Challenge towards a lower aspect ratio tokamak power reactor

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Fusion plasma technology: It is judged that self-ignition (Q ~ 20) and long burn in ITER are achievable. Physics issues on fusion plasma required for the demonstration reactor will be solved by studies in ITER on the long pulse control of high Q burning plasma, the advanced steady-state operation, and the high ? experiments.

Component technology: Since key component technologies required in ITER sufficiently cover the key component technologies of the DEMO reactor, the technological basis of the fusion reactor will be established through the construction of ITER. The technology for the demonstration reactor requires technological enhancement from the present level in some issues, such as the development of high-performance superconducting magnets, which can be expected to be achievable by the steadily continuing R&D of applicable technology.

It can be concluded that the technological goals of the fusion DEMO reactor aiming at demonstration of electrical power generation will be achieved by steady progress in the individual technological aspects. However the prospect of the competitiveness in the market, namely the lower COE (cost of electricity) has not yet showed. The fusion power plant is not a fuel dependence energy source but a high technology based energy source. It means that the reactor construction cost is expensive. Therefore it is most effective way for the lower COE to make the reactor equipment compact and lightweight.

Tight aspect ratio tokamaks with the aspect ratio A in the range 1.2 ~ 2.0 can offer the possibility of compact fusion reactors in the low capital cost way. This scheme is often called the spherical torus (ST) approach. In the usual ST approach, all non-essential components such as inboard blanket or shield, inboard poloidal coil (PF) systems like a center solenoid (CS) coil system are discarded from the inner side of the plasma. The only customary tokamak component that remains on this side is a single turn copper TF coil center post (CP). In spite of the excellent plasma performances granted by very low aspect ratio less than 1.5, it could not sufficiently compensate the Joule losses in the normal-conducting (NC) TF coil as illustrated in the ARIES-ST power reactor design study. If a super-conducting (SC) TF coil system is used instead, approximately 1meter of shielding is required between the SC TF coils and the plasma on the inboard side to protect the superconductors from neutron damage and nuclear heating. Consequently, it has been widely recognized that a super-conducting compact tokamak reactor with such the tight aspect ratio would not be feasible. Our recent study, however, opened up the possibility of realizing such a very compact reactor being compatible with the use of SC TF coil system. The key issue is to find the SC TF coil design solution. How high field and how high current density in the coil windings are required for compensating the handicap of the thick shielding?

The optimization in the CS-less SCTF approarch led to a fusion output of 2.5 GW with a small reactor weight of 8,800 tons. Because of its compactness, CO_2 emission in the life cycle of this power plant was estimated to be as low as 2.9 g-CO_2/kWh, being lower than that of an ITER-sized DEMO reactor (4.9 g-CO_2/kWh). As to the waste management of this power plant, on the basis of reactor design and radiological considerations, we suggested reusing a liquid metal breeding material (PbLi) and a neutron shield material (TiH_2) in successive reactors. According to this waste management, the disposal waste would be reduced to as low as 3,000 tons, which is comparable with the radioactive waste of a light water reactor (4,000 tons in metal).. Furthermore, it was numerically confirmed that such a low-A reactor would have an advantage over ? -particle confinement.

The name of this reactor is VECTOR.