34th EPS Conference on Plasma Phys. Warsaw, 2 - 6 July 2007 ECA Vol.31F, P-2.131 (2007)

Vessel current monitors for KSTAR

J. G. Bak and S.G. Lee

National Fusion Research Center, Taejeon, KOREA

Vessel current monitor (VCM), one of magnetic diagnostic (MD) sensors for the Korea superconducting tokamak advanced research (KSTAR), measures both plasma and vessel currents during a plasma discharge in the KSTAR machine because the VCM encloses a vacuum vessel (VV) in the poloidal direction as shown in Fig. 1. The vessel current, as an eddy current induced in the wall of the VV, can be obtained by subtracting the plasma current from the current measured by the VCM. The plasma current can be measured by a Rogowski coil (RC) inside the VV. The VCM measurement is required to diagnose the eddy current for the plasma control at the initial phase of the discharge in the KSTAR machine. Some VCMs were fabricated by using two different MgO cables and calibrated in a laboratory as a preliminary work [1]. Three VCMs were installed at different toroidal locations on the external wall of the VV, and two of them were located near two RCs (see VCM01 and RC02, VCM03 and RC03 in Fig. 1). The 3D position of each VCM was measured by using a laser tracker system after the installation. The discrepancy between the designed and measured values, which was represented as a toroidal angle, was less than 0.01° (see Table 2 in Ref. 2). These sensors are ready for the initial measurement of the vessel current in the KSTAR machine after finishing the installation of the twisted signal line along the signal path from each VCM to the vacuum feedthrough at the bottom port of the cryostat.

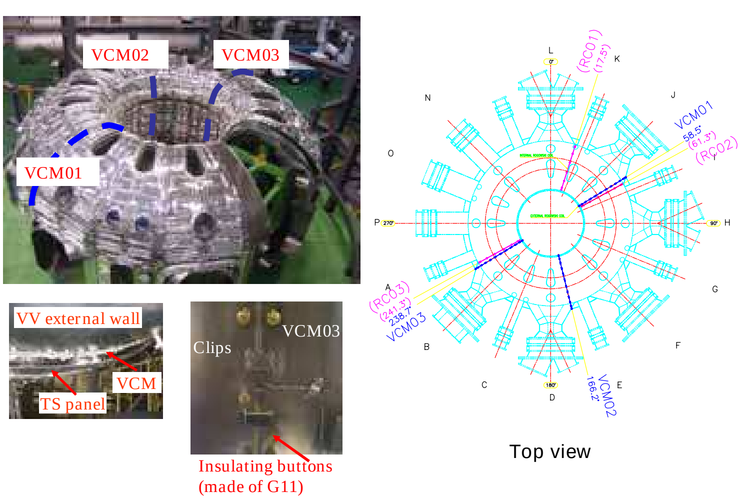

Fig. 1. Three VCMs installed on the external wall of the VV in the KSTAR machine (on the left side); Here, the VCMs are presented by dashed lines because the VV is fully covered with thermal shield (TS) panels. Toroidal locations of sensors in the drawing (on right side).

For the *in-situ* calibration of each VCM, the measurement of a pulse current by using the VCM is carried out in the KSTAR machine as shown in Fig. 2. In the experiment for the

be evaluated by using the relation between magnetic flux Φ_{VCM} and current I as given in Eq. (1).

$$\Phi_{VCM} = \int V_{VCM} dt = V_{VCM} \tau_{RC} = \mu_0 \frac{N_{VCM}}{L_{VCM}} S_{VCM} \int \frac{dI}{dt} dt = k_{VCM} I. \qquad (1)$$

Where V_{VCM} and τ_{RC} are an induced voltages in the VCM and the RC time constant of the integrator, respectively. In addition, N_{VCM}, S_{VCM}, and L_{VCM} are the number of turns, the cross-sectional area and the perimeter length of the VCM, respectively. The sensitivity of the VCM obtained by using Eq. (1) is given in Table 1.

*Table 1. Sensitivity of each VCM from the in-situ calibration. *The values were the measured.*

Sensors	k_{VCM} [10^{-8} Wb/A]	Resistance* [Ω]	Location
VCM01	4.17662	85.9	Vertical bottom port G of cryostat
VCM02	4.25206	81.1	Vertical bottom port C of cryostat
VCM03	4.15021	63.5	Vertical bottom port C of cryostat

In the experiment, the sensitivities of three VCMs and three Rogowski coils (RCs) were calibrated from the simultaneous measurement of the pulse current. Details on the RCs were described in Ref. 5. At the phases of current rise and fall, there is a difference between currents measured with VCMs and RCs as shown in Fig. 4. The difference may be caused from an eddy current induced in the wall of the vacuum vessel during a pulse current. The maximum value of the eddy current was estimated as about 1/2 of the applied current in the pulse current measurement.

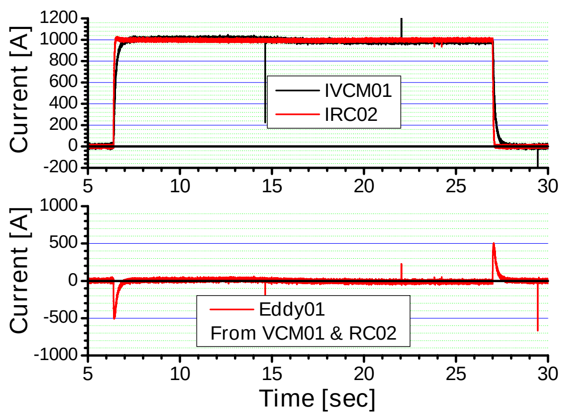

Fig. 4. Currents measured with sensors such as VCM01 and RC02 (upper side), and the eddy current induced in VV obtained from VCM and RC signals (lower side) at the applied pulse current of 1 kA.

The rise time of the pulse current was about 100ms, and the signal from the commercial sensor exponentially grew and decayed with a time constant τ_1 of 30 ms at the phases of the current rise and fall. The value of τ_1 was obtained from the exponential fitting on the signal, which was similar with the value in the RC signal. But the value of τ_2 obtained from the same fitting on the VCM signal was about

130 ms. Thus, the *L/R* time constant $\tau_{L/R}$ of the vacuum vessel could be evaluated as about 100 ms from the difference between τ_2 and τ_1. Figure 5 shows typical signals from the sensors such as VCM03 and Hall sensor at the phases of current rise and fall in the measurement. The inductance of the vacuum vessel was estimated as less than 4 μH by using a resistance of the vacuum vessel that was calculated as higher than 40 μΩ (see Table II in Ref. 6).

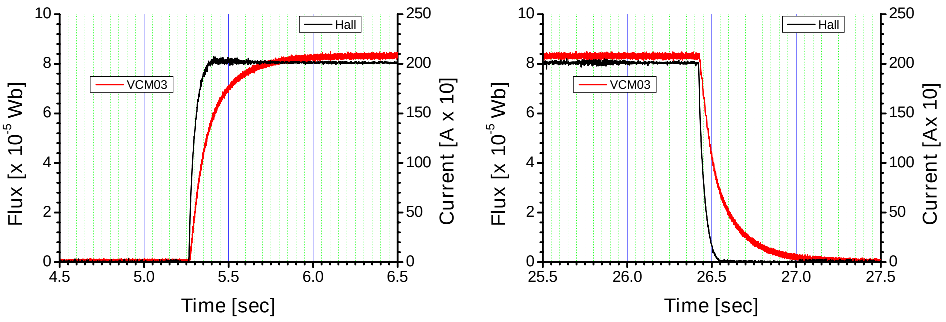

Fig. 5. Two sensor signals at the phases of current rise (left side) and fall (right side) for the applied pulse current of 2 kA.

The *in-situ* calibration of three VCMs installed on the external wall of the KSTAR VV was done from the pulse current measurement by using a dummy coil that was temporarily mounted on the inboard wall of the VV. From the comparison between the VCM and RC signals, the *L/R* time constant $\tau_{L/R}$ due to the vacuum vessel was estimated as about 100 ms, and the maximum value of the vessel current was about 1/2 of the applied current. The further qualitative analysis on the VCM signal obtained in the calibration is needed to study on the vessel current during a plasma discharge in the KSTAR machine.

Acknowledgement

This work was supported by the Korea Ministry of Science & Technology under the KSTAR Project Contracts.

References

[1] J. G. Bak and S. G. Lee, Proceedings of Korean Nuclear Society Spring Meeting, 2005 (unpublished).

[2] J. G. Bak and S.G. Lee, J. Korean Phys. Society 49, S223 (2006).

[3] J. G. Bak, S. G. Lee and D. Son, Rev. Sci. Instrum. 75, 4305 (2004).

[4] J. G. Bak, S. G. Lee and D. Son, Rev. Sci. Instrum. 78, 043504-1 (2007).

[5] S. G. Lee and J. G. Bak, Poster P5.102 at this conference.

[6] M. Kwon, J. S. Bak and G. S. Lee, Fusion Science & Technol. 42, 167 (2002).