SEVENTH FRAMEWORK PROGRAMME

SILER: Seismic-Initiated events risk mitigation in LEad-cooled Reactors

Grant Agreement 295485

PROJECT OVERVIEW

PROJECT AIM

SILER

Seismic-Initiated events risk mitigation in LEad-cooled Reactors

is a Project aimed at

evaluating the risk associated to seismic initiated events in Generation IV Heavy Liquid Metal reactors

and developing adequate protection measures.

Agenzia nazionale per le nuove tecnologie, l'energia e lo sviluppo economico sostenibile

PROJECT PARTNERS

No	Name	Short name	Country	Project entry month[10]	Project exit month
1	AGENZIA NAZIONALE PER LE NUOVE TECNOLOGIE,L'ENERGIA E LO SVILUPPO ECONOMICO SOSTENIBILE	ENEA	Italy	1	36
2	AREVA NP SAS	AREVA NP SAS	France	1	36
3	STUDIECENTRUM VOOR KERNENERGIE	SCK•CEN	Belgium	1	36
4	FIP INDUSTRIALE SPA	FIP Industriale	Italy	1	36
5	Maurer Soehne GmbH & Co. KG	MAURER-SOEHNE	Germany	1	36
6	JRC -JOINT RESEARCH CENTRE- EUROPEAN COMMISSION	EC-JRC	Belgium	1	36
7	SINTEC S.r.l.	SINTEC	Italy	1	36
8	KUNGLIGA TEKNISKA HOEGSKOLAN	KTH	Sweden	1	36
9	BOA BALG - UND KOMPENSATOREN-TECHNOLOGIE GMBH	BOA-BKT	Germany	1	36
10	INGENIERIA IDOM INTERNACIONAL SA	IDOM	Spain	1	36
11	ANSALDO NUCLEARE SPA	ANSALDO	Italy	1	36
12	LATVIJAS UNIVERSITATES AGENTURA LATVIJAS UNIVERSITATES FIZIKAS INSTITUTS	IPUL	Latvia	1	36
13	NUMERIA CONSULTING S.R.L.	NUMERIA	Italy	1	36
14	VCE Holding GmbH	VCE	Austria	1	36
15	S.R.S. Servizi di Ricerche e Sviluppo Societa a Responsabilita Limitata	S.R.S.	Italy	1	36
16	COMMISSARIAT A L ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES	CEA	France	1	36
17	EMPRESARIOS AGRUPADOS INTERNACIONA L SA	EA	Spain	1	36
18	NUVIA TRAVAUX SPECIAUX SAS	NUVIA-TS	France	1	36

THE SNE-TP SRA (1)

…started on October 1° 2011,
SILER configures as an action
in support to the implementation of SRA

On September 21, 2007 the Sustainable Nuclear Energy Technology Platform (SNE-TP) was launched in Brussels.

Through the SNE-TP the European research nuclear fission community joined its efforts to issue a Strategic Research Agenda (SRA), to provide **clearly identified technological road-maps for the development of fission technologies**, being the nuclear energy considered as one of Europe's main low carbon energy technologies.

THE SNE-TP SRA (2)

Three pillars of SRA:

– Generation II and III Light Water Reactors (LWR) nuclear reactors contribute already very positively to the objectives in the EU's energy policy.

– Innovative Generation IV fast reactor systems with a closed fuel cycle will offer greatly improved sustainability.

– Other Generation IV reactors operating at very high temperature will provide low carbon process heat for the mass production of hydrogen and other industrial processes, including desalination.

On the basis of the three abovementioned pillars, the SRA highlights:
– R&D to support present and future LWRs and their further development.
– R&D challenges to further improve the current fuel cycles.
– **R&D for the development of fast neutron systems** (both Generation IV Fast Neutron Reactors (FNR) and Accelerator-Driven Systems (ADS)), along with the need for demonstration.

SILER PROJECT

In this frame, the Project aims at studying the seismic-initiated events risk in Heavy Liquid Metal reactors and developing adequate protection measures.

The attention is mainly focused on:

1) THE EVALUATION OF THE EFFECTS OF EARTHQUAKES
(with particular regards to beyond design seismic events and tsunamis)
and **THE IDENTIFICATION OF MITIGATION STRATEGIES**,
acting both on
structures/components design and the development of isolation devices

2) THE DEVELOPMENT OF GUIDELINES AND RECOMMENDATIONS
for addressing the seismic issue in next generation reactor systems.

3) **THE TRANSFER OF KNOWLEDGE DEVELOPED IN THE PROJECT**
to SFR systems as well as to Generation III advanced systems

SPECIFIC OBJECTIVES

In order to meet the project goal, therefore, specific objectives are:

– the **identification of the main features of lead-cooled reactor concepts (LFR and ADS)** relevant for evaluation of the risks associated with external damaging events

– the **evaluation of the selected system behaviour in case of severe seismic accident**; in particular, a key objective is the evaluation of the seismic related movement leading to failure of the primary system; specific consideration is paid to the study of **sloshing** phenomena

– the **identification of mitigation strategies** through the **design of adequate reactor components** and the development of **specific devices** (i.e., isolation devices) for structural damage reduction as well as the development of suitable layout design options to avoid the release of radioactivity (i.e. from the fuel storage pools)

– the **evaluation of the economic benefits** related to the introduction in the reactor design of measures for reducing the reactor damage due to external events, with the consequent increased standardization in the design

– the **transfer of the knowledge** gained on the advanced measures for increased safety from external risk mitigation **to Gen III LWR technologies**

PROJECT STRUCTURE

On the basis of the abovementioned objectives,

THE PROJECT IS STRUCTURED INTO SIX TECHNICAL WORK PACKAGES,

plus a dedicated work package aimed at managing the consortium activities and one dedicated to the scientific coordination of the activities, as follows

WP1: Consortium management

WP2: System modelling
WP3: Risk analysis for critical components
WP4: Development and characterization of isolation devices
WP5: Additional components design
WP6: Recommendations for standardization
WP7: Dissemination of information

WP8: Scientific coordination

WP1: CONSORTIUM MANAGEMENT

PARTNERS: ENEA, SINTEC

The WP1 consists in the general coordination of the consortium (i.e., management of legal, financial and administrative aspects), guaranteeing the coherence between the different work packages and the links with the European Commission.

Specifically, WP1 covers, *inter alia*, the:

– **general coordination of the consortium** and maintenance of CA;

– **administration of project resources**;

– **elaboration and monitoring of project procedures**;

– ensuring that all partners **share the same level of information** on general issues concerning the project;

– **reviewing of periodic reports** and **post-processing of the EC reviews**;

– **preparation, organisation and minutes of project management meetings** (governing board and external advisory board meetings);

– **follow-up of decisions and action plans**.

The WP groups the activities of the Coordinator and of the Management Office

WP2: SYSTEM MODELLING

PARTNERS: EA, ENEA, SCK•CEN, ANSALDO, NUMERIA, SRS

This WP is dedicated to the numerical modelling of the selected reactor systems (LFR, ADS) for evaluating their behaviour in case of severe seismic accident and for individuating possible countermeasures for limiting the reactor damage.
The so realized models will be based on the preliminary models and results obtained in ELSY/LEDER and CDT Projects.

Moving from the preliminary studies on the dynamic behaviour of the considered systems carried out in the abovementioned Projects, here the attention is devoted to **very severe accidents** (i.e. beyond design earthquakes) as well as to a **complete, modeling of isolators** (up to failure, thanks also to the feedbacks coming from WP4) to have models representatives of the real devices.

The WP outcomes constitute the basis of the evaluation of sloshing effects and for the study of seismic fragility to be implemented in WP3

WP3: RISK ANALYSIS FOR CRITICAL COMPONENTS

PARTNERS: KTH, SCK•CEN, SINTEC, IDOM, VCE,SRS

WP3 is devoted to evaluate the risk of damage of components and structures due to seismic excitation.

Particular attention will be devoted in LFR to the sloshing phenomena.
For the ADS system the issue of the behaviour of both the accelerator and the reactor under seismic excitation and of their coupling is addressed

Focus is also on:
the seismic fragility evaluation, namely the probability of failure of a component (or structural element)

the evaluation of the risks related to the void entrapment into coolant and void transport to the core conditioned to the severity of the ground motion.

WP4: DEVELOPMENT AND CHARACTERIZATION OF ISOLATION DEVICES

PARTNERS: FIP INDUSTRIALE, ENEA, NUMERIA

WP4 addresses development, final design and manufacturing of the seismic isolators (based on the outputs of task 2.3) and the execution of the experimental tests needed for their characterization.

A rubber compound characterized by an equivalent viscous damping of 15% at 100% shear strain and frequency ranging between 0.5 and 0.7 Hz is developed, to be used for the manufacturing of the HDRBs.
In addition, a low damping (5%) rubber compound, characterized by higher failure limits, is developed to be used in the manufacturing of the LRBs.

Based on the outputs of WP2:

at least two full scale prototypes of HDRBs are designed, manufactured and tested,

at least two full scale prototypes of LRB (with 2 or 4 lead cores) is designed, manufactured and tested.

WP5: ADDITIONAL COMPONENTS DESIGN

PARTNERS: SCK•CEN, ENEA, MAURER SOEHNE, EC-JRC, BOA-BKT, IDOM, NUMERIA, VCE, SRS

WP5 is dedicated to:

all those **interface components** connecting the isolated and non-isolated parts of the plant:

i.e the parts connecting the beam line to the reactor vessel

all those **components requiring a specific design** in case of isolation of the system

i.e. cover joint of the seismic gap,
pipe expansion joints,
foundation and isolated concrete slabs,
horizontal fail safe system

WP6: RECOMMENDATIONS FOR STANDARDIZATION

PARTNERS: VCE, ENEA, AREVA NP SAS, SCK•CEN, FIP INDUSTRIALE, MAURER-SOEHNE, EC-JRC, SINTEC, KTH, BOA-BKT, IPUL, NUMERIA, CEA, NUVIA

The WP6 is intended to develop recommendations for mitigating the risks due to external accidents on liquid metal pool type reactors.

Attention is paid to the evaluation of the benefits in terms of economics derived from the mitigation of the failure risk related to earthquakes and earthquake-induced phenomena as well as from the high level of standardization derived from the plant isolation.

A specific objective is the knowledge transfer on external risk mitigation to Gen III LWR technologies.

WP7: DISSEMINATION OF INFORMATION

PARTNERS: SINTEC, ENEA, SCK• CEN, KTH, IDOM, SRS, CEA

The WP7 covers the dissemination and external communication, with the main objective to enhance the diffusion of knowledge and information thanks to the exploitation of the potentialities of the new information technologies as well as using conventional tools.

Two workshops and a training course are foreseen in the Project:
An international thematic workshop will be organized at month 21 to provide an opportunity for dissemination of and feed-back on results obtained in the project.

An educational workshop in support of the training scheme is foreseen at the end of the project (month 34) where PhD students participating in the programme can presents the results of their activity.
A training course will be organized at the beginning of the Project (month 9) in order to address the different topics handled in the project, to give students participating in the initiative the instruments to address the research topics of the Project.

WP8: SCIENTIFIC COORDINATION

PARTNERS: ENEA, SINTEC

WP8 covers:

– the scientific coordination and monitoring of work-packages;

– the supervision of project progress milestones and project global critical path;

– the scientific review of the work performed by the partners including deliverables;

– the research risk management;

– the preparation of the scientific part of the reports to be submitted to the EC;

– the organization and minutes of the periodic general meetings, the EB meetings and of the specific WP technical meetings;

– the coordination of the EB;

– the realization and maintenance of the technical library (minutes of technical meetings, reports, papers, posters, presentations, etc).

EXPECTED OUTCOMES

Thanks to the proposed activities, the SILER Project moves from the results of the preliminary dynamic calculations performed in

FP6 ELSY , FP7 LEADER , FP7 CDT projects

to analyze more severe conditions, to study the appropriate isolation devices and solutions, and to evaluate plant layouts able to mitigate the risks of damage due to beyond design earthquakes and to earthquake-induced phenomena

STATE OF THE ART AND PROGRESSES BEYOND THE STATE OF THE ART (1)

There have been recently a large number of external events that have severely challenged structures and operations of nuclear plants:

several big earthquakes (one of them struck Kashiwazaki-Kariwa, the largest nuclear power plant of the world),

the 2004 Indian Ocean tsunami (which affected the Tamil Nadu reactor in India)

the more recent catastrophe in Japan, which severely damaged the Fukushima plant.

In this context there is a **clear necessity to develop new methodologies, felt by the entire scientific and regulatory community, along with the need to identify new procedures and solutions in order to reduce the overall core damage frequency in case of seismic-induced events.**

…in particular for HLM reactors…

It has to be noticed that, in general, most of the designs of liquid metal reactors developed in USA and Japan are considering the use of seismic isolation:
ALMR (Advanced Liquid Metal Reactor),
S-PRISM (Power
Reactor Innovative Small Module),
DFBR (Demonstration Fast Breeder Reactor)
STAR-LM (Secure Transportable Autonomous Reactor-Liquid Metal).
This because is generally recognised that with respect to water-cooled plants, **the liquid metal cooled reactors are more sensible to seismic excitation.**

STATE OF THE ART AND PROGRESSES BEYOND THE STATE OF THE ART (2)

In general specific attention is needed to be devoted also to study the **isolation devices** most suitable for isolating nuclear power plants.

For a correct use on NPPs, more severe design and qualification procedures shall be adopted, with respect to those used for civil applications.

Specific attention is therefore devoted in the project to the development, qualification and individuation of specific procedures for testing, installation and maintenance of seismic isolators in NPPs.
Contrary to what is the current normal procedures for civil applications, **the behaviour of the isolators in the project is experimentally investigated up to failure, in order to evaluate the real safety margins of the plant in case of beyond design earthquakes.**

STATE OF THE ART AND PROGRESSES BEYOND THE STATE OF THE ART (3)

Recently the use of seismic isolation has been considered also for the Jules Horowitz Reactor, now under construction at Cadarache, France, proving as the general direction now is to consider more seriously the benefits on terms of safety and economics of using isolation.

BUT

there is a dramatic lack of information and experimental results about the behaviour of large isolators in such structures under severe three-directional dynamic conditions

and

no specific standards regulate the application of seismic isolation to NPPs in Europe and USA (only Japan has a specific standards, unfortunately available in Japanese only), which is another important reason for the limited number of application on NPPs.

The present project aims at developing **guidelines specifically addressed to the designers, builders and end-users of NPPs, concerning design, licensing, installation, maintenance and replacement of the seismic isolators and other related interface components**

CONCLUSIONS

The recent violent earthquakes that struck Japanese nuclear power plants (Kashiwazaki-Kariwa in July 2007 and Fukushima in March 2011), renewed international focus on the structural strength of nuclear facilities.

Safety and reliability are essential priorities in the development of sustainable nuclear reactors: they have goals to achieve the highest levels of safety and reliability and to better protect workers, public health, and the environment through further improvements.
This also **reducing the likelihood and degree of damage due to unexpected, strong external accidents with very low probability of occurrence**, like beyond-design earthquakes.

In this view:
SILER is expected to have a strong impact on the overall success of the development program of LFR and ADS systems, which strongly depends on developing, demonstrating and deploying advanced designs that exhibit excellent safety characteristics
and
will impact on one of the critical issues recognized by the SRA in the development of next generation nuclear systems.

Thank you for your attention!