외부 자계 인가에 따른 고온초전도 케이블 도체의 퀜치 특성

임성우, 황시돌, 오제명, 한병성
한전전력연구원 신기술 센타, 전북대학교 전자정보공학부

Influence of external magnetic field on HTS cable conductor

Seong Woo Yim[*,a], Si Dole Hwang[a], Je Myoung Oh[a], Byung Sung Han[b]

a Advanced Technology Center, Korea Electric Power Research Institute
b Division of Electronics and Information Engineering, Chonbuk National University

yimsw@hanmail.net

Abstract – Quench characteristics of HTS cable conductor due to external magnetic field were investigated. Firstly, the influence of critical characteristics of HTS tape on locally applied magnetic field was examined. Secondly, critical current of HTS tapes, which are wound on surface of former, were measured respectively, before the experiment for quench characteristics. Finally, 50mT and 100mT were applied to HTS cable conductor and quench characteristics were investigated through V-I curves. As the results, same as the result of HTS tape, HTS cable conductor showed strong dependence on external magnetic field with direction and magnitude.

1. Introduction

HTS tape made by powder in tube (PIT) method shows strong directional dependence on the magnetic field due to innate nature of Bi-2223 superconductors [1]. In other words, when external magnetic field is applied to HTS tape, critical characteristics of the tape become degraded and the quench is liable to be happened. To cope with these problems, the exact understanding of the material properties such as critical current, temperature and magnetic field is needed for quench study of HTS tape, and this result must be considered to design and protection of HTS devices [2]. Although HTS cable is operated stably, unexpectedly, magnetic field generated by adjacent cables or other conductors can affect the transportation characteristics of the cable. HTS cables, generally, are consists of several layers of HTS tapes wound on former. Since HTS tapes have strong dependence on magnetic field, when HTS cables are exposed to external magnetic field, their critical current become lower than expected.

In this study, we examined the dependence of magnetic field on critical current of HTS tape. Based on the results of the experiment, and then, the influence of external magnetic field on HTS cable conductor was investigated and analyzed.

2. Experimental set up

For these experiments, a HTS cable conductor composed of 10 HTS tapes was prepared. The length of conductors was 18cm and 10 strands of HTS tapes were wound on former of HTS cable conductor in the shape of helical form.

In order to apply the magnetic field to the surface of HTS cable conductor enclosed with HTS tapes, an E shaped magnet was design and fabricated.

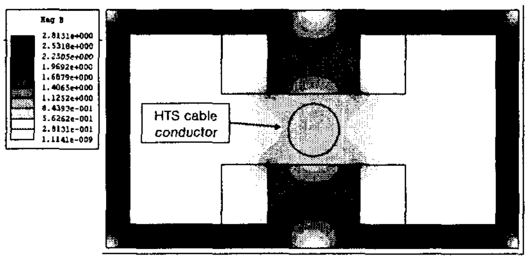


Fig. 1. Distribution of magnetic field in the magnet.

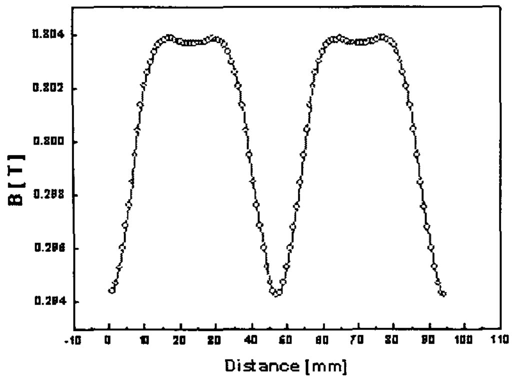


Fig. 2. Distribution of magnetic field along with the surface of cable conductor

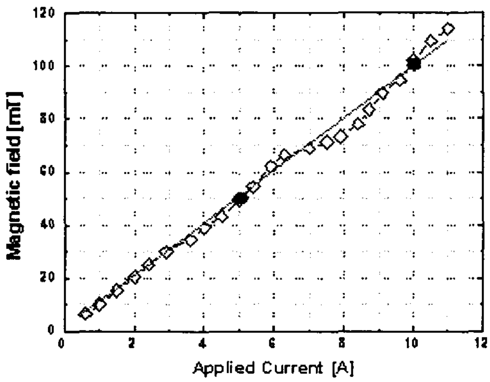


Fig. 3. Magnetic field generated with the amount of the applied current

Fig. 1 shows the distribution of magnetic field in this magnet. The magnet was designed to be operated in liquid nitrogen environment to increase the current capacity. As shown in Fig. 1, most of the magnetic field is concentrated in the center of the magnet, and leak field does not exist nearly. In particular, the generated magnetic field could be distributed uniformly on the surface of HTS cable conductor. That is, this magnet can apply magnetic field equally to HTS tape enclosing the surface of HTS cable conductor. The distribution of magnetic field that is applied along with the surface of HTS cable conductor is presented in Fig. 2. From the result, it is confirmed that almost equal magnitude of magnetic field is applied to the surface of the conductor. Magnetic constant in surface of the cable conductor was 10mT/A as presented in Fig. 3.

The HTS cable conductor was placed inside the magnet, which is fabricated for applying uniform magnetic field as shown in Fig. 4

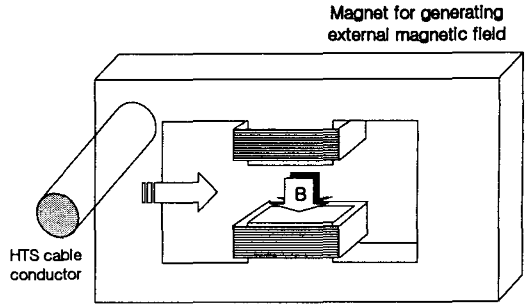


Fig. 4. HTS cable conductor and magnet for applying external magnetic field

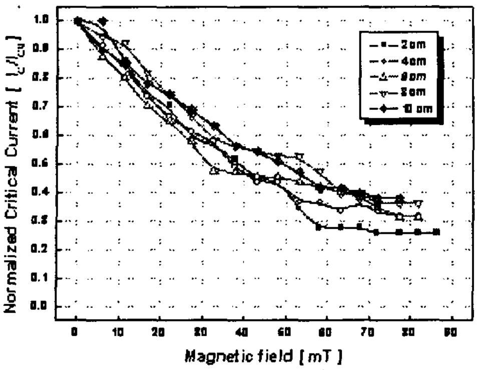
3. Results and discussion

3.1 Dependence of HTS tape on local magnetic field

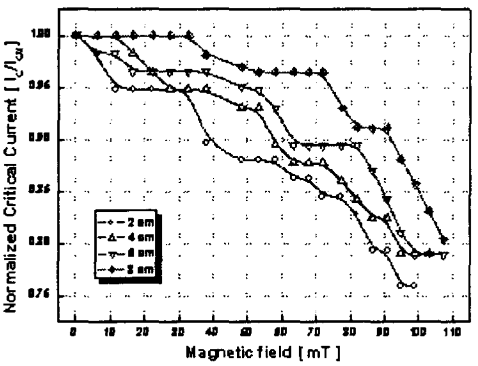
Prior to examine HTS cable conductor, critical characteristics of HTS tape which is applied local magnetic field was tested. For the experiment, the variation of critical current was measured, applying external magnetic field. The length of the tested HTS tape was determined as 20cm, considering the length of the tape of HTS cable conductor. The external magnetic field was applied to 1cm range from center of HTS tape, and distance between voltage taps was defined as 2, 4, 6, 8, 10cm respectively.

In Fig. 5.12 a) and b), variation of critical current in HTS tape, which is applied the local magnetic field in parallel and in perpendicular direction to the plane of the tape, is presented. In Fig. 5.12 a) applied magnetic field in perpendicular direction, when the distance between voltage taps was 2cm and 58mT was applied to HTS tape, the critical current was reduced 30%, compared to the result measured without magnetic field. In the case that the distance between voltage taps was 10cm, 72mT makes 64% of reduction.

Compared to the result of Fig. 5.12 a), the degradation due to the magnetic field applied in parallel direction in Fig. 5.12 b) seems not to be serious. When the distance between voltage taps was 2cm and 95mT was applied to HTS tape, the critical current was reduced 25% than the result measured without influence of magnetic field.



(a)



(b)

Fig. 5. Variation of critical current with applied local magnetic field a) in perpendicular direction, and b) in parallel direction

3.2 Influence of magnetic field on HTS tapes of cable conductor

For applying external magnetic field, HTS cable conductor was fixed in the space between both poles of the magnet, as shown in Fig. 6. Each tape on the surface of the conductor was numbered from 1 to 10 for classification. HTS tapes denoted number 3 and 8 become exposed to the magnetic field in parallel direction to the plane of the tape.

Fixed as described in Fig. 6, critical current of each strand of tape was measured before the experiment. The variation of critical current measured without the influence of magnetic field is denoted as circle shaped marks in Fig. 7. When the magnetic field did not affect the HTS cable conductor, critical currents of HTS tapes except the tape numbered 10 were around 53A on average. The number 10 was, exceptionally, had a high critical current of 62A.

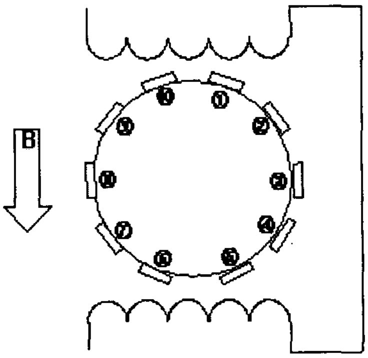


Fig. 6 Direction of magnetic field applied each HTS tape of cable conductor

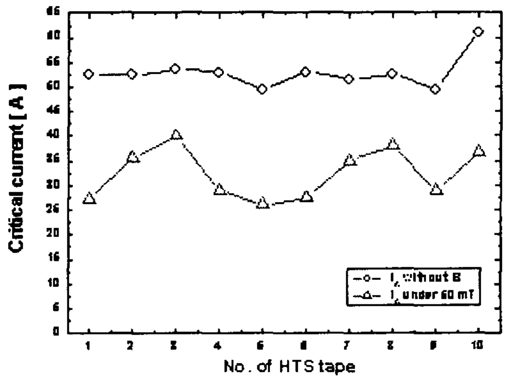


Fig. 7. Variation of critical current with (blue circle) and without (red triangle) external magnetic field

The results of critical currents that measured with applied 50mT from magnet were expressed as triangle shaped marks in Fig. 7. Because HTS tape numbered 3 and 8 were influenced by parallel directional magnetic field to the plane, the degradation of critical current was also the lowest among the tapes. However, although HTS tape numbered 10 was placed in which perpendicular directional magnetic field was applied, that tape shows higher critical current because it had the highest critical current originally.

3.3 Dependence of HTS cable conductor on external magnetic field

When external field was applied, each strand of tapes did not quench simultaneously, because the angles of the exposed magnetic field were different. Applying 50mT and 100mT, dependence of HTS tape on magnetic field was investigated.

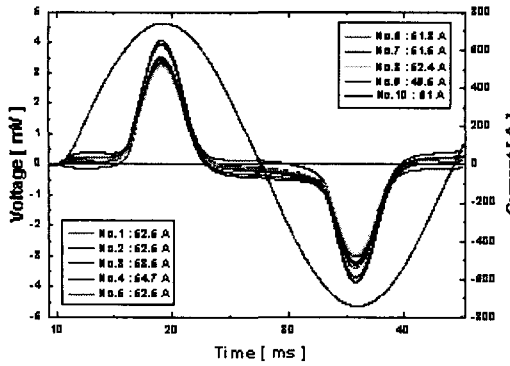


Fig. 8. Quench characteristics without influence of magnetic field

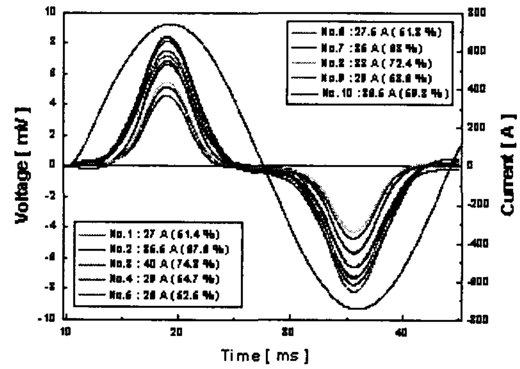


Fig. 9. Quench characteristics with applied 50mT of external magnetic field

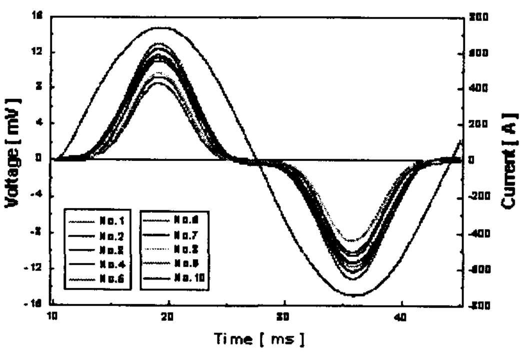


Fig. 10. Quench characteristics with applied 100mT of external magnetic field

In Fig. 8, quench characteristics of HTS cable conductor without influence of magnetic field is presented. Because the influence of external magnetic field does not exist, the quenched voltages of HTS tapes do not show much difference. However, results of Fig. 9 and 10 show different aspects from that of Fig. 8. Due to influence of external magnetic field, the difference of detected voltage comes to be larger than that of Fig. 8. As already expected, the quenched voltage increase in proportion to the magnitude of the applied magnetic field. In addition, HTS tapes numbered 5 and 6, which are influenced by perpendicular directional magnetic field to the plane, show higher voltages than others as expected.

4. Conclusion

The influence of external magnetic field on quench characteristics of HTS cable conductor was investigated. HTS cable conductor, composed of 10 HTS tapes, were prepared. Prior to the experiment, the influence of critical characteristics of HTS tape on locally applied magnetic field was examined. Critical current of HTS tapes of cable conductor were measured respectively, before the experiment for quench characteristics. Finally, 50mT and 100mT was applied to HTS cable conductor and quench characteristics was investigated. Through the experiments, we confirmed that dependance of HTS cable conductor on external magnetic field was strong.

(Acknowledgment)

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