§4. Innovative ICRF Heating System for H-L Mode Transition Plasma

Kumazawa, R., Mutoh, T., Seki, T.

An ICRF heating and current drive has a serious problem in the view point that the reflected RF power fraction is drastically changed due to the large change of the plasma loading resistance in the H-L mode transition. The injected RF power should be stopped using an interlock system, in which the reflected RF power is monitored whether it is more than the allowable lever for the used vacuum tetrode tube. A ratio of the reflected RF power to the RF forward power, so called the reflected power fraction is usually employed to evaluate the goodness of the impedance matching of the ICRF heating system.

The ICRF heating experiment was carried out in ASDEX using a 3dB coupler [1]: The reflected RF power was absorbed to the dummy load connected to the 3 dB coupler without returning to the tetrode tube.

A change of the plasma loading resistance was precisely measured on JET; the impedance was measured to be $Z_H=2\Omega$ and $Z_L=8\Omega$ -jΩ in the H-mode and the L-mode plasma, respectively [2]. In addition the plasma loading resistance was found to change very quickly in the order of less than 1ms.

Recently a new idea referred to as Conjugate T-antenna method has been proposed [3]: The RF power is divided at the T-junction and fed into two antennas. An imaginary part at one antenna has an opposite sign to that of the other, that is to say $Z_1=Z_R+jZ_I$ and $Z_2=Z_R-jZ_I$ employing the different transmission length.

In this section a newly innovative method of the ICRF heating system for the L-H mode transition plasma is presented. A conventional double stub tuner system (as shown in Fig.1) is employed for that. Normalized lengths of transmission lines, A1, A2, A3 and A4 are shown in this figure. An impedance matching calculation found a special condition, i.e., A3=0.0725 and A4=0.425 in the double stub tuner with A2=0.25. When a loading resistance (Rp) is changed from 2Ω to 8Ω, the reflected power fraction can be kept in a low level, i.e., less than 1% by selecting an optimum length of A1, i.e., from 0.075 to 0.15 according to the varied Rp as shown in Fig.2. The reflected power fraction would have exceeded more than 36% at Rp=8Ω with a fixed A1=0.075, in which the impedance matching is obtained at Rp=2Ω. However it can be reduced to less than 1% by selecting A1=0.15.

A frequency feedback control has a feasibility of much faster response to the quickly varied plasma loading resistance than changing stub tuner length. For that purpose a long stub tuner of more than 10 times normalized length is employed to realize an effective change of A1 by the frequency change. The calculating result in three different A1, i.e., A1~5, 10 and 15 is shown in Fig.3. The maximum in the variable frequency range is employed at Δf/f=1%, because a large Δf/f is not allowed in the safety operation in an high power RF generator. In the lower A1~5 the reflected power fraction can not be reduced in 8Ω even in Δf/f=1%. However in A1~15 the reflected power fraction can be reduced less than 1% in the whole range of Rp, i.e., 2Ω<Rp<8Ω.

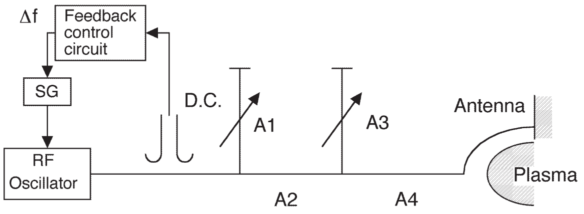

Fig.1 Double stub tuner system.

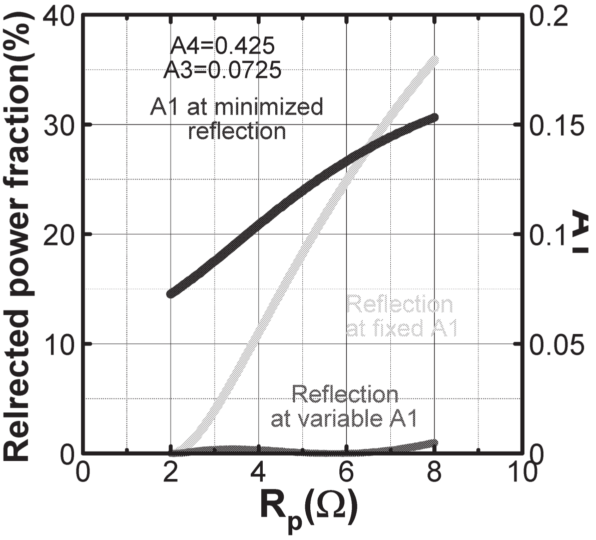

Fig.2 Reduction of reflected power fraction in the loading resistance range of 2W to 8W by changing A1.

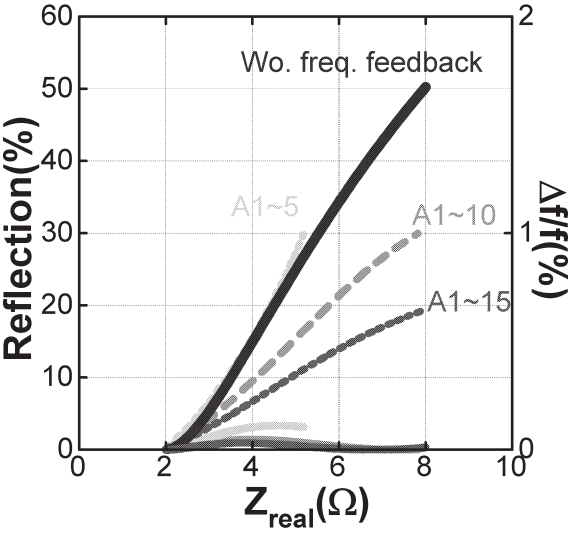

Fig.3 Reduction of reflected power fraction by frequency control.

References
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[2] I. Monakhov et al., 15th Topical Conf. of RF power in Plasmas 2003, AIP Conf. Proc.694, 148
[3] P.U.Lamelle et al., 16th Topical Conf. of RF power in Plasmas 2005, AIP Conf. Proc.787, 158