A Critical Review and Policy Suggestion on Generation IV International Forum (GIF)

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1. Introduction

The Generation IV International Forum (GIF) was created in 2000 by 9 countries and currently consists of 14 members (Argentina, Australia, Brazil, Canada, China, Euratom, France, Japan, Korea, Russia, South Africa, Switzerland, United Kingdom and United States), pursuing technologically innovated and advanced reactor designs and systems aimed to improve sustainability, economics, safety & reliability, proliferation resistance & physical protection (PRPP) [1].

The nuclear energy has played an important role in the transition towards a low-carbon economy, contributing to tackling the climate change. To achieve worldwide decarbonisation goal, the nuclear energy has to cut down the cost on building the power plants [2]. Public concern for the nuclear power in terms of safety includes to tackle the most urgent challenges and opportunities for deploying innovative technological and process solutions [3]. The most significant concern of the nuclear energy to be faced for a long time is related with proliferation of potential nuclear weapons risks, promoting its peaceful use by impeding the diversion or undeclared production [4].

GIF was established in 2000 and since that time has been challenged to meet objectives through the organizational governance structure. GIF launched four task forces- Education and Training (E&T), Advanced Manufacturing and Materials Engineering (AMME), R&D Infrastructure (RDTF) and Safety Design Criteria (DC) leading the realization of the future in the development of Gen IV systems [1].

The governance structure and the general framework for implementing GIF co-operative R&D was already introduced in the paper published in the Korean Nuclear Society Spring Meeting 2011 [5]. The main goals of this research is:

- overview the transition of GIF governance change focused on Task Forces;
- investigate the R&D priorities and challenge needed to meet the system targets;
- investigate the new R&D strategy
- review PRPP evaluation and cyber security
- suggest GIF R&D policy

2. GIF organisation, main achievement and new direction on R&D Collaborations

2.1 Transition of GIF organisation

The initial governance structure established in 2000 was introduced in the Korean Nuclear Society Spring Meeting 2011 [5]. The four task forces of GIF were addressed to support the solution of the crucial issues in the nuclear energy field in this paper. The GIF governance structure is shown in Fig. 1.

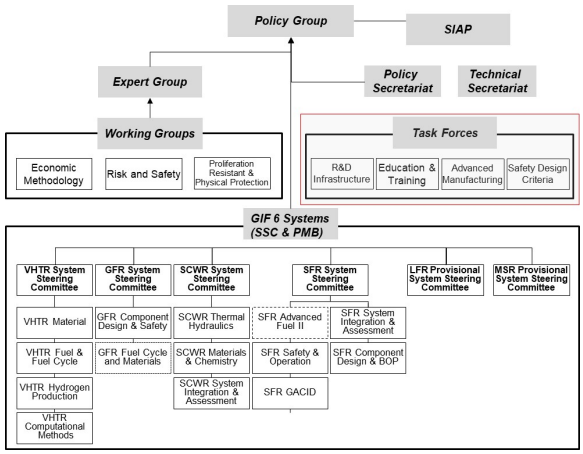

Fig. 1. GIF governance structure (as of March 2020)

First, the R&D infrastructure task force has mission to promote sharing research facilities, database, and reports for collaborative R&D activities among GIF members to reduce the cost of development and operational expense. Currently, regarding the strategy planning, the GIF is working with other internal cooperation initiatives such as IAEA, ICERR, NEA, NEST, and EURATOM [7].

Secondly, the Education and Training task force is making an effort aimed to assure a qualified workforce in the next decades and to encourage a young generation of nuclear experts and leaders. Thus, the GIF is focusing on promoting education and training in multiple ways by aid of GIF website, a newsletter, monthly webinar presented by worldwide leaders, and social network.

Third, the Advanced Manufacturing and Materials Engineering task force was established to identify emerging manufacturing technologies and prioritization to be able to reduce investment and operational costs, increase efficiency and improve safety.

Lastly, the objective of the Safety Design Criteria task force is to set reference criteria for the safety design of structures, systems and components with the aim of achieving the safety goals of a Generation-IV reactor system. The task force developed an integrated safety assessment methodology (ISAM) including the overall work flow shown in Fig. 2 [6].

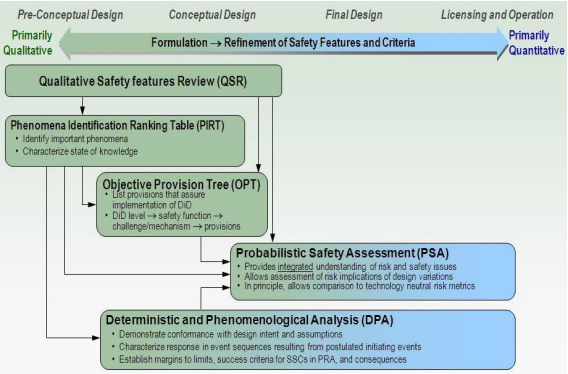

Fig. 2. Proposed GIF integrated safety assessment methodology (ISAM) task flow [6]

2.2 R&D Priorities

This section gives the related R&D priorities in perspective with the Gen IV systems, especially in SFR and VHTR.

SFR system

In the next decade, the key technologies for prototypes development will be focused on the advanced non minor/minor actinides bearing and high burn-up fuels evaluation, optimization and demonstration. Additionally, advanced energy conversion systems, validation of passive decay heat removal, LBB assessment and development of steam generators will be required for the future R&D activities [1.7.8].

VHTR system

In the near term, lower-temperature (from 700°C to 950°C) demonstration target is being pursued to meet the needs of current industries interested in early applications towards medium-term demonstration, market adaptation. Future operation at higher temperatures (1,000°C and above) requires development of composite ceramic materials and the long-term performance. Additionally, the coupling to cogeneration applications and the energy system integration will require more research [1.7.8].

2.3 New R&D directions

SMR development with industry

The ongoing expansion of renewable energy and nuclear power phase out plan will transit composition of the electricity mix. Due to the high capital cost and investment in large-scale nuclear reactors, there is significantly increasing interest in small modular reactors (SMRs). The concept identified in GIF is shown in Fig. 3.

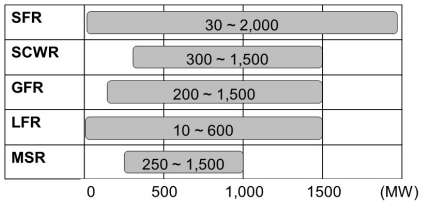

Fig. 3. Design concept of the Gen IV reactors

A point of note is that the design concept covers the full range of power levels, including small, intermediate and large sizes. As SMRs are promising new nuclear technologies for ensuring reduced investment risks, GIF is reconsidering the priority R&D. The R&D cooperation with industry on SMRs is an efficient strategy for implementing the development of the innovative technology.

Enhanced engagement with GIF

GIF has been pursuing on technological innovation R&D for the advanced reactors supported by government organizations with their national budgets. GIF is seeking to find an integration approach to communicating and engaging with industry. In the feasibility phase, the need for universities to participate continually increases. In order to leverage knowledge and deliverables from GIF R&D, they should share infrastructure and experiment facilities with industry, amending the project arrangement to ensure of access to industry in terms of feasibility/performance as well as demonstration/deployment. The Fig. 4 shows a schematic diagram of the engagement mechanism with GIF. Most of all, GIF should collaborate the work on R&D needs, infrastructure, database, reports and compendium with other organizations.

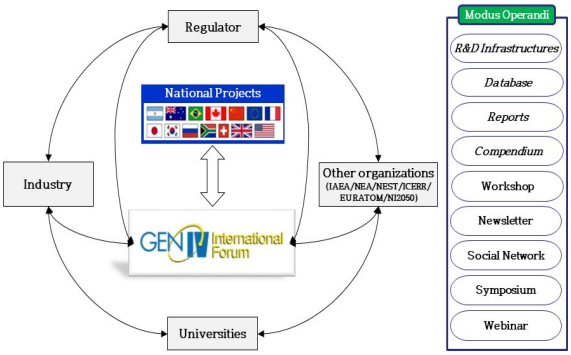

Fig. 4. Schematic strategy Gen IV engagement

The efforts engaging with regulators will be required for reliance on date development from GIF and licensing and oversight of new technologies resulted in saving cost, reducing duplication of effort, creating new ideas and strengthening staff expertise [7].

PRPP methodology and cyber security

The objective of the RPP working group is to assess Gen IV nuclear system against proliferation resistance and physical protection goal, which aims to increase the assurance for diversion or the theft of weapon-usable materials [8]. The PRPP by design is encouraged at the earliest possible stage of design concept and the proliferation flow to fabricate nuclear weapons as shown in Fig. 5. The GIF PRPP working group fulfilled the case study of an example sodium-cooled fast reactor system to demonstrate the methodology, including some typical fuel characteristics and fuel handling. In the next decade, the safeguard and PP strategy will be addressed with estimating cost of extrinsic features [9].

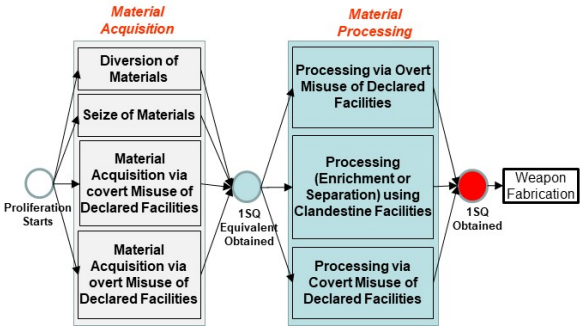

Fig. 5. Proliferation flow to weapon fabrication [7]

Regarding cyber security topic on safety and security the number of digital assets and control systems depends on reactor types and the facility generic features. Cyber security is to defense critical infrastructures from the threats, assuring that nuclear operators and the facility responsible persons take appropriate steps to protect nuclear power reactors and related nuclear fuel facilities from cyber threat. Therefore, the scenarios investigation of PP and its pathway analysis with respect to PR are required. In addition, the cyber security has features in remote and real time in-situ monitoring system of safeguards in terms of secured data and its system. The PRPP WG will continue to work on the cyber security.

3. Policy suggestion for GIF R&D

In order to meet the long-term goal of GIF, the considerations and recommendations on the GIF R&D policy are suggested as follows.

3.1 Information and deliverables management

The GIF R&D projects launched in 2005 after completing the legal documents for international collaboration and finalizing the intellectual property concern from 2000. Currently, GIF has been conducting total 13 R&D projects shown in Table I.

A large number of documents including deliverables and (open or confidential) information have been generated during the course of the projects. It is important to ensure protection of intellectual property, which is produced in the course of the cooperative R&D and contributed by the members from Generated Information (GI) and Background Property Information (BPI). Classification of information and managing project deliverables is the most significant achievement. All the data must be stored in a secured database as a long-term management.

3.2 Launching joint R&D projects

The GIF has been developing the innovative technology of the advanced reactor system for the past 20 years. Completing the feasibility phase, GIF may enter the demonstration and deployment phase requiring strong support from government in the next decade. However, due to the different schedules, design options and limited budget of national programs among GIF members, the driving force of the multinational cooperation has been reduced that initial establishment of GIF. In order to enhance practical cooperation, the joint R&D projects should be carried out to develop the cutting-edge technologies commonly interested among GIF members.

Table I: On going projects of each system in GIF

System	On-going Projects
VHTR	Materials, Fuel & Fuel Cycle, Hydrogen, Computational Methods and Benchmark Validation
GFR	Component Design & Safety, Fuel Cycle and Materials
SCWR	Thermal Hydraulics, Materials & Chemistry, System Integration & Assessment
SFR	Advanced Fuel II, Safety & Operation, System Integration & Assessment, Component Design& BOP
LFR	On preparing projects
MSR	On preparing projects

3.3 New R&D strategy for developing Gen IV systems

The renewable power generation capacity with falling cost of renewable power has been growing and is expected to expand up to 50% between 2019 and 2024. [9]. Due to the large capital investment cost and completion schedule, nuclear power plants are facing the significant challenge, experiencing construction schedule delays and even declaring bankruptcy. The nuclear energy is continually supported to achieve carbon dioxide emissions targets set in the Paris Agreement and as a result many countries decided to

phase out nuclear energy policy because of safety and environmental concern.

GIF challenges nowadays will require an extensive investigation on the future contribution of nuclear power and the energy mix with renewable energy. The nuclear power demand is primarily dedicated to the cogeneration of electricity and heat for industrial application, seawater desalination as well as hydrogen production. There is a growing interest toward SMRs, which are inherently safe and cost effective.

Taking into consideration of the future energy market needs and energy mix, the long-term strategies for developing Gen IV reactors should be rebuilt for risk reduction and control.

4. Conclusions

This paper overviews an activity of GIF's task forces such as R&D infrastructure, education & training, advanced manufacturing & materials engineering and safety design criteria within GIF. The key R&D priorities needed in the next decade for SFR & VHTR systems are outlined. Also, it describes the new R&D direction of GIF including SMR development with industry, engagement with regulators & other organizations and PRPP methodology & cyber security. Lastly, the policy recommendations for promoting successful development of Gen IV systems are suggested.

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