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UKRAINIAN NUCLEAR POWER PLANT SAFETY AND INSTRUMENTATION AND CONTROL SYSTEMS FUNCTIONAL SAFETY

Two aspects of interconnection between nuclear power plants (NPP) safety and NPP instrumentation and control systems functional safety are describes: new systems which were designed by new requirements to functional safety; violations of NPP nuclear safety because I&C.

nuclear power plant; safety; functional safety; instrumentation and control systems; violations.

Connection between nuclear power plant (NPP) nuclear safety and instrumentation and control systems (I&C) functional safety has two sides: NPP safety defines hard requirements to I&C functional safety; lacks of I&C functional safety could lead to violations of NPP safety.

This problem is important as to new NPP units, as to operating units.

Introduction

The most positive event in Ukraine industry for last years – start of two units WWER-1000: Khmelnitsky-2 and Rovno-4.

The construction of KhNPP-2 and RNPP-4 started in 1983 and 1984 respectively. In 1990 the construction of both units was halted due to the Moratorium on construction of new nuclear power plants adopted by Verkhovna Rada of Ukraine (preservation and equipment conservation works were conducted).

At that time the power units were RNPP – 75% and KhNPP – 80% complete. After the Moratorium lifting by the Verhovna Rada Decree the civil works were renewed.

Currently there are 15 operating power units at Ukrainian NPPs, including 13 units with WWER-1000, 2 units with WWER-440. Share of nuclear electricity generation grows annually: in 1996 it was 43,8%, in 2000 – 45,3%, in 2005 – 53,2%. The installed capacity of NPP – only 22,8%.

I&C Systems for New Units

Khmelnitsky-2 and Rovno-4 NPP's received I&C equipment before moratorium (1990). The equipment was preserve all time from 1990. The design was improved during 1998-2003 (tabl. 1).

Table 1

New I&C Systems which have been installed at Rovno-4

Name of System	Safety Classification	Designer
Protection System	2У	Radium (Ukraine)
Reactor Power Control System, Reactor Power Limitation System	2НУ	Radium (Ukraine)
Neutron Flux Monitoring System	2НУ	Impuls (Ukraine)
Computer Information System	3Н	KhIKA, Impuls (Ukraine)
In-Core Monitoring System	3Н	KhIKA, Impuls (Ukraine), SNIIP (Russia)
Group and Individual Control Rod System	2НУ	Skoda (Czech Republic)
Automatic Control Systems of 1-st Circuit	2НУ, 3Н	Shevchenko Plant (Ukraine)
Automatic Control Systems of Machine Room	3Н, 4Н	Shevchenko Plant (Ukraine)
Refueling Machine Control System	2Н	GANZ (Hungary)

The main principles of new design:

A. I&C systems satisfied to new Ukrainian Regulations with requirements to functional safety (which were harmonize with international requirements [1]) and IAEA standards (NS-G-1.3 [2], NS-G-1.1 [3], NS-R-1 [4]) and recommendations (INSAG-12 [5]).

One of examples- requirements to diversity, which were realized in protection systems (apparatus diversity) and automatic control systems of reactor (program diversity).

B. State-of-art technical decisions:

– wide use of digital microprocessor technique;

– modern MMI;

– distributed control, local nets;

– high level of diagnostic;

– using microprocessors and other components which produced by known foreign companies.

Example-protection system (designer – ‘‘Radium”) has main and diverse sets, 3 independent channels in every set , used Field Programmable Gate Array produced by “Altera” (USA), different devices in the sets.

C. Some part of equipment (actuators, cables, some sensors, etc) wasn’t replaced. Special activity of checking and tests was realized before starts.

D. Designers of the most systems were Ukrainian companies:

– companies who have produced computer systems for military aims before conversion (“Khartron”, “Radium”, etc.);

– companies who have big experience (from 1981) in producing I&C systems for Russian, Ukrainian, Bulgarian WWER reactors (“Impuls”, KHIKA, KHGPZ, etc.).

Some systems were designed together with Russian companies (Kurchatov center, SNIIP).

E. Wide approbation of new systems designed by Ukrainian companies (tabl. 2):

– operation of control systems in open loop;

– operation of information systems in emergency control room, etc.

One task couldn’t realized- united component base and instruments for different systems (as was realized in Temelin NPP by Westinghouse – USA).

Table 2

Approbation of new I&C systems

Name of system	**Designer**	**Type of approbation**	**NPP**
Protection system	Radium	Open loop	ZNPP-3
Neutron Flux Monitoring System	Impuls	Open loop	ZNPP-1
		Emergency Control room	ZNPP-4
Refueling Machine Control System	HANZ	Operation	SUNPP-1, 2
Software of In-core Reactor System (Khmelnitsky-2)	INIT Kurchatov institute	Operation	Kozlo-duy-6
Software of In-core Reactor System (Rovno-4)	Impuls Khika SNIIP	Operation	Novo-Voroneg-5
		Operation	Kalinin-1
		Operation	Volgodonsk-1
Hardware of CIS	Impuls	Operation	ZNPP-3

I&C Modernization for operating units

Operator all Ukrainian NPP’s (National energetically company “Energoatom”) accepted Program of step-by-step modernization I&C systems for all Ukrainian WWER-1000 and WWER-440 units. These systems (tabl. 3) coordinated with functional requirements to I&C according standard [1].

Regulatory activity

Specifical peculiarity of nuclear industry is presence in every country of government organization for nuclear regulation.

The name of this organization in Ukraine – “State Committee of Nuclear Regulation”. The three main direction of this committee activity – standardization, licensing, supervision.

All mentioned systems for new and operated units were safety important (safety or safety related according IAEA classification) and were of the subjects of

licensing and preparation of state expert reviews (tabl. 4).

Table 3

I&C systems for operation units

Name of system	Designer	NPP
Control systems		
Protection System	Radium (Ukraine)	ZNPP - 1, 3
Reactor Power Control System, Reactor Power Limitation System	Khartron (Ukraine)	RNPP – 1, 2
Digital Control Systems for Machine Room	Shevchenko plant, LvivORGRES (Ukraine)	ZNPP – 1, 4
Steam Generator Level and Feedwater Control System	WESE (Belgium), LvivORGRES, Westron (Ukraine)	SUNPP-1, 2
	LvivORGRES, Westron (Ukraine)	SUNPP-3
Group and Individual Control Rod System	Skoda (Czech Republic)	SUNPP-1, 2, 3 KhNPP-1, ZNPP-3, 4
Refueling Machine Control Systems	GANZ, EVIG (Hungary)	SUNPP-1, 2
Information systems		
Computer Information System	Westinghouse (USA) Westron (Ukraine)	SUNPP-1
	SYSECA (France)	RNPP-1,2
	Westron (Ukraine)	SUNPP-2, 3
SPDS	Westinghouse (USA) Westron (Ukraine) «ИПЭ АЭС» (Киев)	ZNPP – 1,2,3,4,5,6 KhNPP-1 RNPP-3 SUNPP-1, 2, 3
In-Core Reactor Monitoring System	Tenzor, Kurchatovski institute (Russia)	RNPP-1, 2
In-Core Reactor Monitoring System (low level)	Impuls (Ukraine)	ZNPP-3
Neutron Flux Monitoring System	Impuls (Ukraine)	ZNPP-4 SUNPP-3

Licensing plans included all stage of systems life cycle: from NPP Technical Decision about modernization to beginning in operation. Some conservatism in preparation of licensing plans, volume of tests and expert reviews justified himself during implementation of new systems.

Table 4

Typical stages of licensing and expert reviews

Stage of licensing	Expert review
1. Accordance of NPP Technical Decision about modernization	Expert review of NPP technical decision about modernization
2. Accordance of Terms of Reference (Specification)	Expert review of Terms of Reference
3. Accordance of Permission to Mounting	Expert review of software verification plan
	Expert review of software verification report
	Expert review of report about reliability
	Expert review of preliminary safety analysis report
	Expert review of SAT programs and methodic
	Expert review of experimental operation program
4. Accordance of Permission to operation	Expert review of final safety analysis report

Inference of I&C to NPP safety

Analysis of NPP safety violations because I&C was fulfilled. Information about these violations of all Ukrainian units for 9 years was collected.

An age of the most of I&C equipment (not subjected to modernization) is 15-20 years. For such equipment, a problem of the aging takes place. It is necessary to note that actual Ukrainian safety standards include the following requirements to the safety important I&C instrumentation: each of them at its life end has to be replaced or a possibility of its life extension has to be proved.

This problem has been decided in several directions:

- an analysis of characteristics changes tendencies of equipment important to safety, first of all of reliability measures trend (e.g. failure intensity)
- an analysis of NPP safety violations due to I&C in dependence on unit age and, correspondingly, I&C age.

The dependence of mean violations number caused by VVER-1000 I&C age shown at fig. 1.

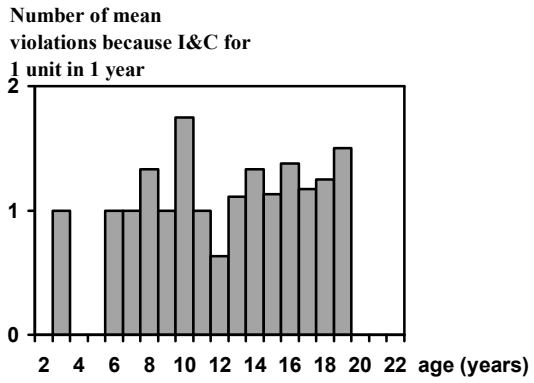

Fig. 1. Dependence of mean violations numbers and age

The basic conclusion on VVER-1000 units is as following:

– violations mean number due to I&C for 1 unit in 1 year has not marked trend in time;

– violations minimum number belongs to the most "young" unit and one "old" unit where the greater modernization scope took place;

– on the whole, total violations number due to I&C at all NPP's rather decreased during last 2 years.

Information about new book "NPP Safety: I&C Systems"

The book "Nuclear Power Plants Safety: Instrumentation and Control Systems" [6] was published in Kiev "Technika" in 2004 (fig. 2). The authors of this book are M. Yastrebenetsky, V. Vasilchenko, S. Vinogradska, V. Goldrin, Y. Rozen, L. Spektor, V. Kharchenko.

The book is based on the experience of State Scientist Technical Center of Nuclear and Radiation Safety in safety assessment and assurance of I&C systems for 13 units WWER-1000 and WWER-440 NPP during 1993-2003 and in creation of standards related to NPP I&C.

I&C systems designed not only by Ukrainian, but designed by Russian, USA, Czech Republic, France, Hungarian companies are used in Ukrainian NPP's. That gives possibility to authors in receiving knowledge of these countries in I&C creation and safety assessment.

Fig. 2. The book "Nuclear Power Plants Safety: Instrumentation and Control Systems"

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