

Scoping and Screening of Systems & Components and Plant Programs Relevant to Long Term Operation of Kozloduy NPP Units 5&6

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Abstract. In the present material main steps and procedures for the plant lifetime extension of Kozloduy NPP Units 5 & 6 are discuss. The paper traces the various stages in the period 2007–2015 important for plant life extension.

Keywords: Ageing, Ageing Management Program (AMP), Plant Life Extension (PLEX), Scoping & screening, Long Term Operation (LTO).

List of abbreviations

SSCs — Structure Systems and Components
 AMP — Ageing Management Program
 PLEX — Plant Life Extension
 LTO — Long Term Operation
 MCP — Main Coolant Pump
 SAR — Safety Analyses Report
 I&C — Instrumentation and Control
 PSR — Periodic Safety Review
 NRA — Nuclear Regulatory Agency
 IAEA — International Agency of Atomic Energy
 SFS — Spent Fuel Storage

1 Introduction

The Kozloduy NPP is the first nuclear power plant in the south-eastern Europe. The most important dates in the operational history of the units are presented in Table 1.

Each of Units 5&6, in operation, has the installed a WWER-1000/B-320 reactor installation located in a hermetic steel concrete protective structure (containment), a turbine generator unit with K-1000/6015002 type turbine, and an electrical generator TBB-1000-4UZ.

For the period 2016-2020, the “Units 5&6 the plant life extension project” and its successful completion within the deadline set is determined as a strategic priority for the plant development.

2 Plant Programmes Relevant to Long Term Operation (LTO)

The design lifetime of Units 5 at Kozloduy NPP expires in 2017. The operational license for Unit 5 of Kozloduy NPP PLC, series E, No. 03000 renewed on 2 October 2009, valid by 5 November 2017 of nuclear facilities, are issued by the Nuclear Regulatory Agency in compliance with the Act on the Safe Use of Nuclear Energy and the Regulation on the proceeding to issued licences and permissions for nuclear energy use for a period of up to 10 years. The renewed licence for Unit 5 is valid by the end of the 30 year design operational lifetime of the unit.

Kozloduy NPP PLC has taken actions for extending the operational lifetime of Units 5 as follow.

2.1 Modernization programme relevant to LTO

In the period 1998 to 2008, a large-scale modernization programme was implemented, thus implementing all the necessary improvements in order to put the units in compliance with the international recommendations in terms of safety and reliability. The programme is based on the IAEA document on the safety issues and their ranking for WWER-1000 Model 320 Nuclear Power Plants (Safety Issues and Their Ranking for WWER-1000 Model 320 Nuclear Power Plants IAEA-EBP-WWER-05, 1996). The programme includes 212 measures to enhance safety, operation and reliability of the units. The implemented measures are included in the following groups:

Table 1. Operational History of Kozloduy NPP plc.

Operating event	Unit 1	Unit 2	Unit 3	Unit 4	Unit 5	Unit 6
First minimum controllable power level	30 Jun 1974	22 Aug 1975	04 Dec 1980	25 Apr 1982	05 Nov 1987	29 May 1991
Connection to the Electricity grid	14 Jul 1974	24 Aug 1975	16 Dec 1980	17 May r 1982	29 Nov 1987	02 Aug 1991
Rated power, MW	440	440	440	440	1000	1000
Fuel Cycle	23	24	22	21	23	22
Shutdown	31 Dec 2002	31 Dec 2002	31 Dec 2006	31 Dec 2006		

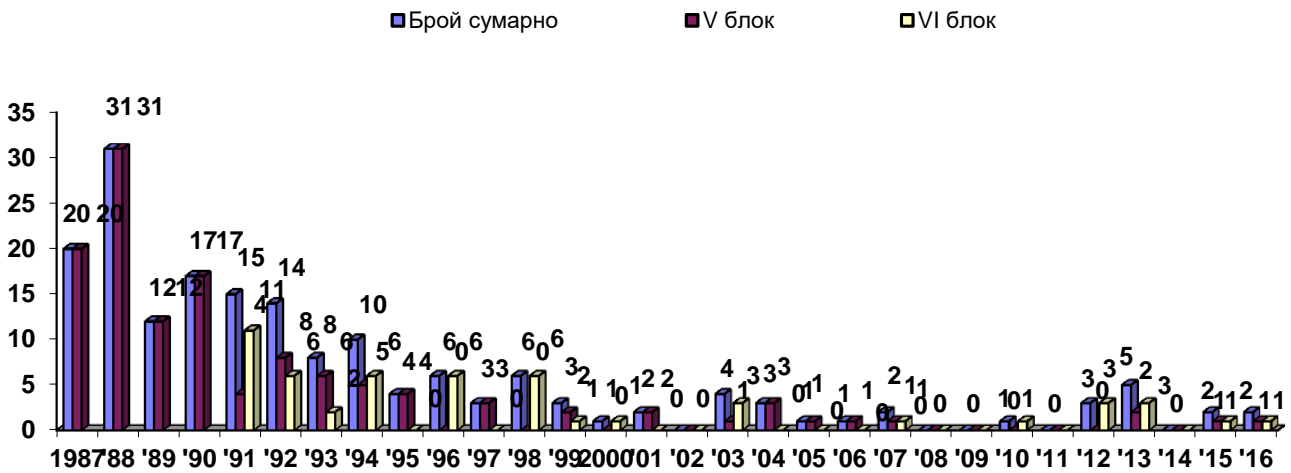


Figure 1. Number of unplanned scrams at Kozloduy NPP Units 5&6 in the period 1992–2015 years.

- Replacement of mechanical equipment;
- Modernization of electrical equipment;
- Replacement of the I&C systems with modern digital control systems;
- Improvement of fire protection and level of seismic resistance;
- Optimization of the conditions for equipment performance.
- containment on-line monitoring and hydrogen recombination system for design accidents;
- reactor pressure vessel measurement and level control system required for transient management (small LOCA, primary to secondary leaks and cool down without operating MCPs);
- automatic reactor pressure vessel cold over pressurization system;
- filter ventilation system to prevent the containment from integrity loss and minimization of the radioactive releases to the environment in case of beyond design accident;
- on-line isolation monitoring of 6 kV motors in stand-by mode.

Different studies and analyses applying the conservative assumptions, contemporary methods and computers codes in compliance with the accepted requirements were carried out. The equipment capability of performing the design functions was verified. The analysis spectra were extended in order to identify the capabilities of the units for management of design and beyond design accidents. The equipment was classified in terms of safety, seismic and quality. Completely new systems were installed such as:

The Units 5&6 Modernization Project of the Bulgarian nuclear power plant is the first and the only programme in the world which applies the full scope of the prescriptions for improvements of the WWER-1000 /320 units identified

Outage duration (days) within the period 2000 - 2015

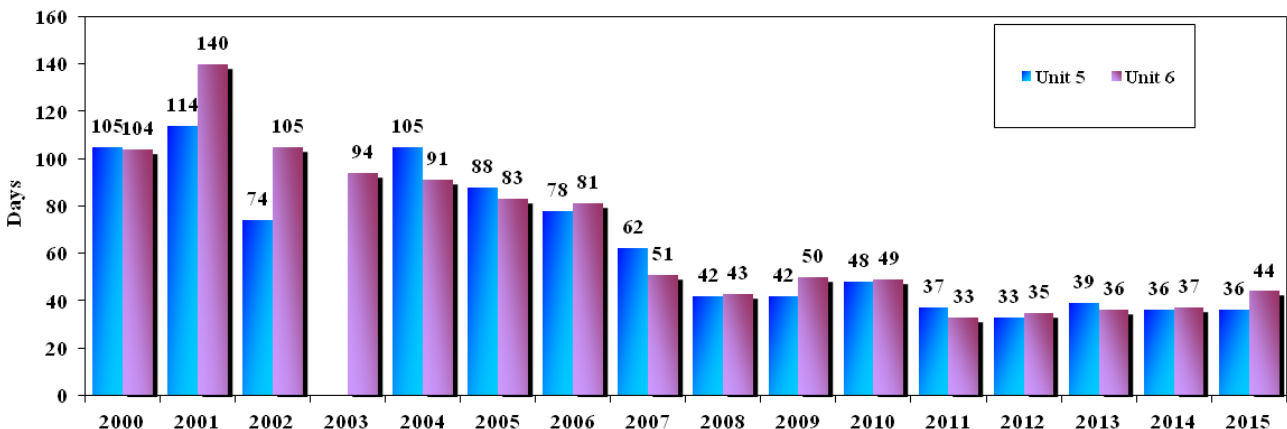


Figure 2. Outage duration of Kozloduy NPP Units 5&6 (2000–2015).

in the Safety Issue Book (IAEA-EBP-WWER-05). The completion of the Modernization Programme is a very important stage of the lifetime of Units 5&6 and provides for the compliance of the plant design with contemporary requirements to safety. Number of unplanned scrams at Kozloduy NPP Units 5&6 in the period 1992-2015 decreased significantly, as it is shown in Figure 1.

After modernization completion, Kozloduy NPP proceeded to the implementation of the Unit 5&6 Investment Programme. The main programme priorities are plant lifetime management and plant lifetime extension, maintain and enhance safety of operation and spent fuel storage (SFS) as well as increase the reliability of open switchyard. The investment programme include measures for safe management and storage of radioactive and non-radioactive waste generated during the plant operation, environmental radiation monitoring, physical protection, fire safety.

In the period from 2008 to 2012, the safety control systems used for establishing a cold condition of reactor system were replaced with new.

The optimization of the maintenance is achieved through: long-term planning of maintenance and repairs, optimization and planning some of the maintenance activities for their implementation during normal operation (without shutdown) of the units, preliminary detailed planning during the preparation of schedules for maintenance and repairs, use of condition monitoring systems; use of developed documentation for specific types of equipment. This provides for shorter outage duration and improves the plant load factors and it is shown on Figure 2.

2.2 Ageing management relevant to LTO

The Kozloduy NPP concept on Units 5&6 ageing management and the planned activities on ensuring the units' lifetime extension are specified in the "Kozloduy NPP Units 5&6 ageing management programme", ID No. 30.OY.00.AJ.58. In relation to the activities on Unit 5 lifetime extension and operating license renewal, an update of the ageing management programme is forthcoming that shall introduce the results from the 2015-2016 periodic safety review (PSR) at Unit 5, and following the design analyses reports, the time limited ageing analyses for Unit 5 (concerning the second stage of the Unit 5 LTO project).

In 2012, Kozloduy NPP initiated a project for the lifetime extension of Unit 5. The project goals were to renew the license of Unit 5 in 2017.

The project includes two stages:

First stage:

Ageing Management Review (AMR) of Unit 5 of Kozloduy NPP

AMR was performed in compliance with the requirements of Methodology for performance of a comprehensive assessment of the residual lifetime of the equipment and facilities at Units 5&6 of Kozloduy NPP, PД ATE.116/02 0806 2012. The objective of the Procedure is assess the actual condition and residual lifetime of the equipment and fa-

cilities (the abbreviation SSCs for structure, systems and components will be used further in the test, as adopted in the international practice) of Unit 5 to identify the capacity and conditions for long term operation (LTO) and development of programmes for preparation of Unit 5 for extended operation.

After the completion of AMR, A Summarized Report for Comprehensive assessment of Actual Condition and Residual Lifetime of SSCs of Unit 5 of Kozloduy NPP OTЧ ATE.116/02 0863 2012, was developed, which summarized the results from the work reports for comprehensive assessment of SSCs considering the results from the assessment of the technical condition, lifetime of SSCs and recommendation for the possibility for lifetime extension of the assessed SSCs. The current report also contains the measures performed by the personnel of Kozloduy within the lifetime extension of Unit 5.

As a result of the performed AMR, Lifetime Extension Preparation Programme of Unit 5 at Kozloduy NPP PLEX-DQA-KNPP-0003-02 was developed and coordinated with the Nuclear Regulatory Agency.

Second stage:

Implementation of the Units 5 Lifetime Extension Preparation Programme

The technical and organizational measures to provide for the operational lifetime of the SSCs to be implemented in the period from 2014 to 2017 for Unit 5 include:

- Replacement of the components that have worked out their operational lifetime;
- Additional analyses and justification of the residual lifetime of non-replaceable components;
- Change in the procedures for maintenance, repair and operation of the components in terms of their long-term operation.

There are 245 measures to be implemented by the end of the license period, which are split into five areas, planned for Unit 5:

- Unit 5 mechanical equipment;
- Unit 5 Electrical equipment and I&C systems;
- Unit 5 civil structures and BoP equipment;
- Measures resulting from the comprehensive study and assessment of the residual lifetime of SSCs at Unit 5 for urgent implementation;
- Measures resulting from the comprehensive study and assessment of the residual lifetime of SSCs at Unit 5 for periodic implementation.

The Unit 5 measure implementation is covered by Programme for Preparation for Lifetime Extension of Unit 5 at Kozloduy NPP, ID. No.PLEX-DQA-KNPP-0003-02.

2.3 Safety analysis report

The results from the Unit 5 Lifetime Extension Project at Kozloduy NP will be used for development of Safety Analysis Report confirming the capability of the plant for extended operation, which should be submitted to the Bulgarian NRA as a part of the required documents for license renewal.

3 Scoping and Screening for LTO

3.1 Scoping and screening and plant programmes relevant to LTO

Kozloduy NPP has developed and compared with international approaches (of USA, France, and Germany) and adopted a classification system in terms of safety, seismic and quality, conforming to the Bulgarian regulatory basis and that of international requirements (OPB88/97, IAEA 50 SG-D1). This classification system lies at the basis of the methodology and criteria for scoping and screening of SSCs for long-term operation.

The new classification of components, important to safety has been developed in the framework of measure 23111 of the Modernisation Programme for Units 5&6, in 2003. This is the key measure that puts in place the whole system for classification and qualification of the components and systems. The design system was improved in conformity with the IAEA recommendations of 2000, which resulted in the revision of 2003. The new classification considers the seismic qualification, the environmental qualification of equipment, and the safety qualification, and is the chief source in terms of establishing supervision on the maintenance and requirements for testing.

The new classification, according to the close-out report on measure 23111 MK-DST-FGER-0005-rev2, was sent to the Bulgarian NRA for approval in 2005. The special approval is reflected in the licensing of the specific modifications of safety related equipment and programmes, and in the approval of the updated SAR for the Unit 5 license renewal in 2009.

Currently, the system comprises more than 55 000 classified components (mechanical, electrical, I&C, HVAC, civil structures and load lifting equipment). The performance of this integrated assessment (or ageing management review, AMR) of Unit 5 was performed over the years 2012-2014, using a methodology that ensures indisputable justification of the Units 5&6 lifetime extension by contractors with past experience in similar projects, satisfying the high level of requirements to any EU member-state.

The ageing management review (comprehensive assessment), as per the Plan for Organisation and Implementation of Comprehensive Assessment of Equipment and Structures of Units 5&6 of Kozloduy NPP, ПД АТЕ.116/02.0800-2012, included:

- Analysis of structures, systems and components, civil structures and hydro-engineering facilities of the safety systems and the systems important to safety, and identification of the main (critical) com-

ponents subject to specialised review;

- Determining the most important mechanisms affecting the ageing and degradation processes of the major (critical) components and identifying or developing of methodologies for management and mitigating the effects of ageing;
- Development of relevant procedures and methodologies for residual lifetime assessment of the main structures and components;
- Residual life assessment of individual systems, components and civil structures;
- Justification of packages of recommendations and measures to ensure the life and maintain the qualification of SSCs of safety systems and systems important to safety on Units 5&6, integrated in the Programme for preparations for plant life extension;

The scoping and screening of SSCs at KNPP Unit 5 for the ageing management review was performed in conformity with the five criteria provided in the List of Equipment (SSCs) for AMR at Unit 5, ПЕ АТЕ.116/02 0804 2012, specified herein below:

- Criterion 1 – SSCs important to safety that will retain their functional characteristics during postulated initiating events, in order to preserve the coolant circuit integrity, the capacity to shut down the reactor and maintain it in a safe shutdown state, and the capability to prevent or mitigate any accident consequences;
- Criterion 2 – SSCs not important to safety, the failure of which may prevent the safety functions performance of other SSCs important to safety;
- Criterion 3 – SSCs not important to safety which have to ensure that functions continue to be performed in the course of plant operation in case of emergency protection actuation failure, and in case of a station blackout;
- Criterion 4 – SSCs not important to safety which have to ensure that functions continue to be performed in the course of operation in conformity with the requirements of fire safety and environmental protection;
- Criterion 5 – SSCs common for the units or part of BOP (balance of plant), required for the sustainable electricity generation throughout the operating life extension period.

The selection of the civil structures for long-term operation included those that might limit the service life of the power generation plant. Simple structures that may be easily replaced, or whose features might be readily restored, are excluded from the list. The scope of the selected SSCs covers major load bearing structures, supports and bracing facilities of the equipment important to safety, as well as seismic category 1 equipment.

The scoping of equipment for ageing management review used the List of Units 5&6 SSCs Important to Safety and Subject to Maintenance and Repair, № 30.OC.00.CIИH.4.

The ageing management review at KNPP Unit 5 comprised SSCs of the lists above, with unit systems and components important to safety, and also common unit systems (balance-of-plant) that assure the unit's operation in design basis modes, following the Methodology for Ageing Management Review and Residual Life Assessment of Equipment and Facilities of Units 5&6 at Kozloduy NPP, Stage 2, ID: ПД АТЕ.116/02 0806 2012. An approved list of the equipment (SSCs) for AMR at KNPP Unit 5, containing safety and seismic classification is provided in Appendix 1 of the Summary Report on the Results from the AMR and Residual Life Assessment of SSCs at Kozloduy NPP Unit 5, ОТЧ АТЕ.116/02 0863 2012, Revision 0, submitted to the Bulgarian NRA as a part of the reporting documentation for conformity to a licensing condition for Unit 5.

The components and systems covered by the ageing management review (Methodology for Ageing Management Review and Residual Life Assessment of the Kozloduy NPP Units 5&6 Equipment and Facilities, Stage 2, ПД АТЕ.116/02 0806 2012) are as follows:

- Reactor pressure vessel (RPV);
- Reactor internals;
- Pressuriser;
- Steam generators (SG);
- Main coolant pump – body;
- Main coolant pump – withdraw able part;
- Main coolant pipelines and the high energy pipelines connected to them;
- ECCS pipeline systems, high and low pressure;
- Secondary circuit pipeline systems – steam, feed water;
- Steam turbines;
- Turbine generator and generator exciter;
- Diesel generators;
- Electrical equipment of the safety systems and the systems important to safety;
- Control rods and I&C of the safety systems, and the systems important to safety;
- Cabling (cables and penetrations of the control rods, the safety systems and the systems important to safety);
- Important civil structures:
 - Reactor building (containment, foundation, pipeline penetrations in the containment, auxiliary facilities);
 - Support structure of the RPV / SG;
 - Turbine hall (TH);
 - Electrical trunking among the sprinkling pools, diesel generator station (DGS) and the reactor building;
 - DGSs including the fore bays and the intake lines between them;
- Buried (underground) pipelines between the DGSs and the spray pools;
- Spray pools;
- Auxiliary building-3 (AB-3);
- Ventilation stacks of units 5 and 6 reactor buildings; Ventilation stack of the auxiliary building;
- Overhead passage between the reactor building and AB-3 (auxiliary building-3);
- Coolant pumping stations (CPS-3 and CPS-4);
- Shaft pumping stations and underground pipelines to them;
- Common plant hydro-engineering facilities;
- Other common purpose plant (BOP) facilities (bank pumping station, open switchyard, diesel fuel and lube oil storage facility, etc.)

Outlines the process of scoping and screening of SSCs for LTO at KNPP units 5&6, in accordance with IAEA Safety Reports Series No. 57 [13], Safe Long Term Operation of NPPs, Vienna, 2008 are presented in Figure 3.

3.2 General information on the Kozloduy NPP Unit 5 lifetime extension and periodic safety review (PSR)

According to the provisions of article 22 of Kozloduy NPP Unit 5 Operating Licence, No. 03000/02.10.2009 [18], before the licence expiry it is necessary to perform an Comprehensive Assessment (Ageing Management Review as per IAEA terminology, or a Plant Integrated Assessment as is the USA NRC terminology) of Unit 5, and develop and implement in practice a Programme for Preparing Unit 5 for Operating Lifetime Extension.

Currently those are the more important steps completed in view of extending the operating lifetime of Unit 5:

- A project management plan for the stage 2 of KNPP Units 5&6 service life extension was issued and updated, ¹ PLEX-DQA-KNPP-0001-03 [21]. It comprises a general time-schedule for performing the plant life extension (PLEX) activities on Kozloduy NPP Units 5&6;
- A corresponding subject item was established and included in the Kozloduy NPP Investment Programme.
- For the purpose of extending the operating life of the units beyond their design life, a contract (No. 222000014) was placed with the Consortium REA-EdF, entitled “Comprehensive Assessment of the Actual Condition and Residual Life Time Evaluation of the Equipment and Facilities on KNPP Units 5&6”.
- A Licensing Plan was developed for renewal of licence series “E”, registration No. 03000 of 02.10.2009, for the operation of KNPP Unit 5, № ДОД.ОУ.ИЛ.1244.

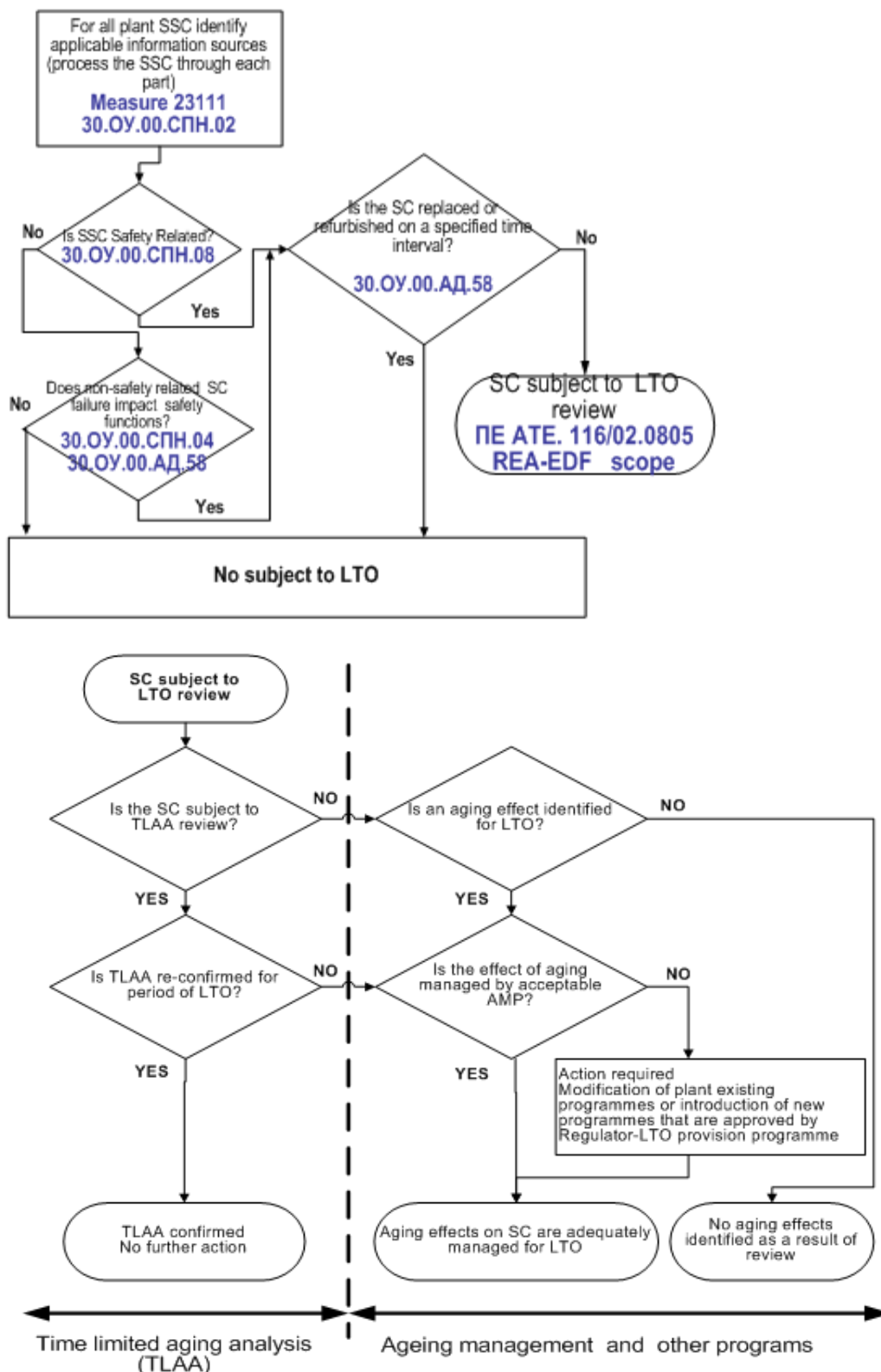


Figure 3. Process of scoping and screening of SSCs for LTO at Kozloduy NPP Units 5&6.

3.3 Periodic Safety Reviews 2008–2016

The Periodic Safety Reviews are comprehensive reviews of the safety of all the nuclear power plant aspects important to safety. They are conducted at regular time intervals to ensure a systematic safety re-assessment and confirmation of the licensing basis or identification of any deviations from the effective regulatory requirements or appli-

cable safety standards. The conduct of PSR throughout the operation of Kozloduy NPP Units 5&6 is an important element of the assurance of a high safety level – a key priority of the plant management policy.

In 2007–2008, a reassessment (review) of safety was performed at Kozloduy NPP, in accordance with the provisions of the Regulation on Ensuring the Safety of Nu-

clear Power Plants and the IAEA's Periodic Safety Review of NPPs, Safety Guide, NS-G-2.10. This Safety Guide also identifies the factors relevant to long-term operation, and their review was adapted to similar safety areas defined in the Regulation on Ensuring the Safety of Nuclear Power Plants. Within this review, a thorough assessment was performed on the current status of the Units 5&6 design including its correspondence to the presently effective and more stringent safety requirements and norms, the ageing of SSCs of safety systems and systems important to safety, knowledge management and preparation of human factor, feedback from operating experience, probabilistic and deterministic analyses, etc. Also, the data on the residual life of SSCs of safety systems and systems important to safety were reviewed. This was a precondition required for renewal of the operating licences of Units 5&6, in 2009. The report from this PSR was submitted for review and evaluation at the BNRA, pursuant to the licence provisions.

The results from the safety re-assessment were used as the grounds for preparing a long-term Programme for Enhancement of the Nuclear Safety and Radiation Protection of Units 5&6, addressing the licence renewal process and required by the IAEA Safety Guide¹ NS-G-2.10, and by the effective Licences of Kozloduy NPP Unit 5, article 26, subsection "e".

The PSR of Kozloduy NPP Unit 5 for (2015-2016) was performed pursuant to article 22, Para 1 of the Regulation on Ensuring the Safety of Nuclear Power Plants, in coordination with the regulatory authority (Bulgarian NRA), giving due consideration to the experience from the 2009 PSR, and the recommendations in the IAEA Safety Guide, Periodic Safety Review of Nuclear Power Plants, No. SSG-25 dated 2013.

The scope and manner of conducting the periodic safety review of Kozloduy NPP Unit 5 has been agreed by the Bulgarian NRA and documented with resolutions from a working meeting between Kozloduy NPP and Bulgarian NRA representatives, MoM № 14.30.0Б.00.ПРТ.1285. The PSR comprises inspection and defining the status of 14 safety factors, as per the recommendations of the IAEA specific safety guide, SSG-25 Periodic Safety Review of Nuclear Power Plants. This project has to be completed by September 2016 (section 6, Order № АД-2092/11.07.2014 of the Kozloduy NPP CEO).

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