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He also participated as I&C expert in the IAEA Safety Review mission on the modernisation programme to Rowno NPP Unit 4.

A FUNDAMENTAL OBJECTIVE IN STRENGTHENING SAFE OPERATION

MODERNISATION OF INSTRUMENTATION AND CONTROL SYSTEMS IN EAST EUROPEAN NUCLEAR POWER PLANTS

J. M. NAVARRO - A. MUÑOZ

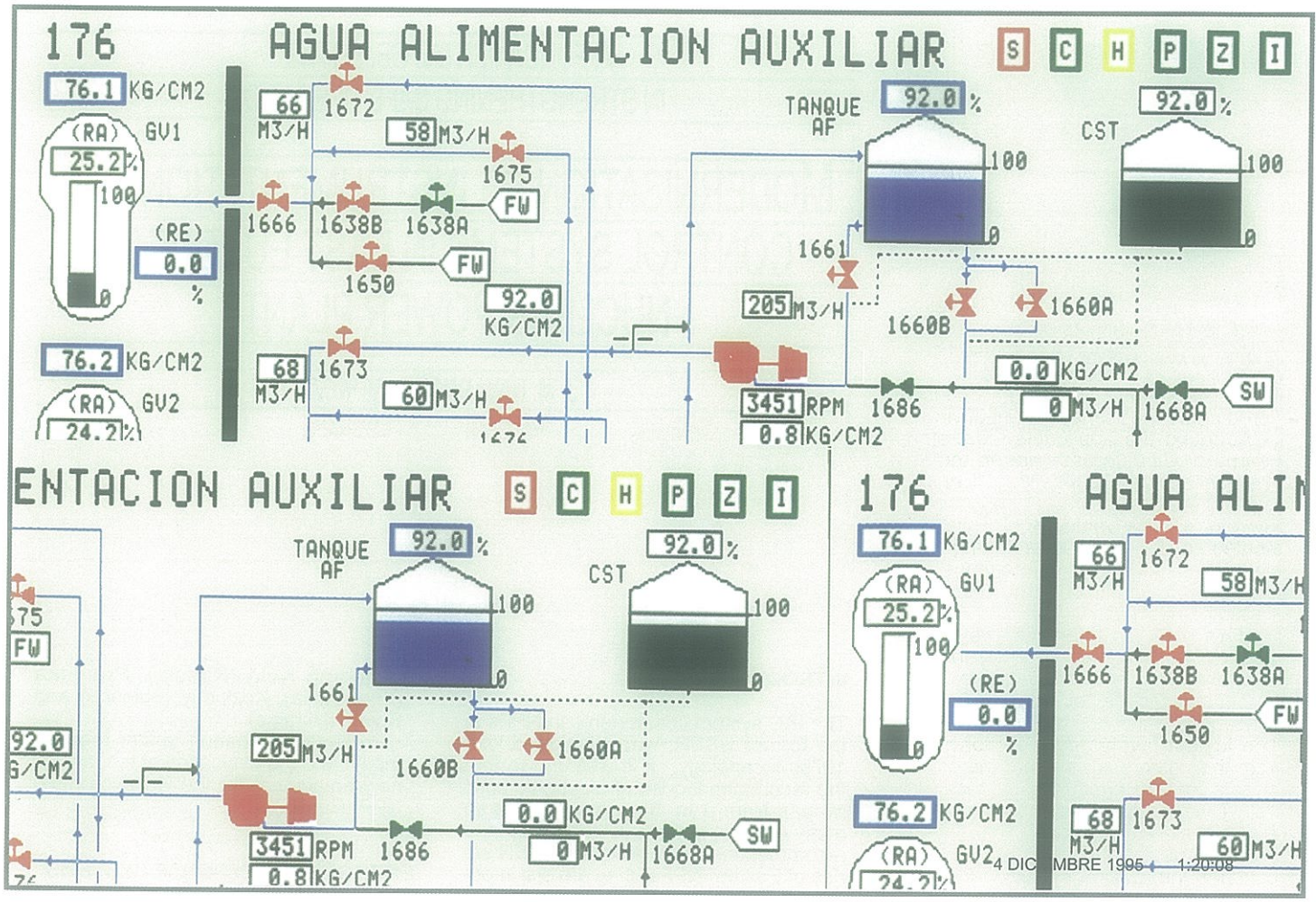
INTRODUCTION

The I&C system components in NPPs in the former USSR, were designed with 1970s technology. It is well known that the recommended life of electronic units ranges from 5 to 10 years. Although many of these units have exceeded their recommended life cycle in the VVER series of Eastern NPPs, they are still in operation.
Spare parts are scarce and often no longer manufactured. This results in constant maintenance with no guarantee of reliability, scheduled plant shutdowns not supported by suitable programmes and significantly longer shutdown times, in comparison with Western plants.
So Eastern NPPs really need to modernise their I&C systems, and this is now one of their fundamental objectives.
Modernisation of I&C begins with specific plant studies and ends with the installation of new equipment, and the training required for its use.
Empresarios Agrupados (EA) has carried out numerous activities in this field, the most important of which are

- Basic engineering and review of reactor I&C supplier documentation for the Temelin NPP in the Czech Republic, including software verification and validation process
- Various studies for I&C modernisation in the South Ukraine NPP and the specification for the new Process Computer and Information System (CIS), including SPDS (Safety Parameter Display System) and definition of required parameters
- I&C equipment qualification programme for the Kozloduy NPP (Bulgaria), including assessment of its qualification status and the methodology needed to update it
- IAEA consultancy for various NPPs including Kola (Russia), Prevlaka (Yugoslavia), Kozloduy (Bulgaria) and Rovno (Ukraine)
- Presently, preparing tender requirements and the evaluation of tenders for new equipment for the Novovoronezh NPP (Russia)

EMERGENCY RESPONSE SYSTEMS

Apart from the control systems, or simply the instruments, that have to be replaced so that the plant can be operated easily and without continuous availability problems, the first necessity, as in Western power plants, is to install an operation supporting system which contributes to ensuring its safety; the so-called SPDS ("Safety Parameter Display System").
The SPDS is an on-line information system, fundamentally developed as a support to the plant operator; it is practical due to its user-friendliness, and the real help which it provides.
It was originally designed to display the state of critical plant operation parameters in emergencies, hence its name. However, since the System must always be operational, the current trend is to design it to completely monitor the Plant under all operating conditions (normal and emergency). For this reason it is often referred to as the Plant Supervision System. (Figure I shows a process system display at Almaraz NPP in Spain).
As the System is still being installed in many Western power plants that still do not have it, the technology is still evolving, and installation in Eastern Europe is simply an extension of a worldwide trend.
An example in Western plants are the plant supervision systems including SPDS installed at the Almaraz and



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Cofrentes NPPs in Spain by Empresarios Agrupados together with General Electric and Tecnatom.

The Almaraz system is called Computerised Operation Support System (*Sistema de Ayuda Mecanizada a la Operación (SAMO)*). It receives about 2,500 process signals and carries out the following functions, among others:

- Emergency diagnosis and recovery
- Normal operation supervision
- Determination of operation mode
- Supervision of reactor core parameters
- BOP performance calculations
- Communication with the vessel level information system
- Process systems graphic displays
- Records, logs, alarms, etc

The Cofrentes NPP system is called ERIS-Computer Integrated System (*Sistema Integrado ERIS-Computador (SIEC)*). It receives about 3,300 process signals and performs the following functions, among others:

- Emergency diagnosis and recovery
- Normal operation supervision
- Three-dimensional monitoring of the reactor core
- BOP performance calculations
- Process systems graphic displays
- Records, logs, alarms, etc

Installing this type of system in Eastern European power plants presents some particular characteristics that require closer examination.

- Firstly, when the SPDS replaces the computer it often has to handle a very large number of process signals: generally over 6000 in each Unit. This is due to the design philosophy for plant instrumentation and must be taken into account, unless the entire plant instrumentation and control equipment is to be redesigned and replaced
- Secondly, it has to be pointed out that good emergency operation procedures are indispensable, but are not always available in many of these plants. As the main purpose of the Emergency Response System is to guide the operator through these procedures, this could be a critical design problem
- Finally, logistics could also be a problem when installing the system: Language and alphabet are a problem; working conditions, and sometimes living conditions, can be problematic; sometimes the only reliable local partner is the plant itself

In spite of these problems, the installation of the System is very desirable, not only because of its contribution to operational safety, but also because, as mentioned above, a good SPDS with a well designed man-machine interface gives a clear and complete picture of the status of the plant. It must be stressed that man-machine interface is a key issue in attaining the objective.

The design of the man-machine interface is no longer an esoteric issue, to be tackled only by specialists. Many applicable standards have been produced in recent years and although, being something of an art, taste is still important, all the criteria are more or less standardised. As the technology matures, international cooperation on shared interest projects such as Advanced Reactors has an important role when establishing a common procedure.

Empresarios Agrupados is also involved with Eastern European power plants as regards SPDS, Emergency Response Systems and Plant Supervision Systems. The most important of activities performed are:

- Specification of a Computer Information System (CIS) for the South Ukraine NPP
- Terms of Reference for the VVER 1000 Safety Panel
- Review of software control documents and of the Post Accident Monitoring System of the Temelin NPP

• List of parameters for the South Ukraine NPP SPDS

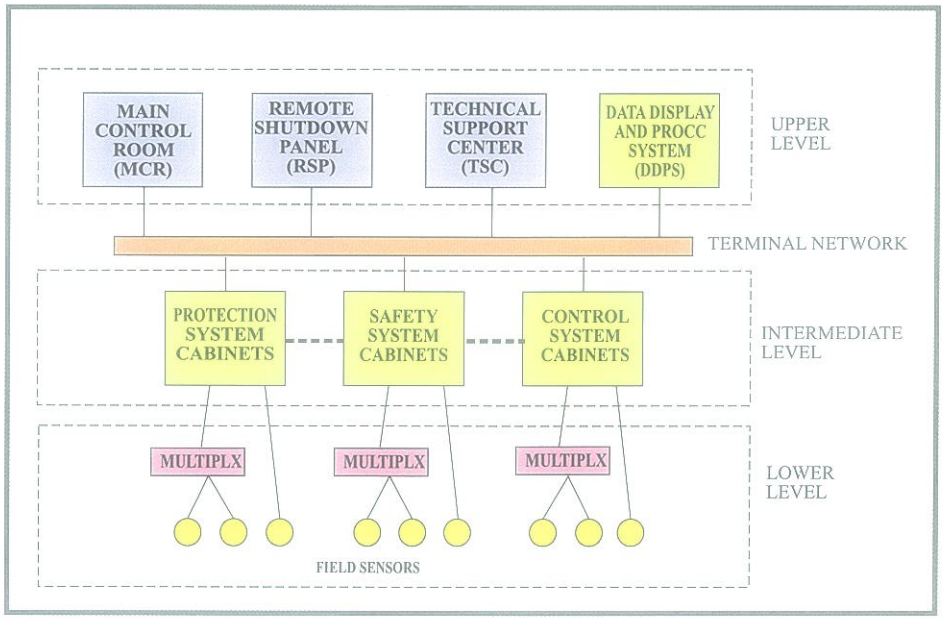
DISTRIBUTED CONTROL SYSTEM

The authorities responsible for nuclear safety in Eastern countries often express some concern when licensing new I&C systems based on digital technology.
This concern arises from aspects, such as:

- Lack of information and familiarisation with new technologies
- Main requirements of distributed control
- System's particularities to be considered under the licensing point of view
- Adapting the applicable legal standards of Eastern countries to the implementation and subsequent licensing of new systems

Therefore, the advantages of digital distributed control systems, regarding reliability, availability and maintenance and from the viewpoint of plant operation, should be explained.
Modern I&C and information systems tend to be designed in a hierarchical structure with series of different levels of functions. These levels combine the concept of distribution and integration.
The lowest levels acquire information from the entire plant and are the source of data for equipment and process control. They also offer services to other hierarchical levels of function.
In these designs (Fig II) the top level contains information systems and control rooms. This is where the operators communicate with plant instrumentation, receive information and operate equipment. The Main Control Room, Emergency Shutdown Panel, Technical Support Centre and data processing and display system are located on this level.
The intermediate level covers plant protection, safety and control systems and functions. All the systems on the intermediate level are divided into subsystems. Functions are interrelated and grouped in cabinets, that contain microprocessor-based modules, and can intercommunicate through information cables or networks. The intermediate level is connected to the top level by means of the terminal communications network.
The lowest level includes field sensors and remote multiplexers. The multiplexers receive signals from the field sensors, multiplex them and send them to the systems cabinets, normally through optic fibre.
Below are some of the innovations offered by the new technology:

- Extensive use of microprocessors in the construction of protection, safety and control circuit modules and cards
- For communication systems optic fibre is generally used instead of the traditional connection cables
- The man-machine interface uses new elements such as touch screens, virtual manual switches, main console with a new design incorporating work stations and a wide panel in the control room which often includes process mimics



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MAIN CONTROL ROOM

The control room designs contemplated in the new technologies are aimed at improving plant reliability from the viewpoint of operation and information, as well as operator efficiency and effectiveness.
The control room configurations incorporate key elements such as a large integrated display panel or a compact main control console. The compact main control console concentrates control and information functions. The operator can take any actions from one position.
The large integrated display panels show critical plant information and the state of the systems, which can be seen by any operator in the control room.
A good man-machine interface and automation of all plant functions ensures easy and error-free operation.
Empresarios Agrupados has participated actively in Advanced Reactor projects (USA and Europe). In the area of instrumentation and control, it has worked on a series of activities applying the most modern technology. The main activities (for SBWR, ABWR or AP600) are:

- Architecture design and functional specification for the multiplexing system
- Architecture and functional specification for the control and monitoring system (process computer)
- Configuration and functional specification for the Waste Processing Building Control Room
- Instrumentation on P&IDs, logic diagrams, hardware/software specifications and wiring diagrams for various Systems; for example, the Remote Shutdown System
- Man-machine interface: definition, requirements documentation and tasks functional analysis

In addition to this, specific problems such as communications reliability, common mode failure, uncertainty in control system response, or the application of new designs like intelligent valves, have been studied and solved.

CONCLUSIONS

Implementation of these modern I&C systems in Eastern European NPPs will no doubt improve their operational reliability and safety. The improvement will result not only from the better design, construction, operation and response characteristics, compared with existing systems, but also from its easy use and maintenance, and the highly elaborate information provided for the operator and other plant staff, as needed in every circumstance. Another important factor is the improved availability of spare parts, which could now be obtained on the international market.
However, these are not the only factors which are improving operational safety: the use of similar technologies in East and West will improve communication between operators and plant managers, who will face similar problems understandable by all of them and who will have to solve them by adopting measures of general interest and common application. It is therefore logical to expect a homogenous safety level in all plants, which will be higher than that attainable in isolation since the group researching improvements and solving problems will be much larger.