Threshold value analysis of YBCO tapes under transient DC over-current impulse

Shizhuo Liu[1,2,3], Dong Xia [1,2,3], Qingquan Qiu [1,2,3], Zhifeng Zhang [1,2,3], Qingfeng Liu [1,2,3], Naihao Song [1,2,3]

1. Institute of Electrical Engineering, Chinese Academy of Sciences, Beijing, 100190, China
2. Applied Superconductivity Key Lab, Chinese Academy of Sciences, Beijing, 100190, China
3. University of Chinese Academy of Sciences, Beijing, 100190, China

Thu-Af-Po4.08-10 [130]

Introduction

Voltage Sourced Converter Based High Voltage DC (VSC-HVDC) transmission is developing fast. However, due to the bottleneck of the HVDC circuit breaker, the short circuit problems of the VSC-HVDC transmission could not be solved well in an effective way. Since FCLs could limit the short circuit current in a short time, they could be a kind of auxilary means for the short trouble. The SFCL may be one of the most prominent method to protect the power systems safely. So the impulse process of superconducting tapes in DC situation should be researched comprehensively.

Samples

The YBCO sample was the 8602 superconducting tape from American superconductor (AMSC). It is a kind of 2G high temperature superconducting (HTS) tapes. The Its structure and parameters are shown in figure 1 and Table 1, respectively.

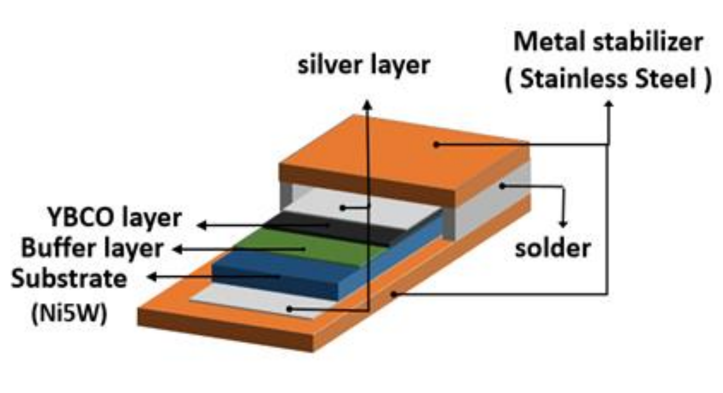


Fig. 1. The structure of the 8602 superconducting tape

TABLE I THE PARAMETERS OF THE 8602 YBCO SUPERCONDUCTING TAPE

Type	8602
Productor	AMSC
Average width	12mm
YBCO layer thickness	0.8μm
Buffer layer thickness	0.2μm
Silver layer thickness	3μm
Substrate thickness	75μm(Ni-5W)
Stabilizer thickness	75μm×2(Stainless steel)
Critical current	260A@77K，0T

System

The schematic diagram of DC over-current impulse experimental system is shown in figure 2. It will generate over-current by the discharge of the capacitance C.

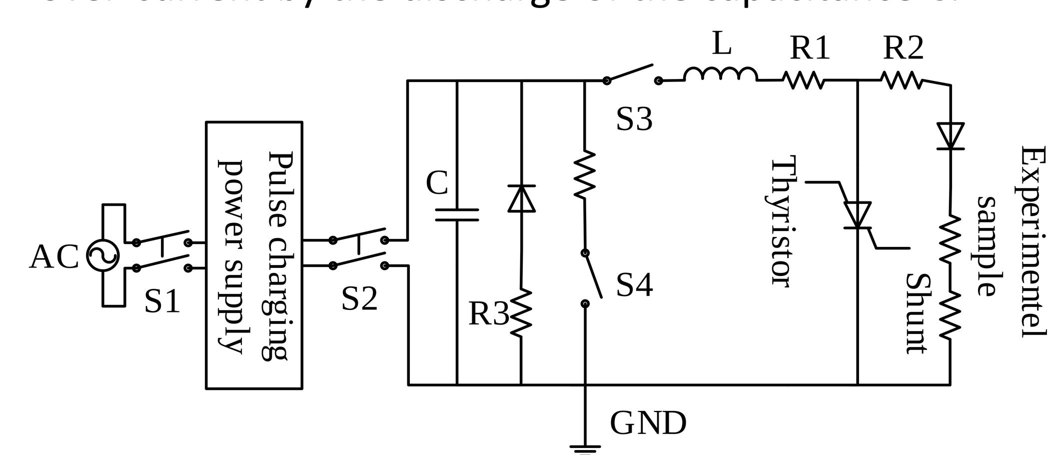


Fig. 2. Schematic diagram of DC over-current impulse experimental system

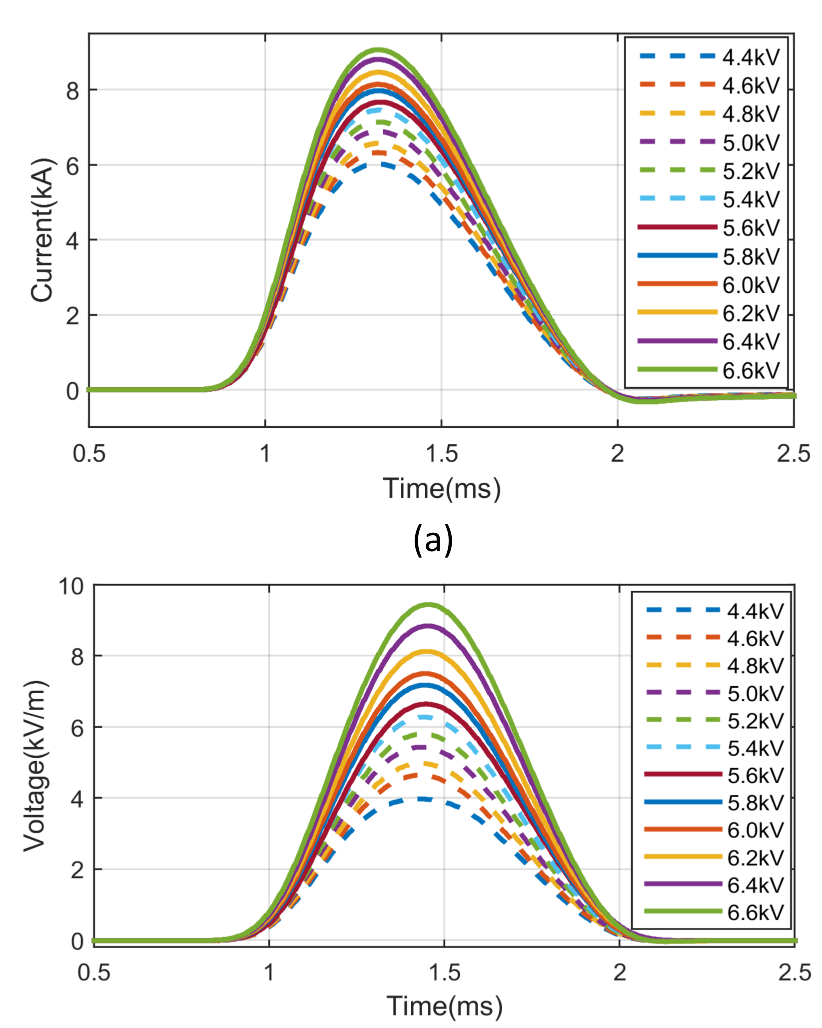
Experimental Results

We chose eleven segments of YBCO tapes as samples. The voltage and current of each tape is measured by four-probe method. The effective length of voltage measurement is 10cm for all the samples. The impulse time is chosen from 1ms to 11ms with the time interval of about 1ms.

The impulse experiment results of 1ms are shown in figure 4. We chose R1 as 0.2Ω, R2 as 0.05Ω, capacitance C as 0.5mF and inductance L as 0.2mH. The voltage of capacitance C increased until the tape is damaged (some part is delaminated or burnt). The tape is damaged with the capacitance voltage of 6.8kV. We eliminate the data of the voltage 6.8kV as once the tape is damaged the data doesn't have reference value. The same experimental procedure were carried out on other samples. The different was the impulse time. The experimental results are concluded in figure 5.

Fig. 3. The experimental tapes. Some part of it is damaged into layers.

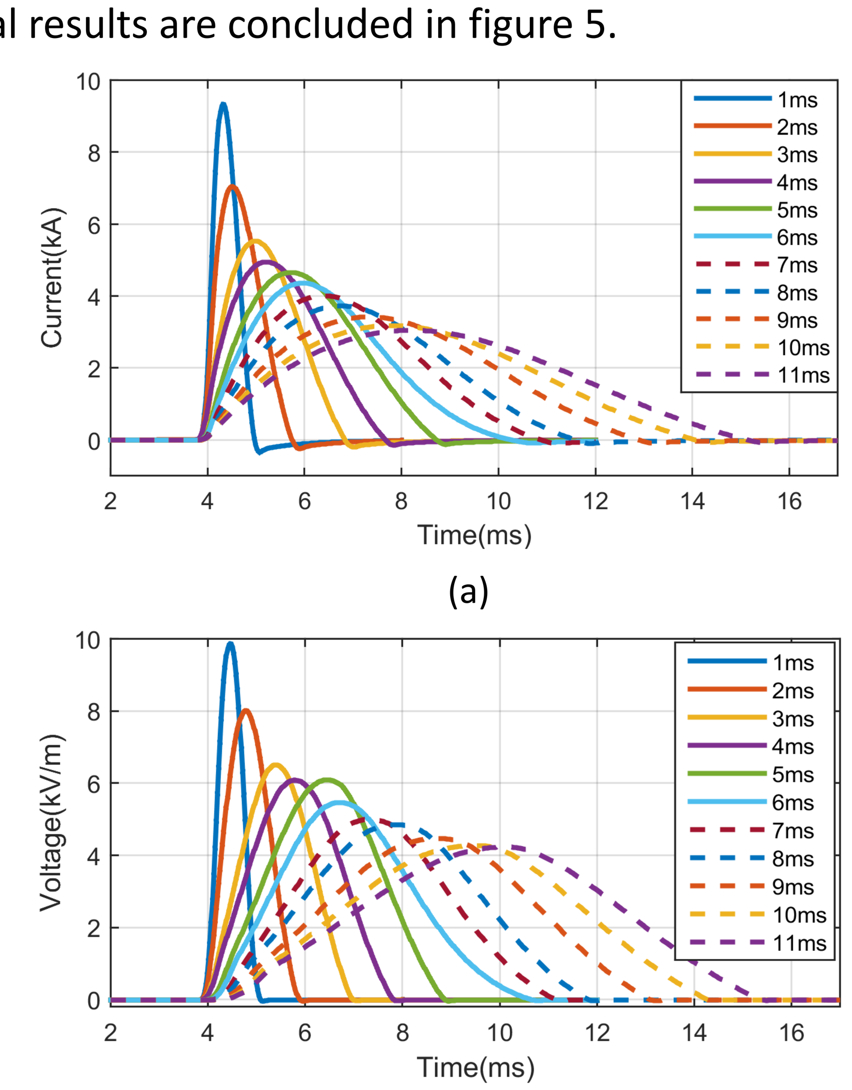
The experimental tapes are shown in figure 3. It can be seen that the tapes are overheated and some part delaminated.



(a)

(b)

Fig. 4. The impulse current and voltage changing with impulse time of 1 ms.



(a)

(b)

Fig. 5. The critical experimental results with different impulse time. (a) The impulse current. (b) The impulse voltage.

Analysis

Resistance characteristics

The resistance waveforms with different impulse time are shown in figure 6.

- In figure 6 the resistance has a transition point at 0.5Ω/m. The transition process is the process of the superconducting tape transforming from superconducting state to normal state through flux flow state.
- The max impulse resistance is about 2Ω/m in figure 6. Through calculation the temperature can achieve about 500K. This temperature exceeds the melting point of soldering tin, and it could cause the delamination of the tapes.

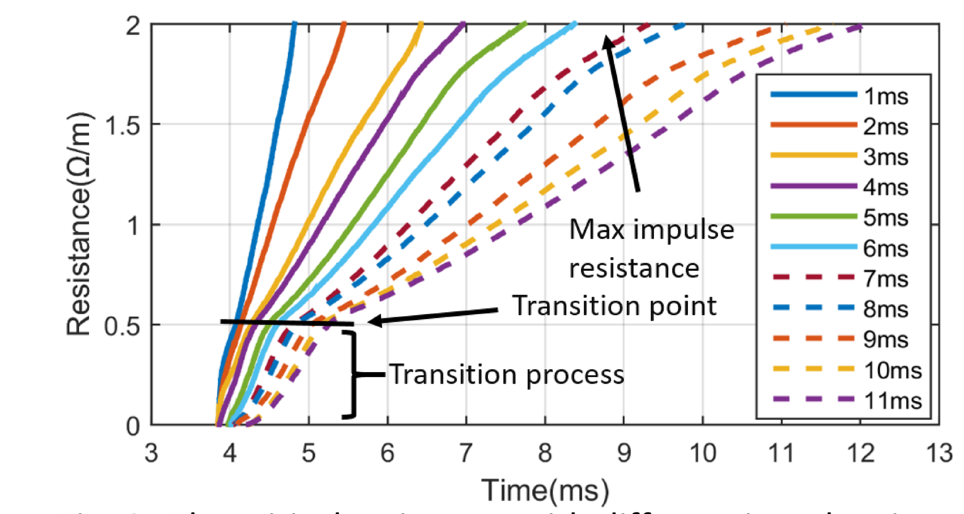
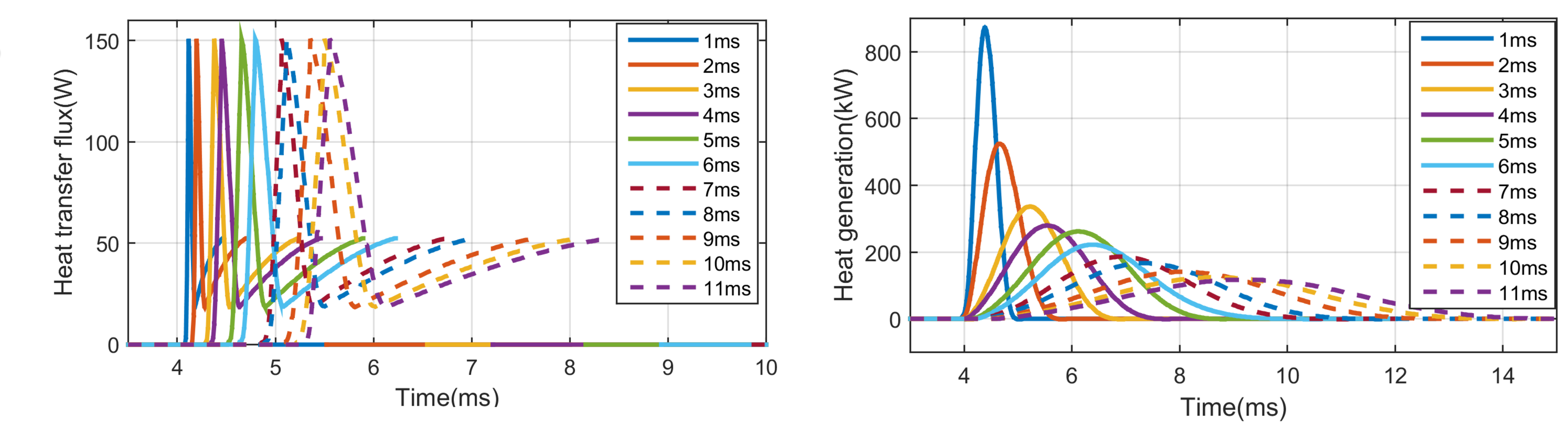


Fig. 6. The critical resistance with different impulse time.

Heat transfer characteristics

In figure 7 the heat generation is much larger than the heat transfer flux under any impulse time. As the impulse time is short enough, such as millisecond level, the heat generation will be kW level. The heat transfer may be only 150W. So the heat transfer can be ignored during transient over-current impulse.



(a)

(b)

Fig. 7. The relationship of the power and the time. (a) The heat transfer flux (b) The heat generation.

Simulation comparison

An electro-thermal coupling model of five layers is established in Comsol in figure 8. YBCO layer is ignored for its high resistance during impulse.

In figure 9 the simulation voltage is consistent with the impulse voltage.

- As shown, the temperature distribution is obviously uneven at 9ms but even at 14ms. It shows that the heat exchange between the layers is not sufficient in several milliseconds.
- In figure 12, the current density focus in the silver layers at 9ms. Due to the same voltage of each layer, heat generation of silver layers is relatively larger. So the shorter impulse time and higher impulse current will lead to more uneven heat exchange.

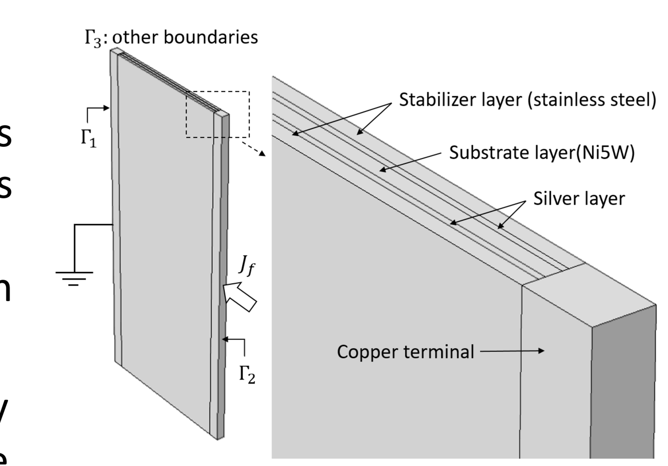


Fig. 8. The structure of the model.

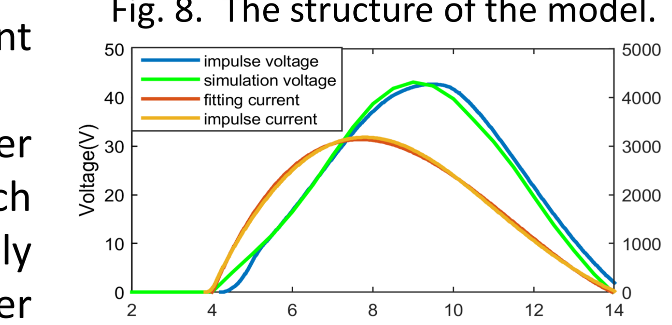


Fig. 9. Simulation results. (a) Current and voltage comparison curve.

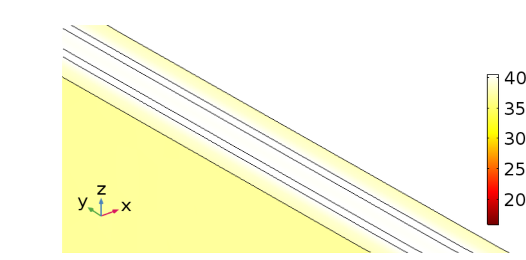


Fig. 10. Temperature distribution at 9ms.

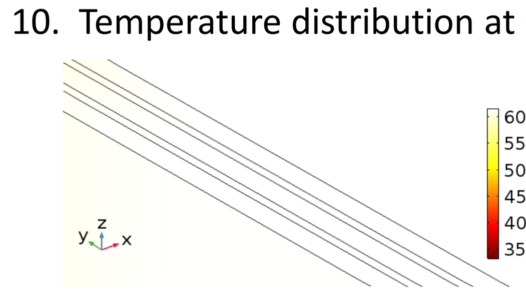


Fig. 11. Temperature distribution at 14ms.

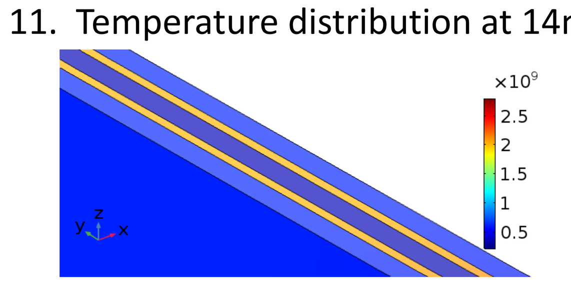


Fig. 12. Current density of different layers at 9ms.

Conclusion

- The YBCO tape has a transition point during quench. Before the transition point the YBCO layer is in flux flow state and after the transition point it changes to normal state.
- Compared to heat generation during transient over- current, the heat transfer flux with liquid nitrogen is very low and can be ignored.
- Although the silver layers are thinner than other layers, they still show low resistance due to their low resistivity. The current density focus in silver layers and generate more heat.
- In milliseconds level heat exchange between different layers isn't sufficient, so the max impulse resistance is lower in shorter impulse times.

Acknowledgement

This work is supported by National Key Basic Research Program of China (973 Program) (2015CB251005), National Natural Science Foundations of China (51577179) and Chinese Academy of Sciences Advanced Research Projects (QYZDJ-SSW-JSC025).