



# A HIGH VOLTAGE VACUUM TYPE HYBRID CURRENT LIMITING FUSES FOR DOUBLE PROTECTION OF THE SHUNT POWER CAPACITORS

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**Abstract:** This paper is designed according to Chinese Standard of GB151665-94, GB110022, GB3988.2, and GB1661.1~5. The rated voltages are 3~35kV. The rated currents are 12.5~200A. The interrupting currents are for capacitive current 20~50 times of rated current and for inductive current 3.15~40kA. The paper gives design processing of high voltage vacuum type hybrid current limiting fuses for double protection characteristics.

**Keywords:** Chinese Standard. Vacuum, Hybrid, Current limiting, shunt power capacitor.

## 1 Introduction

The high voltage shunt power capacitor protection fuses are designed according to GB15166.5-94<sup>[1]</sup>. (IEC standard, Publication-549<sup>[2]</sup>) The rated voltages are 3~35kV as shown in Table 1 and the frequency is 50Hz. It protects single capacitor or parallel capacitors.

Table1 unit : kV

Rated voltage	3	6	10	15	20	35
Highest voltage	3.6	7.2	12	17.5	24	40.5

The rated currents are 12.5, 20, 25, 31.5, 50, 80, 100 and 200A. The insulation level is as GB110022 standard.

Capacitive current interrupting capacity (kA r.m.s.) of the fuse is 20 times or 50 times of rated current. Other parameters are defined by manufacture and users. Inductive current interrupting capacity (r.m.s.) are 3.15, 6.3, 8, 12.5, 16, 25, 31.5 and 40 kA.

The overload protection characteristics of the high voltage fuse are as following: at 1.5 times of rated current, melting time is less than 75s; at 2.0 times of rated current, melting time is less than 7.5s ; and conventional non-fusing current is 1.1 times of

rated current, where fuse element doesn't break in 4 hours.

Temperature rise of the high voltage fuse should be measured by alcohol thermometer as required by GB3988.2.

The interruption performance of the high voltage fuse is shown in Table 2.

The discharge withstanding performance of the high voltage fuse: it should withstand a rush current whose first half cycle amplitude exceeds 70 times of rated current in required procedures.

The anti-erosion layer of the high voltage fuse: all exposed metal surface should be protected that there is no erosion on the nice surface.

Indication device of the high voltage fuse: there should be obvious fused indication and it should work reliably.

Table 2

Interruption performance	
Inductive interruption test	Possibility passing through inductive current <sup>1)</sup>
	Nonpossibility passing through inductive current <sup>2)</sup>
Capacitive current interrupting test <sup>3)</sup>	
Discharge current interrupting test	

Note:1) This application examples are:

- Fuse for capacitors group
- Single fuse of delta connection group of nonseries unit
- Single fuse of star connection group with neutral ground of nonseries unit

2) This application examples are:

- Single fuse of star connection group of neutral without to ground
- Capacitors group of series unit

3) Star connection capacitors group of neutral point without ground is protected by fuse for capacitive current interrupting test

High voltage fuse in the same series products should have same installation size and can be replaced easily.

Basic requirements of discharge withstanding tests:

a. There are 5 discharges in 10 minutes for a fuse, discharge frequency is

i) For fuse whose rated current is less than 31.5A:

$$f(kHz) = 1.2U_m^{+20}_0\%$$

ii) For fuse whose rated current is greater than 31.5A:

$$f(kHz) = 0.8U_m^{+20}_0\%$$

where  $U_m$ —Maximum voltage (kV)

b. There is 100 discharges in a time interval defined by manufacture and discharge frequency is  $8U_m^{+20}_0$  kHz.

For fuses in same series, the fuses with maximum rated current and minimum rated current should be tested.

The test can be done with any voltage level.

Current amplitude ratio of neighbor waves in the discharge test is 0.8~0.95.

In metal short circuit test, fuse can be replaced by a conductor whose impedance is much smaller negligible than that of test circuit.

The required first half cycle current amplitude, oscillation frequency and current decay coefficient can be gotten by adjusting test circuit and the parameters can be confirmed by oscillogram. The fuse should be in conductive state after tests.

## 2 Design of high voltage vacuum type Hybrid current limiting fuse with double protection characteristics.

So far there is no fuse that can meet the requirements of both overload protection and short circuit current protection for the external shunt power capacitor in all over the world.<sup>[3]</sup>

To meet the requirements, a current-limiting fuse that can meet the requirements of both overload protection and short circuit current protection is developed by cooperation and short circuit current protection is developed by cooperation of Xi'an Jiaotong University, Hangzhou Boda Electrical Apparatus Company and Shanghai Kerui Vacuum Electrical Apparatus Company, which follows the GB15166.1 ~ 15166.5 standard. It is shown in Fig.1



Fig.1 A configuration of high-voltage vacuum type hybrid current-limiting fuse with double protection characteristics

There is only an expulsion fuse that is used for shunt capacitor protection in China now, which can only meet the overload requirements. There is a back-up fuse that can be used for short circuit current protection only. If both requirements are needed the 2 fuses should be used in series. But their cost are high and installation are not convenient.

According to Chinese National Standard for high voltage fuse, pre-arc time-current characteristics of expulsion fuse with overload protection should follow that in Table 3. And its conventional non-fusing time should be greater than 4 hours at 1.1 times rated current.

Table 3

Times of rated current	1.5	2.0
Melting time, s	75	7.5

### (1) Design ideas

Generally high voltage current-limiting fuse is belong to back-up fuse as shown in Fig.2. It only meets the requirements of short circuit current protection. For overload current, only current over 3.5 times rated current can be interrupted reliably. For example, a current-limiting fuse with rated current 100A can interrupt current when it exceeds 350A.

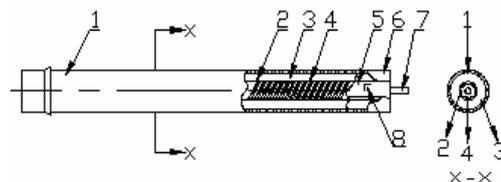


Fig.2 General configuration of high voltage current-limiting fuse

In addition, there is a and explosion hazard, when back-up fuse is used for single capacitor protection. We designed a high speed interrupting fuse element. Many years experience shows that there is no fuse explosion to apply this novel fuse element.

Now let's analyze interrupting principle of expulsion fuse. It uses short fuse element. With overload current, a spring pulls the short fuse element and breaks and breaks it. When the short fuse element is broken, a high temperature arc is initiated, which makes gas-generating material in arc extinguish tube generates a lot of high temperature gas. The gas expulses the arc and makes the arc longer. Thus the arc is extinguished. The expulsion fuse is used for many years. It is reliable and simple. But its structure is open and its size is large. And it has fire hazard. We uses vacuum fuse to replace it. Vacuum fuse has smaller size, high reliability and safety. It meets all requirements in standards and a novel design.

(2) Example of Design

Suppose a fuse for shunt power capacitor protection with rated voltage 6kV, rated current 50A and interrupting current 40kA<sup>[4]</sup>

(a) Vacuum type fuse is used for overload current protection

Basic requirements: fuse element should be melted at 1.5 times rated current (1.5×50=75A) in less than 75s. It should be melted at 2 times rated current (2×50=100A) less than in 7.5s. It should not be melted at 1.1 times rated current (1.1×50=55A) in 4 hours. At first selecting (0.5×4=2mm<sup>2</sup>) copper is used to cut and try method for measuring pre-arc time-current characteristics. By adjusting design size of fuse element many times (0.5×3=1.5mm<sup>2</sup>) copper with length 10mm is chosen finally. Its pre-arc time-current characteristics is shown in Fig.3.

Configuration of vacuum fuse is shown in Fig 4, where 1 is output terminal to connect current fuse copper fuse element and 5 is linkage.

(b) High speed current-limiting fuse is used for high overload current and short circuit current protection

Pure silver is chosen as fuse element. Its total length is 300~320mm. Current density at neck is j=200A/mm<sup>2</sup>. The configuration of high-speed current limiting fuse element it shown in Fig 5.

The length of fuse element is L=2×13+24×12=314mm. The cross-section area of the fuse element is

$$A = \frac{I_n}{j} = 25 / 200 = 0.125 \text{mm}^2 . \quad \text{The}$$

diameter of hole is 1.5mm and their separation distance is 0.2mm. Fuse element width is (1.5+0.2) ×5=8.5mm. Total hole separation distance is 0.2×5=1mm. Fuse element thickness is 0.125/1 = 0.125mm. There should be 2 fuse elements in parallel with rated current of 50A.

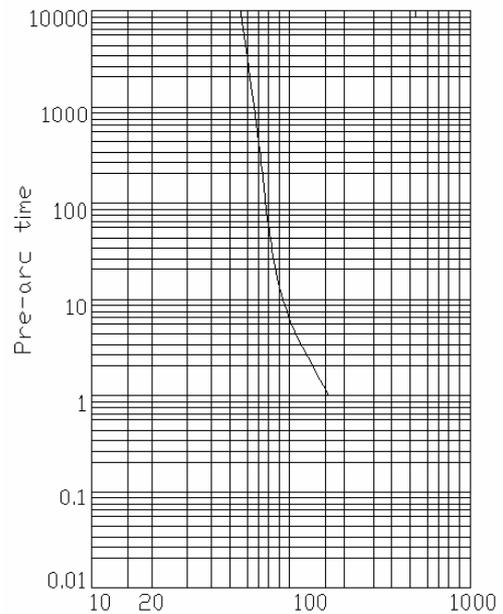


Fig.3 Time-current characteristics under vacuum condition of 5×10<sup>-4</sup>Pa

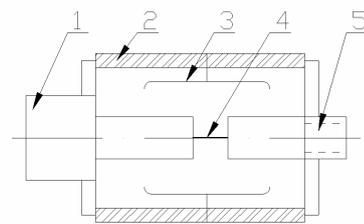


Fig.4 Configuration of vacuum fuse

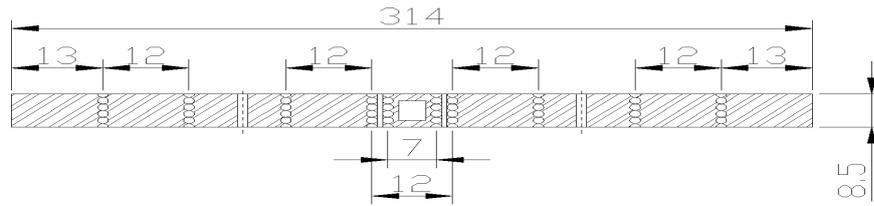


Fig.5 Configuration of high-speed current-limiting fuse element

Most of the available parts of back-up fuse except fuse element can be used in the new designed fuse for high overload current and short circuit current protection.

Fuse element of the high speed current-limiting fuse can be processed as wave shape, as shown in Fig.6.

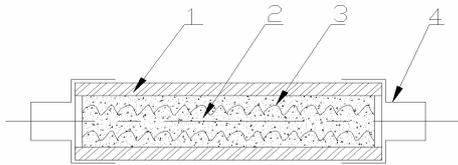


Fig.6 Cross-section configuration of high-speed current-limiting fuse

(c) The designed fuse for shunt capacitor with rated voltage 6kV, rated current 50A and

interrupting current 40 kA has passed interrupting capacity tests in test laboratory of XIHARI. The results show that it meets the requirements of Chinese Standard.

## References

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- [2] IEC Standard. Publication 549 First edition 1976.
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