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Integrated Physics Analysis of Plasma Operation Control Scenario of Helical Reactor FFHR-d1

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Plasma operation control scenario of the LHD-type helical reactor FFHR-d1 was examined using a 1-D calculation code, which calculates temporal evolution of the plasma radial profile by solving a diffusion equation in cylindrical geometry using the model based on LHD experimental results. This study is the first 1-D analysis of the plasma operation control scenario of helical reactors. It was found that direct feedback control of fusion power by the pellet fuelling, which was considered in the 0-D analysis, was difficult because of the delayed response of the fusion power due to shallow pellet penetration in the case of the pellet injection velocity of 1.5 km/s, which is achievable without special technological development. In spite of the fusion power, line-averaged electron density was selected as a controlled parameter because it promptly responds after the pellet injection and there are several kinds of well-established diagnostics. It was confirmed that the line-averaged electron density can be controlled over a wide parameter range by manipulating the pellet injection timing. With a combination of the heating power control based on the measurement of the fusion power, the fusion power can be smoothly increased to the target value and stably sustained. Perturbation in the fusion power is less than 1%. Steady-state sustainment with a smaller fusion power is also achievable with adequate auxiliary heating. In addition, there is no principal physics restriction in the rate of change in the fusion power and then a plasma start-up at a slow rate (e.g., several hours to reach the steady state) is achievable. This high controllability with a small number of simple diagnostics attributes to characteristics of helical system with a net current-free plasma. It is desirable for the operation of peripheral equipment and power plant equipment and indicates another advantage of the helical system. This operation control scenario provides the design conditions of the plasma control system and contributes to the system design of FFHR-d1. Although consistency check with equilibrium, transport, heating profile and impurity effect over a whole time period is needed, the simple control method by the measurement of line-averaged electron density and fusion power is expected to have robustness against the change in the plasma property.

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Author: Dr GOTO, Takuya (National Institute for Fusion Science)

Co-authors: Prof. SAGARA, Akio (National Institute for Fusion Science); Dr SUZUKI, Chihiro (National Institute for Fusion Science); Dr MIYAZAWA, Junichi (National Institute for Fusion Science); Dr YOKOYAMA, MASAYUKI (National Institute for Fusion Science); Dr SEKI, Ryosuke (National Institute for Fusion Science); Dr SAKAMOTO, Ryuichi (National Institute for Fusion Science)

Presenter: Dr GOTO, Takuya (National Institute for Fusion Science)

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