Reconsideration of Korean DEMO role and future step for more actual fusion energy roadmap

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1. Introduction

Fusion energy in Korea has been developed based on the "Fusion Energy Development Promotion Law" since March 2007. According to the Law, National Fusion R&D Master Plan was modified every 5 years and new Master Plan was established on 2016 and 3rd 5-yr plan started from 2017. The following 3 major R&Ds are on-going with each objective;

- ✓ KSTAR for plasma physics and advanced scenario development
- ✓ ITER for burning plasma, fusion engineering, and international collaboration
- ✓ DEMO construction by the 2041 for Fusion Power Plant (FPP)

In order to reduce the technical gap between ITER and DEMO, a fusion neutron source (FNS) are newly proposed [1]. The main objective of this FNS is to compliment the national plan for the integral tritium breeding and handling beyond ITER test blanket module (TBM), and for component test which will be used in DEMO engineering. For more actual plan and roadmap for fusion energy, the role and function of the DEMO was reconsidered and the previous steps were proposed in the present paper.

2. Fusion DEMO role and its development steps

From the review of the development procedure on sodium fast reactors (SFRs) in Japan and Korea, and SMART in Korea, their roles and development steps are summarized as Table 1 [2,3]. Based on the accumulated various experimental researches with separate and integral effect tests (SET/IET) for validating the key components and equipment., next steps such as experimental, prototype, and DEMO reactors were developed for basic principle, technical reliability, and economical efficiency, respectively. And the DEMO was defined as the first of a kind (FOAK) for constructing fusion power plant (FPP).

In current roadmap for fusion reactor, it is assumed that DEMO could be developed after KSTAR for plasma physic and ITER for engineering approach. However, more R&D program for SET/IET and separation of DEMO concept to prototype and FOAK, as shown in Fig. 1 considering the current lack of experience and in order to reduce the gap between ITER and DEMO, especially for the lack of neutron flux, tritium handling, pulse operation, etc. Therefore, the roadmap should include IETs and prototype, and the definition and role of DEMO as a FOAK.

Table 1. Nuclear reactor development steps

Type	Objectives	Key technologies	Examples of facilities			Fusion roadmap
			SFR in Japan	SFR in Korea	SMART in Korea	
SET/IET	Validation of component/equipment	neutronics(fuel), thermal-hydraulics/safety, component/materials/operation etc	AtheNa	SETs, STELLA-1 STELLA-2 (IET)	VISTA-ITL SMART-ITL	(KSTAR) plasma core/physics (ITER TBM) SETs and partial IET for blanket (ITER) burning plasma NO SET/IET plan
Experimental reactor	Basic principle validation safety validation	breeding characteristics nuclear fuel/cladding(irradiation test) safety device	EBR-II, JOYO, CERF, FBTR	-	-	
Prototype reactor	Reliability of technology	system integration long-term operation Na handling/safety	MONJU, Phenix, ASTRID, BN-350, PFBR	SFR proto	-	DEMO phase I : prototype
DEMO reactor	Economical efficiency	Construction cost estimation actual operation FOAK (First of a kind)	BN-800	-	SMART (FOAK)	DEMO phase II (not FOAK)

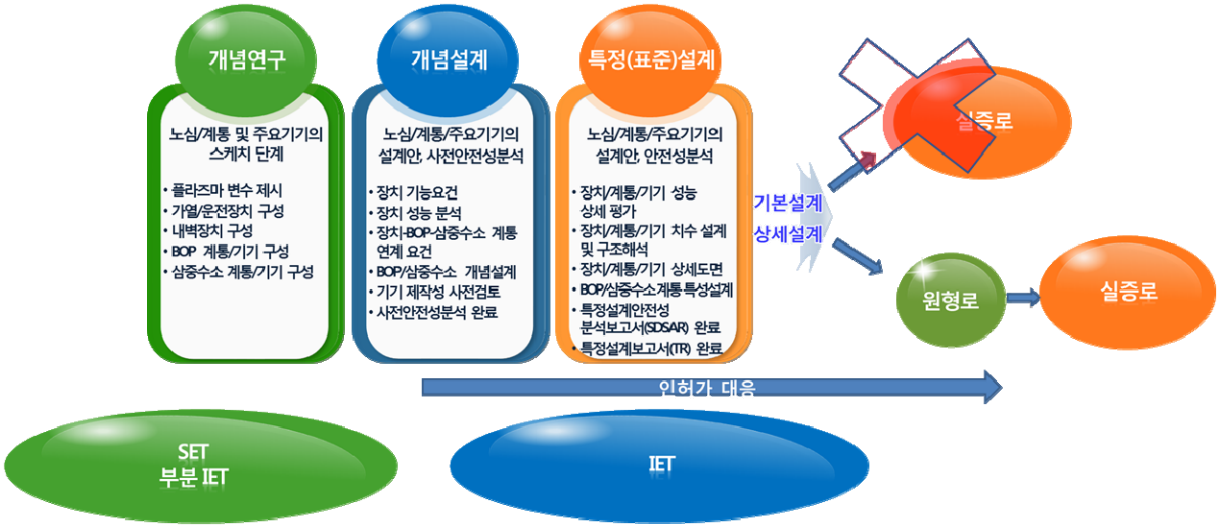

Fig. 1. Proposed development roadmap for fusion power plant

3. Proposed fusion energy roadmap

Because DEMO should show the electricity production and more economical efficiency, it should be a FOAK or compatible with it. Before DEMO, technical reliability should be proven by prototype, in which safety function/devices and licensing, tritium breeding and supplying, and plasma core should be tested. In order to develop the prototype, IET should be constructed to provide the fusion environment such as continuous operation, more than 1 MW/m^2 neutron wall loading, tritium breeding and handling, material testing, and so on considering breeding blanket development, in which volumetric neutron source can be considered. The summarized roadmap is shown in Fig. 2.

Fig. 2. Local roadmap for developing the DEMO: FNS and prototype

In the original roadmap, the prototype and DEMO was combined or shared to reduce the realization time, which was the same strategy to the EU one. However, considering the technical maturity such as material and breeding blanket, and licensing experience, both would be better to be separated. Instead, the prototype could be combined with large scale neutron source, which could provide the IET. Also, in the original roadmap and national fusion plan, the start of the FPP construction was suggested at 2035 after 10 years of ITER DT operation. However, it should be extended up and more the national plan should be complemented including DEMO preparation phase for 20 years and FPP preparation phase for 15 years if we consider the IET and prototype.

4. Summary and concluding remarks

The fusion energy roadmap was proposed to reduce the gap between ITER and DEMO and for more actual plan, in which DEMO definition and role was reconsidered through the study of nuclear reactors development plan. And also, FNS and IET were proposed especially for considering the technical maturity and licensing preparation. The main objective of this FNS is to compliment the national plan for the integral tritium breeding and handling beyond ITER test blanket module (TBM), and for component test which will be used in DEMO engineering.

Acknowledgments

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