§41. ECH Booster Injection to ICRF Sustained Long Pulse Discharge

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In almost all the long pulse ICRH sustained plasma CW ECRH has been injected simultaneously and steadily at the power level of 100 kW. The power level at the MOU output of gyrotron corresponds to 140 to 150 kW for this condition, although the full specification of the gyrotron is 200 kW. During the high power ICRF CW plasma discharge, it is often observed that the arcing occurs near the ICRF antenna or diverter plates near the antenna[1]. This arcing sometimes becomes a source of the iron impurity influx and terminates the discharge due to the radiation collapse, where the radiation power exceeds the externally supplied one. Once the radiation increases more than a certain level and the balance between the heating and radiation loss is destroyed, the negative feedback, the lower the temperature, the less power absorbed and the more the radiation loss, is formed and never heated up again with the normal heating method. Even neglecting the change in the confinement, it is clear that critical density, over which the radiation collapse occurs, exists with a given heating power. It is necessary to assess the margin of the power depending on the heating method near the critical density to achieve stable CW operation with higher plasma parameters. It is important to investigate the cause of the arcing, but this problem should be more or less severe every time one increases the heating power to achieve CW operation aiming at the higher plasma parameters. In the CW operation near the critical heating power for a given plasma parameters it is necessary to develop effective methods to avoid such collapse.

In order to develop the method of avoiding or mitigating the collapse, short pulse ECRH with the power level of 400 kW, 300 ms is prepared and set waiting for the trigger released by detecting the increase of plasma density. Due to the limitation of the duty cycle of the gyrotron operation, this system can deliver only one shot every 60 s. Figure 1 show the time evolutions of electron density, and typical ECE radiometer channels indicating the change of the electron temperature profile during the ICRF long pulse operation trial. Fig. 1 a) shows whole plasma discharge of more than 200 s. Pulsed electron temperature rises in the whole plasma region at about 15 and 120 s are the result of NB injection to investigate the NBI heating effect. In contrast, averaged electron density decreases during the NB injection may be due to the particle confinement degradation associated with the electron temperature rise. Other than these active heating, many spiky electron temperature drops are observed in co-relation to the arcing near the ICRF antenna or the diverter plates set near the antennas. The example of the time expanded behavior of the spike is shown in Fig. 1 b) where several small temperature drops are seen successively, but not so hard to trigger the radiation collapse. Just before t=200 s, relatively large temperature drop accompanied by a fast density increase is seen. The electron temperature in the periphery are not affected so much by this first blow as seen in Fig 1 c). Just at the time when the electron temperature toward the center tends to settle at the lower level, second events occurred and again the temperature in the whole plasma region started to drop. It was just after this drop that the ECRH booster injection is triggered. Due to the central focused beam, central temperature of $\rho < 0.2$ sharply increases and the rise in the peripheral temperature followed. Though the electron density become double as compared with that before the event, peripheral temperature is raised back. The central temperature is also set back due to the gradual decrease of the density. This is a typical example that the booster ECRH injection critically relieved the discharge from radiative collapsing.

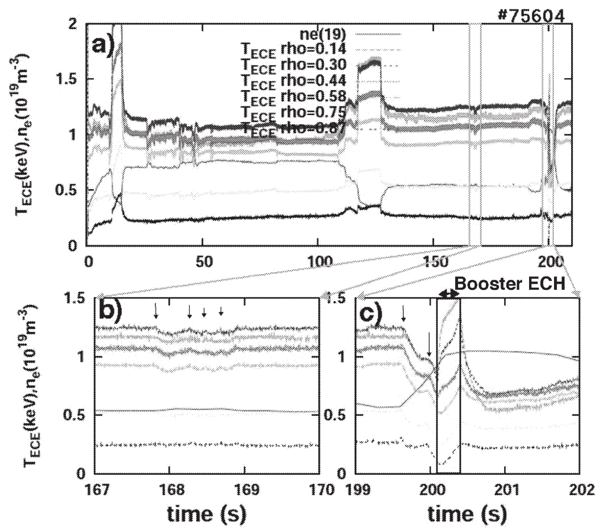

Fig. 1. $n_{e,ave}$ and $T_{e,ECE}$ evolutions for the booster successful shot. a) full discharge , time expanded display around b) t=168 s at small events and c) t=200 s at ECRH booster injection.

However, not all such radiation collapses are avoided with the ECRH booster injection. Possible explanations of the failure would be the quantity of the iron impurity, delay of the trigger, the shortage of the power for booster and their combinations. The fact that the peripheral temperature dropped down before the effect reaches from the center might indicate that the optimum heating position had been in the periphery. In order to clarify the mechanism and to find optimum collapse avoidance method, long term accumulation of data for many cases are necessary, since such events are often but sudden and not reproducible.

references

[1] KUMAZAWA, R. *et al.*, *Nuclear Fusion*, 46 (2006) S13-S21.