KNS - 2024 Annual Meeting and 57th General Assembly

Submission for oral abstract/presentation

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TsunamiFloodProtection – System/ TFP-System

1. Introduction

1. How can nuclear power plants be better protected against the effects of tsunamis and severe flooding?
2. Does diversity in flood protection walls make sense?

The protection of nuclear power plants against the effects of tsunamis and severe flooding is of critical safety importance, particularly in view of the potentially catastrophic effects of such events.
A sensible strategy to increase the safety of nuclear power plants is the diversification of protection devices. By combining different protective measures, potential vulnerabilities of individual systems can be minimized and the overall safety of the power plant can be increased.

In some cases, this is already being implemented by reinforcing or supplementing the existing structural measures, for example by building higher or more robust flood protection walls designed to withstand extreme flood waves. Another option is the installation of special flood protection doors or barriers at critical locations within the power plant site.

In addition, advanced monitoring and early warning systems could be implemented to respond to potential threats in time or to take appropriate measures in advance.

Alternatively, additional protective devices could be installed that act independently of the existing flood protection walls. These additional protective devices could serve as a supplementary safety measure and improve the overall resistance of the nuclear power plant to the effects of tsunamis and severe flooding.

<u>Initial situation</u>
The threat to nuclear power plants from the effects of tsunamis is a highly relevant issue, particularly in view of global climate change.
There are currently 74 reactors at 23 nuclear power plant sites worldwide (as of 2012, source: Civil nuclear power at risk of tsunamis, Natural Hazards 63(2):1273-1278DOI:10.1007/s11069-012-0162-0) that could potentially be affected by tsunamis - and the trend is rising as the construction of new reactors gathers pace in various parts of the world.

The effects of climate change must also be taken into account, particularly with regard to the parameters for flooding and storm surge events. Rising sea levels and the increase in extreme weather events increase the risk of flooding and tsunamis, which could potentially endanger nuclear power plants.
In addition, global political instability must not be ignored, which leads to further threats. The idea that terrorist attacks could deliberately trigger flooding of coastal areas and nuclear power plants is very worrying.
Overall, this highlights the multiple risks and threats that nuclear power plants face in relation to tsunamis and flooding.

Part of the Fukushima problem

The Fukushima disaster in 2011 illustrates the devastating effects that tsunamis can have on nuclear power plants and represents an alarming turning point in the debate about the safety of these plants.
Although the Fukushima Daiichi nuclear power plant already had a flood wall of 4 meters in height, this was raised to 5.7 meters after the Indian Ocean tsunami in 2003 - a response to the lessons learned from this event.
However, in view of the enormous wave heights of the tsunami of March 11, 2011, even this increased protective wall proved to be insufficient, reaching a height of 14 meters at the peak and 10 meters at the site of the nuclear power plant (see Fig. 1).
The effects were devastating: the external power supply was destroyed and the critical infrastructure of the nuclear power plant, such as the emergency diesel, emergency standby and transformer buildings, were flooded.
The subsequent collapse of the internal battery supply meant that the cooling water pumps and the emergency pumps for cooling the reactors could no longer be supplied with power - a decisive factor in the nuclear disaster that followed.

This tragic sequence of events has revealed the weaknesses of existing safety precautions against the effects of tsunamis and underlined the urgency of developing more robust and reliable protection systems. It has become clear that the construction of flood walls alone is not sufficient to cope with the potential risks of tsunamis for nuclear power plants. A multidisciplinary approach and, in the best case, a complementary passive system is needed to increase the safety of these plants and thus prevent similar disasters in the future.

Figure 1 Flood scenario Fukushima NPP 2011

Solution approach

For this purpose, it is urgently necessary to identify building openings of a nuclear power plant that are important for safety and to protect them from flooding, regardless of their height.
In an emergency diesel building (critical infrastructure), for example, this includes the combustion air intake, the diesel exhaust system, the fresh air intake and the exhaust air openings.

2. Methods and Results

Approach to the development of INNOMECOM AG

The development of the **T**sunami**F**lood**P**rotection (TFP) system by INNOMECOM AG was based on a specially specified qualification plan to ensure the effectiveness and reliability of the system.

An important goal in the development of the TFP system was to achieve diversity compared to the existing flood protection walls. Ensuring the functionality of the system was to be independent of the height of the tsunami. A key aspect was the passive operation of the system, both when closing and opening. The system's independence from an external power supply ensures a high level of reliability, as it continues to function even in the event of power failures or technical problems. The control of the single fault criterion and a redundant design were further important features in the design of the TFP system. This ensures that the functionality of the system is maintained even if individual components fail. The system to be developed should also be able to withstand various environmental conditions, such as flotsam, muddy water, high and extreme outside temperatures and high exhaust gas temperatures. In addition, strict requirements were set with regard to earthquake safety in accordance with specific nuclear regulations, such as KTA 2201.4 or KTA 3211.2.

Production should be carried out in accordance with nuclear-specific quality standards (e.g. KTA 1401 and IAEA 50-C-Q). An additional application of the TFP system is the prevention of internal flooding from room to room. This can also prevent possible contamination carry-over.

This comprehensive approach illustrates the need and the ambition with which the TFP system was developed to provide the highest safety standards for nuclear power plants.

Debris protection TFP system

In order to maximize protection against potential debris and other external influences, an associated debris protection system was developed in addition to the TFP system, which follows various design approaches.

One of the most important functions of debris protection is to protect against floating loads, such as floating debris like gas tanks or trees.
In addition, debris protection is designed to minimize the impact of blast pressure waves. For this purpose, reinforced concrete structures are used to reduce the effects of pressure waves and protect the system components. It is also conceivable to extend the structure with explosion pressure flaps.
Furthermore, the debris protection is designed to withstand extreme weather conditions such as extreme winds, ice loads and extreme outside temperatures.
In addition, an earthquake decoupling system is integrated into the debris protection to protect the systems from the effects of an earthquake and minimize damage. The debris protection is anchored using anchor plates and/or in conjunction with the existing building reinforcement to ensure stability.

Further plant-specific protective measures can be implemented in the debris protection system to protect nuclear facilities from additional threats.
These include protection against debris from an aircraft crash (FLAB), where the design aims to minimize the impact of such an event.
In addition, precautions can be taken to protect nuclear facilities from damage caused by tornadoes and/or tornado-induced loads.
Depending on the requirements, debris protection can be further developed to defend against terrorist attacks by reinforcing the structures and implementing object protection grids, for example.

The result of these requirements is the patent-pending TFP system

In order to meet the high nuclear safety standards, the closing function of the **T**sunami**F**lood**P**rotection (TFP) system was reduced to the essentials. Double floating systems were designed according to specified buoyancy forces, which run in guide rods and close a constructed base plate tightly in the event of a tsunami (see Fig. 2). This system is bolted into a specially developed modular mounting frame for maximum flexibility and integrated into the debris protection (see Fig. 3). The international search report was positive and patentability of the TFP system was promised by the international patent office in Brussels.

Abbildung 2 Prototyp TFP-Modul

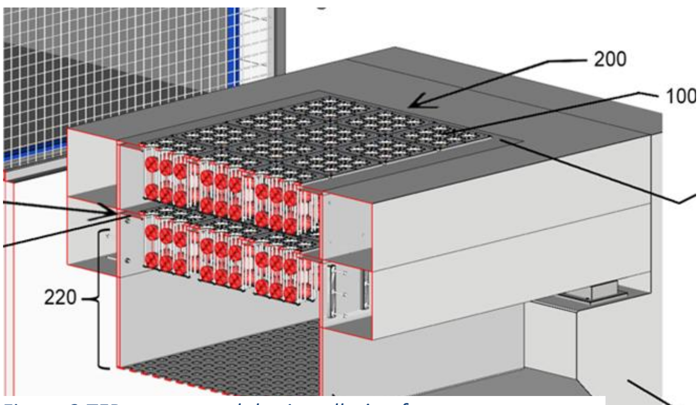

Figure 3 TFP system modular installation frame

Thanks to its special design, the TFP system is passively inherent and fully redundant. It can withstand large masses of mud and floating debris, extreme weather conditions as well as high earthquake loads. This fulfills all of the previously defined and described requirements. The system therefore also falls into the desired IAEA Passive Category C.

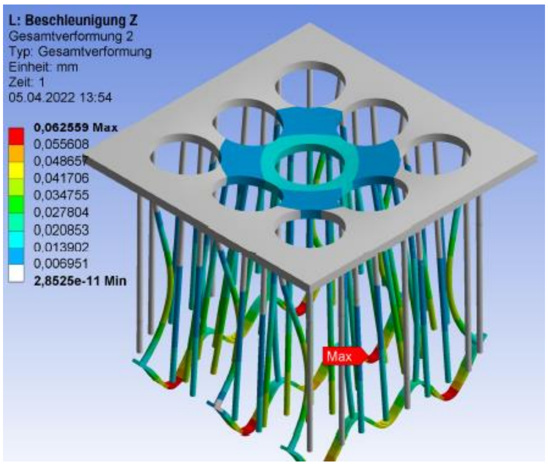

Figure 4 TFP module earthquake verification

The TFP system was calculated in accordance with the earthquake verifications of the KTA regulations in order to prove its effectiveness under seismic conditions.
Part of the development of the TFP system was the iterative approach to creating the FEM model (finite element model) in order to simulate the high earthquake loads (see Fig. 4). An overload (elastic deformations) was deliberately provoked in the first prototypes in order to determine the material and design limits.
An additional calculation in accordance with ASME is also currently being implemented.


Figure 5 TFP system pressure drop test

TÜV SÜD IS GmbH was consulted to determine the pressure loss for a TFP module (see Fig. 5).
The pressure losses and the ZETA value of the component were determined using a specially designed pressure loss test rig. The pressure losses determined are necessary for the overall design of the system in which the TFP system is to be integrated in order to generate as few additional pressure losses as possible, especially in an existing system.

Figure 6 Tsunami test stand

A specially specified tsunami test stand from INNOMECOM AG enables individual TFP modules to be subjected to specific mud and water masses (see Fig. 6).
Tsunami characteristics, such as high water velocities and various forms of sludge, can be tested on each TFP module on this test stand. It is possible to take into account the individual sludge compositions of the existing coastal and soil structures of a nuclear power plant.
The proof of function on the tsunami test stand for the TFP system was accompanied independently by TÜV SÜD IS GmbH under specified tsunami conditions

Installation examples

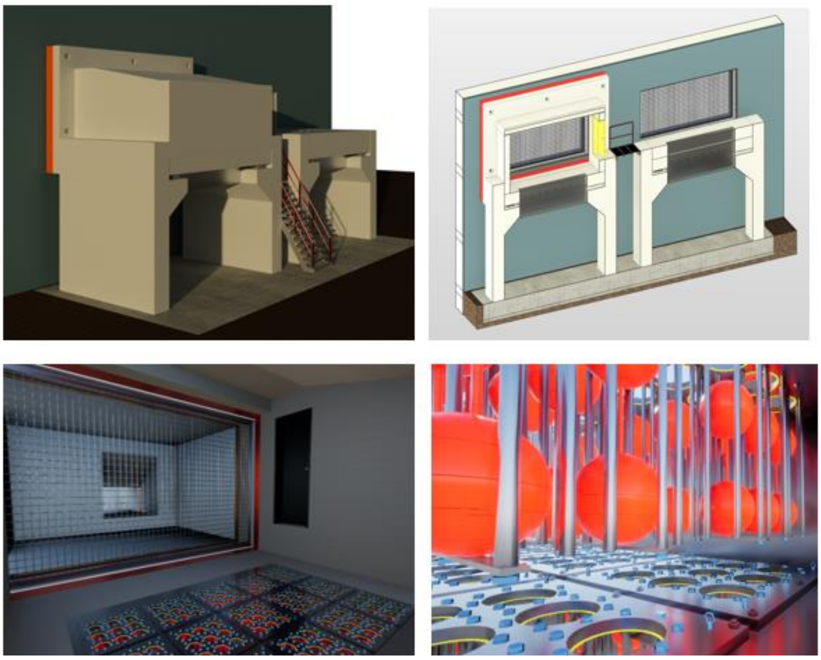

Figure 7 Installation examples TFP system

The TFP system can be installed in conjunction with the debris guard in both the intake and exhaust air path of a ventilation system (see Figure 7).

The debris protection is divided into a lower and upper section, with the lower section connected to the ground and the upper section connected to the building (see Fig. 3)

In order to achieve effective earthquake decoupling, special spring damping elements were installed that meet the nuclear requirements. These elements play a crucial role in absorbing vibrations and help to maintain the structural integrity of the system during seismic events.

In addition to keeping debris out, the debris shield is designed to break tsunami waves and severe flooding and direct water to the TFP system. This function is critical to protecting the system from the effects of extreme hydrodynamic forces.

The selection of appropriate space conditions for the installation of the TFP system and the associated protection devices is of great importance. Taking the spatial requirements into account ensures that the installation and periodic inspections of the TFP system can be carried out properly.

3. Conclusions

In summary, the TFP system can make an additional contribution to safety and to protecting the capital expenditure of nuclear facilities in the event of tsunamis and flooding.However, it is important to emphasize that no single protective measure or strategy can completely eliminate all risks.
A comprehensive approach to safety, based on a combination of different protection devices and measures, is therefore crucial.

With its robust design, passive and self-sufficient function, extensive testing and independent verification by TÜV SÜD IS GmbH, the patent-pending TFP system underlines its effectiveness and relevance to nuclear plant safety.