Generic Model for Management of Safety of Technical Installations Powered by Small Modular Reactors

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Abstract: - Technical installation powered by small modular reactors (SMRs) is perspective industrial object due to high need of energy of new technologies and problems in the world. They are critical installations due to content and work with dangerous substances because these are sources of fire, explosion and environment contamination. Therefore, for human society and its development, it is necessary to manage not only their nuclear safety, but also their integral (complex) safety, because just integral safety ensures the security and development of human society. The approach to safety and concept of safety management used by manufacturer, operator and regulator must be same. For this purpose, we give in article a tool showing the main features and requirements for management of the integral safety of such installations.

Key-Words: - Small modular reactors (SMR); Technical installations with SMR, Risks, Integral safety, Generic model of safety management.

Received: March 11, 2022. Revised: January 4, 2023. Accepted: February 15, 2023. Published: April 3, 2023.

1 Introduction

Small modular reactors (SMR) have been in development for decades. The International Atomic Energy Agency [1] defines small, medium and large reactors according to output electrical performance; reactors up to 300 MWe are classified as small reactors. They are increasingly used in practice, as they are cheaper and their area of emergency planning is smaller compared to large nuclear power plants [2-4].

In the Czech Republic , we work on the Energy Well reactor [5], which we want to use as energy sources in technical installations producing the energy for: train and ship drive [6,7]; operation of industrial object, which need great amount of energy; operation of processes as reverse osmosis; hydrogen production and hydrogen storage [2]; and mining the minerals in remote regions [7].

Technical installations powered by the SMR as other technical installations are threatened by risks caused by harmful phenomena: occurring in the locality, in which they are located [8,9]; originating at the operation by failure of technical fittings, components or their interconnection and their wear over time; associated with the human factor, in particular in the design and organization of operation management [10,11]; and, last but not least, by low possibilities of humans to anticipate sudden changes in the development of the world.

From above given reasons, the technical installations with SMR are critical objects and it is necessary to manage not only their nuclear safety, but also the integral safety, because they ensure the security and development of human society, however, costs on their operation must be acceptable to society.

Based on current knowledge and experience which are systematically enforced into practice by the IAEA and OECD and are continuously presented in the ESREL conferences [12-25], a generic model for the management of integral safety of technical installations powered by the SMR is created, based on the principles of: risk-based design; and risk-based operation. It is also shown way, how to adapt this general model to real site conditions. Next paragraphs summarize main principles of model in question and process models for its construction.

2 Sources of Risks for Technical Installations with SMR

On the basis of the analysis of 7829 accidents and failures of technical installations including the nuclear installations [10,26], the sources accidents and failures of the technical installations are mainly:

- natural disasters,
- defects and failures of technical equipment, components, production lines and systems,

- traffic accidents especially at transport hazardous materials, spent fuel etc.,
- accidents in storage of hazardous materials, spent fuel etc.,
- organizational accidents caused by a human factor, in particular by a poor safety culture in designing, manufacture and operation,
- deliberate attacks.

Therefore, it is necessary to consider that these phenomena will also lead to failure and accidents of technical installations powered by SMR.

The world dynamically changes, and therefore, new data on risk sources originating and they must be permanently considered. For safety improvement , it is necessary to evaluate each failure or accident of each technical installations and to determine lessons learned which is important for improving the prevention and response. Special attention must be given to technical installations powered by SMR because for them a low number of information.

3 Data and Method for Compilation of Generic Model of Management of Risks towards Safety

Real risk size depends on both, the hazard of specific disaster that is the source of the risk, and the vulnerabilities of the local monitored assets and their interconnections. It is site and temporally specific, because it depends on the amount and vulnerabilities of assets in a given territory and at a given time [10,11]. From this reason, model of safety management of each entity (asset, fittings, technical installation etc.) needs to respect site conditions, i.e.”

- set of disasters determined according to All-Hazard-Approach [8,9],
- local knowledge level,
- requirements of local legislative,
- possibilities of local society.

With regard to current knowledge, it is necessary to link:

- existing norms and standards, because they contain previous knowledge and without their application there would be a repetition of past mistakes from the past
- and the results of risk management,
- as recommended now by a number of standards, e.g., ISO 31 000, ISO 31010, ISO 9000, etc.. The method of linking the standards and risk analysis results is e.g. in [27].

Depending on the specific possibilities of a given human society, the risks are divided into acceptable, conditionally acceptable and unacceptable [10,11,28]. Basis for risk management is:

- high risk is intolerable and cannot be justified even in extraordinary circumstances,
- ALARP risk is tolerable only if risk reduction is impracticable or if its cost is grossly in disproportion to the improved gained, i.e. if cost of reduction would exceed the improvements gained
- and acceptable risk, at which it is necessary to check during time if risk maintains at this level.

In accordance with OECD requirements [28] and results for technical installations [10,11], each manager of technical installation shall have a safety management system (SMS) containing the safety management program that is based on qualified risk management, from design to construction up to operation. Due to the present importance of the role of cyber infrastructure associated with an automated management system, the SMS must also ensure the cybersecurity. The model of safety management of technical installation with SMR in time is the analogy of model constructed in [29], and it is shown in Figure 1. The main goal of technical installation security in automatic control is so that the instructions for control systems of technical installation may be clear and precise, i.e. not affected by phenomena that can distort them.

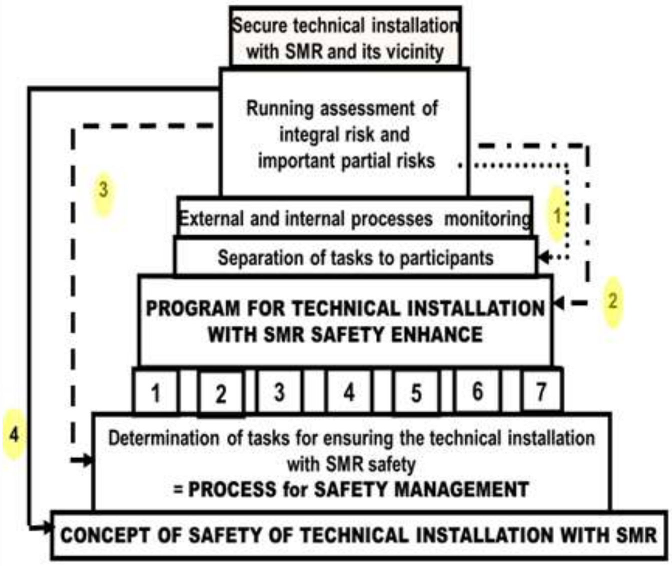

Fig. 1: Model of safety management of set of technical installations powered by the SMR with automated control [29]. Processes: 1- conception and management; 2 - administrative procedures; 3 - technical matters; 4 - external cooperation; 5 - emergency preparedness; 6 - documentation and investigation of accidents; 7- cyber security. Feedbacks: numbers 1-4 in a yellow circle.

At technical installation powered by SMR as for each technical installation, it needs to be monitored, the partial risks connected with big disasters and the integral risk, which include contributions from elements and links and couplings among them (more than 80 % accidents and failures of technical installations is caused by random combination of small errors in short time interval [10]). The tool for determination of integral risk in the form of decision support system (DSS) was constructed by using the principles of decision with multiple objectives [30]. Generic model of DSS determined for:

- designing the technical installation is given in [27]
- and for operation of technical installations is given in [10].

Due to limited human possibilities and finances, the risk management measures costs may not exceed the human society sources [31]. The way of determination of acceptability of integral risk is described in details in [11].

Generic model is a tool which describes a process how to work with risks towards safety. It solves tasks how to:

- determine risk sources in locality according to All-Hazard-Approach [8,9],
- determine important external and internal risk sources for technical installations with SMR by critical analysis of qualified data sets (how historical data on big events need to be considered),
- evaluate sizes of hazards for all important risk sources [10]
- propose concept of technical installations with SMR which copes with all important risks´ sources; namely either in design or in operation (by response).

For construction of generic model of safety of technical installations with SMR we consider requirements of [1,32,33], recommendations of Perrow [34] and procedure used by OECD [28] which was elaborated in [10] and tested in practice [12,35].

4 Generic Model of Management of Safety

Determination of risk sources and determination of their hazards is summarized e.g. in publication [36]. The basic principles of safety management of industrial object powered by the SMR are given thereafter. According to knowledge summarized in works [10,27], they are described by pictures:

- Figure 2 shows way of planning the safe technical installation powered by the SMR,
- Figure 3 shows way of creation of risk-based design of technical installation powered by the SMR,
- Figure 4 shows way of comparison of important parameters of technical installation powered by the SMR.

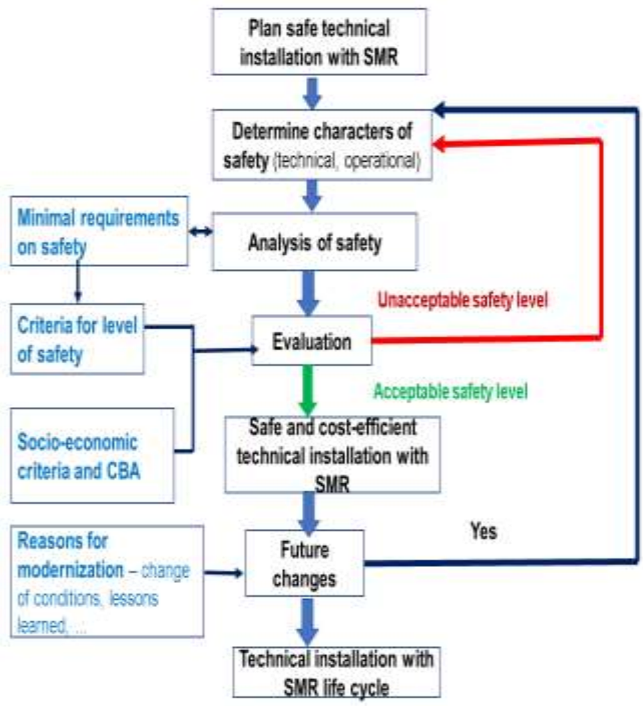

Fig. 2: A Generic model of planning the safe technical installation powered by the SMR.

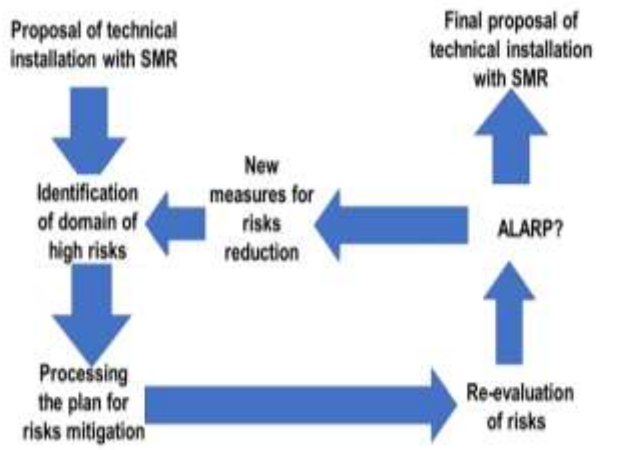

Fig. 3: Flowchart of risk-based design of technical installation powered by the SMR.

Considering the knowledge summarized in foregoing chapters, the other important parts of generic model of safety management of technical installation powered by the SMR at operation are:

- process of risk management towards safety of technical installation powered by the SMR during the operation, which is shown in Figure 5,
- tasks of safety management system (SMS), which need to be specified in technical installation powered by the SMR, which are shown in Figure 6.

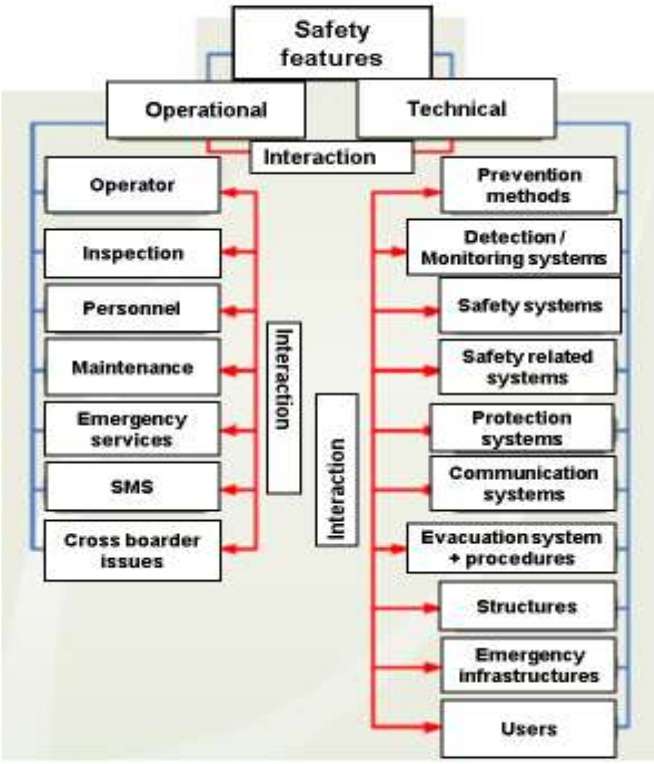

Fig. 4: Safety features of technical installation powered by the SMR.

Fig. 5: Safety management of technical installation powered by the SMR at operation.

Fig. 6: Tasks specified in the safety management system (SMS) of technical installation powered by the SMR.

At technical installation powered by the SMR, we distinguish the basic levels of safety management that need to be aligned, namely [36]:

- political,
- strategic,
- tactical,
- operational/functional
- and technical. In knowledge-based process management, the strategic level determines the basic directions of development, from which it follows which processes need to be modified or created, what organizational changes will need to be made, where to get know-how, financial resources, etc.

5 Conclusion

An important document of the safety report for technical installation powered by SMR is the continuity plan [10], because such industrial object is critical facility, which is vital to ensuring the basic functions of the State.

The continuity plan is the strategic plan for the management of safety and development of technical installation powered by SMR. The plan is based on the way of integral safety management and it contains not only data important for the operation of technical installation with SMR, but also a way of solving the problems that can seriously disrupt the operation and competitiveness of technical installation powered by the SMR [10].

In accordance with [10], the entity continuity plan has higher goals than the risk management plan and it includes procedures how to:

- deal with risks that have a source outside the technical installation powered by SMR and seriously affect it. It contains clearly determined responsibilities and procedures for resolving the conflicts between the public interest and the technical installation with SMR operator,

- ensure a safe technical installation powered by SMR for the planned lifetime, so that technical installation powered by the SMR may deliver quality products and services, it is competitive and does not endanger itself and its surroundings,
- coordinate changes caused by dynamic development of technical installation powered by SMR and its surroundings, which are not necessarily synergistic,
- respond to the change of conditions, including the emergency and crisis management measures, which are elaborated in detail and ensured in all aspects for all levels of management of technical installation powered by the SMR., i.e. it is attached a crisis preparedness plan that contains measures and their ensuring, and way for support the State in critical situations.

To ensure the correctness and expertise of the safety report, it must be approved by the State authority, i.e. the State must have a safety oversight authority, which is codified by law. Due to reality that risks are site-specific, the generic model presented above must be adapted to site conditions,

To introduce the SMR in practice, it is necessary to solve many important problems. We have started to solve the following ones:

- dynamic behavior of SMR as it is shown in [37],
- cyber security of I&C for SMR as it is shown in [38],
- safety and resiliency of industrial object powered by SMR, which is important for practice.

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Contribution of Individual Authors to the Crea-tion of a Scientific Article (Ghostwriting Policy)

The author contributed in the present research, at all stages from the formulation of the problem to the final findings and solution.

Sources of Funding for Research Presented in a Scientific Article or Scientific Article Itself

No funding was received for conducting this study.

Conflict of Interest

The authors have no conflict of interest to declare that is relevant to the content of this article.