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# Technical development of the world's first HTS power tansformer using Y-based superconducting wire

## - Verification of short-circuit performance and current limiting function using transformer winding - Significant progress toward practical use and new functional advancement of HTS transformers

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Kyushu Electric Power Co. is working on superconductivity technology as the one that provides flexible measures to cope with the impact on electric power system due to the increase in electricity demand and the introduction of renewable energy and to contribute to the low-carbon society. In particular, HTS transformers are being developed. Recently, a HTS power transformer using Y-based superconducting wire (GdBCO, etc.) (after this ; Y-based transformer) was developed for the first time in the "Development of Y-based transformer," a part of the "Technical development of Y-based HTS power equipments[1)]" relegated by New Energy and Industrial Technology Development Organization (NEDO) in cooperation with Kyushu University, International Superconductivity Technology Center, Fujikura Ltd., and SWCC Showa Cable Systems Co. Using the transformer, the short-circuit performance as well as the limiting function[2)], which is a new function of HTS transformers, was verified for the first time in the world.

The use of superconducting wires makes transformers smaller and more efficient. In particular, early commercialization of Y-based transformers is desired since its critical current is large and it enables loss reduction using thin wires and lower cost in the future. Especially in distribution transformers (66/6.9 kV-20 MVA), the weight of the Y-based transformers is expected to be reduced by 1/2 and volume by 2/3, and loss by 1/6 compared to the conventional oil-immersed transformers.

The results of the test promise a significant advancement in practical use the commercialization of Y-based transformer,Y-based transformers with a hope for the practical use of "Y-based transformer provided with fault current limiting (after this ; FCL) function[3)]," which enables to suppress the accident current and is effective for lowering and suppressing the momentary voltage drop.

### 1. Verification of short-circuit performance of Y-based superconducting transformer

The short-circuit performance of the Y-based transformer, (400 kVA) that endures short-circuit current that occurs accidently in electric power system, and the strong electromagnetic force accompanied by the large short-circuit current was verified. As the measures for the transformer to cope with the short-circuit occurrence, the following elements were uniquely adopted: ① the capacity was set to 400 kVA (about 1/50 of the practical transformer), which corresponds to the minimum capacity that can be verified using 20 MVA commercial transformer, and the short-circuit current and electromagnetic force were set to 398 A, which is comparable to those of commercial transformer; ② the original stabilized layer consisting of silver and copper was applied to the Y-based wires; ③ original transposition (wires are aligned alternately) was applied to the (three-layer) secondary wire winding to homogenize the current (Fig. 1).
The voltage (primary/secondary) and current of the practical transformer were 66 kV/6.9 kV and 175 A/1674 A, respectively, and the wire consisted of 3 pieces/24 pieces. The voltage and current of the HTS

  

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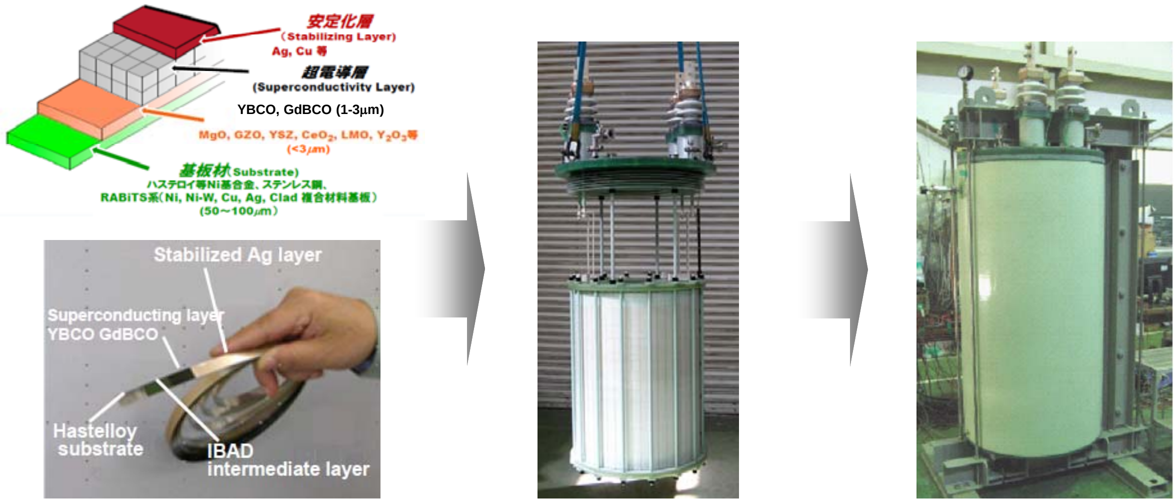
transformer was 6.9 kV/2.3 kV and 58 A/174 A, respectively, and the wire consisted of 1 piece/24 piece.




Y-based superconducting wire

Appearance of winding wire
(φ565 mm, H810 mm)

Appearance of transformer
(inside is cooled by liquid nitrogen)
(φ738 mm, H 2300 mm)

Fig. 1 Y-based superconducting transformer (400 kVA)

To verify the technical measures for short-circuit, short-circuit test was conducted by cooling the transformer to subcool-liquid-nitrogen temperature (−207°C) and applying a voltage of 6.9 kV for 0.2 s. A desired result was obtained at a short circuit current of 1040 A (about 6 times the rated current of 174 A) (Fig.2). The values of the impedance measured before and after the tests were comparable with each other, which confirmed that the winding was sound after the test (Fig.3).

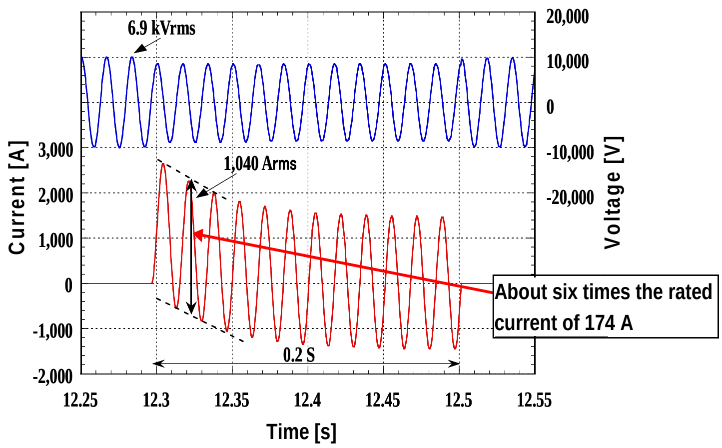



Fig.2 The results of the short-circuit test

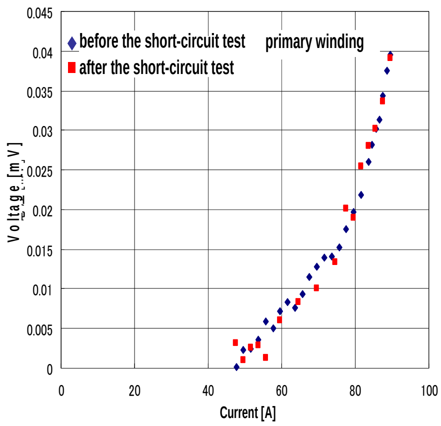



Fig. 3 The winding characteristics before and after the short-circuit test

**2. Verification of fault current limiting function (new function) of Y-based small transformer**

Current limiting function, which is a new function of the HTS transformer, was verified using a winding of the Y-based transformer (10 kVA) provided with a FCL function. Although the transformer is normally used as a conventional transformer, it was verified that it exhibits a function as a FCL that suppresses the accident

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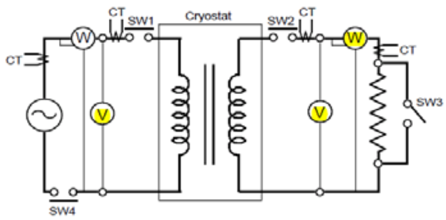
current and voltage drops because of the instantaneous transformation of the superconducting winding wires into a normal conductor (current resistance occurs) as a result of the accident current (large current).

The elements of the FCL technology are: ① the transformer endures short-circuit load in accident while it normally acts as a transformer; ② the mechanism in which accident current is suppressed by the transformation of the superconducting winding wire of the transformer to normal conductor (generation of resistance) was theoretically analyzed, and the winding condition was uniquely applied. The specifications of the transformer are: voltage (primary/secondary) is 400 V/400 V, current is 25 A/25 A, and winding wire is six layers × 50 turns (Fig.4).




Constitution of transformer
(including test circuit)

Appearance of transformer
(φ200 mm、H250 mm)

Fig. 4 Y-based small transformer with FCL function

In the verification test of FCL function, the following items were confirmed: ① normal operating characteristics as a transformer; ② the FCL performance that suppress the short-circuit current to 1/30 (1200 A→43 A) and momentary voltage drop (Fig. 5); ③ the position of transformation to normal conducting increases in proportion to voltage so that the adjustment of FCL effect is possible.

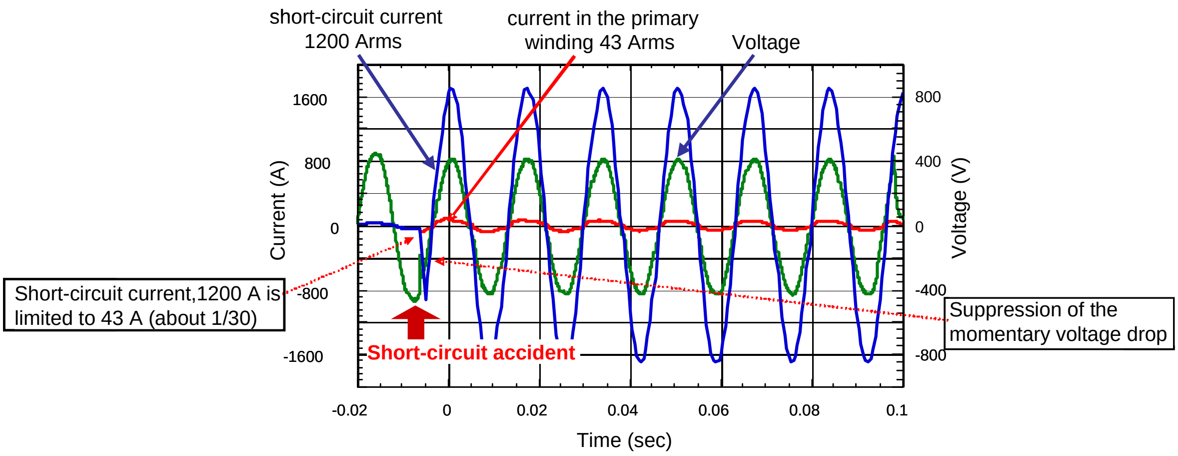



Fig. 5 Test results of current limiting function

Early commercialization of the 20 MVA class superconducting distribution transformers is aimed at by steadily bringing forward the present project through the development and verification of 2 MVA superconducting transformer systems.

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**1)** "Technical development of Y-based superconducting transformers," part of "Technical development of the yttrium-based superconducting electric power devices" (FY 2008 to FY 2012: part of "Technical development of Y-based superconducting transformer," which is an NEDO subsidy project funded by the Agency for Natural Resources and Energy) is being implemented by Kyushu Electric Co. in cooperation with Kyushu University, International Superconductivity Industrial Technology Center, Fujikura Ltd., and SWCC Showa Cable Systems Co. The development of an elementary technology is proceeding smoothly, and an intermediate assessment has been conducted this month. The plan of the project was published in the November 2009 issue of Web21, and the progress status will be published in November 2010 issue.

**2)** "Current limiting function" is a function that suppresses the current before the short-circuit accident current in an electric power system reaches the maximum (within 4 ms) (it is also possible to suppress momentary voltage drops), and provides significant effect on the suppression of the short-circuit capacity in an electric power system including transformers (also economically advantageous if measures for electrical, mechanical, and thermal stresses are alleviated). Because existing technology cannot provide such a "current limiter," superconducting current limiters are being developed desperately all over the world.

**3)** "Superconducting transformer provided with current limiting function" is a transformer that utilizes the superconducting winding wire of superconducting transformer as a current limiter. Downsizing is realized by using the components for dual purposes rather than using separately, thereby resulting in better efficiency and cooling performance. There have been no successful developments so far.

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