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Human Factor as an Important NPP Safety Factor

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Abstract. The important aspects of safety of an operating nuclear power plant addressed in a Periodic Safety Review (PSR) are termed 'safety factors'. Fourteen safety factors are identified in the Safety Guide SSG-25, which may be used to subdivide the PSR. The review of safety factors should determine the status of each safety factor at the time of the PSR and should assess future safety at the nuclear power plant at least until the next PSR and, where appropriate, up to the end of planned operation. This should include a review of the capability of the operating organization to identify potential failures and either prevent them or mitigate their consequences before they could lead to a radiological incident.

The paper presents the methodology used at the last PSR carried out in Kozloduy NPP regarding Factor 12 – Human Factor. From the results obtained it can be determined whether the human factor aspects are managed in conformity with the referenced normative documents, whether the announced by the plant management policies regarding safe operation of the plant are observed, and whether effective programs for human factor management are implemented. The purpose is to maintain high level of safety culture by all Kozloduy NPP staff and to take well-founded and feasible measures for improvement if necessary.

Keywords: safety, safety culture, safety factors, human factor.

Abbreviations

Bulgarian Nuclear Regulatory Agency (BNRA)

International Atomic Energy Agency (IAEA)

Periodic Safety Review (PSR)

Western European Nuclear Regulators Association (WENRA)

1 Introduction

The objective of IAEA SF-1 is to establish the fundamental safety objective, safety principles and concepts that provide the bases for the IAEA's safety standards and its safety related program. Related requirements and guidance on meeting these regulations are provided in other safety publications [1].

Safety is concerned with both radiation risks under normal circumstances and radiation risks as a consequence of incidents, as well as with other possible direct consequences of a loss of control over a nuclear core, nuclear chain reaction, radioactive source or any other source of radiation.

Safety measures include actions to prevent incidents and arrangements put in place to mitigate their consequences if they were to occur.

Safety culture is the attitude, beliefs, perceptions and values that employees share in relation to safety in the workplace. Safety culture is a part of organizational culture. A good safety culture can be promoted by senior management commitment to safety, realistic practices for handling hazards, continuous organizational learning, and care and concern for hazards shared across the workforce.

The IAEA safety standards reflect an international consensus on what constitutes a high level of safety for protecting people and the environment from harmful effects of ionizing radiation. They are issued in the IAEA Safety Standards Series, which has three categories:

Safety Fundamentals present the fundamental safety objective and principles of protection and safety, and provide the basis for the safety requirements.

Safety Requirements: An integrated and consistent set of Safety Requirements establishes the requirements that must be met to ensure the protection of people and the environment, both now and in the future. The requirements are governed by the objective and principles of the Safety Fundamentals. If the requirements are not met, measures must be taken to reach or restore the required level of safety. The format and style of the requirements facilitate their use for the establishment, in a harmonized manner, of a national regulatory framework. Requirements, including numbered 'overarching' requirements, are expressed as 'shall' statements. Many requirements are not addressed to a specific party, the implication being that the appropriate parties are responsible for fulfilling them.

Safety Guides provide recommendations and guidance on how to comply with the safety requirements, indicating an international consensus that it is necessary to take the measures recommended (or equivalent alternative measures). The Safety Guides present international good practices, and increasingly they reflect best practices, to help users striving to achieve high levels of safety. The recommendations provided in Safety Guides are expressed as 'should' statements.

The purpose of the Safety Guide SSG-25 Periodic Safety Review (PSR) for Nuclear Power Plants is to provide recommendations and guidance on the conduct of a PSR for an existing nuclear power plant. The Safety Guide is intended for use by operating organizations, regulatory bodies and their technical support organizations, consultants and advisory bodies.

The safety culture of an organization and its safety management system are closely related, but the relationship is not simply that the safety culture complies with the formal safety management system. The safety culture of an organization cannot be created or changed overnight; it develops over time as a result of history, work environment, the workforce, health and safety practices, and management leadership. An organization's safety culture is ultimately reflected in the way safety is addressed in its workplaces and how the policies and procedures are implemented into the workplace, which will be influenced by the safety culture of the organization or workplace, preparedness and response for nuclear or radiation incidents. Emergency plans have to be exercised periodically to ensure the preparedness of the organizations having responsibilities in emergency response.

2 Safety Factors in a PSR

The important aspects of safety of an operating nuclear power plant addressed in a PSR are termed 'safety factors'. Fourteen safety factors are identified in the Safety Guide SSG-25 [2], which may be used to subdivide the PSR.

The review of safety factors should determine the status of each safety factor at the time of the PSR and should assess future safety at the nuclear power plant at least until the next PSR and, where appropriate, up to the end of planned operation. This should include a review of the capability of the operating organization to identify potential failures and either prevent them or mitigate their consequences before they could lead to a radiological incident. Ageing related degradation mechanisms that could lead to failures of SSCs important to safety that could potentially limit the plant's operating lifetime should be identified to the extent possible. Safety factors that should be assessed at PSR are described below:

Safety factor 1: Plant design

Plant SSCs important to safety should be appropriately designed and configured in such a way that there is a high degree of confidence that they will meet the requirements for safe operation of the plant and for performance in compliance with design characteristics, including the prevention and mitigation of events that could jeopardize safety (i.e. fulfillment of their safety functions). Adequate design information, including information on the design basis, should be made available to provide for the safe operation and maintenance of the plant and to facilitate plant modifications.

The objective of the review of plant design is to determine the adequacy of the design of the nuclear power plant and its documentation by assessment against the current licensing basis and national and international standards, requirements and practices.

Safety factor 2: Actual condition of SSCs important to safety

The actual condition of SSCs important to safety within the nuclear power plant is an important factor in any review of the safety of the plant design. Hence, it is important to document thoroughly the condition of each SSC important to safety. Additionally, knowledge of any existing or anticipated obsolescence of plant systems and equipment should be considered part of this safety factor.

The objective of the review of this safety factor is to determine the actual condition of SSCs important to safety and so to consider whether they are capable and adequate to meet design requirements, at least until the next PSR. In addition, the review should verify that the condition of SSCs important to safety is properly documented, as well as reviewing the ongoing maintenance, surveillance and in-service inspection programmes, as applicable.

Safety factor 3: Equipment qualification

Plant equipment important to safety (that is, SSCs) should be properly qualified to ensure its capability to perform its safety functions under all relevant operational states and accident conditions, including those arising from internal and external events and accidents (such as loss of coolant accidents, high energy line breaks and seismic events or other vibration conditions). The qualification should adopt a graded approach consistent with the safety classification of the SSC and should be an ongoing activity.

The objective of the review of equipment qualification is to determine whether plant equipment important to safety has been properly qualified (including for environmental conditions) and whether this qualification is being maintained through an adequate programme of maintenance, inspection and testing that provides confidence in the delivery of safety functions until at least the next PSR.

Safety factor 4: Ageing

All SSCs important to the safety of nuclear power plants are subject to some form of physical change caused by ageing, which could eventually impair their safety functions and service lives.

The objective of the review of ageing is to determine whether ageing aspects affecting SSCs important to safety are being effectively managed and whether an effective ageing management programme is in place so that all required safety functions will be delivered for the design lifetime of the plant and, if it is proposed, for long term operation.

Safety factor 5: Deterministic safety analysis

Deterministic safety analysis should be conducted for each nuclear power plant, in order to confirm the design basis for SSCs important to safety and to evaluate the plant behavior for postulated initiating events.

The objective of the review of this safety factor is to determine to what extent the existing deterministic safety analysis is complete and remains valid when the following aspects have been taken into account:

- The actual plant design, including all modifications of SSCs since the last update of the safety analysis report or the last PSR;
- Current operating modes and fuel management;
- The actual condition of SSCs important to safety and their predicted state at the end of the period covered by the PSR;
- The use of modern, validated computer codes;
- Current deterministic methods;
- Current safety standards and knowledge (including research and development outcomes);
- The existence and adequacy of safety margins.

Safety factor 6: Probabilistic safety assessment

A review of the probabilistic safety assessment (PSA) should be conducted to identify weaknesses in the design and operation of the plant and, as part of the global assessment, to evaluate and compare proposed safety improvements.

The objectives of the review of the PSA are to determine:

- The extent to which the existing PSA study remains valid as a representative model of the nuclear power plant;
- Whether the results of the PSA show that the risks are sufficiently low and well balanced for all postulated initiating events and operational states;
- Whether the scope (which should include all operational states and identified internal and external hazards), methodologies and extent (i.e. Level 1, 2 or 3) of the PSA are in accordance with current national and international standards and good practices;
- Whether the existing scope and application of PSA are sufficient.

Safety factor 7: Hazard analysis

To ensure the delivery of required safety functions and operator actions, SSCs important to safety, including the control room and the emergency control center, should be adequately protected against relevant internal and external hazards.

The objective of the review of hazard analysis is to determine the adequacy of protection of the nuclear power plant against internal and external hazards, with account taken of the plant design, site characteristics, the actual condition of the SSCs important to safety and their predicted state at the end of the period covered by the PSR, and current analytical methods, safety standards and knowledge.

Safety factor 8: Safety performance

Safety performance is determined from assessment of operating experience, including safety related events, and records of the unavailability of safety systems, radiation doses and the generation of radioactive waste and discharges of radioactive effluents.

The objective of the review of safety performance is to determine whether the plant's safety performance indicators and records of operating experience, including the evaluation of root causes of plant events, indicate any need for safety improvements.

Safety factor 9: Use of experience from other plants and research findings

Experience from other nuclear power plants, and sometimes from non-nuclear facilities, together with research findings, can reveal previously unknown safety weaknesses or can help in solving existing problems. Reference [3] requires the operating organization to obtain and evaluate information on operating experience at other plants and to derive lessons for its own operations. This should include information from other plants for which the operating organization is responsible and wider experience, including relevant information from non-nuclear facilities.

The objective of the review of this safety factor is to determine whether there is adequate feedback of relevant experience from other nuclear power plants and from the findings of research and whether this is used to introduce reasonable and practicable safety improvements at the plant or in the operating organization [4, 5].

Safety factor 10: Organization, the management system and safety culture

The operating organization is required to have in place a management system that ensures that policies and objectives are implemented in a safe, efficient and effective manner. Similarly, the organization should have a strong safety culture so that all individuals carry out duties important to safety correctly, with alertness, due thought, full knowledge, sound judgment and a proper sense of accountability.

The objective of the review of this safety factor is to determine whether the organization, management system and safety culture are adequate and effective for ensuring the safe operation of the nuclear power plant.

Safety factor 11: Procedures

Procedures important to the safety of the nuclear power plant should be comprehensive, validated, formally approved, appropriately distributed and subject to rigorous management control. In addition, the procedures should be unambiguous and relevant to the actual plant (with modifications taken into account); they should reflect current operating practices and due consideration should be given to human factor aspects [3, 6].

The objective of the review of procedures is to determine whether the operating organization's processes for managing, implementing and adhering to operating and working procedures and for maintaining compliance with operational limits and conditions and regulatory requirements are adequate and effective and ensure plant safety.

Safety factor 12: Human factors

Human factors influence all aspects of the safety of a nuclear power plant. The review should examine the human factors at the plant and within the operating organization to determine whether these correspond to accepted good practices and to verify that they do not present an unacceptable contribution to risk. In particular, the review should determine whether operator actions claimed to be in support of safety are feasible and properly supported.

The objective of the review of this safety factor is to evaluate the various human factors that may affect the safe operation of the nuclear power plant and to seek to identify improvements that are reasonable and practicable.

Safety factor 13: Emergency planning

The design and operation of a nuclear power plant are required to prevent or otherwise minimize releases of radioactive substances that could give rise to risks to workers or the public or to the environment. Emergency planning for the possibility of such releases is a prudent and necessary action, not only for the operating organization but also for local and national authorities.

The objective of the review of emergency planning is to determine: (a) whether the operating organization has in place adequate plans, staff, facilities and equipment for dealing with emergencies; and

(b) whether the operating organization's arrangements have been adequately coordinated with the arrangements of local and national authorities and are regularly exercised.

Safety factor 14: Radiological impact on the environment

The operating organization should have in place an established and effective monitoring programme that provides data on the radiological impact of the nuclear power plant on its surroundings.

The objective of the review of this safety factor is to determine whether the operating organization has an adequate and effective programme for monitoring the radiological impact of the plant on the environment, which ensures that emissions are properly controlled and are as low as reasonably achievable.

3 Periodic Safety Review of Safety factor 12: Human factors) [SSG-25/2013]

3.1 Scope and tasks

The review of human factors should consider the procedures and processes in place at the nuclear power plant to ensure the following:

- Adequate staffing levels exist for operating the plant, with due recognition given to absences, shift working and restrictions on overtime;
- Qualified staff are available on duty at all times;
- Adequate programmes are in place for initial training, refresher training and upgrading training, including the use of simulators;
- Operator actions needed for safe operation have been assessed to confirm that assumptions and claims made in safety analyses (for example, PSA, deterministic safety analysis and hazard analysis) are valid;
- Human factors in maintenance are assessed to promote error-free execution of work;
- Adequate competence requirements exist for operating, maintenance, technical and managerial staff;
- Staff selection methods (for example, testing for aptitudes, knowledge and skills) are systematic and validated;
- Appropriate fitness for duty guidelines exist relating to hours, types and patterns of work, good health and substance abuse;
- Policies exist for maintaining the know-how of staff and for ensuring adequate succession management in accordance with good practices;
- Adequate facilities and programmes are available for staff training.

The following aspects of the human–machine interface should also be reviewed:

- Design of the control room and other workstations relevant to safety;
- Human information requirements and workloads;
- Clarity and achievability of procedures.

3.2 Methodology

The review of human factors should include the above tasks and should take account of recognized national and international good practices. The review should be carried out with the assistance of properly qualified specialists. Because of the difficulties associated with carrying out an objective review of what is essentially the performance of its own staff, the operating organization may decide that specific elements of the review should be carried out by external consultants.

Table 1. Typical inputs and outputs for the review of SAFETY FACTOR 12

Inputs	Outputs
Standards and requirements: • Current national and international requirements; • Current national and international good practices for ensuring that human factors do not affect the safe operation of the nuclear power plant. **Plant specific documents:** • Policy to maintain the know-how of the plant staff; • Training records, also for training in safety culture, particularly for staff in management positions; • Staffing records; • Fitness for duty requirements; • Programmes for the feedback of operating experience for failures and/or errors in human performance that have contributed to safety significant events and their causes, and consequent corrective actions and/or safety improvements; • Audits and self-assessments of hours of work and time records. **Operating experience:** • Operating experience involving human factors at plants in the State and in other States; • Safety significant events involving human factors. The review of this safety factor may require input from other safety factors.	The review of human factors may lead to findings in some of the following areas: • Staffing levels; • Training programmes; • Operating, maintenance and engineering practices; • Competency management; • Staff selection and recruitment and succession management; • Knowledge management; • Use of external technical resources; • The human–machine interface; • Communications. Results from the review of this safety factor may provide inputs for other safety factors.

The review of the human–machine interface should examine the actual condition of the plant using, for example, plant walkdowns by specialists.

If deficiencies in the procedures and processes or in the design of the human–machine interface represent a potentially significant adverse contribution to risk, the PSR should make proposals for corrective actions to be considered in the global assessment. These may include improvements in procedures, enhanced training or redesign of human–machine interfaces.

Typical inputs and outputs for the review of SAFETY FACTOR 12: HUMAN FACTORS are shown in the Table 1.

3.3 Case Study (PSR of Kozloduy NPP)

The extent of unification of common valuables, attitude and way of behavior describe the level of the human factor impact on the NPP operation and define the safety culture of the operational organization.

The human factor development is a process that has to be covered by the plant's management policy, by which it is declared that the safety is of high priority before all other activities and commitment is undertaken to stimulate the staff for critical attitude to the work implementation with a purpose for achievement of the highest safety level at NPP operation.

Analyzing the factors determining the safety culture level at NPP, conclusion can be made that the human factor has influence on all safety aspects in every NPP.

From the results obtained it can be determined whether the human factor aspects are managed in conformity with the referenced normative documents, whether the announced by the plant management policies regarding safe operation of the plant are observed, and whether effective programs for human factor management are implemented. The purpose is to maintain high level of safety culture by all Kozloduy NPP staff and to take well-founded and feasible measures for improvement if necessary.

The human factor assessment together with the other safety factors assessment at carrying out of PSR in Kozloduy NPP gives possibility to be defined whether the human factor in the framework of the operational organization corresponds to the accepted good practices and to be confirmed that it is not unacceptable risk.

In conformity with the recommendations, described in IAEA SSG-25/2013 Periodic Safety Review and with the requirements of the Bulgarian Nuclear Regulatory Agency (BNRA) Regulation for providing the safety of nuclear power plants, the verification of the Safety factor No. 12 Human factor has to be completed with consideration of the following requirements:

- The analysis is to be focused on the human factor aspects that may have influence upon the safety, with a purpose of evaluation the efficacy of the applied tools for their management.

- The verification of the factor has to be comprehensive and profound.
- For ensuring of comprehensiveness and thoroughness of the verification should be used all current national and international standards, regulating requirements to the human factor.
- The human factor verification should take into consideration the accepted good national and international practices.

Eleven elements with total 43 criteria are included in the scope of the Safety factor No. 12 Human factor evaluation. The elements for evaluation are developed on the basis of documents of BNRA, IAEA, RF and WENRA. The elements reflect the important characteristics of the safety factor verified. For ensuring of succession and comparability of the results, updated criteria from the previous PSR of Units 5 and 6 of Kozloduy NPP, carried out in 2009. The elements and the criteria are presented and coordinated with BNRA.

The assessment of Safety factor No. 12 Human factor is performed in conformity with the requirements of the documents developed by Kozloduy NPP for implementation of the project:

- Methodology for carrying out of Periodical Safety Review of Unites 5 and 6 of Kozloduy NPP, № 30.ОБ.00.МТ.24/2.
- Quality Management Plan for a project "Periodical Safety Review of Unites 5 and 6 of Kozloduy NPP", № 30.ОУ.ОК.ПЛ.09/1.
- Methods for assessment of Safety factor No. 12 Human factor for PSR of Unites 5 and 6 of Kozloduy NPP, Appendix 12.
- Methods for categorization of the nonconformities, detected at carrying out of the "Periodical Safety Review of Unites 5 and 6 of Kozloduy NPP", № 30.ОБ.00.МТ.13/3.
- Quality Management Plan for a project "Periodical Safety Review of Unites 5 and 6 of Kozloduy NPP", № 30.ОУ.ОК.ПЛ.08/1.

The assessment method used consists of analysis of the human factor status towards the requirements defined in the criteria and described in details in the methods for verification of the Safety factor No. 12 Human factor [7].

For the purposes of the analysis are determined:

- Normative documents/standards (references) applicable for the assessment;
- The criteria (requirements) for assessment;
- The documents for presentation of the necessary information;

The activities for the factor assessment have been implemented in the following succession:

- Description of the current state of the specific criteria in the unified form;
- Analysis and assessment of the conformities/nonconformities towards the defined requirements in the normative documents;
- Categorization of the nonconformities according to approved methods;
- Determination of the recommendations for elimination of each nonconformity;
- Generalization of the factor assessment results;
- Inclusion the assessment results in a report for the status of Safety factor No. 12 Human factor.

The following priorities are observed at comparing with the requirements of the referential documents during the process of evaluation the current state of Factor No. 12 Human factor:

- First priority – Bulgarian safety documents;
- Second priority – IAEA documents (in cases when Bulgarian normative documents do not contain specific technical or methodical requirements);
- Third priority – other normative documents, identified in the process of implementation and in the cases, when they are applicable to the assessment and supplement, but are not in contradiction with the documents of the first and second priority

The current state of the elements/criteria of Safety factor No. 12 Human factor is determined on the basis of analysis of the information from the existing documentation, received from the Employer under established order as input data for implementation of the contract. The documents cited in the forms for assessment of the conformity/nonconformity of the criteria with the requirements of the normative documents, used in the version, are available by the electronic information system of the plant "SmartDoc".

4 Conclusion

Human capital is a distinctive resource which, if properly managed, has the potential to become an abundant source of competitive advantage both for the company and for individual staff. Individuals accumulate human capital over their lifetime. Its elements include not only formal knowledge, skills, competence and abilities, but tacit knowledge and experience gained over time.

Safety culture in an organization is created by:

- Provision of common understanding for the key aspects of the safety culture in the plant;
- Provision of tools by which the organization support the persons and teams for safe and successful implementation of their tasks, taking into account the interaction between the staff, the technology and the organization;

- Institutionalization of relationships that allow setting questions and continuous improvement of the knowledge at all levels in the organization;
- Provision of tools for meeting the continuous ambition for development and improvement of the safety culture in the plant.

The review of safety culture is an assessment of commitment to safety and should include the following:

- A review of the safety policy to verify that it states that safety takes precedence over production and to confirm that this policy is effectively implemented;
- A review of procedures to ensure that nuclear and radiation safety are properly controlled and that appropriate measures are applied consistently and conscientiously by all staff;
- An assessment of the extent to which a questioning attitude exists and conservative decision making is undertaken in the organization;
- Verification that there is a strong drive to ensure that all events that may be instructive are reported and investigated to discover root causes and that timely feedback is provided to appropriate staff on findings and remedial actions;
- Verification that unsafe acts and conditions are identified and challenged in a constructive manner wherever and whenever they are encountered by plant employees and external staff (contractors);
- Verification that the organization has a learning culture and that it strives continuously for improvements and new ideas, and benchmarks against and searches out best practices and new technologies;
- Verification that there is an established and effective process for communication of safety issues;
- Verification that there is a process in place for prioritization of safety issues, with realistic objectives and timescales, that ensures that these issues receive proper resources;
- Verification that there is a method in place for achieving and maintaining clarity of the organizational structure and managing changes in accountability for matters affecting safety;
- Verification that there is adequate training in safety culture, particularly for managers.

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