Module for feedback control of neutron rate in TRANSP

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1 Introduction

This document describes a TRANSP module for matching the measured and calculated neutron rates in TRANSP analysis runs. Initially, this will be done by adjusting the anomalous fast ion diffusivity, but the module may be extended at a later time to include the neutral density as another means of modifying the calculated neutron rate.

2 Algorithm

The anomalous fast ion diffusivity is considered to be of the form

$$D_a = U(t) \times D_a^{prof}(x,t)\,,$$

where D_a^{prof} is a spatial profile, which could potentially change in time based on namelist input, and $U(t)$ is a time varying scale factor for the profile. It is this scale factor that will be modified during the run to match the measured and calculated neutron rates.

2.1 Calculation of the profile shape

The profile shape $D_a^{prof}(x,t)$ is calculated after each time that the namelist input for fast ion diffusivity is read in (expert call l3loadpsheater kpoint=2). The fast ion diffusivity is the variable DIFB. First, calculate

$$U_0 = difb(2)/s_a,$$

where $s_a = 10^4$ is a scale factor for the fast ion diffusivity. The term U_0 will represent the pre-programmed part of the term U. The profile shape is calculated as

$$D_a^{prof} = difb/U_0.$$

If $difb(2) = 0$ (i.e., $U_0 = 0$), then D_a^{prof} should be a flat profile, with all values equal to s_a.

2.2 Calculation of the magnitude

To keep the diffusivity from becoming negative or getting unreasonably high, limits are placed on the magnitude $U(t)$. Denote these limits as U_{max} and U_{min}. The saturated output $U_{sat}(t)$ is given by

$$U_{sat}(t) = \begin{cases} U_{max} & \text{for } U_{unsat} > U_{max} \\ U_{unsat} & \text{for } U_{min} \leq U_{unsat} \leq U_{max} \\ U_{min} & \text{for } U_{unsat} < U_{min} \end{cases}$$

The unsaturated magnitude $U_{unsat}(t)$ is made up of a pre-programmed part, a feedback part, and an anti-windup part i.e.,

$$U_{unsat}(t) = U_0(t) + U_{fb}(t) - U_{aw}(t).$$

The feedback part is calculated as the sum of a term proportional to the difference between the measured and calculated neutron fluxes and a term proportional to the integral of this difference, i.e.,

$$U_{fb}(t) = k_p u_c(t) + k_i \int_0^t u_c,$$

where $u_c = (n_c - n_m)/s_n$, $s_n = 10^{13}$ is a scale factor, n_m is the measured neutron rate (XNEUTD), and n_c is the calculated neutron rate (TOTNTNS).

The anti-windup part is calculated as

$$U_{aw}(t) = k_{aw} \int_0^t u_{aw}$$

where $u_{aw} = U_{unsat}(t) - U_{sat}(t)$.