# § 26. Study on Irregular AC Losses in Large CIC Conductor

Hamajima, T., Tsuda, M., Kakusho, Y., Hoashi, K.
(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. 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, about 15 μH for 11.3m LCM in the LHD-IV conductor.

In order to estimate the time constants $\tau = L/R$ of the long LCM loops, we measured the cross contact resistance between the two strands of the SMES and LHD in LHe. The test results showed that the cross contacting resistances were about 50 μΩ for both conductors. The results suggest that the time constants are around 0.1 s for SMES and 0.3 s for LHD, which are shorter than the measured time constants of 5 to 100 s.

It is important to investigate the contact conditions and the contours of the loops. We orderly labeled all strands in a real CIC conductor, disassembling carefully the cable after peeling the conduit. The orderly labeled strand positions on a cross section for the SMES 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 fraction of the triplets with largely displaced strands is computed for the SMES conductor and the LHD-IS and OV conductors, as listed in Fig. 2. It is found that around 5 % of all triplets have largely displaced strands. However, it is confirmed from the data on both sides of the 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 the largely displaced strands have longer line contact length than point contact one. The line contact length must be more than 10 mm, while the point contact radius is estimated to be about 10 μm from Hertz theory. This leads to contacts more than 3 order long, and explains the observed long time constants.

Moreover, the loops with largely displaced strands have irregular flux linked with the field. The irregularly linked fluxes cause the additional irregular AC losses.

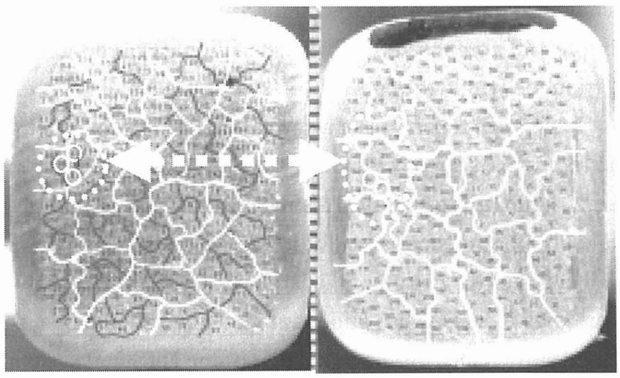

Fig.1. Labeled strands in a CIC conductor

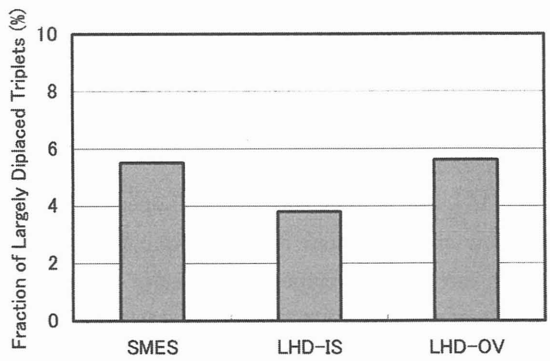


Fig. 2. Number of the large displaced triplets in CICCs.

Reference

1) Hamajima, T., et al., IEEE Trans. on Appl. Supercond. **11**, (2001) 1860
2) T Hamajima, et al., IEEE Trans. on Appl. Supercond. **12**, (2002) 1616