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Disruption mitigation in tokamak reactor via reducing the seed electrons of avalanche

The disruption mitigation technology remains the key issue of safe and reliable device operation in future large tokamaks including ITER. In this report, we analyze a novel approach aiming at an essential reduction of seeds causing the avalanche runaway electron generation after the thermal quench (TQ) but does not use injection into the device vacuum vessel a large mass of gas, liquid or solid/dust matter. The essence of the approach is to inject a projectile into the plasma from the material that is from the list of PFC materials. Fig.1 shows a schematic of the approach using the tungsten rod ~8 mm in diameter and 80 mm in length, that crosses the plasma volume with the velocity of 0.8 km/s perpendicular to the toroidal magnetic field. The projectile is injected just after TQ and crosses the plasma dimension in equatorial plane (4 m) at a time of ~5 ms. It collects all runaway electrons existing in plasma sequentially cleaning magnetic surfaces from runaways remained in the plasma after TQ. Such cleaning allows us to escape the runaway avalanche (or delay the time of the avalanche development) if the amount of primary runaways born during the plasma operation would be significantly reduced. The optimal scenario for this technology uses the following steps: control of the plasma stability and switching on the rail gun at the finish of the thermal quench; accelerating the projectile during 1.5 ms in the equatorial zone of device being aimed at collection of the seed electrons crossing the plasma during 5 ms; additional reconnection events stimulating seed runaway losses; capturing the injected projectile inside the collector sited inside the inner blanket zone of the tokamak-reactor. Runaway electrons within the 1~25 MeV energy range are terminated by the W projectile with the 8 mm dimension along the magnetic field according to the stopping power estimations. The 80 mm length and the 0.8 km/s speed of the projectile were chosen to provide existence of the projectile shadow to reduce seeds for the runaway avalanche. Fig. 2 demonstrates currents during the current quench (CQ) of the unintentional disruption calculated with the Ohmic decay time of ~0.3 s corresponding to *T*_{*eCQ*} = 40 eV, *Z*_{*eff*} = 1.7, the e-fold avalanche time of ~19 ms and the hot-tail *I*_{*seed*} ~ 5 kA evaluated under assumption of the 1 ms temperature decay time during TQ. Fig.2 shows that for *I*_{*seed*} ~ 5 kA the large runaway current of *I*_{*run*} ~ 6 MA will replace the total current at ~0.5 s. Two orders reduction of the *I*_{*seed*} results in a delay of the avalanche development so that the current replacement will take place at ~1.0 s with *I*_{*run*} ~ 1.5 MA. Thus, collecting the seed runaways provided by the W fast speed injected projectile is capable to reduce the runaway current to MA level acceptable for the ITER disruption mitigation challenge.

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