SAFETY ASSESSMENT, SAFETY PERFORMANCE INDICATORS AT THE PAKS NUCLEAR POWER PLANT

BAJI, C., VÁMOS, G., TÓTH, J.
Paks NPP, P. O. Box 71,
H-7031 Paks, Hungary
Fax: +3675506733; Email: bajics@npp.hu

Abstract

The Paks Nuclear Power Plant has been using different methods of safety assessment (event analysis, self-assessment, probabilistic safety analysis) including performance indicators characterizing both operational and safety performance since the early years of operation of the plant. Regarding the safety performance the indicators include safety system performance, number of scrams, release of radioactive materials, number of safety significant events, industrial safety indicator etc.

The Paks NPP also reports a set of ten indicators to WANO Performance Indicator Programme which, among others, include safety related indicators as well. However a more systematic approach to structuring and trending safety indicators is needed so that they can contribute to the enhancement of the operational safety. A more comprehensive set of indicators and a systematic evaluation process was introduced in 1996. The performance indicators framework proposed by the IAEA was adapted to Paks in this year to further improve the process. Safety culture assessment and indicators characterizing safety culture is part of the assessment process.

1. INTRODUCTION

According to the Nuclear Safety Code of Hungary "The safety is such a feature of a nuclear power plant which —using technical and administrative measures — excludes the possibility of presenting risk to the human life, the health and the life conditions of the present and the future generation and the environment above the internationally accepted risk levels" or as the IAEA document (Design for Safety of Nuclear Power Plants) states in a more simple way "The safety is the protection of all persons from undue radiological hazards". However, the problem is that the safety cannot be measured. A high level of safety is the result of the interaction of a good design, operational safety and human performance. From this it can be seen that there are different aspects of safety. One is that may be called as design safety or engineering safety that depends on how the plant is designed. It depends upon how the design basic principles were applied during the design and construction, e.g. how many redundancies are built into the systems, whether the system components fulfill the single failure criteria etc. Another aspect is the operational safety that depends on how professionally the plant is operated and maintained. A significant component of this is the human performance. The design safety of the plant can be assessed based on deterministic and probabilistic evaluations which is included into the Safety Analysis Report. It is more difficult to evaluate or measure how well the plant is operated. This question depends on many factors the most of which cannot be measured, they can only be estimated.

2. SAFETY ASSESSMENT

There are different methods to evaluate the operational safety of the plant. One is the event analysis with root cause analysis. This method can be considered as a so called 'mitigative' one because it is based on events that already occurred and the operational safety is analysed based on the past 'negative' experience. For these events detailed investigation is performed and corrective actions are defined in order to eliminate the root causes. A more proactive way is the analysis of low level events or near-misses because in this case corrective measures can be defined without real significant events. But the analysis of low level events needs the allocation of more human resources. At the Paks NPP only a small part of the low level events are investigated in details. Another part of those events are only recorded and trended. For the first part corrective actions are defined, for the other part corrective actions are taken only if

negative trend can be observed. Other methods of the assessment are the self-assessment, quality assurance, probabilistic safety assessment, regulatory inspection etc.

In the last 10 years the term 'safety culture' has been given significant attention. According to the IAEA definitions the safety culture is that assembly of characteristics and attitudes in organisations and individuals which establishes that, as an overriding priority, nuclear plant safety issues receive the attention warranted by their significance. The assessment of safety culture of the operating organisation of a nuclear power plant can provide nearly a full picture of the operational safety. The safety culture can be assessed either separately or using indicators which characterize safety culture as a subset of indicators in the overall system. At the Paks Nuclear Power Plant both ways are applied as it is described in this paper. The most complex way of the assessment of operational safety is the use of a complete set of indicators. A comprehensive set of indicators will definitely include elements of all the different methods mentioned above.

3. SAFETY PERFORMANCE INDICATORS

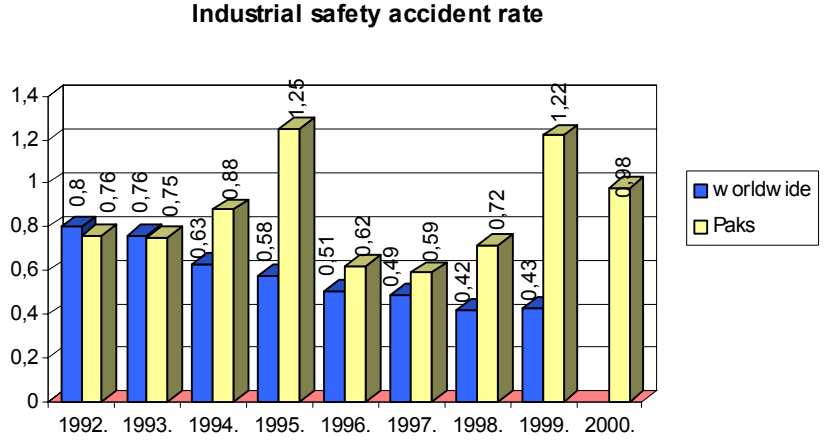
3.1. Background information

Indicators have been used at the Paks NPP from the early years of operation. The first set consisted of six indicators such as load factor, forced outage rate, unplanned automatic scrams, thermal performance, collective radiation exposure and ESF actuation. These indicators were selected based on international practice and were merely used for comparison and trending without any feedback. The introduction of WANO indicator system in the early 90's was a big step. The WANO system was a more systematic set of indicators but still far from being a full set to evaluate the operational safety in complex. In 1996 a system of 28 main (as a total 55) indicators was defined which set was quite comprehensive and covered a wide scope of activities that have relationship to safety. Those main areas are the following:

- fire safety;
- significant event;
- technical specification;
- quality;
- safety system reliability;
- training;
- environmental impact (radioactive wastes and releases);
- risk (core damage frequency).

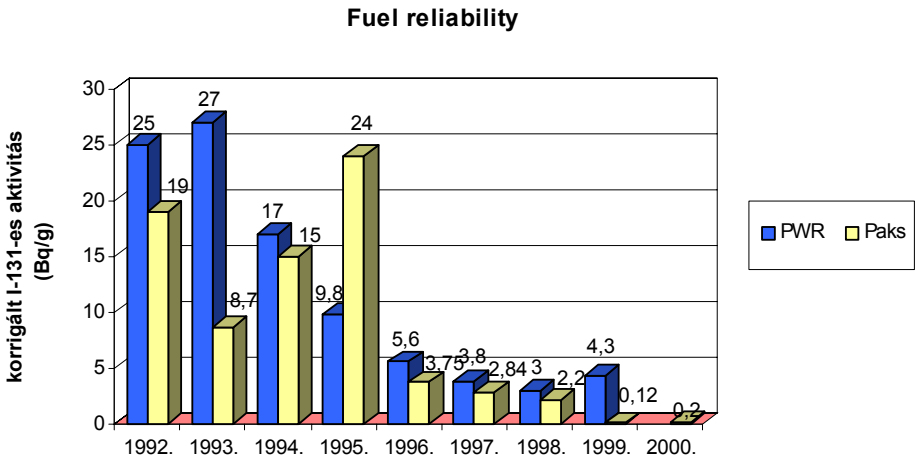
3.2. The use of indicators

So far the indicators have been analysed in detail yearly. A report on the indicators is prepared and reported to the Operations Review Committee for assessment at the annual meeting. In case of negative trend corrective actions are defined to improve the area for which the indicator provides indication. In the system that had existed until 2000 the assessment was performed based on qualitative considerations using trends or international comparison. Two examples of the indicator trend will be given in this paragraph. The most recent negative trend have been observed in the industrial safety indicator (as an example) as it can be seen on the following diagram.



The causes of the 1999 high value were carefully analysed, international benchmarking with other nuclear power plants and national benchmarking with other industrial enterprises in Hungary were conducted in 2000. Based on the results of the major causes of the incidents some corrective actions were implemented in 2000 and more corrective actions have been defined to be implemented in 2001. There was a slight improvement in 2000 but more significant improvement is needed in order to reach an acceptable value of this indicator.

The other example is to present an indicator with a positive trend that is the fuel reliability indicator. The trend graph with world-wide comparison is presented on the diagram below. This is an indicator which have been improved by two orders of magnitude in the last few years. This indicates the high reliability of the implemented fuel and the good water chemistry of the primary systems.



Most of the rest of the indicators are either slowly and gradually improving or the variation of the indicator remains within an acceptable range. As it can be seen from the above the basis for international comparison is the WANO indicator system. The plant reports data to WANO quarterly and WANO issues assessment report twice per year. The results of the safety indicators analysis is also published in a yearly coloured brochure with other results of the yearly evaluation of safety. Some of the indicators which may be interesting for the public are displayed on a large board at the entrance to the plant. The safety indicators are also available on the Intranet system.

3.3. Recent initiatives

In the second half of 2000 the safety indicator system was reviewed. It was identified during the self-assessment in the Periodic Safety Review (PSR) process that the system needs to be revised and modified in accordance with the international practice. As a basis for the review the IAEA proposed framework was used. The Paks NPP did not participate in the IAEA pilot study but was very carefully following the activities in the project. After the IAEA issued TECDOC-1141 (Operational safety performance) indicators, the results were analysed and the Paks safety indicator system was modified. The major changes made to the existing system included the following:

- the framework with the 3 safety attributes (Plant operates smoothly, Operational safety and Attitude towards safety) were adopted and the existing indicators were categorized according to the attributes;
- new indicators were defined in order to make the system complete and to cover all the areas of safety related activities;
- the frequency of the assessment of the indicators was set to quarterly (previously some of the indicators were evaluated only annually).

Now this new system is in the implementation phase. The structure is given in the attached figures. The first flow-chart shows the overall framework and the full system is shown on the other three flow-charts attached to this paper. The indicators shown in italics are those which are newly defined, the rest are those which existed in the previous performance indicator set at Paks.

3.4. Safety Culture Assessment

Though the safety performance indicators include a number of indicators that characterize the safety culture and one attribute of the newly implemented system (attitude towards safety) is practically a subset of safety culture indicators, the safety culture at Paks have been given high importance and has been analysed within an individual project in the last 5-7 years.

3.4.1. *Enhancement of Safety Culture at the Paks NPP*

In 1993 the plant management initiated a programme for the improvement of safety culture. Based on that decision an IAEA Model Project titled 'Strengthening Training for Operational Safety' at Paks NPP was launched in 1994. This project as one of the three major elements also contained enhancement of safety culture. The first main actions to improve Safety Culture a clear plant Safety Policy was issued and distributed, an IAEA Safety Culture Workshop was organized at Paks, examples of good safety culture practices were developed and safety culture survey was carried out among the employees. The last item is the one which established the basis for the regular assessment and monitoring of the safety culture level at Paks. The first safety culture assessment carried out for Paks NPP employees in 1994 was repeated in 1999 and also performed for the plant management in 2000.

3.4.2. *Safety Culture assessments at Paks*

Safety Culture Indicator is a function of many variables. Important contributing factors are the clear safety policies and management expectations with priority of nuclear safety, sound procedures and adherence to procedures, implementation of self-assessment and reviews and staff training and education. The list of questions provided in the INSAG-4 document with some addition and modification were used as the basis for the survey. As part of the above described safety culture improvement project an initial evaluation of the safety culture level was performed in 1994. The objectives of the survey were definition of the basic safety culture level at the Paks NPP, assessment of the attitude of the plant personnel towards nuclear safety and identification of good practices and corrective actions.

In 1999 a repeated assessment was performed using the same approach with the same questions. Contrary to the 1994 survey - which was carried out by the experts of the plant - in 1999 a professional organisation the Department of Ergonomics and Psychology of the Budapest University of Technical and Economical Sciences was contracted for performing the survey and analysing the results. In 2000 the assessment among members of the management had the goal to underline the changes carried out since the first evaluation and to point out the differences not only between professional organisations but also between employees and managers and between different levels of management.

3.4.3. *Method of the assessments*

The survey for employees in 1999 was based on the 1994 evaluation, but the questions were slightly modified in order to assess both components of safety culture properly. They covered Operations, Maintenance, Radiation and Engineering disciplines. At least 30 representatives were randomly selected from each discipline for the survey. Taking into account mainly the ASCOT guidelines method the 80 questions covered the following components: organisation, team, individual, technology. The interviews with a limited number of people were specified as 'semi-controlled' in order to collect both specific information and individual opinion.

The management assessment covered all the technical organisations of the plant with a few representatives from Human and Economics Divisions. So it was performed with the participation of 77 managers of different levels and plant shift supervisors. All of them filled in the questionnaire and 22 of them participated in the interviews, making additional comments, recommendations and pointing out areas where improvements are necessary. The questions and structure of the interview were similar to the 'employee survey' in order to make possible the comparison of the results.

3.4.4. *Analysis of the results*

The information provided in the questionnaires were analysed with a systematic input data checking by statistical hypothesis analysis. A numerical value was calculated for the groups of questions and

eventually a single indicator was processed for the different plant attributes and an overall indicator for the whole plant. The comparison of the safety culture levels are given in the following table.

	1994 (%)	1999 (%)	2000 (%)
Safety culture level	61	77	76

In 1994 the main deficiencies were communication, training, attention to human factor. In 1999 the main contributing factor to increasing of the measured safety culture value was the increased attention to safety and also high positive expectations from the new management. Deficiencies indicated were: complicated documentation, frequent organisational structure changes, the problem with the external contractors. In 2000 the management the survey pointed out some positive aspects of the safety culture level but there remained areas which need improvement such as global company—level vision, a stable plant organisation and clearly regulated working processes.

4. SUMMARY

The performance indicators should be a tool for the management to assess the operational safety performance and to indicate areas where improvement is needed. For this purpose an indicator system is needed that covers all the areas of safety related activities. For this reason the system of safety indicators has been revised at the Paks NPP and the IAEA framework has been adopted. The safety indicators are used at Paks as one of the tools for safety assessment in parallel with other methods such as event analysis, root cause analysis, self assessment etc. A special attention is paid to the safety culture and it is analysed in parallel with the safety indicators implementing periodic assessment of the safety culture using statistical survey among the employees of the power plant.

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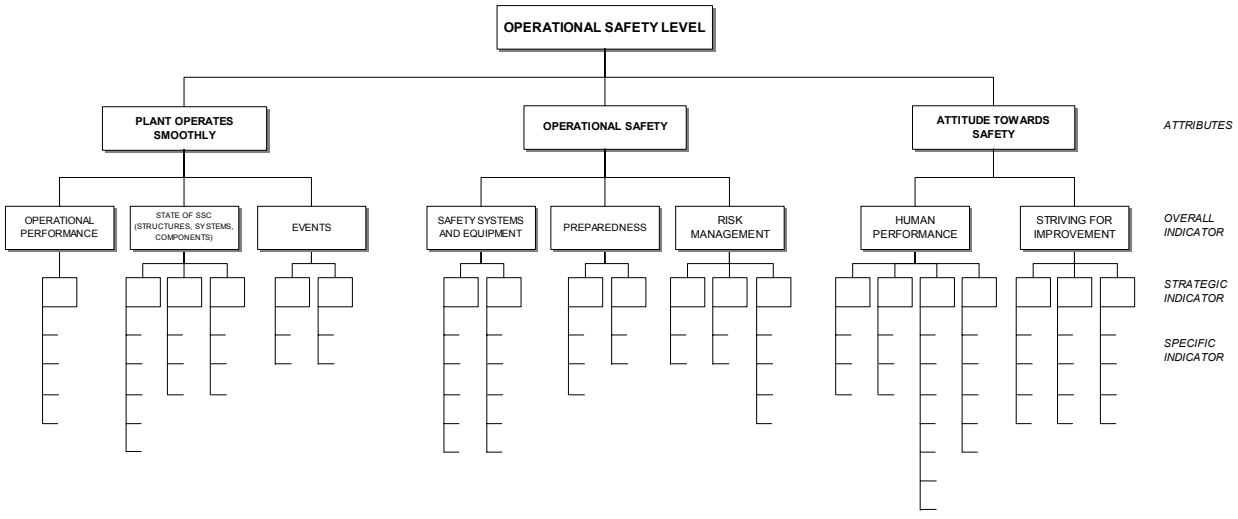
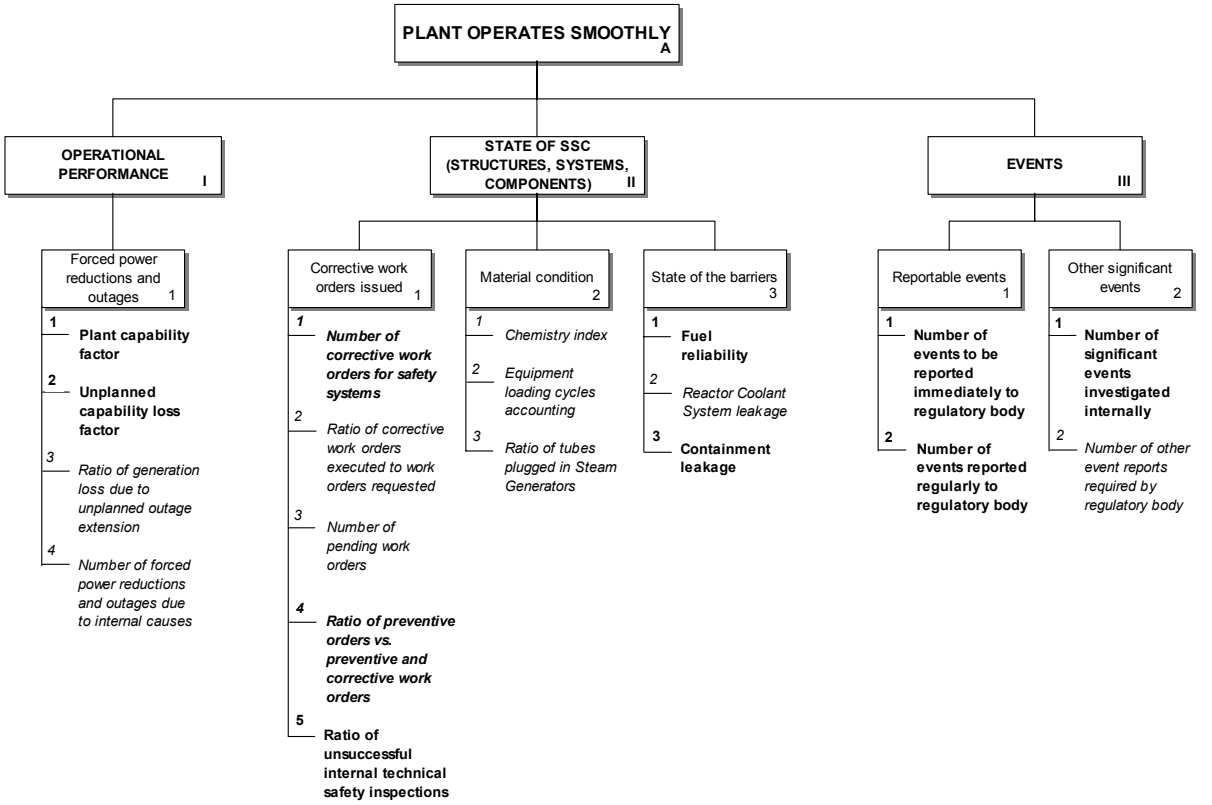
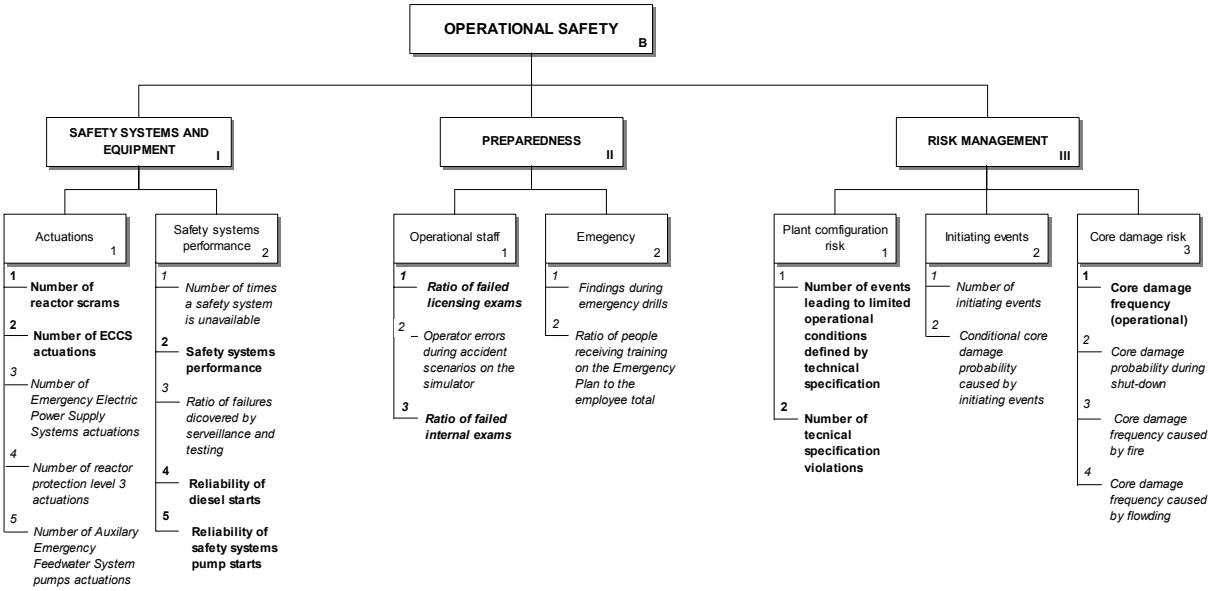
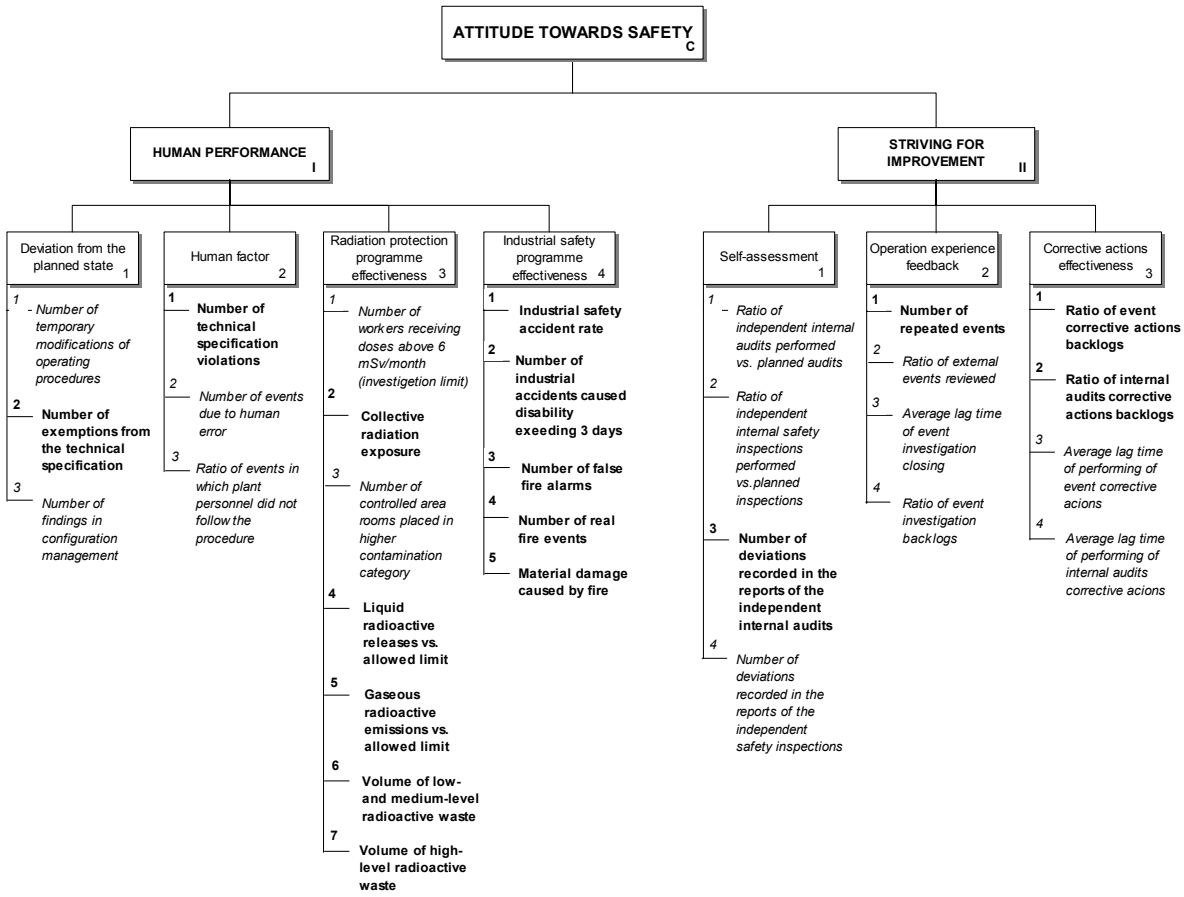



PLANT OPERATES SMOOTHLY
A
OPERATIONAL PERFORMANCE
I
STATE OF SSC (STRUCTURES, SYSTEMS, COMPONENTS)
II
EVENTS
III
Forced power reductions and outages
1
1 Plant capability factor
2 Unplanned capability loss factor
3 Ratio of generation loss due to unplanned outage extension
4 Number of forced power reductions and outages due to internal causes
Corrective work orders issued
1
1 Number of corrective work orders for safety systems
2 Ratio of corrective work orders executed to work orders requested
3 Number of pending work orders
4 Ratio of preventive orders vs. preventive and corrective work orders
5 Ratio of unsuccessful internal technical safety inspections
Material condition
2
1 Chemistry index
2 Equipment loading cycles accounting
3 Ratio of tubes plugged in Steam Generators
State of the barriers
3
1 Fuel reliability
2 Reactor Coolant System leakage
3 Containment leakage
Reportable events
1
1 Number of events to be reported immediately to regulatory body
2 Number of events reported regularly to regulatory body
Other significant events
2
1 Number of significant events investigated internally
2 Number of other event reports required by regulatory body


OPERATIONAL SAFETY
B
SAFETY SYSTEMS AND EQUIPMENT
I
PREPAREDNESS
II
RISK MANAGEMENT
III
Actuations
1
1 Number of reactor scrams
2 Number of ECCS actuations
3 Number of Emergency Electric Power Supply Systems actuations
4 Number of reactor protection level 3 actuations
5 Number of Auxilary Emergency Feedwater System pumps actuations
Safety systems performance
2
1 Number of times a safety system is unavailable
2 Safety systems performance
3 Ratio of failures dicovered by serveillance and testing
4 Reliability of diesel starts
5 Reliability of safety systems pump starts
Operational staff
1
1 Ratio of failed licensing exams
2 Operator errors during accident scenarios on the simulator
3 Ratio of failed internal exams
Emegency
2
1 Findings during emergency drills
2 Ratio of people receiving training on the Emergency Plan to the employee total
Plant comfiguration risk
1
1 Number of events leading to limited operational conditions defined by technical specification
2 Number of tecnical specification violations
Initiating events
2
1 Number of initiating events
2 Conditional core damage probability caused by initiating events
Core damage risk
3
1 Core damage frequency (operational)
2 Core damage probability during shut-down
3 Core damage frequency caused by fire
4 Core damage frequency caused by flowding


ATTITUDE TOWARDS SAFETY
C
HUMAN PERFORMANCE
I
STRIVING FOR IMPROVEMENT
II
Deviation from the planned state
1
1 - Number of temporary modifications of operating procedures
2 Number of exemptions from the technical specification
3 Number of findings in configuration management
Human factor
2
1 Number of technical specification violations
2 Number of events due to human error
3 Ratio of events in which plant personnel did not follow the procedure
Radiation protection programme effectiveness
3
1 Number of workers receiving doses above 6 mSv/month (investigetion limit)
2 Collective radiation exposure
3 Number of controlled area rooms placed in higher contamination category
4 Liquid radioactive releases vs. allowed limit
5 Gaseous radioactive emissions vs. allowed limit
6 Volume of low- and medium-level radioactive waste
7 Volume of high-level radioactive waste
Industrial safety programme effectiveness
4
1 Industrial safety accident rate
2 Number of industrial accidents caused disability exeeding 3 days
3 Number of false fire alarms
4 Number of real fire events
5 Material damage caused by fire
Self-assessment
1
1 – Ratio of independent internal audits performed vs. planned audits
2 Ratio of independent internal safety inspections performed vs.planned inspections
3 Number of deviations recorded in the reports of the independent internal audits
4 Number of deviations recorded in the reports of the independent safety inspections
Operation experience feedback
2
1 Number of repeated events
2 Ratio of external events reviewed
3 Average lag time of event investigation closing
4 Ratio of event investigation backlogs
Corrective actions effectiveness
3
1 Ratio of event corrective actions backlogs
2 Ratio of internal audits corrective actions backlogs
3 Average lag time of performing of event corrective acions
4 Average lag time of performing of internal audits corrective acions