# Vacuum type high voltage fuse for external protection of shunt capacitors

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Abstract

The high voltage shunt capacitor protection fuse are designed according to GB15166.5-94 standard[1]. The rated voltage is 3~3.5kV as shown in Table 4.3.1 and the frequency is 50Hz. It protects single capacitor or parallel capacitors.

**Table 4.3.1:** unit: kV

| Rated voltage | 3 | 6 | 10 | 15 | 20 | 25 |
|---|---|---|---|---|---|---|
| Highest voltage | 3.6 | 7.2 | 12 | 17.5 | 24 | 40.5 |

The rated current 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 40kA.

The overload protection characteristics of the high voltage fise 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 thermoneter as required by GB3988.2 standard.

Keywords: vacuum, shunt capacitor, fuse.

## 1. Introduction

The interruption performance of the high voltage fuse is shown in Table1.

**Table 1**

| Interruption performance | |
|---|---|
| Inductive interruption test | Possibility passing througth inductive current 1) |
| | Nonpossibility passing througth inductive current 2) |
| Capacitive current inerrrupting test 3) | |
| Discharge current interrupting test | |

Note: 1) this application examples are:

——Fuse for capacitors group

——Single fuse of dalta connection group of nonserise

——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

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.

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:

$$f\,(kHz) = 1.2U_{m0}^{+20}\%$$

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

$$f\,(kHz) = 0.8U_{m0}^{+20}\%$$

Where $U_m$——Maximum voltage (kV)

b. There is 100 discharges in a time interval defined by manufacture and discharge frequency is $0.8U_{m0}^{+20\%}$ 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. Study on Vacuum-type Full-Range High Voltage Fuse for Single Shunt Capacitor Protection

So far there is no fuse that can meet the requirements of both overload current protection and short circuit current protection for a single shunt capacitor in all over the world[2].

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 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** Vacuum type high-voltage current-limiting fuse with double protection characteristics

There is only an expulsion fuse that is used for single 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**

| Time of rated current A | 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.

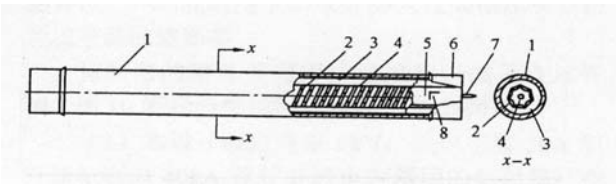


**Fig.2** General configuration of high voltage current-limiting fuse

In addition, there is overvoltage and explosion hazards when back-up fuse is used for single capacitor protection. We designed a quick interrupting 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 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

Fuse for shunt capacitor protection with rated voltage 6kV, rated current 50A and interrupting current 40kA[3]

(1) 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 75s. It should be melted at 2 times rated current (2×50=100A) 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$^2$) 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$^2$) copper with length 10mm is chosen finally. Its pre-arc time-current characteristics is shown in Fig.3

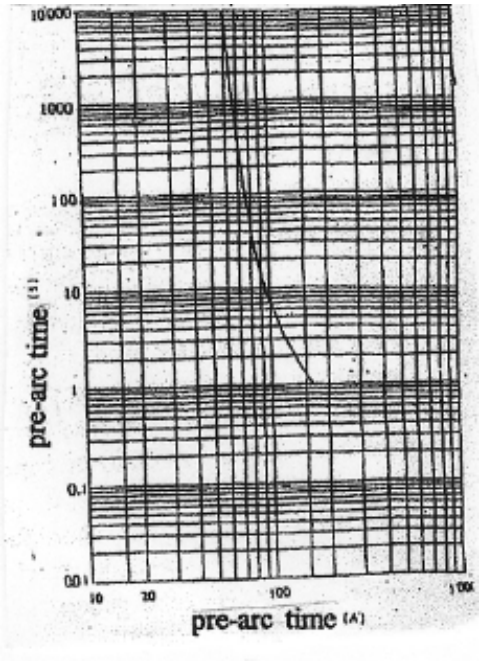


**Fig.3** Time-current characteristics under vacuum condition of $5\times10^{-4}$Pa

Configuration of vacuum fuse is shown in Fig.4, Where 1 is output terminal to connect current fuse terminal, 2 is ceramle envelope, 3 is shield, 4 is copper fuse element and 5 is linkage.

(2) 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$^2$. The configuration of high-speed current limiting fuse element 4 is shown in Fig.5.

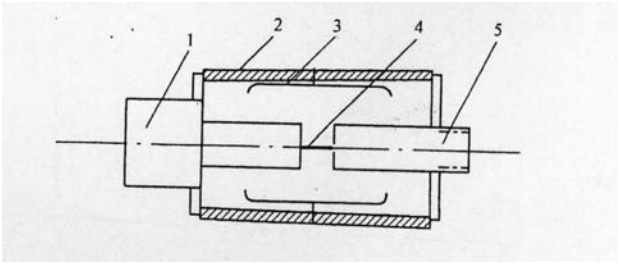


**Fig.4** Configuration of vacuum fuse

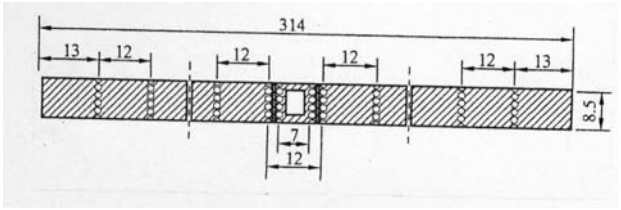


**Fig.5** Configuration of high-speed current-limiting fuse element

The length of fuse element is $L = 2\times13 + 24\times12 = 314$ mm. The cross-section area of the fuse element is $A = \frac{I_n}{2} / j = 25/200 = 0.125$ mm$^2$. The hole diameter is 1.5mm and their separation distance is 0.2mm. Fuse element width is $(1.5+0.2)\times5 = 8.5$ mm. 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.

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.

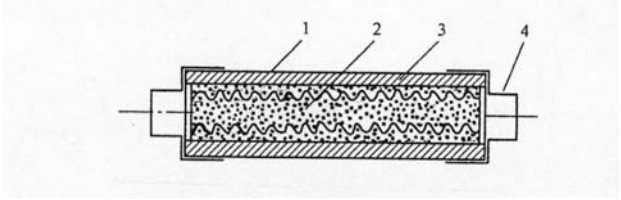


**Fig.6** Cross-section configuration of high-speed current-limiting fuse

(3) The designed fuse for shunt capacitor with rated voltage 6kV, rated current 50A and interrupting current 40kA has passed interrupting capacity tests in test laboratory of XIHARI. The results show that it meets the requirements of Chinese standard.

## REFERENCES

[1] Chinese Standard GB15166.6-94

[2] Wang-Jimei. “Study on special current-limiting fuse of protection shunt power capacitors”, Electrical Technology No.1, 2005

[3] Wang Jimei, “High voltage vacuum type full-range current-limiting fuse electrical Technology, No.9, 2002”

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# VARISTOR FUSE OR FUSE WITH INTEGRATED VARISTOR

M. Sc. Mitja Koprivšek