Lessons not Learned from the Fukushima Accident

Risks of the European NPPs

10 years later

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I. 10 Years Later: Lessons Not Learned from the Fukushima Disaster

The Fukushima disaster in 2011 shed light on serious deficits of the nuclear safety concepts and the plants' safety levels, also in Europe. The Fukushima disaster showed:

- Nuclear Power Plants' vulnerability against natural hazards is much higher than assumed before 2011
- Power supply for the plant and heat removal are not robust
- Possibilities to prevent radioactive releases during a severe accident with melt-down are actually very limited

The Lessons Learned consisted in identifying those natural hazards and upgrading the plant's protection, including safety margins. Applying state-of-the-art methods for re-evaluations of plant-specific natural (e.g. seismic) hazards and increase protection if necessary to ensure that the nuclear power plant is adequately protected against these hazards was necessary for many plants.

Secondly, means had to be found and installed to achieve more robust power supply and heat removal systems with additional alternative heat sinks and bunkered power supply when e.g. earthquakes cut off the nuclear power plant from external power supply and thirdly severe accidents measures had to be set up to have reliable systems to mitigate the impacts by limiting the radioactive releases.

In Europe ENSREG, the European Nuclear Safety Regulators Group was responsible for this task and conducted the EU stress tests for nuclear power plants. The ENSREG Chairman gave a clear explanation of the planned EU Stress Tests on May 25 2011:

Starting with June 1, 2011, all the operators of nuclear power plants in the EU will have to review the response of their nuclear plants to extreme situations, in particular operators will have to check and improve mitigation measures available after a potential loss of safety functions, caused by any reason. That includes the loss of electrical power or loss of ultimate heat sink for heat removal from the reactor, the management of loss of core cooling functions in their reactors as well as in spent fuel pools and the maintenance of containment integrity[1].

The resulting deficits and measures considered necessary to achieve the new safety level were agreed upon in the National Action Plans with the goal of being implemented with due urgency.

However, the stress tests did not focus on important shortcomings in the original design basis of European nuclear power plants. While the operator and national regulator had to discuss the conformance of the plant with its design basis, they were

[1] http://ensreg.eu/sites/default/files/25-05-11%20Statement%20of%20ENSREG%20Chairman%20about%20EU%20Stress%20Tests_0.pdf

not required to consider the design’s compliance with modern standards such as the WENRA Safety Objectives for New Power Plants.

The design deficiencies of older plants were not fully covered by the results of the EU Stress Test. For example, for a loss of electrical power, important factors such as the physical separation or protection of the emergency power supply system were not analysed in detail, even though the Fukushima disaster clearly showed that design flaws such as placing all emergency diesel generators and switchyards in the basement of the building without protection against flooding of the site can have a severe impact on the safety of a plant.

Many plants would have to undergo long outages while serious upgrades are implemented at the plants, causing enormous costs. If investment is rather avoided or if the plant cannot be upgraded, there is only one responsible solution: permanent shut down, which for several NPP is the only safe option. This applies in particular to those plants where significant improvements cannot be achieved by the planned deployment of mobile equipment only or by having plants on the grid in the current status for many more years while evaluations and assessment are under preparation and again later back-fittings would start. In France for example, this is officially scheduled to take up to 20 years.

The measures to cope with severe accidents are heavily relying on the “new magic solution” to severe deficiencies at the plants due to design or the conditions at the site: mobile equipment, which is easy to plan and store in the plant and therefore a cheaper solution compared to comprehensive back-fitting measures. But under severe accident conditions, it is very unlikely that the mobile equipment can be put to work as quickly as necessary; to rely to such a large extent on manual actions is in regard of the consequences of a severe accident irresponsible.

The prevention of hydrogen explosion is one of the most important lessons learnt from the Fukushima accident. However, most operators and several regulators concluded after performing analyses there is no explosion risk in their specific reactor. Remaining uncertainties are analysed until they “disappear” – they will resurface during the next accident.

The following examples show how seriously ENSREG, EU Commission, national governments, nuclear regulators and nuclear power plant owners took this task and what was achieved 10 years after the Fukushima disaster.

The current situation is the result of a nuclear safety regulatory system, where nuclear safety remains fully in the hands of the individual states and there are only two parties involved in the actual status and operation of NPP: The owner/operator of the nuclear power plant and the nuclear regulator on the other. There is very little transparency and no drive to achieve the highest possible safety level, because it would be very costly or technically impossible.

Nuclear industry has a different take on the situation in Europe. In 2016, Foratom as the nuclear industry's lobby organization explained on its website that ***an accident like the one at Japan's Fukushima NPP cannot happen in Europe****, that "European nuclear plant designs include consideration of significant natural events such as floods, storms, and earthquakes."* Regarding severe accident, Foratom continues: *Nuclear operators are prepared to face any emergency situation under the supervision of the national regulatory body.*

For this Greenpeace study, the ENSREG recommendations and the actual status of 11 nuclear power plants in Europe were analyzed in depths. The key insights gained by this enormous task can be found in the following overview, where it is clear, that most effort of the operators of nuclear power plants went into preventing the implementation of measures, which the disaster Fukushima proved to be necessary as a minimum. If operators conclude that those upgrades are too costly, the only acceptable safe solution is the permanent shut-down. Those Lessons have to be taken very seriously mainly when decisions are taken to extend the lifetime of nuclear power plants, the main issue for nuclear power operating companies and nuclear safety regulators in Europe.

I.1. Spain, Almaraz – NPP with limited scope of upgrades

As a result of the stress tests in response to the Fukushima disaster, the Spanish nuclear regulator set up a structure for the necessary upgrade measures. Already in 2014 a delay in the evaluation of the earthquake and flooding hazards and in the implementation of the containment filter venting system was accepted, though the stress test conclusion demanded a seismic hazard assessment with geological and paleo-seismological data; even today the seismic hazard assessment is not completed yet. It should be completed in 2021, but this means that planning starts, followed by the actual back-fitting of the plants. Clearly this will take several more years. Very similar the treatment with other external hazards the ENSREG voiced concerns about, including the heavy rain scenario. However, not even the necessary evaluation of the hazards is yet done, because the specific regulations are still lacking. And then it will take several years to implement the necessary back-fitting measures necessary to protect the plant against external hazards.

Other key issues the stress tests considered problematic such as the spent fuel pools during accidents when the external power supply (station-black-out - SBO) is cut off. Little progress was achieved her: mostly mobile equipment was acquired to compensate design weaknesses. The mobile equipment is much cheaper, but the prevention of severe accidents depends on the action of the staff during severe accidents. And not surprising: A crash of a large or a midsize airliner is very likely to cause a major damage of the reactor building. Such a crash – accidentally or deliberately – can result in a severe accident. The same is true for the spent fuel pool building.

I.2. Slovak Republic, Mochovce – NPP without alternative heat sink

As a result of the stress tests conducted after the Fukushima disaster, the ENSREG Peer Review Team recommended considering prioritization of the seismic upgrading measures for Mochovce. The National Action Plan took this up and included the seismic reinforcement of structures as the highest priority which has to be finished by 2015, calling it “prevention of accidents because of natural risks and limitation of their consequences”. However, current status: The Slovak regulator UJD SR took into account the complexity of the project on seismic reinforcement and accepted the proposal of the licensee to reschedule the date for the completion of seismic reinforcement until 2022.The incomplete seismic reinforcement program also means that the Emergency Center will not be available after an earthquake.
Even 10 years after the accident in Fukushima, the seismic upgrade has not been completed. It turned out to be a difficult task because sufficient documentation of the existing components is missing. Also an evaluation of the resistance against extreme weather events (floods caused by heavy rain, high and low external temperatures, direct wind and other relevant events) has not been completed, and adequate protection against extreme weather events is not in place.

An independent diversified alternate ultimate heat sink, necessary for cooling the reactor does not exist nor is it planned to prevent the loss of the primary heat sink. Only for the emergency feedwater source to steam generators a measure was taken: A mobile high-pressure sources.
In case of an accident the staff working at the plant first has to move and install those mobile sources. The ENSREG Peer Review also saw the need for filtered containment venting and other potential technical measures for long-term heat removal from the containment, but it will not be implemented at Mochovce NPP.

The VVER 440/V213 reactors have safety deficits which cannot be remedied: The reactor buildings do not provide sufficient protection against external impacts like airplane crashes. The spent fuel pool (SFP) is located outside the containment barrier in the reactor hall. Taking into account the existing risk of terrorism, it is irresponsible to operate a nuclear power plant with such a high vulnerability to external attacks. Mochovce 1&2 is a nuclear power plant with severe design deficiencies. At the same time, the Nuclear Regulator and the operator have not developed a reliable approach to safety and security culture.

I.3. Czech Republic, Temelin – NPP without means to cope with a severe accident

After Fukushima, the stress tests were also performed for Temelin and led to the Peer Review Team’s recommendation to ensure a diverse ultimate heat sink. Instead: Water needed for core cooling during an accident will be pumped from fire trucks into the steam generators. This constitutes the Czech response to the ENSREG recommendation calling for “provisions for the bunkered of ´hardened´ systems to provide an additional level of protection...(...).” Here the prevention of a severe accident depends strongly on sufficient actions of the staff.

The Peer Review Team stated as a result of the stress tests: In general, the core melt coolability, stabilisation and termination of severe accidents is still an open issue for the Temelín NPP. However, the measures to stabilize the core melt and prevent overpressure of the containment are not implemented yet – and no plan suggesting they will be implemented, because an Ex-Vessel Cooling was investigated for years to be implemented, in 2022 and then –cancelled for economic reasons.

In the last 10 years, only limited improvement measures – depending mainly on actions of the staff – have been performed to remedy design deficiencies. Also a lesson learned from Fukushima: Hydrogen explosion are real. But for Temelin ten years later, it is still unclear whether re-combiners (PARs) will be installed in the area of the spent fuel pool to prevent hydrogen explosions during severe accidents, as was recommended by ENSREG. Temelín NPP has no sufficient means to cope with a severe accident because it lacks both the measures to cool the molten core and the filtered containment venting system. Thus, a severe accident with a major radioactive release would be the result.

I.4. Krško, Slovenia – NPP with very high seismic hazard

The Krško site is endangered by an extreme earthquake hazard as well as a flood hazard. Even after Fukushima, the nuclear safety authority and the operator took only insufficient measures. The Krško NPP has only one water intake structure, an additional alternative UHS was planned at first and then - cancelled for economic reasons. Another lesson not learned: After an extreme earthquake with a PGA over 0.6g, with the destruction of the NPP and the infrastructure it seems is rather impossible to prevent a core melt accident using only mobile equipment – but this is the current solution applied at Krško. Also the ageing management of the reactor pressure vessel shows deficiencies compared to the safety level expected by ENSREG for Europe after the stress tests. Slovenia intends to continue operation for another 20 years and build one more reactor on this seismically active site.

I.5. Ringhals, Sweden – NPP unprotected against extreme weather events

Also Sweden has still serious safety problems, 10 years after Fukushima. The protection against extreme weather conditions seems not to be sufficient and it is unclear how long this situation will last. To evaluate extreme weather events and to ensure appropriate protection a research project will be started – only now, 10 years after the Fukushima accident. The primary ultimate heat sink for all units at Ringhals is sea water; there is still no alternate ultimate heat sink.

The Independent Core Cooling System (ICCS) is the most important safety measure in the Swedish Action Plan which resulted from the stress tests. It should reduce the risk of core melt accident and of a major radioactive release and is finally available since December 2020. However, the Swedish nuclear regulator SSM identified a number of shortcomings and the ICCS would possibly fail in extreme situations of severe accidents. Certainly not increasing safety: In 2015, a huge power uprate has been approved for Ringhals 4. Power uprates also accelerate the development of accidents and lead to considerably higher releases.

I.6. Doel and Tihange, Belgium – Flooding remains a very serious threat

In April 2011 right after the Fukushima accident, Electrabel commissioned a probabilistic seismic hazard analysis (PSHA) using a state-of-the-art methodology for its nuclear power plants. This PSHA resulted in a considerable increase of intensity of the design basis earthquake (DBE).. But FANC does not consider the back-fitting measures to be sufficient, thus an adequate protection against earthquakes is not provided yet.

The flood protection and the possible consequences call the disastrous accidents at Fukushima NPP 2011 to mind. Because of the dangerous situation, a wall was built to protect the Tihange NPP. Although the flood hazard will obviously increase in the next decade sufficient safety margins most likely have not been not used for the protection wall. In case of a flood beyond-design, or when the wall would fail, non-conventional means (NCM) that consist mainly of mobile equipment should be used. The prevention of accidents depends strongly on actions performed by the staff while a severe accident is developing. However, it will be very difficult and dangerous for the staff to prevent a core melt accident during a flooding of the site and parts of the nuclear power plant with mobile equipment. This is an irresponsible approach to achieving safety margins for extreme flooding events, in particular regarding the increasing risk of flooding events caused by climate change effects. The already difficult and dangerous actions of the staff during flooding of the site and the plant will be even more difficult and dangerous when boats are used for transport*.* All in all, flooding will remain a dangerous hazard for the Tihange NPP.

A lesson definitely not learned is severe accident management in Belgium, as this example illustrates: To deal with a flooding induced by an earthquake, only the seismic management procedures were modified: After an earthquake, a person is to be sent out as quickly as possible to check if the cooling tower is overflowing and if so, to shut down the pumps. This is one example of many where design deficiencies of the plants were solved by the introduction of procedures. This is one example of many where design deficiencies of the plants were solved by the introduction of procedures.

Doel-3 and Tihange-2 stopped operating in 2012, after the discovery of thousands of flaws in their reactor pressure vessels (RPV). They are thought to having originated from the casting and forging process and seem to grow during operation; the assessment of the safety implications remains the subject of intense controversy. But the reactors were restarted, even though the risk of failure of the reactor pressure vessel is not practically excluded and would lead to major releases of radioactive substances.

I.7. Beznau, Switzerland – NPP operating without adequate seismic protection

The nuclear power plant Beznau is the oldest operating NPP in Europe with design weaknesses that cannot be remedied by retrofits or only to a limited extent. But for Beznau, the ageing management is not taken seriously, as ENSREG found out in 2017. One of the important lessons learned from the Fukushima accident was the need to improve the prevention of hydrogen explosions. But for the Beznau NPP the necessary measures have not been completed yet. The other issue Fukushima highlighted – earthquake hazard – is still not solved, even though extensive studies on the earthquake risk have been carried out over the last 20 years. Already in 2011 it was known that the seismic hazard evaluation was inadequate. Because the nuclear regulator ENSI has assessed only the first stage of the required new analyses, sufficient protection is still not guaranteed. And: ENSREG's recommendation to retrofit the automatic scram after an earthquake will not be taken up. Another Lesson not Learned: The retrofits regarding improved protection for the particularly relevant extreme weather events have not been completed. This is not justified in terms of risk minimization, as climate change is causing extreme events to occur more frequently and more intensively.

I.8. France, Gravelines and Cattenom – NPPs waiting for Hardened Safety Cores

The land of 56 nuclear power plants is still preparing the implementation of Lessons Learned from Fukushima. Safety important systems, for example the fire-fighting systems and the filtered venting systems of the containment, are not seismically qualified, i.e. these systems would fail during an earthquake. These weaknesses have been known since the stress tests however, the necessary reinforcement will be carried out only in the next decade(s). None of the French reactors is equipped with an alternative ultimate heat sink, but recent events highlighted the vulnerability of the existing ultimate heat sinks (UHS). In case of the loss of the UHS, respectively its unavailability, the core could be uncovered in just a few hours. However, the danger will persist until an alternate heat sink will be built as part of the implementation of a Hardened Safety Core. 10 years after the Fukushima accident the Hardened Safety Core needed to prevent core melt accidents and mitigate consequences of core melt accidents have not been implemented and this will probably take at least another decade.

In France, a fundamental problem of nuclear safety is particularly evident; while on paper attempts are made to increase the level of safety, the reality in the plants is different. In addition to aging issues and design deficiencies, there are problems with quality control and safety culture. On top of all safety issues, there are several security issues.

I.9. Germany, Gundremmingen – NPP looking forward to the end of operation

Germany certainly drew the right conclusions from the Fukushima disaster, when the complete phase-out of nuclear power was decided on a step-by-step basis.

Gundremmingen is among those NPP still operating. The stress tests revealed that the Gundremmingen site will be flooded in case of a design basis flood (DBF). A new study was made to “show” the site will probably not be flooded and no actual improvement of flood protection will be implemented. Rather a simple but not convincing solution was chosen: Gundremmingen NPP acquired boats to improve accessibility of the plant grounds during a flood. Also other extreme weather impacts were reviewed, but no information made available. The stress tests found that the severe accident prevention at Gundremmingen NPP relies on outdated (severe) accident management measures which are insufficient to respond to external hazard conditions or the need of long-term heat removal. The operability of accident management measures has been reviewed. However, for Gundremmingen the scope and the time schedule for necessary improvements are not known. Most likely the improvements consist of paperwork mostly.

II. Conclusions

The examples of 11 nuclear power plants in Europe show with shocking clarity, that the nuclear regulators and operators in Europe invested a lot of effort into preventing necessary upgrades for the nuclear power plants for economic reasons rather than trying to implement to obviously very needed improvements to prevent another Fukushima from happening. The EU stress tests delivered clear guidelines and recommendations however, the responsible authorities allowed the nuclear power plants to continue operating without having achieved those upgrades for ten years and even longer into the future.

Due to the very low electricity prices of the past years, the economics of nuclear power plant operation are very strained. Thus the operators need to avoid any investment for the remaining operation time or has to get the licence for operation time extension in exchange for as little upgrades as possible. For many of those plant operators are applying for life-time extensions to continue running those plants beyond their original design life time for additional 10, 20 or even 30 years – without Lessons Learned and fully aware that their plants don’t fulfil even those recommendations set during the stress tests.