ESTIMATION OF DIELECTRIC STRENGTH OF COMMERCIAL VI

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ABSTRACT

Combined conditioning and test method suitable for estimation of dielectric strength of commercial vacuum interrupters has been offered. Comparison with the conventional "up and down" method has been provided. Method has been successfully applied for a range of commercial vacuum interrupters.

1. INTRODUCTION

The estimation of the dielectric strength of a commercial vacuum interrupter (VI) presents a complex task.

First of all, dielectric strength presents a statistical phenomenon, which is dependent on the method of testing [for example, 1]. Strictly speaking, every application of a test action changes the dielectric strength of the VI. In addition, dielectric strength generally varies with time. Finally, when the dielectric strength of a VI is considered one has to regard two types of breakdown: metal-vacuum and breakdowns originating from triple points.

The dielectric strength is usually determined by "Up and down method"[for example, 2]. The method consists in general of the sequence of voltage impulses applied to VI. The next impulse voltage is decreased or increased depending on the result of previous impulse (breakdown or success). The sequence is going on until several sequential breakdowns appear at a certain voltage level.

The use of this method as a method of conditioning and dielectric strength evaluation has some disadvantages:

-long conditioning;

-poor reproduction of test results;

-uncertain termination criteria – the choice of number of successive breakdowns determining termination condition is quite arbitral;

-impossibility to estimate probability of success for standard BIL test;

-impossibility to evaluate time degradation of the dielectric strength.

The present paper offers a new method of conditioning and testing of the dielectric strength of a commercial VI that is free from the mentioned disadvantages.

2. METHOD DESCRIPTION

The offered method consists of 3 steps:

-conditioning;

-evaluation of the dielectric strength after conditioning;

-evaluation of the time degradation of the dielectric strength.

The same actions – the sequences of lighting impulses differed by magnitude and numbers - is used for all steps.

2.1 Test circuit

Test circuit is shown in Fig. 1. In fact it represents standard BIL generator with series resistor R1. BIL generator provided standard 1.2x50μs lightning impulses with variable magnitude. Resistor R1 served for limitation of discharge current. It was selected to be equal to 4.3kOm to guarantee that in case of breakdown just one cathode spot appeared. Breakdown voltage was measured with the aid of digital oscilloscope providing sampling step equal to 50ns, resulting in the following voltage measurement accuracy: +/-4% for rising impulse section and +/-1% for decaying section.

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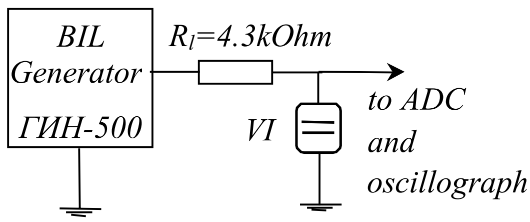

Fig. 1 Test circuit

2.2 Test sequence

Step 1 - conditioning

During conditioning procedure a set of impulses with amplitude A_c being high enough to cause breakdown at rising impulse section is applied. Conditioning is continued until stable breakdown level U_c is achieved (Fig.2).

Step2 – evaluation of the dielectric strength after conditioning

Sequential series consisting of M lighting impulses are applied. First series has impulse magnitude A_m equal to A_c. The following series has impulse magnitude reduced by 5kV compared with the previous one (Fig.2). Number of breakdowns $N_b(A_m)$ is registered for each series. When $N_b(A_m)$ equals 0 series is considered as successful. Relevant impulse magnitude is called “level of success” A_s, the ration. The value $P_b(A_m)=N_b(A_m)/15$ is the estimate of the breakdown probability related to magnitude A_m.

After *Step2* both steps are repeated for reverse polarity of breakdown voltage.

Step 3 - evaluation of the time degradation of the dielectric strength

After chosen time intervals T_s (generally some hours or days) impulse voltage being high enough to initiate breakdown at the rising impulse section is applied in both polarities. Breakdown voltage $U(T_s)$ is recorded (Fig.2).

2.3 Data processing

The following parameters can be taken from experiment data (refer also to Fig.2):

-first breakdown voltage U_0;

-breakdown voltage after conditioning U_c;

-breakdown voltage after a given time interval $U(T_s)$;

-level of success A_s;

-probability of breakdown at a given voltage level $P_b(A_m)$;

The following parameters can be calculated based on the measurements:

-conditioning factor k_c : $k_c = U_{after} / U_0$

-time degradation factor k_l: $k_l = U(T_s)/U_c$

-guaranteed success level A_g: $A_g = A_s * k_l$

Breakdown probability $P_b(A_m)$ allows to calculate the probability of success for standard IEC BIL test procedure at a given voltage A_m:

$$P_{success}(A_m)= [(1- P_b(A_m))^{15}+15\, P_b(A_m)(1- P_b(A_m))^{14}+C_{15}^{2}\, P_b(A_m)^{2} *(1- P_b(A_m))^{13}]^{2}$$

However, for statistically reproducible results substantial number of tests is required.

3 APPLICATION EXAMPLES

3.1 Overview of tested VI

The overview of commercial VI tested by offered method is shown in table 1. The contact material bases on CuCr composition.

Table 1

VI type	1	2
Contact diameter, mm	65	55

3.2 Conditioning. Influence of discharge current limitation

The influence of discharge current limitation is well seen in Fig. 3. The VI of type 2 only have been tested, for 6VI the discharge current have been limited by.

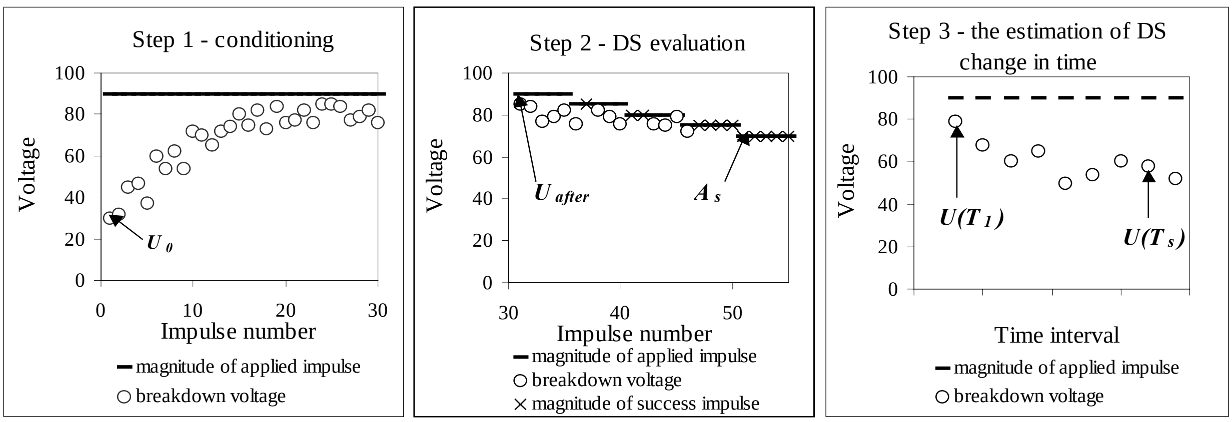

Fig. 2 Sketch of dielectric strength estimation method

<50A, 3VI have been tested without special current limitation. Contact gap is 10mm. The notations "F-" and "M-" in Fig. 3 and below mean "the cathode is the fixed electrode" and "the cathode is the movable electrode''.

For all results below the discharge current is limited by <50A.

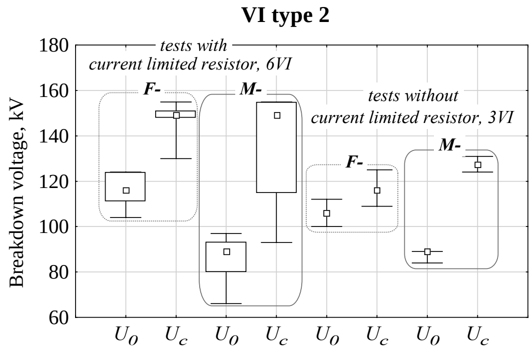

Fig. 3 Influence of discharge current

3.3 Dielectric strength evaluation

The probability of breakdown $\boldsymbol{P_b(A_m)}$ when the impulse with magnitude A_m is applied to the opened contact for VI type 1 is shown in Fig. 4.

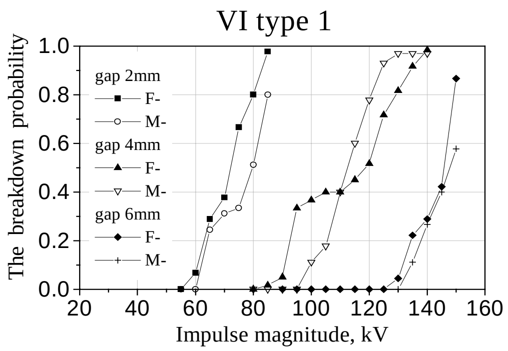

Fig. 4 Breakdown probability for different contact gaps

Fig. 5 demonstrates the change of dielectric strength on the different step of experiment for VI of type 2, contact gap – 2mm.

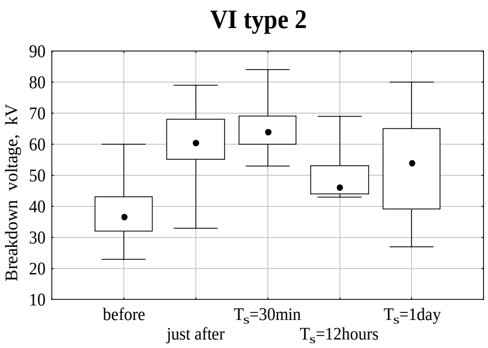

Fig. 5 Evaluation of the time degradation

4. THE CASE OF NEGATIVE RESULTS OF CONDITIONING BY BREAKDOWN CURRENT

The samples manufactured to investigate the triple-point breakdown (the design excluded the metal-vacuum breakdown) have demonstrated the decrease of dielectric strength during the described conditioning procedure (Fig. 6).

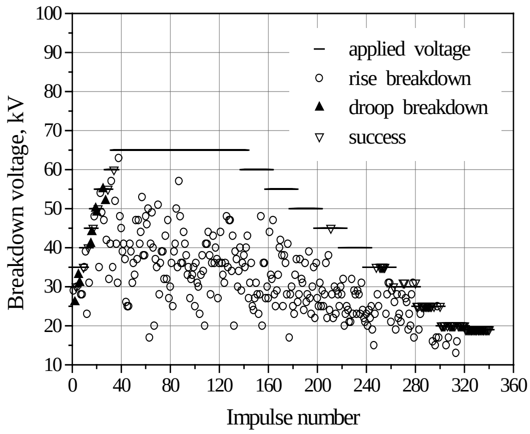

Fig. 6 Triple-point conditioning

5. DISCUSSION

The deep limitation of discharge current by <50A is preferable to by some kA, the conditioning factors are correspondingly 1.5 and 1.2 (Fig. 3). It may be assumed that the high discharge current leads to the creation of projections commensurable with initial.

The preliminary conditioning (step1) allows to achieve the reproducible results, for example, for different polarities and to distinguish the VI dielectric strength for different contact gap (Fig. 4).

Gathered for several VI $\boldsymbol{U_0}$, $\boldsymbol{U_c}$, $\boldsymbol{U(T_s)}$ and $\boldsymbol{A_s}$ let calculate the conditioning and the time degradation factors for contact material:

$$k_c = 1.6;$$

$$k_l = 0.9.$$

If we assume that the contact-metal breakdowns dominate on the gap 6mm, it is easy to estimate the guarantee success level of the standard impulse tests:

Guarantee level is

$$k_l * A_s = 0.9*120 = 108kV$$

The suggested method can't be used for triple-point breakdown investigation. In the photo of cut off samples well seen the results of triple-point breakdowns – the metallized parts of ceramic (Fig. 7). This fact should be kept in mind when the offered method is used.

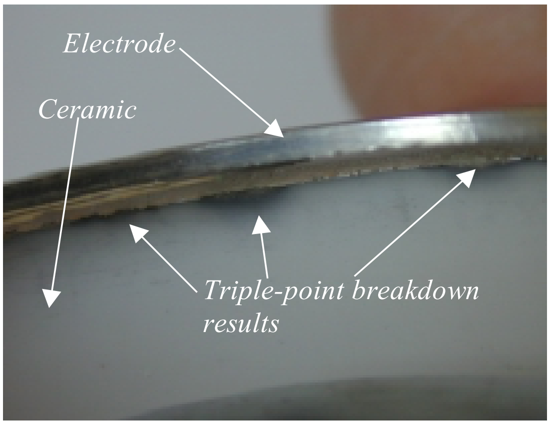

Fig. 7. Metal spraying because the triple-point breakdown

6. CONCLUSIONS

Combined conditioning and test method described in the present paper offers several benefits compared with traditional "up and down" method:

-shorter conditioning;

-better reproduction of test results;

-possibility to deduct important statistical data describing VI dielectric behaviour including probability to pass standard BIL test procedure.

Care shall be taken when this method is applied for VI having triple-point breakdown level comparable with the breakdown level between open contacts.

7. ACKNOWLEDGEMENTS

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8. REFERENCES

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[2] T. Shioiri, et. al., XIX ISDEIV Proceedings, p.17, 2000.