Current Status of the Gas Fast Reactor Demonstrator ALLEGRO

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ABSTRACT

The goal of the ALLEGRO Project is to design, build and operate the first Gas cooled Fast Reactor (GFR) Demonstrator. The GFR in Europe represents together with the Lead cooled Fast Reactor (LFR) a longer timescale alternative to the Sodium Fast Reactor (SFR), all of them belonging to the 4th generation of nuclear reactors. The original concept of ALLEGRO was designed in France by CEA in 2002-2009 with the aim to develop a high temperature (850 ºC) fast flux test facility suitable for testing the new U-Pu carbide fuel in ceramic SiC/SiCf claddings in prototypic helium coolant conditions. Because ceramic fuel is still under development, in particular by the CEA, MOX fuel was chosen for the first ALLEGRO core producing helium temperatures of 530 ºC. The ALLEGRO design studies have been shared in the project GCFR 6th FP since 2005 and in the project GoFastR 7th FP since 2010. As French CEA gave priority in 2009 to the development of the SFR demonstrator ASTRID, CEA proposed the continuation of the ALLEGRO project to three institutes from Central Europe: MTA EK (Hungary), ÚJV Řež, a.s. (Czech Republic) and VUJE a.s. (Slovak Republic), CEA continuing the GFR activities, in support to the Central Europe consortium, with fuel development and safety analyses only.

The present paper gives insight into the continuation of the ALLEGRO project since 2010. MTA EK, ÚJV Řež, a.s. and VUJE a.s. signed a Memorandum of Understanding in May 2010 that defines the preparatory phase of the ALLEGRO project (preparation of basic documents including a roadmap) aiming at ending the viability phase in 2013 in order to make a decision in 2013-2014 for further detailed design and construction. The three Central European (CE) countries wish to host the ALLEGRO reactor and will prepare the basic project documents by using their own financial resources, in combination with expected governmental support in their countries as well as with a potential international support from the EU Framework Programs and/or EURATOM Generation-IV funds. Project ALLIANCE was submitted for this purpose in the frame of the 7th FP (second call). Regulators of the three countries and the French regulator will be invited to participate in the preparatory phase of the project by reviewing the Licensing roadmap, content of the Preliminary safety analysis and the Criteria of siting.

This paper describes the current structure of the project and the steps planned to be done before the end of 2013.
1 INTRODUCTION

Three Central European members of the European Union, the Czech Republic, Hungary and Slovak Republic are traditionally prominent users of nuclear energy. They intend to use nuclear energy on the long run and beside the lifetime extension of their nuclear units, each country decided to build new units in the coming years. Considering the potential advantages of the 4th Generation reactors regarding uranium resources and high level waste management, because of the significant experience in these countries in applying nuclear energy, in order to maintain the competence of their nuclear community by deepening the knowledge on future reactors, to attract leading edge technology development into the region and to share the common responsibility of EU member states in achieving sustainable energy production and contributing to the mitigation of climate change, the idea emerged that the Czech Republic, Hungary and Slovak Republic could host a major European nuclear facility as part of R&D efforts aiming at the development of fast reactors.

Fast reactors are especially important from the point of view of sustainability of nuclear energy since they represent the main tool for closing the fuel cycle. Closing the fuel cycle has a double purpose: to reduce the amount of high level radioactive waste and at the same time to generate fissile materials to be used again in nuclear power plants.

Gas cooled Fast Reactors (GFR) are considered in Europe as a potential alternative of the sodium cooled fast reactors (SFR), which is the reference technology in fast reactor development [1]. GFR offers the unique advantage of fulfilling two missions:

- To be a sustainable nuclear energy source through efficient use of the natural uranium resource and through the reduction of the amount of radiotoxicity of wastes by recycling minor actinides.
- To be able to deliver high temperature heat for industrial processes such as hydrogen production. Application of GFR would reduce the industrial consumption of fossil fuels to produce high temperature process heat.

The GFR is prioritized by the Strategic Research Agenda (SRA) of the Sustainable Nuclear Energy Technology Platform and within the long term visions under the SET Plan this Fast neutron Reactor system (FRs) is one of the key structures of the possible future sustainable nuclear fission energy producer.

2 THE CENTRAL EUROPEAN COMMON EFFORT

The three respective nuclear research organizations of the region (ÚJV Řež, a.s., Czech Republic, Centre of Energy Research of the Hungarian Academy of Science (MTA EK), Budapest, Hungary and VUJE a.s., Trnava, Slovak Republic) signed a “Memorandum of Understanding” (MoU) in May 2010 to facilitate the start of a joint project aiming at the preparation for a decision on the construction and operation of the French based ALLEGRO Gas Cooled Fast Reactor in one of the countries [2], [3], [4].

The signed MoU defines the preparatory phase of the ALLEGRO project (preparation of basic documents including a roadmap) aiming at ending the viability phase in 2013 in order to make a decision in 2013-2014 for further detailed design and construction. The three CE countries wish to host the ALLEGRO reactor and will prepare the basic project documents by using their own financial resources, in combination with expected governmental support in their countries as well as with a potential international support from the EU Framework Programs and/or EURATOM Generation-IV funds.
A Steering Committee was established to decide on policy matters and to direct and handle the coordinated preparation of connections with the respective governments and regulators, EU organizations, communication strategy, rules concerning intellectual property rights, forming workgroups and to coordinate the activities in the preparatory phase of the ALLEGRO project. For the preparatory phase works seven Work Groups were created and Terms of Reference for each workgroup were defined: Project Coordination (WGC, lead by the Steering Committee), Design & Technology (WGD, VUJE), Safety Concept (WGS, ÚJV), Fuel Problems (WGF, MTA EK), Licensing - Environmental Impact Assessment and Site Issues (WGL, MTA EK), Governance & Intellectual Property Rights (WGG, MTA EK), Financing (WGF, ÚJV).

For the time being a preliminary schedule can be given for the entire ALLEGRO Project. Agenda is under development and also the milestones associated with the various phases of the project are under definition. The preliminary agenda of the ALLEGRO Project is divided into the four main phases:

- Preparatory phase 2010-2013
- Licensing & Construction phase 2013-2025
  - 2013-2017 Detailed design
  - 2017-2018 Site permit
  - 2017-2018 Environmental license
  - 2017-2018 Construction license
  - 2018-2024 Procurement, construction
  - 2025-2026 Commissioning
- Operation phase of the ALLEGRO reactor 2026-2046
  - 2026-2036 Demonstrative operation based on MOX fuel
  - 2036-2046 Demonstrative operation based on ceramic fuel
- Decommissioning phase 2046-2076

The preparation of the base documentation of the project constitutes the Preparatory phase. The decisions taken based on these documents shall be followed by the licensing, construction, commissioning and operation of ALLEGRO, and decommissioned after the termination of its operation. Moreover, the project specification for the Licensing & Construction phase, for R&D, as well as for the operational and decommissioning phases should be elaborated in the preparatory phase. This specification contains among others the licensing roadmap and the financing and project organization setup.

The project base documentations should be elaborated during the Preparatory phase of the ALLEGRO Project:

- General description of the project (definition of objectives and agenda)
- Licensing roadmap
- Preliminary design
- Preliminary safety analysis
- Support Research & Development studies
  - Fuel development (roadmap, research program, qualification)
  - R&D support programs (core neutronics, sub-assembly design, gas loops, material tests, instrumentation and control, safety devices, test of components, computer codes and simulation models, cogeneration system, etc.)
  - Hot cell needs
  - Spent fuel management strategy
  - Site studies
  - Analysis of required services (fuel fabrication, transportation, etc.)
• Preliminary environmental impact analysis
• Criteria of siting, rules of the site selection process
• Financing analysis, identification of potential partners

The Project devotes a special attention to licensing issues in the Preparatory phase, and a separate Licensing Roadmap will be elaborated. Licensing is obviously based on further safety studies to be conducted in the Preparatory phase. Since GFR represents a new technology, research and development is naturally a basic element of the Project. R&D Roadmap is under development too. It will cover R&D in the various phases with the following grouping:

2010-2013 Preparatory phase - R&D needed for licensing
2013-2025 Licensing & construction phase - R&D needed for constructing reactor
2026-2046 Operation of the ALLEGRO
  - In-pile test and qualification of advanced fuel
  - Experiments demonstrating the feasibility of the GFR technology
  - Use ALLEGRO as a fast spectrum research reactor

Organizations ÚJV, MTA EK and VUJE intend to sign a Consortium Agreement at a later stage of the preparatory phase to fix the deliverables and the roadmap of the preparatory phase, to specify the individual contributions of the participating institutes and to agree on the deliverables in later stages of the ALLEGRO project.

3 THE ALLEGRO GFR REACTOR DEMONSTRATOR

Gas cooled fast reactors (GFR) is one of the six Generation IV reactor concepts and represent one of the three European candidate fast reactor types, the two other being sodium cooled fast reactor (SFR) and lead cooled fast reactor (LFR). There is a considerable experience worldwide on SFR and the European prototype of the future SFRs will be built in France in the next decade. Because of the usual uncertainties of R&D success, an alternative solution is also sought for and this may be either GFR or LFR. Technically, GFR is a realistic and promising alternative thanks to its specific advantages connected with high temperatures.

The basic concept of the ALLEGRO GFR demonstration reactor (without electricity generation) has already been developed in France by CEA with the contributions of several European organizations cooperating in EURATOM projects. The French CEA agreed with ÚJV Řež, a.s., MTA EK and VUJE a.s. on the transfer to the related French results of research and technology development to the three institutes.

The ALLEGRO reactor would function not only as a demonstration reactor hosting GFR technological experiments, but also as a test pad of using the high temperature coolant of the reactor in a heat exchanger for generating process heat for industrial applications and a research facility which, thanks to the fast neutron spectrum, makes it attractive for fuel and material development and testing of some special devices or other research works.

3.1 The reactor design with the redesigned secondary circuit

The demonstration of the GFR technology assumes that the basic features of the 2400 MWth GFR reactor can be tested in the 75 MWth ALLEGRO. Therefore, most of the main parameters of both reactors are similar to each other (power density, etc.).

The original CEA design of ALLEGRO is shown in Figure 1. The whole primary part including the three decay heat removal (DHR) loops is integrated in a pressurized cylindrical guard vessel. The secondary circuit (not shown in the Figure 1) uses water as coolant. To
maximize the similarity with the GFR2400, the Consortium ALLEGRO proposed to insert an intermediate gas circuit (He or He+N₂) into the scheme, see Figure 2. The second reason was to minimize the risk of a massive water leakage into the primary circuit filled with hot helium (corrosion, criticality). The proposed He turbine is a safety feature. The third circuit, conducting the heat to the cooling tower, contains either water or air.

Figure 1: Initial ALLEGRO Design by CEA: Primary circuit enclosed in a guard vessel

Figure 2: Scheme of ALLEGRO with an intermediate gas (He+N₂) circuit with MOX core
3.2 The fuel design

The 75 MWth reactor shall be operated with two different cores. The starting core with MOX fuel in stainless steel claddings will serve as a driving core for six experimental fuel assemblies containing the advanced carbide (ceramic) fuel, which is under development at CEA. The second core will consist solely of the ceramic fuel and will enable to operate ALLEGRO at the high target temperature. Details are given in Table 1. Fuel development to satisfy the needs of a GFR is one of the basic goals of the ALLEGRO project. Safety considerations may strongly influence the fuel development.

Table 1: Base characteristic of the ALLEGRO Cores

<table>
<thead>
<tr>
<th></th>
<th>MOX Core</th>
<th>Ceramic Pin Core</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power density (MW/m³)</td>
<td>100</td>
<td>92</td>
</tr>
<tr>
<td>I. circuit helium pressure (MPa)</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>Core helium inlet/outlet temp. (°C)</td>
<td>260/530</td>
<td>400/880</td>
</tr>
<tr>
<td>Fissile core mass flow rate (kg.s⁻¹)</td>
<td>53.5</td>
<td>36.1</td>
</tr>
<tr>
<td>Fuel sub-assemblies (S/A)</td>
<td>Pins within hexagonal tube metallic structure</td>
<td>Pins within hexagonal tube SiC structures</td>
</tr>
<tr>
<td>Fuel form</td>
<td>(U, Pu)O₂ pellets in stainless steel claddings</td>
<td>(U, Pu)C pellets in SiCf/SiC tubes</td>
</tr>
<tr>
<td>Fuel pellet diameter (mm)</td>
<td>5.42</td>
<td>6.64</td>
</tr>
<tr>
<td>Cladding thickness (mm)</td>
<td>0.45</td>
<td>1.08</td>
</tr>
<tr>
<td>Fissile core height / diameter (m)</td>
<td>0.86 / 1.12</td>
<td>0.86 / 1.12</td>
</tr>
<tr>
<td>Number of fuel pins per S/A</td>
<td>169</td>
<td>90</td>
</tr>
<tr>
<td>Pu/U+Pu(%)</td>
<td>25</td>
<td>27.5</td>
</tr>
<tr>
<td>Number of fissile sub-assemblies</td>
<td>81</td>
<td>87</td>
</tr>
<tr>
<td>Number of absorber sub-assemblies (shutdown + control rods)</td>
<td>10 (4+6)</td>
<td>10 (4+6)</td>
</tr>
<tr>
<td>Number of in core steel/experimental sub-assemblies</td>
<td>6/0</td>
<td>0</td>
</tr>
<tr>
<td>Number of reflector sub-assemblies</td>
<td>174</td>
<td>174</td>
</tr>
<tr>
<td>Reflector material</td>
<td>15-15 Ti steel</td>
<td>ZrC</td>
</tr>
</tbody>
</table>

4 EURATOM 2012 FP7 PROJECT ALLIANCE

The consortium countries wish to host the ALLEGRO reactor by using their own financial resources, in combination with the expected governmental support as well as with a potential international support from the EU FPs and EURATOM funds. Project ALLIANCE was submitted for this purpose in the frame of the 7th FP (second call in March 2012) [5].

In accordance to the topic for Coordinating and Support Actions in the EURATOM Work Program 2012, Fission-2012-2.3.2 “Non-research activities in support of the implementation of the Strategic Research Agenda of SNE-TP”, the ALLIANCE project focuses on the preparation of support documents for the later decision on the construction and operation of the ALLEGRO demonstrator of the gas cooled fast reactor in one of the candidate countries (Czech Republic, Hungary or Slovak Republic).
The baseline of the ALLIANCE project will focus on strengthening links between parties involved in the preparation of the ALLEGRO gas fast demonstrator reactor (Regulatory bodies, utilities, research and technical support organizations, industry and engineering companies, governmental research organizations and universities) as well as to maintain communication with OECD and IAEA programs focused on gas cooled reactor systems. Information from the horizontal working groups of the Generation IV International Forum (GIF) and results from other EURATOM FP projects (GCFR, GoFastR, ADRIANA, etc.) will be taken into account.

This support action should create conditions for efficient exchange of information and cooperation links for improved communication among relevant GFR technology stakeholders, identify and clearly define the required R&D tasks in terms of experimental programs and computer codes, and suggest a realistic roadmap for further steps to be taken in order to develop this kind of technology as envisaged in the SRA. The results of the project work should serve not only as a technical guidance for future steps but also as explanatory arguments for national and European decisions makers whose political and financial support will be needed for further development of the GFR demonstrator ALLEGRO.

The project ALLIANCE envisages providing more information focused to the technical advantages and barriers to be overcome and withdrawing safety issues in association with significant educational, research and innovative institutions from the EU.

Figure 3 shows the location of the ALLIANCE activities within the ESNII roadmap containing all the concerned fast reactor systems. The work in the ALLIANCE project is planned for a 24 months period and is structured into seven Work Packages, see Figure 4. The Work Packages (WPs) are designed to address key project topics and constitutes the individual “logical entities” of the project.
5 SUMMARY

Fast reactors will play a significant role in developing the sustainable use of nuclear energy. Nuclear energy remains a decisive component of electricity production in the 21st century. In the last years the GFR development started and has been driven by the French national program with significant contributions from EURATOM and Switzerland. With the Central European Consortium project ALLEGRO is now becoming a wider European project and it is our hope, that ALLEGRO can fulfill the role as a European GFR technology demonstrator and fast neutron irradiation facility too.

In the framework of the Visegrad cooperation (V4) the relevant European governments (of the Czech Republic, Hungary, Slovak Republic and Poland) have already started to discuss hosting the GFR ALLEGRO in the region. The tendency of the Central European effort to design, build and operate the GFR demonstrator was confirmed by the signature of the ALLEGRO MoU by Poland (having the status of an observer) in June 2012.

REFERENCES


