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Guidelines and Recommendations

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Summary

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Approval

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METIS

Seismic Risk Assessment
for Nuclear Safety

Research & Innovation Action

NFRP-2019-2020

Recommendations from peer-review group for METIS case-study

Deliverable D3.3

Version N°1

Authors:

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Disclaimer

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Abbreviations and Acronyms

Acronym	Description
EAB	External Advisory Board
EUG	End-Users Group
IAB	Internal Advisory Board
IM	Intensity Measure
GM	Ground motion
LOCA	Loss-of-coolant accident
NPP	Nuclear Power Plant
PGA	Peak Ground Acceleration
PSA	Probabilistic Safety Assessment
PSHA	Probabilistic Seismic Hazard Assessment
rotD50	Median of response spectra of the two horizontal components projected onto all nonredundant azimuths
Sa	Spectral acceleration
SSC	Structures, Systems and Components
SSHAC	Senior Seismic Hazard Analysis Committee
SSI	Soil Structure Interaction
Vp	Pressure wave velocity
WP	Work Package
WPL	Work Package Leader
ZNPP	Zaporizhzhia Nuclear Power Plant

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Keywords

METIS case-study, Probabilistic seismic hazard assessment, Fragility curves, Seismic Probabilistic safety assessment

1. Introduction

The METIS case-study allowed project partners to test and confront developed methodologies to existing practices. Deliverable D3.2 "Peer-review of METIS case-study: technical, organizational points and minutes of meetings" presents the main characteristics, datasets, and main accomplishments and limitations for the case-study, as well as the organizational points for the peer-review conducted during the project. This document focuses on the outcomes of the peer review.

2. Main remarks and recommendations from the peer-review group

The following sections present the main remarks and recommendations from the peer-review group, annotated during technical meetings. Each of the following sub-sections provides remarks on the work performed by WP4-7. The last section collects general remarks and recommendations for the case-study and the project. Most of these remarks were directly implemented in the reviewed Deliverables as part of their review process. The METIS project gracefully acknowledges the contribution of EAB, IAB, and EUG members in the peer-review group.

2.1. Seismic hazard at rock (WP4)

Reviewed Deliverable: D4.6 "Preparation of the METIS case-study (WP4) and application"

Remark #1

- The peer-review group and project partners agreed that the METIS case-study hazard model is sufficiently complex and adapted for the project applications. The project tried to follow SSHAC's philosophy, looking to capture the seismic hazard centre, body, and range, although it was not compliant with the SSHAC procedure.
- Good practice is to check hazard models and results against past observations and simulations.

Remark #2

- The methodology used for the METIS case-study to decluster the catalogue is based on an objective criterion, and not just on models available in the scientific literature (which might be based on information collected from areas presenting different tectonic regimes).
- The declustering method impacts the final hazard calculation and should be carefully chosen and assessed.

Remark #3

- Fault sources were not considered in the METIS case study due to a lack of information. Seismic hazard models for NPPs consider large return periods and

are expected to consider rare, low-probability events coming from capable faults.

- The peer-review group recommends assessing the presence and impact of capable active faults in real PSHA studies.

Remark #4

- The proposed mainshock-aftershock methodology used in the METIS case study, based on obtaining aftershock hazard after the mainshock, is appropriate for PSA studies.
- The joint occurrence probability of mainshock-aftershock events needs to be assessed to conduct mainshock-aftershock risk studies.
- More research is required to assess the possible impact of aftershocks on NPPs' safety. However, aftershocks are expected to have a minor impact on risk assessment due to the shutdown following the main event.

2.2. Ground motion selection and site response (WP5)

Reviewed Deliverable: D5.4 "Hazard consistent surface ground motion time histories for METIS case-study"

Remark #5

- Deconvolution of rock surface ground motions to bedrock motions: ground motions at rock surface and at the bedrock are usually considered the same, neglecting attenuation at rock.
- In cases where substratum depth differs significantly across the site, it is important to define a common substratum depth and a characteristic seismic motion compatible to the different soil columns, or to assess and integrate differences across the site correctly.

Remark #6

- The project considered initial (elastic) Vp values for convolution of vertical ground motions from bedrock through the soil column. Another common practice is to consider constant bulk modulus to obtain compatible Vp values from reduced Vs values.
- More research is necessary to establish the validity domain for vertical component convolution methodologies. These are not well-stablished from existing borehole databases (e.g. KiK-net network) as for the horizontal ones.

Remark #7

- Project considered weak motions only to define a criterion to assess 1D or 2D/3D site response for the METIS case-study.
- The peer-review group stresses that site response for NPPs requires strong motions. The considered dataset can only be used to verify if topography and basin effects are to be considered and not to assess site response.

Remark #8

- Choice of fragility curves based on multiple IMs for PSA process: how to consider, in the PSA process and risk analysis, the fact that possible different SSC would have fragility curves on different IMs. One way to circumvent this issue is to consider an averaged spectral acceleration as IM, covering the frequencies of interest for the different SSC.
- The benefit and feasibility of considering different IMs on a vector approach for PSHA, fragility analysis and risk assessment require more sensitivity studies.

2.3. Structural response and fragility analysis (WP6)

Reviewed Deliverable: D6.8 "Fragility computations for METIS case-study"

Remark #9

- The peer-review group suggests that simplification hypotheses and modelling approaches for soil-structure interaction (SSI) and structural models in the METIS case-study should be clearly stated (e.g. pre-stressing, soil springs calibration).

Remark #10

- The peer-review group recalls that fragility analysis aims to inform when SSC stop performing its safety function, and the damage states used to estimate fragilities are different according to the safety function. The damage state considered in METIS case-study for structures is the concrete crushing of shear walls, therefore related to structural resistance only.
- The peer-review group recommends that this important point should be educationally explained in the METIS deliverable.

Remark #11

- The structural models for METIS case-study considered uncertainty for concrete and steel parameters related to structural capacity. However, the fragility analysis for reactor building and diesel generator building did not consider uncertainty on the capacity threshold.

- The peer-review group invites the project to check if all uncertainties are considered and otherwise to add appropriate beta values for the missing terms.

Remark #12

- The service water pump capacity is very low, and close to the usually considered fragility for loss of offsite power, which is very unusual. It is necessary to add a clear explanation of the failure mode of this component in the Deliverable.
- The peer-review group suggests that in real seismic PSA projects this value would need to be verified / double checked. Most designs consider multiple water pumps for the same safety function and considering correlations in PSA will be an important issue for this component.
- The peer-review group invites the project to focus on methodological comparisons for fragilities estimation and PSA.

2.4. Seismic PSA (WP7)

Reviewed Deliverable: D7.9 "Application to METIS study-case (WP7)"

Remark #13

- Fragility modelling by lognormal distribution: lognormal hypothesis holds for the body of the distribution, but it inaccurately represents the fragility tails (as it considers higher probabilities of failure at low accelerations, which is conservative).
- The peer-review group stresses that this may be considered for improvements on low seismicity regions and should be pointed out in the report.

Remark #14

- Discussion on acceleration levels contributing to risk: from peer-reviewer's experience, PGA levels higher than 0.3g still largely contribute to risk and should be considered in the PSA. Low contributions to risk are expected for hazard annual probability of exceedance around 10^{-7}.
- It is necessary to cover all the hazard curve and carefully chose the binning of the hazard. The peer-review group invites the Deliverable to consider higher PGA levels for the METIS case-study PSA.

Remark #15

- For the METIS case-study, seismic hazard at rock was estimated for rotD50. Conditional mean spectra anchored by intensity measures PGA and T=0.25s were then considered for time-history selection. For simplicity's sake, fragilities were estimated for the PGA of geometrical mean of horizontal components. In

real PSA projects the same intensity measure should be used both for hazard and risk.

Remark #16

- The peer-review group stresses the importance of acceleration spectral shape on estimate fragilities, although they are indexed only on PGA.
- Conditional spectrum method in its original form enforces consistency of hazard spectral shape for the selection of time-histories. Including other characteristics of the ground motions in the methodology is possible (e.g. Magnitude-Distance, duration,…) but there will be a trade-off between enforcing these characteristics and the sufficiency of existing databases to select natural time-histories.

Remark #17

- The peer-review group recommends to clearly state that PSA was performed by considering specific fragilities from METIS case-study calculated only for a reduced set of predefined SSC. Fragilities for all other equipment in the fault-tree models are the same from the original ZNPP PSA.
- The peer-review group invites the project to introduce a disclaimer on METIS case-study summary Deliverable study pointing out that this case-study is intended to provide basis for comparison of different methodologies, but it doesn't represent a real PSA for a real NPP.

Remark #18

- Discussion on initiating event probability for large LOCA: peer-reviewers remind that large piping (which would lead to large LOCAs if it were to fail) has higher capacity than small piping (which would lead to a small LOCA if it were to fail). This difference in the initiating event probability (extremely low for large LOCA, somewhat higher for small LOCA) is not considered in the presented analysis in the deliverable. This is why large LOCA appear to be strong contributors, while they are usually not significant contributors to risk, as these events have a low probability to occur. In summary, the presented results reflect the extremely conservative assumption regarding the initiating event probability of a large LOCA. Handling small LOCAs is however one important point on accident mitigation.
- The peer-review group recommends that the presented results should be complemented by the above statements.

2.5. General remarks for the METIS case-study

Remark #19

- The peer-review group acknowledges the difficulties the project had to undertake to (i) avoid inconsistencies in interfaces between different scientific fields (seismic hazard, geotechnical and structural engineering, risk analysis) and (ii) construct a well-balanced case-study, intended to be simple enough but covering all the subjects and issues arising from more complex seismic PSA configurations.

Remark #20

- The peer-review group suggests adding a summary in the front of the case-study listing accomplishments and limitations.
- The peer-review group also suggests adding to the final report a systematic view to describe what was done: advancements in the state of the art, application of the state of the art, application of today's practice, and observation of today's practice. Categories will help the reader know in which ways the project made contributions.

Remark #21

- The peer-review group invites the project to prepare (a) a summary suitable for journal publication, including citations, but not to be submitted for journal publication --- rather, to be included as the "Summary" section of the main METIS report; (b) one or more journal articles, each suitable for submittal to a peer-reviewed journal; and (c) one or more conference papers, each with the summary of the project containing a critical assessment of what was accomplished, and a discussion of the limitations. The summary under (a) should probably be broader in scope than the scope of any of the individual journal articles to be developed under (b). The conference papers under (c) might cover different scopes so as to fit the scopes of specific conference(s).

Remark #22

- The data produced for the METIS case-study can be used as benchmark of methods for NPPs in the different fields such as: seismic hazard, ground motion selection and site response, fragility analysis and PSA. The OpenMETIS at Zenodo (https://zenodo.org/communities/openmetis/) can be used to share open data, however the data and reports related to fragilities and PRA from ZNPP are confidential.

3. Bibliography

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