

FAST REACTORS ACTIVITIES IN ROMANIA

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INTRODUCTION: Nuclear energy is a strategic option for Romania, and the development of the Advanced Lead Fast Reactor Demonstrator (ALFRED) has been included among the national strategic objectives. The ALFRED Project was conceived as a thorough demonstration program for the technology. The on-going efforts devoted to ALFRED implementation are performed on more than one direction: enlarging the experimental infrastructure, preparational activities for licensing the design, intensive research studies regarding the technology, contributions to development of commercial SMR LFR reactors.

1. OVERVIEW ON THE NUCLEAR PROGRAM

Nuclear energy is a strategic option for Romania. Romania shares the European Commission long-term vision [2], that by 2050 the European electricity mix will be based on significant renewable energy sources, which, together with a nuclear power share, will be the foundation of a carbon-free European power system [3].

As main energy policy document of Romania, the Integrated National Energy and Climate Plan (NECP) [1], represents the country commitment to the joint European effort to meet the targets set in the field of energy and climate for 2030 and 2050, respectively. Romania's targets are ambitious: to reduce by 2030 the CO₂ emissions by 55% (compared to the 2005 levels), and to reduce its dependence on energy imports to 17.8% (from 20.8%), which can be translated in sustained investment in carbon-free or transitional generation capacity. Furthermore, it is estimated that without investment in the nuclear industry, both in extending the lifetime of units approaching their initial operating limit and in new nuclear capacity, the cost of transitioning to a sustainable economy would increase drastically [3].

The Romanian Energy Strategy [4] indicates the long-term commitment to nuclear energy, the nuclear project being the largest potential investment in the Romanian energy sector over the next decades. The National Strategy for the Development of the Nuclear Field in Romania is aiming for Security of energy; Sustainable development; Competitiveness as strategic objectives.

Romania has 2 operational nuclear units at Cernavoda NPP, covering approx. 18% of country total energy production. In the National Nuclear Plan a contribution of nuclear with about 40% to the total national electricity production is foreseen for 2025-2050. In this direction, efforts are made for Unit 1 Cernavoda refurbishment project, which will extend the operational life with another 30years [5]. The Government Program has as Priority projects: construction of Cernavoda NPP U3 and U4, stimulation of R&D in nuclear field and technology transfer of GenIII to GenIV reactors. Moreover, Romania will deploy by 2030 a NuScale SMR 6 module power plant (462 MW), each module with an installed capacity of 77 MW.

2. LEAD-COOLED FAST REACTOR – NATIONAL EFFORTS

Romania shares the opinion that Lead-cooled Fast Reactor (LFR) is one of the most promising Generation IV technologies which could bring important advantages by: increasing the nuclear safety level and eliminating the need for off-site emergency response; increasing efficiency of the natural uranium resources use (from 0.5% in the open fuel cycle technology of natural uranium, to over 80%

in the case of LFR closed fuel cycle), extending therefore the time horizon of the current reserves; reducing the quantities of waste generated and their radiotoxicity; increasing the economic performance; strengthening resistance to proliferation.

Considering the Research, Innovation and Competitiveness dimension of the Energy Union [6] Romania has included the development of the Advanced Lead Fast Reactor Demonstrator (ALFRED) among the national objectives, and supports its implementation as a mandatory strategic step. Following the participation of the Institute for Nuclear Research (RATEN ICN) in a large number of Euratom research projects dedicated to LFR technology, and the improvement of research capabilities, the Government of Romania expressed, through Government Memorandums No. 1925 / 03.02.2011 and 21104 / 07.01.2014, the availability to host the ALFRED demonstrator in Romania.

The strong commitment of Ansaldo Nucleare, ENEA (from Italy) and RATEN ICN from Romania for promotion and implementation of LFR technology was once more confirmed through the signature of the FALCON (Fostering ALFRED Construction) International Consortium, aimed at managing the R&D strategic needs and securing the necessary funding for siting, licensing and construction of ALFRED.

The ALFRED Project is now included in Romania's relevant strategies (National Research, Development and Innovation Strategy [7], National Research Infrastructure Roadmap [9], Smart Specialization Strategy of the South-Muntenia Region [10], RATEN Strategy [11]).

ALFRED is considered as a game-changer for nuclear industry, due to its multiple facets:

- a key facility for testing and qualifying in a relevant environment new structural materials and nuclear fuels, as well as innovative components and systems;
- a design for increased safety, sustainability and competitiveness;
- an opportunity to improve the knowledge, competences and skills in a comprehensive and well-structured framework, on all operational aspects of LFR technology.

RATEN ICN is the representative organization for the R&D activities and all supporting activities for deployment of the ALFRED in Romania. The activities dedicated to fast reactors, focused on LFR technology, are performed mainly under the RATEN R&D programme “Advanced Nuclear Reactors and Fuel Cycles”, funded from the national budget. Annually, around 30 R&D projects (around 1 mil. Euro) were devoted to LFR technology development, being focused on:

- Investigation of materials behaviour and technologies development for Advanced Nuclear Systems;
- Nuclear Reactors Physics & Thermohydraulics
- Safety Evaluations for Advanced Reactors;
- Modelling and simulations of operational regimes in experimental installations;
- Infrastructure Development for Study, Characterization, Testing and Qualification of Materials and Components for Gen IV Reactors;
- Methodologies for evaluating and monitoring the operating behaviour of LFR structures;
- Preparational activities for Advanced and Modular Reactors Siting and Licensing;
- Investigation of scenarios for integration of innovative reactors in the national energy program.

As main outcome of this programme, RATEN increased its capacity in addressing and solving technical & scientific issues regarding the design, development and implementation of lead cooled reactors and the supporting experimental infrastructure.

On the European research scene, the RATEN activities for fast reactors are leveraging on the extensive research performed within the synergistic frame of EURATOM research programmes. In the last years, RATEN has contributed (mainly for LFR technology) to the planned activities of many projects

dedicated to advanced reactors: **PASCAL** (Proof of Augmented Safety Conditions in Advanced Liquid-Metal-Cooled Systems), 2020-2024; **PATRICIA** (Partitioning and Transmuter Research Initiative in a Collaborative Innovation Action), 2020-2024; **HARMONISE** (Towards Harmonisation In Licensing Of Future Nuclear Power Technologies In Europe) 2022-2025; **ANSELMUS** (Advanced Nuclear Safety Evaluation of Liquid Metal Using Systems) 2022-2026; **INNUMAT** (Innovative Structural Materials For Fission And Fusion) 2022-2026; **FREDMANS** (Fuel Recycle and Experimentally Demonstrated Manufacturing of Advanced Nuclear Solutions for Safety) 2022-2026; **LESTO** (Lead fast reactor Safety design and TOols), 2024-2027.

The notification of the intention to licence and construct the lead-cooled demonstration reactor was the starting point for multiple meetings and discussions between Romanian National Commission for Nuclear Activities Control (CNCAN) and FALCON members. Even from the beginning of the interactions, both parties, CNCAN and FALCON Consortium, agreed that adding a preparational phase (pre-licensing) will be beneficial to the whole licensing process. Going through a pre-licensing stage should help in developing and using strong safety, security, and radiation protection arguments in the licensing application.

The ALFRED Project was conceived as a thorough demonstration program for the technology, in which the ALFRED reactor will be supported by a distributed research infrastructure covering the research, development and qualification programme for both the short and long-term. In Romania, the infrastructure will include the following installations:

- **ATHENA** is designed to test the behaviour of full-scale components in liquid lead, with a particular focus on the investigation of the steam generator tube rupture, the fluid-structure interaction, lead stratification and freezing in a pool configuration system;
- **ChemLab**, a laboratory specialized in the chemistry of lead and cover gas, will allow a better understanding of the oxygen and other impurities control and monitoring in both environments;
- **HELENA2** will serve to test and demonstrate the thermal-hydraulic behaviour in pure liquid lead of full-scale ALFRED fuel assemblies and of the safety and control rods, in normal and forced flow regimes;
- **ELF** will be designed for endurance tests of the operation of ALFRED components, equipment and systems, as well as for the measurement of the reliability characteristics.
- **Meltin'Pot** will serve for the investigation of the phenomenology associated to severe accidents in LFR systems by complex studies on the interaction between fuel, cladding and coolant, including fuel dispersion during a severe accident, fission products retention in pure lead, etc.;
- **HandsON** will be devoted to test the handling of the full-scale fuel assemblies and control rods of the ALFRED demonstrator, in operational conditions.

The main stages in implementing at RATEN ICN this infrastructure consisted on the following:

- *PROALFRED project* (2019–2020) [8] was funded under the framework of the National Plan for Research, Development and Innovation 2015–2020 (PNCDI III), and provided technical documentation and feasibility studies for the research supporting facilities, elements for licensing process preparation, the research agenda and the human resource strategy associated to the ALFRED project.
- *ALFRED – Stage 1, support research infrastructure: ATHENA (pool-type facility for thermohydraulic experiments and tests) and ChemLab (laboratory for lead chemistry) project* was founded by Competitiveness Operational Program (POC). The activities started in 2020, and the project is close to finalization. In October 2024 the financing contract for the phasing of the ATHENA project was signed, with an estimation for the completion of the activities for the commissioning and technological tests of the ATHENA facility in the first part of 2026.
- *Research Activities and Experimental Infrastructure for the Demonstration of Lead-Cooled Fast Reactor Technology (4ALFRED) project* aims to develop 4 experimental facilities (HELENA-2, ELF, HandsOn, MeltinPot) and carry out research and development activities in support of the further development of LFR technology and the authorization of the ALFRED. The activities are financed from European structural funds through the Operational Programme

for Smart Growth, Digitalization and Financial Instruments (POCIDIF). The contract was signed on 26 February 2025.

At international level, the activities to support the Memorandum of Understanding between ANSALDO Nucleare, ENEA, RATEN, SCK.CEN were continued, with the objective of creating a partnership for the development of commercial SMR LFR reactors. The EU-SMR-LFR project (based on ALFRED design), proposed by SCK and FALCON members, was selected among the 9 projects [12] that are considered for the working groups of the European Industrial Alliance on Small Modular Reactors. The activity will continue with creation of the working groups, that will elaborate several implementation projects. A joint pre-licensing project is foreseen, with the regulatory authorities of Belgium (FANC/Bel V), and Romanian (CNCAN), through an IAEA extra-budgetary project.

3. CONCLUSIONS

Implementing a new innovative technology requires sustained efforts, both on national and international level. Romania has included the development of ALFRED among the national objectives, and supports its implementation. The on-going national efforts are devoted to: enlarging the experimental infrastructure, preparational activities for licensing the design, intensive research studies regarding the technology, and contributions to development of commercial SMR LFR reactors.

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