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核融合炉運転に向けた制御ロジック構築に関する研究
Study on Construction of the control logic for nuclear fusion reactor operation

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1.Introduction

In operating fusion experimental and DEMO reactors, control of many various parameters would be indispensable from the viewpoints not only of plasma performance but also of engineering requirements. For example, one is required to keep the plasma density, temperature, fusion power and so on to the target values, by taking many physical and/or engineering constraints such as the limitation of the heat flux to the divertor into account. For satisfying these requirements, the consideration on the diagnostics and the actuators is very important, because almost all of diagnostic tools might be unavailable under the environment of high radiation and methods of active control would be quite limited. Taking these limitations and constraints, it is, therefore, required to identify the combination of diagnostics and actuators and to construct the control logic [1-3].

In this research, we focus on the construction of the control logic. In the future reactor, we must control the multiple plasma parameters with the multiple actuators, and each actuator doesn't only have an effect on single plasma parameter but on multiple plasma parameters. For example, the NBI have the effects on not only the plasma current but also on the plasma temperature. Construction of the control logic requires us to consider these effects.

For the first step of the construction of the control logic, we made the 0-D (0-dimensional) control logic from the simple 0-D model of plasma physics. The detail will be shown in next section.

2. 0-D Control logic

Ideally, we want to control the plasma parameter profile (i.e, density profile), but it is difficult. In this research, for simplify, we control the 0-D integrated value. The physical models which we use for construction of 0-D control logic are shown in eq. (1) and eq. (2)

$$\frac{dN}{dt} = -\frac{N}{\tau_p} + N_{puff} - N_{loss} \qquad (1)$$

$$\frac{dW}{dt} = -\frac{W}{\tau_e} + S_\alpha - L_{rad} + P_{NBI} \qquad (2)$$

Where N, W, N_{puff}, N_{loss}, S_α, L_{rad}, P_{NBI}, τ_p,and τ_e are the total plasma ion particle amount, the total plasma stored energy, the gas-puff amount, the particle loss due to the fusion reaction, the alpha heating power, the radiation loss, the NBI power, the particle confinement time and the energy confinement time respectively. Because N_{loss}, S_α and L_{rad} are the function of N and W, equation (1) and equation (2) can be written in the form of eq.(3).

$$\frac{d}{dt}\begin{pmatrix} N \\ W \end{pmatrix} = \begin{pmatrix} D(N,W) \\ E(N,W) \end{pmatrix} + \begin{pmatrix} N_{puff} \\ P_{NBI} \end{pmatrix} \qquad (3)$$

From eq. (3), we can make the control logic like eq. (4).

$$\begin{pmatrix} N_{puff} \\ P_{NBI} \end{pmatrix} = \begin{pmatrix} k_1(N_{ref} - N) \\ k_2(W_{ref} - W) \end{pmatrix} - \begin{pmatrix} D(N,W) \\ E(N,W) \end{pmatrix} \qquad (4)$$

Where N_{ref}, W_{ref}, $k_1$and k_2 are the target value of N, target value of W, gain 1 and gain 2 respectively. Deciding proper k_1 and k_2 , We can control N and W. Using this control logic, we solve the eq. (1) and eq. (2) with runge-kutta method. The example result is shown in Fig.1. In the annual meeting, we will show the more detailed results and discussion.

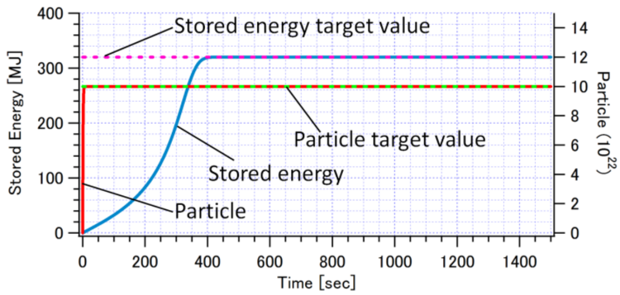

Fig. 1 The red line, the blue line, green dashed line and purple dashed line represent the particle amount, stored energy, particle target value and stored energy target value respectively.

References

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