Characteristic of YBCO Thin Film for Current Limiting Device

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Abstract. We investigated application of YBCO thin film without covering of metal layer to current limiting device, because electric resistance of YBCO film was very high after quenching, and so it is suitable for current limiting device. We tried to get endurance voltage ability. Also we used a high-speed camera to observe break down phenomena of an element and it was found that breakdown always occurred at the peak transient voltage after quench. When we connected a parallel capacitor to slow down the time to the peak, still breakdown always occurred at the peak. From these result, breakdown voltage depends on not to joule heating but critical current, Jc. Also it is necessary to connect elements in series for current limiting device. When one element was superconducting state but the others were quenched, significant voltage appeared on these elements and thus breakdown occurred. But by connecting resistance in parallel with elements, we observed a uniform voltage sharing was achieved.

1. Introduction

Fault current in power system have been increasing because of the continuous growth of power systems and the increasing of distributed generators. To resolving these problems, it is proposed to install a Superconducting Fault Current Limiter in power systems. So far, various SFCL have been developed, we studied Resistive SFCL using Vacuum Interrupter to limit the heat to the element by limiting current interruption within a first half cycle. Hence, we tested YBCO thin film without covering of metal layer. Because quench characteristics of this element is unknown when current conduction is only half cycle. So, we carry out experiment on endurance voltage ability.

Fault current limiting device must be designed in a limited size and quality. So, parallel connection of elements is necessary for large current application and series connection is essentially necessary for high voltage application. But series connection gives many problems. Therefore we investigated the series connection.

2. Specification of YBCO thin film

Fig.1 shows the specification of YBCO thin film made of Metal-organic deposition (MOD process)
3. Experiment

3.1 Experiment of current limiting without shunt

Fig.2 shows the experimental circuit. The experiment on current limiting was carried by conducting the current of a half cycle. At first supplied voltage was 10Vrms and then increased by a step of 10Vrms until element was damaged. We carried current conducting for three times in each voltage step. Also we used a high-speed photography to observe breakdown phenomena of the element, where speed set at 10,000 frames/second.

At first, we investigated the current limiting element of 3.3MA/cm² measured by induction method. The results of experiments are shown in Fig3. The circuit current indicated Fig.3 is measured by coaxial shunt. The “voltage” indicated in Fig3 is the voltage drop in the element. The supplied voltage of (a), (b), (c) in Fig.3 is 35Vrms, 60Vrms and 70 Vrms respectively. From these result, current at the beginning of the current limiting process was not changed until conducting the current at (c) in Fig.3.

If there was damage or destruction in the element, current at the beginning of current limiting process must decreased. So it is concluded that the element was not damaged or destruction until conducting the current at (b). In the experiment at (c), we observed the arc by high-speed camera and the element was destroyed. Photographs of arc are shown in Fig.4. From Fig.3(c) and Fig.4, it was considered that the arc occurred at transient voltage peak, and disappeared at current zero. Fig.5 shows the result that we tested the YBCO thin films of various Jc. ○ (circle) and × in Fig.5 mean success and failure in current limiting test respectively. From this result, allowable voltage depends on Jc.
3.2 Experiment of current limiting with capacitor

The arc is observed at transient voltage peak immediately after current limiting. So we connected a capacitor (440 μF) in parallel with element to slow down the peak. Fig.6 shows the circuit of this experiment.

At first, we investigated the element of 1.7MA/cm². The results of current limiting experiments are shown in Fig.7. The supplied voltage of (a), (b) and (c) in Fig.7 is 90Vrms, 110Vrms (first) and 110Vrms (second) respectively. The circuit current and HTS current indicated in Fig.7 are measured by coaxial shunt and current transformer. From these results, current at the beginning of the current limiting process was not changed until conducting the current at (c) in Fig.7. So it is concluded that the performance of current limiting is not changed until conducting the current at (c) in Fig.7. In conducting at (c) Fig.7, HTS current is 0A at 25ms, and voltage is constantly 80V at 25ms. Also the arc is observed at 15ms when voltage is peak and the element was destroyed.

We tested various type of Jc. The result is shown in Fig.8. Fig.8 shows that allowable voltage does not change compared with that of Fig.5, regardless of arising much heat in element.
3.3 Series Connection for application of high voltage

Conductors used in current limiting device are limited in size voltage capacity. Therefore series connection is essential for high voltage application. Various institutes have been investigating this problem \(^1\). Also we investigated series connection technology.

At first we connected element A (Jc=1.0MA/cm\(^2\)) and element B (Jc=1.2MA/cm\(^2\)) in series. Fig.9 shows the experimental circuit. The results of current limiting experiments are shown in Fig.11. The supplied voltage of (a) and (b) in Fig.11 is 10Vrms, 50Vrms and 80Vrms respectively. “V1” and “V2” indicated in Fig.11 is voltage drop of element A and element B. From these result, element A only quenched regardless of increasing supplied voltage. The reason is that resistance of element A increase in proportion to supplied voltage.

In this paper, YBCO thin films without covering of metal layer are investigated on characteristic of current limiting. From these experiments, breakdown occurs at voltage peak after quenching. And allowable voltage depends on Jc and does not change, regardless of connecting capacitor in parallel with the element.

Two elements are connected in series for high voltage application. When two elements are connected in series without parallel resistor, one element only quenched regardless of supplied voltage. But elements connected in series are quenched when shunt resistor is connected with element respectively and supplied voltage is sufficient.

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References
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