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Runaway electron mitigation in ITER disruptions by injection of high-Z impurities

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Large amounts of MeV runaway electrons (REs) can be generated during disruptions which pose a serious threat for future large tokamak devices like ITER. Thus, it is an urgent task to develop robust and confident systems for their control and mitigation. The injection of high-Z impurities by MGI or SPI constitute one of the most promising schemes. Here, with the aim of evaluating the suitability of the injection of high-Z impurities for RE control and mitigation in ITER, the effect of injecting high-Z impurities on the RE dynamics during different phases of the disruption (before the thermal quench (TQ), during the current quench (CQ) and during the RE current plateau) is studied. First, mitigation by Ar or Ne injection before the TQ is considered with the aim of controlling the primary generation of REs during the TQ. The impurities are found to have a strong effect, leading to very low RE current generation for the shortest CQ times compatible with acceptable forces on the ITER vessel and in-vessel components in the case of Ne injection, while for the longest CQs high RE currents can be found. Mixed Ar+deuterium (D) or Ne+D injection before the TQ can be effective in controlling the generation of the RE current if a sufficient amount of Ar/Ne and D is assimilated in the plasma. If the formation of a primary RE seed cannot be avoided, impurities can be injected during the CQ with the aim of reducing the avalanche RE multiplication. The efficiency of this scheme vs. the time at which the impurities are injected and the amount of assimilated impurities (and/or D) is analyzed. Finally, if a RE plateau current is formed at the end of the CQ, impurities can be injected with the aim of yielding the dissipation of the RE current before a strong interaction with the PFCs can take place. A simplified approach to the RE beam dissipation including the effect of the collisions with the plasma particles and impurities, and the electron synchrotron and bremsstrahlung radiation, is applied. It is suggested that injection of a few kPa·m3 of Ar could be enough for RE electron mitigation before the characteristic time for the vertical instability growth in ITER. The effect of the RE scraping-off during the decay of the current and the consequences on the amount of impurities that should be injected for an efficient RE dissipation is also analyzed.

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