RUSSIAN REGULATORY APPROACH TO EXTENSION OF NUCLEAR POWER PLANT SERVICE LIFE

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Abstract. The report presents not only general system of regulatory legislative acts in the field of nuclear and radiation safety but also all legislative acts and regulatory documents concerning plant life extension (PLEX) in the Russian Federation.

On demand of Rostechnadzor SEC NRS developed federal norms and rules (FNR) "The Main Requirements for Extension of the Operational Life of NPP Unit" (NP-017-2000) and FNR "Requirements for Substantiation of Possibility of Extension of the Operational Life of Nuclear Facilities and Installations" (NP-24-2000), where methodology of operational life extension of NPP unit and Nuclear Facilities and Installations is considered.

The report presents general provisions of NP-017-2000 and examples of application of full set of regulatory documents for operational life extension of NPP units in the Russian Federation.

1. Introduction

Due to wide experience in NPP operation (more than 50 years) there's a wide legislative base in the field of nuclear energy use in Russia.

Since the operational life (30 years) of first-stage NPP units came up by 2000, on demand of Rostechnadzor the specialists of SEC NRS developed federal norms and rules (FNR) "The main Requirements for Extension of the Operational Life of NPP Unit" (NP-017-2000) [1] and FNR "Requirements for Substantiation of Possibility of Extension of the Operational Life of Nuclear Facilities and Installations" (NP-24-2000) [2]. It's necessary to mention that the methodology of operational life extension unit of NPP is stated fully in the FNR NP-017-2000[1].

2. General system of regulatory legislative acts and regulatory documents in the field of NPP unit operation life extension in Russian Federation.

There's 5 stages general system of regulatory legislative acts and regulatory documents in the field of nuclear energy use in the Fig.1. According to the stages of the mentioned pyramid we list Russian regulatory documents on methodology of PLEX.

2.1. Federal laws (I):

- "On the Use of Nuclear Energy".
- "On Radiation Safety of the Population".

2.2. ***Regulatory legislative acts of the President of RF and the Government of RF*** **(II)*:***

- "RF Program of Nuclear Power Engineering Development for the Period of 2007-2010 and up to 2015"approved by the Decree of the Government of RF of 06.10.2006.
- "Regulations on Licensing Activity in the Field of Nuclear Energy Use" approved by the Decree of the Government of the RF of 14.07.1997.

2.3. Federal rules and regulations **(III):**

- "General Regulations on Ensuring of Nuclear Power Plants Safety", OPB-88/97, NP-001-97 (p.5.1.14).
- "Rules on Design and Safe Operation of Components and Pipelines of Nuclear Power Installations", PNAE G-7-008-89, (p.2.1.11).
- "The Main Requirements for Extension of the Operational Life of NPP Unit", NP-017-2000.
- State standard «Reliability of NPPs and their Equipment».

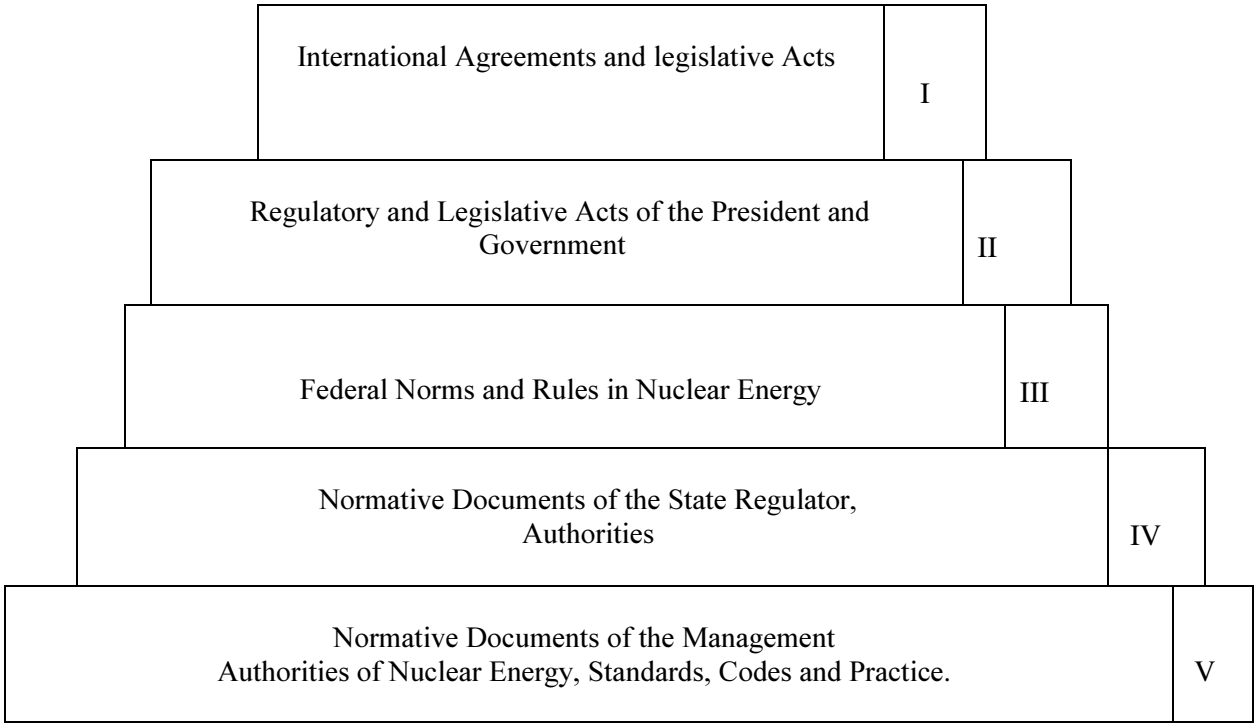

Fig. 1 General system of regulatory legislative acts and regulatory documents in the field of nuclear energy in Russian Federation.

2.4. Regulatory documents of Rostechnadzor **(IV):**

- Regulatory Guideline (RD): «Requirements to the Set and Contents of the Documents Justifying Safety during Additional Operating Lifetime of the NPP Unit» (RD-04-02-2006).

- Safety Guidelines (RB):

    1. “Guidelines to the Contents of the Report on In-Depth Safety Assessment of Operating NPP Units» (OUOB AS), RB-001-05.
    2. “Contents and Composition of the Report on NPP Unit Comprehensive Survey for Extension of its Operational Life”, RB-027-04.[1]
    3. “Discrepancy Analysis of NPP Unit with regard to Requirements of Actual Regulations “, RB-028-04.[1]
    4. “Contents and Composition of Documentation on Justifying Residual Lifetime of NPP Unit Components for the Purpose of the Operational Life Extension”, RB-029-04.[1]
    5. «Operational Experience Analysis for the Purpose of NPP Unit Operational Life Extension”, RB-030-04.[1]
- Documents on certification of equipment, products and technologies:
  Certificates on extension of the operational life of different NPP components
  (vessels, pipelines, pumps, valves, etc).

2.5. Regulatory documents of the concern “Rosenergoatom” (V):

- Regulatory Guideline “Standard Program of Comprehensive Survey of NPP Unit for Extension of the Operational Life”, RD-EO-0283-01.
- Regulatory Guideline “Provision on Management of Resource Characteristics of NPP Units Components”, RD-EO-0281-03.
- Regulatory Guideline “Program of Quality Assurance of Activities on Extension of the First Generation NPP Units Operational Life (standard)”, RD-EO-0291-01.
- “General Provisions on Extension of the Second Generation NPP Units Operational Life”, RD-EO-0327-01.
- Standard “The Procedure of Organization and Modernization of NPP Systems and Equipment”, ST-EO-0542-2004.
- Methodological documents and guidelines on the problems of residual life-time assessment of different types of equipment (more than 50 documents).

It’s necessary to mention that according to the concepts given in the regulatory documents, NPP unit is a part of a nuclear power plant in compound of nuclear reactor (NR), radiation sources, nuclear materials and radioactive substances storages, and radwaste storages. Thus speaking about PLEX, we understand activity on preparation for operation during additional term of all the mentioned items. In the federal norms and rules “Requirements for Substantiation of the Possibility of Extension of the Operational Life of Nuclear Facilities and Installations” (NP-024-2000) these items are defined as “nuclear energy facilities” (OIAE-NEF) [2]. Decision on PLEX or decommissioning shall be made 5 years before the design operational life is expired.

3. Content of the Federal Norms and Rules “The main Requirements for Extension of the Operational Life of NPP Unit” (NP-017-2000).

The main federal regulatory document on safety regulation of NPP operational life extension is FNR “The main Requirements for Extension of the Operational Life of NPP Unit”.

This document contains general provisions, criteria of the possibility of the NPP unit operation during additional operating lifetime, requirements for the unit preparation for additional operating lifetime, and general provisions on comprehensive survey of the NPP unit.

According to the requirements of these regulations duration of NPP unit operating lifetime above the design operating lifetime (DOL) (or 30 years) shall be established taking into account technical and economic factors which include:

- Possibility of ensuring and maintenance of safety during NPP unit operation;
- Presence of necessary residual life of non-recoverable NPP unit equipment;

[1] Within the frames of IAEA project RUS/ 9/003 the Rostechnadzor documents in question were developed and put in force.

- Possibility of interim storage of additional amount of spent nuclear fuel or its removal from the NPP site;
- Possibility of safety ensuring during management with radwaste formed during additional operation term;
- Possibility of NPP unit safety assurance during its decommissioning.

To extend NPP unit operational life the operating organization shall carry out the following arrangements:

- Fulfill comprehensive survey;
- Develop a program of NPP unit preparation for extension of its operational life;
- Carry out preparation of NPP unit for extension of its operational life including justification of safety and residual life of the components, replacement of overage equipment and modernization and reconstruction of NPP unit if necessary.
- Carry out necessary tests.

Besides in the regulation NP-017-2000 the following criteria of the possibility of the NPP unit operation during additional operating lifetime:

- NPP unit operation on power over the design operating lifetime is possible in case if all the necessary technical and organizational measures were taken to bring NPP unit to conformity with criteria and requirements of the current rules and regulations in the field of nuclear energy use;
- Technical state of NPP unit during additional operating lifetime must meet requirements of technical (design, engineering and manufacturing) documentation;
- During additional NPP operational lifetime it’s necessary to carry out activities on increase of safety taking into account requirements of regulatory documents in the field of nuclear, technical, fire and ecological safety;
- Residual life of non-recoverable elements important for safety shall be justified and sufficient within additional operational lifetime;
- Management of reliability (resource) of equipment, buildings, constructions and building structures of NPP unit shall be executed wherefore the program for management of these components resource shall be developed and fulfilled;

- Effectiveness of methods and measures for control of the technical state of equipment, buildings, constructions and NPP unit building structures important for safety shall be enough for identification and prevention of initiating events.

4. Two main stages of NPP unit preparation for its operational life extension.

4.1. The first stage includes:

(a) comprehensive survey of the unit;
(b) estimation of technical possibility of the operational life extension for unit components or their replacement;
(c) safety assessment of the NPP unit.

Within the frames of this stage calculations of economic effectiveness of PLEX investment project are carried out. Results of these calculations allow making decision on possibility of switching to the second stage or unit decommissioning after design operating lifetime expiration from the point of view of economic expediency.

During comprehensive survey the real technical state of NPP unit and residual life of its components are defined. The main attention shall be paid to the technical state of the components important for safety. Besides it's necessary to define the following:

1. Components important for safety with expired operating lifetime that are to be replaced;
2. Components important for safety with expired operating lifetime, but having possibility of its extension at the expense of periodical maintenance and repair;
3. Components important for safety which have residual lifetime and their operation may be extended for a definite period of time;
4. Non-recoverable (irreplaceable) components and preliminary assessment of their residual lifetime;
5. Possibility of storage of spent nuclear fuel and radwaste formed during additional operating lifetime;
6. Possibility of safe radwaste management.

Special importance for safety and possibilities of PLEX is given to assessment of technical state and justification of residual lifetime of important for safety NPP components mentioned in points 2 and 3 and also possibility of further operation of non-recoverable (irreplaceable) components.

There are the following non-recoverable (irreplaceable) components: reactor vessel and its in-vessel components and constructions, graphite stack, primary system pipe, primary circuit pump, biological shielding and some other devices and mechanisms.

During assessment of the technical state and NPP components residual lifetime, justification analysis of the design deviations from the modern requirements of the regulatory and technical documentation, analysis of these components operation history shall be carried out and also complex of material-related activities during which data on equipment metal are analyzed, additional tests are carried out and metal state change prognosis is done.

Conclusion on technical state and residual lifetime of NPP unit equipment is given after the equipment strength calculations.

Similar activities and evaluation of residual lifetime is carried out also for the equipment of buildings, constructions, building structures, foundations and understructures referred to safety levels 1 and 2.

By results of the comprehensive survey conclusions are made about the following:

- About results of expert evaluation of residual lifetime, including the list of overage components;
- About the current state of the systems (components) according to the results of control, tests and research during survey;
- About the state of the systems (components) and recommendations on measures, which are necessary for guaranteeing their working capacity and reliability.

Thus, for reactors RBMK-1000 type a new three-channel fast long-cooling system for reactor emergency cooling was introduced end etc. The following activities were done during modernization of WWER-440/V-230: the concept “leak before break” was implemented (diagnostics and non-destructive testing systems), the problem of reactor vessel embrittlement was solved, technical devices for reactor control and protection were replaced, etc).

In conclusion NPP unit safety level is estimated, assumptions on the programs of additional activities for definition of residual life of NPP unit systems (components) are done, the scope and nomenclature of activities on preparation for PLEX are defined and investment project of PLEX is prepared.

4.2. The second stage includes:

(a) justification of operational life extension for non-recoverable and irreplaceable elements;
(b) implementation of complex program for unit modernization;
(c) justification of NPP unit safety during additional operating lifetime;
(d) receiving of Rostechnadzor license for operation during additional operating lifetime.

At this stage a set of activities is implemented with the aim to ensure safe operation of the unit during additional operating lifetime. At this time investment project PLEX is implemented.

The second stage is finished with implementation of a more profound NPP unit safety analysis and development of the report on in-depth safety assessment (DSAR).
DSAR is developed in accordance with recommendations from Rostechnadzor (RB-001-05) taking into account all the modifications implemented at the unit. DSAR consists of the summary book and four appendices.

Summary of DSAR carries general information about the unit starting from the decision on construction.
There’s unit safety concept in DSAR which:

- presents design criteria and safety principles;
- shows how nuclear and radiation safety requirements are met;
- defines and describes safety systems;
- gives the value of safe operation limits and design limits for design basis accidents;
- carries information on fire safety;
- gives the list of expected levels of extreme natural and man-induced impacts with recurrence more than 10^{-2}/year;
- presents conditions of normal operation at design modes;
- expounds general principles and criteria of physical safety;
- gives arrangements plans in case of accidents.

In DSAR there's characteristic of site, description and state of systems important for safety, equipment and NPP constructions and also deterministic safety analysis and operation analysis.

Four appendices are developed to the summary:
Appendix 1 "Materials on technical safety justification (TSJ)";
Appendix 2 "Materials on additional safety justification";
Appendix 3 "Probabilistic safety analysis";
Appendix 4 "Analysis of beyond design basis accidents".

There are arrangements aimed at assurance of further NPP unit safe operation (beyond design lifetime) listed in the report on in-depth safety analysis.

5. Implementation of PLEX at NPP units under operation.

At present time at the territory of Russia there're 10 nuclear power plants (31 units) with total power 23,2 GWt which provide about 16% of country demand for electric energy .

According to the plan expounded in "The strategies of nuclear power engineering development in Russia in the first part of the 20th century", by 2020 it's planned to commission 39 nuclear reactors in Russia that will allow (taking into account decommissioning of 12 reactors) to achieve the level of 52,6 GWt of total installed power of NPP. This growth of total installed power will allow increasing the share of electric energy generation by NPPs from 16 up to 23%.

Simultaneously with construction of new units Russia extends for 15 years the operating lifetime of the functioning units of the first generation with reactors of EGP-6, WWR-440 and RBMK-1000 types. Activities on operational life extension for 11 NPP units of the first generation are carried out (see Table 1).

Table 1. First generation units of Russian NPPs.

Name of NPP	Unit No.	Reactor type	Capa-city (MWt)	Gene-ration	Commis-sioning (year)	Expiration of design operational life (30 years)	Duration of additional operation term, years
Bilibino	1	EGP-6	12	I	1974	2004	15
	2	EGP -6	12	I	1974	2004	15
	3	EGP -6	12	I	1975	2005	15
	4	EGP -6	12	I	1976	2006	15
Kola	1	WWR-440	440	I	1973	2003	15
	2	WWR-440	440	I	1974	2004	15
Kursk	1	RBMK-1000	1000	I	1976	2006	15
Leningrad	1	RBMK-1000	1000	I	1973	2003	15
	2	RBMK-1000	1000	I	1975	2005	15
Novovoro-nezh	3	WWR-440	440	I	1971	2001	15
	4	WWR-440	440	I	1972	2002	15

Besides in the period of 2005-2008 “Rosenergoatom” carries out arrangements aimed at preparation of the operational life extension for eight NPP units which design operating lifetime of 30 years expires after 2008 (in the period up to 2013). Within the units whose operating lifetime is planned to be extended for more than 15 years there’re units of the second generation (See Table 2).

Table 2. Second generation units of Russian NPP, which design operating lifetime expires in the period up to 2013.

Name of NPP	Unit No.	Reactor type	Capa-city (MW)	Gene-ration	Comms-sioning (year)	Expirati-on of design operati-onal life (30 years)	Duration of additional operation term, years
Beloyarsk	3	BN-600	600	II	1980	2010	15
Kola	3	WWR-440	440	II	1981	2011	25-30
Kursk	2	RBMK-1000	1000	I	1979	2009	15
	3	RBMK-1000	1000	II	1983	2013	15-20
Leningrad	3	RBMK-1000	1000	II	1979	2009	15-20
	4	RBMK-1000	1000	II	1981	2011	15-20
Novovoronezh	5	RBMK-1000	1000	II	1980	2010	25-30
Smolensk	1	RBMK-1000	1000	II	1982	2012	15-20

6. Conclusion.

In conclusion it's necessary to mention that full set of regulatory documents on operation life extension of different types NPP units was developed in Russian Federation.

Besides there're activities on modernization of regulatory documents of different levels in accordance with scientific and engineering achievements in the field of nuclear energy use and process of harmonization of regulatory RF and IAEA documents.

On the base of the set of regulatory documents complex of activities on PLEX is realized on modernization with the aim of safety increase, on comprehensive survey and equipment lifetime justification, in-depth safety assessment for NPP units (11 Units are operated beyond design life). Such activities allow to continue safe operation of energy units and to guarantee electric energy production and preservation of resources for further construction of units.

Wide Russian experience in the field of development of regulatory documents for nuclear power plants operational life extension may be used in international cooperation.

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