A MW-class ADS Facility at the Troitsk Site of the Moscow Institute for Nuclear Research of the Russian Academy of Sciences

Executive Summary

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Context

Finite fossil energy resources, which represent 80% of the world consumption, with devastating impact on public health, environment and climate, must be replaced on a relatively short time scale, well before the end of the 21st century. This is a formidable challenge for Society, that can only be met through vigorous R&D. iThEC is an international, not for profit association, located in Geneva, Switzerland, promoting energy research based on thorium. Its goals are the development of innovative, safe, clean and abundant energy sources and the destruction of long-lived nuclear waste. iThEC is acting as a catalyst for international collaboration on the CERN scientific experiment model. The aim of the proposed collaboration is to construct an Accelerator-Driven System (ADS) facility, which will, for the first time, couple a proton beam from an accelerator to a fast-neutron subcritical core, at substantial thermal power ($\geq 1\ MW_{thermal}$), and demonstrate the feasibility of destroying nuclear waste efficiently. An Accelerator-Driven System is a leading candidate for the exploitation of thorium in nuclear energy plants of the future. iThEC is advocating ADS as a fast neutron, subcritical system using thorium fuel instead of uranium, on the model proposed by Nobel Laureate Carlo Rubbia.

iThEC and INR are in the process of preparing a technical proposal, including applications for licensing and gathering an international collaboration to design, build and commission a first ADS of significant power within 5 years. Russia is a country with longstanding experience in nuclear energy, where an accelerator, a spallation neutron source and a well-suited experimental site already exist, at Troitsk, near Moscow.

Motivation

In 2015, nuclear energy produced 27% of the electric power in Europe (77% in France), without emitting greenhouse gases, without polluting the atmosphere with SO_X, NO_X, or particulate matter, while reducing significantly the dependence on fossil fuels. However, a massive deployment of nuclear energy requires a drastic change in present nuclear systems. Safety and nuclear waste management must be improved, and the proliferation of weapon-grade materials must be avoided. It has been shown at CERN, by Carlo Rubbia and his team, that an accelerator-driven system, using thorium fuel, fulfills these requirements. "***Thorium is a practically sustainable source of energy, on the human timescale***", said Carlo Rubbia at the ThEC13 conference at CERN, in October 2013. The physics of such systems is very well understood, and detailed computer simulations of the behavior of the sub-critical core and its waste-burning capabilities already exist. What remains to be achieved on the political front is a demonstration of the efficient destruction of minor actinides and of long-lived fission fragments, even though the principle has already been established in experiments at CERN. On the technical front, a facility of significant power is needed to learn how to operate such systems, to demonstrate the superior safety case of a sub-critical core and its impact on cost, and to optimize the choice of technological components in view of industrialization: the proton accelerator, the interface between the accelerator and the subcritical core (spallation neutron source), the nature of the fuel, its configuration in the core, the coolant, and the much-simplified safety. The deployment of such systems requires the development of a new thorium-based fuel cycle, which will have to be simpler to operate, inherently safer and cleaner than for instance current MOX fuel technologies.

iThEC's strategy for building quickly and efficiently such a facility rests on adapting an existing infrastructure, a powerful neutron source, at INR, at Troitsk, at a relatively modest cost (**60 M$**) and on a relatively short time scale (**5 years**). This project will be far cheaper and faster than presently envisaged alternative projects, and will provide in addition an affordable fast neutron flux test facility that can be used for other purposes such as Gen IV or fusion material research.

Accelerator: After refurbishing the Troitsk LINAC for a minimal configuration, the proton beam power will range between 25 and 90 kW (at a beam energy from 247 to 300 MeV and an average beam current up to 0.2 mA). With these characteristics, it will be possible to study ADS properties up to a thermal power of 2.5 MW, varying the neutron multiplication factor, k_s, up to 0.98.

Spallation source: A solid tungsten or uranium-molybdenum alloy target is envisaged, with a design that will maximize the neutron yield at an average beam power of 60 kW. A proton with a kinetic energy 300 MeV produces 4.25 neutrons, corresponding to a neutron source of 5×10^{15} neutrons/s. The goal is to achieve, around the neutron source, a neutron flux similar to that of a fast reactor ($\sim 10^{14}$ n/cm^2/s).

Subcritical core: The core will be subdivided into three regions: a compact spallation source, surrounded by a solid lead transmutation area with channels for inserting detectors for the determination of the neutron flux map or minor actinide samples, and a neutron driver area, where fission neutrons are produced and which can receive initially uranium- and later thorium-based fuel rods. A reflector blanket will also be considered for the transmutation of long-lived fission fragments (^{99}Tc and ^{129}I).

Project Roadmap

The project will proceed in four main phases, over a total period of 5 years. The first step will consist of the preparation of a conceptual design needed for approval of the facility by the Government of the Russian Federation, and the formation of an international collaboration:

1– Preliminary phase – Specifications of technical parameters

2– Conceptual design

3– Obtaining Government authorization, in three steps:

- ***Declaration of intent***
- ***Estimate of the impact on the environment***
- ***Funding plan***

4– Technical design

5– Licensing

6– Permission for construction and installation

7– Construction and installation

8– Permission for commissioning and operation

Strategy for an International Collaboration

After initiating the project, iThEC and INR will have a coordinating role in the collaboration. Responsibilities will be agreed upon among partners as is usually done in CERN experimental collaborations.

iThEC and INR Moscow will jointly organize a workshop dedicated to the project, and will actively seek the support of IAEA, CERN, PSI, EPFL, FASO of Russia, RAS, ROSATOM, MOS RF, and other institutes interested in the project, especially in India and China, where the interest in exploiting thorium is greatest.