Addressing Off-site Consequence Criteria Using PSA Level 3 - Enhanced Scoping Study

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Abstract: Based on an inquiry from the Nordic PSA Group (NPSAG) and the Nordic Nuclear Safety Research group (NKS), a consortium of Swedish nuclear risk consultancies (Lloyd's Register Consulting, ES-Konsult and Risk Pilot) and the Finnish research institute VTT has begun a multi-year study of Probabilistic Off-site Consequences Analysis, commonly referred to as Level 3 Probabilistic Safety Assessment (Level 3 PSA). Level 3 PSA is infrequently performed and generally regarded as a less developed analysis when compared to Level 1 and Level 2 PSA. Interest in the Nordic countries has been spurred based on new nuclear construction projects and plans. These activities have raised interest in objective, risk-based siting analyses for new nuclear reactors in order to better understand the risks of off-site consequences in the wake of the multi-unit disaster at the Fukushima Daiichi site. The objective of this study is to further develop understanding within the Nordic countries in the field of Level 3 PSA, in order to determine the scope of its application, its limitations, the appropriate risk metrics, and the overall need and requirements for performing a Level 3 PSA. The project's first year focused on the development and analysis of an industrial survey about Level 3 PSA, which included several workshops and meetings with Nordic utilities, regulators, and safety experts. Level 3 PSA risk metrics including health, environmental, and economic effects have been researched and discussed in the first year's project report. The project has generated significant interest internationally and has interfaced with international organizations including the IAEA and the American Nuclear Society. The long term objective of the work is to set the foundation for performing a "state-of-the art" Level 3 PSA for Nordic conditions.

Keywords: PSA, PRA, Level 3

1. INTRODUCTION

Level 3 PSA (Probabilistic Safety Assessment) provides a probabilistic assessment of off-site consequences from a radioactive release. The input to a standard Level 3 PSA is derived from several sources. The results from the identification and assessment of the accident sequences leading to core damages, which are provided by Level 1 PSA, and the severe accidents and radioactive source term analyses, which are provided by Level 2 PSA, are combined with meteorological, population and agricultural data to estimate the off-site societal, environmental, and economic risks posed by a nuclear facility.

The field of Level 3 PSA is generally weakly understood, but has been receiving significant attention by the risk community. Many diverse groups stand to benefit from the proposed activities. Those in particular are utilities with operating plants, utilities pursuing new construction, regulatory bodies, public health organizations, and emergency preparedness networks. For the utilities, both the ones with operating plants and those that pursue construction of new plants, it has been noted that the risk

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presented in a Level 3 PSA is of particular interest for the owners of the utilities (shareholders) and the insurance companies.

1.1. Purpose

The project was initiated because due to the Fukushima accidents and the continuing interest in new reactors, interest in Level 3 Off-site consequence PSA has risen within the Nordic region, and around the world. This interest has been reflected in the volume of recent activity in the area of Level 3 PSA at the International Atomic Energy Agency (IAEA) and the large scale projects in the United States and elsewhere.

The goal of this study is to further develop the Nordic understanding of the potential for Level 3 PSA to determine the influences and impacts of off-site consequences, the effectiveness of off-site emergency response, and the potential contributions of improved upstream Level 1 and Level 2 PSAs. Level 3 PSA provides a tool to assess the risks to society posed by a nuclear plant, and could be integral in making objective decisions related to the off-site risks of nuclear facilities.

1.2. Scope of project

The project will develop guidance on several significant topics. The reports and seminars will include guidance on the following topics:

1. A summary on industrial purpose for performing Level 3 PSA
2. Recommended risk metrics for Level 3 PSA
3. Requirements on existing Level 1 & Level 2 studies set by the Level 3 analysis.
4. Insights on abilities of existing Level 3 PSA tools/codes and possible needs for further development.
5. Collection of current regulations, guides and standards toward Level 3 PSA
6. Methodology guidance document

1.3. Project organization

The project includes several separate tasks that are being conducted in parallel. Several of these tasks started during 2013, while others will start up in 2014 and be finalized in 2015. The project tasks address the following topics:

- Industry and Literature Survey,
- Appropriate Risk Metrics,
- Regulation, guides and standards,
- Development of a Guidance document
- Pilot Application including tools for dispersion and consequence analysis

1.4. Project interfaces

The project has had significant interaction with Nordic utilities and regulatory authorities. These include a Stakeholder Meeting where the project financiers provided input on the scope and direction of the project and the industry survey. These stakeholders also responded to the questionnaire that was developed in Task 0, and then assisted in drawing conclusions from the questionnaire during a "Questionnaire Response Workshop". Finally the working group held a seminar on January 21st, 2014 to summarize the progress during the first year of the project and to receive input on the pathway forward for the project.

The project has aroused interest in many international organizations and has fostered Nordic participation in several international Level 3 PSA activities. Currently, the IAEA is developing Level 3 PSA guidance through the drafting of a TECDOC. This project has allowed the working group to contribute to this effort through member participation in IAEA Technical Meeting & Consultant Meetings as well as an expert lecturer an IAEA Regional Workshop on Level 3 PSA. The project has also interfaced with groups such as OECD/NEA Working Group RISK and the ANS/ASME Level 3 PSA standard writing committee.

2. INDUSTRY AND LITERATURE SURVEY

2.1. Background

The first step in this task included the formation of the industrial questionnaire and for this a literature study was performed. The questionnaire was based on earlier similar studies and discussions between the working group and project stakeholders. The purpose of the questionnaire was to collect base information about current international practices and the motivations of utilities and regulators for Level 3 PSA. Even though Level 3 PSA is required only in a few countries, the interest is broader. The results from the questionnaire will therefore contribute to the ultimate objective and outcome of the project in total, a guiding document to provide clear and applied guidance towards regulators, utilities and Level 3 practitioners.

2.2. Questionnaire summary – Risk comparison and development of Level 3 PSA

Risk comparisons for society made risks are possible to do in theory; however, this might not be possible in practice. One reason is the difficulty in finding comparable units, based on risk. If risk comparisons are to be done this must be done carefully. The survey respondents were not in agreement whether or not risk comparisons between different nuclear power plants or between nuclear power and other energy sources are needed. From the questionnaire, it can be concluded that risk comparison in itself is not a strong driver for performing Level 3 PSA.

2.3. Questionnaire summary – Needs for Level 3 PSA

The scope for Level 3 PSA and the use of the results from this type of analysis need to be established before the "need" or value for Level 3 PSA can be fully defined. The main expected motivations for performing a Level 3 PSA are, however, to use the analysis as an objective guidance tool for decision making, e.g. regarding costs for rebuilds and emergency preparedness work.

The respondents attempted to define "unacceptable effects" of a nuclear accident. This was viewed differently between the nuclear expert respondents and the respondents from insurance companies. This indicated the needs for more clearly defining the scope for Level 3 PSA and the use of results.

This difference in opinions can be exemplified by looking at how a risk metric defining unacceptable health effects could be defined:

- Unacceptable health effects, from a nuclear expert's point of view, could be defined from national and international safety standards, e.g. no immediate deaths caused by radiation. Possible, unacceptable, health effects in long term could be compared to other health risks, for example background radiation. There is also the possibility of defining unacceptable health effects by setting dose criteria.
- An example of unacceptable health effects, from an insurance company's point of view, could be: all kinds of health effects that require a visit to hospital and would not exist if the accident would not have happened, the general public should not have any adverse effect from the operation of a nuclear power plant.

Another example of this difference in opinion is related to definition of economic impacts, which can be difficult to define in general. From the utility point of view, an unacceptable economic impact can be when the “bills” are higher than the economic preparedness. From an insurance company’s point of view, however, it could be defined as costs related to third parties in terms of compensation to third party. The taxpayers should not be called upon to pay for the damages.

2.4. Questionnaire summary – Advantages of using Level 3 PSA and risk communication

If the use of Level 3 PSA could lead to defining the risk with nuclear power and expressing the risks in terms that are possible to compare, discuss and calculate (e.g. in monetary values) with other societal risks then the results would be communicable. Making the risks communicable could help to improve the communication between the nuclear industry, authorities, insurance companies and the community. The most important communication path consists of two parts. One consists of the communication from experts to authorities and the other one is from authorities to the community (e.g. private persons, non-governmental organizations, and media). However, the authorities are in a double role because they are both experts and authorities. Communication by authorities is more important than communication by experts.

The way of how to grade important communication paths may differ between different groups and persons. Different communications paths may vary in importance for different parts of the society. For example, media may rely on information coming from the government while information between two private persons can be of equal importance for an individual person. Within the questionnaire the respondents were asked to grade the most important communication paths and the result is displayed in the matrices below where the color coding is:

Red=Important, Yellow=Medium, Green=Not so important

From → To↓	Experts	Authorities and Government	Media	Health and Envorinment	Private person
Private person	3	4	3	3	2
Health and Envorinment	3	4	1	2	
Media	3	4	2		
Authorities and Government	4	3			
Experts	3				

Figure 1 – Communication path importance graded by nuclear experts.

From → To↓	Experts	Authorities and Government	Media	Health and Envorinment	Private person
Private person		5	3		
Health and Envorinment	5				
Media	3	3	1		
Authorities and Government	2	3			
Experts	3				

Figure 2 – Communication path importance graded by insurance companies.

One of the main conclusions from this is that a Level 3 PSA can be an efficient tool when it comes to communication of risk between different stakeholders. The most important communication path consists of two parts:

1. From experts to authorities
2. From authorities to everybody else (private persons, non-governmental organizations, media).

2.5. Questionnaire summary – Challenges with Level 3 PSA

There are several possible uncertainties involved in Level 3 PSA, e.g. those that are related to the dispersion and consequence assessment, those that are related to the chosen risk metrics to be used (health, environmental and/or economic) and the uncertainties that stem from the Level 1 and 2 PSA. Other challenges are related to the fact that the Level 3 PSA might be expensive to perform and require a lot of work and therefore there is a risk for a large gap in time between performing Level 3 PSA studies which leads to problems with knowledge transfer. On the other hand, there are many possible advantages of performing a Level 3 PSA. One of the (unique) advantages that Level 3 PSA can provide is the possibility to compare negative impacts from different technologies. There is also a possibility to see the uncertainties with Level 3 PSA to be, in fact, one of the reasons why the analysis is needed.

One conclusion from the "Questionnaire Response Workshop" was that "*The challenges are also the reasons for performing a Level 3 PSA*", i.e. the challenges themselves do not motivate not performing a Level 3 PSA. To be able to work uniformly with Level 3 PSA suitable risk metrics should be defined, together with safety criteria that shall be met. There is also a need for specifying guidelines on how to perform the analysis.

3. APPROPRIATE RISK METRICS

3.1. Introduction

The main goal of this task was to discuss appropriate risk metrics for Level 3 PSA. The results from the task will contribute to the ultimate objective and outcome of the project in total, a guiding document to provide clear and applied guidance towards regulators, utilities and Level 3 practitioners. No safety goals, i.e., no numerical criteria, were explicitly connected to the risk metrics presented. However, safety goals were touched upon as a reference to which risk metrics that could be used. In the previous performed work in the NKS/NPSAG Safety Goals project [1], information can be found on what safety goals are being used in different countries and industries, together with arguments and historical background on why different criteria are being used in these countries. Some of the safety goals are related to Level 3 PSA.

There are a number of countries worldwide which have more or less clear safety goals or off-site consequence criterion connected to Level 3 PSA or risks with hazardous industries, see references [1], [2], [3], [4] and [5] for examples. Most of the off-site consequence criteria used in different countries are related to health effects, both to individuals and to the society at large. For numerical criteria, see e.g. [4].

3.2. Risk metrics for Level 3 PSA

Risk metrics of Level 3 PSA have two components: 1) probability metric and 2) consequence (or impact) metric. Regarding the probability metric, it is a matter of choosing the normalization unit for risk comparison purposes. The consequence metric is associated with the impacts which are quantified in the consequence assessment part of a Level 3 PSA. The following main group of consequence metrics has been identified:

- Health effects - Dose
- Environmental impact
- Economic impact (can include every other risk metric).

3.3. Probability units

The results of a PSA, at any level (1, 2 and 3), are typically presented as probabilities of the unwanted events (core damage, large release, offsite impact) per year, and, hence, it can be interpreted as a frequency. The interpretation of the probability per year is that it represents the average risk for a certain nuclear plant that has been analyzed. "Probability per year" is the unit which is used in the regulatory framework and it is almost always associated with a single reactor, since operating licenses are reactor specific. However, in some countries a "probability per year per site" is used (see [6]).

Since "probability per year per reactor" is the probability unit applied in the regulatory context, the probability metric is mainly considered here. Probability units "per lifetime" and "per produced energy over the complete fuel life cycle" can be considered for risk comparison purposes

3.3. Health effects — Dose

Both individual dose and collective dose are of interest for both short-term and long-term effects. From the individual short-term and collective long-term dose both prompt fatalities and cancer fatalities can be calculated.

The following metrics related to health effects are identified:

- Collective dose/individual dose (short- and long-term) [mSv]
- Prompt fatalities (short term)
- Cancer fatalities (long term).

The advantage with the dose related metric is that it is rather straight forward to calculate from the release of radioactive material following a nuclear accident. The dose metric can also be connected to fatalities both in short and long term. It should also be relatively straightforward to define consequence criterion to the dose risk metric. Both the individual and societal consequence can be estimated using dose risk metric (or fatality risk metric). The dose metric can also be used to improve plant design and emergency preparedness. The disadvantage with the dose related metric is that it does not cover the complete consequences of a nuclear accident. The impact to the biosphere is not captured with the dose related risk metric, e.g. contamination/restrictions (evacuation) on land and sea, impact on wildlife is not covered by the dose related metric.

The uncertainties connected to dose and fatalities are the general uncertainties with respect to dispersion calculations (which also affect all other risk metrics). Once the release and dispersion of radioactive material is calculated it is rather straight forward to calculate the dose exposure both on an individual and collective level if population densities are available. From the dose exposure it is easy to estimate fatalities. There is, however, uncertainties related to the validity of the linear, no threshold hypothesis used in the proposed way of calculating cancer deaths. It is being debated whether cancer risk is linearly proportional to dose, when doses are small. Some claim, small doses do not cause cancer or are even healthy, some claim the opposite, the model assume linear relation. This assumption can have a significant impact on the cancer risk estimate, since in many potential studies a major part of the population would get just small doses in case of an accident

3.4. Environmental impact

Different levels of contamination can be used. One level of contamination could result in a restriction for living within a certain area and another level of contamination could result in restrictions from farming and harvest within a certain area.

The following metrics related to environmental impact are identified:

- Ground contamination level due to Cs-134 and Cs-137 [Bq/m^2] or [mSv/year]
- Non-usable areal of land and sea [km^2]

Similar to dose related metrics, it should be relatively straightforward to calculate the environmental metric at least in terms of affected land area (sea may be more challenging). This metric can be further refined from the time perspective point of view (temporary land use restrictions and long term restrictions) and the type of land point of view. Environmental metric is in many respect closely related to the health based metric and these two metrics could be evaluated in an integrated manner. Environmental metric thus compensates part of the disadvantages of health impact metric. The disadvantage is that there is not yet any commonly agreed approach to evaluate different environmental impacts. A single number measuring the area of restricted land use does not reflect the differences between site locations. Type of land and time period of impact are relevant factors to be accounted, but then conversion factors need to be defined if the results are to be compared. This leads to the definition of economic metric.

The uncertainties connected to environmental impact are the general uncertainties with respect to dispersion calculations as well as the estimation of the long term impact on environment. The first issue is common to all other impact metrics, and the second one depends on the quality of environmental impact models. In practice, there should be sufficient input data for environmental impact estimation but the models include uncertainties, e.g., given that the release and dispersion can be calculated and given that the characteristics of the contaminated land area are known, it may be difficult to predict the time periods for land use restrictions and the significance for biosphere. Release to sea or river is even more complex to quantify but the air pathway is usually much more important than the sea pathway. Uncertainties are thus related to the definitions of the surrogate environmental impact metric that need to be applied.

3.5. Economic impact

The following metric related to economic impact is identified:

- Total cost of accident, EUR

Economic impact has the obvious theoretical advantage that all impacts of an accident can be converted into a single metric, which allows consistent risk comparisons and cost-benefit analyses. In principle, this kind of metric should be applied in decision making, while the other impact metrics are surrogates to it. In practice, it can be difficult to agree on what should be included in the quantification of economic impact and how to convert different impacts in a monetary scale. This is a general problem for risk decision making and not specific to nuclear power plant risk analysis, although nuclear accidents have specific complicating aspects such as multitude of impacts and involved stakeholders and the low probability of an accident. Despite the difficulties to evaluate economic impact, it should be sufficient to estimate the order of magnitude of different kinds of accidents, e.g., the Three Mile Island type of core damage accident with practically no external release would mean certain economic impact. Depending on the order of magnitude of release and direction of dispersion some other orders of magnitude of economic impact could be assumed. Knowledge from costs of other natural or industrial catastrophes could be also used as references to estimate the order of magnitude of a nuclear accident.

Despite possible difficulties to convert non-monetary impacts to monetary scale, it might nevertheless be useful to do this exercise, i.e., to try find some commonly agreed conversion factors. This process should lead to increased understanding of risks and facilitate risk communication. Given an economic impact assessment with explicit (parameterized) conversion factors, it is always possible to do sensitivity studies to determine the items that would be most critical to the economic impacts – even with the presence of uncertainties. Example for a multi-criteria decision analysis related to health, environmental, economic and societal impacts, see [7].

Since the economic impact assessment includes any consequences, the range of uncertainties is large and covers all kinds of uncertainties from the incompleteness issues, modeling uncertainties to parametric uncertainties.

3.6. Risk metrics for different stakeholders

Different stakeholders may need different risk metrics. Health effect and environmental impact metrics should be relevant to all stakeholders, but the way economic impact is assessed is more stakeholder dependent. The issue in selecting risk metrics for different stakeholders is thus mainly the question which costs are taken into account and in which way they are weighted. For instance, the safety authority may not necessarily want to take any position on the economic impact, while the utility and the insurance company may look at the economic impact on different risk perspectives.

It may be assumed that the Level 3 PSA is primarily done by the licensee and it would be advisable to consider a wide range of risk metrics (health effects, environmental and economic impact). The aggregation of different risk metrics into single risk metrics should be done explicitly with parametric models, which allows different weightings. The issue of selecting risk metrics can be reduced to the discussion on weightings of risk metrics.

3.7. Comparison with level 1 and 2 PSA risk metrics

The risk metrics related to Level 1 (core damage frequency) and 2 (unacceptable release frequency) PSA are to a large extent independent of the siting (location) of the plant. The only impact from the location of the site in Level 1 and 2 PSA is from the determination of external events which to some extent are dependent on the location. In Level 3 PSA the location of the site is of paramount importance since e.g. metrological data and distance to population and agriculture areas are affecting the output. Hence, Level 3 PSA can give useful information about siting issues. Basically, Level 1 PSA analyze the plant systems which are designed to prevent core damage and Level 2 analyze the plant systems design to prevent and mitigate the consequences of a severe accident. Level 3 PSA will give useful information about both off-site emergency response or preparedness and plant safety systems.

Risk metrics for Level 2 PSA can be applicable as surrogates for Level 3 PSA risk metrics. There is a strong correlation between the release magnitude/timing metric and the health effect/environmental impact risk metrics. The correlation is site-specific. In practice, at certain site it is only the effect of dispersion and evacuation which give variation in the consequence scale given certain release category. Core damage risk metric of Level 1 PSA is not a sufficient surrogate risk metric for Level 3 PSA purposes. On the other hand, if economic impact will be considered in Level 3 PSA, it would be consistent to consider economic impacts event at Level 1 PSA, i.e., to expand the consequence categories of Level 1 PSA to include even major economic losses (without a core damage). From the risk comparison point of view, there may be economically significant consequences without external release or even without core/fuel damage.

4. REGULATIONS, GUIDES, AND STANDARDS

4.1. Introduction

The probabilistic assessment of off-site consequences, often referred to as Level 3 PSA, was the subject of many large studies and international interest in the late 1980s, Organizations such as the IAEA, NEA, European Commission, and US NRC published reports or funded Level 3 PSA programs and studies. It was observed that relatively little has been done in the field since that time, but activities have started within some of these same organizations [2]. The purpose of this task is to provide the ability to observe and influence the development of Level 3 PSA regulations, guides, and standards. This task has also provided input to the other tasks within the project, as well as, provided feedback to external organizations based on the findings of the working group's activities.

Activity in the field of probabilistic off-site consequence analysis has had many peaks and valleys over the years. Internationally and within the Nordic countries, there was a large effort in the field of Level 3 PSA in the late 1980s, which included significant Probabilistic Consequence Analysis (PCA) methods work, large scope studies, and IAEA meetings and publications. Several countries have been performing Level 3 PSA consistently for many years (e.g. the Netherlands, South Africa). However, generally speaking, there was a significant drop-off in the work performed on Level 3 PSA methods and the number of studies performed since the work of the late 1980s and early 1990s. The interest in Level 3 PSA has risen in the last several years. This is based on several reasons, the fact that many of the large-scope well known studies are aging, the development and construction of new reactor units, and perhaps most significantly, the disasters at Fukushima. These reasons have prompted many in the nuclear safety community to re-investigate Level 3 PSA.

The primary focus of this task has been to follow the ongoing work regarding the peer review standards ANS/ASME 58.24 (Level 2 PSA) and ANS/ASME 58.25 (Level 3 PSA) and Level 3 PSA activities at the IAEA. The ANS/ASME 58.24 (Level 2 PSA) and ANS/ASME 58.25 (Level 3 PSA) standards have been under development in writing committee over the past several years. It is anticipated that it will take another several years until these standards will be published. It was envisioned that this task will allow the project to influence and report on the progress of these standards. The work performed under this task has also include monitoring and if possible participation in the development of international guides and regulations. This includes the developments made by the IAEA, the United State Nuclear Regulatory Commission, and similar organizations. Finally, any additional, applicable regulations, and standards will be included in this task, particularly those identified in the work performed for Task 0 and Task 1.

4.2. ANS/ASME Level 3 PSA standard 58.25

The ANS Standards 58.24 and 58.25 regarding Level 2 PSA and Level 3 PSA respectively have been under active development for several years. During this time a member of the working group has been actively involved in the 58.25 writing committee. This project will be integral in providing the resources to continue to engage in the ongoing work and report on the progress of these standards.
Since the work is relatively modest over the past year a large majority of the work to date in the area of the ANS/ASME 28.25 standard was provided in the thesis work provided in reference [2].

The standard is being written by a committee of American Nuclear Society (ANS) and American Society of Mechanical Engineers (ASME) members. The committee was first funded and assembled in the early 2004. Since that time, a draft standard has been completed and released for review. To date, approximately 800 responses have been collected critiquing the draft version of the standard. The ANS/ASME-58.25 standard provides requirements for application of risk-informed decisions related to the consequences of accidents involving release of radioactive materials to the environment. The consequences to be addressed include health effects (early and late) and longer term environmental impacts. These requirements are articulated for a range of technical Level 3 PSA areas in a specific structure. This structure is consistent with previously published ANS/ASME risk standards.

4.3. IAEA activities in Level 3 PSA

The IAEA issued a procedure guide on Level 3 PSA in 1996, IAEA Safety Series No. 50-P-12, "Procedures for Conducting Probabilistic Safety Assessments of Nuclear Power Plants (Level 3)," following significant work performed in the US, Europe, and Japan in the field of Level 3 PSA methods. The IAEA has recently reopened the issue of Level 3 PSA with an IAEA Technical Meeting on Level 3 PSA, which took place in July of 2012. The meeting was the first activity specifically discussing Level 3 PSA since the publication of the IAEA Safety Series No. 50-P-12.

Following the IAEA Technical Meeting, two further IAEA activities have taken place. The first was an Eastern European Regional Workshop on Level 3 PSA, and the second was a Consultant Meeting on Level 3 PSA. The funding provided by the project allowed the working group to participate in both activities. The Consultant Meeting on Level 3 PSA took place in Vienna Austria from November 25-28, 2013. The meeting included several individuals from countries with active Level 3 PSA projects. The recommendation from the attendees of the Technical Meeting was that the IAEA should provide further guidance on Level 3 PSA. The purpose of the IAEA Consultant's meeting was to determine in what form the IAEAs guidance on Level 3 PSA should take.

Following the Technical Meeting a Regional Workshop (Eastern Europe) on the topic "Level 3 PSA development and related issues" took place in July of 2012, which was the first activity specifically discussing Level 3 PSA since the publication of the IAEA Safety Series No. 50-P-12. The motivation for the meeting was due to the relative difficulty in finding information on Level 3 PSA. Due to this difficulty and many open questions in the Region, a 3-day workshop could provide significant insight into the basic constituents, uses, and scope of a Level 3 PSA.

During the course of the IAEA Technical Meeting it became apparent that widely varying approaches and opinions surround Level 3 PSA were held among the group of participating member states. As a result of this, the IAEA decided to pursue further guidance through the development of a TECDOC (IAEA Technical Document).

The objectives of the TECDOC are the following:

- Outline the methodology and indicate the techniques most widely used to date.
- Provide general guidance for conducting a Level 3 PSA with description of major technical elements (e.g. interface between Level 2 and Level 3 PSA, atmospheric dispersion, countermeasures, consequence results interpretation).
- Survey of current practices and computer codes available for consequence assessment (real difficulties learned by Level 3 PSA analysts).
- Provide information on the use of Level 3 PSA and applications, and effective presentation of the results.
- Identify areas of further research.
- Update previous (now outdated) IAEA of the previous IAEA Level 3 PSA publication.

The general scope of the TECDOC should not be completely different from the scope outlined in the IAEA Safety Series No. 50-P-12, publication. As today the TECDOC is planned to have the following scope:

- Level 3 PSA for nuclear power plants considering all facilities at the nuclear power plant (NPP) site is the primary focus of the document.
- Since the general methodology may be also applicable for other parts of the nuclear fuel cycle, (e.g. reprocessing plants, spent fuel storage installations, and research reactors), the document should not exclude these types of facilities, but should maintain the focus on NPP applications.
- The document shall provide guidance but refrain from being prescriptive in its guidance.

4.4. Task 2 Continuing Activities

The work in the area of regulation and standards will continue through 2014. The focus on the continuation of these activities will be the development of the IAEA Level 3 PSA TECDOC, which will have several Consultant meetings over the coming years. Progress on the Level 3 PSA standard has been modest over the past year and it is anticipated that there are several years before completion. IAEA work is poised to continue through the next several years. The IAEA TECDOC is in the very early stages of development, and several more Consultant Meetings will be required to continue and eventually complete it. Internationally there is significantly more work being done in Level 3 PSA. Countries such as the Netherlands and South Africa continue to maintain Level 3 PSA models as it is part of their regulatory requirements. A large scale US NRC study is underway and preliminary results will begin to be discussed and later published in the coming years. Development of a possible replacement to the COYSMA program "PACE" is underway and being discussed. There is also significant interest in this NPSAG / NKS project on Level 3 PSA and the next year seminar shall be planned at least 6 months in advance to accommodate the international participants.

5. PILOT APPLICATION

The pilot project will be completed in two parts, a Finnish project that will utilize Finnish tools and methods, which is also incorporated in the Finnish nuclear safety research program (SAFIR), and a Swedish project, which will utilize Swedish tools and methods. The Finnish project began during 2013, while the Swedish portion of the project will begin during 2014. This section details the progress of the Finnish project during this past year. Some of the overall goals with the pilot application are; to clarify the insights given by Level 3 PSA; demonstrate required resources; get clearer understanding of key uncertainties; provide more knowledge about how current Level 2 release categories structure fits into off-site consequence modeling needs; gain insights in the use of proposed risk metrics; and to support the guidance document and provide practical background to the guidance.

5.1. Specific goals of the Finnish pilot study

The goals of the Finnish pilot study are:

- to gain experience in the application of the IDPSA (Integrated Deterministic and Probabilistic Safety Assessment, sometimes referred to as "Dynamic PSA") methodology (originally developed for Level 2 PSA) to Level 3 PSA studies, and to evaluate its usefulness on Level 3 PSA,
- to apply and evaluate risk metrics identified in Task 1,
- to develop methods for taking into account multiple source terms at different times and from different sources (as was the case in Fukushima),
- to gain experience in conducting Level 3 analysis for the development of a new Level 3 code, and
- to study how uncertainties proliferate through Level 3 analysis

The pilot allows also other uses. For example, comparisons between the IDPSA approach and the current Swedish approach might be made. The pilot will also give perspective on what input should be expected from PSA level 2 analyses. Such uses may be implemented in later years. The goal of the first year in Task 4 was to create a plan for the Finnish pilot study.

5.2. Finnish pilot study in brief

Within the plan for the Finnish pilot study it has been decided that it will be applied to Fukushima Daiichi NPP disaster utilizing IDPSA methodology. There are several issues concerning Fukushima. The first is that there were several source terms at different times from different sources (reactors and used fuel storage). Significant sources of uncertainty include source terms, and the amount of population in the affected area (much of the area was depopulated after the tsunami). All of these issues have to be addressed computationally in the pilot.

In IDPSA, deterministic methods and tools are used to address computationally heavy parts of the system (such as plant response on Level 2 PSA), and probabilistic methods are used to handle uncertainty. Normally the deterministic and probabilistic parts are integrated in the way that the needs of the probabilistic part determine what kind of computations are done in the deterministic part, and some central results of the deterministic part (such as timing information) are fed to the probabilistic part. In the pilot, atmospheric dispersion computations and dose calculations are handled deterministically, and source terms, meteorological conditions, countermeasures and population behavior probabilistically.

The scope of the Finnish pilot study is to estimate population doses and related health effects caused by atmospheric dispersion of the radioactive release in the selected case. Emphasis will be on short-term health effects. Another metric that will be studied is the averted dose, that is, the dose averted by the population due to countermeasure(s). Also the number of persons whose received dose exceeds a certain limit will be examined as a metric. Other consequences, such as land contamination through radioactive fall-out, may be considered.

6. CONCLUSIONS

The first phase of this scoping study of Level 3 PSA has been completed. Focus during this phase has been to get input from different stakeholders on the needs and challenges with Level 3 PSA, to study possible risk metrics that can be used and to participate in international guidance development in the area of Level 3 PSA. The work is planned to continue for two more years and the focus will now be to gain experience by performing pilot applications and to develop a Nordic practicable guidance document.

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