www.nugenia.org

# NUGENIA+ / WP6.11: INTEGRID : Impact of the new Grid Codes on the local distribution network of Nuclear Power Plants

**Presenter: Michel Rioual** (EDF, michel.rioual@edf.fr)

François Duffeau (EDF), Kostas Kopsidas, Robin Preece (UNIMAN), Waldemar Geissler, Jimmy Lorange (AREVA), Ignacio Marcelles, Sarah Ruiz (TECNATOM)

NUGENIA+ Final Seminar, Helsinki 29-31 August, 2016

NUGENIA is mandated by SNETP to coordinate nuclear Generation II & III R&D

www.snetp.eu

*This project has received funding from the Euratom Seventh Framework Programme under grant agreement No 604965.*

# Summary


- 1. Introduction
- 2. Objectives
  - Scope
  - Partners
- 3. Tasks
- 4. Results
- 5. Dissemination
- 6. Impact
- 7. Conclusions
- 8. Next steps

# 1. Introduction (1)

- New GridCodes developed requiring increased flexibility from existing power plants, including NPPs

- Aim of the greater integration of Renewable Energy Sources (RES)

-The INTEGRID Project (March 2015 -August 2016) addressing this topic

- Important topic considering the percentage of the Nuclear production in Europe (nearly 30%)

- Elements also for the integration of future NPPs in the next decades in the energy mix, involving different kind of production means (nuclear, hydraulic, wind, photovoltaic, etc…).

# 1. Introduction (2)

- **Description in the NUGENIA and NUGENIA+ frames.**

- **The INTEGRID project developed in NUGENIA+ under the NUGENIA frame**
- **A connexion in those platforms, on the following points:**
  - **-Improve modelling of phenomena in NPPs**
  - **-Prepare the future to avoid technology obsolescence**
- **A link with the SRA (Strategic Research Agenda)**
  - **-Area 1: « Plant safety and risk assessment »**
  - **-Sub_area 1.4: « Effect of electrical Grid disturbances »**
- **Also new equipment mentionned, as « modern electronics » and « digital equipment »**
- **In accordance to the « Safety Vision » of the SRA: « need for safety research expressed by the main stakeholders, including TSOs ».**

# 2. Objectives

## 2.1 Scope/Description of the Integrid Project

- 14 Items identified addressing electrical, mechanical, and thermal aspects.
- Network addressed:
  - Power delivery at the primary side of the auxiliary transformer
  - Distribution at the secondary side of the auxiliary transformer
- Two distinct but linked subnetworks

## 2.2 Organisation

- 4 Partners

- Two Milestones and 2 Deliverables
- Kick-off meeting held in Paris in May 2015
- Meetings in Madrid (Oct. 2015) and Manchester (April 2016)

# 3. Tasks (1)

## 3. Description of the 14 items.

### 3.1 Description of the different items

- *New grid codes and past / review* (***Item 1*** / ***EDF***)
- *Impact on the stability aspects* (***Item 2 /UNIMAN***)
- *Stresses on generators /fluxes, thermal* (***Item 3*** / ***EDF***)
- *Stresses on generators / vibrations /* (***Item 4 / TECNATOM)***
- *Development of tools / existing ones and new developments* (***Item 5 / EDF, UNIMAN***)
- *Measurements on generators/data acq.* (***Item 6 / TECNATOM***)
- *Development of monitoring systems* (***Item 7 / TECNATOM***)
- *Mitigating solutions for the generators / equipment* (***Item 8 / EDF***)
- *Mitigating solutions for the generators / network issues* (***Item 9 / EDF***)
- *The distribution network of the NPP and its main equipment/list* (***Item 10*** / ***AREVA***)

# 3. Tasks (2)

- *Impact of the new Grid code on the Distribution Network / consequences and studies to be performed (**Item 11**/**EDF and AREVA GmbH**)*
- *Evolution of the electric Distribution equipment installed in NPPs in the last decades, including new technologies and DC aspects (**Item 12**/ **AREVA GmbH**)*
- *Impact of new equipment on the Distribution Network / studies to be performed (**Item 13**/ **AREVA GmbH**)*
- *Design and operation Recommendations (**Item 14**/ **All**)*

## 3.2 Description of the work performed

- *9 items selected and developed in the first part of the Project*
- ***Five examples given below** (items 1, 2, 5, 6 and 11)*
- *Remaining items and perspective in Deliverable 2/August 2016.*

# 4 Results (1)

## 4.1 New Grid codes and past/review (item 1)

❖ **Review of past and newly grid codes provided by the ENTSO-E :**

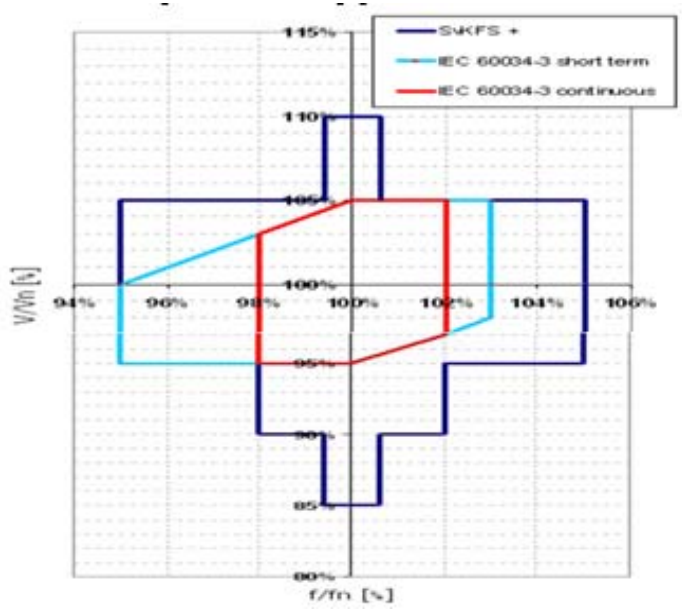


**Figure 1**: GridCodes (old and new frames)

❖ **Stresses in term of voltage or frequency may be higher inside the NPP, with contractual values at the Delivery point and a maximum value of 1.10 p.u.**

❖ **Impact of frequency ranges on the stability of generators connected to the network.**

# 4. Results (2)

## 4.2 Impact on the stability aspects addressed by the new Grid-codes (item 2)

- Case study developed by UNIMAN on a 1000 MW NPP, with regulations for generators derived from IEEE standards.

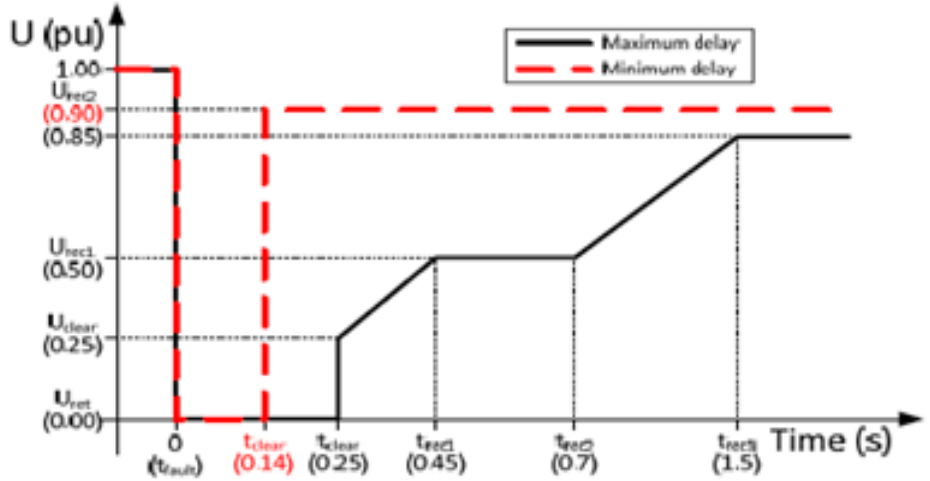


**Figure 2:** Fault ride through (FRT) in the ENSO-E grid code.

- In the worst cases, the frequency quite close to the upper margin of the codes; additionnal studies to be required.
- Influence of the voltage also to be determined, prior to the faulty conditions.

# 4. Results (3)

## 4.3 Development of tools and codes (item 5)

- **Use of tools in order to adresse this topic, an important issue; different types of electrical tools to consider:**
  - Impact on the stability system, when new frequency ranges must be considered (PSS/E type programs).
  - Impact on the fast transient phenomena in networks and their impact on the equipment (EMTPs programs)
  - Impact on the non-linearities involved in electrical networks (AUTO type programs).
- **Development of software code and algorithms, also an important issue to consider.**
  - Automated analysis of the stresses generated in the equipment, as fluxes, temperatures and vibrations.

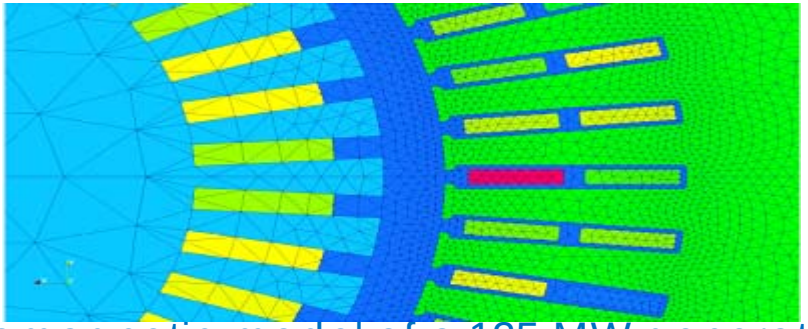

**Fig 3:** 3D electromagnetic model of a 125 MW generator (Carmel code).

- A point linked to item 8 « Mitigating solutions for the generators ».

# 4. Results (4)

## 4.4 Measurements on Generators and NPPs main equipment / sensors (item 6)

- Investigation made through simulations using training and engineering NPPs simulators connected to the electrical Grid.
- Possibility to gather measurements issued from elementary systems Hydrogen, Electrical, etc…), and the acquisitions of many sensors (temperatures, vibrations, etc…)
- Scenarios consisting of introducing transients from the high voltage Grid side and starting from normal operating conditions.

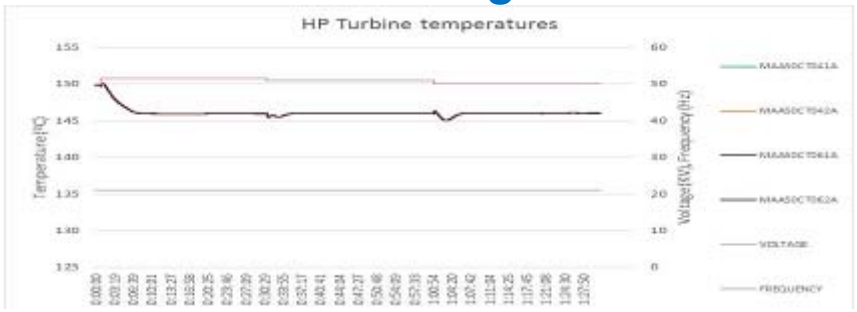


**Figure 4:** HP turbine temperatures considering a case of a variation of the frequency from 51. 5 Hz to 51 Hz (30 mn)

- Preliminary studies showing that changes in frequency may be the most critical issue
- Necessity to incorporate new (actual or virtual) sensors for a detailed analysis, and also address critical locations.

# 4. Results (5)

## 4.5 Impact of the new Gridcode on the Distribution Network/consequences and studies to be performed (item 11)

- Different variations of the Single Line Diagram, depending on the safety and process requirements and national standards.

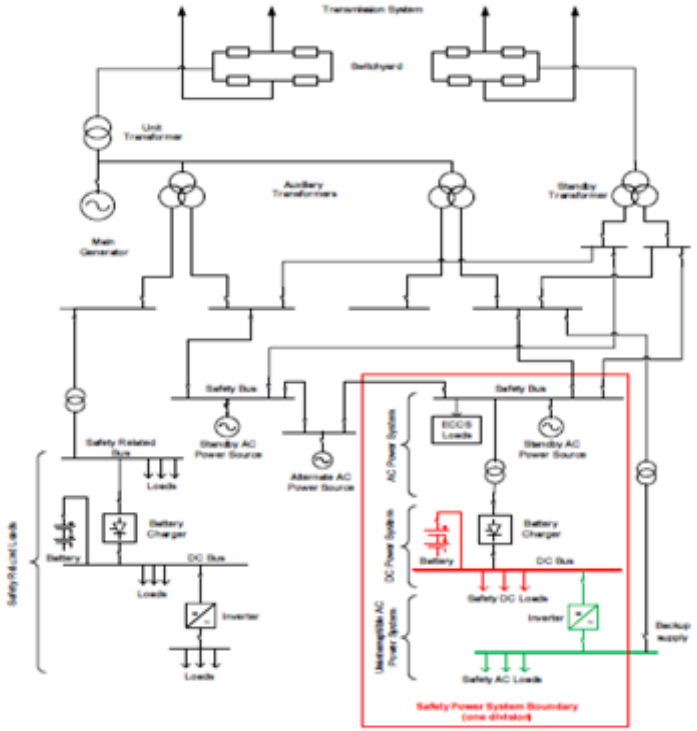


**Figure 5:** Single line diagram of a 1000 MW NPP implemented

- New steady-state conditions on the equipment (auxiliary transformer, cables, MV/LV transformers) implying PD devices.
- List of electromagnetic transients and their possible impacts.

# 4. Results (6)

## 4.6 Description of relevant points addressed in the Project.

- Detailed description of each item, especially the points to be adressed for further detailed studies.
- Items written by experts in their area, with complementary skills (University, Designer, Utility, Nuclear expertise)
- A list of tools provided (stability and transient programs, 3D codes, non linear tools) with the main points to be addressed
- First simulations made showing that the new Grid-Codes may affect the actual functionning of the power plants
- A list of monitoring systems to be installed
- A description of the studies to be performed considering their impact of the equipment of the Distribution electrical system
- More than 150 references provided considering the topics covered.

# 4. Results (7)

## 4.7 Future developments

- Further to the actual Project, further aspects (transformers, etc…) may be considered in the future.
- Description of those points in the Deliverable 2 of the Project.
- Further to their description, they could be illustrated in the future through detailed studies, a good way to address the topic on specific cases which could be generic for other NPPs.
- In that aim, a proposal made concerning this topic, called also « MORE INTEGRID » in the Project, adressed initially in the NUGENIA Platform as a « Template 2 ».
- Possible answers to future calls (Euratom ones or H2020), from September 2016.

# 5. Dissemination

- **Publications :**
  - Sociedad Nuclear Espanola , 42 REUNION ANUAL , 28-30 septembre 2015
  - IEEE General Meeting 2017, July 2017, Chicago
  - Others (CIGRE, etc…..)

- **Presentations:**
  - AIEA, Technical Meeting, Amsterdam, June 2016
  - AIEA, Technical Meeting, Zagreb, September 2016
  - IEEE General Meeting (Panel Sessions_2017)
  - Others (to be defined)

# 6. Impact

- **Scientific :**
  - New challenges as new subjects to be addressed, especially when the equipment is highly stressed
  - New tools or existing ones with improved capabilities
- **Industrial :**
  - Upgrade of the existing equipment
  - New specifications and also tests
  - New equipment
- **Societal :**
  - Sustainable Nuclear Energy
  - A step for the integration of the NPPs in future energy mix; discussions between Producers, TSOs, ENTSO-E

# 7. Conclusions (1)

- Description of the Project « INTEGRID » and new challenges
- Description of the Objectives of the Project, with 14 points addressed
- Deliverables 1 and 2 provided by the end of December 2015 and August 2016 respectively, with contributions provided by the different Partners, in the area of their expertise, with complementary skills.
- Main points described, as detailed description of each item, list of tools, more than 150 references provided.
- Dissemination and impact addressed
- 2 Milestones (kick-off meeting of the Project and presentation at the NUGENIA+ Meeting in Paris).
- 3 meetings held (kick-off in Paris in May 2015, at TECNATOM/Madrid in October 2015 and at UNIMAN/Manchester in April 2016).
- Next steps

# 7. Conclusions (2)

- Technical aspects:

- Impact on the stability and stresses generated close to the limits defined by the ENTSO-E Grid Code in the case of faulty conditions. A point to investigate in the future with more detailed modelling (electrical network, regulation of machines, etc…).

- Higher vibrations reached in the turbogenerators. A point to investigate in the future, having a link with the reactive power.

- Simulations performed using different scenarios involving the frequency and also the voltage at the TSO side; increase of the temperature in the components (generators, step-up transformers, also the bearings); possible trippings of some components if the frequency levels go below certain values and durations.

- Additionnal sensors needed in the future and also other scenarios; improvement of simulators with additionnal variables.

# 8. Next steps

- Examination of H2020 Calls (April 2017) and possible proposals with additionnal Partners, starting from the existing team.
- Participation to IAEA Activities
- Publications
- Others

European Commission

EURATOM

NUGENIA
NUclear GENeration II & III Association

www.nugenia.org

# Thank you for your attention

NUGENIA is mandated by SNETP to coordinate nuclear Generation II & III R&D

SNETP
Sustainable Nuclear Energy Technology Platform

www.snetp.eu