

§15. Establishment of Partial Discharge Protection Technology for Reliability Improvement on Electrical Insulation of LHD

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The world's largest class superconducting coil is used in the "Large-scale Helical Device" in NIFS. Its electrical insulation system is exposed to considerably severe multiple stresses including cryogenic temperature, large mechanical stresses and strong magnetic fields. It is therefore very important to study its electrical insulation performance under these severe conditions in order to establish the reliability of the coil. If a superconductor quenches from superconducting state to normal state, the liquid coolant vaporizes very easily and turns into high-density gas at cryogenic temperature. In these bubbles, partial discharge (PD) easily occurs and would lead to the breakdown.

We already detected an electromagnetic (EM) wave emitted from PD using an antenna. However, physical relationship between EM radiation and PD current waveforms in liquid nitrogen have not yet been clarified in detail. In this paper, we made an electrical circuit generating the nano-second current waveform which simulated PD current and investigated the physical relationship between EM radiation and PD current waveforms.

Figure 1 shows the simulated PD current generating circuit. Figure 2 shows the two types of simulated PD current waveforms. The nano-second current waveform was obtained by charging and discharging the capacitor. Then, we controlled the current peak value and half width of the simulated PD current waveform by changing capacitor from 100 pF to 1 nF and applied voltage from 5.5V to 10 V. The simulated PD current waveform was measured using the detecting resistor with 50 Ω and the EM radiation was measured using the patch antenna with frequency band of 1.8 GHz. The output of the patch antenna is a digital signal processing pulse voltage with a peak value corresponding to the received EM radiation. The patch antenna was placed 15 cm from the detecting resistor.

Figure 3 (a) and (b) show the PD current waveform in liquid nitrogen and simulated PD current waveform. From figure 3 (a), the current peak value of PD current waveform in liquid nitrogen is mA order and half width is ns order. As shown in figure 3 (a) and (b), the simulated PD current

waveform is considered to be similar to the PD current waveform in liquid nitrogen. Figure 4 shows the relationship between rising differential value and amplitude EM wave in simulated PD current. The rising differential value was defined the slope from 10 % to 90 % of current peak value in simulated PD current waveform. From this result, it was revealed that the rising differential value of simulated PD current was positively correlated with the EM radiation strength, whose correlation coefficient was 0.78. The result suggested the possibility that the EM radiation strength could be used to classify the PD current waveforms with different rising differential values in liquid nitrogen.

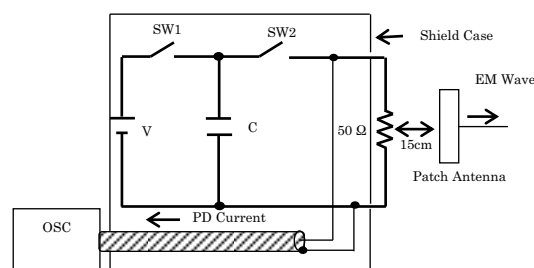
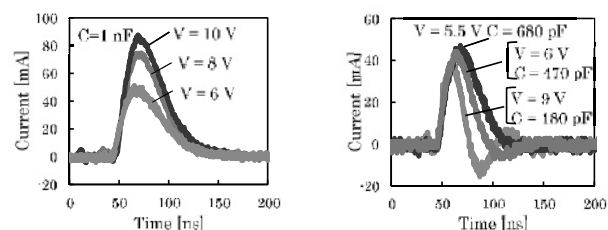
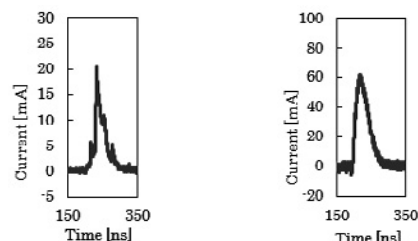


Figure.1. Simulated PD current generating circuit



(a) Different current peak with constant half value width
(b) Different half value width with constant current peak

Figure.2. Simulated PD current waveform



(a) PD current waveform in liquid nitrogen
(b) Simulated PD current waveform

Figure.3. Comparison of PD current waveform in liquid nitrogen and simulated PD current waveform

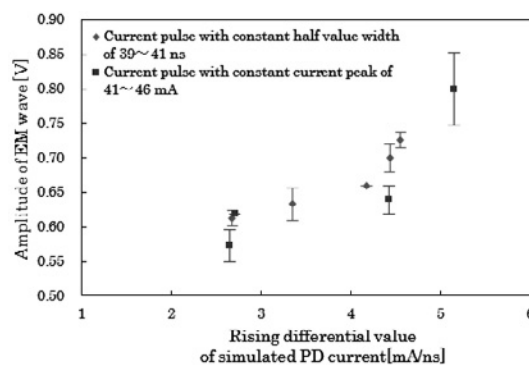


Figure.4. Relationship between rising differential value and amplitude EM wave in simulated PD current