THE IMPACT OF A FLYING COLLECTOR ON RUNAWAY ELECTRONS DURING CURRENT DISRUPTION IN A TOKAMAK

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Recently, in [1,2], a new method was proposed for controlling the disruption of the discharge current in a tokamak without a noticeable increase in plasma density, using injection of a moving collector absorbing runaway electrons (RE) during their avalanche-like multiplication. This technology may be of interest for the development of the next generation of tokamaks with intensive thermonuclear fusion (ITER, DEMO), including Fusion Fission Hybrid Systems. The synopsis presents information on new physical processes initiated by a collector in a tokamak current quench (CQ) plasma, and the results of numerical simulation of emergency current output in a tokamak with ITER scale parameters.

The zero-dimensional model of discharge disruption [1] has been improved. The first equation describing the evolution of the decrease in plasma current I_{tot} with a resistive time $\tau_{\mathrm{res}}=(L_{int}{\cdot}S)/(2{\cdot}R{\cdot}\eta)$ has not changed, where L_{int}, S, η are the inductance, cross-sectional area and resistivity of the plasma, respectively and R is the large radius of the tokamak. In the second equation describing the generation of the runaway electron current I_r due to avalanche multiplication, a term was added that takes into account the loss of runaway electrons on a tungsten collector moving through the plasma with a characteristic time $\tau_L=V/(c{\cdot}l_t{\cdot}d_t)$. A tungsten collector with a transverse dimension of d_t and a length of l_t absorbs RE particles moving at the speed of light c in a tokamak plasma of volume V. The time of its stay in the CQ plasma L_{tr}/v_t is determined by the velocity v_t and the length of the trajectory L_{tr}. For the plasma conditions of the ITER tokamak, the optimal trajectory for sequential injection of several collectors was chosen directed vertically through a plasma axis with a length of $L_{tr} \cong 6.8$ m.

The parameters of the discharge simulation were selected in accordance with the data of [3]. Argon is injected into the discharge in order to obtain a resistive time τ_{res} = 34 ms. The plasma temperature T_{eCQ} = 4.4 eV, the effective charge Z_{eff} = 1.75, the Ar density $n_{Ar} = 5.6{\cdot}10^{19}$ m^{-3} and the plasma density $n_{eCQ} \cong 2.3{\cdot}10^{20}$ m^{-3} are obtained as in [3] from the zero-dimensional balance of Ohmic electron heating due to the radiation of injected argon. The parameters are assumed to be constant during the CQ stage. The initial current of the RE seeds, $I_r(0)$ = 0.4 kA, was estimated, as in [1], by the "hot-tail" mechanism with a 1 ms temperature decay time during TQ in accordance with [1,3]. The results of modeling the dependence of the avalanche current of escaping electrons on the collector parameters are shown in Fig. 1 and in Tbl 1.

It can be seen from Fig. 1 and the first row of the Tbl. 1 that when the discharge parameters are selected without collector injection, an unacceptably large current of escaping electrons $I_r \cong 8.4$ MA is generated. Calculations with the collector parameters from [1], shown in row 2 of Tbl. 1, demonstrate that the current $I_r \cong 6.5$ MA remains unacceptably high. Tbl. 1 shows that it is possible to reduce the IR current by increasing the collector area visible by runaway escaping electrons, reducing their speed and increasing the number of sequential injections. Results of calculations with the parameters of row 10 of Tbl. 1 is shown in Fig. 1.

The report will provide estimates of the collector heating in plasma by runaway electrons and estimates deviating the collector trajectory from linear motion, which are important for organizing collectors capture after plasma passage.

Criteria will also be formulated for selecting the optimal collectors injection scenario, providing acceptable values for the following parameters: avalanche current of escaping electrons, noticeably lower than 1 MA; collector temperature, significantly lower than the melting point of tungsten 3595 K; permissible from an engineering point of view deflections of the collector trajectory after passing the plasma no more than 3 centimeters. The results of their use will be presented in the report.

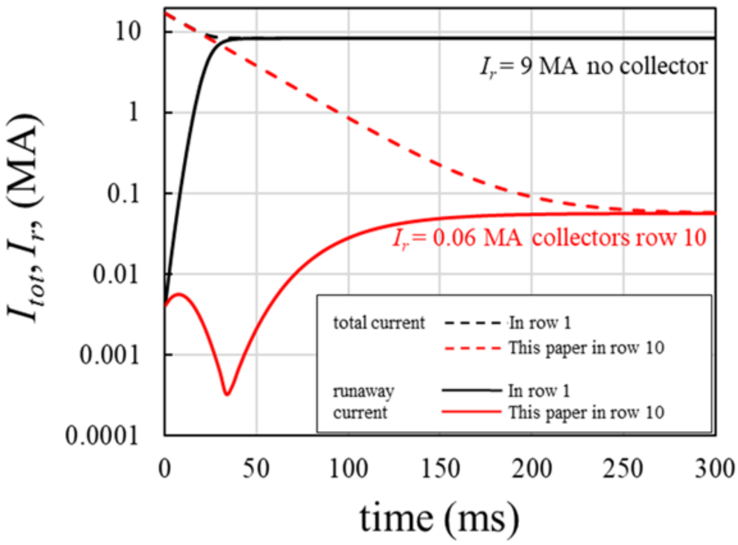

Fig. 1. Currents of disruptions.

Tbl. 1. Impact of collector on runaway current.

row	*Number injections*	d_t mm	l_t mm	v_t m/s	m_t gm	I_r MA
1	-	-	-	-	-	8.4
2	1	8	80	800	100	6.5
3	1	16	80	800	400	4.6
4	1	8	80	400	100	4.6
5	2	8	80	400	100	1.4
6	3	8	80	400	100	0.1
7	1	16	80	400	400	1.4
8	2	16	80	400	400	0.002
9	1	10	100	400	200	2.7
10	2	10	100	400	200	0.06

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