Practical Elimination -
Experiences for Units in Use, in Construction and in Design

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Abstract: The article describes Finnish principles and practices for continuous development of safety of NPPs, concentrating on practical elimination of large releases and early releases. As guiding principles, related Finnish legislation and regulatory requirements are summarized. Definitions for large release and early release are presented. For operating NPP units, SAM principles, safety development and practical elimination are presented, and the success of safety enhancement is demonstrated. It is shown that the conclusions are not sensitive to the exact definitions of “early” and “large”. Practical enhancement of safety can be implemented and demonstrated even when the concepts or boundary conditions are vague.

The paper discusses severe accident prevention and application of PRA levels 1 and 2 to identify risk contributors and demonstrate the impacts of modifications.

Keywords: PRA, severe accident, early release, large release, practical elimination.

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1. INTRODUCTION

This article presents Finnish requirements related to continuous development of NPP safety and their application on operating NPPs and NPPs under construction. Practical elimination of early or large releases is a continuum and part of the concept of continuous development of safety. In Finland, the concept of practical elimination is consists of two essential viewpoints. One is presented in Regulatory Guide YVL B.1 [1] and another in YVL A.7 [2].

The concept of continuous improvement of safety means that the safety of nuclear energy use is maintained at as high a level as practically possible. For operating NPP units, the practice of practical elimination is strongly related to plant modifications based on operating experience, deterministic analyses, PRA, research and advances in science and technology. For plants under design or construction, practical elimination means readiness for design changes.

2. PRINCIPLES

2.1. Practical Elimination in Legislation

An introduction to the development of the Finnish requirements related to practical elimination is given in [3]. This article presents only a short summary of current guiding principles of practical elimination in Finland and concentrates more on the application of the concept.

The idea of continuous improvement of safety was introduced in Finnish requirements in the renewal of the Atomic Energy Act (356/1957) and publication of the Nuclear Energy Act (990/1987) and subordinate regulations. The regulations issued safety requirements for new reactors, including the principle that all the reasonably practicable safety improvements shall also be made for already licensed nuclear power plants.

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Currently, Nuclear Energy Decree 12.2.1988/161 [4] states the following in section 22b (4-6) in relation to severe accidents:

- *"The release of radioactive substances arising from a severe accident shall not necessitate large scale protective measures for the public nor any long-term restrictions on the use of extensive areas of land and water.*
- *In order to restrict long-term effects the limit for the atmospheric release of cesium-137 is 100 terabecquerel (TBq). The possibility of exceeding the set limit shall be extremely small.*
- *The possibility of a release requiring measures to protect the public in the early stages of the accident shall be extremely small."*

The Nuclear Energy Decree was amended in the beginning of 2018 so that the above statements are not applied to nuclear power plants that received their first operating license before year 1990, unless their application is justifiable according to principles in Nuclear Energy Act (990/1987) [5] section 7a, taking into account the technical properties of the plant.

Section 7a of the Nuclear Energy Act is named "Guiding Principles": *"The safety of nuclear energy use shall be maintained at as high a level as practically possible. For the further development of safety, measures shall be implemented that can be considered justified considering operating experience and safety research and advances in science and technology."*

The second paragraph of Section 7a (enforced 1.8.2013) contains graded approach principle: "*Safety requirements and actions for ensuring safety shall be graded and targeted in proper relationship considering the risks of nuclear energy use*" (free translation).

2.2. Practical Elimination in Regulatory Guides

Regulatory Guide YVL B.1, paragraph 423 states that *Events that may result in a release requiring measures to protect the population in the early stages of the accident shall be practically eliminated.*

Regulatory Guide YVL B.1, paragraph 424 states that *Events to be practically eliminated shall be identified and analysed using methods based on deterministic analyses complemented by probabilistic risk assessments and expert assessments. Practical elimination cannot be based solely on compliance with a cut-off probabilistic value. Even if the probabilistic analysis suggests that the probability of an event is extremely low, all practicable measures shall be taken to reduce the risk. As an example, events to be practically eliminated include:*

1. *a rapid, uncontrolled increase of reactivity leading to a criticality accident or severe reactor accident;*
2. *a loss of coolant during an outage leading to reactor core uncovery;*
3. *a load jeopardising the integrity of the containment during a severe reactor accident; and*
4. *a loss of cooling in the fuel storage resulting in severe damage to the spent nuclear fuel.*

Regulatory Guide A.7 defines term "extremely small" used in Nuclear Energy Decree more accurately. Paragraph 306 states that

a) *the mean value of the frequency of a release of radioactive substances from the plant during an accident involving a Cs-137 release into the atmosphere in excess of 100 TBq is less than* $5 \cdot 10^{-7}$*/year;*
b) *the accident sequences, in which the containment function fails or is lost in the early phase of a severe accident, have only a small contribution to the reactor core damage frequency.*

Thus, the concept of large release is well defined in Finnish Regulatory Guides (YVL Guides). The early release is not bindingly defined, but its interpretation is based on Nordic guidelines for protective measures in early and intermediate phases of a nuclear accident [6]. The Nordic guidelines and recommendations are based on the Finnish guides for radiological emergency situations [7]. The guidelines state the following:

The recommended planning basis for carrying out protective measures for the public in the emergency planning zones is that the measures can be completed in about four hours after decisions on protective measures have been made.

Accordingly, the time span related to protective measures in the early phase can be considered to be four hours. In analyses related to early releases it has been assumed that within one hour from the initiating event, site emergency has been declared and enough information has been transferred to relevant authorities to initiate the preparation and execution of necessary actions. In addition, the emergency preparedness organizations of the plants are normally able to initiate their operation within one hour. Thus, early releases are interpreted as releases occurring within five hours from the initiating event.

In Finland, practical elimination is applied also to spent fuel storages. Severe accidents in spent fuel storages have to be eliminated, because the storages reside outside containment. Both Loviisa and Olkiluoto have implemented modifications to secure the cooling of the fuel in the pools and to avoid fragmentation of the fuel due to heavy load drop. Early releases are practically eliminated, and according to the PRAs for fuel storage, large release frequencies are very small. Spent fuel storage is not discussed in this article.

3. PRACTICAL ELIMINATION IN PRACTICE

Practical elimination of large or early releases and continuous development of safety are expressions of a strong safety culture: if a safety vulnerability is exposed by whatever means, it is treated as an opportunity to enhance safety. In Finland, practical elimination is strongly linked to three disciplines: 1) deterministic accident analyses, 2) failure analyses and failure tolerance analyses, and 3) probabilistic risk analysis. The relationships of the disciplines are presented in more detail in [8]. Practical elimination does not happen by itself, but requires vigilant analysis and search for possibilities to improve safety. Weaknesses may also be exposed by operating experience, but the experiences must be analyzed with a relevant combination of the above three types of analysis.

Linked to the renewal of regulatory YVL Guides, the licensees of operating plants in Finland had to submit analyses of practical elimination of early releases to STUK by the end of 2017. Practical elimination of large releases has already been standard practice from 1990s, although at that time the concept was known as continuous development of safety.

The fulfillment of probabilistic requirements in YVL Guides by Finnish NPP units is shown in Table 1. Operating Olkiluoto and Loviisa NPP units have different strengths and weaknesses, some of which are discussed later. Olkiluoto NPP unit 3 fulfills numerical PRA safety goals, but even then it does not escape continuous development of safety as required in Section 7a of the Nuclear Energy Act. One could also state that the fulfillment of PRA safety goals is at least in part due to application of practical elimination during design and construction.

Table 1: Fulfillment of Probabilistic Requirements (YVL A.7) by Finnish Units

Unit	CDF < 10^{-5}	LRF < 5×10^{-7}	ERF is small fraction of CDF
Loviisa 1	No	No	Yes
Loviisa 2	No	No	Yes
Olkiluoto 1	Yes	No	No
Olkiluoto 2	No	No	No
Olkiluoto 3	Yes	Yes	Yes

The operating plants do not fulfill the requirements on Large Release Frequency (LRF). Loviisa NPP units and Olkiluoto NPP unit 2 do not (yet) fulfill the requirement on Core Damage Frequency (CDF). More details on the development of CDF for operating NPP units are presented later in the article.

Olkiluoto NPP units 1 and 2 do not fulfill the requirement that Early Release Frequency (ERF) should be a small fraction of CDF.

Below the practical elimination is discussed from the following viewpoints: specific types of events to be eliminated, severe accident management, core damage frequency, large release frequency and early release fraction. One could assume that decreasing the core damage frequency would decrease large release frequency and early release frequency. Mostly this is true, but all core damage scenarios do not lead to early release or large release, and therefore some caution is necessary. Specific types of initiating events may lead nearly always to early release or large release, and special consideration have to be put into practical elimination of these.

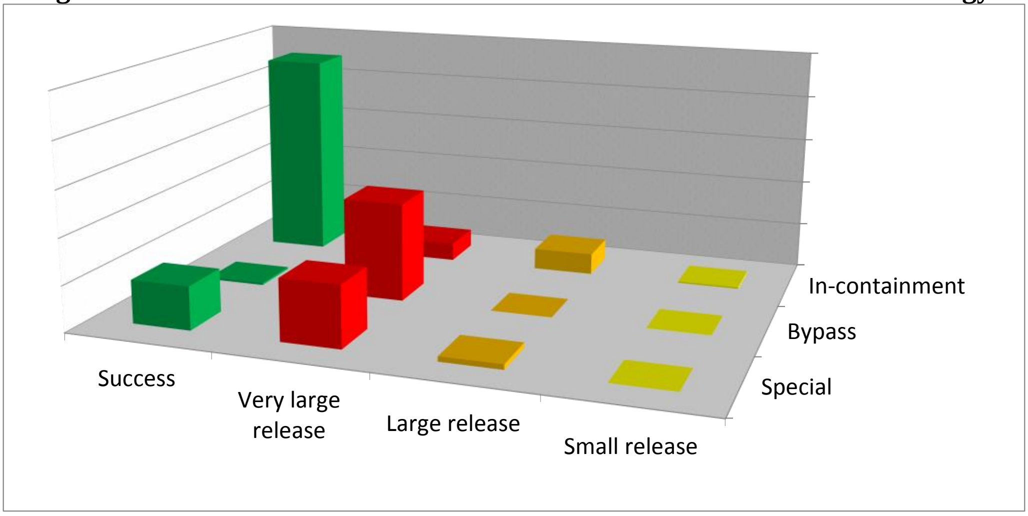
3.1. Practical Elimination Applied to Loviisa NPP Units LO1, LO2

Loviisa NPP consists of two VVER units, operated by Fortum Power and Heat Oy (Fortum). The units were connected to the electrical grid in 1977 (LO1) and 1980 (LO2). The nominal thermal power of the units is currently 1500 MW (originally 1375 MW).

In 1990s, a comprehensive severe accident management (SAM) strategy was developed for Loviisa NPP to mitigate the consequences of severe accidents. The strategy is based on SAM safety functions whose purpose is to ensure containment integrity and isolation. The central parts of the strategy are in-vessel retention of corium by reactor pressure vessel external cooling, primary circuit depressurization and hydrogen management. Water routes to enable effective cooling of the RPV were arranged by installing a mechanism for lowering the thermal shield of RPV lower head. In addition hydrogen management systems were installed: efficient containment atmosphere mixing is ensured by forcing the ice condenser doors open and removal of hydrogen is performed by catalytic recombiners. Fast hydrogen production peaks are managed by glow plugs installed in the lower containment compartments. For the long-term heat removal from the containment and prevention of the containment overpressurization, containment external spray system was installed.

The above strategy successfully managed large fraction of severe accidents. However, when PRA for Loviisa was completed, it revealed that containment bypasses (VLOCA) remained outside the SAM strategy. In-vessel retention is based on flooding the reactor cavity and thus assumes the presence of water. In VLOCAs, water is lost outside the containment instead, eventually leading to breach of the vessel and failure of reactor cavity. The secondary effects of VLOCAs can also cause loss of instrumentation systems; this is discussed in more detail below. In addition to in-containment and bypass scenarios, there were also other, special events that effectively bypassed the severe accident management. Figure 1 shows the probabilities of different consequences for these three types of events.

Figure 1: Probabilities of LO1 Accident Scenarios after Initial SAM Strategy.



As seen in Figure 1, the severe accident management worked well for in-containment scenarios, whose most probable consequence is “Success”. However, bypass scenarios almost completely escaped the severe accident management, leading to “Very large release”. Special scenarios are events that either lead to core damage almost directly or events, whose progression is difficult, if not impossible, to predict. Special events include reactivity-induced accident, RPV brittle fracture, loss of I&C room cooling, loss of DC power, high-energy lightning, or very strong wind causing collapse of structures of turbine building. By definition, special scenarios are good candidates for practical elimination.

Another viewpoint for practical elimination is that the small reactor cavity of Loviisa containment does not tolerate vessel failure. If the cavity is dry, the high temperature of corium fails the door of the cavity. In case of flooded cavity, pressure shocks caused by molten corium fail the cavity. Since SAM strategy - in-vessel retention - requires flooding of the cavity, bypass LOCAs have to be practically eliminated in order to be able to flood the cavity and cool the vessel. In 1992-1994, Fortum improved detection of leakages outside containment and added automated isolation of leakages via coolant purification system.

Already during the preparation of the first level 1 PRA in 1989, Fortum identified candidates for improvement of the safety and reduction of core damage frequency. One of the first remarkable modifications was the new redundant air cooling system for instrumentation rooms in 1990, which still remains the single most effective decrease of the CDF. This modification practically eliminated a complex and hard-to-analyze sequence possibly leading to large releases.

In 1994–1996, Fortum improved the management of primary to secondary leakages, reducing their contribution to CDF from 1.6×10^{-4} 1/a to 9×10^{-7} 1/a. The modifications included

- Automated isolation of a leaking steam generator (1994)
- Improved detection of steam generator leakages (1995)
- Additional emergency core cooling water storage tank (1996)
- Additional pressurizer spray line (1994-96)

In 2000 and 2001, Fortum performed additional VLOCA studies to identify risk contributors and implemented several plant modifications. PRA demonstrated that one main scenario of the bypass risks is the breach of the primary coolant pump seal water line outside containment. New instrumentation was installed to detect bypass leaks and to improve the reliability of containment isolation. In addition, even very small VLOCAs were noticed to cause high risks if the leaks occur in rooms containing safety related instrumentation, since the thermal energy of the leaks may be very high, failing sensitive equipment in transmitter rooms, leading to loss of information on the state of the plant. For decreasing the risk due to small VLOCAs, several improvements were made. For example, sampling lines of steam generators were removed from transmitter room and additional flow limiters were installed to the impulse lines of primary circuit measurements.

Figure 2[†]: Development of LO1 Large Release Frequency 2006-

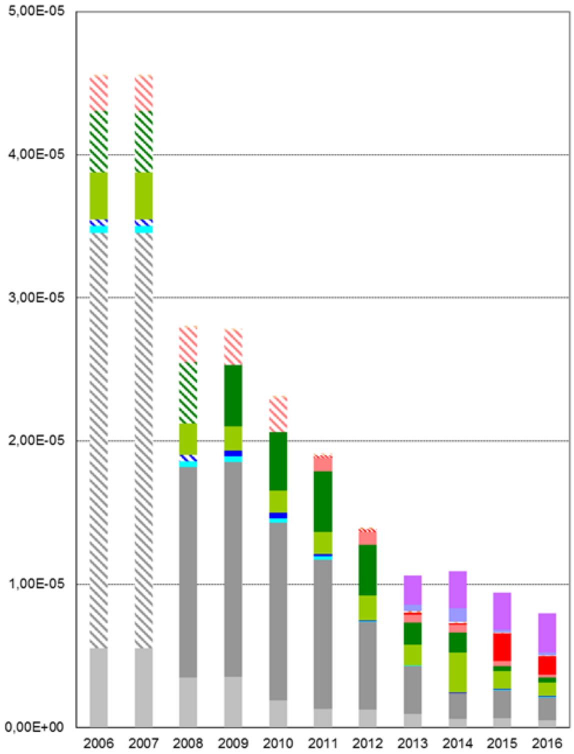


Figure 2 shows the decrease of LO1 Large Release Frequency since 2006. In order to analyze early releases, the time frame and the smallest release to be included in the analysis have to be defined. For the timing, Fortum has used 5 hours as stated above. Fortum has based the release limit on requirement 516 of YVL Guide C.5:

The objective of protective action taken in a radiation hazard is to keep human radiation doses as low as reasonably achievable. Even in the severest radiation hazard, the objective is that, after the implementation of protective actions, radiation dose does not exceed the maximum radiation exposure level of 20 mSv during the first year…

Fortum assumed that in order to limit the yearly dose to 20 mSv, it is needed that in the precautionary action zone the dose without protective measures during the first 24 hours remains below 10 mSv. This would allow enough time to implement protective measures and still remain below 20 mSv yearly dose. This assumption leads to release fraction limit of 0.1% for noble gases and 10^{-5} for Iodine. Thus, Fortum defines early release as release occurring within 5 hours from the initiating event and releasing more than 0.1% of noble gases or fraction 10^{-5} of Iodine.

The results of the analysis show that the fraction of early releases leading to protective actions in Loviisa is less than 2% of the core damage frequency. In most cases, the core damage does not begin before 4-5 hours, since the water inventory of the primary circuit and steam generators is large. In station blackout, the batteries begin to lose their capacity also somewhere between 4 and 5 hours. Within the first hour, relevant releases may be caused only by reactivity accidents and large LOCA. Within 3 hours, relevant events are rupture of more than 10 steam generator tubes, brittle fracture of the RPV and ATWS. Still at 6 hours from the initiating event, the risk of releases requiring protective actions is small, but then begins to increase rapidly.

Fortum performed also sensitivity study, adjusting the early release limit between 1..10..100 mSv. The conclusions remained the same, and the results are not sensitive to the actual numerical limit. This is because with high confidence, the core damage does not begin before 4-5 hours, and hence there is

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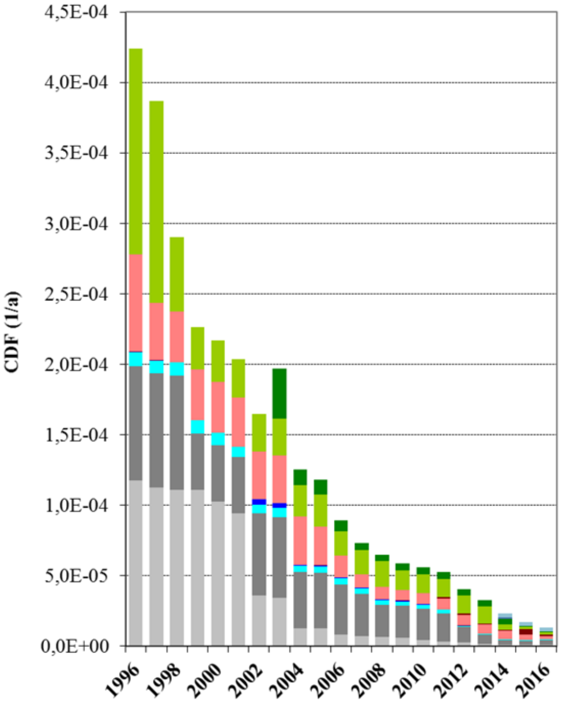
[†] Fortum Power and Heat Oy

no significant activity to be released. Fortum also added the early release scenarios in the PRA model, in order take the viewpoint of early releases into account in future modifications of the Loviisa NPP units.

Most modifications implemented at Loviisa NPP units have decreased core damage frequency, and thus also early release frequency and large release frequency. Figure 3 shows the development of Core Damage Frequency of LO1 due to modifications.

Figure 3[‡]**: Development of LO1 Core Damage Frequency**



According to recent analyses, effective options for severe accident management have been exhausted. Thus, the most efficient way to further decrease the risk of Loviisa NPP units is to decrease core damage frequency. The latest modifications include cooling towers as diverse protection against loss of seawater cooling chain, new automation for reactor protection system and partial renewal of polar crane to decrease the risk of heavy load drop. The core damage frequency of Loviisa NPP is currently 1.3×10^{-5} 1/a, which is still slightly above 10^{-5} required in Regulatory Guide YVL A.7. STUK has granted an exemption for Loviisa NPP, but application of practical elimination is required to a reasonable degree. In the report of practical elimination, Fortum presented some viewpoints for further elimination of early releases. However, STUK requested Fortum to present concrete possibilities for further elimination of early release scenarios by the end of this year.

3.2. Practical Elimination Applied to Olkiluoto NPP Units OL1, OL2

Olkiluoto NPP units OL1 and OL2 are BWR units operated by Teollisuuden Voima Oyj (TVO). The units started commercial operation in 1978 (OL1) and 1980 (OL2). The present nominal thermal power of both units is 2500 MW. The original power level of both units was 2000 MW. The Operating Licences are under renewal/reassessment in 2018, and the application for the operating license has practically been reviewed at the time of preparing this paper. Some conditions of the operating license will be linked to practical elimination, as explained below.

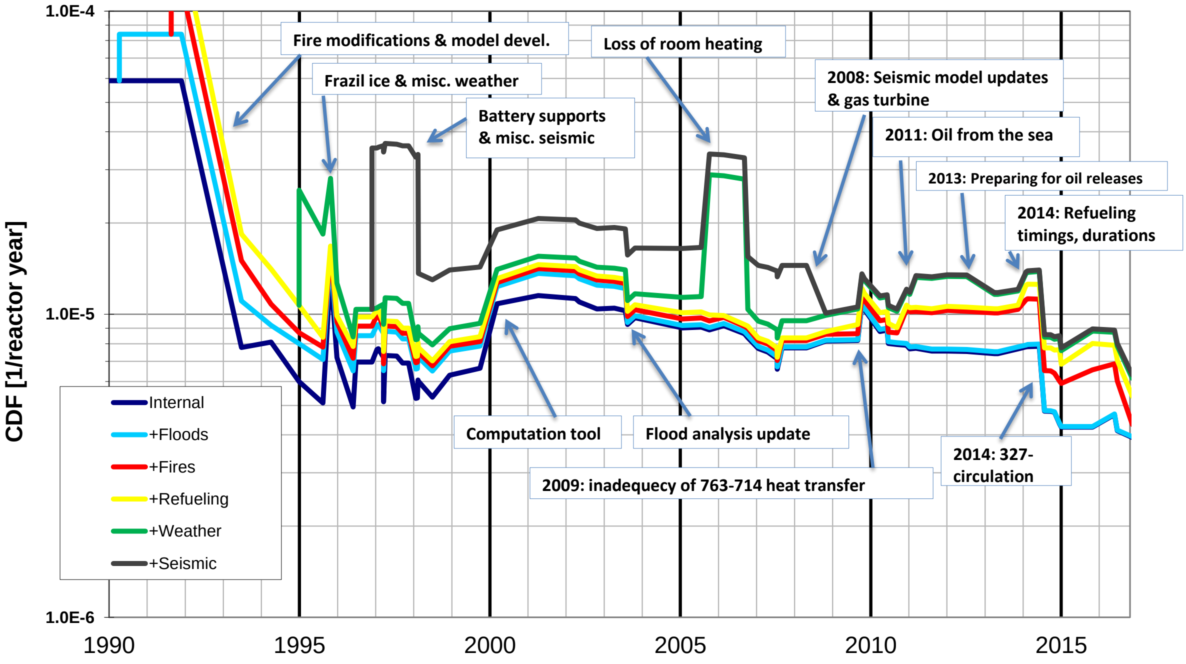
[‡] Fortum Power and Heat Oy

The strategy for severe accident management was established and major plant modifications were implemented in 1980's. These include lower drywell flooding, containment water-filling from an external water source and containment pressure control through filtered containment venting. All SAM actions were designed to be manually controlled and thus independent from the normal automatic safety systems. The flooding of the lower drywell from the wetwell is initiated by opening the valves manually. The water-filling of the containment is performed with diesel-operated portable fire pumps.

The first results from the level 2 PSA in 1997 suggested several modifications on the plant and procedures. Level 2 PSA showed that the manual containment venting would be applicable only in a minority of severe accidents. Besides the potential modifications of the plant systems and structures, modifications in the shutdown and startup procedures were considered. Core damage during the refueling outage became important, because the containment is open during refueling outage. Installation of the filtered containment venting system (FCVS) was the largest SAM modification for Olkiluoto NPP units. Venting is actuated automatically by rupture disc at containment pressure 0.55 MPa. The venting line can be closed by manually operated valves from the reactor building at a location providing adequate shielding against radiation from the radioactive material in the FCVS. For improved retention of iodine inside the containment, pH control system was installed in 2001. The system is common for both units and is connected to the containment spray system.

As a result of different PRA studies, several modifications have been performed to decrease the identified risks and core damage frequency of OL1 and OL2 NPP units. Most important modifications are shown in Figure 4. Many of these modifications decreased the possibility of initiating events leading to accident sequences, in which severe accident management is not performing well.

Figure 4[§]: Development of OL1 Core Damage Frequency



In Figure 4, the CDF increases when the coverage of the PRA is expanded (e.g. fire in 1991, seismic in 1997) or when new initiating events are identified (e.g. loss of room heating during cold weather in 2006). In 1990’s PRA identified risks due to fire, frazil ice and seismic events. Timely plant modifications were implemented and the risks were soon lowered, as also seen in Figure 4. On the other hand, what is not shown in the core damage frequency curve are some consequences of the modernization project in 1990’s. In the modernization, new diverse relief valves were installed in

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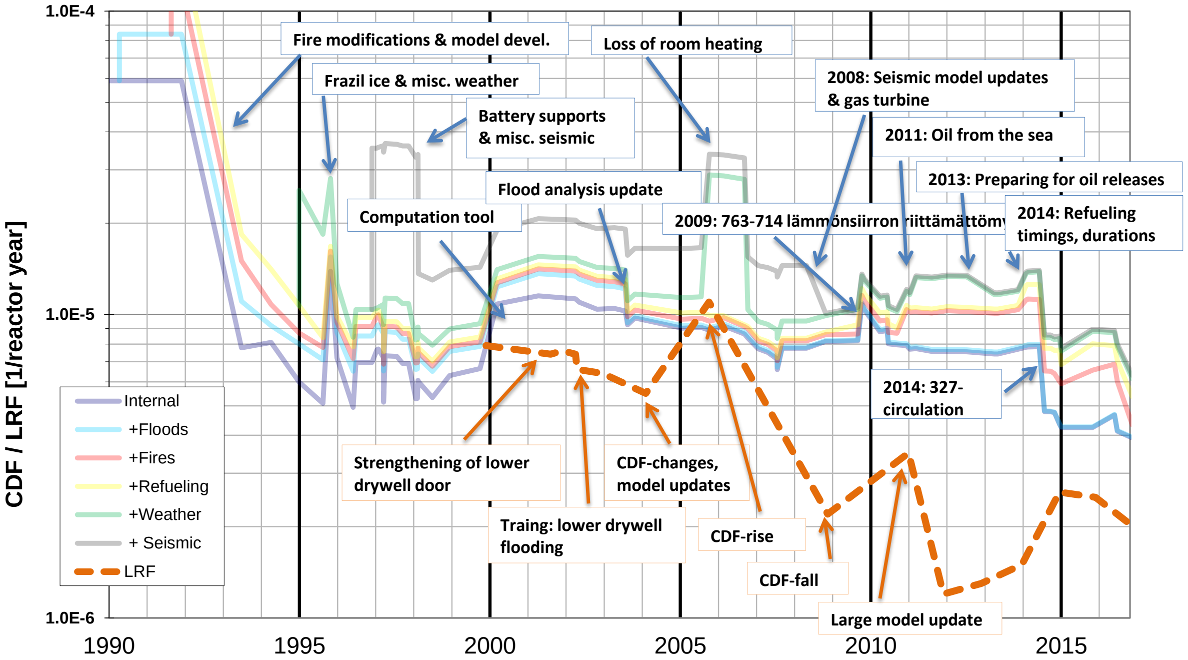
[§] Teollisuuden Voima Oyj

overpressure protection system 314. As a consequence, a large fraction of high pressure sequences was transformed to low pressure sequences, posing less threat to the small containment of OL1 and OL2. The CDF remained the same, but the core damage profile became more manageable by SAM systems. Currently the core damage frequency of OL1 is below the limit required for new NPP units, 10^{-5} 1/a. Due to some pending modifications, CDF of OL2 is still above this limit, but these improvements will be implemented in near future.

Figure 5 shows the development of OL1 large release frequency after 2000. No major modifications for SAM provisions have been made during this period, and thus the large release frequency practically follows the core damage frequency.

Figure 5[**]: Development of OL1 Large Release Frequency



According to the practical elimination study in the end of 2017, no additional remarkably efficient SAM provisions could be found. One option could be to decrease the duration when containment is non-inerted during outages. According to Operational Limits and Conditions, in order to avoid hydrogen deflagration, the containment atmosphere shall be inerted, except in the interval of 8 hours before shutdown and 24 hours after startup. By decreasing the non-inert time, a reduction in the large release frequency could be obtained. However, the operations inside the containment could suffer and become more error-prone. TVO is currently examining the amount of reduction that could be obtained with practical arrangements.

For OL1 and OL2, early release frequency is roughly 1/5 of the core damage frequency. “Early” is specified in the same way as for Loviisa NPP, i.e. within five hours from the initiating event. However, for the minimum release to be studied as early release, TVO has defined 1% of noble gases or iodine. On the basis of the analysis it is clear that the fraction of early releases compared to core damage frequency is not small. This conclusion is not sensitive to adjustments in analysis boundaries and is related to the plant architecture (small volumes and strong dependency on electricity).

Therefore, the most effective option to reduce the risk of early release for OL1 and OL2 is to reduce the core damage frequency. Important modifications to be implemented in 2018 is the steam turbine operated auxiliary make-up water pump and fire water injection system, which reduces the core damage frequency by 30%, large fraction of which reduces also early release and large release

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[**] Teollisuuden Voima Oyj

frequencies. In addition, the steam turbine pump introduces additional delay to the releases of remaining core damage sequences. Other currently ongoing modifications decreasing the CDF are the renewal of diesel generators, diversification of RPV level measurements, and modifications in OL2 auxiliary feed water system to remove dependency on external cooling.

TVO has studied the possibilities of I&C system diversification since 2008. In the course of years, several modifications have been implemented, but the risk of the common cause failure of the final trip relays has remained significant (currently 8% of CDF). In the renewal for operating license in 2018, STUK requested TVO to analyze the options for reducing this risk.

3.3. Practical Elimination Applied to Olkiluoto NPP Unit OL3

Olkiluoto 3 is a 1600 MWe European Pressurised Water Reactor (EPR). A turn key delivery is provided by the Consortium Areva NP and Siemens. The commissioning tests are ongoing. STUK is currently finalizing the review of the operating license application, which TVO submitted to the Ministry of Employment and the Economy in April 2016. Operating License is needed prior to loading nuclear fuel into the reactor core.

Severe accident management was incorporated as part of the EPR basic design. SA management is based on core melt control by corium management and cooling in a dedicated cooling area. Hydrogen management is based on catalytic recombiners. Decay heat from the containment – i.e. corium cooling and containment spray – is performed by independent and dedicated systems. High pressure core melt that could lead to a large release is prevented by single failure tolerant dedicated pressurizer valves. SA I&C is dedicated and separated from the safety I&C with dedicated electricity and batteries.

As a result of the design, large release frequency and early release frequency are small, as shown in Table 2. Early release frequency is less than 1% of total release frequency and roughly 1.2% of core damage frequency. Results of level 2 PRA do not indicate small early release, since early sequences, including containment isolation failure, produce large releases.

Table 2: Release Categories in Olkiluoto 3 PRA for Operating License.

Release type	Frequency 1/a	% Release
Large release before 3h	9.40×10^{-09}	0.3
Large release 3..10h	1.88×10^{-08}	0.6
Large late release	7.10×10^{-08}	2.2
Small release before 6h	≈0	≈0
Small release after 6h	3.18×10^{-06}	97

Even though the probabilistic safety criteria were reached, the results of the initial PRA for operating license indicated that some aspects of practical elimination should be further discussed. Two examples are presented below.

Roughly 80% of early large release frequency was due to a short time during start-up when the pressurizer is solid and primary circuit heating is going on. An overpressure transient at this period would lead to brittle fracture of the vessel and an unmanageable severe accident. This was an unacceptable concentration of very high risk during a short time. STUK requested additional information, and it was found that the initial PRA was based on incorrect configuration of safety systems during solid pressurizer phase. When configuration was corrected according to the Operational Limits and Conditions, the contribution of solid pressurizer phase was decreased by more than one order of magnitude.

In level 2 PRA, the contribution of ATWS sequences in some plant damage state frequencies was high. In spite of acceptable PRA results, ATWS sequences are prone for practical elimination, and additional analysis was requested. The probabilities of ATWS sequences were based on conservative assumption of 3 rod drop failures. When the failure patterns were replaced with more realistic ones, containing 3, 5 or 9 rod drop failures depending on the pattern, ATWS contributions were significantly reduced.

Another example of practical elimination is the installation of a second gate valve for the isolation of the fuel transfer tube. The original design included only one manually operated gate valve. In case of a severe accident during fuel unloading/loading with open RPV, a stuck-open gate valve would have prevented the isolation of the containment. Containment overpressure slightly above 1 bar would have driven the water pool though the transfer tunnel, opening release route via fuel building. The second gate valve makes the isolation of the transfer tube single failure tolerant.

The Nuclear Energy Decree defines large release as release exceeding 100 TBq of Cs-137. The results of OL3 level 2 PRA show that the releases are typically either much smaller or much larger. In fact, the large release frequency of OL3 would remain almost unchanged for release limits between 1 and 1000 TBq. Based on OL3 level 2 PRA and level 2 PRAs of other Finnish NPP units, a rather general conclusion can be drawn: in a severe accident, the release is small if the containment is intact, or if there exists a small containment failure and the containment sprays are operating. In all other cases the release is large (as defined in Finnish requirements).

4. CONCLUSION

Finland has a long history of continuous improvement of the safety of operating nuclear power plants. Even for operating NPP units constructed a long time ago, efficient provisions can be implemented to significantly decrease the frequencies of early releases and large releases. Safety improvement and practical elimination are achieved only when real weaknesses are identified and practical modifications are implemented. It is a significant achievement of Finnish licensees that the core damage frequencies of older NPP units approach and even reach the quantitative criteria set for new NPP units. The definitions and interpretations related to practical elimination may sometimes be vague, but it can be demonstrated that the results and practical applications can be robust and not sensitive to the definitions.

The continuous development of safety rests on the basic attitude that identified safety vulnerabilities are treated as candidates for further enhancement of safety. Even then, practical elimination does not happen by itself, but requires vigilant search for vulnerabilities and research for new possibilities to overcome those.

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