УДК 621.039.58:004.9

M. Yastrebenetsky[1], Yu. Rozen[1], A. Klevtsov[1], M. Gashev[2]

[1]*State Scientific and Technical Center for Nuclear and Radiation Safety, Kharkov, Ukraine*
[2]*State Nuclear Regulatory Inspectorate of Ukraine, Kiev, Ukraine*

Strategy of NPP I&C systems' modernization in Ukraine

The stages of modernization of Ukrainian NPP I&C systems are described in the paper. The first stage (1993—2000) was characterized by use of systems designed by foreign (including USA) companies. The second stage (2001—2011) was characterized by use of systems designed by Ukrainian companies. The modernization strategy is analyzed in two aspects: the strategy of operators and the strategy of I&C systems' designers. Some features peculiar to the strategy of designers are: an aggregate of hardware, software and service apparatus called "hardware-software complex" (HSC) as central part of systems, which are delivered to NPPs in full assembly and are connected to peripheral equipment at NPP; use of FPGA for performance of safety functions; elaboration of new equipment families. The third stage starts in 2012 and is related to construction of two new units (Khmelnitsky-3 and 4). A new regulatory framework, including regulatory requirements, will be elaborated for I&C systems of these units.

Keywords: instrumentation, control, system, nuclear power plant, modernization.

М. О. Ястребенецький, Ю. В. Розен, О. Л. Клевцов, М. Х. Гашев

Стратегія модернізації ІКС АЕС в Україні

Міжнародні конференції «Інформаційні та керуючі системи АЕС і техніка людино-машинного інтерфейсу», що організовуються кожні два-три роки Ядерним товариством США, збирають учасників практично з усіх країн, де експлуатуються або будуються АЕС.

У статті наводяться матеріали доповіді «Стратегія модернізації ІКС АЕС в Україні», представленої на 8-й конференції, що відбулася в липні 2012 р. в США (секція «Досвід модернізації АЕС»). Автори аналізують три стадії модернізації ІКС АЕС в Україні. Перша стадія (1993—2000) характеризується використанням систем, розроблених зарубіжними компаніями, друга (2001—2011) — вітчизняними розробниками, третя (з 2012 р.) стадія пов'язана з розробкою нової нормативної бази з ІКС АЕС і підготовкою до спорудження двох нових енергоблоків.

Ключові слова: атомна електростанція, контроль, інформаційні та керуючі системи, модернізація, нормативна база.

There are currently 4 NPPs with 15 units operating in Ukraine: 13 units WWER-1000 and 2 units WWER-440. All NPPs are managed by one operator: National Nuclear Energy Generating Company "Energoatom". The first reason that necessitated I&C modernization was the obsolescence of these systems. I&C systems were designed in 1979—1983 and do not conform to the modern level of computer technology. I&C systems had a lot of safety deficiencies — unsatisfactory level of reliability, diagnostics, qualification, resistance to external impacts, man-machine interface, etc.

The distribution of units by age is shown in Figure 1. The lifetime of all units is 30 years. The lifetime of most instrumentation is less than 30 years. Hence, the second reason for I&C modernization was necessitated by units' life extension and expiration of instrumentation's lifetime.

First stage of modernization

The first stage (1993—2000) was characterized by using the systems designed by foreign companies: USA — Westinghouse, Czech Republic — Skoda, Russia — Kurchatov Institute, France — Syzeca, etc. Most of these systems were safety-related.

Ukraine had no uniform strategy for I&C modernization at that time. Some of these systems had good fate and continue to operate now. This concerns first of all 11 SPDS for all Ukrainian WWER-1000 units which operated at that time. SPDS was designed by "Westinghouse" (USA) together with joint USA — Ukrainian company "Westron".

Some of these systems (e. g. computer information systems designed by Syzeca (France)) were replaced during the second stage of modernization.

Ukraine did not have its own regulations related to I&C systems during that time. The Ukrainian Regulatory Authority used USSR standards and standards of the countries-designers in licensing process for these systems [1].

Second stage of modernization

The second stage was implemented during 2001—2011. The main peculiarities of this stage are:

– modern computer techniques were widely used;
– new national regulatory framework was developed;
– most I&C systems were designed and produced by Ukrainian companies;
– modernized I&C were not only safety-related systems but safety systems as well (e.g., reactor protection systems).

The modernization strategy is analyzed in the following aspects:

– strategy of operators (NPP or National Nuclear Energy Generating Company "Energoatom");
– strategy of I&C systems designers.

The main features peculiar to the strategy of operators are as follows:

• Most modernizations take place during shutdown for refueling. This time is limited, and in some cases the shutdown period is insufficient for modernization. In these cases, modernization is implemented in 2 or 3 stages. (Examples: complete modernization of the unit computer information system or neutron flux monitoring system). The presence of several stages required additional activities to ensure the compatibility between modernized and non-modernized parts of the systems.

• All I&C modernizations can be divided into pilot (modernizations implemented for the first time at NPP with spe-

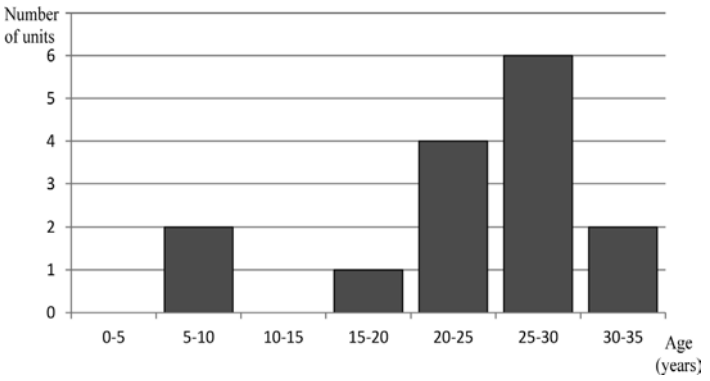

Figure 1. Distribution of units by age (as of 1 January 2012)

cific reactor type) and replicated (modernizations implemented before at a specific NPP type in Ukraine and showed positive results). Of course, use of replicated systems is preferable in terms of safety justification and cost for acquisition of systems. The scope of licensing actions for replicated modernizations is substantially smaller than for pilots. A specific stage in the implementation of a pilot system is its trial operation with extensive support from the designer and prompt feedback from the NPP to the designer, involving analysis of all failures, faults or NPP personnel comments.

• Most modernizations used existing technological algorithms, which were proven by long-term operation of WWER units in Ukraine, Russia and other countries. The algorithms were modified to include new functions, e.g. control of primary-to-secondary leakage accidents.

• Modernizations can be related to the central part of a system or to a system as a whole, together with sensors, cables, actuators. At the beginning of this stage, modernizations involved only central-part of systems (as a rule, computer-based). In recent times, replacement of cables and sensors is included into the scope of modernizations.

• Extensive I&C modernization took place before unit life extension. "Energoatom" paid special attention to these actions and assigned resources for unit life extension, including replacements of old I&C systems. The Regulatory Authority requested these replacements from the NPP to receive a license for unit life extension. An example is I&C systems of South Ukraine NPP Unit 1, which were modernized to obtain approval for unit life extension (Table 1).

The main features peculiar to the strategy of designers are as follows:

• Use of an aggregate of hardware, software and service apparatus called "hardware-software complex" (HSC) as the central part of systems. HSC are delivered to NPPs in full assembly, after checkout and testing, with high level of factory availability. HSC is connected to peripheral equipment at NPP.

• Ukraine ("Radiy" Company, Kirovograd) pioneered the application of FPGA for performance of safety functions (reactor protection systems, ESFAS, etc.). Since 2004, more than 40 FPGA-based systems have been installed at Ukrainian NPPs. IAEA Independent Engineering Review of Instrumentation and Control Systems Mission took place at the "Radiy" site for review of FPGA technology in December 2010.

• The diversity requirement was not implemented at Ukrainian NPPs before 2000. Ukrainian regulation [2], issued in 2000, included this requirement for reactor protection systems as necessary and for other systems of safety class 2 (the highest) as recommended. It would be noted that the diversity requirement

Table 1. South Ukraine Unit 1 I&C systems that were modernized for approval of life extension

Name of system	Designer
Reactor protection system	Radiy (Ukraine)
Reactor power control and limitation system	Radiy (Ukraine)
Engineered safety features automated system	Radiy (Ukraine) Westron (Ukraine)
Automatic regulators (turbine hall)	Shevchenko Plant (Ukraine) LvovORGRES (Ukraine)
Steam generator level and feedwater control system	Westron (Ukraine)
Refueling machine control system	EVIG (Hungary)
Neutron flux monitoring system	Impuls (Ukraine)
In-core reactor monitoring systems	KhIKA (Ukraine), SNIIP-Atom (Russia)
Radiation monitoring system	Westron (Ukraine)

caused many contradictions and discussions between the developers of regulations and operators and designers. After discussions, this requirement was included in regulations as obligatory only for protection systems. After a five-year period, specialists began to perceive these requirements as a usual task. The diversity principle has been now incorporated in all reactor protection systems (designer — "Radiy") and in other systems (e. g., automatic regulators for engineered safety features automated systems designed by Shevchenko plant).

• Ukrainian companies have elaborated new, their own equipment families (platforms). The parts of these platforms are closed and can be used only by their designer. Examples are "Radiy" platforms with wide use of FPGA, "Westron"–"Vulcan" platforms for safety-related systems (analog of Westinghouse platform WDPF-II) and "Vulcan-M" platforms (for safety systems). The platforms designed by "Impuls" (e. g. complexes MSKU and working stations PS-5120) are open and can be used by different companies. USSR platforms UKTS (UKTS-D, UKTS-BL, UKTS-DKI) modernized in Ukraine are open as well.

• Ukrainian designers have the possibility to use the hardware components from any foreign country. This was impossible before in the USSR, when designers of NPP I&C systems had to use only USSR components.

•An important step was wide use of fiber optic communication lines instead of wire lines.

A set of Ukrainian regulations were developed to support I&C modernization [2] (Fig. 2). These regulations were harmonized as much as possible with requirements of international safety standards and guidelines published before the preparation of these documents. It should be noted that the main principles of IAEA NS-G-1.3 [3] were taken into account in the Ukrainian regulations before the official issue of this document.

All safety important I&C systems designed and produced by Ukrainian companies were brought into compliance with Ukrainian regulations.

The main results of modernizations are as follows [4]:

— increase of equipment dependability, availability and reliability;

— increase of equipment resistance to external impacts;

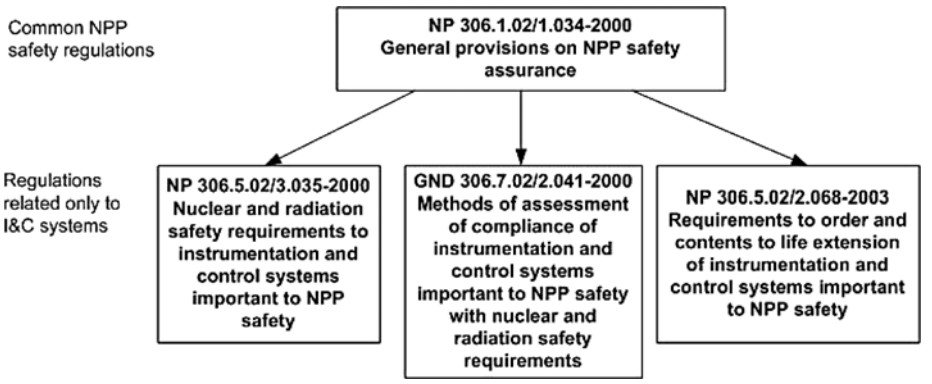

Figure 2. Acting pyramid of Ukrainian regulations

— increase of accuracy and time response in the control and checking processes;

— decrease of time for modernization during unit shutdown for maintenance;

— improvement of operator information support as well as visualization of technological processes and parameters;

— improvement of diagnostic functions for I&C systems and technological equipment;

— decrease of contacts and clip connections by more than 10 times because of high level of integration and fiber-optic lines;

— compliance with requirements of international safety codes, guides and standards.

Wide approbation of I&C systems at Ukrainian NPPs increased the level of international confidence in these systems. This was demonstrated by delivery of systems and hardware of Ukrainian designers to foreign NPPs.

Successful experience in operation of new I&C systems at Ukrainian NPPs provided the possibility to manufacture and implement similar systems for foreign NPPs (Table 2).

The drawbacks of the modernization strategy are analyzed as well:

– absence of overall I&C systems modernization design;

– presence of different systems (designed by different companies) with the same functions at NPPs.

Third stage of modernization

The main areas of activities on I&C systems will be the following:

– actions related to life extension of units and equipment;

– development of I&C systems for two new units — Khmelnitsky-3 and 4. The construction of these units began in 1985, stopped in 1990 pursuant to the Ukrainian Parliament's decision on moratorium to build new NPPs and renewed after 2005. The feasibility study has been completed. The type of new reactors is WWER-1000, V-392B design (same as Balakovo NPP), which has some improvements in comparison

Table 2. New instrumentation and control systems produced by Ukrainian companies for foreign NPPs

NPP and unit number	Country	Name of system	Ukrainian manufacturer — designer of system	Comment
Kozloduy 5, 6	Bulgaria	Engineered safety features automated system (trains 1, 2, 3)	Radiy	
Koeberg 1, 2	South Africa	Computer information system	Westron	Together with Westinghouse (USA)
Almaraz 1, 2	Spain			
Asco 1				
Armenia 2	Armenia	Diesel-generator control system		
		Steam generator level and feedwater control system		Together with LvovORGRES (Ukraine)
Leningrad 3, 4	Russia	SPDS		Together with PNNL (USA)
Dukovany 1, 2, 3, 4	Czech Republic	Radiation safety control system (emission through air pipe)		Together with I&C Energo (Czech Republic)
Volgodonsk 1 Balakovo 1, 2	Russia	Computer information system	Impuls, KhiKA	
Balakovo 3 Kalinin 1, 2, 3, 4	Russia	Turbine control system	Shevchenko plant	
Kaiga 3, 4 RAPP 5, 6	India			

with operating WWER-1000, V-320 design. The first steps of I&C design have started;

– consideration of the Fukushima accident lessons for improvement of operating systems and development of new systems (e. g., post-accident monitoring system);

– appearance of new technologies (e.g. wireless sensors) and new requirements (e.g. to cyber security) which should be taken into account during development and safety assessment of new I&C systems.

A common action for all areas is updating of the Ukrainian regulatory framework and harmonization with modern international standards. This framework has to include:

– regulation developed by the Ukrainian Regulatory Authority with safety requirements for I&C systems;

– standard of the National Nuclear Energy Generating Company "Energoatom" with technical requirements for safety important I&C systems.

These two documents are consistent.

Conclusions

After 2001 Ukraine has passed from a country that imported I&C systems for its own NPPs and has become a country that not only satisfies its own needs but exports these systems. Some features peculiar to the strategy for NPP I&C modernization in Ukraine may be of interest to specialists from other countries: use of an aggregate of hardware, software and service apparatus called "hardware-software complex" (HSC) as the central part of systems, HSC are delivered to NPPs in full assembly, after checkout and testing, with high level of factory availability, which can decrease time to replacement for modernization; use of FPGA for performance of safety functions, including reactor protection systems.

References

1. Licensing Review of Foreign I&C Systems for Ukrainian Nuclear Power Plants / O. Brenman, R. Denning, etc. — NPIC&HMIT-5. — Albuquerque, NM, 2006.

2. Ukrainian NPP I&C standard base: elaboration and application / M. Yastrebenetsky, Yu. Rozen, A. Siora, V. Bezsaly. — NPIC&HMIT-7. — Las Vegas, NV, 2010.

3. *IAEA NS-G-1.3.* Instrumentation and control systems important to safety in nuclear power plants. Safety guide. — Vienna, 2002.

4. Nuclear Power Plants Safety: Nuclear Reactors Control and Protection systems / M. Yastrebenetsky, Yu. Rozen, S. Vinogradska, G. Johnson, etc. — Kiev : Osnova-Print, Ukraine, 2011. — 764 p. — (in Russian).

Retrieved 03.10.2012.