Abstract

New Russian regulations [2], published in 2016, introduce modernized rules for classification of NPP systems and elements. Updated classification rules take into account IAEA requirements, experience of existing classification rules application, the results of safety analyses (primarily results of PSA studies) and operational experience (including Fukushima accident experience). The paper shows that the new classification criteria reflect classified element impact on NPP safety. Also the paper demonstrates compliance of the new classification criteria with contemporary international practice reflected in IAEA standards and in various national regulatory documents from different countries.

All the NPP items important to safety shall be classified as stated in Requirement 22 of the IAEA Safety Standard [1]. Classification is required to present graded regulatory requirements for different systems and elements of a nuclear power plant depending on (a) their functions, and (b) their importance to safety. According to [1], the NPP items classification shall be established with a due account taken of factors such as: safety function to be performed by the item; the consequences of failure; the probability of a safety function to be performed by an item; the time following a postulated initiating event at which or the period for which, the item will be called upon to perform a safety function.

Strictly speaking, appropriate safety requirements can be developed without a classification, but the use of the classification allows development of safety requirements in a less cumbersome way and to make them better structured and traced.

Obviously, the classification of items (systems and elements) by their NPP safety importance should consider ranking when stricter regulatory requirements are applied to the items of the highest safety importance for the NPP. Meanwhile, grading of the regulatory requirements by functions (for instance, the systems are divided into protective, control, and supporting) performed by an item (system, element) may not be of the ranking nature.


Both NPP systems and elements are primarily ranged by [2] by their importance to safety, there are two grades: systems (elements) which are important to safety, and systems (elements) which have no safety impact. Table 1 provides classification rules and appropriate classification features established in [2].
TABLE 1. THE RULES OF ATTRIBUTION OF NPP SYSTEMS (ELEMENTS) TO THOSE IMPORTANT TO SAFETY [2]

<table>
<thead>
<tr>
<th>Rule No.</th>
<th>Contents of a rule</th>
<th>Applied classification features</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Affiliation with safety systems (elements)</td>
<td>Involvement of a system (element) into implementation of the third level of the Defence-in-Depth (DiD). Decrease in NPP preparedness for design basis accidents (degradation of the third level of the DiD) in case of a system (element) failure.</td>
</tr>
<tr>
<td>2</td>
<td>Affiliation with systems (elements) of normal operation whose failure jeopardizes normal operation of a plant, if the conditional possibility of this failure developing into a severe accident is $10^{-6}$ or higher</td>
<td>Involvement of a system (element) into implementation of the third level of the DiD. Degradation of the DiD first level in case of a system (element) failure, the need in actuation of systems related to the further DiD levels due to the failure of an NPP element. The probability of inefficient operation of further DiD levels (conditional possibility of a system (element) failure developing into a severe accident).</td>
</tr>
<tr>
<td>3</td>
<td>Affiliation with systems (elements) of normal operation whose failure prevents from elimination of operational occurrences at a plant, if the conditional possibility of this failure developing into a severe accident is $10^{-6}$ or higher</td>
<td>Involvement of a system (element) into implementation of the third level of the DiD. Decrease in NPP preparedness for reacting to abnormal operation (degradation of the second level of the DiD) due to a failure of an NPP system (element). The probability of inefficient operation of other DiD levels (conditional possibility of a system (element) failure developing into a severe accident).</td>
</tr>
<tr>
<td>4</td>
<td>Affiliation with NPP systems (elements) whose failure leads to excess of established values for maximal permissible releases or permissible discharges of radioactive substances, or permissible levels of NPP premises radioactive contamination</td>
<td>Involvement of a system (element) into implementation of the third level of the DiD. Radiological consequences of a system (element) failure.</td>
</tr>
<tr>
<td>5</td>
<td>Affiliation with systems (elements) provided in the NPP design for accident management during first three days after an initiating event (or during another period determined in the NPP design which shall be at least three days);</td>
<td>Involvement of a system (element) into implementation of the fourth level of the DiD. Time period since the moment of an initiating event occurred after which a system (element) should be in operation.</td>
</tr>
<tr>
<td>6</td>
<td>Affiliation with the systems (elements) of radiation monitoring.</td>
<td>Involvement of an NPP element into implementation of the DiD (levels 2-5 of the DiD) as regards to the monitoring of radiation parameters</td>
</tr>
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</table>

Thus, [2] applies the following classification features to define safety importance of a system (element):  
- Involvement of a system (element) into implementation of the second level of the DiD;  
- Probability of inefficiency of the DiD levels, other than the level directly degrading in case of a failure of a classified system (element), i.e. conditional probability of a system (element) failure development into a severe accident; and  
- Time period since the moment of an initiating event occurred after which a system (element) should be in operation.

The first of the features is the main one (according to [2], only systems involved into the DiD are considered to be important to safety; classification rules Nos. 1-6 given in Table 1 provide classification features related to all the levels of the DiD). The second and third features are specifying and they allow not to consider systems and elements as important to safety (although they are involved into the DiD but have minor impact on NPP safety) because in case of a failure they stay operable, and engineering and organizational measures are sufficient to ensure...
extremely high probability of non-development of such a failure into a severe accident (Classification Rules Nos. 2&3), or their failure does not impact the accident behavior in the course of the first three days after an initiating event and, if required, such systems (elements) can be simply replaced by other operable systems (elements) (Classification Rule No.5).

It is worth mentioning than ranking per Table 1 is not always sufficient. Safety important systems (elements) specified among others with the help of the rules provided in the a.m. table may have significantly different impact on NPP safety.

While manufacturing and operating equipment (elements), stricter requirements to reliability assurance shall be applied to equipment (elements) with higher impact on NPP safety. It is reasonable to perform further regulatory ranking of equipment (other elements) by its safety impact. We would like to emphasize the fact that for the grading purposes of reliability assurance during manufacturing and operation the ranking shall be applied to elements but not to systems because the systems contain elements that may have a different impact on NPP safety.

For this purpose, General Provisions [2] introduces NPP elements classification, i.e. elements are related to one of the four safety classes in line with the classification rules provided in Table 2.

TABLE 2. THE RULES OF ASSIGNMENT NPP ELEMENTS TO SAFETY CLASSES

<table>
<thead>
<tr>
<th>Safety Class</th>
<th>Classification rule</th>
<th>Applied classification features</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st</td>
<td>Fuel elements and elements whose failure is an initiating event for a Beyond Design Basis Accident (BDBA) leading under a design operation of safety systems to damage of fuel elements beyond the limits established for design basis accidents.</td>
<td>Failure of the first, second, and third levels of the DiD due to a failure of a classified element.</td>
</tr>
<tr>
<td>2nd</td>
<td>Elements whose failures are initiating events which under design functioning of safety systems lead to damage of fuel elements within the limits established for design basis accidents.</td>
<td>Failure of the first and second levels of the DiD due to a failure of a classified element.</td>
</tr>
<tr>
<td>2nd</td>
<td>Elements of safety systems with single failures resulting in violation of design limits established for the design basis accidents when such accidents occur.</td>
<td>Failure of an element leads to NPP unavailability for overcoming a design basis accident (failure of the third level of the DiD due to a failure of a classified element).</td>
</tr>
<tr>
<td>3rd</td>
<td>Safety important elements other than safety classes 1 and 2.</td>
<td>Assignment of an element to those important to safety (or non-assignment).</td>
</tr>
<tr>
<td>4th</td>
<td>Elements which do not have safety impact and are not classified as safety classes 1, 2, and 3.</td>
<td>Assignment of an element to those important to safety (or non-assignment).</td>
</tr>
</tbody>
</table>

It is clearly seen that different classes (from the first to the third) are applied to safety important elements depending on consequences of a failure of such a classified element for the DiD, i.e. if due to a failure three levels of the DiD degrade (from the first to the third), then the element is assigned to Class 1; if due to a failure of an element the first and second levels of the DiD or the third one become inefficient, then the element is assigned to Class 2. In all other cases safety important elements are referred to Safety Class 3. Elements which are not important to safety are referred to as Class 4.

Thus, primary ranking of systems (elements) by their safety impact is made in [2] based upon a deterministic criterion which considers involvement of a system (element) in the DiD with two specifying features applied, probabilistic and temporal (see Table 1). Further additional ranking of NPP elements applies additional (in relation to those provided in Table 1) classification features related to the scope of impact on the DiD as a whole caused by a failure of classified NPP elements.

A number of regulatory requirements provided in the Russian rules and regulations (both in [2] and others) covers safety important systems (elements) and do not cover NPP systems (elements) which have no
safety impact (this, using the basic ranking of systems and elements given in Table 1). Alongside, a number of regulatory requirements apply additional ranking of NPP elements, i.e. safety classes (assigned in line with the rules provided in Table 2), requirements to analysis of reliability of elements [2], requirements for production, operation and control of equipment (in particular, [5]), seismic resistance requirements [6], etc. 1

In addition to the ranking of systems and elements given in Tables 1 & 2, the General Provisions [2] provide other classifications (which are not ranking): systems (elements) are divided into systems (elements) of normal operation, safety systems (elements) and special technical means for DBDA management, safety systems (elements) are also divided into protective, localizing, control, and supporting ones.

Thus, the classification rules for systems and elements provided in [2] comply with the requirements of the IAEA standards [1], [9]; the Russian classification rules base on deterministic approaches supplemented, if necessary, with probabilistic considerations and taking into account the temporal factor (thus, the classification takes into account all the four aspects which shall be accounted as per requirement 22 [1]). However, there are differences from the recommendations of SSG-30 [10].

Let us highlight the following case of use of the classification. When there is a need to grade regulatory requirements by implementation of the independence, redundancy and diversity principles, the object of classification shall not be NPP equipment or elements, nor the NPP systems because safety functions subject to the requirements related to the a.m. principles are implemented by functional groups which may or may not be equivalent to the systems. For instance, a functional group may consist of several systems, a system train, may be an aggregate of several channels of different systems, and other options are also possible. In that case functional groups are subject to ranking. Such an approach (with functional groups of categories A, B, and C) implemented in 2016 in the requirements for safety important control systems [7] which take into account the provisions of both the IEC standard [8] and the Russian regulatory documents. Whilst, the mandatory character of redundancy and diversity principles is established for the groups of category A, the possibility of refusal to follow these principles if appropriate justification is available is established for the functional groups of category B; and optionality of implementation of these principles is established for the functional groups of category C.

It is necessary to mention common features in the Russian classification rules provided in [2] and actual regulatory requirements of other countries, for instance, Finland. In line with the guidance [11], NPP systems are divided into Classes 2, 3, EYT/STUK and EYT; and the first three classes of the systems are considered as important to safety, and Class EYT involves systems which do not have safety impact. Only the systems of Class 2 may be considered as available in the analysis of design basis accidents. In case of this approach, assigning a system to Class 2 is similar to assigning a system to the safety systems in the Russian regulations. For the analysis of anticipated operational occurrences, NPP safety assurance may be considered with the account taken for the operation of other systems. EYT/STUK Class is actually a supplement to Class 3 (the regulatory requirements for the systems of these classes do not differ significantly). But if deterministic ideas are applied when assigning systems to Class 3 (as it is in case of Russia, such ideas are related to the DiD), then the rules of assignment to Class EYT/STUK also contain probabilistic criteria. As per [11], structures and components are related to the same safety class as the system. However, the class of a component (structure) may be decreased if it is demonstrated that there is no (or low) impact by the component on operation of the system, and it may be increased if the component is at the boundary with a system of a higher class. [11] also provides additional rules for classification of components and structures. In compliance with the rules, the reactor pressure vessel and other primary equipment whose failure has intolerable consequences are assigned to Class 1, while equipment whose failure has a threat of uncontrolled chain reaction is assigned to Class 2.

The analysis demonstrates that the totality of classification rules for systems, components, and structures provided in [11] considers involvement of a classification object into the DiD. It also considers probabilistic and a number of other ideas. The classification is made at the level of systems and other specific elements. All these things serve as evidence of common features of the Russian and Finnish classification rules.

The regulatory documents of Hungary apply different approaches to NPPs in operation (provided in [12]) and new NPPs (13). To a large extent, the approach suggested by [12] is similar to that of [3]. Safety functions (Classes F1A, F1B, F2), physical barriers (levels B1, B2, B3) are classified in compliance with [13]. The classification rules for systems and components are developed as unified ones (Classes ABOS1, ABOS2, ABOS3).

1 Rules [5] and [6] apply additional classifications which take into account the safety classes established in line with [2].
ABOS3 are considered for systems and components with safety impact. Class ABOS4 is applied to systems and components with no safety impact. Classification criteria are related to the DiD. Probabilistic criteria or ideas related to time are not formulated in a clear way. [13] also contains instructions that state probabilistic criteria should be applied as auxiliary ones together with deterministic criteria. It is obvious that the approach suggested by [13] has similar features with the classification approach implemented by [2], but there are significantly less similarities than in case the Finnish regulation [11].

CONCLUSION

The approach to classification of systems, elements and functional groups implemented in newly introduced Russian Federal rules and regulations [2], [7] complies with the provisions of the IAEA standards SSR-2/1 [1] and GSR Part 4 [9]. However, it has some differences in comparison with the approach provided in SSG-30 [10]. The accumulated experience of classification rules provided in [3] was taken into account in the process of development of the classification rules of [2]. The classification approaches suggested by [2] have similar features as the approaches provided in the requirements for classification of NPP systems and elements of some European countries [11-13].

REFERENCES

[8] IEC 61226:2009 Nuclear power plants - Instrumentation and control important to safety - Classification of instrumentation and control functions