Development of Innovative Nuclear Systems

October 9, 2019

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Non-Fossil fuel in Japan

Fast Reactor Fuel Cycle

- Light Water Reactor (LWR)
- Spent Fuel Reprocessing Plant
- Spent Fuel Interim-Storage Facility
- Fuel Fabrication Plant
- Fast Reactor

Plutonium Utilization in LWR
Potential of Innovative Nuclear Systems

**Hybrid systems**
- Reliable Grid: Load following, Heat Storage
- Heat Usage for Hydrogen Production & Water Desalination (Gen-4)

**Sustainability**
- Effective Use of Uranium Resources (Gen-4)
- Minimize Radioactive Waste and Burden (Gen-4)

**Safety**
- Passive Features of Feedbacks
- Passive Shut down Systems
- Passive Decay Heat Removals: Natural Circulations, etc.
- Safety Design Criteria for International Safety Standards

**Cost Competitive**
- R&Ds on Innovative Systems
- Cost Challenges based on recent Gen-3+ experiences
- Suitable Scale for Market Needs (SMR)
The concept of an integral fast reactor (IFR) consists of reprocessing the fuel debris, fabricating TRU fuel, burning it in a small MF-SFR and recycling the spent fuel by reprocessing.

Amount of heavy metals (HM), such as uranium, contained in fuel debris: Approx. 250 tons and TRU elements account for approximate 1.9 tons.

Configuration
- A Metallic Fuel (MF)-SFR with inherent safety features (reactor output: 190 MWt)
- Application of a MF pyro-processing method that makes debris processing possible.

Debris Processing Scheme and TRU Reductions

- The amount of fuel debris could be processed within 10 years.
- In 25 years after the launching the IFR, the 1.9 tons of TRU present in the debris will be reduced to a total of 1.2 tons in the reactor and in the spent fuel. Because of the shortage of TRU required to fabricate fuel, it will be necessary to procure TRU from breeder reactor core or external sources in order to continue operation of the reactor.

Concept diagram of debris processing scheme
Current development plan of fast reactor in Japan

Prototype Fast Breeder Reactor “Monju” (280MWe)
- First Criticality in 1994
- Demonstration of reliability as a power reactor
- Establishment of sodium handling technology

Experimental Fast Reactor “Joyo”
- First Criticality in 1977
- Demonstration of fuel breeding and safety
- Accumulation of know-hows of maintenance and repair, etc.

Basic development of advanced fuel technology, etc.

Commercial Fast Reactor
- Latter half of The 21st century
- Next Fast Reactor
  - Evaluation of economy of commercial reactor
  - Demonstration of technical performance

Around the middle of the 21st century
- Feasibility study on commercialized fast reactor cycle systems
- Fast reactor cycle technology development project

1999 2005
FS* Fact Project**
Japanese METI launched in 2019 the **Nuclear Energy x Innovation Promotion (NEXIP)** initiative supporting private sectors to develop nuclear technologies which enhance Safety, Economy and Maneuverability of nuclear power plant

Two categories of technologies will be subsidized:

1. Innovative nuclear technologies to meet social requirements
   - Feasibility study on innovative reactor technologies which enhance the Safety and Economy
   - Obliged to attain at least one feature among Maneuverability, Multipurpose uses, Effective use of resources, Reduction of radioactive waste, and others

2. Technologies enhancing the safety of NPP
   - Development of innovative elemental technologies which enhance the Safety of commercial NPP (light water reactor)
Technologies studied in “NEXIP” Initiative

Small Modular Reactor (SMR)

“NuScale” Design and others

Generation-4 Reactors

6 reactor types selected by GIF

Gas-cooled Fast Reactor (GFR)

Molten Salt Reactor (MSR)

Lead-cooled Fast Reactor (LFR)

Sodium-cooled Fast Reactor (SFR)

Very High Temperature Reactor (VHTR)

Supercritical Water Reactor (SCWR)
Steps of “NEXIP” Initiative

- **R&D policy**
- **Strategic roadmap**

**STEP 1**
Promotion of competition

**STEP 2**
Narrowing down and focusing on the technology

**STEP 3**
Examination of subjects and the time schedule for FR operation

A FR is expected to start its operation around mid 21st century

- After 2020, the scope of varieties of technologies will be narrowed

In the first five years

\(~2024\)
Balancing Demand and Supply of Electricity

Demand following by < Other Renewables + Nuclear + Fossil with CCS >
Conclusion

- From the viewpoint of global warming, expansion of non-fossil power resources including nuclear power is indispensable.

- Innovative nuclear systems such as Gen-4 systems and Small Modular Reactors (SMRs) have potential features on sustainability, Safety and so on.

- In Japan, Nuclear Energy X Innovative Promotion (NEXIP) Initiative was launched supporting private sectors to develop nuclear innovative technologies. After 2020, the scope of varieties of technologies will be narrowed in about 5 years.

- Harmonization of renewable energy is expected to be an important characteristics for future nuclear energy.
Thank You for Your Attention!