RELIABILITY OF OPERATING VVER MONITORING SYSTEMS

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ABSTRACT

The elaboration of VVER monitoring systems reliability measures is described in this paper. The evaluation is based on the statistical data about failures what have collected at the Ukrainian operating nuclear power plants (NPP). The main attention is devoted to radiation safety monitoring system and unit information computer system, what collects information from different sensors and system of the unit. Reliability measures were used for decision the problems, connected with life extension of the instruments, and for another purposes.

1. INTRODUCTION

NPP with pressurised water reactors VVER-1000 are the most wide - spread in the Ukraine : now 11 from 15 Ukrainian units are operating in the Ukraine, include unit 6 Zaporozhye NPP, what started in the end of 1995. The instrumentation and control systems (I&C) of all unit VVER-1000 type V-302 and V-320 in the Ukraine, Russia, Bulgaria was created by similar typical design. This design was fulfilled in 1980-1982, and after that monitoring systems had only nonconsiderable modernisation.
In spite of the spreading of VVER-1000 and long time of operation of these units, reliability measures of their I&C are not published. This confirmation relates to monitoring systems. Short information about reliability analysis of these systems was published only in [1].

The goals of this investigation were:
- evaluation of the reliability measures of the instruments (different types of sensors, computers, etc.) and the monitoring systems, what are operated at the Ukrainian NPP-1000;
- elaboration of the recommendation about reliability assurance;
- analysis of instrument failures point stochastic processes, including analysis of the trend in these processes for definition of possibility of life extension;
- comparison between reliability measures in technical specifications and standards with reliability measures, what were received in the operating conditions. (According to USSR standards, what now acted in the Ukraine, requirements to reliability measures have to include to technical documentation of different industrial instruments and systems. These requirements take place for different NPP I&C systems - not only for Safety systems).

Data bases about NPP I&C reliability have elaborated and supported in Department "I&C NPP reliability" of Ukrainian Scientific Technical Center of Nuclear and Radiation Safety. In present time, Ukraine has not common systems for collection and analysis of information about reliability of different NPP equipment (similar for example, NPRDS in the USA). General system for collection information about reliability of different NPP equipment will be created in the Ukraine in 1996-1998.

Information in our base was received from NPP documents, what are destined for managing of operation, but not especially for collection of information about failures. We only fulfilled some actions for improving of authenticity of this information. The collection of information about failures took place during some years.

The main attention in this paper is devoted to two systems - radiation safety monitoring systems and unit information computer system. Radiation safety monitoring system (type - ÀÊÐÁ-03) realise monitoring of the following parameters:
- water volume activity in the circuits, the water body and the tanks;
- aerosol volume activity in the compartments;
- steam and air mixture volume activity in the releases of the turbine;
- gas volume activity;
- neutron and gamma - quantum fluxes from the circuits;
- gamma radiation dose rate, etc.
Structure schema of this system is shown at fig.1.

Unit information computer systems type "Complex-Titan 2" collect information from different sensors of temperature, pressure, difference of pressure, level, etc., of main technological equipment and from different systems, including in-core reactor monitoring system. Structure schema of "Complex-Titan 2" is shown at fig. 2.

Both systems were created by same principal: hierarchical closed structure without computer nets.

2. RELIABILITY OF THE INSTRUMENTS

Reliability measures of the instruments, what include in radiation safety monitoring system, are shown at fig. 3. Reliability measures of instruments, what include in unit information computer system, are shown at fig. 4.

Reliability measures at fig. 3-4 are average for all systems at the Ukrainian NPP. The reliability measures of any identical instruments had essential difference for different units and plants. The reasons of this difference caused by the different quality of the manufacture, setting, maintenance and statistical straggling.

The analysis of the failures point stochastic processes showed, that there was the infant mortality time for many types of the instruments. The value of this time equals 0,5-1,5 years, as rule. This analysis also showed, that the hypothesis about the aftereffect absence was not confirmed in many cases. The relation between the dispersion of the number of the failures and the mean of this number is not equal to 1, as in the Poisson process, and equals 2-4. One of the classes of these processes is the twice stochastic Poisson process (D.Cox process [2]), which has essential aftereffect. The failure intensity of this process in each it's realization is, the in turn, a realization of some other stochastic process. We proposed the common model of this process and some particular cases [3].

The collected information was used for decision of the tasks, connected with the life extension of the instruments. The life extension problem of Ukrainian NPP instruments is particularly important because the following reasons:
- the regiment Soviet instruments durability measures equaled 8-10 years: this is less then durability measures of whole NPP;
- the ageing of the instruments are equal of the ageing the technological eguipment, and many instruments are near to end-of-installed life or exceed to this value ;
- the instruments manufactures are located in Russia and other countries of former USSR; the economic connections with these countries are very hard now;
- the instrument cost for replacement grows faster than the inflation;
- the USSR designers and producers determined the durability measures without sufficient tests and basis.

STRUCTURE SCHEMA OF RADIATION SAFETY MONITORING SYSTEM ÀÊÐÁ-Ì3

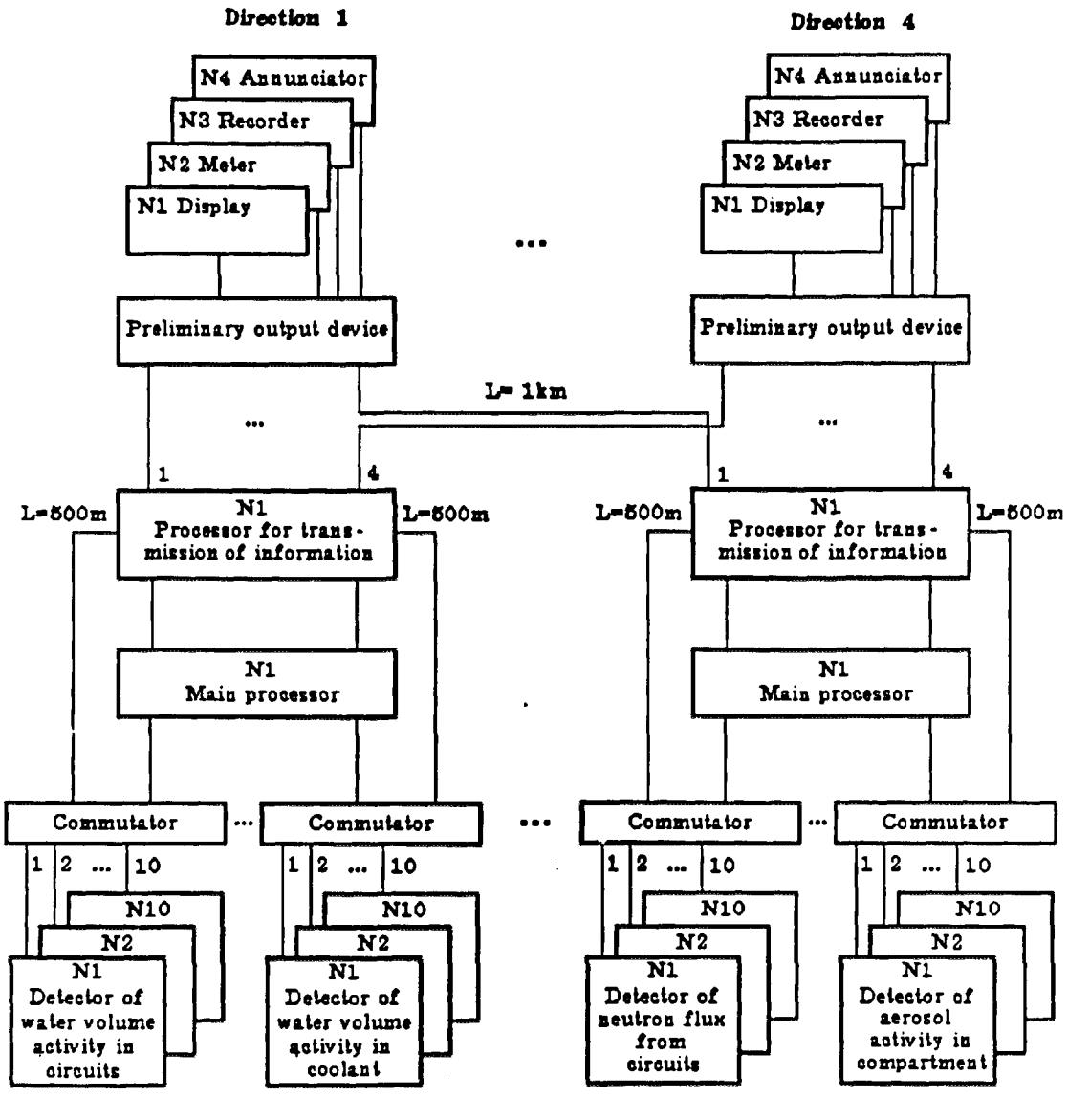


Fig.1

STRUCTURE SCHEMA OF UNIT INFORMATIONAL COMPUTER SYSTEM "COMPLEX-TITAN 2"

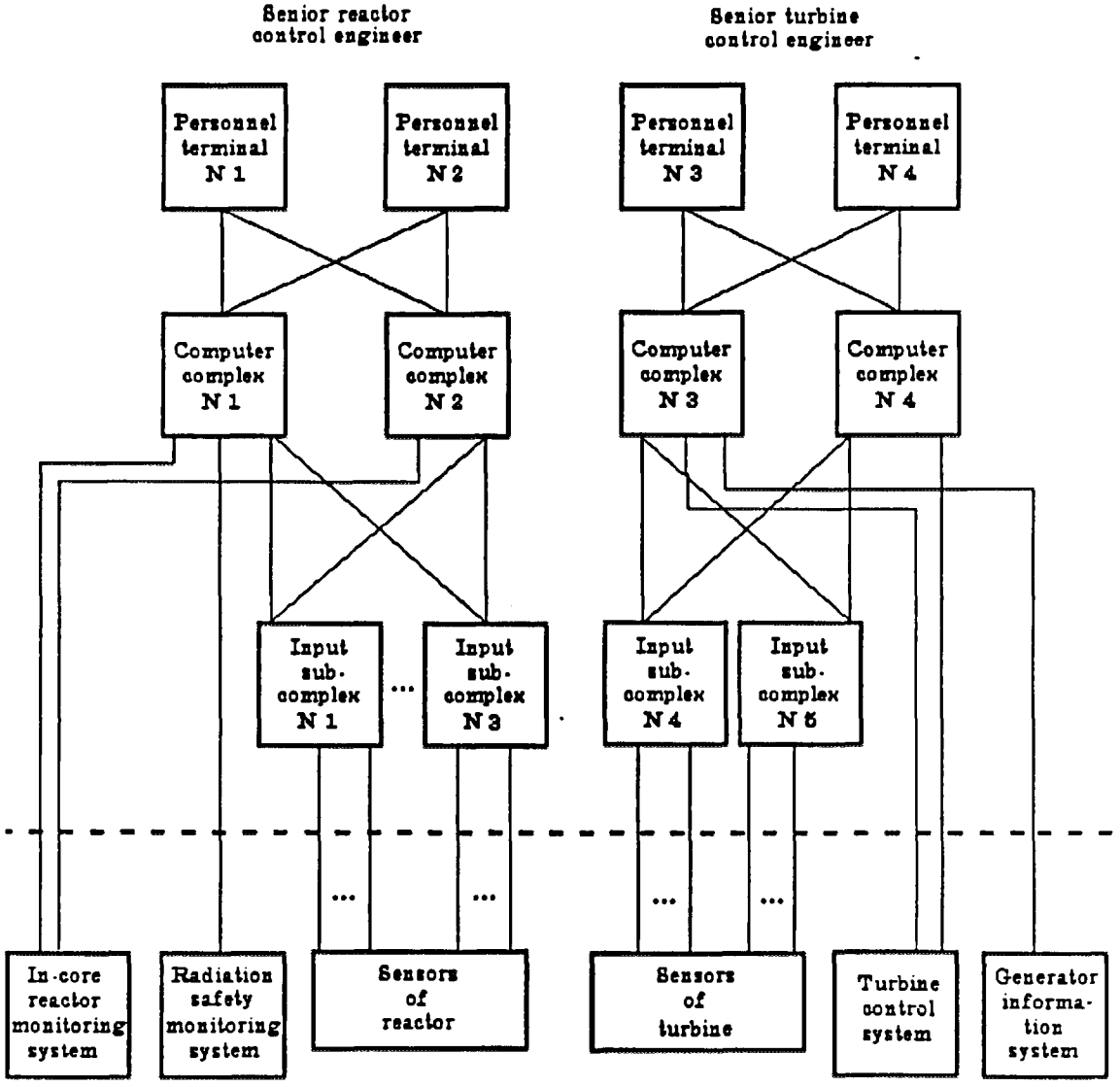


Fig.2

RELIABILITY MEASURES OF DEVICES WHAT INCLUDE IN REACTOR SAFETY MONITORING SYSTEM ÀÊÐÁ-03

Name of device	Type	Number of devices	Operating time, 10^3, h	Number of failures	MTBF, h
Detector for monitoring of neutron flux from circuits	ÓÄÈÍ-02	13	557	4	139000
Detector for monitoring of gamma-quantum flux from circuits	ÓÄÏÃ-03	16	1090	69	16000
Detector for monitoring of steam and air mixture volume activity in release of turbine	ÓÄÏÁ-03	28	977	22	44000
Detector for monitoring of water volume activity in circuits	ÓÄÆÅ-04	488	977	35	28000
Detector for monitoring of water volume activity in water bodies and tanks	ÓÄÆÅ-14	215	2430	140	17000
Detector for monitoring of aerosol volume activity in compartments	ÁÄÀÁ-05 ÁÄÀÁ-06	110 48	6240 1989	117 46	53000 43000
Detector for monitoring of gamma radiation dose rate	ÁÄÌÅ ÓÄÌÅ	1141 127	5330 3480	150 18	35000 193000
Detector for monitoring of gas volume activity in the systems for gas purification	ÓÄÅÁ	342	16700	297	56000
Commutator	ÓÂÀ-09	326	19600	65	301000
Main processor	ÓÏÏ-100Ì	29	1190	192	6200
Processor for transmition of information	ÓÈ-28	30	1322	122	10800
Preliminary output device	ÁÂÖ	127	4990	51	97800
Annunciator	ÁÂÈ - 13 ÁÂÈ - 12	276 1272	13800 52800	41 154	334000 342000
Display	ÓÂÊ-13	27	1050	52	20200
Meter	ÓÂÈ-09	10	737	22	33500

Fig.3

RELIABILITY MEASURES OF THE SYSTEMS

Name of function	Type of function	Criterion of failure	MTBF, h	Availability
RADIATION SAFETY MONITIRING SYSTEM ÀÊÐÁ-03				
Parameters measurement	Simple (channel)	Absence of indication about parameters	1700-2400	
Parameter annunciation	Simple (channel	Absence of annunciation about parameter or spurious failure	3200-4000	
INFORMATION COMPUTER SYSTEM "COMPLEX-TITAN 2"				
Technological parameters measurement	Composite / Simple (channel)	Absence of indication about more, then 5% parameters during the time, more 10 min / Absence of indication about parameter	8800 / 6300	
Technological parameters recording	Composite / Simple (channel)	Absence of recording about more, then 10% parame-ters during the time, more 1 h / Absence of recording about parameter	5300 / 2500	
Emergency situation recording	Composite	Absence of recording about more, then 5% events (parameters) during the time, more then 10 min	-	0,9993

Fig.4

Statistical processing of failures point stochastic processes was realized by the methods, described in books [2,4,5]. The processing included the statistical hypothesis test about absence of failure intensity growth, which showed the absence of the trending. (These imstruments and systems are restoration objects, and the failure intensity was choosed as main reliability measure for trending analysis).

The example of relationship between summary failure intensity and time for all components of information computer complex is shown at fig. 5a; the example of relationship between summary failure intensity and time for all components of radiation safety monitoring system is shown at fig. 5b. In fig.5 the fixed observation time corresponds to the different ageing of instruments because the different starting moments of the units and therefore of the instruments and systems.

The analysis of ageing showed that hypothesis about raising of the tranding of the point stochastic process was not confirmed for the most types of the instruments ; failures point stochastic processes are stationary for the investigation time range. The results of investigations showed, that lifetime may be extended for the most types of instruments.

Analysis of operating reliability is only a part of the working for elaboration of the instruments life extesion possibility. It's necessary to remark, that life time according of IEC Vocabulary [6] is defined by the going object to the term-limiting state. Durability measures in the standards are connected with the time to going into this state. But durability measures in technical documentation for instruments what include to monitoring system is presented without any exact definition of limiting state. Methodology for working of life extension is discribed in the document ÍÄ 306.711-96"Life extension of NPP instrument and control system equipment what important to safety. General requirements to work procedure and consistence". This document was elaborated in the Ukrainian Scientific Technical Center of Nuclear and Radiation Safety.

The work has 6 stages .
1. elaboration "Program of definition of possibility of life extension";
2. analysis of technical state;
3. testing;
4. analysis of reliability using operating experience;
5. elaboration "Conslusion about results of possibility of life extension";
6. elaboration "Decision about life extension".

These results were used for example for life extension of radiation safety monitoring systems unit 1-4 Zaporozhye NPP, unit 1-3 Yuzhno-Ukrainsk NPP, unit 1 Hmelnitsky NPP .

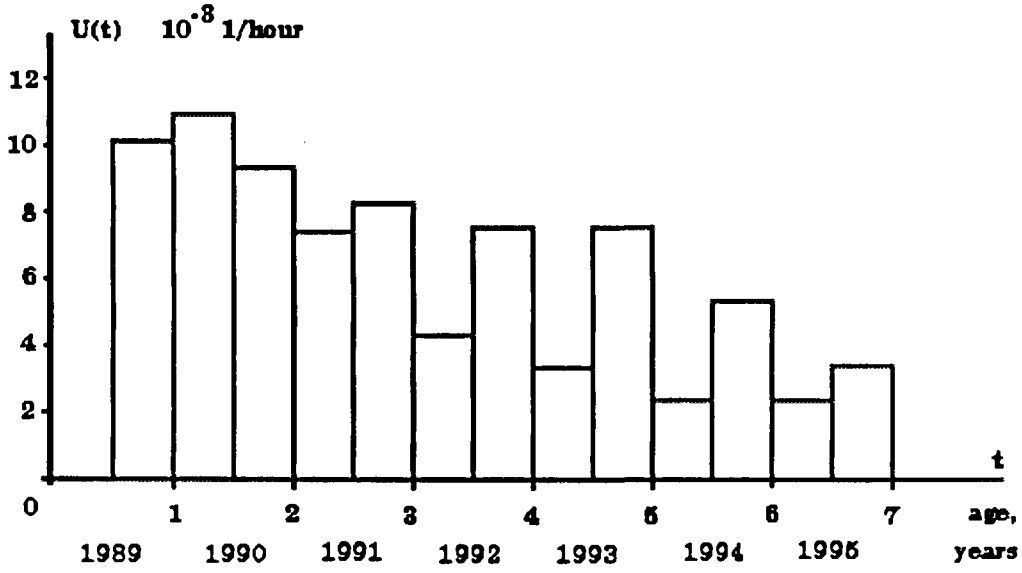
3. RELIABILITY OF THE SYSTEMS

Mathematical analysis of systems reliability was fulfilled by decomposition these systems on the set of functions (for example, measurment, annunciation, registration). The function are classified by complication into simple and composite. Simple functions are not decomposed to components; as rule, they consist in receiving information from one technological parameter and realise by one channel. Composite functions include some simple functions, what are jointed according to community of their purpose, constructive and other signs.

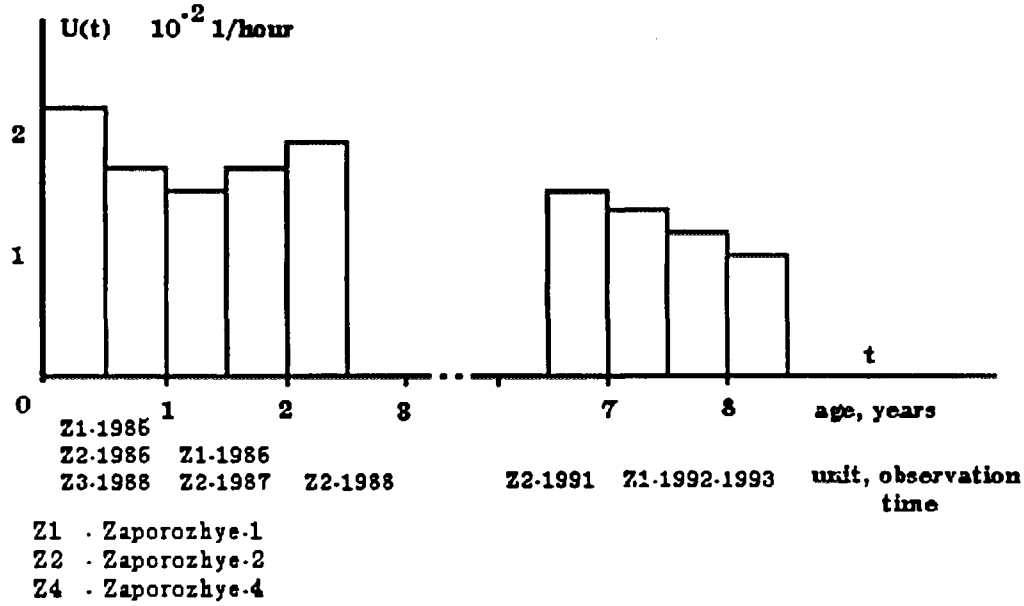
Definition of failure criterions of simple functions not causes any hardness. Definition of same criterions of composite functions usually is chosen from techological reasons. In the most cases, failure of composite function is event, when definite number or definite sets of simple function is faulted.

Reliability measures of simple functions of radiation safety monitoring system, simple and composite functions of information computer systems are shown at fig. 6.

RELATIONSHIP BETWEEN SUMMARY FAILURE INTENSITY AND TIME



a. Radiation safety monitoring system ÀÊÐÁ-03 (Yuzhno-Ukrainsk -3)



b. Information computer complex "Complex-Titan 2" components

Fig.5

RELIABILITY MEASURES OF DEVICES WHAT INCLUDE IN UNIT INFORMATION COMPUTER SYSTEM "COMPLEX- TITAN 2"

Name of device	Type	Number of devices	Operating time, 10^3, h	Number of failures	MTBF, h
Input subcomplex:	ÊÑÎ Ì-64				
Input analog device	ÁÃÐ	3440	55300	971	57000
Input discrete device	ÌÅÄ	1200	19300	252	77000
Commutator and primary processor	ÑÑÎ-Ê (central part)	160	10300	2708	3800
Concentrator	CÑÎ-Ó	24	1540	906	1700
Computer complex:	CM-2M				
Processor	A131	32	626	198	3200
Internal memory	A211	64	1252	88	14000
External memory	A322	32	626	382	1700
Personnel terminal:	ÐÎÒ-02				
Processor	À135	24	178	70	2500
Keyboard	À513	24	178	24	7400
Display	À543	48	356	71	5000

Fig.6

Evaluation of functions reliability fulfilled with acception of following circumstances:
- all failures of components included malfunctions (short-term operating violations what eliminated by automatic or manual restart without repairing) were calculated;
- term of disconnection of redundand devices for maintenance was calculated;
- repairing personnel are working during 8 hours per day.

The goals of evaluation of systems reliability:
- comparation with measures, what was written in technical documentation and standards;
- elaboration of requirements to reliability to modernized monitoring system, what will replace instead existing systems (This modernization proposed to 1997-2002 at the most of Ukrainian units VVER-1000).

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