Fusion research and development strategy for JA DEMO investigated in QST

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This paper reports on the recent activities towards JA DEMO at QST in accordance with "the fusion energy innovation strategy" formulated by the cabinet office, Government of Japan in April 2023. QST has been strengthening collaboration with a wide range of industries and promoting industrialization of fusion technologies. QST has also started to investigate the acceleration scenario of DEMO program where a phased approach strategy is adopted with ITER size toroidal coils and enhancement of facilities and equipment necessary for full-scale DEMO R&D is proposed.

1. Introduction

The potential role of fusion energy has been globally emphasized from the perspective of the transition towards a Net-Zero Society. Research and development activities for realization of fusion energy is being accelerated both in public and private sectors. The fusion energy innovation strategy in Japan highlights development of the fusion industry as well as development of fusion technology. In this strategy, QST is requested to establish a framework for conducting R&D by bringing together, centering on QST, academia and private companies for DEMO development such as establishment of fusion technology innovation hub. QST has been promoting the activities in accordance with the strategy [1].

2. Steps for realization of fusion energy

Japanese fusion program has three steps for realization of fusion energy, i.e. establishment of physics/engineering bases, fusion energy production and electricity production. We are in the step of fusion energy production. QST is contributing to ITER project and promoting BA activities in EU-JA collaboration. QST aims at early transition to the next step of electricity production by integrating ITER project, BA activities and domestic activities. In the next step, construction of JA DEMO is planned, where electric power of >100 MW will be generated.

3. Research and development activities for JA DEMO

3.1. Fusion technology innovation hub

Based on the strategy, QST establishes fusion technology innovation hub where promotion of industrialization and acceleration of DEMO reactor development are centrally implemented in collaboration with private companies and academia. Also, in addition to strengthening the basic infrastructure, transfer of technologies, development of new technologies and industrialization, construction of new facilities are aimed in both Rokkasho and Naka institutes.

3.2. DEMO design

The conceptual design of JA DEMO has been developed [2] based on ITER technologies and industry experiences in the Joint Special Design Team for Fusion DEMO launched from 2015 in the framework of industry-academia collaboration at Rokkasho Institute for Fusion Energy. Recently, the number of members from industry increased to 95 reflecting the formulation of the strategy and the total number reached 211 (67 from universities/institutes and 49 from QST). A wide range of industries including not only manufacturing companies and plant companies, but also general conductor companies, infrastructure companies, trading companies and start-up companies joins the team. Fusion science and technology committee in MEXT required the three objectives for JA DEMO. These are electric power of several 100 MW, availability sufficient for commercialization and self-sufficiency of fuel. In order to satisfy these conditions, JA DEMO design adopted a major radius of 8.5 m which is 1.4 times larger than ITER, and fusion power of 1.5 GW in steady state operation. PWR cooling water condition was also adopted based on many industry experiences. Gross electric power of 640 MW and net electric power of 250 MW extracting on-site electric power were estimated.

3.3. Ensuring safety and standardization

For the construction of JA DEMO, safety regulation and standardization are important. QST contributed to publish the initial recommendations from Agile Nations working group on fusion energy regulation. QST provided technical advice as an expert and analyses results for accident events such as Ex-VV LOCA. The Working group recommended the development of a regulatory framework for fusion energy that maintains appropriate protections for people and the environment, proportionate to the hazards of fusion energy while remaining transparent and pro-innovation. QST has also contributed to the task force established to formulate basic ideas on ensuring safety for fusion energy in the cabinet office. Furthermore, QST is leading the discussion of ideas on ensuring safety and standardization with academic societies such as the Atomic Energy Society of Japan, the Japan Society of Mechanical Engineers and the Japan Society of Maintenology. QST has also started the activities for international standardization in fusion energy system.

3.4. Industrialization

Some of the fusion technologies have been already attempted to be industrialized. Start-up companies MiRESSO and LiSTie have been established as QST venture base on the refining technology of beryllium (Be) using the low energy consumption process with alkali and RF power and the recovery technology of lithium (Li) using ionic conductor, respectively. These technologies are developed for securing resources for blanket functional materials. QST is aiming for a fusion technology spin-off using these start-up companies and feedback of these technologies matured in the market to the DEMO project.

4. Investigation for acceleration scenario of DEMO program

Acceleration scenario of JA DEMO has been investigated as a separate scenario from the present JA DEMO design described in Section 3.2 in accordance with “Integrated Innovation Strategy 2024 (Cabinet decision)” describing that “Japan will aim to realize fusion energy as soon as possible by preparing a timetable that includes necessary national efforts toward achieving the first demonstration of power generation in the 2030s ahead of other countries”. In this investigation, a phased approach strategy is adopted to accelerate JA DEMO program with the same toroidal field coil size as ITER [3] considering the experience of manufacturing ITER components. As shown in Table 1, objectives are demonstration of electricity production with almost zero net electric power in Phase I; demonstration of tritium breeding with present JA DEMO blanket design in Phase II; and demonstration of steady-state operation with 100 MW level electric power using high β and high confinement plasma and thin improved breeding blanket in Phase III. As phase changes, enhanced plasma performance and improved blanket are required. In order to utilize key technologies acquired through ITER project and BA activities for the acceleration of the DEMO project, QST has proposed to enhance facilities and equipment in Rokkasho and Naka Institutes such as fuel cycle safety test facility, blanket development facility, neutron source facility, superconducting magnet facility, plasma heating test facility.

	(Phase I) Demonstration of electricity production	(Phase II) Demonstration of tritium breeding	(Phase III) Demonstration of steady-state operation
Obj.	Short pulse (several min.) $P_{gross} > 200$ MW $P_{net} \sim 0$	Long pulse (several hours) $P_{net} > \sim 0$ Self-sufficiency of fuel	Steady-state operation $P_{net} > 0$ (~100MW) Self-sufficiency of fuel
Spec.	ITER baseline scenario Fusion output: 500 MW Q value: 10 Pulse length: ~400 s Electricity production BLK Same size as ITER shielding BLK to secure the large plasma volume	JA DEMO baseline scenario Fusion output: >500 MW Q value: 10 High β_N: 3.4 Tritium breeding BLK JA DEMO breeding BLK Increased blanket area Reduced diagnostics & smaller divertor	JT-60SA scenario (High β & High confinement) Fusion output ~1 GW High efficiency heating and current drive Tritium breeding BLK Improved breeding BLK (thin BLK)

Table 1 Phased approach strategy for acceleration scenario of JA DEMO program

5. Future prospect

QST envisions contributing to a future society considering the realization of our basic philosophy “Creation of Harmonious Diversity” through construction of JA DEMO and establishment of new industries utilizing related fusion technologies.

References

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