Design study of the magnetic diagnostic system for merging scenarios in VEST

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1. Introduction

For the purpose of basic research and education of fusion plasmas, it has been planned to construct a spherical device, VEST (Versatile Experiment Spherical Torus), at Seoul national university. VEST was designed to demonstrate merging scenarios that generate two small plasma columns and merge them in the mid-plane during the plasma start up phase. Magnetic diagnostic systems such as Rogowski coils, pickup coils and flux loops have been developed to measure the magnetic information from the plasma. Design and preliminary experimental results of the magnetic diagnostic systems for VEST are presented in this paper.

2. Magnetic diagnostic system

2.1 Rogowski coil

Rogowski coils are designed to measure the plasma current as well as the TF (Toroidal Field) and PF (Poroidal Field) coil currents. The flux from the plasma current is given by

$$\Phi = \mu_0 nAI \qquad (1)$$

where n is the number of turns of the coil per unit length, A is the cross-sectional area, I is the plasma current to be measured [1], respectively.

In VEST, Rogowski coils are installed at both inside and outside the vacuum vessel. The coils installed at the outside the vacuum vessel can measure a sum of the plasma current and the vacuum vessel eddy current. The coils installed at the inside the vacuum vessel can measure the plasma current only. Therefore, comparing results from the two types of Rogowski coils, time evolutions of the total vacuum vessel eddy current can be measured.

The Rogowski coil outside the vacuum vessel in VEST is composed of a 3 mm*16 mm Teflon core and a 0.25 mm insulation wire. The sensitivity of the coil is designed to be 1 mV/A. Rogowski coil inside the vacuum vessel consists of an 8 mm*8 mm Teflon core and a 0.25 mm insulation wire. The sensitivity of the coil located outside the chamber is also 1 mV/A.

A sample Rogowski coil was designed and tested for reference. The sample Rogowski coil is composed of a 8 cm*8 cm Teflon bar and a 0.25 mm insulation wire. It has 217 turns/m and 5.46 μs L/R time for about the 10 kHz bandwidth, conservatively. A deep cycle battery employed for the TF coil current supply is used as a current source to investigate the performance of the sample Rogowski coil. The output signal is integrated using numerical methods. The result is compared to the reference data measured by a commercial Rogowski coil as shown in figure 1.

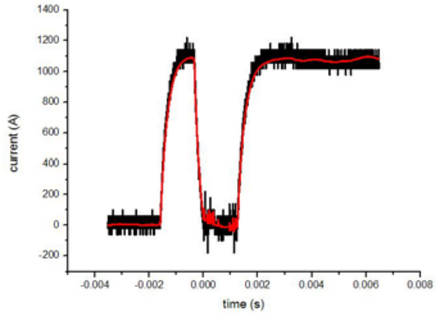

Fig. 1. Black signals are from a commercial Rogowski coil and red signals are from the sample Rogowski coil using a numerical integrator. Total current is 1100 A. Sample Rogowski coil has 6.59 mV offset voltage and $1.388*10^7$ calibration factor.

2.2 Magnetic probe

Magnetic probes are used to measure local poloidal magnetic field. The output of the magnetic probe is proportional to the measured flux,

$$\Phi = BNA \qquad (2)$$

where B is the local magnetic field component to be measured, A is the coil cross-section area, N the turn number of the coil [1].

The magnetic probes in VEST are mounted on the inner vacuum chamber bar with bolt taps. Tap distance is determined by the magnetic probe size. Magnetic probes are protected from hot plasmas using 1 mm stainless steel plates. However, the stainless steel plate has a magnetic shielding effect that restricts measurements of over about 1 MHz magnetic field variations.

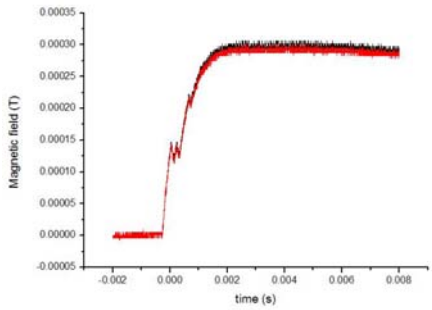

Fig. 2. Black signals are calculated magnetic fields using the current data from the commercial Rogowski coil. Red signals are measured data by the sample magnetic probe. Offset

voltage of the magnetic probe is 0.282 mV and calibration factor is 50000.

A sample magnetic probe is also designed and tested using the TF coil current source deep cycle battery. The magnetic probe is composed of a 6 mm diameter Teflon cylinder, a 200-turns double layer coil made by 0.2 mm copper wires and a size of 1.7 cm. The distance from the current to the magnetic probe is 9.5 cm. The output signal is integrated using numerical methods and the result is compared with the magnetic field calculated from the current data measured by using the commercial Rogowski coil as shown in figure 2.

2.3 Flux loop

The poloidal magnetic flux near the vacuum chamber is measured using flux loop. The flux loop is a single turn coil in the toroidal direction on the horizontal plane. The flux linked by the loop is

$$\Phi=2\pi\psi\ . \qquad (3)$$

The measured flux data from flux loops will be used for the equilibrium reconstruction and plasma position control.

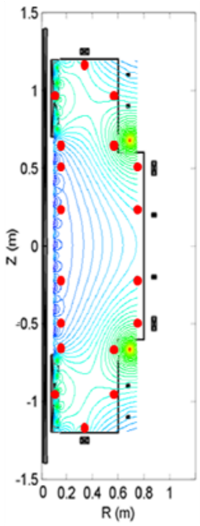

Fig. 3. Distribution of flux loops for the equilibrium reconstruction, merging scenario monitoring and plasma position control.

In VEST, 18 flux loops will be installed inside of the vacuum vessel. Positions of flux loops are determined not to overlap with vacuum chamber ports. Flux loops are fixed by bars on the inside of the vacuum chamber also used to fix magnetic probe.

For measuring plasma flux only, the flux of the central solenoid must be removed. The flux of the central solenoid is measured by flux loops on the center stack wall. 8 flux loop pairs are installed on the center stack wall and inside of the outer vacuum chamber wall on the same horizontal plane. Other two flux loops are installed on the top and bottom chamber wall, respectively.

3. Conclusions

The sample Rogowski coil and magnetic probe are designed and tested for effective design of the VEST magnetic diagnostic system. For analyzing plasma equilibrium parameters and merging scenario, Rogowski coil turn number, magnetic probe turn number, magnetic probe number and position distribution will be studied and applied to VEST in the near future.

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