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Characteristics of the integration system for the KSTAR magnetic diagnostics

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The analogue integrator, which automatically compensates a drift, had been developed for the flux measurement by using inductive magnetic sensors in the KSTAR machine. The design specification and performance test of the integrator for the KSTAR magnetic diagnostics (MDs) have been previously reported [1-3]. A long signal cable of up to 100m, from each sensor to the integrator, is required for the flux measurement in the KSTAR machine. Thus, a low noise and low drift differential amplifier with passive filters has been developed for the long distance signal transfer in order to reduce the EMI noise from each sensor and power line, and in order to minimize effects of source impedance and ground loop on the flux measurement. Two differential amplifiers are added to the signal path from each sensor to the integrator; one is a transmitter for the impedance buffering and the other is a receiver transferring the differential signal to the integrator.

The analogue integrator for the KSTAR MDs gives the digital integrated data, together with the analogue data [2]. Figure 1 shows the digital signal from a BUS driver in the integrator during an integration time. The signal is stored as a data file in a PC controlling the integrator. The signal can be used for a real-time monitoring of the integrated signal in the flux measurement.

Fig. 1. Digital signal monitored by a program in a PC controlling the integrator.

In the previous performance test of the integrator [2, 3], there were some effects on the integrated signals such that the noise picked up in the signal under an rf environment and the integrated value was under estimated when the resistance of the sensor was higher than 100 Ohm because the input impedance of the integrator was 1kOhm. Thus, a low noise and low drift differential amplifier with passive filters was added to the signal path from sensors to the integrator. Figure 2 shows the experimental set-up for the performance test of the integration system for the KSTAR MDs. The integration system consists of an analogue integrator and a PC controlling the integrator. In the experiment, a pulse current of 200A was applied to a cable during a time of about 20s, and magnetic sensors fully encircled the cable carrying the current measured the magnetic flux. The paired cable (Belden, model 9841) of 100m was used as a signal line. Its nominal conductor DC resistance is about 8 Ohm for the length of 100 m. The current power supply for applying the current was controlled by a "PC2" (see Fig.2), and the current was monitored by a commercial sensor (Sypris, model RS -1000A). The integrator was actuated by a program in a "PC1" (see Fig.2) or an external trigger. The "PC1" can be remotely controlled by a "master PC". The integration time was set as about 104s. The compensated integrated signal was obtained from a digitizer after finishing the integration. In addition, the digital signal was able to be obtained directly from the "PC1" during the integration.

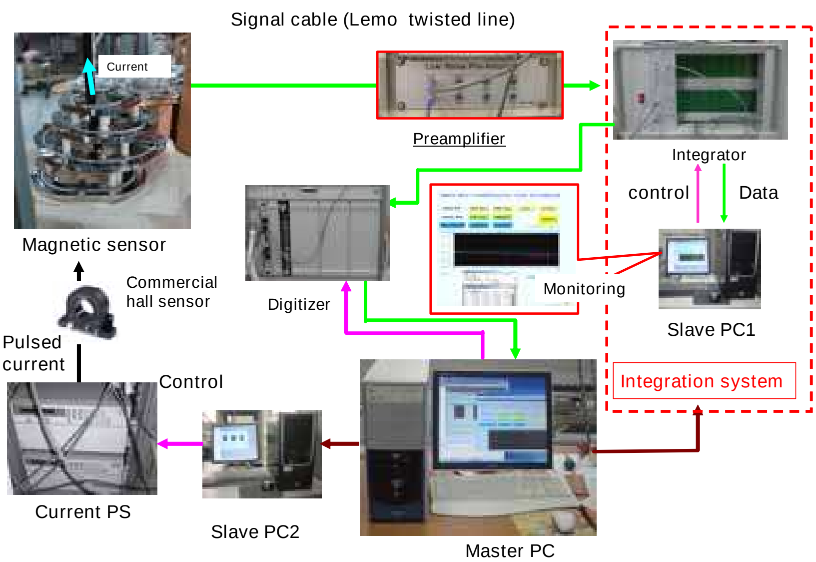

Fig. 2. Experimental set-up for the performance test of the integration system for the KSTAR MDs.

Figure 3 shows the integrated signals for the comparison between two signals from the integrator with a differential amplifier in the signal path (case A) or with the amplifier (case B). The integrating drifts for two cases are less than 2×10^{-6} Wb during an integration time of 104 s as shown in Fig.3 (a). Here, the input channels were shorted to the signal ground in the measurement to investigate the drift characteristics of the integrator itself. Figure 3(b) shows the drifts from the integrator connected to the magnetic sensors with zero input signals. The values of the cases A and B are 3×10^{-6} Wb and 8×10^{-6} Wb, respectively. The drift was larger than 1.5 times that of the integrator itself. Figure 3(c) shows the fluxes measured by two sensors, and the values are 4.8×10^{-6} and 5.2×10^{-6} Wb for the cases A and B, respectively. Also, the integrating drift as a baseline level in the flux measurement are 8×10^{-6} and 11×10^{-6} Wb, respectively. The integrating drift in the case A was smaller than that in the case B.

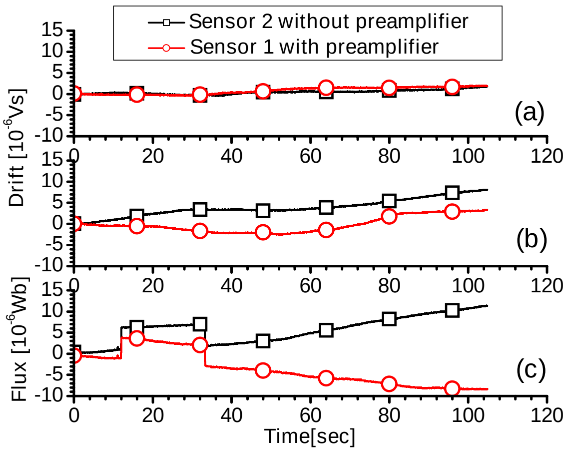

Fig. 3. Typical integrated signals from the integration system with and without the differential amplifier in the signal path from sensor to integrator: (a) the integrating drift of integrator itself, (b) the integrating drift for a zero input signal from the sensors, and (c) fluxes obtained from the sensors in the current measurements.

The performance test of the integration system under an rf environment was carried out in the flux measurement by using a diamagnetic loop (DL) in the Hanbit magnetic mirror device [4]. The integration was triggered by a single pulse with the amplitude of 5 V and the width of 100 μs, and was done during an rf discharge of about 400 ms. Figures 4(a) and 4(b) show typical signals from the integration system with and without a differential amplifier in the signal path from DL to the integrator, respectively. The signals are diamagnetic fluxes measured by a DL during a Hanbit plasma discharge. The signal obtained from the integration system with the amplifier has a lower noise width. Also the offset of the baseline in the signal became smaller as compared with the previous measurement.

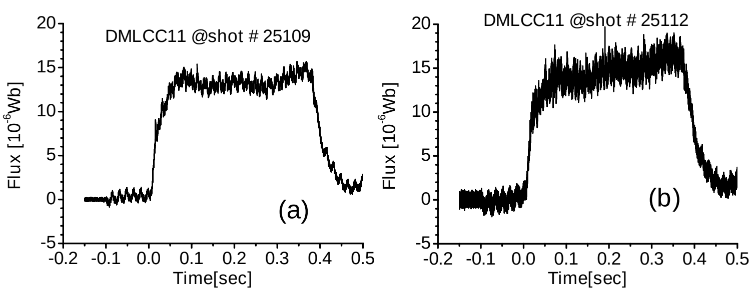

Fig. 4. Diamagnetic flux from the integration system during a Hanbit plasma discharge: (a) with and (b) without the differential amplifier.

The small oscillating signals (60Hz and 360 Hz in the FFT spectrum) appeared in the flux were due to ripples from the current power supply for producing a dc magnetic field.

Some of the KSTAR MDs such as Rogowski coils, vessel current monitors, flux loops, magnetic field probes and a diamagnetic loop will be installed on the wall of the KSTAR machine at the end of this year for measuring basic parameters of the first plasma in the KSTAR machine. The details of the MD sensors were described in Ref. [5, 6]. The integrators will be connected to the vacuum feedthroughs for the MD sensors at flanges in the ports of the KSTAR machine with a long signal cable of about 100m. The value of magnetic flux Φ picked up by each MD sensor during a plasma discharge was calculated by using some parameters proposed for the KSTAR operation such as $B_T = 1.5$ T, $I_p = 100$ kA, and $B_P = 0.02$ T at a sensor position. The value of Φ was estimated as 0.12 ~ 490 mWb. The error in the flux measurements due to the integrating drift was estimated as less than 4.5 % by considering the integrating drift of about 5×10^{-6} Wb during the plasma discharge.

In the performance test of the integration system for the KSTAR MDs, it was found that the integrating drift was less than 1.5×10^{-5} Wb during an integration time of up to 104s which was less than the value required in the design of the integrator. From the flux measurement under an rf environment, it was confirmed that the performance of the integration system was improved by reducing the noise width and the offset of the baseline had appeared in the previous measurement [2,3] because the differential amplifier was added to the signal path from the sensor to integrator. Thus, it is estimated that the integrator can be used in the long pulse operation of the KSTAR in the future. In order to achieve the purpose, the reduction of the integrating drift as a baseline level is especially required for the measurement of smaller signal such as the diamagnetic flux and the local poloidal field.

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