Transactions of the Korean Nuclear Society Autumn Meeting
Gyeongju, Korea, October 27-28, 2016

Review of EU-APR Design for Selected Safety Issues of WERNA RHWG 2013

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1. Introduction

Western European Nuclear Regulators' Association (WENRA) was established in 1999 to develop a harmonized approach to nuclear safety and radiation protection and their regulation. In 2013, the Reactor Harmonization Working Group (RHWG) of WENRA sets out the common positions on the seven selected key safety issues. [1] This paper is to introduce the regulatory positions of WENRA RHWG 2013 and to review the compliance of the EU-APR with them. [2]

2. WENRA RHWG Positions for Safety Issues

2.1 Defense-in-Depth (DiD) approach for new NPPs

The levels of DiD proposed by RHWG is to consider multiple failure events and core melt accidents in the design of new nuclear power plants as shown in Table 1.

Table 1 DiD Structure of WERNA RHWG 2013

DiD	Plant Condition	Objectives
Level 1	Normal operation	Prevention of abnormal operation and failure
Level 2	Anticipated operational occurrences	Control of abnormal operation and failure
Level 3	3.a (Postulated single initiating events)	Control of accident to limit radiological releases and prevent escalation to core melt conditions
	3.b (Postulated multiple failures events)	
Level 4	Postulated core melt accidents (short and long term)	Control of accidents with core melt to limit off-site releases
Level 5	-	Mitigation of radiological consequences of significant releases of radioactive material

2.2 Independence of the levels of Defense-in-depth

Independence between different levels of DiD shall be maintained to the extent reasonably practicable so that failure of one level of DiD does not impair the DiD ensured by the other levels involved in the protection against or mitigation of the event. The appropriate means to achieve independence between Structures, Systems and Components (SSCs) are diversity, physical separation by structure or distance, and functional isolation.

2.3 Multiple Failure Events

The multiple failure events characterized as below should to be considered in the design of new NPPs:

(1) A postulated common cause failure or inefficiency of all redundant trains of a safety system needed to fulfil a safety function necessary to cope with an anticipated operational occurrences (AOO) or a single (Postulated Initiating Event (PIE)

(2) A postulated common cause failure of a safety system or a safety related system needed to fulfil the fundamental safety functions in normal operation

2.4 Provisions to mitigate core melt and radiological consequences

Provisions shall be equipped to prevent accidents which would require protective actions for the public that could not be considered as limited in area and time (large release) and also to prevent accidents which would require protective actions for the public for which there would not be sufficient time to implement these measures (early release). These provisions have to make such accidents physically impossible to occur or to make it possible to consider with high degree of confidence that they are extremely unlikely to arise.

2.5 Practical elimination

In order to practically eliminate accident sequences with a large or early release of radiological materials, the appropriate measures should be taken to achieve the followings:

(1) Physically impossible for the accident sequence to occur or

(2) High degree of confidence for accident sequence to be extremely unlikely to arise

2.6 External hazards

The safety assessment for new NPPs should demonstrate that threats from external hazards are either removed or minimized as far as reasonably practicable. This may be done by showing that all relevant safety SSCs required to cope with an external hazard are designed and adequately qualified to withstand the conditions related to that external hazards.

2.7 Intentional crash of a commercial airplane

The following safety functions required to bring and maintain the plant in a safe state after such a crash shall be designed and protected adequately:

(1) Reactivity control, including reactor scram

(2) Residual heat removal (including in the long term) from the core in the vessel and the fuel pool in order to exclude core or fuel melt

(3) Confinement of radioactive materials

3. EU-APR Designs regarding WENRA Safety Issues

3.1 DiD approach

The EU-APR adopts successive five levels of DiD to prevent the release of radioactive material to the environment as shown in Figure 1. Five levels of protection are implemented in such a way that should one level fail, the subsequent level comes into play. The mechanical, electrical and I&C systems providing safety and non-safety functions are designed based on the different design principles for each DiD level.

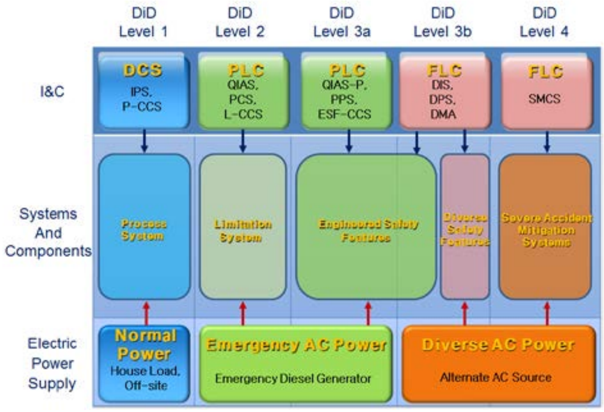

Figure 1 EU-APR DiD Architecture

3.2 Independence of the levels of Defense-in-depth

Each SSC performing a safety function in each DiD level is assigned to one specific safety function or family of safety function. As shown in Figure 1, the safety features performing the required safety functions for DBC 2, DBC 3&4, DEC, and SAs are dedicated to each DiD level, respectively.

3.3 Multiple Failure Events

The EU-APR is designed to cope with multiple failure events such as ATWS, SBO, Loss of Ultimate Heat Sink, and Loss of Spent Fuel Pool Cooling. The diverse system performs the required safety function in case that the front system fails to conduct its assigned safety function as described in Table 2. [3]

Table 2 Diverse Design against Multiple Failure Events

Safety Function	Front System	Alternative Measures
Core Cooling	SIS	RCS Depressurization using secondary ADVs + SIT Injection + IRWST water Injection by SCS
	AFWS	Primary feed and bleed operation using POSRVS and safety injection
Spent Fuel Cooling	SFP Cooling System	SFP Makeup System
Reactor Shutdown	Control Rods	Emergency Boration System
Emergency Power	EDGs	AAC DGs

3.4 Provisions to mitigate core melt and radiological consequences

The EU-APR adopts the Severe Accidents (SAs) dedicated mitigation systems listed in Table 3 as well as double containments to minimize radiological consequences by ensuring the containment integrity during the SAs. [3]

Table 3 SAs Dedicated Mitigation System

System	Function
Passive Corium Cooling System (PECS)	Preventing interaction between molten core and pressure-bearing materials of the containment walls or ceilings
Rapid Depressurization System (RDS)	Preventing high pressure core molten ejection
Containment Spray System (SACSS)	Preventing containment over-pressurization
Passive Hydrogen Control System (HMS)	Maintaining hydrogen concentration in containment below 10 v/o

3.5 Practical elimination

In the EU-APR, accident sequences that have the potential to cause a large or early release have been identified based on deterministic analyses and probabilistic assessment. Also, the safety structures of the plant are designed to practically eliminate accident sequences with core melt resulting from external hazards which would lead to early or large releases.

The EU-APR plant practically eliminates accident sequences with a large or early release of radiological materials to the extent reasonably practicable by adopting redundant and independent safety system design for Design Base Accidents, Diverse designs to cope with multiple failure events, SAs dedicated mitigation system, and double containment design with annulus filtered vent system.

3.6 External hazards

The standard site parameters of the EU-APR are set not lead to core melt accidents due to natural or man-made external hazards as follows: [4]

(1) Ground level: Safety shutdown maximum sea level + Margin

(2) SSE: Free field PGA for the horizontal/vertical direction: 0.25g/0.17g with Seismic Qualification considering vibration caused by earthquakes and airplane crash

(3) Ultimate weather conditions prescribed in EUR

(4) Other man-made hazards described in EUR

3.7 Intentional crash of a commercial airplane

The safety buildings of the EU-APR is designed to maintain the leak-tightness of primary containment and to protect safety-related SSCs, fuel handling area and main control room against intentional crash of a commercial airplane (APC). As shown in Figure 2, the EU-APR adopts secondary containment and the auxiliary building is structurally reinforced. In addition, the intake structures of ESWS and buildings of EDGs and AACs are physically separated between each division against APC. [3]

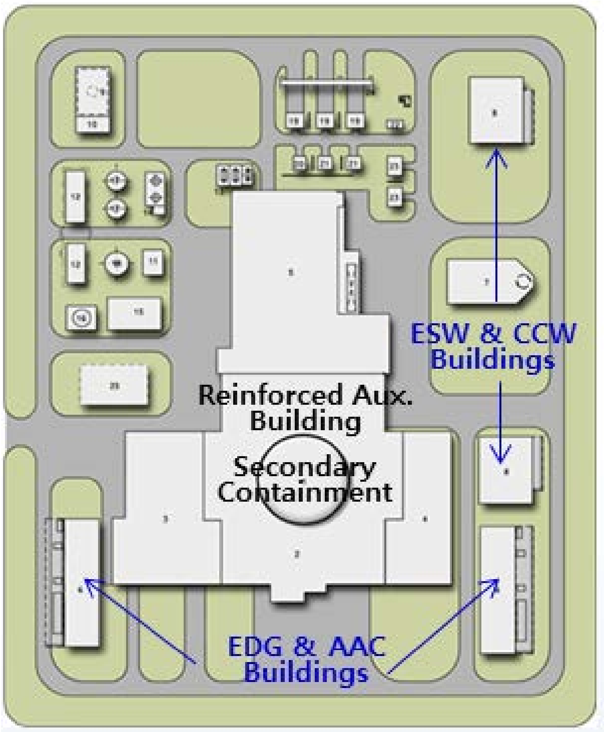

Figure 2 Safety Building Design against APC

4. Conclusions

In this paper, we reviewed the compliance of the EU-APR regarding seven safety issues for new NPPs presented by WERNA RHWG in 2013. The EU-APR design fully complies with all WERNA RHWG safety issues since the following measures have been incorporated in it:

(1) Successive five levels of DiD maintaining independence between different levels of DiD

(2) Diverse design against multiple failure events such as ATWS, SBO, Loss of Ultimate Heat Sink, and Loss of Spent Fuel Pool Cooling

(3) SAs dedicated mitigation systems to ensure the containment integrity during the SAs.

(4) Practically eliminates accident sequences with a large or early release of radiological materials by diverse designs for multiple failure events, SAs dedicated mitigation system, and double containment design

(5) Standard site parameters not lead to core melt accidents due to natural or man-made external hazards

(6) APC protection design such as secondary containment, reinforced auxiliary building, and physically separated arrangement of safety buildings

ACKNOWLEDGMENT

This work was supported by the Major Technologies Development for Export Market Diversification of APR1400 of the Korea Institute of Energy Technology Evaluation and Planning (KETEP) grant funded by the Korea government Ministry of Trade, Industry & Energy.

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