NATIONAL REPORT ON NUCLEAR POWER PLANT CONTROL AND INSTRUMENTATION IN CZECHOSLOVAKIA

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Introduction

At present, there are five operating PWR units in Czechoslovakia all of them equipped with the novo-voronezh type reactor VVER 440. The sixth unit of the same type is being commissioned. Four units are sited at Jaslovské Bohunice, the other two ones are located at Dukovany - see Tab. 1.

Tab. 1

Plant name	Unit No.	Site	Nominal electric power [MW]	First connection to grid year - month
V1	1	Jaslovské Bohunice	440	1979 - 04
V1	2	- " -	"	1981 - 01
V2	1	- " -	"	1984 - 08
V2	2	- " -	"	1985 - 08
V3	1	Dukovany	"	1985 - 02
V3	2	- " -	"	under commissioning

Further two units of the nuclear power plant V3 are at advanced stage of construction. Construction of four units of the plant V4 at Mochovce has already started. It is expected that by the year 1990 total number of operating VVER 440 MWel units will amount up to 12. The first 1000 MWel unit shall be put into operation at the beginning of the nineties.

The power plants V2, V3 and V4 are equipped with the modernized V-213 reactor, a confinement with a pressure-suppression system, main circulating pumps with a prolonged run out time and some other innovated components as well as instrumentation and control systems. A brief description of a power plant VVER 440 can be found elsewhere, e. g. in [1].

Research, development and design efforts in the field of nuclear power plant I&C systems have been recently aimed at solving the following problems:

- setting the parameters of the VVER 440 units control and protection systems and testing them in the power phase of commissioning
- design and simulation of the VVER 440 units control system performance under the conditions of steam bleeding for a centralized heat supply system
- development of a simulation model of the unit VVER 1000 dynamics for the purpose of I&C systems investigation and design
- design of innovated I&C systems for VVER 440 and VVER 1000 units.

Tunning of the control system parameters, dynamical experiments during commissioning of VVER 440 units, simulation analysis

A detailed analysis of the impact of various parameters of the unit´s power control system upon the process transients have been carried out for both units of the plant V2 which have been equipped with more advanced, in comparison with the plant V1, technological equipment as well as I&C systems. Commonly adopted performance indices such as the integral of the squarred control error or minimum transient duration turned out to be inefficient when employed for such complicated multivariable system as that of the plant power control system.

Tunning of this control system - see [2] - was aimed at meeting the following safety, technical and economical requirements imposed upon the transients of the most important variables initiated at the unit's different power levels either in normal operating conditions or under anticipated operational occurrences:

- the unit shall automatically reach a new steady state which meets all operational safety requirements
- limit values of process variables, corresponding to trip settings of the plant protection systems, shall not be exceeded during the transients
- safety valves of the pressuriser and the steam generators shall not open
- pressurizer relief valves or the main steam collector relief valves to the atmosphere are allowed to open for a short time during cumulation of disturbances only
- the transients should, as far as possible, be monotonous or with minimum overshoots only and they should primarily meet those requirements imposed upon the plant components which are pertinent to their life-time
- step-wise changes of the reactor power due to disturbances in the unit's load shall not exceed the values which account from the point of view of the fuel life-time
- the number of actuation systems' actions shall be minimized
- unnecessary wasting of steam in the by-pass stations to the turbine condensers should be minimized.

The following events are considered for the VVER 440 units as the anticipated operational occurrences: outage of the main circulating pump, outage of one of the two turbines, disconnection of the unit from the grid and lowering the load to the home consumption level, outage of one of the steam generators feeding pumps etc. Functioning of the unit's I&C systems under these anticipated operational occurrences at different power levels is tested during commissioning namely at power start-up phase. The scheduled experiments are aimed at checking the functions of all components of the plant equipment as well as design values of a number of plant variables. They also provide a unique chance to find out whether the control and protection systems setting is correct, whether these systems function as per design and whether the transients correspond with the results of simulation studies.

During the first start-up of a VVER 440 unit approximately 15 up to 20 dynamical experiments is carried out at selected reactor power levels /usually at 35, 55, 75, 90 and 100 per cent of the nominal power/. The purpose of them is to test full capabilities of the main controllers under severe conditions caused by the anticipated operational occurrences. Simulation of the expected transients of about 20 up to 30 process main variables is, as a rule, run in advance.

Monitoring of these experiments is performed by means of a digital data acquisition and processing system HP 3052 which employs the HP 9845 desk calculator. It scans about 200 analog signals and about 250 binary signals selected from a special purpose set of about 1000 variables. Right after completion of an experiment the transients of the main process variables are presented in a graphic form and performance of the control and protection systems is evaluated on the basis of a comparison studies with the results obtained by simulation. This approach turned out to be very efficient and helpful in detection of I&C systems failures or deviations from the design. It however, calls for a well validated mathematical model of both the process and control systems dynamics. Lot of efforts have been made in the past years to develop such a model and to verify it against the data acquired during the plant commissioning as well as plant operation.

Nuclear power plants of the VVER 440 type are to be run in Czechoslovakia also in a regime when they deliver steam to the centralized heat supply systems. Results obtained from simulation studies - see [4] - indicate that only minor modifications of the control systems will be required to provide for such type of the nuclear power exploitation. The basic assumption of these studies was that the plant is operated in "constant steam pressure in the secondary circuit" mode and the deviations in load originating in the centralized heat supply system are to be counter-balanced by turbine load changing without affecting the reactor power. Adequate selection of both the reactor and turbine controllers operation modes in combination with specific tunning of these regulators provides for satisfactory meeting all the limiting factors originating from the involved technology even under the conditions of the fast lost of load of the heat supply system.

Simulation studies of the plant transients proved to be of significant value also for cause-effect evaluation of failures occurring during normal operation. A situation that illustrates the need for such studies arose recently at the 2-nd unit of the V1 plant when during shutting down of one of the cooling loops an unacceptable reactor power excursion took place. Reconstrucion of the operator´s actions and their sequencing in time has been performed employing simulation techniques on a computer. The original cause of this event, i.e. the fact that the demanded value of pressure in the reactor controller was set higher than set point of the pressure controllers of the by-pass stations to the turbine condensers, has been revealed in this way - see [5].

Development of the VVER 1000 units dynamics model

In correspondence with design and construction of the first VVER 1000 MWel unit early activities in development of a model of its components as well as I&C systems dynamics have been started. The purpose of these efforts is to provide an efficient and fast tool for simulation of the overall plant transients under normal conditions as well as anticipated operational occurrences in order to facilitate design, analysis and optimization of the unit´s main control systems. The model is mainly based on mathematical identification but experience gained from testing and validation of the plant VVER 440 models has also been taken into account. So far the first part of the model, i.e. the model of the plant´s main technological equipment, has been completed - see [6]. It is a non-linear lumped parameters model of a modular structure represented by a set of first-order differential equations augmented by a number of algebraical and logical expressions and equations. It consists of the following modules:

- core neutronics including reactivity feedback effects due to changes in the fuel and primary coolant temperature as well as due to xenon concentration changes
- core residual heat generation represented by 10 equivalent groups of β and γ - rays emitters
- heat transfer in the core which is considered to be divided in the axial direction into two parts
- reactor lower chamber dynamics
- reactor upper chamber dynamics
- dynamics of two groups of primary cooling loops including the hot leg, primary side of the steam generator, cold leg and the main circulating pump
- dynamics of the primary coolant volume
- dynamics of pressure and coolant level in the pressurizer
- dynamics of the secondary side of the steam generators including water level dynamics in the drum
- dynamics of pressure in the main steam collector including steam flow through the relief valves to the atmosphere
- dynamics of the steam pipe-lines in the secondary circuit
- dynamics of the turbogenerator set including high pressure turbine as well as low pressure turbine description, steam

dryer and reheating system dynamics, and steam flow through the by-pass stations to the turbine condensers
- dynamics of the feed water high pressure regeneration system.

Two different algorithms have been employed for initial steady states calculation. The data base of the model is abundant in information about the nominal steady state which facilitates easy modular computation of the model variables values in this initial state. This, however, is not the case for the non-nominal steady states and a separate iterative algorithm for the overall model had to be developed for non-nominal initial steady states determination.

The model, its data base and the above mentioned algorithms for initial steady states calculation have been implemented on the ODRA 1305 computer in the framework of the FORSIM simulation system. The corresponding program occupies about 44 000 locations of the CPU operational memory. It provides for simulation of transients of the main process variables in the absence of the unit´s control systems. Individual disturbances as well as combinations of disturbances can be selected from the following set of events or variables: outage of one out of the four main circulating pumps, primary coolant flow rate in the 1-st or 2-nd group of cooling loops, position of a group of control clusters, feeding/bleeding of the primary coolant, flow rate to the pressurizer sprinklers, steam flow rate through the pressurizer relief valve, power of the pressurizer electrical heaters, high pressure turbine control valve opening, openings of the control valves of the by-pass stations /both to the turbine condensers and to the atmosphere/. If the CPU run time is considered then the ratio of a transient simulation time to the transient real time is varying in the range from 4:1 to 10:1.

Innovation of I&C systems

Control of both continuous and discrete variables at all units of the V1, V2 and V3 plants has been implemented employing conventional analog and relay hardware. Data acquisition and processing systems of these units /excluding the V1 plant/ are computer based systems of Soviet origin, i. e. the so-called KOMPLEX - URAN system.

At the power plant V4 at Mochovce, which construction has been recently started, the Czechoslovak distributed microprocessor system DERIS 900 with two level bus arrangement will be employed. It shall control continuous as well as discrete variables of individual functional units both in the primary and secondary circuit of the plant. It will be interconnected to the computerized information system based on the Soviet computers SM3 and SM4. The design of I&C systems for the V4 plant has been carried out in close co-operation with Soviet experts. Implementation of the DERIS 900 system at nuclear units will be preceded by extensive tests on stands in Czechoslovakia and the Soviet Union which shall examine functional and signal compatibility of the Czechoslovak and Soviet instrumentation. Some segments of the DERIS system will be also tested in normal operation conditions at conventional power plants. At present the main efforts in DERIS 900 project concentrate upon the problems of achieving required redundancy and development of control algorithms.

The power plant V4 will be provided with electrically driven feeding pumps with hydraulic clutch. It is expected that beside energy conservation employment of such actuating equipment will result in improvements of the steam generators feeding systems dynamic performance.

Design of I&C systems for control of continuous and discrete variables of individual functional units in primary and secondary circuit of the Czechoslovak first VVER 1000 plant is considered in two variants. The first variant is based on employment of the Czechoslovak minicomputer system DASOR which has been succesfully applied at a conventional 500 MWel plant, while the second variant is derived from the design of I&C systems at the Soviet VVER 1000 plant at Zaporozhe which makes use of a modernized microprocessor system. The plant´s information system will be based on Soviet computers.

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INSTRUMENTATION AND CONTROL IN THE CANADIAN NUCLEAR POWER PROGRAMME: 1986

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REACTOR PROGRAM STATUS

A lot has happened on the CANDU scene, during the two years that have elapsed since the last meeting of this Working Group. The last three 500 MWE units of the eight unit Pickering Station were brought on line. However Pickering units 1 and 2 are still shut down for retubing. Consequently, the current station output is 3000 MWE, instead of 4000 MWE. Our second eight unit station at Bruce has six of its 750 MWE reactors on line giving an output of 4500 MWE. The seventh Bruce reactor is only a couple of months away from "in-service".

In addition to the construction work on Bruce 8, the work on the four 850 MWE reactors at Darlington is proceeding. Completion of the first unit is projected for 1988. Offshore, there are CANDU 600 MWE reactors being built in Romania. No commitment has yet been made for a second CANDU 600 MWE reactor on the Point Lepreau site. This reactor would be totally devoted to electricity export to the U.S.A.

Actual retubing of one of the Pickering reactors has started. This replacement of a critical reactor component (the primary pressure boundary) gives us confidence that extensive retrofitting is feasible so that the operation of CANDU reactors can be extended beyond their design lifetime of 30 years.