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DEVELOPMENT OF 20 kV CURRENT LIMITING FUSE WITH FULL RANGE CLEARING ABILITY

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I. INTRODUCTION

Power fuses include current limiting types (enclosed) and non current limiting types (exposed). Recently, the features of the enclosed current limiting power fuse have been recongnized[1] and these fuses are widely used in the 3 to 70 kV voltage range.

However, this type of fuse has the following defects:

1) Usually in power current limiting fuses, the minimum fusing current and the minimum interrupting current are different and explosions occur often since interruption is not possible even though fusing has occurred. According to the former standard for power fuses, JEC–113, the minimum interrupting current is to be three times the rated current and there are no restrictions on current below this. In the new fuse standard, JEC–175 however, it states that each manufacturer must indicate the minimum interrupting current value and protection must be provided using a series connected auto-trip device for currents below this minimum value. In the IEC standard, " General Purpose Fuse " and " Back-up Fuse " are differentiated and a fuse is considered suitable if there is no explosion during use and also no danger to humans.

2) The overvoltage at the time of short-circuit current interrepting is generally high. The current limiting fuse is different from a circuit breaker in that an overvoltage usually arises at the current limiting point and therefore an explosion occurs when used in such devices as lightning arrestors. In both the IEC standard and JEC–175, it is stipulated that the overvoltage must be limited to a value about 2.3 times the rated voltage. Fuji Electric has already developed 3 kV and 6 kV general purpose power fuses in which the above two defects have been eliminated. This article will describe the development of a 20 kV general purpose fuse in keeping with the changeover to 20 kV distribution. The overvoltages of these fuses during short-circuit current breaking are within the limit specified in the IEC standard. This has been mentioned in the reports of cooperated research with High Voltage Power Laboratory Foundation, Inc.[3] [4].

II. REQUIREMENTS OF GENERAL PURPOSE FUSES

The reason for the differentiation between general purpose and back-up fuses in the IEC standard is that when an explosion occurs because interuuption is impossible even when the fuse has been melted by a low current, there is a danger both to people and equipment and therefore fuses which can not interrupt when melted by low currents are classified as back-up fuses. These fuses must be provided with an auto-trip mechanisms to protect against small currents. On the other hand, fuses which always interrupt when they are melted are known as general purpose fuses. Reasons for the necessity of general fuses will be explained below.

When the load current in a transformer circuit is 50 A, the fuse must have a rated current two or three times the load current in order to prevent the fuse from belowing due to transformer excitation currents. This rated current is selected according to the permissible current/time characteristics of the fuse. This means that a fuse with a rated current of 100 to 150 A is required. Hower, when the minimum interrupting current must be three times the rated current, it becomes 300 to 450 A which is six to nine times the load current. In such a case, the fuse can not interrupt even when melted by a small current and an explosion will occur.

At a current of six to nine times the load current, it is generally easy for the initial accident current to occur. Since the currents in this range can not be interrupted and a fatal explosion can happen, it is essential to provide an auto-trip mechanism with the back-up fuse.

III. RATINGS

A view of the 24 kV general purpose fuse can be seen in *Fig. 1*. *Table 1* gives the ratings and types of these fuses. As is evident from the ratings, the fuses can be used for primary protection in transformers with capacities up to 1,000 kVA.

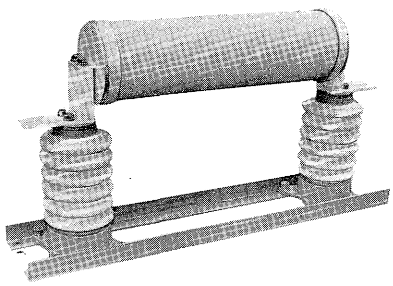

Fig. 1 View of 24 kV general purpose fuse

Table 1 **Ratings and types of 24 kV general purpose fuse**

Rating				Type	
Voltage (kV)	Current (A)	3-phase interrupting capacity (MVA)		Fuse link	Fuse holder
		Sym-metrical value	Unsym-metrical value		
24	5	1,000	1,600	HF339/20/5	HF329/20
	10			HF339/20/10	
	20			HF339/20/20	
	40			HF339/20/40	
	75			HF339/20/75	

IV. CONSTRUCTION

The construction of current limiting fuses becomes more difficult the higher the applied voltage and the larger the rated current. When current limiting fuses of the 20 kV class are designed, it is not possible just to expand the same ideas used in the 3 kV and 6 kV models; completely new design concepts must be devised.

In current limiting fuses, the length of the fuse wire depends on the applied voltage and when this voltage is high, the wire must be correspondingly long. For this reason, the fuse tube to which the wire is attached must also be large, but if this tube is too large, there will be an increase in the space required for attachment and the cost will also be higher. Therefore, the fuse wire in this general purpose fuse has been arranged in the spiral manner shown in *Fig. 2,* so that the fuse is not too long.

In order to improve the small current interrupting characteristics, the number of fuse wires in parallel must be increased and the diameter of each wire must be as small as possible. With this arrangement, when any one of the fuse wires in parallel are melted due to an overcurrent, the remaining wires are melted in succession until finally only one wire carries all the current. The final wire is completely vaporized and interruption occurs.

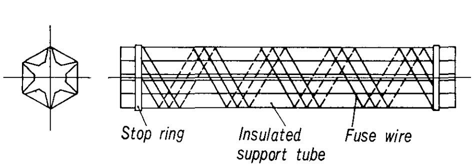

Fig. 2 Fuse element of general purpose fuse

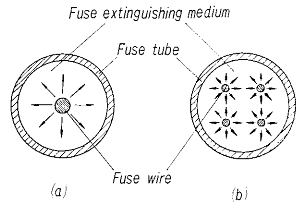

Fig. 3 Internal structure of fuse link

A large number of wires is very effective when interrupting large currents. *Fig. 3* (*a*) shows the case where there is one fusable wire and (*b*) shows four wires in parallel for the same rated current. As is evident from these figures, the almost complete dispersion in the fuse tube of the large arc energy which occurs when short circuit currents are interrupted is due to the excellent cooling effect of the arc extinguishing sand which fills the area surrounding the wires. In fuses with high applied voltages such as the 24 kV current limiting fuse, the arc energy also increases and the dispersion results have a considerable influence on the interrupting characteristics.

Fig. 4 Shape of fuse element

Small diameter wires are supported in the tube and the standard dimensions of the spiral pitch are difficult to maintain during construction. Therefore, as can be seen from *Fig. 2,* the fuse wires are wound around an inner tube which acts as an insulator.

As can be seen from *Fig. 4,* the main fuse wires in the center of the element are very thin and the diameter gradually increases toward either end. In this way, the position of the arc due to the overcurrent is always at the middle of the fuse wires and this improves the small current interrupting characteristics and solves the problem of supressing overvoltages induced during interruption of short-circuit currents. Generally, the arcing position is not constant with small currents and when it is near the ends of the fuse tube, the arc reaches the end of the tube before its length is sufficient for interrupting the current, the arc is projected into the gap and interruption is impossible. However, when large currents are interrupted, this special configuration

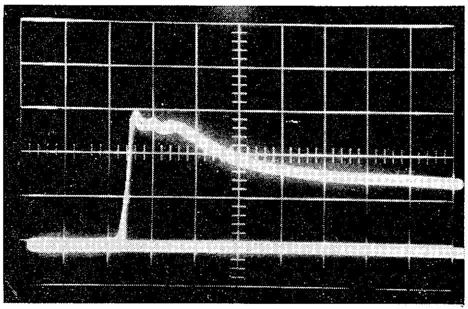

Fig. 5 Photo of overvoltage measured by synchroscope

supresses induced overvoltages and the overvoltage generated during interruption is kept to a low value as is evident from the oscillogram shown in *Fig. 5*. In order to supress the induced overvoltage, a groove is made in the fuse wires or a hole is made in the center of the flat fuse element. This is considered to be a method of changing the sectional area of the fuse element but the arrangement shown in *Fig. 4* is considered to be the most effective.

The 24 kV general purpose fuses are also constructed in such a way that overvoltages induced during interruption of large currents are suppressed and small current interrupting characteristics are improved.

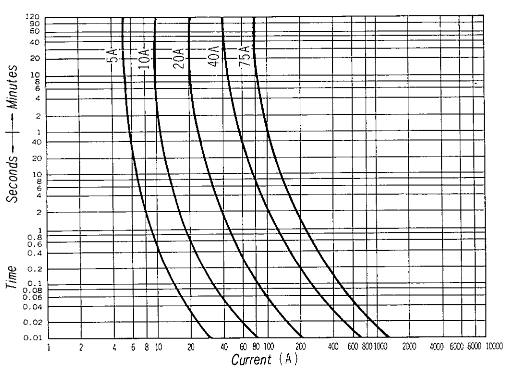

Fig. 6 Pre-arcing time/current characteristic curves

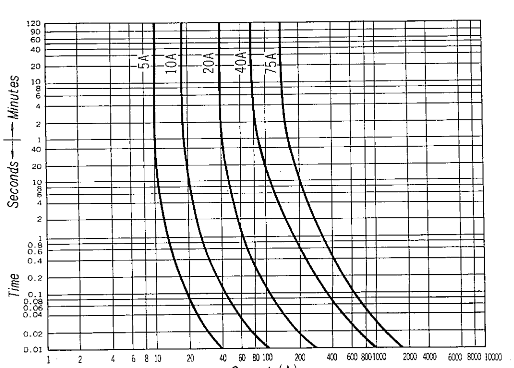

Fig. 7 Permissible time/current characteristic curves

***Table 2* Results of minimum and medium current interrupting test**

Fuse tested	Test voltage (kV)	Inter-rupting current (A)	Melting time (minutes, second)	Arcing time (ms)
HF339/20/5	24.0	10.3	16 min 21 s	171
HF339/20/5	24.0	10.8	19 min 21 s	188
HF339/20/20	24.0	71	200 ms	20
HF339/20/20	24.0	550	4.0 ms	5.0
HF339/20/40	24.0	195	406 ms	3.8
HF339/20/75	24.0	381	51.0 ms	4.1

***Table 3* Results of short-circuit current interrupting test**

Fuse tested	Test voltage (kV)	Inter-rupting current (kA)	Limit current (kA)	Over-voltage (ms)	Melt-ing time (ms)	Inter-rupting time (ms)
HF339/20/5	20.9	24.1	0.525	65.3	0.2	5.59
HF339/20/10	20.9	24.1	0.645	51.5	0.47	5.08
HF339/20/20	20.9	24.1	1.47	56.3	0.61	5.58
HF339/20/40	20.9	24.1	5.41	52.5	0.7	6.00
HF339/20/75	20.9	24.1	9.02	53.5	1.1	6.2
HF339/20/75	20.9	24.1	9.12	50.0	1.2	6.3

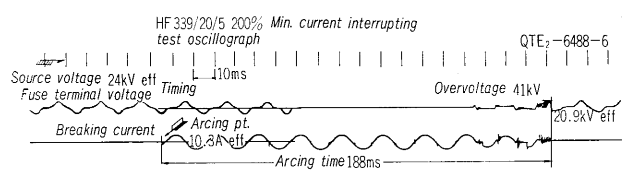

Fig. 8 Oscillogram of minimum current interrupting test

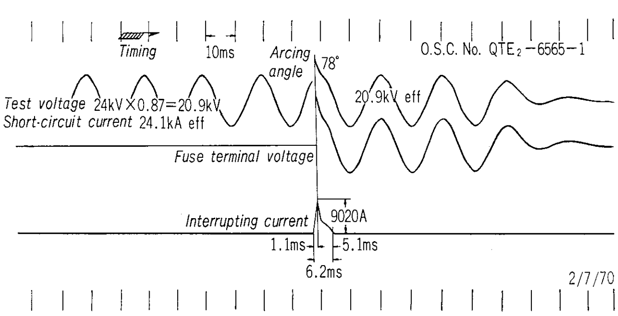

Fig. 9 Oscillogram of short-circuit current interrupting test

V. CHARACTERISTICS AND TEST RESULTS

Fig. 6 shows the preacring time/current characteristic curves and *Fig. 7* shows the permissible time/current characteristic curves. For the 24 kV general purpose fuse, interruption is ppssible when the fuse has melted at any point on the curves shown in *Fig. 6*.

Table 2 shows the results of minimum and medium current interruption tests and *Fig. 8* is part of the oscillogram for these tests. *Table 3* contains the results of the large current interruption tests and *Fig. 9* shows the oscillogram. At these test values; the generator voltage, the fuse terminal voltage, and the interrupting current were measured with an electromagnetic oscillograph and the overvoltage occurring during interruption was measured with an oscillograph and amplified by a synchroscope. The overvoltage during interruption was in the 51.5 to 66 kV range, which means that there are sufficient margins in respect to the standard value.

VI. CONCLUSION

In keeping with increases in the capacity of light power receiving equipment, devices for 20 kV will no doubt come to replace the former 6 kV equipment. In such cases, the use of load switching equipment with highly reliable power fuses will probably become more prevalent instead of AC circuit breakers. It is hoped that this article will contribute something to the application of such power fuses.

Referemces :

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(3) Kato, Shibuya: 1966 Tokyo Meeting of the Institute of Electric Engineers 161

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