Plant Life Extension
Recent Developments in EDF’s Nuclear Fleet

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EDF NUCLEAR POWER PLANTS FLEET

58 reactors in operation
1 reactor (EPR) under construction
Technology : PWR
Spread out over 19 sites

- Nuclear generation = 80 % Total Electricity Generation

<table>
<thead>
<tr>
<th>NPP</th>
<th>PWR 900 MW</th>
<th>PWR 1300 MW</th>
<th>PWR N4 1450 MW</th>
<th>EPR 1630 MW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nb Unit</td>
<td>34</td>
<td>20</td>
<td>4</td>
<td>1 under construction</td>
</tr>
</tbody>
</table>
### Status of the french NPP’s

<table>
<thead>
<tr>
<th>Model</th>
<th>1st 10 yrs Visit 10 yrs</th>
<th>2nd 10 yrs Visit 20 yrs</th>
<th>3rd 10 yrs Visit 30 yrs</th>
<th>4th 10 yrs Visit 40 yrs</th>
</tr>
</thead>
<tbody>
<tr>
<td>900MW (34)</td>
<td>completed</td>
<td>completed</td>
<td>2009 à 2020 (18 completed)</td>
<td>2019 à 2030</td>
</tr>
<tr>
<td>1300MW (20)</td>
<td>completed</td>
<td>Completed end of 2014</td>
<td>2015 à 2024</td>
<td>2025 à 2034</td>
</tr>
<tr>
<td>1500MW (4)</td>
<td>completed</td>
<td>2019 à 2022</td>
<td>2029 à 2032</td>
<td>2039 à 2042</td>
</tr>
</tbody>
</table>

- End of 2013, 5 Units (900 MW series) formally authorized for 10 years beyond 30 years with special requirements to be performed (exemple basemat thickening at Fessenheim)
- In the US, 73 units out of 100 reactors in operations have been granted a license extension up to 60 years.
A NON-REPLACEABLE MECHANICAL COMPONENT : REACTOR VESSEL (1/1)

- **Status for lifetime up to 40 years**
  - **900 MW Units.** Vessel Safety Case accepted by the regulator (ASN) in June 2010 for all units with the provision of in service inspection and controls during the 3rd 10 years outage.
  - Satisfactory inspections and controls for the 18 first units including TRICASTIN 1 which is inspected every 5 years.
  - **1300 MW Units.** Safety Analysis file sent to regulator (ASN) in March 2013. Regulator’s Position expected in 2015 for beyond 30 years.

- **Favorable features of French Reactor Vessels**
  - Steels chosen for their capability against irradiation induced embrittlement, extensive fabrication controls, in service inspection and controls every 10 years since the beginning.
  - Low “transition temperatures” for 900 MW units at 40 years: 60 to 90°C with respect to US Units at same age (130°C)
The two major ageing mechanisms:
- Irradiation embrittlement of the core shells
- Thermal ageing of the nozzles

EDF Prognosis: Expected End Of Life 60 years
- Good quality of design and manufacturing
- Detailed ten year controls, from the beginning
- Good experience feedback.
- Regulator’s first generic position beyond 40 years expected for 900 MW Units in 2015

Long term operation strategy
- EOL prognosis based on a deterministic conservative approach
- State-of-the-art methodologies (mechanics & thermal-hydraulics)
- Mitigation and surveillance actions
  - Low leak core management
  - Irradiation surveillance program on-site (capsules)
- Optional: if necessary beyond 40 years, increase of safety injection temperature
A NON – REPLACEABLE CIVIL WORK COMPONENT : CONTAINMENT

900 MWe series
Simple wall + liner

1300 MWe and N4 series
Double wall

- Ageing phenomena studies
- Periodic pressure test (every 10 years) at design pressure
- Technological solution under development
REPLACEABLE COMPONENTS

SG Replacement

I&C Modernization

Condenser: Renovation of
1. Tube Bundles of some units
2. Cleaning System

Renovation of Main Turbine LP Cylinders

Replacement of Unit Transformers and Metal-clad Substations

Replacement of Cooling Tower Packing

Main Generator
1. Rotor Renovation
2. Stator Replacement

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The French 2006 law (TSN) and the regulatory context

General policy: continuous improvement of nuclear safety, with regard to the state-of-the-art of scientific knowledge, to the worldwide operation feedback, and to the safety improvements of new reactors

Periodic safety review (PSR) every ten years for each unit

No limited licensing life time but advice by the French Nuclear Safety Authority, on a case by case analysis for each unit, to operate for another ten year period. Generic approval for 900 MW units given in 2009 for operation beyond 30 years.

Numerous modifications already implemented on the plants (after TMI, Tchernobyl, Blayais site storm in 1999, summer heat wave in 2003, ...). Among them: sand filters on containment (1986), Hydrogen recombiners, new concept of emergency procedures, man-machine interface (N4 series), etc...
EDF safety goals for long term operation

As far as reasonably practicable

For design basis accidents, mitigating its consequences and avoiding radioactive releases that would require off site emergency measures (iodine ingestion, evacuation)

Continuing to reduce the risk of core melt, already divided by ten since the commissioning of the plants in case of internal events

Significantly enhancing plant resistance to hazards

Minimizing time and space-related countermeasures in the event of a severe accident, making use of the important modifications required by the regulator (ASN) as part of the post Fukushima EDF action plan
Taking into account Fukushima’s event

Following the Complementary Safety Assessments performed by EDF, the French Safety Authority (ASN) issued the following statement (January 2012):

• "the ASN considers that the plants show a level of safety sufficient that enables her not to ask the immediate shutdown of any of them.

• At the same time, the ASN considers that it is necessary to increase, in a time as short as possible, beyond the safety margins already in place, the robustness of the plants to cope with extreme situations.”

A three step post-Fukushima EDF action plan submitted inside the French action plan to the European Peer Review Exercice of 2012
STEP 1: 2012-2015

- Coping with situations of water and electricity losses more severe than today (several units of a site, long duration)

- By the use of crisis means and provisory modifications
  - Mobile devices (pumps, pipes, generators…)
  - Provisory modifications (diesels generator on the roof of the electrical buildings, nozzles …)
  - Upgrade of the crisis organisation
  - Automatic reactor shutdown in case of earthquake
  - Earthquake and Flood protection reinforcement (SMS and CMM)
STEP 2 : 2015 – 2019

- Coping with situations of water and electricity losses more severe than today by design changes, anticipated vs. initially planned for lifetime extension programme

  - Construction of the DUS (ultimate back-up diesel generator)
  - Implementation of ultimate water supply
  - Protection against extreme flooding
  - Construction of new Local Crisis Centres (CCL)*
  - Filtration system reinforcement against earthquakes
  - Passive tight seals for primary main cooling pumps (if qualified)
  - Reinforcement of shift teams on the NPPs (ability to manage a Fukushima situation by their own)

*first : in 2016 (Flamanville). For the following : planning under study (end after 2019)
STEP 3 : FROM 2019 (AS PART OF THE FLEET LIFE EXTENSION)

Completion of the hardened safety core

- Implementation of the step 3 from 2019 onwards:
  - SG residual heat removal (dedicated feed water pump, dedicated SG tank, ultimate water supply)
  - Ultimate primary injection pump
  - Containment residual heat removal
  - Extreme earthquake and flood requirements

- The implementation of the three steps of the post-Fukushima action plan makes it possible to reach on the existing fleet in operation a safety level as close as reasonably practicable to the safety level of Generation 3 reactors. This is a requirement of the French Safety Regulator (ASN) to extend the operating life of the plants beyond 40 years.

- Ongoing discussion with ASN since 2008; letter of June 2013, important work programme between now and 2019: 4th 10 years outage of Tricastin 1 Unit
THANK YOU
3 STEPS TO IMPLEMENT MODIFICATIONS

**STEP 1**
Mobile means, Transitory means, FARN

- Mobile means, connecting points, transitory diesel...
- Licensing process
- Ultimate water system (first part)
- Other modifications

**STEP 2**
First elements of the hardened safety core

- Ultimate Diesel Generator
- Ultimate water system (end)
- Emergency Control Centre
- Other modifications

**STEP 3**
Hardened safety core

- Licensing process
- Deployment

2012 2013 2014 2015 2019 2025

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The Materials Ageing Institute for R&D relative to plant life extension

- Need for Predictive Capability for
  - Inspections
  - Mitigations
  - Replacement

- Through Mechanistic understanding of ageing processes

- 80 Researchers and technicians involved
- 20 universities / institutes associated
- 11 M€ annual budget in 2013
- 11 Members representing 66% NPPs
- 35 M€ total EDF’s Investment (2008-2016)
- 250 participants yearly in the E&T program