§5. Frequency Feedback Control for H-L Mode Transition Plasma in ICRF Heating

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In the previous section the twin stub tuner is introduced as works the long stub tuner with more than 30 normalized length. In this section a feasibility of frequency feedback control against the large change in the plasma loading resistance during the H-L mode plasma transition is described. Here the plasma loading resistance in H- and L-mode plasma was employed as those measured in the JET plasma discharge. The impedance was Z_H=2Ω and Z_L=8Ω-jΩ in the H- and L-mode [1], which is shown in Fig.1. The difference between those imaginary parts in the H- and L-mode is important. Therefore the impedance in H-mode has no imaginary part. It should be noted that the change in the impedance is less than 1 ms. and a very quick frequency feedback control is required.

A typical example of the frequency feedback control is shown using the twin stub tuner. The employed parameters are as follow: A_1=0.0725, A_2=0.25, A_3=0.0642, A_4=0.425, A_S=0.015. The result is shown in Fig.2. The abscissa and ordinate are a real part of the impedance R_p and the reflected power fraction. The required frequency modulation to minimize the reflected power fraction is also plotted. It is found that the reflected RF power fraction can be reduced to lower than 1% in the change of R_p from 2Ω to 8 Ω. Here the imaginary impedance was also changed along the dashed line shown in Fig.1. The required frequency modulation rate is up to 0.012%. When the frequency modulation is not applied, the reflected power fraction should have been increased up to 50% at 8Ω.

In this example the required frequency modulation, i.e., Δf/f is 0.12%. On the other hand various parameters of the RF generator are optimized at the employed frequency to maximize the output power. Therefore the RF power may be reduced when the applied frequency is changed from the maximized one. In general the output power is limited by the increase in a screen grid current, which is increased with the output power because of increasing swing RF voltage at the anode of the vacuum tetrod tube. The experiment was carried out using the existing RF generator. The RF output power was kept at the constant, i.e., 1MW and the frequency range of $-0.36\% < \Delta f/f < 0.36\%$ as shown in Fig.3. The detected screen grid current referred to as IG2 was gradually increased in the higher frequency, but was less than 1A, which was much smaller than the interlock level of IG2=5A. Therefore an allowable frequency modulation range was decided as |Δf/f|=0.72%. The required frequency for the H-L mode transition Δf/f~0.1% is much less than 0.72%.

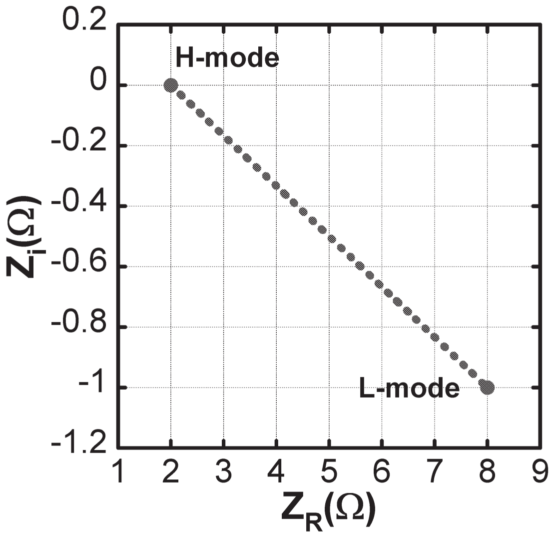

Fig.1 Antenna impedance in H- and L-mode plasma plotted in real and imaginary impedance plane.

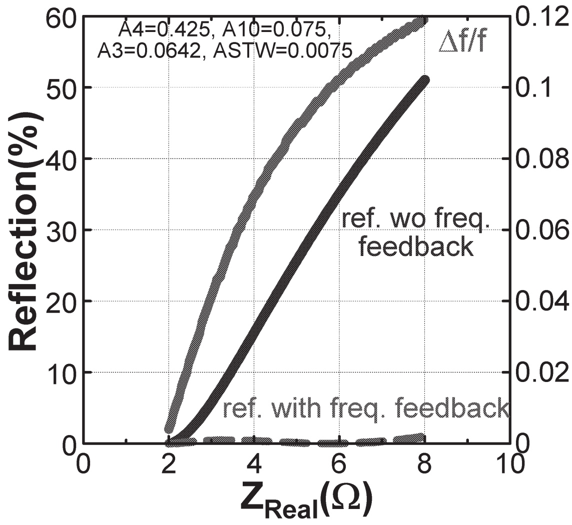

Fig.2 Reduction of reflected power fraction in the loading resistance range of 2Ω to 8Ω by changing frequency.

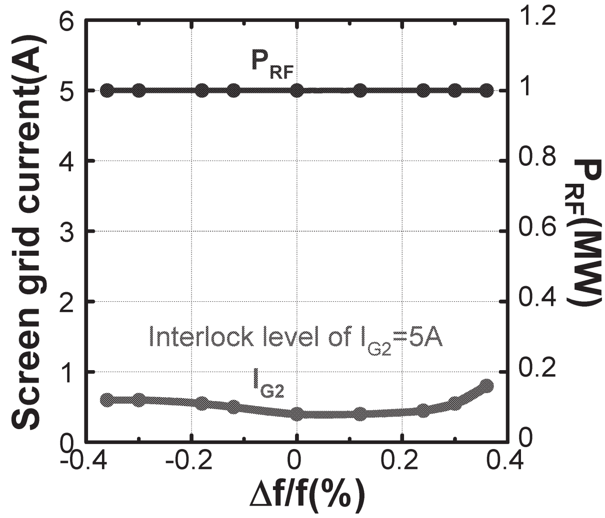

Fig.3 Dependence of screen grid current on frequency at RF output power of 1MW.

Reference

[1] I.Monakhov et al., 15th Topical Conf. of RF Power in Plasmas 2003, AIP Conf. Proc. 694, 148.