Multiplet effects in radiation losses during discharge quenching by intense argon injection in ITER

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The disruption instability is the most dangerous plasma instability in tokamaks. It leads to the intense deposition of plasma energy on a rather small area of divertor plates that can lead to their destruction. Now for mitigating the disruption instability it is planned to reradiate a considerable part of plasma energy, using the massive injection of inert gases, in particular, argon and neon. While modeling in [1] the Ar and Ne massive gas injection (MGI) in the ITER 15 MA baseline scenario it was supposed that the MGI is carried out at the quasi-stationary stage of the discharge (flat-top of the current). For modeling of main plasma parameters, the ASTRA transport code [2] is used, which is integrated with the ZIMPUR code [3] describing the dynamics of charge states, radiation losses and transfer of impurity (description of radiation losses was carried out in [1] for optically thin coronal plasma). For calculation of the gas outflow from the MGI system, the phenomenological model [4] was used.

Here for illustration we consider radiation of two argon ions – Ar+15 and Ar+3, which have spectral lines of high intensity and could be used for plasma diagnostics. We estimate the correction of radiation power losses caused by the account of the level multiplet splitting and the plasma opacity effects for these ions at two stages of the discharge with MGI, namely, before and after the thermal quench (TQ). We use a simplified non-coronal radiative-collisional model, to assess the level multiplet effects, and the "escape probability" model of the line radiation escape from plasma (see, e.g., surveys [5, 6]), to assess the opacity effects. It has been already shown that for strong lines of argon ions Ar+3 и Ar+15 the plasma opacity has no significant effect upon the total radiation power losses for scenario modelled in [1]. On the contrary, the role of level multiplet effect may appear to be essential. It may provide the increase of radiative losses, e.g., by a factor of ~2 for low ionized atoms at low temperatures, because the resolution of the fine structure of atomic levels for Δ*n*= 0 transitions leads to contribution of levels with lower excitation energy than that in the model of multiplet-average radiative transitions. Therefore, for carrying out the analysis of the role of all non-coronal effects and, e.g., comparing with [7] where the importance of plasma opacity effects during the MGI was shown, it is necessary to use the atomic levels structure with multiplet splitting taken into account.

References

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