ALARA STUDIES FOR EDF NUCLEAR POWER PLANTS

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UTO is an Operational Unit of The Nuclear Power Plant Operations Division (DPN) of EDF's Industry Branch, and has the objective to serve the Nuclear Power Generating System in all aspects of its core missions, helping it to achieve the targets established by the DPN.

In the past years, ALARA studies performed by EDF plants were quite simple and empirical, mostly based on feedback experience and common sense. These solutions are useful and efficient for simple cases when the exposure situations are not complex, (i.e. within a simple environment, with a single source and for a single exposure point).

However, in some cases this is not enough to ensure that current solutions are well implemented, within the ALARA principle. Common sense is not able to handle complex situations when many sources contribute to the workplace dose-rate and when workloads at the same workstation are very different from one outage to the other.

Therefore, it is necessary to perform more complex analyses relying on the use of radiological protection software and codes. EDF uses its national corporate engineering as a support for its nuclear power plants in order to perform modelling studies and to provide them with an optimised scenario concerning radiation protection options.

Within the framework of these studies EDF/UTO is developping a methodology and a prototype tool aiming at collective dose reduction for maintenance operations in French nuclear power plants.

*These studies, based on the justification of biological protections implementation during a unit outage, underlines the importance of the overall draft "**tool** (calculation code PANTHER-RP and scenario optimisation prototype tool based on EXCEL), **data** (input data, measurement), **methodology** (workstation radiological assessment associated with nuclear sources influence analyses)" in ALARA studies.*

*The prototype tool is currently developed as an engineering tool and will need further evolutions before on-site implementation. Its aim is to calculate the **integrated dose** for each workstation (maintenance and shielding) with or without radiation protection options and to calculate **the dose gain**. The tool will also settles the source contribution for each workstation, helping health physicists to select the best radiation protection options for a specific maintenance programme. The final purpose is to help stakeholders to determine the ALARA optimal scenario through dose calculation (and not only dose-rate such as the current practices).*

Moreover, the role of the on-site operational team is extremely useful for several reasons:

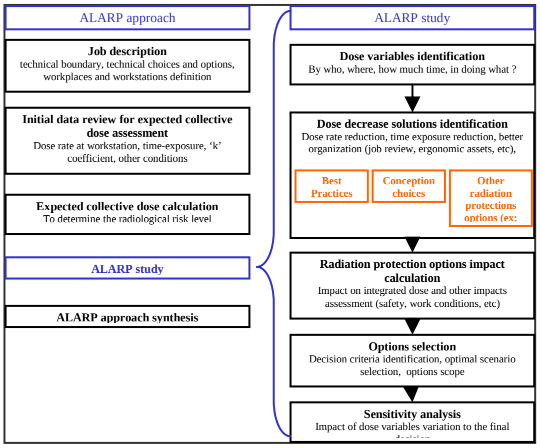
- ◊ *input data gathering,*
- ◊ *the global organisation definition that is needed to implement the optimised ALARA scenario*
- ◊ *facilitating links with shielding contractors.*

Thus, the global methodology that is currently developed by EDF/UTO and on-site operators involvement are expected to lead to an important decrease of the collective doses for the operators for all the EDF nuclear power plants, based on the implementation example of TRICASTIN - a 900 MW power plant.

I. Introduction

External exposure to radiation is the main risk that people are exposed to in nuclear power plants. If no technical or organisational means are efficient, radiation protection optimisation is one of the major answers to reduce the integrated dose <u>As Low As Reasonably Achievable</u> (ALARA). Its main purpose is to establish the expected integrated dose for a specific task and then select the optimal radiation protection options to reduce it.

This may be summarised in the following sketch:



However, important challenges may arise in practice:

- System modelling and simulation: variety and number of inputs; accurate and meticulous definition of the dose-rate sources influence, plural sources/workstations; numbers of activity, radiological context evolution during the outage, shielding contractors integrated dose consideration, etc
- Methodology and radiation protection options selection: it is now required to legitimate the optimisation process and to explain radiation protection choices through **dose gain** calculations, sources' contribution to each workstation evaluation and the order of options implemenntation. Moreover, some on-site stakeholders are consulted to ascertain that the choices are relevant and easily implemented considering technical, organisational and environmental constraints.
- Limits of dose-rate calculation for the optimal scenario definition: PANTHER-RP helps to calculate dose-rate considering some radiological sources for a specific workstation. It doesn't take into account the duration ok the task, i.e. it doesn't calculate a dose. Nuclear power plants objectives are express in terms of dose decrease for a specific outage, not in terms of dose-rate decrease. That is why the prototype tool currently being developed is very useful.

UTO is developing a global approach to achieve ALARA studies within this framework.

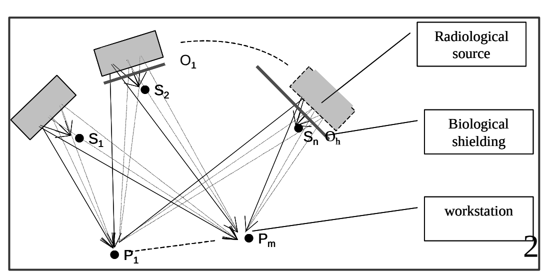
This approach is based on three steps:

- Environment attributes elucidation with PANTHER-RP: This enables us to define the radiological, physical and organisational environment in order to take into account all problem features.
- Optimum scenario selection with a prototype tool: The objective is, after having depicted the global scene, to define an ALARA scenario with the EDF-UTO prototype tool by picking up and combining different radiation protection options. The goal is to identify the one with the maximal global **dose gain** and minimal integrated dose for the shielding contractors. This scenario may then reviewed with the main stakeholders to take into account the technical and organisational constraints.
- On-site implementation, data collection and best practices assessment: The shielding is then implemented by the contractor and its efficiency is compared to the one expected. It is also very useful to collect data such as the time needed to install the shielding, its real efficiency, the environmental and job constraints and the associated risks.

Dose gains resulting from the 2006 methodology implemented in TRICASTIN, compared to the ones resulting from 2003 power plant practices are evaluated as equal to 30%. This also has organisational advantages. Possible impacts on nuclear safety and risk management have been identified and taken into account in the ALARA studies, to prevent them from arising. The targets of the methodology and prototype tool development is to extend this experimentation for every EDF nuclear power plant and to make the process more practical and industrial through random routines in the tool.

II. Environment characterisation

Maintenance jobs are carried out within a complex radiological 3D environment with multiple sources and workstations. Radiation protection options such as shielding are placed between the radioactive sources and the workstations. This can be represented in the following sketch:



The environmental characterisation is based on the radiological conditions description, the job definition (for maintenance and shielding contractors) and the radioprotection options characterisation (type, materials, logistical needs, …). The steps of the methodology are the following (the methodology described below is empirical and has not yet been totally implemented on-site):

A- Environment simulation with PANTHER-RP

1. Using PANTHER-RP, a 3D radioprotection software, a **geometric model,** based on installation design maps and technical specifications (civil engineering maps, isometric drawings, etc…) is designed by CAD specialists.
2. Then the radiological sources and their specific activities are fed into the model in order to define the **radiological context**:
    - First, the sources are labelled: one source is homogenous from a radiological point of view (same activity and same pipe or vessels).
    - Then, a generic radiological spectrum is used to define the activity of each source. This spectrum has been elaborated by the EDF-SEPTEN engineering department and is updated annually through in-site measurement campaigns.
3. The maintenance workstations are identified using the outage activities planning (for each activity, the local and the technical references of pipes and vessels maintained are listed). The shielding workstations are defined by the contractors or thanks to the data already gathered from prior outages. The workstations and other specific points (ambient dose rate, access areas, frequent path areas, etc), are then fed into PANTHER-RP as '**reception points**'.
4. PANTHER-RP is then used, with specific hypotheses (no water, no shielding, no thermal insulation), to calculate dose rates coming from each source for each reception point, thus determining the generic radiological reference context, represented in a **generic dose rate matrix**.
5. In order to implement real **on-site data** in PANTHER-RP, spectrometry data coming from annual measurement campaigns are used. Moreover, special radiological mappings are performed by EDF/UTO in order to collect dose rates in specific points (maintenance workstations, shielding workstations, ambient dose rate, access areas, frequent path areas, etc). Measurements are carried out at the radiological source contact (to prevent other radiological sources from influencing the measurement) or at 50 cm of the pipe or vessel to collect the workstation dose rate due to the overall sources.
6. These reactor building visits also enable us to list **important elements influencing the dose rate**: water level in pipes and vessels (water decreases dose rates by 30%), thermal insulation, hot spots or biological shielding,
7. All on-site measurements and data related to the 'real' on-site environment are then fed into PANTHER-RP to calculate the **updated on-site dose rate matrix**.

B- Radiation protection options selection with the EDF prototype tool

Caution: all the steps described below are empirical and need to be validated and implemented on-site. Methodology and tool are is still theoretical and will need further development to really be considered as industrial ALARA approach.

8. Each possible **radiation protection option** (water level management, equipment decontamination, system flushing, biological shielding, irradiating equipment removal, etc) **is characterised** in terms of type and nature, logistical needs associated (scaffoldings; shielding, etc), number of person required and the time exposure. For shielding, lead blanket numbers, thickness (6mm or 12mm), stationary support presence, best planning time-period for mounting and dismounting are also stated.
9. Using EDF prototype tool it may be achievable to calculate the **dose-rate reduction coefficient** for <u>each option</u> in regards of each source and workstation. The results are also displayed in a matrix (sources in lines and workstations in columns, dose rate reduction coefficient at the intersection) for each option. This dose-rate reduction matrix may be linked up with the updated 'in-site' radiological context in order to calculate the dose-rate with a specific radiation protection option.

III. ALARA studies

The aim of these studies is to help nuclear power plants to validate the implementation of radiation protection options during outage and thus avoiding dose transfer to shielding contractors.

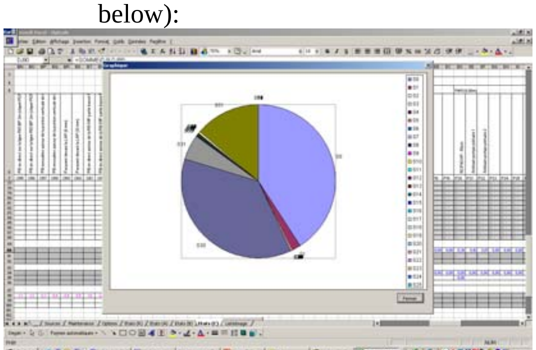
The studies are based on dose calculations:

- the integrated dose for the shielding contractors to implement the radiation protection option,
- the avoided dose for maintenance workers if these options are in place.

Their ratio, ie the dose gain, is one key point contributing to the decision to implement or not the option. But it is not the only one, indeed elements such as technical feasibility, technical and planning constraints or safety and work conditions are also taken into account and discussed with the stakeholders to ascertain that the option is worthwile.

The final decision, involving several actors, is the result of a global process as described below (this description is based on TRICASTIN's practices):

1. For a specific maintenance programme during an outage, maintenance workstations and the associated exposure time are listed and the integrated dose that is expected for each activity is calculated.
2. In order to reduce the dose-rates, several options are available such as water level management, equipment decontamination, system flushing, biological shielding, irradiating equipment removal etc. The impacts of each option in terms of dose-rate decrease are calculated with PANTHER-RP using a dose-rate reduction factor. The integrated dose for their implementation is also evaluated.
3. A combination of several options is then selected, based on three decision elements:
   a) **The sources' contribution to each workstation** (as shown in the graph below):



This graph helps to find out which sources contribute the most to the dose rate for a specific workstation.

   b) **The collective integrated dose gain of each radiation protection option**: the gain is the ratio between the avoided dose compared to the dose taken to implement the option. An empiric rule is to consider that an option is efficient if its gain is above 20%.
   c) **The order of option implementations**.

All these elements are expected to be directly available in the prototype tool that EDF/UTO is elaborating.

4. The final scenario, i.e. a list of selected radiation protection options regarding a specific maintenance programme, leads to a global dose decrease for the outage, also specified by activity. It is necessary to ascertain the relevance, efficiency and applicability of the scenario. Therefore, it is submitted to the nuclear power plant stakeholders: health physicists, logistic engineers, outage engineers, logistic contractors, etc, to confront it with technical, safety and organisational constraints.

IV. Options implementation and data gathering

During the options implementation by logistic contractors, EDF/UTO is present on-site, if possible, in order to gather data and advise the stakeholders if needed. This has several objectives:

1. **identify the real implementation conditions** (water level, heat insulation in place, etc),
2. **identify the options** that are correctly implemented, partially implemented, or not implemented at all,
3. **identify the difficulties** to implement the options as recommended (safety, work conditions, access conditions, lack of handlings means, etc) and collect the contractors' points of view, best practices or recommendations,
4. **identify the resources** (personnel, tools and means) precisely: scaffoldings, type and number of lead mattresses for example,
5. **obtain dose data** to adjust the geometric or the calculation model:
   a) identify geometric model mistakes or omissions in order to correct them for future outages,
   b) measure dose-rates at the different workstations and reception points

that have been used in the calculation model (without radiation protection options) in order to update them or detect potential uncertainties that may have had an impact on the final decision,

c) measure dose-rates at the same points, after implementation of the radiation protection options, in order to finf out if the calculated dose-rate reduction coefficient is close to the one measured,

d) Measure or fetch the duration of the exposure for each options,

e) Collect the integrated dose for each option through PREVAIR, an EDF tool that enables power plants to prepare controlled area activities and prevent radiological risks, and also collect feedback data. The PREVAIR results analysis is useful to compare the calculated integrated dose with the ‘real’ one to define the loss or gain due to correct or partial option implementation.

V. The advantages of the methodology based on TRICASTIN example.

All the collected data enable EDF/UTO to compare, for a standard outage, the collective integrated dose for maintenance workers and for logistics contractors whether or not they apply the methodology described in this paper. Indeed, in 2003, EDF/UTO studied an outage in TRICASTIN in terms of radiation protection options implementation and collected the data listed above. The conclusion was that the options selection was mainly empirical or based on habits. With the EDF/UTO ALARA theoretical methodology in the same context, an optimised option selection has been carried out, based on dose gain calculations. The dose decrease was evaluated (without the EDF prototype tool) as approximately equal to 30%. This progress, based on TRICASTIN example, is due to:

1. **Contributing sources identification**: the radiological context evaluation prior to the ALARA study helps to decipher which sources have most impacts on the workstation dose rate, thus giving clues on which sources should be protected first.
2. **More radiation protection options**: more biological shielding is recommended, thus decreasing the workstation dose-rate for a minor dose increase for the shielding contractor.
3. **New radiation protection options**: tool progress and new implementation techniques enable the contractors to protect the radiation source at the closest.
4. **Justification of the lead mattresses’ thickness from 6 mm to 12 mm**: calculations show that 12mm lead mattresses do not increase the shielding contractors’ dose much, but drastically decrease the global integrated dose at each workstation.
5. **Optimal scenario definition**: this consists in selecting only the option with the highest dose reduction with minor dose increase for the shielding contractors. This selection prevents from contractors’ dose transfer.
6. Thanks to **mechanical stress calculations** it is now legitimate that we may directly put a biological shielding on a pipe without specific support during an outage. This is an important time reduction means for the shielding contractor.
7. **Permanent shielding support**: several nuclear power plants have installed fixed structures in the reactor building in order to prevent scaffolding installation for biological shielding. This reduces the exposure duration for the shielding contractors by approximately 50%.

Meetings with all stakeholders, including the outage manager, also has the advantage, beyond the constraints identification and a secure communication between all involved parties, of defining the best calendar for shielding installation and removal. This also prevents non-authorised shielding removal. Indeed, if shielding is installed prior to a specific maintenance activity, such as pipe radiographic inspection - requiring the pipe to be directly accessible, it is often removed by the maintenance workers and not re-installed at the end of the job.

VI. Conclusion

The ALARA approach that is being developed by EDF/UTO is mainly based on three aspects:

- the **use of PANTHER-RP software** that enables us to seize the radiological 3D environment.
- The **use of a prototype tool ta calculate dose gain** for multiple sources, multiple workstations and multiple radiation protection options, thus permitting an optimal ALARP scenario selection based on PANTHER-RP calculations,
- The **involvement of several nuclear power plant stakeholders**, giving us major informations on the environmental, technical and organisational constraints and to help determining optimal shielding installation planning.

These elements may lead to **encouraging collective integrated dose decrease** compared to the historical and empirical approaches that were previously implemented on-site. But the approach presented above is still empirical and need further development and on-site validation. Key points are still being studied in order to make the methodology and the prototype tool really considered as industrial. A simple version that will be tested on site is due in 2 years. It will be tested on a real outage in Tricastin in 2010.

References

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