§6. Study on Irregular AC Losses in Large CIC Conductor

Hamajima, T., Tsuda, M., Shimamura, H., Kakusho, Y. (Yamaguchi Univ. Faculty of Eng.),
Satow, T., Takahata, K.

In recent years there has been a growing interest in irregular AC losses that cannot be measured from short conductor sample tests. While, regular AC losses are estimated from the short sample test results, and thereby are proportional to the largest twist pitch squared.

The irregular AC losses with long time constants were typically observed in a Japanese SMES model coil, and the similar long time constants were estimated in a poloidal superconducting coil conductor of Large Helical Device in National Institute for Fusion Science in Japan. Current loops, which must be irregularly formed in the cable, decay with the long time constants, and hence enhance the AC losses. The loops can induce an imbalanced current distribution in a conductor, and lead to RRL (ramp rate limitation), which was observed in DPC coils at Japan Atomic Energy Research Institute.

In this research, we propose a mechanism forming the long loops. The CIC conductor is composed of several staged sub-cables. If one strand on the surface of a sub-cable contacts with the other strand on the surface of the adjacent sub-cable, the two strands should encounter each other again at LCM (Least Common Multiplier) distance of all staged cable pitches, and thereby result in forming a pair of a long loop. There are a number of such long loops in the CIC conductor. The time constants of these loops are fundamentally described as ratios of their inductances to their contact resistances. The inductance of the loop is estimated to be about 5 μH for 3.6m LCM in the SMES CIC conductor.

We measured the cross contact resistance between the two strands of the SMES in LHe. The test results showed that the cross contacting resistances were about 50 μΩ. The results infer that the time constants are around 0.1 s, which are shorter than the measured time constants of 5 to 100 s.

We orderly labeled all strands in a real CIC conductor, disassembling carefully the cable after peeling the conduit, in order to investigate the contact conditions and the contours of the loops. The orderly labeled strand positions on a cross section for the LHD-IV conductor are shown in Fig. 1. It is found that the strands in a triplex are widely displaced from their original positions as indicated by bold circles.

The number of the triplets with largely displaced strands is computed for the SMES conductor and the LHD-IV conductor, as listed in Table 1. It is found that 10 to 20 % of all triplets have largely displaced strands. However, it is confirmed from the data on both sides of conductor about 1 m in length, that almost of all the triplets with displaced strands on one side become regular triplets without displaced strands on the other side.

This suggests that some of the long loops have irregular flux linked with the field and also have longer contact length between the pair strands. The irregularly linked fluxes cause the additional AC losses. The strand displacement produces longer contact length than the cross contact, and hence makes the contact resistance become even lower. The observed long time constants can be explained.

We have plans to measure the contact resistances of the strands for LHD-IV coil to make clear the mechanism of the long time constants, and also to investigate other CIC conductors for LHD poloidal coils.

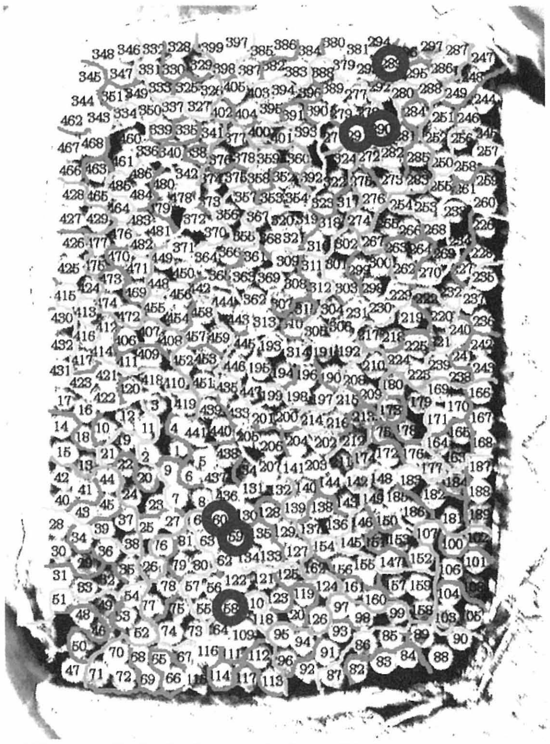

Fig.1. Labeled strands in a CIC conductor

Table 1. Number of the large displaced triplets in CICCs.

	CICC for SMES	CICC for IV
Number of largely displaced triplets	8	35
Total triplets	81	162
Ratio	10 %	22 %