

Assessment of the EU-APR standard design versus the European Utility Requirements

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1. Introduction

The European Utility Requirements (EUR) organization unites most of the companies involved in electricity generation from nuclear power in Europe, with the main goal of defining and continuously maintaining a wide set of technical requirements for new Light Water Reactor (LWR) Nuclear Power Plants (NPP) in Europe.

The EUR document, currently comprising some 5000 requirements for the Nuclear Island (NI), has been continually refined and updated over the last 25 years to reflect changes to European regulations and to incorporate engineering and operating experience from existing plants and new build projects. The EUR document therefore conveys a broad and common viewpoint on the desirable features of new NPP designs for the European market and current European best-practices, covering a large range of areas, such as nuclear safety, plant performance and grid compatibility, design of structures, systems and components, choice of materials, design methodology and process, operability, constructability, lay-out and maintenance, environmental impact assessment and decommissioning.

In addition to maintaining the EUR document as a widely recognized technical reference, the EUR organization offers to perform, at the request of any NPP Vendor targeting the European market, a full assessment of its NI standard design against the European Utility Requirements. At present, most worldwide LWR Vendors have had a Generation 3 NI standard design assessment done by the EUR. The result of a design assessment by the EUR shows the degree of compliance of the NI design with European rules. The resulting assessment documentation is a valuable instrument for the NI designer to further develop the standard design into a site-specific design for a European construction project. Hence, a full assessment against the EUR is generally considered to be an essential step in the introduction of an LWR design to the European market.

Korean Hydro & Nuclear Power developed the Korean APR1400 reference plant into a modified design, named EU-APR, aiming to comply with the

EUR document, and also with European Codes and Standards and the main safety requirements from most recent WENRA and IAEA publications. The EU-APR standard design is a two-loop pressurized water reactor of the range of 1400MWe, very similar to the APR1400, but with several additional features designed for the purpose of complying with European rules. These EU-APR specific features include, among other, additional redundancy for important safety functions, diverse measures for reactor shutdown and power supply, protection against external hazard, aircraft crash resistance, independent Severe Accident (SA) mitigation systems including a core catcher, and a secondary containment vessel. KHNP has implemented in its EU-APR design the reinforced Defense-in-Depth approach as defined in WENRA report "Safety of new NPP designs", which includes an additional Defense-in-Depth level for control of postulated complex sequences and multiple failures by means of Engineered Safety Features (ESF) or Diverse Safety Features (DSF).

Following ratification by the EUR Organization of KHNP's request to independently assess its EU-APR standard design, a two-year assessment process started in autumn of 2015. The conclusive document of the assessment received final approval by the EUR Organization in September 2017 with the delivery of the EUR assessment certificate on the 21st of November 2017 in Helsinki, Finland. The EU-APR was assessed against Revision D of the EUR document.

2. Assessment process and methodology

2.1 Assessment, review and synthesis activities

The assessment process involved both discipline-specific evaluation of the design by technical experts from the participating EUR companies versus each single NI-related requirement of the EUR document, and extensive review by the project team and the permanent bodies of the EUR organization (the EUR Administration Group and EUR Steering Committee).

The syntheses of the requirement-by-requirement assessments per chapter were collected in the principal project output: the EU-APR dedicated subset of Volume 3 of the EUR Document. This Volume 3 subset

(Subset I) also contains a technical description of the plant, issued by KHNP and reviewed by the EUR organization. Furthermore, it explains the assessment process and highlights its main results.

The EUR policy is to review a “frozen design”, i.e. a design which is not modified throughout the assessment. The documentation that defines the design (Design Description Documentation - DDD) therefore remained similarly unchanged during the assessment project. KHNP delivered sufficiently extensive and comprehensive documentation. However, when there was a need to clarify outstanding issues, receive supporting information or obtain justification of the provided data, a Question & Answer process was initiated between the assessing expert and his/her KHNP-nominated counterpart for the concerned technical domain. Valuable supplementary information exchanged in this process was systematically captured within Q&A forms under KHNP document control. Consequently, the Q&A documents issued throughout the assessment phase form an important addendum to the DDD.

In the working files, the compliance assessment for each requirement is documented by:

- a reference to the relevant analyzed parts of the EU-APR DDD;
- the result of the assessment, using specific predefined acronyms (“assessment labels”, see further);
- the expert’s justification for the given assessment result (“assessment statement”).

2.2 Assessment labels

The applicable assessment labels as defined by the EUR Organization are COM, NOC, CWO, NAN, POS and NAP.

COM stands for “Compliance”, implying that the design meets the requirement or goes beyond it. NOC (“Non-Compliance”) means the opposite: the design does not meet the requirement.

CWO (“Compliant With Objectives only”) can have two slightly different meanings. In a straightforward way, CWO means that a different approach from the one stipulated by EUR is applied to achieve the same objective(s). However, alternatively, CWO can be used when the presented approach is not yet sufficiently defined for granting the COM label, but the provided information and Vendor’s experience give rise to a fair expectation that the requirement will be fulfilled in a later design phase. The latter meaning of CWO allows an assessor to evaluate design items that are

insufficiently mature at the freeze point of the assessment. Where evidence indicates that a requirement will be met, for example by showing examples from previous projects and a commitment to respect the requirement, the assessing expert and the different EUR-collaborators involved in the review can jointly make the engineering judgement that KHNP is indeed capable of satisfying the requirement and can do so if an EU-APR is constructed. As KHNP has several construction projects of its APR1400 plant ongoing in recent years, many documents from the detailed design phase of the APR1400 can serve as such evidence. KHNP has appended many of these documents (or extracts from them) to the DDD of the EU-APR. It was agreed that these could be used to show full compliance with requirements that demand demonstration of KHNP’s competence and experience, or familiarity with practices, methods and procedures. The use of qualitative or quantitative data (real contents) from such reference plant documents for demonstrating CWO implied accurately checking their relevance to the EU-APR design and consistency with the EU-APR DDD.

The NAN label is applied when the design or the verification will be developed in a later stage of the design process and this is considered acceptable. However, if information is missing because the design has been insufficiently developed compared to the expectations of the EUR, the NOC label applies.

The POS label is for requirements where a site, an Owner or a specific project is needed for the design to evolve sufficiently to achieve compliance. Hence, generally, POS is assigned when the fulfilment of the requirement lays beyond the generic design phase (site-specific aspects) and/or the Vendor’s responsibility.

NAP is mainly used for requirements concerning technological solutions not applicable for the design, for instance BWR-related requirements or requirements on some passive systems (revolutionary LWR designs).

In EUR Volume 3 Subset I, the statistical distributions of the labels per chapter are presented as percentages of the total sum of labels COM, CWO, NOC and NAN; i.e. the requirements that are within Vendor’s responsibility.

For the assessment of the EU-APR, a consistency checking review was performed to compare the results to those obtained for the previous assessment, the assessment of Mitsubishi Heavy Industry’s EU-APWR standard design versus EUR revision D. The latter is the only other assessment which has been performed against revision D, and therefore the most relevant for

such benchmarking. Moreover, consistency with all previous assessments in requirement interpretation and labelling has been continually monitored by the permanent bodies of the EUR organization.

3. Main assessment results

The EU-APR standard design was considered to be compliant (COM) with the majority of assessed requirements: 89.7%, excluding the assessed requirements labelled NAP and POS (as those are considered not to lie within the Vendor's area of responsibility). 96.5% were labelled as COM or CWO.

The EU-APR standard design can be considered as being in the late basic design phase. Nevertheless, the portion of requirements that were deemed not assessable (labelled NAN) is only 2.7%. The reason for this very low figure lies with the abundance of reference plant (detailed design) documentation, which often helped to demonstrate, by means of examples, KHNP's adherence to the design principles established for the EU-APR.

In total, only 0.8% of the assessed requirements (excluding NAP and POS) were labelled NOC. The main non-compliances relate mostly to the choice of design principles and analysis methods that differ in detail from those stipulated by EUR, and to the relatively low level of development of reactor core and fuel studies available to demonstrate operational plant maneuverability and fuel cycle optimization with respect to safety margins and economics.

As mentioned above, the full technical overview of the main assessment results is given in the principal project output: the EU-APR dedicated subset of Volume 3 of the EUR Document [1]. A more concise report highlighting the main assessment results [2] is (to be) presented at 26th International Conference on Nuclear Engineering (ICONE26) in London, UK (July 22-26, 2018).

REFERENCES

[1] European Utility Requirements for LWR Nuclear Power Plants – Volume 3, Subset I, dedicated to EU-APR, developed by Korean Hydro & Nuclear Power (KHNP), Revision A, September 2017, EUR Organization (restricted access)

[2] C. Declercq, A. Ballard, G. Ferraro, A. Touré, "The EUR Assessment Process and Highlights of the Compliance Analysis for the EU-APR Standard Design", Proceedings of the 2018 26th International Conference on Nuclear Engineering, paper ICONE26-81889