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SEISMIC ISOLATION OF LEAD-COOLED REACTORS: THE EUROPEAN PROJECT SILER

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SILER (Seismic-Initiated event risk mitigation in LEad-cooled Reactors) is a Collaborative Project, partially funded by the European Commission in the 7th Framework Programme, aimed at studying the risk associated to seismic-initiated events in Generation IV Heavy Liquid Metal reactors, and developing adequate protection measures. The project started in October 2011, and will run for a duration of three years. The attention of SILER is focused on the evaluation of the effects of earthquakes, with particular regards to beyond-design seismic events, and to the identification of mitigation strategies, acting both on structures and components design. Special efforts are devoted to the development of seismic isolation devices and related interface components.

Two reference designs, at the state of development available at the beginning of the project and coming from the 6th Framework Programme, have been considered: ELSY (European Lead Fast Reactor) for the Lead Fast Reactors (LFR), and MYRRHA (Multi-purpose hYbrid Research Reactor for High-tech Applications) for the Accelerator-Driven Systems (ADS).

This paper describes the main activities and results obtained so far, paying particular attention to the development of seismic isolators, and the interface components which must be installed between the isolated reactor building and the non-isolated parts of the plant, such as the pipe expansion joints and the joint-cover of the seismic gap.

KEYWORDS : Seismic Analysis, Seismic Isolation, Generation IV Reactors, Lead-Cooled Reactors

1. INTRODUCTION

The latest violent earthquakes that struck Japanese nuclear power plants (in particular Kashiwazaki-Kariwa in July 2007 and Fukushima in March 2011) renewed international focus on the structural strength of nuclear facilities. This has forced the nuclear engineering community to concentrate a significant research effort in the evaluation and mitigation of risks associated with earthquakes. In this contest, the SILER Project has been developed, accepted, and funded by EURATOM since 2011, within the 7th Framework Programme.

SILER is a Collaborative Project aimed at studying the risks associated with seismic initiated events in Gen IV Heavy Liquid Metal reactors, and developing adequate protection measures. The attention is focused on the evaluation of the effects of earthquakes, with particular regard to unexpected (beyond design) events, and to the identification of mitigation strategies like seismic isolation.

The SILER Consortium is composed by ENEA (Co-ordinator, Italy), AREVA (France), SCK•CEN (Belgium), FIP Industriale (Italy), MAURER-SOEHNE (Germany), JRC (Ispra, Italy), SINTEC (Italy), KTH (Sweden), BOA (Germany), IDOM (Spain), ANSALDO (Italy), IPUL (Latvia), NUMERIA (Italy), VCE (Austria), SRS (Italy), CEA (France), EA (Spain) and NUVIA (France).

The Project deals with both Lead Fast Reactors (LFR) and Accelerator-Driven Systems (ADS). In particular, reference is made to ELSY (European Lead Fast Reactor, § 2.1) for LFR, and to MYRRHA (Multi-purpose hYbrid Research Reactor for High-tech Applications, § 2.2) for ADS. Subsequent sections of the paper are devoted to the isolators (§ 3), the joint-cover of the seismic gap (§ 4.1) and the flexible joints for pipelines (§ 4.2). Finally, section 5 illustrates other activities of SILER and the dissemination of information program.

2. REFERENCE DESIGNS

2.1 ELSY

The European Lead Fast Reactor is under development since September 2006, in the frame of the ELSY project, sponsored by the 6th Framework Programme of EURATOM. The project, coordinated by Ansaldo Nucleare, involved a wide consortium of European organizations.

The ELSY reference design is a 600 MWe pool-type reactor cooled by pure lead (Fig. 1). The ELSY project demonstrates the possibility of designing a fast critical reactor competitive and safe using simple, engineered technical features, whilst fully complying with the Generation IV goal of sustainability and minor actinide burning capability. Sustainability was a leading criterion for option selection for core design, focusing on the demonstration of the potential to be self sustaining in plutonium and to burn its own generated minor actinides. To this aim, different core configurations have been studied and compared. Economics was a leading criterion for primary system design and plant layout. The use of a compact and simple primary circuit, with the additional objective that all internal components be removable, is among the reactor features intended to assure competitive electric energy generation and long-term investment protection. Low capital cost and construction time are pursued through simplicity and compactness of the reactor building (reduced footprint and height). The reduced plant footprint is one of the benefits coming from the elimination of the Intermediate Cooling System, and the low reactor building height is the result of the design approach which foresees the adoption of short-height components and two innovative Decay Heat Removal systems. Among the critical issues, the impact of the large mass of lead has been carefully analysed, notwithstanding, it has been demonstrated that the effects given by the high density of lead can be mitigated by more compact solutions, and improvement of the design of the Reactor Vessel support system (i.e. the adoption of seismic isolators for a full seismic-resistant design).

A more detailed description of the ELSY project and its main results is provided in [1]. The project ended in 2009, but the development of the ELSY reactor continued in the LEADER (Lead-cooled European Advanced Demonstration Reactor) project [2] which has been funded in the 7th Framework Program. Some partners of ELSY and LEADER also participate in SILER and cooperate to provide the input data to allow the design of the seismic isolation system and the related interface components. Thus, in the framework of SILER, a complete seismic analysis of ELSY, in both isolated and fixed base conditions, were carried out, with the aim of evaluating the effects (and the benefits) of the adoption of seismic isolation on the behavior of the most critical components, like the tank and its supports.

For the purposes of this study, a Finite Element Model of the plant aimed at reproducing the general layout of the buildings, their masses and centers of gravity (CoG), was implemented in the ABAQUS code (Fig. 2). Each building was considered as a box with the proper shape, having the total mass and the CoG position of the real one. The internal structure, roughly modeled, has only the aim to provide the correct mass distribution. The total mass acting on the isolation system is 1.36×10^8 kg, included the common basement.

Two series of three-directional artificial accelerograms, implemented by partner Empresarios Agrupados, were used in the analyses. The first tern was selected to be spectrum-compatible with the RG 1.60 (extended to the east coast, hard soils). The second one was selected to be compatible with the Eurocode 8 type 1, soil E (soft soils). The maximum PGA considered was equal to 0.3g in DBE (Design Basis Earthquake) conditions. Several parametrical analyses have been performed in order to design and optimize the isolators layout (§ 3.1). More information about this activity is given in refs. [3, 4].

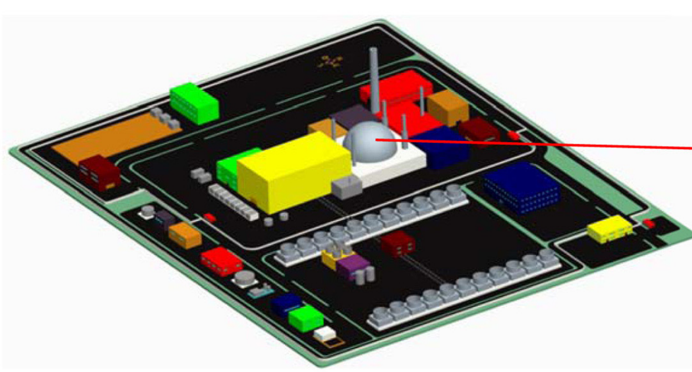

Fig. 1. Sketch of the ELSY Plant Layout. Seismic Isolation is Applied to the Whole Reactor Building.

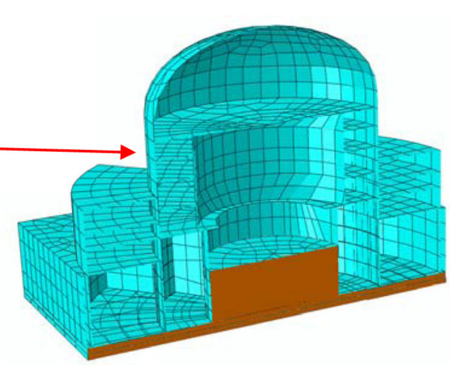

Fig. 2. Section of the ELSY Reactor Building FEM Provided with Base Isolation.