USING A PARALLEL RESONANCE CIRCUIT TO MEASURE TIME-CURRENT CHARACTERISTICS OF HIGH VOLTAGE CURRENT-LIMITING FUSES

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Abstract: **This paper describes the peculiarities of a parallel resonance circuit to measure time-current characteristics of high voltage current-limiting fuses. The principle of construction of this circuit and the method of measuring time-current characteristics of fuse are introduced. Finally, how to design power condensers and high-current reactor is described.**

Keywords: **parallel resonance circuit, current-limiting fuse.**

1. Introduction

In general, fuse manufacturers may necessarily have a large capacity of single-phase power transformer for determining the pre-arc time-current characteristics of current-limiting fuses. In addition at the same time they correspondingly need a large power source. By using the new test equipment for high-voltage current-limiting fuses not only produce a low price with using a low capacity single-phase power transformer, but also doesn't need a large power source. The manufacturer can easily undertake the pre-arc time-current characteristics of current-limiting fuses.

2. Basic Circuit of Parallel Resonance

The basic circuit of parallel resonance is shown in Fig.1 consists of two parts: AC power source U and a parallel resonance circuit that is composed by capacitor C and inductor L. The peculiarity of the parallel resonance circuit would be as follows. Fig.2 shows the vector diagram of currents of capacitor C and inductor L. Ic is a capacitive current vector which is leading the voltage vector U, an angle 90°and Il is an inductive current vector which is lagging the voltage vector U. an angle of 90°. Due to the inductive impedance Zl is equal to the capacitive impedance Zc. namely resonance occurs to the circuit, the current of the capacitor is equal to the current of inductor L. Because their vector is in opposite, so no current comes from source. Due to they're being some dielectric loss in the capacitive and some resistance loss in the inductor. In this time, there is a small amount current supplying from source only.

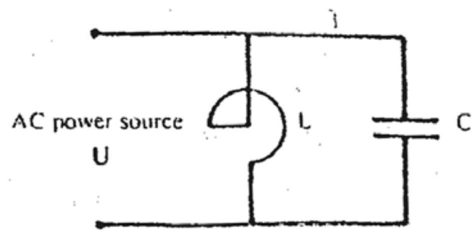

Fig. 1: Basic circuit of parallel resonance

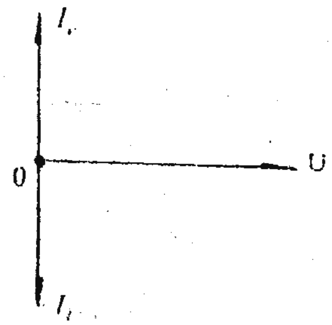

Fig. 2: Vector diagram

3. Test Circuit and Procedure

(a) Test Circuit

The test circuit of pre-arc time vs. prospective current characteristics of high-voltage current-limiting fuses

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are as shown in Fig.3. In this Figure. U—A.C. Source of 50Hz, 220/380V selecting current 50~100A; A—low voltage automat circuit breaker, 220/380V, 30~40A; T_1-voltage regulating transformer, input 220/380V, output 0~1200V; C—capacitor, rated voltage 1200V, 18000μF, L—inductor, 1200V, 0.56mh; F—fuse sample, K—link switch, A—ammeter with current transformer of 5000/5; FL—shunt with a

(b) Testing Procedure

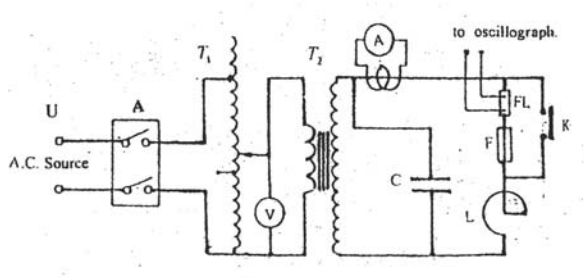

Fig .3: Test circuit for prearc time v.s. prospective current characteristics of high voltage current-limiting fuses

(1) Set voltage regulating transformer T_1 to zero voltage position, link switch K in closed position, and connect fuse sample F.

(2) On low voltage automat circuit breaker A and observe voltmeter V, indicate in zero voltage.

(3) Increase voltage to a given value. (For example. if a rated current of fuse sample is 250A, look at Table 1. or Fig.4 when prearc time is at 0.1s and the prospective current is 3100A,then rise up voltage by voltage regulating transformer to 3100A which is read from ammeter, and open link-switch immediately. We can read actual values of prearc time against prospective current from oscillograph.

(4) All switches and control devices return to original position, then for preparing next test of a same rated current new fuse sample.

Table 1. Prearc time v.s. prospective current datum from Fig.4

Time	Rated current of fuse element									
	40A	50A	63A	80A	100A	125A	160A	200A	250A	400A
0.1s	320	420	560	770	970	1250	1600	2450	3100	5300
1s	200	270	330	460	560	700	920	1400	1800	3900
10s	150	200	250	330	390	490	620	890	1150	2700

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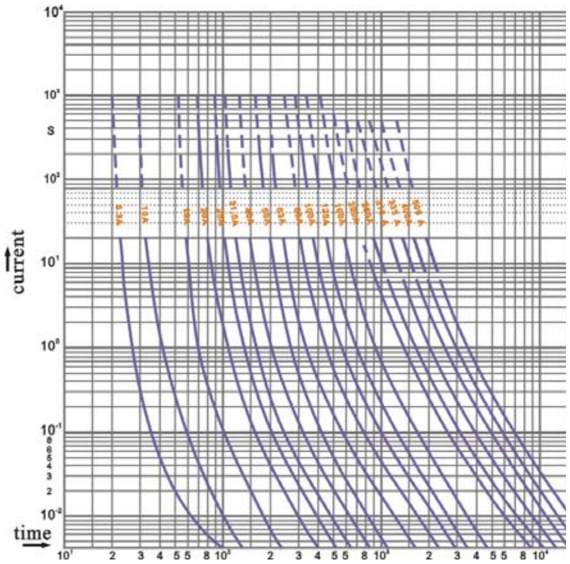

Fig. 4 "Prearc time v.s. prospective current curves" from SIBA

4. Determination of Parameters of Testing Devices

According to 400A rated current of SIBA fuse to estimate the parameters of testing devices for prearc time v.s. prospective current characteristics as follows

(1) Parameters of Power Capacitor

The capacity of power capacitor is

$$C = \frac{I_c}{2\pi f \cdot U_c} = \frac{5300}{2\pi(50)(1000)} = 0.1687F = 16870\mu F$$

where

I_c——Discharge current, 5300A (prearc time=0.1s)

U_c——Applied voltage, 1000V

Selected 100 units of power capacitors in parallel. Each of them is 180μF. Now we select the discharging current to

5300×(180.0/168.7)=5650A

(2) Parameter of Reactor

Reactance of reactor is

$$L = \frac{U_1}{2\pi f \cdot I_1} = \frac{1000}{2\pi(50)\cdot(5650)} = 0.000563H = 0.56mh$$

The construction of reactor is a dry type non-iron core.

(3) Link-switch

Link-switch is a single-phase vacuum contactor of 5000V and 1000A.

(4) Low voltage automat circuit breaker is a single or three phase mold-circuit breaker of 380V or 500V, 100A.

(5) Voltage regulating transformer is a single-phase of input 220/380V, output 0~380V or 450V.

(6) Voltmeter

Voltmeter is a panel type of 100V~124V with 1000/100 potential transformers.

(7) High voltage oil-immersed power transformer

A single-phase oil-immersed power transformer of input voltage 220/440V. output voltage 0~1100V with 15kVA is used.

(8) Ammeter

An ammeter is a panel type of 7.5A with low voltage current transformer 5000/5 is used.

(9) Memorize oscilloscope

Two canals memorize oscilloscope with printed device.

5. Design and Calculation of Reactor

In the most satiation, reactor is designed and manufactured by the manufacture it-self.

The process of design and calculation steps are as follows. According to basic parameters, the construction and dimensions are shown in Fig.5. The calculation formula is from U.S.S.R reference[1].

The average diameter and hight of each coil respectively D=50cm, W=4.5cm. turns of coil

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n=5, total turns N=5×8=40 gap between coils d=1cm, thickness of coil. B= (0.5+0.2)×5 =3.5cm, Total hight of reactor is h= 7×d+8×w = 7×1+8×4.5 = 7+36 = 43cm.

$$L_1 = 10.5 N^2 D \left[\frac{D}{2(h+d)} \right]^{3/4} \times 10^{-6} = 0.681 mH$$

The calculation value 0.681mH is large than original given value 0.53mh, it may be regulated by gaps distance d between reactor coils to satisfy given value of 0.53mh.

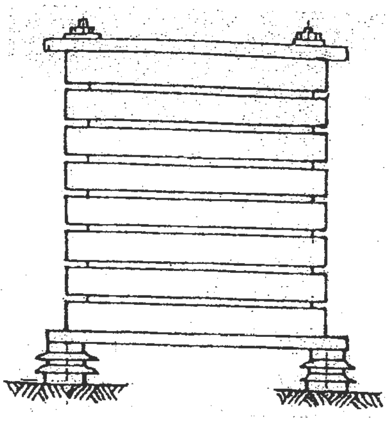

Fig. 5 Lay out of reactor

(1) Calculation of reactor coil

Sketch of coil is shown in Fig.6. Outer diameter of coil is D_w=53.5cm, Inner diameter of coil is D_n=46.5cm. Section of coil is A=5mm×40mm. Current density of coil is

J=In/S=5650/200=28.25a/mm^2.

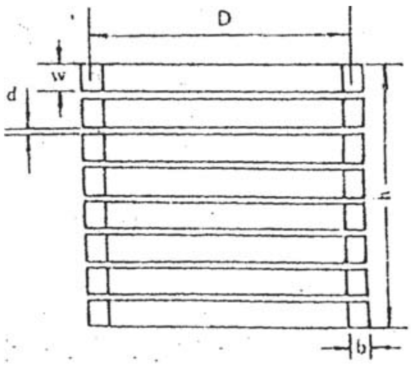

Fig. 6 Sketch of coil

Length of reactor coil is L= (50π×5+14) =799.4≈800cm=8m

Weight of coil is W= 800×0.5×4×8.9×10^{-3} = 14.5kg. Total weight of 8 coils is W_T = 14.5×8=116kg

(2) Insulation of coil arrangement

Fig.7 shows a section view of reactor coil insulation between turns of reactor coil is 0.1mm of PTPE trap with 5 layers.

The total thickness is 1mm. Then this 5 layers coil is tied by white cotton trap with 2 over lap layers, the thickness about 1.5mm. Final this coil is treated by varnish in vacuum oven.

(3) Check by Dynamic force

To prevent reactor coil deformation under large current passing through coil, laying out 8 rods around in coil as shown In Fig.8.

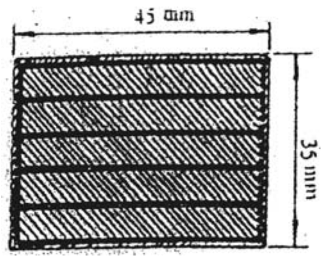

Fig. 7 Section view of coil

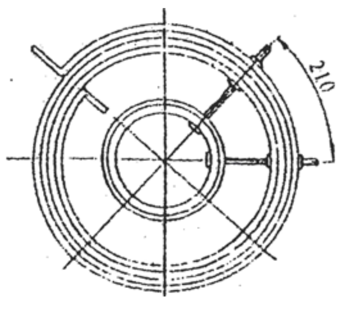

Fig. 8 Supporting of reactor coil

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According to reference[1], we can calculate dynamic force per cm. As using following formular

$$F = \frac{q}{L}\sqrt{\frac{24\sigma^3}{E}}$$

where

q ——section area of outer layer turn of reactor coil, $4\times0.5\text{cm}^2$

L ——distance between outer layer turn of reactor coil, $L=53.5\pi/8=21\text{cm}$

σ ——permit tensile strength of copper, 1600kg/cm^2

E ——modulus of elasticity of copper, $1.13\times10^6\text{kg/cm}^2$

The dynamic force under coil turn is

$$F = \frac{4\times0.5}{21}\sqrt{\frac{24\times1600^3}{1.13\times10^6}} = 28.1\ \text{kg/cm}$$

According to reference[1], we can calculate max. current under above dynamic force, 28.1kg/cm.

$$\text{Im} = 10^4\sqrt{\frac{F\times h}{\beta}} = 10^4\sqrt{\frac{28.1\times43}{10}}$$
$$= 110\text{kA(peak)}$$

h—— height of reactor.

β—— from reference[1],Table 12-8.

The value of 110kA is more than the actual value of $5.65\times\sqrt{2} = 8$ kA

6. Conclusion

Parallel resonance circuit method is a best way to obtain pre-arc time against prospective current characteristics curve. Manufacturers of fuses can easily set up this installation.

References

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