Progress in understanding halo current in EAST tokamak

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1. Introduction

Plasma in typical elongated cross-section tokamaks are inherently unstable against vertical displacements, when plasma loses the vertical position control, which will lead to move downward or upward, during this disruption a large of halo currents are generated helically in ex-plasma (typically in SOL) and flow into the vacuum vessel through in-vessel components, which give rise to the largest forces experienced by the vessel and the in-vessel components [1] [2].

Some researches of halo current have been done in a large number of conventional tokamak devices [3][4][5][6]. In EAST, for measuring halo current, 4 sets of halo sensors were installed in last EAST experiment, and these halo sensors were located in different location, as shown in Figure 1. And the interesting thing is that there is almost a current spike in halo sensor, which is proved to be toroidal eddy current. Experiment has shown that halo current is much larger in H mode phase than that in L mode, typically because plasma in H mode has larger poloidal beta, EAST experiment has also shown that plasma was firstly landing on the outer plate and halo current went into inner structure through outer support, dome and then back to plasma through inner support. The present EAST database demonstrates that the maximum $\frac{TPF \times I_h}{I_p} / I_{p0}$ is 0.65. The test of mass gas puffing system has shown good success in reducing plasma temperature and increasing radiation power, in next experiment mass gas puffing system will be applied in reducing halo currents.
2. Experimental setup and method

In last EAST experiment, as one part of the EAST magnetic diagnostic system, Rogowskii coils have been installed behind the supporting structure of divertor plate and dome (halo5, halo6, halo7 and halo8 shown in Figure 1), they are intended to measure the current collected by individual plate titles.

The major cause of diagnostic error for these halo current sensors is the non-uniformity of their winding. The non-uniformity of the Rogowskii coil windings derives from the external error field, including PF coils, toroidal plasma current and eddy current, if the Rogowskii coil has a uniform winding, the output voltage caused by a change of the external magnetic field should be zero when no current flows inside the Rogowskii coil[7]. We check this error by cancelling the error field which is coming from PF coils and toroidal plasma current, seen in Fig 2, and the result $I_h$ is the real current signal, shown in formula 1, the later halo current data is all proceed like this.

$$I_h = I_{h0} - \sum (c_i \times p_{f,i} + c_p \times I_p)$$

3. Experiment result analysis

3.1 Analysis of current spike in halo sensor

In EAST tokamak experiments, almost in all the halo current signals there is a spike, as shown in Fig.3, it is proved to be eddy current in toroidal direction. That is to say, a fraction of toroidal eddy current is measured in halo sensors. Especially in plasma start up period, halo current is correlated to loop voltage and eddy current well, and this is the same in the disruption phase, the reversed current spike (last for 3 ms) is driven by the rapid change of plasma current. So we should
cancel this part of eddy current from halo current waveforms.

![Waveforms of halo currents in plasma start up period and VDE period.]

Figure 3.

3.2 Characteristics of halo current in H-mode and L-mode discharges

In this EAST tokamak experiment, a variety of H-mode has been achieved, because with an elongated cross-section, plasma easily loses its vertical position and moves toward the first wall. As shown in Fig.4, shot #38860 is a typical H-mode disruption, discharge accesses to H-mode in 3.5 s and $H_d$ has a rapid drop, stored energy increases to 100kJ. The H-mode lasts for 1s, in 3.5s plasma suddenly lost its vertical position and disrupted, halo current was generated as large as 30 kA for one tile for this motion, compared with the another shot #38857, which had a H-mode phase firstly, then transform to low mode phase, plasma stored energy dropped, in 10.32s, plasma moved toward the first wall and the maximum halo current is 20 kA for one tile.

![Comparison of halo currents from the disruption in H-mode phase (a) and L-mode phase (b).]

Figure 4.

3.3 Sketch of halo current flows

From the waveform of halo current measured by the different location of poloidal Rogowski coils, halo8 (halo current measured in outer plate support) is much larger than the one measured in others, from the trace of halo5 (halo current measured in one support of dome) and halo6, they are coinciding with each other very well, similarly with the halo7, just as shown in Fig5. From the trace of these halo currents, we can guess when plasma were landing on the outer plate, large of halo current generated in the SOL area were flowing into the vessel through the outer support (about 15 kA), then went...
into inner plate through the DOME (about 10 kA) and at last went back to plasma through inner support as shown in Fig 6.

3.4 TPF in EAST

The limit of $TPF \times I_{h,max}/I_{p0}$ is 0.65, which is used for the structure analysis as a design value[12], in this formula $I_{h,max}$ is the experimental maximum halo current, estimated by the 4 sets of halo sensors.

4 Future work

In EAST mitigation of disruption experiment, MGI (mass gas injection) system has shown good success at increasing radiated power.

5 Conclusion

Discharges with VDE disruption will generate large amounts of halo current in SOL area, it is very damage for the device. And more stored energy, more halo currents, so H mode phase disruption will give more damage for the divertor. In next experiment, for avoidance of halo current mass gas injection (MGI) system will be experienced, and for better studying halo current, reconstruction of the plasma boundary will be also done in VDE period with MIT.

References