§ 12. Long-Time Real-Time Sensorless Sensing of Plasma Parameter

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In a long-time discharge as in LHD, it is necessary to measure plasma parameter and display the result in a real time, and to adjust the plasma parameter during the discharge. It is desirable to measure a new plasma parameter without setting up a new plasma sensor. In this collaboration research, the final object is to construct a long-time real-time sensorless sensing system, which needs no new sensors inside the LHD. In the LHD, no-plasma-current discharge is standard, it is easy to apply a sensorless sensing method without being disturbed by plasma current. And it is possible to apply neural network for the real time analysis.

In the case of power supply for poloidal coil, the voltage and the current are measured to use for the feedback control and the urgent protection. But the correlation between the voltage and the current is meaningful to pay attention, since it changes according to with or without plasma current. And since the mutual inductance changes according to the plasma position, the correlation also changes. From the change in the correlation, it is possible to deduce the change in the plasma position. Even in the case of almost no change in the current, it is important to notice the change in the ripple component due to phase (firing angle) control of thyristor (SCR). It is possible to deduce the plasma position from the small ripple current due to the ripple voltage. Although the change in the current may be extraordinarily small, it is possible to detect and process the signal using the recent technique on AD converter, noise rejection and signal extraction.

In a feedback control system of the plasma horizontal position x_P, this is controlled by a vertical magnetic field made by vertical field coil current I_V driven by the applied voltage V_V. When the plasma shifts outward horizontally, mutual inductance between the plasma and the vertical field coil increases, and the effective inductance of the vertical field coil decreases. In a voltage controlled power supply, I_V is increased, and in a current controlled power supply, V_V is reduced. Therefore we can obtain some information on x_P from the V_V and I_V, and we may deduce the x_P from them.

We consider the electrical equivalent circuit equations of the plasma (P) and vertical field coil (V) at ripple frequency of power supply with SCR. Since the mutual inductance (M) between them depends on x_P in the first-order approximation concerning elongation ratio and inverse aspect ratio,

$$\left(L_P + \frac{dL_P}{dx_P}x_P\right)(sI_P) + \left(M_{PV} + \frac{dM_{PV}}{dx_P}x_P\right)(sI_V) = 0\,, \quad (1)$$

$$\left(M_{VP} + \frac{dM_{VP}}{dx_P}x_P\right)(sI_P) + L_V(sI_V) = V_V\,, \quad (2)$$

where s is an operator for Laplace transformation and L is inductance. Using these equations, we can calculate x_P from the V_V and I_V.

In 2002, a high-speed AD converter was set up to acquire data of poloidal coil voltage and current, and the data were acquired on January 14. Positions of the magnetic axes were different between shot number 40742 and 40744 (R = 3.6 m), and shot number 40727 and 40728 (R = 3.75 m). The data are being compared.

Figure 1 shows firing angle dependences of average output voltage, amplitude and phase of the ripple component in the case of 3-phase full-wave converter. In the case of pulse width modulation, the phase is constant and only the amplitude changes. But in the case of firing angle control, not only the phase but also the amplitude change, and therefore it is necessary to notice the phase difference and amplitude ratio of the current and voltage ripple. In all superconducting LHD, the ripple component of the current is easy to be shielded by the superconducting coil, but it is hard to decay and therefore possible to detect in comparison with normal JT-60U, superconducting Tore Supra, HT-7 and TRIAM-1M.

In a nuclear fusion reactor, some kinds of diagnostic systems should be used for reactor protection and plasma control. Since the sensors are used under severe irradiation circumstances, the number of diagnostic sensors is desired to be small or zero. Therefore it is important to develop a sensorless diagnostic system.

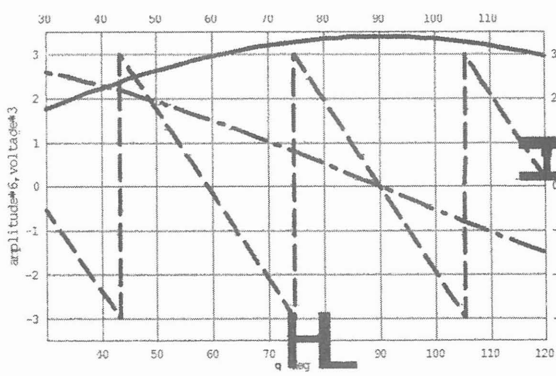

Fig. 1. Firing angle dependences of average output voltage (dashed dotted line), ripple amplitude (solid line) and ripple phase (broken line).