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# Methods and practices used in incident analysis in the Finnish nuclear power industry☆

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**Abstract**

According to the Finnish Nuclear Energy Act it is licensee's responsibility to ensure safe use of nuclear energy. Radiation and Nuclear Safety Authority (STUK) is the regulatory body responsible for the state supervision of the safe use of nuclear power in Finland. One essential prerequisite for the safe and reliable operation of nuclear power plants is that lessons are learned from the operational experience. It is utility's prime responsibility to assess the operational events and implement appropriate corrective actions. STUK controls licensees' operational experience feedback arrangements and imlementation as part of its inspection activities. In addition to this in Finland, the regulatory body performs its own assessment of the operational experience. Review and investigation of operational events is a part of the regulatory oversight of operational safety.

Review of operational events is done by STUK basically at three different levels. First step is to perform a general review of all operational events, transients and reactor scram reports, which the licensees submit for information to STUK. The second level activities are related to the clarification of events at site and entering of events' specific data into the event register database of STUK. This is done for events which meet the set criteria for the operator to submit a special report to STUK for approval. Safety significance of operational events is determined using probabilistic safety assessment (PSA) techniques. Risk significance of events and the number of safety significant events are followed by STUK indicators. The final step in operational event assessment performed by STUK is to assign STUK's own investigation team for events deemed to have special importance, especially when the licensee's organisation has not operated as planned. STUK launches its own detail investigation once a year on average.

An analysis and evaluation of event investigation methods applied at STUK, and at the two Finnish nuclear power plant operators Teollisuuden Voima Oy (TVO) and Fortum Power and Heat Oy (Fortum) was carried out by the Technical Research Centre (VTT) on request of STUK at the end of 1990s. The study aimed at providing a broad overview and suggestions for improvement of the whole organisational framework to support event investigation practices at the regulatory body and at the utilities. The main objective of the research was to evaluate the adequacy and reliability of event investigation analysis methods and practices in the Finnish nuclear power industry and based on the results to further develop them. The results and suggestions of the research are reviewed in the paper and the corrective actions implemented in event investigation and operating experience procedures both at STUK and at utilities are discussed as well.

STUK has developed its own procedure for the risk-informed analysis of nuclear power plant events. The PSA based event analysis method is used to assess the safety significance and importance measures associated with the unavailability of components and systems subject to Technical Specifications. The insights from recently performed PSA based analyses are also briefly discussed in the paper.


*Keywords:* Nuclear power plant; Operational safety; Event investigation

## 1. Use and control of nuclear energy in Finland

Finnish nuclear power plants are located on the south and west coast of Finland. The Fortum Power and Heat Oy, operates two 510 MWe VVER-440 type pressurised water reactor units, Loviisa 1 and Loviisa 2, near the city of Loviisa. On the west coast of Finland Teollisuuden Voima Oy operates two 870 MWe ASEA-ATOM type boiling water

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reactor units, Olkiluoto 1 and Olkiluoto 2, in Eurajoki. Both utilities have increased the electrical output of their stations at the end of 1990s, by 9 and 15% respectively. The first unit, Loviisa 1, was connected to the national grid in 1977, and the fourth, Olkiluoto 2, in 1980. These four reactors generate about 30% of the Finish annual electricity output.

In November 2000, Teollisuuden Voima Oy (TVO) submitted to the Finnish Government, through the Ministry of Trade and Industry (MTI), an application for a Decision in Principle (DiP) for the fifth nuclear reactor unit. The Government approved the application in January 2002. The Finnish Parliament ratified the decision in May 2002. Call for tenders was sent out by TVO at the end of September 2002, and tender documents were received by the end of March 2003. In October 2003, TVO selected Olkiluoto-site for the location of the new plant unit and made also public the preferred alternative for the plant type. The main contract was signed at the end of 2003. It is expected that a construction permit will be issued by MTI in the beginning of 2005.

According to the Finnish Nuclear Energy Act it is licensee's responsibility to ensure safe use of nuclear energy. Radiation and Nuclear Safety Authority (STUK) is the regulatory body responsible for the state supervision of the safe use of nuclear power in Finland.

## 2. Review of operational events

One essential prerequisite for the safe and reliable operation of nuclear power plants is that lessons are learned from operating experience at national and international level. Operational experience feedback is utilised by identifying and removing any causes of failures, deficiencies and deviations and by emphasising the importance of proven procedures. It is regulatory body's requirement that the Finnish licensees analyse their own operational events and send the results to the department of Nuclear Reactor Regulation (NRR) of STUK for information.

A review and investigation of operational events at nuclear facilities is a part of the regulatory oversight of operational safety. STUK inspects and assesses, that the procedures and the activities at power plants meet the legal requirements. The assessment of instructions, procedures, and reports are carried out at STUK's office while the inspection of the utilities' activities is performed at the plant site.

### *2.1. Regulation and requirements*

Requirements for licensees relating to analysis of incidents and operating experience are presented in the legislation and exactly in the "Decisions of the Council of State on the general regulations for the safety of nuclear power plants". According to these requirements operating experience from nuclear power plants shall be systematically followed and assessed. For further safety enhancement, actions shall be taken which can be regarded as justified considering operating experience and results of safety research as well as the advancement of science and technology. More detailed requirements for the review of operational events are presented in relevant YVL guides[1], developed by STUK.

Procedures and plant arrangements in place applicable to systematic analysis of operational events, clarification of root causes, and carrying out of corrective actions are presented in the quality assurance programme of licensees. This programme also presents requirements and procedures applicable to the assessment of operational events abroad and initiation of potential actions. Requirements for the organisation to establish adequate resources to carry out these mentioned activities are presented in the Guide YVL 1.9, "Quality assurance during operation of nuclear power plants".

In addition, Guide YVL 1.11, "Nuclear power plant operational experience feedback", sets forth the criteria and requirements for nuclear power plant operational experience feedback. It requires that a licensee examines all operational events which have safety significance, using a sophisticated root cause analysis method if an event's root causes are not evident. The report on the root cause analysis is submitted to STUK for information.

Requirements for reporting events and for contents of the plant operational event reports are presented in the Guide YVL 1.5, "Reporting nuclear power plant operation to the Radiation and Nuclear Safety Authority". Amongst the other, this guide establishes the reporting and notification processes to be followed by the utilities for events that have to be reported at a regular time intervals and events for which a prompt reporting is needed.

Event reports are prepared on events and issues which need to be reported in detail after the event has occurred and certain criteria have been met. These event reports can be divided into three categories: operational disturbance report, scram report, and special report. A special report will be submitted to STUK for approval within one month of an incident. Reports include the following detailed data as applicable: event description, safety assessment, causes of the incident, and measures to avoid recurrence.

### *2.2. Inspection and review of operational events at STUK*

The Safety Management Office (SMO) of NRR has the primary responsibility at STUK to monitor the operation of NPPs and also operational events. This is performed on site by resident inspectors and by reviewing licensees' daily and other regular and event reports. Reported events and significant failures are discussed on regular basis at SMO, which co-ordinates the review of event reports at NRR. The resident inspectors inform the management and personnel of NRR about operational disturbances as well as about safety

[1] By virtue of the Nuclear Energy Act and Governmental Resolutions, STUK issues detailed regulations that apply to the safe use of nuclear energy and physical protection, emergency preparedness and safeguards.

significant events or incidents immediately by phone call and by e-mail during office hours.

Incidents and failures in equipments and systems not having nuclear safety importance, minor deficiencies in periodic tests, and near misses as well as other low level events are normally reported in weekly reports of resident inspectors and discussed in supervisory meetings held every other month at NRR. SMO performs a preliminary investigation of operational events right after incidents in order to inform the NRR department, management, and public if necessary. Specific events that may require regulatory actions are presented by SMO in the department meeting of directors and office heads of NRR held every other week. The meeting may decide if deeper inspections or any other actions are required before or after the routine reporting of the utilities. Reactive inspections are made in the case of an important event or inadequate performance of the licensee.

Procedures for regulatory oversight and inspections are described in details in the Guide YTV 4.2. A review and assessment of the event is processed in accordance with the Guide YTV 4.5 and a procedure for STUK operations in connection with the plant events are described in the Guide YTV 4.6. Rating of operational events by using International Nuclear Event Scale (INES) is performed in accordance with the Guide 4.8 of NRR Quality Manual.

Event reports from utilities are reviewed at NRR according to internal quality procedures presented in the Guide YTV 4.3. In the review of event reports, the fulfilment of reporting requirements is checked, and also the main contributing human and organisational factors are evaluated. Based on the characteristics of the event the report will be inspected by experts with the required competence and by the event investigation manager of NRR. During the review the safety significance and causes of the event will be assessed as well as the corrective measures performed or suggested by the utility. If necessary, further investigations or corrective measures will be required.

Review of operational events is done basically at three different levels. First step is related to the performance of a general review for operational events, transients and reactor scram reports, which are submitted for information to STUK. The second step is to enter an event in NRR's database on operational events (TAPREK) in accordance with the Guide YTV 4.5. The third step is to assign STUK's own investigation team for events deemed to have special importance.

Number of operational events in different categories, and associated with different causes of events are followed by STUK's plant performance indicator system. Risk significance of operational events is followed by PSA based indicators as well.

### 2.3. Event database

Event database (TAPREK) is an NRR's formal tool to review domestic operational events. It is also used to follow the implementation of corrective measures at NPPs, as well as to identify the recurrence of events.

Based on the inspection of operational events SMO presents in the department meetings those events that should be reviewed and entered in TAPREK database. The 16 pages TAPREK form should be fulfilled during the inspection of an event report if some of the following criteria are met: event is rated INES 1 or higher, event is reported with a Special Report, event is an operational transient with organisational deficiencies or causing major structural or procedural modifications at the plant, and event is associated with multiple or common cause failures in one or more subsystems.

The form contains several choices for causes of events, related factors, and responsible organisational units. Also root causes for the event will be assessed and failed defensive barriers will be evaluated. The database enables to perform queries and to perform follow-up of recurrence of events.

### 2.4. Event investigation by STUK

STUK assigns its own investigation team to analyse in details operational events deemed to be of a special importance. Such an investigation is carried out usually when STUK considers important to perform an independent investigation due to the nature of an event or due to deficiencies in licensee's performance. The proposal for formation of STUK's investigation team is made by the director or by office heads of NRR, and the assignment is confirmed in the department meeting. STUK launches its own investigation team once a year on average.

The decision for performing a specific inspection is done on case-by-case basis. STUK can nominate its own investigation team to carry out a more detailed investigation of an event if on the bases of the special report it is obvious that the licensee has not investigated root causes well enough. STUK also appoints always a team to investigate the plant events, which are classified INES 2 or higher. In these cases, the investigation team reviews the special report and draws an investigation report where the team describe the event and its causes, performed inspections and makes a proposal for recommendations of corrective actions, if necessary. The investigation team is launched especially for those cases when the licensee's organisation has not acted efficiently enough or operated as planned, or if an event is assessed to lead to significant plant modifications or changes in operational instructions. It is also possible to nominate investigation team to investigate a number of events together in order to look for possible generic issues associated with the events. In these last-mentioned situations, there are normally no reports available in advance by the utility.

The clarification of: what happened, why it has happened, responsible persons and organisational units, and failed barriers and procedures, is based on plant's documents, STUK's decisions and inspectors' memorandums, and interviews of licensee's and STUK's personnel. Issues listed in the event

register database form are used to support the investigation. STUK assesses its own activities in connection with an event to find out whether deficiencies in STUK's activities have contributed to the initiation of the event, and to use that information to improve STUK's operations. An investigation report with recommendations for corrective actions addressed both to the licensee and STUK is prepared and presented in the department meeting of NRR. The report is sent to the licensee in question. An action plan with proposals for improvements to respond to these recommendations is later provided by the licensee to STUK for approval. The follow-up of implementation of licensee's actions for improvements are performed by nominated offices to handle individual recommendations as a part of regulatory control and in connection with specific inspections of the periodic inspection programme. NRR also makes an action plan for improvements as a reply for the recommendations focused on the performance of its own. The director of NRR delivers an action plan to the Director General for approval.

### *2.5. Assessment of human and organisational factors of the event or incident*

Interviews are the main tool for gathering data in investigation, when human and organisational factors are suggested to have major influence. The event reports prepared by the utilities and STUK preliminary interpretation on the event form the basis for the initial analysis of the human and organisational factors.

The interviews and the analysis are made by a pair or team of inspectors, including experts in organisational psychology, engineers and scientists as necessary. The team of inspectors interviews the involved members of utility organisation (or regulatory body) one by one or in groups. In most cases individual interviews yield more information. However, some particular background information or event technical details may be obtained in group discussions more effectively.

On the basis of information obtained in interviews, a sequence of actions and the course of event is formulated in a written form and common understanding of what has happen and what were the major human and organizational factors is sought. In some cases, this process is rather complicated and needs a lot of interviews and analyses to be performed before identifying the event root causes and needed improvements.

### *2.6. PSA based event analysis method*

In Finland, the application of the probabilistic safety analysis (PSA) in the risk follow-up of events started with pilot studies in the beginning of 1990s. The PSA based event analysis (risk follow-up) method is used to assess the safety significance and importance measures associated with the operating events. The analysis is based mainly on licensees' event reports. The PSA based method is used to assess the safety significance of incidents causing component unavailability, which however did not result in a real initiating event. For the risk follow-up, risk contribution of the following operating events is considered: exemptions from the Technical Specifications, failures of devices covered by the Technical Specifications, and preventive maintenance of devices covered by the Technical Specifications. Calculated risk figures are included in STUK's plant performance indicator system.

Plant specific living PSA models are applied for calculations of the events significance. Conservative assumptions and model simplifications are often used in order to reduce the analysis burden. The conditional core damage probability is calculated based on the increased risk level due to the failure and the duration of the failure. The need for the risk based analysis of initiating events and precursor type of events is assessed on case-by-case basis.

### *2.7. INES classification and communication to the public*

INES classification is one of the important parts of the review of operational events. Classifications made by the utility in written form according to the Guide YVL 1.12 are always reviewed at STUK, and an inspection memorandum is developed in each case. The classification work is usually co-ordinated by a nominated INES person of NRR according to the procedures of STUK internal quality manual (YTV 4.8). If possible, based on the nature of the event, risk significance of the event is calculated using plant specific living PSA models. STUK has developed and applies also some Conditional Core Damage Probability (CCDP) criteria for events classified into INES level 0–3. STUK uses INES levels when communicating the event importance to the general public.

STUK reports to the public all events which are safety related or which may for some other reason be of general interest. Basically there are three alternative cases:

- Events of great public concern that require immediate information release using methods developed for emergencies. In such cases, there is no need to consider the communication issue alone, and the whole situation would be handled using STUK's emergency plan and arrangements.
- Events not requiring emergency measures but only prompt reporting on the same day of the event.
- Events that will be reported in the quarterly and/or annual STUK reports.

The decision on informing the public and international organisations on operational events at Finnish nuclear power plants is made by the management of NRR. The internal STUK guidelines set criteria according to which prompt reporting is needed whenever an event is evidently to be classified INES scale 1 or higher. According to STUK's directions INES level 0 events are to be reported on grounds of a special reason only. STUK has found useful also to report certain no safety significant events which, however, raise concerns in peoples minds. All operational events classified

at INES level 2 or higher shall be reported to the International Atomic Energy Agency (IAEA) within 24 h. Events that are to be classified later due to a need for additional information and research shall be addressed in STUK's Quarterly Report on the operation of Finnish nuclear power plants and facilities located near Finnish territory. A press release is usually issued in relation to all safety significant operational events and the information is available through various communication tools, e.g. teletext pages in the state-owned TV-network, too.

For the benefit of the international nuclear community STUK reports also, to the extent considered necessary, safety significant issues to the international Incident Reporting System (IRS) which is operated in co-operation between the IAEA and the Nuclear Energy Agency (NEA) of the OECD countries.

### *2.8. Review of international events*

The procedure for handling at STUK international event reports such as those distributed by IRS is presented in YTV Quality Manual. The purpose of this activity is to review independently from the licensee international operational events and if needed to require actions at Finnish nuclear power plants.

Event reports from IAEA and NEA IRS system are being reviewed by a nominated IRS group at NRR. IRS group also screens out reports which are not considered to be applicable for the Finnish nuclear power plants. Remaining reports are submitted to the experts in specific fields to be assessed for further actions and corrective measures, if needed. IRS group follows that all reports are handled in an adequate manner.

## 3. Review of operational experience feedback at NPPs

The Guide YVL 1.11 sets forth the criteria and requirements for nuclear power plant operational experience feedback concerning licensees' organisational arrangements, resources, and methods for data collection, analysis and result processing.

STUK controls the appropriateness of the licensees' operational experience feedback arrangements within the scope of STUK inspection activities. This control includes a review of instructions, procedures, and reports submitted to STUK and on site checks that the instructions are complied with. Operational experience feedback activities at the plant are reviewed in different connections during periodic inspection programme of STUK.

Reports on the utilisation of operational experience are submitted to STUK for information once per year. Reports contain a description of operational experience feedback activities and also a list of events for which corrective measures have been implemented or are under implementation by the utilities. The report is reviewed by all NRR offices to assess the stage of implementation and the adequacy of corrective measures to avoid recurrence of such events. The reports are inspected to assure that operational experience feedback activities are carried out as described in YVL guides and in quality assurance manuals of the utility.

## 4. Assessment of methods and practices used in incident analysis in Finland

An analysis and evaluation of event investigation methods applied by STUK, and the two Finnish nuclear power plant operators TVO and Fortum was carried out by the Technical Research Centre (VTT) at the request of STUK at the end of the 1990s [1]. The study aimed at providing a broad overview of the whole organisational framework in place in Finland to support event investigation practices at the regulatory body and at the utilities. The main objective of the research was to evaluate the adequacy and reliability of event investigation analysis methods and practices in the Finnish nuclear power industry and based on the results to suggest means for further improvement.

The study showed that the evaluated organisations had rather comprehensive incident analysis arrangements. All the tree organisations had different approaches to event investigation with differences mainly related to recording, assessment and classification of new events and observations, use of existing operating experience data, utilisation of different information technology tools, and allocation of work and resources.

Although rather comprehensive all systems could benefit from better focussing and prioritisation of assessment activities. It appeared that there were no indicators or any measures used to evaluate the effectiveness of event investigation and operating experience feedback.

The researchers suggested a more efficient operating experience feedback loop to be implemented for safety significant events. It was also recommended that the effectiveness of operating experience feedback activities could be followed by implementing periodic operational experience reviews. A strategy document for the operating experience feedback process, and firm and clear procedures for the initial assessment of new events and the carrying-out of data analyses would also be of help.

The review formed a good ground to further develop event investigation methods and operating experience feedback activities in all three organisations.

The results and suggestions were examined and their possible utilisation at STUK and utility organisations was considered. At STUK a new office, Human and Organisational Factors, was established in autumn 1999. Among others, HOF co-ordinated event investigations and incorporated also the knowledge of behavioural sciences for focusing on human performance deficiencies and organisational problems in operational events. In connection with the reorganisation of NRR in the beginning of 2002, the HOF office was closed and the supervision and assessment of the performance of

licensees' organisations, organisational changes and safety culture were assigned as new duties to the co-ordinating Safety Management Office (SMO).

STUK has recently intensified the utilisation of its event database (TAPREK) focusing especially on recurring events. In 2000, the recurrence of events, recorded in TAPREK and all reported events during 1995–2000, were reviewed using similar causes and consequences of events as screening criteria. The recommendations of this study has been taken into account in the latest event investigations of STUK.

### *4.1. Evaluation of the investigation practices of utilities*

It was evaluated that the goals of TVO's event investigation practice were in general clearly and explicitly defined and documented. A pro-active approach towards safety was being emphasised and the prevention of the recurrence of events was generally regarded as a very important objective for the practice. However, it was not quite clear to what extent TVO's key personnel did share a common view of what kind of operating experience feedback policy they should adhere to in the future.

It was evaluated that the goals of Fortum's Loviisa NPP's event investigation practice were in general clearly and explicitly defined and documented. A pro-active approach towards safety was being emphasised and the prevention of the recurrence of events was generally regarded as a very important objective for the practice. In addition, the main investigation policy alignment e.g. in relation to the role of the Plant Safety Branch (PSB) and other units were well articulated and evidently applied in practice, too, although not always documented. It appeared that quantitative indicators had not been developed or sufficiently used for assessing the effectiveness of Loviisa NPP's event investigation practice. Like in case of TVO, prevailing performance measurement systems were mostly too general to provide the practice with precise and useful feedback. It was assumed, however, that the application of regular quality assurance reviews as well as the annual internal operating experience feedback reports partly compensated that deficiency.

On the basis of common deficiencies identified in the event investigation methods of all Finnish nuclear industry organisations following general recommendations were given:

- The initiating part of event sequences, the originating failures, and causes should be better studied in case of latent failures.
- Analysis of common cause failure mechanisms, latent failures and recurrent failures should be periodically performed.
- The analysis criteria on activity, procedure and human performance related problems should be defined in a more comprehensive manner. In general, human and organisational factors should be more clearly addressed in the root cause analysis reports.
- Failed or broken defensive barriers (technical as well as organisational) should be more thoroughly surveyed, and reasons for such failures analysed adequately.

## 5. Evaluation of operational experience feedback

STUK has contributed to the introduction and use of more elaborated event investigation methods and practices in the Finnish nuclear industry, especially since the 1990s when STUK's own event investigations started. STUK has a good access to plant information and operational event data. STUK has established a good framework for its own investigation practice through clear and well-documented investigation and event classification criteria. The TAPREK database is a useable information system and provides substantial support for the practice. Generally there is enough competent personnel for the carrying-out of STUK own selective incident investigations, reviewing utilities' investigation practises and reporting, and motivating utilities to further develop their incident analysis methods and practises.

TVO's goals with respect to the operational experience feedback are clearly defined and documented. TVO's Group of Operating Experience (KÄKRY) has an important role in conveying the lessons learned to the organisation and campaigning in particular problem areas. Co-operation with Swedish utilities and research organisations has potential for sharing useful information. A no-blame investigation atmosphere contributes to the quality of inspection results. The near-miss reporting practice provides a sound framework for the recording and assessment of novel events and observations of non-technical in nature. There is a clear emphasis on personnel training, reviews and development activities.

Fortum's goals are clearly defined and documented, and the main investigation policy alignments are well articulated and apparently applied in practice, too, although not always well documented. The practice possesses process characteristics including a nominated process owner and a clear action plan resulting in a practical distribution of tasks and co-ordination of activities. The event investigation practice appears to have enough independence and integrity. The prevailing Operational Event (KT) reporting practice provides a sound framework for the recording and assessment of novel events and observations. The Human Failure Reports contain a fairly comprehensive event classification model that could be tailored for analysing all significant operational events. A no-blame investigation atmosphere contributes to the quality of investigation results and the line organisation is successfully mobilised to contribute to the event investigation practice. Personnel training appears to be successful, and enough resources are allocated to the practice.

Despite of the very many good features of the established operational experience feedback practices in Finland it was recognised that at the time when the VTT survey was performed there were no explicit performance indicators for evaluating the effectiveness of its investigation practices. As

a result, it is difficult to gain reliable information on the degree to which the practice reaches its goals. On the other hand, at that time the goals were only generally specified.

The recording and assessment of new internal events lacked systematisation and clear operating principles at power plants. There were no regular and systematic practices or written instructions to specify concrete procedures or arrangements for the detection of recurrence or common cause failure (CCF) mechanisms.

Neither STUK or licensees did not conduct regular and systematic reviews of the bulk of existing operating event data in addition to some limited efforts. Given that fact, it was quite obvious that a number of important recurrent, common cause and latent failure mechanisms were yet to be identified at Finnish nuclear power plants. Information systems did not support comprehensive data analyses. The maintenance and operational event data were stored in different systems and the integration of existing information would require manual work.

The event investigation practice lacked process qualities and resources, which was characterised by the dispersion of responsibilities into different offices, branches, and informal groups and the responsible persons suffered often from fragmented job descriptions. It was estimated that this was likely to have a negative impact on the coverage, thoroughness, and methodology of event investigation practice. The situation at STUK has improved with the establishment of a position of the Event Investigation Manager to co-ordinate investigations since the beginning of 2002. The utilities have also undertaken several activities to enhance their operational experience feedback practices.

## Reference

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