§19. Monitoring of Superconducting Bus-line Using Fuzzy Theorem

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In the LHD system, the superconducting coils are fed by superconducting power-leads, i.e. the superconducting bus-lines. Considering electric insulation aspects, the superconducting bus-lines don't have voltage detection leads just close to the conductor. The voltage detection leads are running along the thermal insulation pipe apart from the conductor. Therefore, we have to take into account some difficulties to detect the normal voltage of the bus-lines due to the heavy electromagnetic noises into the detection signal. In order to solve this problem, the authors proposed a detection system to cancel the voltages of the positive and the negative bus-line conductors each other. And, in this system, Fuzzy theorem is applied incorporating not only the voltage signals but also other signals, e.g. the liquid He inlet flow rate, the currents, etc.. The signals are digitally processed by PCs, and through some Fuzzy calculation we obtain the "dangerous rate" of the bus-lines.

As shown in Figure 1, the voltage taps are attached on the power lead terminals both at the power supply side and the SC coil side. As for the voltage signal cable, the positive and the negative voltage signal wires are wound together tightly on the thermal insulation pipe of the bus-lines..

The quench detection system basing on this principle was applied to the superconducting bus-lines, and the data were collected at some excitation experiments of the LHD. Two PCs and A/D converters were used. Signal wires were connected to A/D converter board. A quench detection experiment was carried out at the LHD site. The monitored signals are, 1) the voltage of the positive polarity bus-line, 2) the voltage of the negative polarity bus-bar, 3) the liquid He flow rate, 4) coil current. The voltages of the positive and the negative polarity bus-lines are subtracted each other, and the difference voltage is created. The experimental result shows that although some voltage noise with a magnitude of about 1mV was observed both in the positive and negative polarity bus-lines, by making the subtraction between these two voltages, the noise can be reduced to lower than 0.1mV. The calculated "dangerous rate" are shown in Figure 2 and 3.

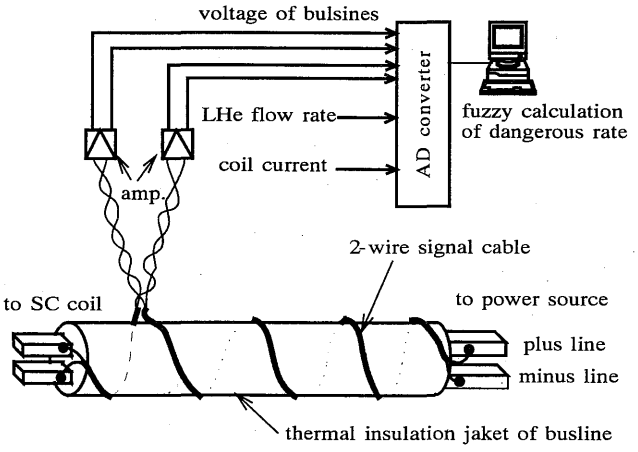

Fig.1 Conceptual figure of fuzzy monitoring system

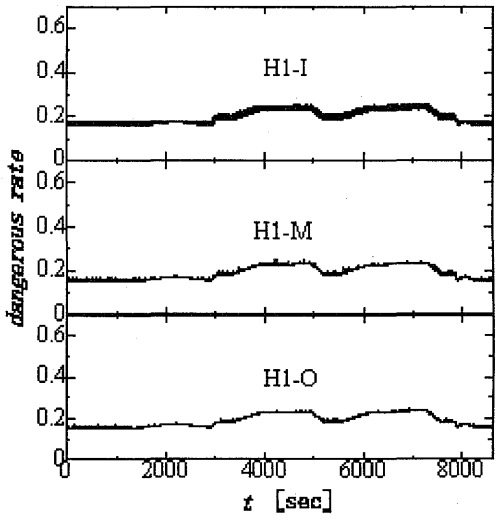

Fig. 2 Dangerous rate of SC buslines for Helical coils

As can be seen in Figure 2, the calculated dangerous rates of the bus-lines do not exceed 0.3 which is enough smaller than the threshold value of 0.5. From this experimental result, we can conclude that the superconducting bus-lines are kept highly stable in conventional excitation operation up to 3T.

Meanwhile, as can be seen in the Figure 3, we can understand that the dangerous rates just after the emergency shutdown of the LHD coil are effected by induced voltages.

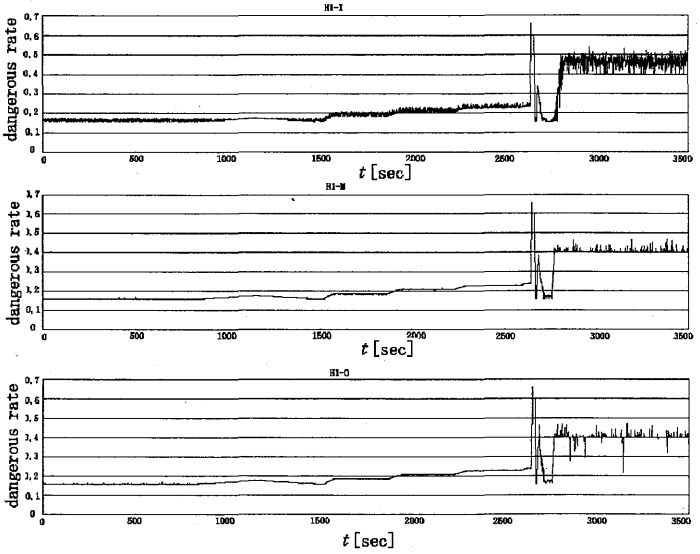

Fig. 3 Dangerous rate of bus-lines for Helical coils with emergency shut-down.