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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.

Table 1. Electricity production and supply in Finland

	1987 TWh	1988 TWh	Share in 1988 %
Nuclear power	18.5	18.4	31
Back-pressure power and district heating	13.8	14.3	24
Hydropower	13.7	13.4	23
Condensing & gas turbines	4.9	5.2	9
Production	50.9	51.4	87
Net import	5.6	7.4	13
Total supply	56.5	53.7	100

Table 2. Capacity factors of nuclear power plants in 1988

Loviisa 1	(5/77, 442 MWe)	86.7 %
Olkiluoto 1	(10/79, 710 MWe)	92.9 %
Loviisa 2	(1/81, 442 MWe)	93.1 %
Olkiluoto 2	(7/82, 710 MWe)	91.9 %
	Average	91.4 %

The operating licenses for all the four plants were renewed in 1988 according to the new atomic energy act, which also was enacted in the same year. The licenses were granted for Olkiluoto plants for a 40 years plant life-time but for Loviisa plants for the moment only until the end of 1998, when an application for a renewal of the licenses has to be filed.

In February 1986, the two Finnish nuclear utilities, IVO and TVO, established PEVO (Perusvoima Oy), to develop new nuclear capacity in the country. In the next month, PEVO applied to the Council of State for a decision-in-principle on building new nuclear plant capacity of about 1000 MWe, and a positive decision was expected before the end of 1986. Public opinion in response to the Chernobyl accident, however, put the effort on hold. The new government elected in 1987 declared against building new nuclear power plants. As a result, a decision to proceed again to build new capacity will not occur before the next elections scheduled for 1991. According to the new atomic energy act, the decision-in-principle on the construction of nuclear plants is to be taken by the parliament and a change of the present political climate to be more favorable for nuclear power is thus required before any new plant can be built.

In the meantime, PEVO and its owners are involved in two ongoing technical programs related to the proposed new nuclear capacity. One involves the plant alternatives presented in the original decision-in-principle application, and the other involves review of advanced light-water reactor technology. Readiness to start the construction of a new plant immediately after a positive political decision is thus preserved.

Existing and planned production capacity will according to the newest consumption forecasts be sufficient until the end of 1993, but at the end of the century a gap of 1500 MWe in capacity is predicted. Taking into account the new awareness of the consequences of fossil power such as acid rains, global change of the climate due to the greenhouse effect etc., it is hard to see how this gap could be filled without nuclear energy.

MODIFICATION, UPGRADING AND DEVELOPMENT WORK AT UTILITY COMPANIES

One component of the good operation history of the Finnish nuclear power plants is connected to the continuous development, modification and upgrading work, which is proceeding in all existing plants. In the following a short description is given on recent activities related to the I&C-systems of the plants.

1 Process computer systems

Mainly due to the maintenance problems and computing capacity restrictions both IVO and TVO have renewed their plant and process computer systems during the recent years. The configuration and tasks of the computer systems are slightly different in IVO's and TVO's plants and therefore, the time schedules and details of the updating projects differ.

In Loviisa plants, there is a centralized process computer in each unit and a common stand-by machine for these. The computers are of type ARGUS 500 manufactured by Ferranti Ltd, UK. The system was delivered by the Finnish company Nokia Oy, and it has an important role in the process supervision. The new system was bought from Nokia Oy and is delivered by Afora Oy, a former subsidiary of Nokia but now owned by Combustion Engineering Co. The computers will be replaced with a cluster of VAX-computers connected through an ETHERNET local area network. The control room interface is realized by using high-resolution full-graphic color displays. The field connections of the old system will be retained, all other parts of the system are renewed. The software for the computers is completely rewritten, IVO has written some part of application programs by himself as well as realized the process displays and reporting system.

The connection of the new system to the process was realized at unit 1 during the refuelling outage in summer 1988 and will be done at unit 2 in summer 1989. The new system has (for testing and software development purposes) been in use at the unit 1 in parallel with the old one since November 1988 and will be changed as master in May 1989. At the simulator the new computer system has been in parallel operation since January 1989 and operators have been trained to use the system. The VAX-clusters at each unit and at the simulator are connected together with bridges which makes data transfer between plant units and simulator possible.

After the physical replacement of the computer system is done also new control room displays and computerized operator support functions will be realized. IVO has been developing Safety Parameter Display System (SPDS)-programs, which will be included in the new process computer system after they have been tested and validated at the training simulator. Other new functions already implemented include a comprehensive plant history and trend display system, logic system status displays, zooming, panning and window functions etc. The total renewal project probably has been the largest of its kind so far realized.

At the TVO plants there is a more distributed computer system comprising mainly of Norsk Data's NORD-minicomputers. These computers have been replaced and completed piece-wise during the years 1985-1988. Studies on the replacement of the existing man-machine

interface in control room and new operator support systems has also been done in Olkiluoto. For the moment TVO is defining the functional requirements of the system. Concerning the hardware realization of the man-machine interface TVO is waiting for experiences from the work-station techniques, which will be used in their new training simulator. Decision on the technology selection for the renewal of the man-machine interface will be done in summer 1990.

2 Training Simulators

IVO has had a plant-specific full-scope training simulator for its Loviisa plant in operation since the year 1980. The computing capacity of the original PDP 11/70 simulation computers was becoming a restrictive factor for the continuous development and upgrade of the simulator and also the maintenance of old machines was seen getting more difficult. Therefore, the simulation computers has been replaced with a VAX-cluster during the past two years. Also the old process computer replica has been replaced with a new one corresponding the new configuration at the plant. Now there are good possibilities to enhance the simulation domain and accuracy; for example, a new containment model has been developed and the simulation level of control room instrumentation has been improved.

Besides operator training, the Loviisa simulator has extensively been used for various research and development work as well as for plant analyses and testing. These tasks have included eg. human factor analyses for the PSA-studies, analysis of thermal shock during emergency core cooling, testing of operation procedures and new process computer functions.

The operators of the TVO plants have this far been trained at the Barsebäck-1-simulator at KSU AB in Studsvik, Sweden. In January 1988, nowever, TVO ordered an own full-scope training simulator from Singer Link-Miles Simulation Corporation and the simulator will be ready for use in March 1990.

3 Operation procedures

A new symptom-based general emergency operation procedure and a set of supporting event procedures have been taken into use in the Olkiluoto plant. A control room review realized in co-operation with VTT showed that the present control room interface and some new group-displays created for the plant computer system satisfactorily supports the use of these procedures. Additional improvements can still be achieved by using advanced operator support systems planned to be realized in connection of the renewal of the process computer man-machine interface.

At the Loviisa plant the renewal of the operation procedures is also in progress, but is expected to need more time than at TVO. A new plant status based emergency operation master guide has been implemented and contains also the principles of the critical functions to be included in the new SPDS-system. The new process computer system gives good possibilities for computerized operator support functions.

4 Severe Accident Management

The present Finnish safety guide on the design principles of nuclear power plants requires severe accidents to be taken into account in the design of the containment; in 1986 this requirement was extended to apply also to existing old plants. The utility companies have started back-fitting the plants to cope with this requirement. The actions include the validation of the existing containment instrumentation to stand the containment conditions after a severe accident as well as adding some new instrumentation. At the Loviisa plant, some instrumentation cable penetrations will also be renovated.

At the Olkiluoto plant, a filtered containment venting system has been ordered from KWU, while in Loviisa the need of venting the containment is still under consideration.

More generally the power companies are checking and reconsidering the safety classification of I&C-systems and equipment. The transmission of data on plant status and releases to the authorities will also be intensified.

5 Radioactive Waste Management

In contrast to IVO, who is sending the spent fuel back to Soviet Union, TVO has yet no agreement on the final disposal of spent fuel. Therefore, TVO has started studies on finding a proper place of repository for the spent fuel in Finnish bedrock. Five sites are now under study. In 1992 two or three will be selected for further study and the final site will be selected in 2000. Some test drilling of bedrock has been done and new unique instrumentation and measurement technology developed for measurement of bedrock integrity and ground water flows.

TVO has also constructed an interim storage facility for spent fuel which is capable of storing the life-long production of spent fuel and this gives time to consider various alternatives for the final disposal. Further it is also building a repository for low- and intermediate-level wastes, for which instrumentation for long lived phenomena in bedrock has been developed.

6 Probabilistic Safety Analysis

Probabilistic safety analysis (PSA) work for both Loviisa and Olkiluoto plants has commenced for a few years time and the studies will be completed during this year. The concept of a "living" PSA means however that plant changes cause a continuing need to update these analysis during the whole lifetime of the plant. The analyses for the moment are going to be forwarded to the safety authority, the Finnish Centre for Radiation and Nuclear Safety, for approval. The purpose of the PSA study has been to examine the probability of severe core degradation and identify the weakest points of the plants. It will also be used in planning design changes - for determining the effects on total risk. It also can be used for improving operation procedures etc. and human factors have been an important part of the studies. The studies has been done primarily by the plants' own staffs' and has thus also been a good training experience for them.

RESEARCH ACTIVITIES AT VTT

Research and development work on nuclear power plant C&I and related matters in Finland outside the utility companies is mainly done at the Laboratory of Electrical and Automation Engineering of the Technical Research Centre of Finland. In the following a short description on these activities is given.

1 Advanced Information Technology (INF)

The Nordic Liaison Committee for Atomic Energy (NKA) co-ordinates and sponsors Nordic research projects on nuclear safety. These programmes have included Nordic co-operation projects on "Control room design" (NKA/KRU, 1977 - 1980) and "Human reliability in complicated energy systems" (NKA/LIT, 1981 - 1985).

A new project (NKA/INF, 1985 -1989) on the application of artificial intelligence (AI) and expert system technology for aiding nuclear power plant operators and safety personnel during disturbance and accident situations was started in 1985 aiming for development and testing a couple of experimental systems later on.

Accident scenarios and related decision processes and information needs were mapped and basic features of the support system defined, and the construction of a first prototype system on a SYMBOLICS-machine has been finished at the end of 1988. This prototype will be tested and evaluated and its features refined for further development and finally recommendations and guidelines about these kind of systems will be produced during 1989.

2 Probabilistic Safety Analysis (RAS)

VTT is also participating in the Nordic NKA/RAS-project on safety analysis. The work has been directed towards the improvement of the safety technical specifications, methods for probabilistic safety analysis and general safety principles.

3 Information Technology Support for Emergency Management (ISEM)

VTT is participating in the international ISEM-project scheduled for 1989 - 1991 and belonging to the European Esprit II research programme. Other participating organizations are from Belgium, Denmark, Federal Republic of Germany, Finland, Italy, Spain and Sweden. The prime contractor is Risö National Laboratory in Denmark. The other partners include companies specializing in computer systems, nuclear power, research and development, software, and testing.

The objective of the project is to develop distributed decision support systems that are suitable for emergency management. An approach chosen in the ISEM-project is to develop an application generator that can be used to produce an emergency management system to suit a given set of application domain needs.

The applications considered are process industries, specifically nuclear power emergencies, and emergencies within such service industries that often are based on computers operating in a network. There are other potential applications such as chemical industries, that have not been included in the present phase of the project.

The Application Generator consists of knowledge bases that have been combined into an Emergency Management Knowledge Base, and software tools that support requirements analysis, specification, implementation, and configuration management of the emergency management system. The tools can be divided into two groups, the System Building Tools, and the End User Tools.

4 Characterization, assessment and development of operational skills

The development of the cognitive and co-operational skills of the operators of heavily automated production plants and processes includes many difficulties and conflicts. Producing the necessary competencies for the operators through their whole professional career is therefore of most importance.

Based on earlier experiences and observations eg. from simulator training a more complete picture on the operator competence and its basic components is strived after and new methods for development and assessment of the operational skills are searched.

5 Validation and Licensing of Digital I&C-systems

New distributed digital automation systems are conquering the major part of the automation system market and they are in foreseeable future also coming to the nuclear power plants. The licensibility of these systems for the use in safety related systems and functions however is an open question because there are no generalized and systematic methods for the evaluation of the reliability of these systems. Many new problems such as the data transfer capacity of the system buses and the reliability of software arises.

Development of methods for licensing evaluation of digital automation systems was started already in 1985 in cooperation with licensing authorities and power utility companies. The work has however been severely delayed and will continue during 1989.

6 Software Quality/Validation of Knowledge

VTT has been working with the OECD Halden Reactor Project on software reliability since 1976. A formalized software specification language (X) and a computerized support system (SPEX) has been developed as well as the principles of diverse software tested.
Part of the co-operation work in 1989 is still devoted to the software reliability study. Methods for testing and evaluation of software product quality will be developed and reported together with Halden project and CEGB from United Kingdom.

A new research area on evaluation and validation of expert systems has been started in 1988 and will be continued during 1989. Methods based on the use of qualitative modelling and formal proof of theorems are tested and applications in validation of computerized operation manuals and intelligent alarm handling systems studied.

7 Advanced Simulation System APROS

VTT realized during the years 1986 - 1988 an extensive research programme on "Numerical simulation of processes". As a part of this programme VTT together with Imatran Voima Co (IVO) developed a new simulation environment APROS for flow and heat transfer processes. Here the latest developments in computer software and hardware technology are employed. Special attention is paid to the ease of defining and running the models and the presentation of simulation results.

The process model is constructed by selecting the process components from a comprehensive module library and defining the connections between them. This is done either by using a command language or even more easily with an interactive graphics system. In case the module library does not include the desired component, the user can proceed to the bottom level of the system and define this component to the library. Given this information the system automatically constructs the model data bases, queries component parameters, constitutes model equations and chooses integration algorithms. During the simulation run the user can continuously follow process parameters of his choice either as numerical values or curve plottings, start and stop the run, and control the operations. Desired changes to the parameters and the simulated process can be made without the need of new compilation and linking of the programs.

During the APROS-development project a comprehensive simulation model for the IVO-owned peat powered condensation power plant was constructed. It models the whole plant and its control systems from fuel intake to the electric grid and flue gas stack. The model will be used during the start-up phase for the planning of the commissioning tests and pretuning of control parameters.

Also a simulation model for the reactor and primary coolant circuits of the Loviisa nuclear power plant has been constructed. This model will be extended to a comprehensive and detailed nuclear plant analyzer (MPA - Modular Plant Analyzer), and will be validated for safety analysis purposes.

As a result of these applications a comprehensive and well validated model library of conventional and nuclear power plant components has been created in the APROS-system. This makes it straightforward to construct new design and training simulators for power plants of same type.

ATTACHMENT

NUCLEAR ENERGY RELATED RESEARCH
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RECENT NUCLEAR POWER PLANT CONTROL AND INSTRUMENTATION ACTIVITIES IN THE GERMAN DEMOCRATIC REPUBLIC

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Abstract

In the GDR NPP's with Soviet WWER-type reactors are in operation and in commissioning. Their control and instrumentation systems have been delivered by the Soviet Union. In order to enhance the level of nuclear safety a few additional equipments basing on domestic hardware have been installed, e.g. systems for early failure detection. At time backfitting of the control and instrumentation systems of the units 1 to 4 of Greifswald NPP is in preparation. In recent years a computerized training simulator for WWER-440 NPP's has been developed.

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1. Nuclear Energy in the GDR

At present lignit is the main source of primary energy in the GDR. It delivers 70% of the primary energy. For the GDR the use of nuclear energy is very important because the national resources of lignit are limited and the ecological effects of lignit combustion are negative. Besides lignit there are no other national fossil fuels.

Our country needs more and more nuclear energy not only for the production of electricity but also for the generation of low temperature heat. In the next decades the share of nuclear energy on the primary energy will be growing continuously.

Today the share of nuclear energy on the primary energy amounts to 3%, whereas 12% of the total electricity are generated in Nuclear Power Plants.