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Performance test of vessel current monitors for KSTAR

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Vessel current monitor (VCM) is an external Rogowski coil (RC), one of magnetic diagnostic (MD) sensors for Korea Superconducting Tokamak Advanced Research (KSTAR), which is used to diagnose eddy current induced in the wall of vacuum vessel of the KSTAR machine during a plasma discharge because the diagnosis of the eddy current is required for the plasma control at the initial phase of the discharge. The eddy current can be obtained by subtracting plasma current from the current measured by the VCM. Three VCMs and internal RCs were installed successfully on the internal and external walls of the KSTAR vacuum vessel, respectively [1,2], and the *in-situ* calibration of each sensor was done from the measurement of the toroidal current produced by a dummy coil within the vacuum vessel [3,4]. Using the data in the previous measurement, the error in the measurement using each VCM was investigated for the current of 200 A/turn. Here, the sensitivity of each VCM calibrated at the applied current of 100 A/turn was used and the error was evaluated from the discrepancy between two measured values from the commercial current sensor and each VCM. The error in the measurement by using each VCM is less than 2% as given in Table 1.

Table 1. Result from the current measurement for the applied current of 200 A/turn.

Value from Hall sensor [A]	Value from sensors [A]			Discrepancy [%]
	VCM01	VCM02	VCM03	
201.25	204.38			1.6
201.29		197.72		-1.8
201.35			198.89	-1.2

The performance test of the VCMs was carried out by measuring the eddy current induced in the vacuum vessel (VV) during a pulse current applied to the poloidal field (PF) coil pairs before the first plasma in the KSTAR machine. The measurements were done before and after the cool- down of the superconducting magnetic coils.

Figure 1 shows the experimental set-up for the test before the cool-down. In the experiment, a program-controlled DC power supply (LAMDA, 1 kA/10 V) applied a pulse current of 45 - 100 A/turn to the PF7 coil pair in the KSTAR machine. The number of turn is 72 for each PF7 coil. The signals measured by using VCMs during the pulse current are transmitted to the analog integrator [5,6], and then the toroidal fluxes are obtained from a digitizer (D-TACQ, model ACQ196CPCI). In the measurement, the paired cable (Belden, model 9841) of about 80 m was used as a signal line from the KSTAR machine in the tokamak hall to the integrator in the diagnostic room.

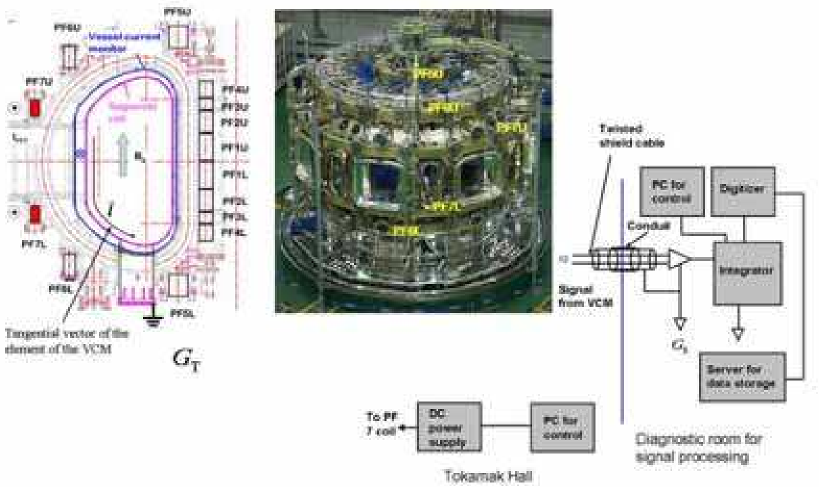

Figure 1. Experimental set-up for the flux measurement before the cool-down of the magnet coils.

Actually, the VCMs pick up both eddy current induced on the VV and a poloidal flux during a pulse current applied to the PF coil pair. Thus, internal RCs were also used in the measurement during the pulse current for the compensation of the poloidal flux in the VCM signals. Figures 2 (a) shows the waveform of the pulse current applied to the PF7 coil pair for the measurement. In the measurement, an *RC* time constant of the integrator was 1 ms and the integrating drift on each signal increased was up to 3.29×10^{-4} Wb during 200 s. The integrating drift appeared as a baseline of each sensor signal and it was fitted by the 2nd order polynomial for a baseline subtraction in each signal. Thus, the signals are obtained from the VCM and the RC in the measurement as shown in Fig. 2 (b).

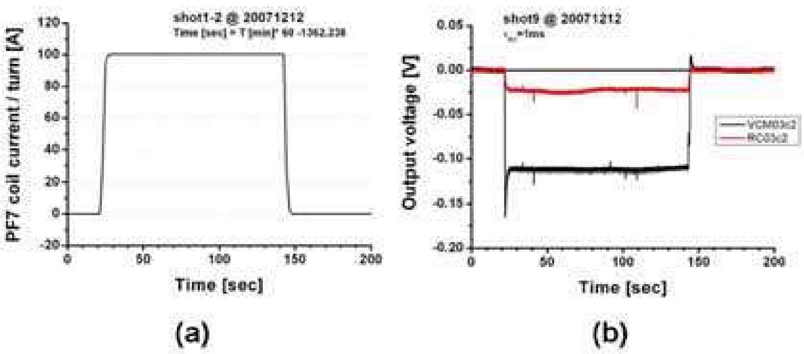

Figure 2. Poloidal flux measurement: (a) a typical waveform of a low pulse current applied to PF7 coil pair and (b) VCM and RC signals. Here, VCM03 and RC01 mean vessel current monitor and Rogowski coil, respectively.

The values of the poloidal flux in the flat-top region of the VCM and RC signals are -0.1124 mWb and -0.0231 mWb during the pulse current of 100 A/turn, respectively. The overall time evolution of the VCM signal is similar to that of the RC signal except for two additional peaks in the VCM signal. Figure 3 shows the eddy current obtained from the VCM signal. The subtraction of the poloidal flux in the VCM signal was done by using the RC signal.

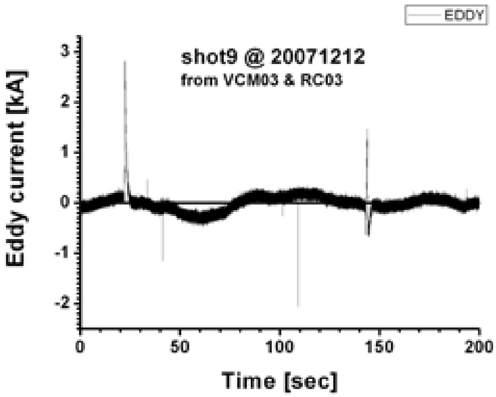

Figure 3. Eddy current obtained from the VCM and RC signals in Fig.2.

After the cool-down of the magnet coils, the performance test of the VCM was done during the commission test of the PF coils. Figure 4 (a) shows a typical waveform of the pulse current applied to the PF1 coil pair. The number of turns is 180 for each PF1 coil. At the rise and fall phases of the current, its ramping rate is 1 kA/s. The current of about 1 kA sustains in the flat-top region up to about 1 s. The experimental set-up before the cool-down of the magnet coil (see Fig. 1) was used for the test of the VCM. Figure 4(b) shows the signals from a VCM and a RC. The VCM picks up both eddy current induced on the vacuum vessel and the poloidal flux during the pulse current applied to the PF1 coil pairs. The poloidal flux in the VCM signal was compensated by using the RC signal as described above.

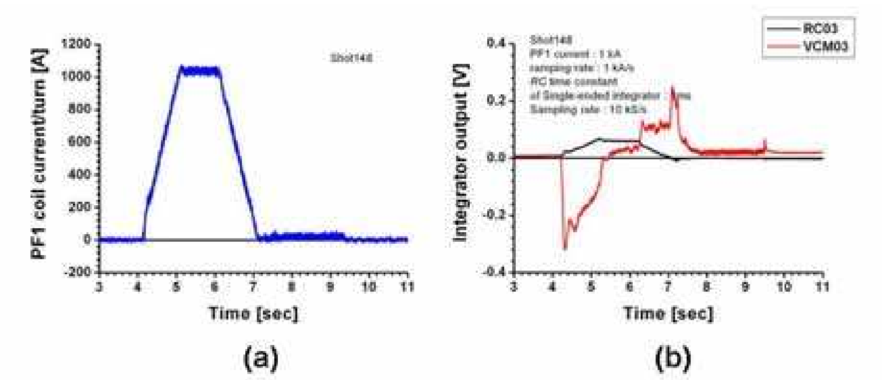

Figure 4. Performance test of the VCM and RC during the commission of the PF coil after the cool-down of the superconducting magnet: (a) the wave form of the PF1 coil current and (b) VCM and RC signals.

For the compensation of the poloidal flux, the balance coefficient between two sensors was obtained from a ratio of two signals in the flat-top region. The averaged values at the flat-top are 0.0601 mWb and 0.0255 mWb from the RC and the VCM signals, respectively. Figure 5 shows the eddy current evaluated from the VCM and RC signals. The maximum value of the eddy current is up to about 10 kA at the rise phase of the coil current.

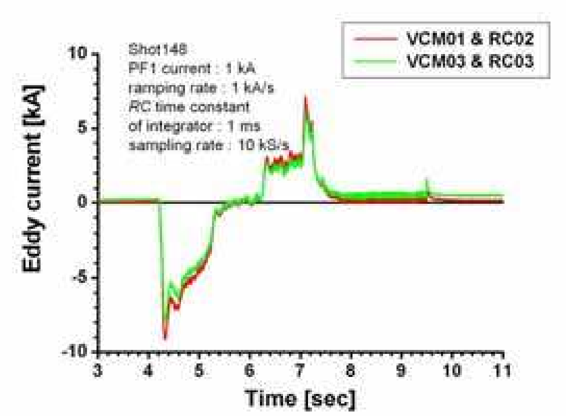

Figure 5. Eddy current evaluated from the VCM and RC signals in Fig. 3.

The performance test of the VCM for diagnosing the eddy current was carried out from the VCM measurement during a pulse current applied to the PF coil pairs before the first plasma in the KSTAR machine. The further analysis on the VCM signal obtained in the measurement is needed to study the effect of the eddy current on the plasma control during a plasma discharge in the KSTAR machine.

Acknowledgement

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