The revival of nuclear power and radioprotection challenges

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Prospects for the development of nuclear power

The international community is currently faced with a rise in electricity consumption world wide and the control of the greenhouse effect necessary in an energy environment where the price of oil has risen for good and hydrocarbon deposits are expected to run out. The International Energy Agency is expecting a 60% increase in energy consumption by 2030. Control of climate warming will increasingly constrain countries to rely on fuels which do not emit CO_2, particularly in electricity generation. Renewable forms of energy, which do not emit CO_2 (solar and wind energy, etc.) cannot, however, form the basis for a country's electricity generation and it will take a number of years for them to have a significant place in the world energy balance. Hydrocarbon resources should run out within 40 years, in the case of oil, 70 years for natural gas and the price of a barrel of oil reached the $100 mark in December 2007.

Against this backdrop, a growing number of countries consider that nuclear power could be an answer to future energy needs. On the new world energy scene, electricity generation by nuclear power plants has therefore become very competitive compared with coal and gas.
At the end of 2007, 25 reactors were under construction in the world, ¾ of them in Asia, while the World Nuclear Association counted a total of 220 projects at the study stage. It is estimated that by 2020, prospects for commissioning new nuclear generation capacities will stand at 160 GW. Such development will indeed imply significant challenges in the area of radiation protection.

With its fleet of 58 nuclear plants, France's rate of energy independence has now reached 50%, against 23% in 1973. 66% of generation capacity is provided by nuclear energy and 21% by hydraulic and renewable energy. In 2007, over 80% of electricity generation was nuclear in origin. France's nuclear power generation puts it in a good position in efforts to control CO2 emissions: 50g/kWh as against 400g/kWh on average in Europe.

Plants are designed with a lifespan of 40 years. An increase in lifespan beyond 40 years is technically possible for elements considered non-replaceable. There is logically no technical reason preventing the plants in the EDF fleet from reaching life spans comparable to those planned today for reactors of the same type world wide and EDF is working along these lines.

The building of the EPR in Flamanville (Normandy - FRANCE), where work on construction of the nuclear island started in December 2007, is a major asset for positioning the Group in nuclear generation revival projects world wide.

This nuclear revival world wide gives EDF the opportunity to be one of its relevant stakeholders. EDF wants to be an investor and industrial partner for the construction and operation of new nuclear power plants in Europe and worldwide. It will go into countries choosing the nuclear option in the short term, which are well disposed to EDF's efforts. Four priority countries have been chosen by the Group, where the nuclear revival will be played out in the short term: the USA and China, where strategic industrial agreements were signed in 2007 under nuclear equipment programmes, the United Kingdom, where the government has embarked upon a process of building new plants and South Africa where EDF has cooperation links going back a long time.

The nuclear revival in the world requires nuclear safety and radiation protection to be impeccable and faultless. In these two areas, experience shows that we need to seek constant progress, otherwise the workers' commitment and standards tend to naturally erode. This presentation aims to show how Radiation Protection has progressed in EDF over the last 20 years and the targets set to factor in new challenges.

Radiation protection achievements and performance

1/ Collective radiation exposure

The implementation of the ALARA (As Low As Reasonably Achievable) approach has been compulsory in France since the end of the 80' (French decrees of 1986 and 1988 on the protection of staff against ionizing radiation). The regulation thus states that "equipment, processes and and work organization have to be designed and organized in such a way as to maintain individual and collective staff radiation exposure as low as reasonably achievable". Unforeseen technical problems concerning the control rod guide tubes on Bugey unit 3, then on all the fleet, acted, in the 1990s, as a catalyst for the ALARA approach introduced by EDF as early as 1992.

The approach involved EDF management and workers, but its contractors very quickly became also stakeholders in the approach. In 1997, a charter signed between EDF and its contractors put Radiation Protection among the priorities. The 23,000 EDF personnel and the 20,000 outside contractor personnel are all subject to the same requirements in planning, prevention and control of the effects of ionising radiation.

For 10 years, from 1992 to 2002, considerable progress was made thanks to this ALARA approach. In particular the major high dose jobs were identified and recommendations or good practices applicable to all sites were drawn up on the basis of operating experience. The 1998 statutory changes strengthened this work by the systematic introduction of dose planning and an optimised approach.

In 2002, while the optimisation campaign was continued, an initiative was undertaken to reduce exposure at the source. It was based on 2 parts: a “polluted unit cleanup” project and zinc injection experiments.

There were big differences in radiation exposure results between units in the EDF fleet. Despite preventive and remedial efforts to control radiological contamination of systems, actions undertaken locally by nuclear sites, high collective doses were recorded on certain units. Improvement at the units with the highest doses was crucial if the overall reduction in doses expected in the management of radiation protection at EDF were to be obtained.

In 2003, to deal with the units with the highest doses based on an overall approach, the DPN (Generation Nuclear Power Operations) decided to introduce a “polluted unit cleanup” project. Cleaning up units is an important tool in reducing the source term of units in operation. In this context, four units for which the integrated dose was far higher than average, were chosen - Chinon B2 (2004), Flamanville 1 (2006), Gravelines 3 (2007) and Bugey 2 (2008) – to return them to a satisfactory radiological condition (average for their type). Dealing with these priority units represents investment of around €1m for EDF.

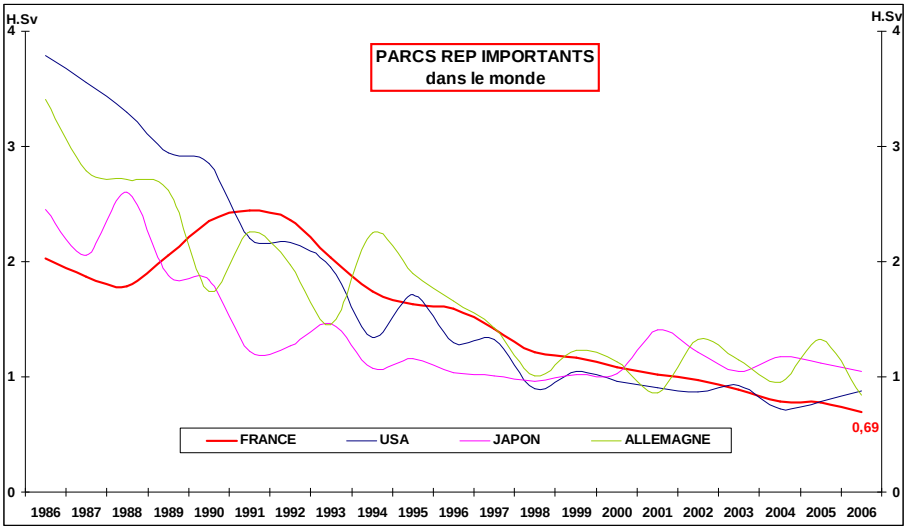
An action plan specific to each unit is drawn up based on the different data input items provided by the 4 units concerned and resulting from analysis of the radiological status of the unit (origin of the pollution, actions taken on the site, etc.), as part of an overall approach.

In order to determine the dose reductions achieved thanks to decontamination activities and justify these operations, calculations are made using the PANTHERE code (EDF – home made software).

The concrete results of a unit cleanup can be illustrated by those of Chinon unit 2 (see appendix 1). A series of measurements, undertaken over the last two years, confirms the absence of recontamination of systems treated in 2004.

As a result of international operating experience, experiments on zinc injection to reduce primary system contamination have been conducted on Bugey units 2 and 4, since 2004 and 2005, respectively. Bugey unit 2 was chosen for being significantly contaminated by cobalt.

Initial results seem to show a reduction in Co60 of around 20% on Bugey units 2 and 4, after 3 injection cycles. As regards unit 4, the first cycle after the steam generator exchange is under way and will finish on 26 July 2008. The impact of zinc on the prevention of post-steam generator exchange recontamination phenomena will be quantified through gamma spectrometry measurements.



To summarise, the efforts by EDF and contractors have reduced collective radiation exposure by a factor of four per reactor in nearly 15 years (from 2.44 M.Sv in 1991 to 0.63 in 2007).

2/ Individual radiation exposure

EDF also places great importance on individual radiation exposure, since, for the individual, this is what counts. Progress can be measured through the following data:

- in 1992, 1200 workers, EDF or contractors, recorded annual doses above 20 mSv, against none as from 2004,
- in 1998, 125 workers recorded doses between 20 and 18mSv, against none as from 2004,
- In 2001, 92 workers recorded doses between 18mSv and 16 mSv, against 2 in 2007,
- Finally, the average individual dose dropped from 4.6 mSv/year in 1992 to 1.47 in 2007.

However, progress only makes sense if it benefits the most exposed populations as a priority. Analysis of individual doses according to category of craft showed that insulators were the most exposed population. The collective dose of this population remains high (around 11 to 12% of the collective dose for contractors during outage), directly related to the large volume of activities. A study on working conditions in conjunction was conducted with ergonomists.

This study led to actions consisting of several phases, designed to reduce the dose and hardship of the work.

The population of heat insulators still receives the highest dose in the fleet, with an average individual dose in 2007 of 3.31 mSv (against an average of 1.47 for the fleet), but a real downward trend can be noted. Activities which had been identified by ergonomists as particularly hard and involving high doses were carried out under relatively good conditions on the 2007 worksites.
Finally, insulation removal/installation operations, during hydraulic tests, have shown a very clear improvement. For example, below is the change in collective radiation exposure for insulators on the Paluel site:

Year	Unit	Main primary system index	Collective dose for insulators (M.Sv) on main primary system hydraulic testing
2005	2	0.3	0.235
2006	1	0.5	0.240
2007	3	0.3	0.145

**The RCP index is representative of the contamination level in the primary loops. This index is the average of contact dose rates, still in the same conditions.*
The higher the index (0.5 being a strong index), the higher the radiation exposure. This applies specifically for heat insulation workers working on the primary loops.

3/Control of high risk situations

EDF has paid a great deal of attention to the management of high risk situations, in particular places with high dose rates called red areas (dose rate above 100 mSv/h) and gamma ray tests.

Concerning red areas, in addition to the requirements of French regulations, EDF has set out additional requirements to be adhered to in all plants:

- All red areas must be locked. A red area where it can be guaranteed that the dose rate will remain below 100 mSv/h during the period of the work activity can be declassified, if it is necessary to access the area, but the dose rate must be guaranteed for the whole period of declassification,
- Red area rooms must be identified and managed. All accesses to a red area (doors, hatches, inspection ports, etc.) must be identified and made impossible to open by a double locking system. Access to red areas can only be gained through 2 different keys which must be used simultaneously by 2 people, one of whom comes from the department competent in radiation protection. There is a procedure for managing each of these keys, applicable to everyone, including the plant manager:
    - the 2 keys cannot be held by or entrusted to the same person,
    - the first key is given to the department competent in RP. It can only be used upon written instruction by the plant manager or his delegated representative,
    - the second is held by the plant manager or his delegated representative.

- As part of declassification operations, the following requirements apply: a risk assessment has to be carried out and the related counter-measures defined, the opinion of the department competent in radiation protection and the agreement of the plant manager or his delegated representative have to be obtained and the radiological conditions at the opening of the red area have to be validated by the department competent in RP, as a prerequisite to any access.

In 2007, these lines of defence were completed by an increase in the application of human performance tools to situations with a radiation protection risk.

As to the control of another high risk situation, gamma radiography, the incident which occurred in a French NPP (Blayais) in April 2001 (a gamma radiography operator integrated a dose of 16 mSv during a test) raised awareness of the problem and the potentially serious consequences related to this activity.

An initial series of essentially technical measures (e.g.: dosimeters with alarms compulsory for operators within and outside the RCA) was then decided upon in 2002.

Then, thanks to an ergonomic study, technical facilitation and safety measures were improved (trolleys, luminous barriers, sentinel barriers, etc.), as well as the human, organisational and managerial aspects of the activity.

Standardisation of radiography permits, the drawing up of standard barrier and markoff plans, the radiologist's charter and the concept of radiography with specific risks are important items pertaining to the improvements introduced in 2005; in addition coordination and scheduling elements were implemented in 2007.

At present, the requirements on this matter are extremely wide-ranging. Even so, a general audit carried out this year shows that over 53% of them are in place. Likewise, "events" where a part of these requirements is not implemented, are now:

- 14 red area events in 2007, for the EDF fleet as a whole,
- less than 20 "radiography testing" events in 2007, out of 30,000 annual tests.

Future challenges for radiation protection

It is clear that progress over the operational fleet must be continued.

The quest for progress in collective radiation exposure will require continuation of the cleanup program: either of units or specific systems. The stated aim for the next part of the cleanup is to study the decontamination of "target" systems on all units of the fleet. This requires good knowledge of their radiological status. The zinc injection experiments will also be continued. In addition to these actions, work on individual radiation exposure will be continued.

As for control of high risk situations, in particular management of red areas and gamma radiography testing, our rationale is no longer based on development in regulations or requirements, but on the necessity of ensuring that all workers know and apply the standards. The role of the management is crucial in terms both of the guarantee that workers are trained and of measures for checking the implementation of the processes defined for controlling risk.

However, at the same time, 3 major challenges are ahead of us:

- Renewal of skills (succession planning), within EDF as well as within French nuclear entities, with the retirement over the next 10 years of the actors who have driven progress over the last 20 years. If we are not careful, this change in generation could lead to a backward trend: hence, the importance of anchoring radiation protection in our industry's culture.
- The addressing of radiation protection arrangements in countries turning to or increasing the role of nuclear power, benefiting from those of the most advanced countries and encouraging continuing progress. EDF is ready to engage in sharing experience with all regarding the improvements achieved over these past 20 years.
- The general adoption of radiation protection practices in all professions using ionising radiation, since a lot is to be gained from this optimisation: recent research has shown that by merely properly adjusting radiogenic devices in one French region, the equivalent of the dose received annually in the whole of the EDF fleet could be "saved". This challenge goes way beyond EDF's reach but also explains our presence among the community members of radiation protection experts.

We consider that these challenges will require the commitment of the whole world radiation protection community and that there is a lot more to be gained in responding to them than in further increasing the statutory framework.

Appendix 1

Results of the Chinon unit 2 cleanup

The average exposure rate during outage (an indicator corresponding to the collective operational dose divided by the number of hours spent in the RCA in a given outage) has dropped, as shown in the graph below. This indicator has been constantly falling since the 2002 refuelling outage.