- general purpose hardware that supports portable software, and
- CANDU dual-DCC transfer-of-control logic to support a redundant hot-standby configuration for fault tolerance.

To date, PROTROL has been used for several different applications on nuclear power reactor systems, linear accelerators and nuclear research reactor control.

5.3 OH-180

Programmable logic controllers (PLC) are extensively used at the 4-Unit Darlington NGS. About 97% of these (i.e., 1320) are the Ontario Hydro developed OH180 PLCs. The OH180[6] was designed as a replacement for logic relay hardware used in earlier stations. Control logic changes are much easier and faster to implement in PCCs than in logic relay hardware.

6. CONCLUSIONS

Significant advances are being made in many areas of I&C for both existing and future CANDU plants. This includes work on:

- human-machine interfaces,
- alarm annunciation systems,
- distributed control systems,
- plant display systems,
- relay logic replacement, and
- software technology.

These advances will lead to improved CANDU plant performance, and reduced capital and operating costs.

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RECENT ACTIVITIES IN THE FIELD OF NUCLEAR POWER PLANT CONTROL AND INSTRUMENTATION IN CZECHOSLOVAKIA

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Abstract

The report presents a review of Czechoslovak nuclear power plants that are in operation and in the course of construction.The present state of the instrumentation of the newly built NPP's is described,and a special attention is given to work on the control of spacial power distribution in the reactor core of VVER 1000,the first unit to be installed in NPP Temelin.A project of a secondary circuit diagnostic system of this unit is described.

1.Present state of the nuclear power industry in Czechoslovakia and an outlook to the future.

In CSFR there are eight nuclear power plant units in operation.All of them are with reactors of the PWR type VVER 440 of soviet construction.Four of these units are situated in Dukovany in the south of the Czech republic,and the other four are near Trnava in the south of Slovakia.Six of these units (i.e. in Dukovany and two in Slovakia) have a reactor and a secondary circuit of improved construction,a containment with a sprinkling system for LOCA suppression,main circulation pump with an increased inertia.The reactor control system and instrumentation has also been improved /1/.Other four units with VVER 440 are in construction in the South of Slovakia in Mochovce;the first of them is to be commissioned in 1993.These units have been designed with the enhanced seismic resistance.The first NPP unit with the reactor VVER 1000 under soviet project is being built in southern Bohemia at Temelin;it is expected to be commissioned in 1994.Construction of the second unit with a reactor of the same make has already started,too.The third and fourth unit will probably be built after a project of another firm.

The list of all Czechoslovak nuclear power plants and their units is in Table 1.

Table 1.

NPP	unit number	site	capacity MWe	first connection to grid
V1	1	Jaslovske Bohunice	440	1979
V1	2	Jaslovske Bohunice	440	1981
V2	1	Jaslovske Bohunice	440	1984
V2	2	Jaslovske Bohunice	440	1985
V3	1	Dukovany	440	1985
V3	2	Dukovany	440	1986
V3	3	Dukovany	440	1987
V3	4	Dukovany	440	1987
V4	1	Mochovce	440	in construction
V4	2	Mochovce	440	in construction
V4	3	Mochovce	440	in construction
V4	4	Mochovce	440	in construction
V5	1	Temelin	1000	in construction
V5	2	Temelin	1000	in construction

2.Instrumentation and control systems of Czechoslovak NPP units

Experience from the operation of Czechoslovak NPP's with VVER 440 reactors shows that the system of control and instrumentation (C&I)is capable to ensure the operational reliability of the units both in basic mode of operation and in the mode of variable load /2/.The C&I is capable to automaticaly transfer the unit to new stable state in case of main circulation pumps trips,turbine load shedding,turbine trips,steam generator feed pump failures etc.Data acquisition,their processing and presentation to the operational personnel is realized by a Soviet computer system KOMPLEX URAN.The analysis of disturbances can be performed only in an off-line manner on the basis of a post-incident record made by the system.

The design of C&I,i.e. of the safety and control system of the reactor and of the secondary circuit is of the Soviet origin.The control systems of the secondary circuit on all of the units operating in CSFR are of Czechoslovak production.The turbines in these units have been produced by ŠKODA works and all of them are equipped with an original control system of ŠKODA make that makes possible a fully automatic operation.

For all Czechoslovak NPP units the C&I has been designed by the Soviet contractor and a substantial part of the instrumentation,control algorithms and their software realization are of Soviet origin,too.It can be explained by the fact that the Soviet contractor based every new control and instrumentation project on an analogous project verified already in the operation.

The increased share of Czechoslovak technical means of automation ought to have been realized in nuclear power plants Mochovce and Temelin.The Czech firm ELEKTROMONT offered the Soviet contractor Czechoslovak hardware for the systems of automatic regulation and discrete control for both the primary and secondary circuits (with the exception of reactor power control and reactor safeguard system).

For the case of NPP Temelin the control and instrumentation system of VVER 1000 originally used in the Soviet power plants ZAPOROZHSKA and ROVENSKA has been inovated in the functions of automatic control and discrete logic control.Instead of the Soviet control complexes ULU2-EVM the project assumed to use the Czechoslovak minicomputer modules DASOR 600J [28 doubled units] and instead of the Soviet logic control system UKIS the use of Czechoslovak diode-relay system DIAMO-K [approx. 10 000 units].Both these systems of the Czechoslovak origin and production have been installed and their functionality proved in conventional power plants.Number of units of these systems in individual installations has,however,been much smaller than it would have been in the NPP Temelin.Results of recent analyses have shown that these systems cannot fulfil the strict reliability requirements .The first Czechoslovak NPP unit with VVER 1000 shall then be equipped with some other imported system,purchased on the result of an international tender. In case of the Mochovce NPP the Soviet contractor inovated the computer information system.Instead of the former Soviet computers SM - 2M other Soviet computer system SM 1800 has been suggested.Inovation of systems of automatic regulation and logic control has also been proposed.Instead of the classical PID regulators and relay logic automata [earlier used in the NPP Dukovany] the project assumed the use of Czechoslovak fully programmable bus control system DERIS.This system,however, has not been verified in operation of a complex system installation in any,though even a conventional power plant environment.From these reasons it has recently been decided to purchase the whole control system from the German producer SIEMENS.

The Power Research Institute Praha has built up a complex mathematical simulator of a NPP unit with the reactor VVER 1000 in order to analyse the control system functions and to study the dynamic behaviour of the unit in the short - term region [i.e. the transients of several hundreds of seconds].The dynamic behaviour of the system has been studied in dependance on parameters and setpoints of individual regulators and on the operational conditions [5].

The simulator has recently been used for the solution of a new control task of feeding the steam generators with variable speed feed pumps operating to a common header. Further it is intended to use in order to find the setting of the unit s control system during the period of the Temelin first unit commissioning.

3. The spacial power distribution control in the reactor core of VVER 1000

The Soviet project of spacial power distribution control in the reactor core of the first unit of NPP Temelin assumed to use only manual control to keep the axial offset in acceptable limits. Half length control rods positioned in accordance to given algorithm are used as the control organs.Such control is, however, considered by both the power plant staff and by the state authorities as unsatisfactory. On basis on this work on automatic control of the spacial power distribution in the reactor core has been initiated. This activity is also supported by the expert study of IAEA. In the first period of this work a simplified one dimensional (axial) model of core dynamics has been constructed (3). It is based on nodal approximation of the point-kinetics equations enlarged by additional terms representing the neutron transport to and from the neighbouring nodes. The short-term dynamics of 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. These analyses include the reactivity disturbances caused by various actuators (boron acid, control rods in different grouping) in conditions of à general control rule characterised by constant steam pressure (as requested in the project) and also in conditions of other control programme characterized by constant average temperature in the primary circuit. On basis of these investigation the structure of integral power control of the core and of the axial offset has been elaborated and in simulated conditions verified (4).

In the proposed control circuit the reactor integral power controller (as in the original project) has been utilized. This controller will cooperate with an axial offset regulator and with the regulator of control rods positioning. The proposal assumes two types of control rod groups: a group of great reactivity worth and several groups of small reactivity worth.

The simulated verification of the control circuit for the reactor integral power control and the axial offset control has been done by a one-dimensional axial model of the core. Nevertheless, such approximation has its limitation. Mainly it does not make possible to investigate the power distribution along the core radius and to evaluate the volume peak factor in dependance on core azimuth. Similarly as in other advanced reference projects the aim of this work is to construct a nodal model in which every fuel assembly is divided into several nodes and the power produced by every node can be determined. Due to the fact that the core pattern of VVER 1000 posses a circular symmetry in 60 degrees

segments such three-dimensional model amounts 1630 nodes if the core is vertically divided into 10 layers.

The basic mathematical description of the 3D model has been derived from the diffusion equation for a quasi-steady state of the system (5).From these equation the difference equations for individual nodes have been derived on the presumption that every node is influenced only by the neighbouring nodes.This influence has been expressed by the interactive factors that depend only on the positions of the neighbouring nodes.

These models of core dynamics will also be used in the development of a support system for the reactor operator, as well as for the preparation and evaluation of the first power unit of NPP Temelin.

4. The diagnostic system

The ŠKODA works has been engaged with the elaboration of a power unit diagnostic system for the first and second units of NPP Temelin (6). In an extensive set of diagnostic systems and subsystems an important role have the automated systems of the unit technology. The systems can be divided into:

- automatic diagnostic system of the primary circuit
- automatic diagnostic system of the secondary circuit.

Both the systems represent specialized measurement and information subsystems of the common information and calculation system of the NPP.

The primary circuit technology supplier,i.e. the ŠKODA works equips his supply with the diagnostic system bought from a German producer KWU.This system,however,is not up to the time adapted to the Soviet design of the primary circuit and there is no link to the control and instrumentation system of the power unit.

The secondary circuit diagnostic system will be developed and supplied by ŠKODA.Its design for the first unit of Temelin is based on the following requirements:

- experience with the existing diagnostic systems on conventional units with steam turbines of 200 MW capacity,
- experience from the operation of the Soviet units with VVER 1000,
- the necessity to implant the diagnostic system into the common control and information system structure,
- the requirement of a multiple utilization of the diagnostic system during the commissioning activities and at the long-term development tests of the turbogenerator set in the course of its operation,
- the requirement of the unification of the system,i.e. the possibility its utilization for the diagnostics of other similar technology in conventional power plants,
- the requirement of flexibility,i.e.the design of such a system,that would be independent on the hardware used for its realization in the future.

In accordance with these requirements a technical structure of such a diagnostic system has been elaborated,that enable a current check of the unit s technology and ascertain its instantaneous state .

The subjects of the diagnostic procedure are:
the turbogenerator unit,the feed pump turbines and the feed pumps,the reheater and separator,condensers,the low pressure and high pressure feed water heaters,feed water storage vessel,live steam conduits.

The following diagnostic tests will be utilized:

- vibrodiagnostics,
- turbogenerator and turbo-feed pump bearings test,
- turbogenerator and turbo-feed pump valves test,
- steam conduit drain functionality,
- pressure pulsations in the separator - reheater,
- efficiency of energy transformation,
- 1000 MW alternator stator winding cooling,
- electromagnetic torque and torsional vibrations of the alternator rotor,
- alternator rotor winding cooling,
- indication of rotor winding short-cuts,
- logging of alternator electric current and voltage values and changes,
- vibration of the frontal parts of alternator stator winding,
- hydrogen leak test,
- hydrogen coolers test and ventilation circuit test,
- secondary circuit tubing test within the containment,
- condensator deaeration system state.

The diagnostic measurements can be divided to quasi-static and dynamic procedure.The diagnostic signals are rendered either by special diagnostic subsystems with their sensors,or a common measurement subsystem of the control and instrumentation system of the NPP unit.The diagnostic system of the secondary circuit process approximately 1000 input signals.The supply of the diagnostic system equipment is shared by Czechoslovak and several foreign producers (Rosemount,Heraeus,Brüel-Kjaer,Dynisco,Jokogawa,Philips and Peekel).

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NUCLEAR POWER PLANT CONTROL AND INSTRUMENTATION ACTIVITIES IN FINLAND

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Abstract

Finland has remarkable achievements in nuclear power. The existing four plants have some of the best operating records in the world - high capacity factors, low occupational doses and short refuelling outages. Public opinion was strongly turned against nuclear power after Chernobyl accident, and the previous government decided not to allow for the construction of a fifth nuclear unit during its period of reign. The opposition has however slowly been diminishing. According to the latest polls the opinion is almost balanced. Finnish power companies are going to file an application for a decision-in-principle to build a new plant to the new government appointed in April 1991. A readiness to start new construction project immediately after a positive political decision is made has been maintained during the intermediate period. Continuous research, development, modification and upgrading work provide important components of the good operational history of the Finnish nuclear power plants. Efforts have also been devoted to identifying possible new problems arising from the use of distributed digital C&I technology. The following a short description is summarizing recent activities related to the C&I-systems of the nuclear power plants.

STATUS AND PROSPECTS OF NUCLEAR POWER IN FINLAND

There are two nuclear power plant sites with a total of four operational units in Finland. In the Olkiluoto site there are two ASEA-Atom (now ABB Atom AB) 735/710 MW(e) (gross/net) boiling water reactors (BWR) owned by Teollisuuden Voima Company (TVO). In the Loviisa site there are two Soviet VVER-440 465/442 MW(e) (gross/net) pressurized water reactors (PWR) owned by Imatran Voima Company (IVO). The units produced in 1990 a total of 18.1 TWh of electricity constituting 35 % of the whole production (51.7 TWh) and 29 % of the electricity supplied to consumers (62.5 TWh).

Table 1. Electricity production and supply

	TWh		Share, %	
	1989	1990	1989	1990
Nuclear power	18.0	18.1	30	29
Cogeneration	15.1	16.3	25	26
Hydropower	12.9	10.8	21	17
Condensing & gas turbines	5.2	6.4	9	11
Production	51.2	51.7	85	83
Net import	8.9	10.8	15	17
Total supply	60.1	62.5	100	100

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