER IN FINLAND

The four existing nuclear power plants in Finland, the two ASEA-Atom (now ABB Atom AB) 710 MWe (net) boiling water rectors in Olkiluoto owned by Teollisuuden Voima Company (TVO) and two Soviet VVER-440 442 MWe (net) pressurized water reactors in Loviisa owned by Imatran Voima Company (IVO), produced in 1988 totally 18.4 TWh of electricity constituting 36 % of the whole production (51.3 TWh) and 31 % of the electricity used (58.7 TWh) in Finland.

Finnish nuclear power plants have some of the best operating records in the world - high capacity factors, low occupational doses and short refuelling outages.