User Requirements and Approaches of Development for Future Nuclear Energy System

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1. Introduction

Technology innovation is one of the key issues in every field for the future of the technology. In early 21st century, international nuclear society has a common recognition on the necessity of innovative nuclear energy system to cope with new trend and increasing energy demand, several international programs were initiated for development of new systems that secure stable energy supply and have improved public acceptance, safety, and cost-effectiveness. This paper surveyed status of international activities on future innovative nuclear energy systems, and describes the user requirements of future nuclear energy system for the deployment in the future. The approaches to development of the innovative nuclear energy technologies for meeting future goals were discussed.

2. International Activities for Development of Innovative Nuclear Energy System

Exemplary programs organized internationally for the development of innovative nuclear energy system are Generation IV of GIF, IAEA INPRO and Three Agency Study.

2.1 Generation IV International Forum

The Generation IV International Forum (GIF) was organized for collaborative development of new generation nuclear energy system aiming 2030 that can be accepted in public and energy market with excellent technical features and competitiveness in economics.
Ten member countries leading nuclear utilization and development and the EURATOM take part in the GIF. GIF selected six systems of the most promising concepts as Generation IV nuclear energy system and completed and issued the technology roadmap for development of these systems.[1]
From 2003 GIF is preparing the R&D plan of each system and multilateral agreement for conducting collaborative R&D. Start of international collaborative R&D on Generation IV is expected in 2005.

2.2 IAEA INPRO

The International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO) was initiated for the purpose of considering jointly the international actions required to achieve desired innovations in nuclear reactors and fuel cycles, about twenty countries are members of the project, as of 2004.

The INPRO investigated role of nuclear energy in 21st century for sustainable development and determined requirements and criteria of innovative technologies for nuclear fuel cycles and nuclear power. The results were published as the technical report of IAEA.[2] From 2003 case studies for examination of innovative nuclear energy technologies against criteria and requirements areconducted.

2.3 Three Agent Study

Three Agency Study is a joint project of among the International Energy Agency (IEA), the OECD Nuclear Energy Agency (NEA) and the International Atomic Energy Agency (IAEA). The study reviewed innovative nuclear reactor technologies to describe how new technologies are attempting to address the challenges facing nuclear energy today and to identify potential areas for international cooperation.[3]
The list of innovative reactor designs under development was compiled with approaches to meet goals for innovative reactors and enabling technologies, R&D needs and opportunities for collaboration were suggested.

3. Outlook of Nuclear Energy and Requirement of Future Nuclear Energy System

3.1 Role of Nuclear Energy in the 21st Century

Inter-governmental Panel of Panel on Climate Change (IPCC) published a Special Report on Emission Scenarios (SRES) in 1992 and revised the report in 2000, the SRES presents 40 reference scenarios of four groups considering economic growth, technology development and social condition and the report predicts future energy consumption to 2100.
Based on these, International Institute for Applied Systems Analysis (IIASA) selected 4 possible scenarios for nuclear energy in mid-21st Centuries and analyzed the portion of nuclear energy in total energy mix and estimated the potential market for nuclear energy products.
As a whole, the results predict mainly electricity production and limited application in process heat till 2050, but considerable market of hydrogen production and process heat after 2050.
According to two studies global energy use grows between 1.7 and 3.7-fold between 2000 and 2050, the scale of nuclear energy market in 2050 is from 3 to 10 times comparing 2000.

3.2 Requirement of Future Nuclear Energy System

Current principal issues surrounding nuclear energy are economic competitiveness, safety and reliability, environment and waste, and proliferation resistance and physical protection,[5] the INPRO determined the basic principles and user requirement of innovative nuclear energy system and developed the criteria for evaluating the system in the field of these areas which cover economics, sustainability and environment, safety of nuclear installation, waste management and proliferation resistance.

Economics principles include competitiveness of life cycle cost, attractiveness of capital investment, environment principles are acceptability of environmental effects and fitness for purpose of efficient use of non-renewable resources. Basic principles of safety are incorporation of enhanced defence-in-depth, reduction or containment of radioactive and hazardous materials, inherent safety characteristics, safety analysis codes, and holistic life-cycle analysis. Protection of human health, environment and future generation were considered in waste management principles. Finally proliferation resistance principles treat intrinsic features and extrinsic measures against nuclear proliferation.

4. Approaches of development for Future Nuclear Energy System

Three Agency Study offered some recommendation to the developers of nuclear energy technologies and the organization of fostering collaborative R&D. The first is "Make better use of experience to date", which can be explained to confer previous design and past experience and procedures. The second is "Increase cross fertilization of ideas", and this can serve the opportunities for considering potential alternatives approach to meet design requirements. The third is "Take greater advantage of components and technologies developed in others", and the fourth is "Increase cooperation in R&D", which is more comprehensive than above three recommendations and current international collaborative R&D activities of Generation IV and INPRO can be understood as the same scheme.

The study describes the enabling technologies relevant to the development of several types of innovative designs as natural circulation, high temperature materials, passive devices, in-service inspection and maintenance methods, advanced monitoring and control technologies, delivery and construction method, and safeguards technologies and approaches.

5. Conclusion

In energy policy, nuclear energy is still considered one of the main energy source in respect of security of energy supply and abatement of CO_2 emission, however issues surrounding nuclear energy as economics due to high initial investment cost and concerns on safety and waste of public, impede deployment of new nuclear power.

The technology for improving performance of current plant is essential in nuclear industry and to be developed continuously, and now the systems of innovative technical features needed for the future of nuclear energy. Innovative nuclear energy systems can have comparative advantage in liberalized market and improved public perception with enhanced safety, reduced waste generation and proliferation resistance.

International effort to resolve these issues are now produced as the requirements of future innovative nuclear systems in the INPRO and the technology roadmap of the Generation IV, and the approached for development innovative nuclear energy systems are suggested in Three Agency Study.

In conclusion, successful resolution of current technical problems of nuclear energy depends on combination of the past experiences and emerging new technologies. In addition to these technical R&D, systematic organization of social and economical consideration for adaptation of nuclear energy to the future society is to be studied.

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