Computers for reliable nuclear power plant control

by G. Sitnikov*

Control and instrumentation of nuclear power plants has improved rapidly and significantly in recent years as demands for reactor safety, availability, and reliability increased. Development and design of modern, highly automated systems have become possible as new measurement and control methods were introduced together with new data processing techniques based on recent advances in electronic components, transducers, and computers.

There is now a new generation of computerized nuclear power plant control systems which meet the high demands for reactor safety and decrease the risk of accidents.

Two IAEA symposia on nuclear power plant control and instrumentation, held in 1973 and 1978, proved to be important opportunities for international information exchange on the subject. A third symposium on the same subject**, held in Munich, accordingly attracted great interest, reflected in the number and quality of the papers submitted.

The technical sessions showed that constructive experience has been accumulated in the general field of man-machine interface engineering. The new control-room designs use numerical analysis techniques on a large scale and have been subjected to extensive ergonomic analysis. One accepted consequence of these studies is an adjustment of operating procedures. It is now considered essential that operators should have an active role in the design of control rooms to improve not only the safety and reliability of nuclear power plants but also the operators' working conditions. Control rooms are so complex that the construction of a model is justified despite the high cost. The great progress which now has been achieved in design of control rooms indicates that old ones in many cases should be updated and possibly completely rebuilt.

This is only one aspect of the problem of obsolescence of control and instrumentation equipment in nuclear power plants constructed 10 to 15 years ago. In many cases it will be necessary to modify control systems and instrumentation of those plants very extensively. Such modifications are feasible, since replacement of electrical equipment is relatively simple. The cost of modifications, however, can be extremely high in certain cases but the resulting improved safety justifies this.

It is now generally accepted that control and instrumentation equipment could be revised and updated several times during the life-time of nuclear power plant. New technological developments are being introduced continuously to new control-system designs.

Some specific problems arise in developing countries in connection with the installation of turn-key nuclear power plants. Maintenance facilities have some times proved inadequate because support functions were too weak. Large investments have proved necessary to ensure better performance of the plant although most of the capital has not been available for this purpose.

Large-scale research on advanced systems for operator support, during normal and abnormal plant conditions, is being carried out in many countries. Almost all studies are at the stage of planning, design, or simulation tests, showing not only that progress in this field is very rapid but also that there is still a broad field where new ideas or techniques are required. Papers presented at the symposium described some particular systems for operator support, mainly in disturbance analysis, display of safety parameters, guidance to plant operators and plant diagnostics. Their specific application depends upon the type of reactor and the safety standards and nuclear regulations in different countries.

The variety of operator-supporting systems and the different approaches to their design indicate that there is still much research work to be done and that greater exchange of information internationally on this subject could be very useful.

A Comprehensive Computerized Operator Support System (COSS) is being developed for both pressurized light-water reactors (PWRs) and boiling light-water reactors (BWRs) by a group of Japanese companies. The system includes many advanced techniques of information processing and display, making extensive use of CRTs and plant simulators. Considerable efforts are being devoted to developing ways and means of providing useful and accurate information about the current state of the plant to the operator. It became clear from the discussion that the development cost will amount to about US $30 million over a period of five years. Each partner in the effort is designing his own system but following the common defined goals for the project.

The STAR Disturbance Analysis System developed in the Federal Republic of Germany is another example of practical results in introducing operator-supporting systems. The STAR concept is an off-line data-base system developed in the course of the Grafenrheinfeld PWR project. It can handle functions like alarms, post-

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trip analysis, etc. The future application of STAR would be multipurpose to aid the operator in a number of tasks. One of them might be a safety parameter display system (SPDS).

Designers seem to be following generally similar approaches in the development of protective systems due to the similarity in objectives and common access to the same stock of electronic components and computers.

Many speakers at the symposium were rather apprehensive about the introduction of computers and microprocessors in protection systems. The need to keep both hardware and software simple and testable was emphasized, as were the well-known principles of diversity and redundancy for both hardware and software.

An interesting concept for nuclear power plant *Leittechnik* (the term summarizes all the equipment necessary to protect, guide, and supervise) has been developed by KWU. This concept includes: operational systems; the protection systems, divided into limitation systems; and protection systems in the narrower sense.

Between these categories the safety requirements vary by orders of magnitude. With this systematic classification it has been possible to introduce computers into those systems which are less important for reactor safety. It was noted that limitation systems improved both the availability and the safety of the plant because they treat disturbances before these lead to safety actions, and help the operators to avoid errors.

The hardware and software of computerized systems are only in the first stages of acceptance by licensing authorities. It was suggested at the symposium that computerization should be introduced step-by-step in order to gain acceptance.

The experience gained by the Canadians in using computers in reactor-control systems and in monitoring the status of safety systems, has shown the benefits which can be gained from fully computerized shut-down systems. They are reliable, flexible in design, and give a better man-machine interface.

Similar computerized systems are being developed for fast breeders. Microcomputers and their software will dominate future systems. Computers and their peripherals, e.g. graphical colour CRTs will become the major source of information for the operator for this reactor type also.

An advanced plant-monitoring and control system Nucamm-80 has been developed in Japan. It includes automatic start-up and shut-down procedures to reduce risks for potential errors and to improve operational management. The control methods employed are mainly supervisory computer control and direct digital control. In the "break point" control, the operator is informed on the results of automatic actions several times during start-up and shut-down. The next stages then are initiated manually by push buttons on the panel. But the most important plant controls are executed by automatic systems.

New results have appeared in measurement techniques and methods including various methods of measuring power distribution in a reactor core. Interesting results in this field were presented to the symposium by Canadian specialists. They described their experimental and theoretical work on vanadium, platinum, and relatively new inconel detectors which appear to have a nearly 100% prompt response with quite predictable burn-up characteristics. A particular form of platinum-clad inconel detector was proposed, which should have a dynamic response closely matching that of the power in the fuel elements.

Sodium self-powered detectors have been used in the German Democratic Republic in PWRs of the WWER-440 type. Together with above-core thermocouples they give a good picture of the power distribution.

Experiments carried out in Hungary show the possibility of using ^{16}N activation for measurement of coolant flow in a water-cooled reactor. Experiments in their research reactor had given an accuracy of about 2% for a 60-second measurement time.

Discussions on reliability, qualification, and maintainability at the symposium showed concern mainly as regards qualification, but problems of application of reliability analysis in the field of control and instrumentation systems still remain.

A new reactor-protection system *Spin* has been developed in France for introduction in all new 1300MW PWR plants in that country. *Spin* consists of four redundant logic units. Each of them is equipped with a microprocessor and two redundant parts for actuation of the two-train safety systems. The qualification process, proceeding together with the development of the system, has now reached the stage of functional performance tests for a first series. The system is now ready for on-line implementation in the first 1300MW units and has already got a full licence from the Service Central de Sûreté des Installations Nucléaires.

Canadian experience with computerized distributed systems will be used in the future for modernization of the *Candu* reactor-control systems. A first step is the implementation of a distributed network of six processors for data acquisition in an older research reactor. The further development of this system will improve its failure detection and recovery possibilities.

Problems related to licensing and methods which are to be developed for verification tests, failure-effect analysis, and maintenance provoked lively discussions at the symposium. These problems appear to be serious but are considered solvable. It is now expected that computerized control systems will find practical application in the near future as soon as problems of licensing, man-machine interface, including new control-room lay-outs and operator training, are solved.