GIS HIGH SPEED EARTHING SWITCH (HSES) MAKING TEST IN SYNTHETIC TEST CIRCUIT

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Abstract - This paper presents results of making current test performed on high speed earthing switch as one part of common development project of 300 kV gas insulated metal enclosed switchgear (GIS).
High speed earthing switch with high speed at closing operation and ability to close two times on the peak value of short circuit current without maintenance was used.
Very wide searching through standards has been done in order to define real status of this in standards not enough clarified switching apparatus.
One possible approach of making test has been introduced, test procedure explained and test results interpreted.

Keywords: Gas insulated metal enclosed switchgear, high speed earthing switch, making current test, synthetic test circuit

I. INTRODUCTION

What is and which task has high speed earthig switch inside of substation with gas insulated metal enclosed switchgear installed?
High speed earthing switch (fast acting or rapid earthing switch) in comparison with standard maintenance earthing switch has ability to earth line under voltage and withstand stresses during the three main closing intervals: high voltage, pre arcing and latching. This operation can be performed two times without maintenance.
This characteristic is required on high speed earthing switch in GIS due to possible mistaken operation by standard maintenance earthing switch when internal arc can occur and course very severe damages.
High speed earthing switch instead normal, standard solution of maintenance earthig switch has been usually installed on the all energy supply points where probability of earthing line under voltage can be met, i.e. overhead line or cable connection to the bay.

One typical GIS bay either overhead line as shown on Fig. 1 or cable bay consisting of certain number of electrical switching apparatus and components like busbars (1), busbars disconnectors (2,3), earthig switches (4,7), current transformer (5), circuit breaker (6), line disconnector (8), high speed earthing switch (9) and bushings (10) [1,2].

The accessibility to all conductors under potential in GIS technology is prevented by metal envelope and provisional earthing like in conventional type of air insulated switchgear is not possible. To obtain earthing of each key element or group of apparatus maintenance earthig switches are permanently installed, Fig. 1, pos. 4,7.

High speed earthing switch has been installed on the entering point in the bay, pos. 9 on Figure 1.
In some praxis all earthing switches in one substation with full making capacity have been used.

In general earthing switch with full making capacity has been designed with motor drive and spring. Closing operation consists of the first part while spring being charged to the "dead" point, after that spring is released automatically what gives enough speed of moving contact to close on the peak value of short circuit current without severe damage.
Opening operation has been performed very slow by motor only.

Until now common standard which cover this apparatus does not exist. To prove ability of high speed earthing switch to carry out full making test, a few standards have been used, [3,4,5,6].

II. SHORT CIRCUIT MAKING TEST IN BASIC STANDARDS

During a closing operation onto a short circuit, the high speed earthing switch contact gap is subjected to the applied voltage corresponding to the r.m.s. value of the rated voltage which causes its breakdown. After this moment, the HSES is subjected to the making current which is expressed by its maximum amplitude i_p in Fig. 2 [4,5].

In a synthetic test circuit the applied voltage is supplied by a separate voltage source and the short circuit current is supplied by a reduced voltage current circuit. This latter is connected to the HSES immediately after breakdown of the contact gap by means of a fast making device, e.g. a triggered spark gap.

Prior to making, a HSES withstands the rated phase to earth voltage applied across its terminals; during making, it carries the rated short circuit current. If closer attention is paid to the voltage and current stresses during the making test, Fig. 2, three main intervals can be registered: high voltage, pre arcing and latching intervals.

High voltage interval

The high voltage interval is the time from the commencement of the test, with the HSES in the open position, to the moment of the breakdown across the contact gap.
During this interval the HSES shall be stressed by the test circuit in such a way that the starting conditions for the pre arcing interval, within the tolerance to be

specified, are the same as under reference system conditions.
Three phase tests should preferably be made on three pole switches at the rated voltage of the switch.

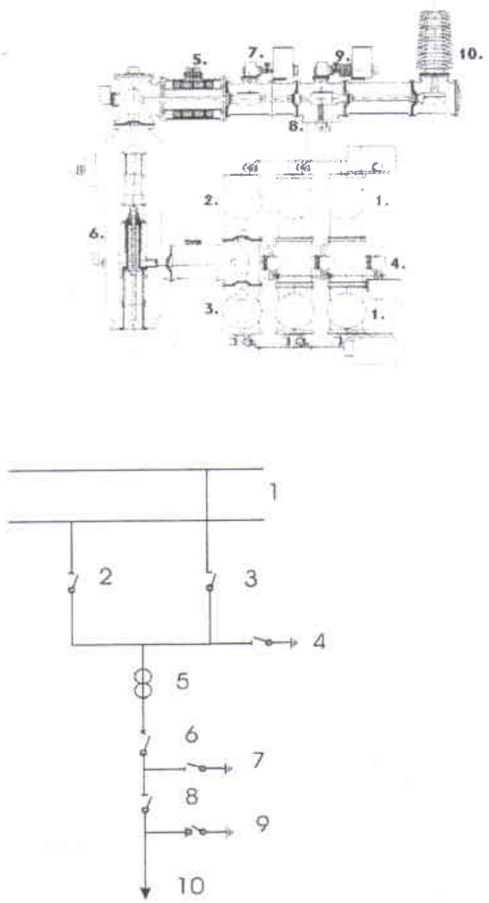


Fig. 1. Standard GIS overhead line bay type GA I3 rated voltage 300 kV and corresponding single line diagram

Single phase tests on a three pole switch may also be made, provided it can be shown that conditions of [6] are met. Additionally, it must be shown that the severity of single phase tests with regard to the mechanical forces produced on each pole and on the operating device are equal or more severe than those produced during a three phase test.

Laboratory limitation at the higher voltages may be such as to make direct tests at rated voltage and rated current extremely difficult. A synthetic making circuit may be used under these circumstances so as to produce the required test voltage from one supply and the rated making current from a second supply.
Under certain conditions, tests may be performed at a reduced voltage. It must be shown that reduced voltage tests are not less severe than tests at the proper voltages as indicated in Table I. A means shall be provided of causing the initiation of arcing on closing at the same distance as that which would be attained at the proper three phase or single phase test voltages. There should be no significant distortion or interruption of the making current during the closing period.
Therefore the conditions in accordance with sort of test being performed, single phase or three phase and type of drive shall be met prescription given in Table I, [6].

However, when performing synthetic tests on HSES having a high closing speed and consequently a short pre arcing time a reduced applied voltage can be used provided that the maximum pre arcing time determined in accordance with [4] does not exceed $1/\omega$ s (3.2 ms for 50 Hz and 2.7 ms for 60 Hz) as shown in Fig. 3.

TABLE I. TEST VOLTAGE AND CURRENT AT SHORT CIRCUIT MAKING TEST

At test duties for	Rated voltage	Test voltage (+10%, -10%)	Test current (+10%, -10%)	Number of cycles or operation
Three phase tests on three pole switches	All	U	I_p	2 making operation
Single phase test on three pole switches with 0.5 cycles or less non simultaneity	All	$U/\sqrt{3}$	I_p	2 making operation
Single phase test on three pole switches with more than 0.5 cycles non simultaneity and switches operated pole after pole	All	U $1.5U/\sqrt{3}$	$0.87\ I_p$ I_p	1 making operation 1 making operation

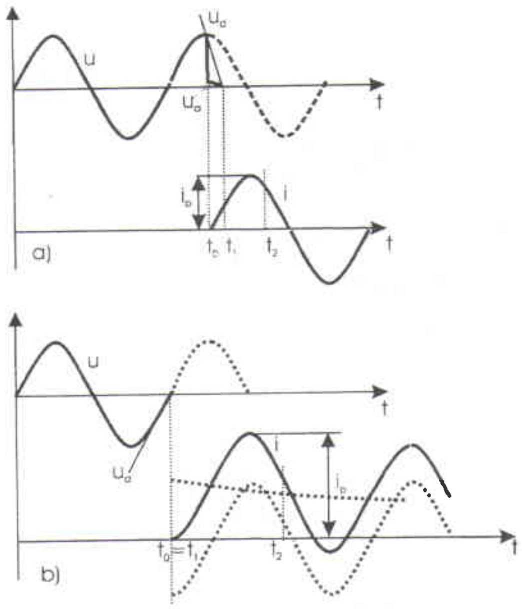


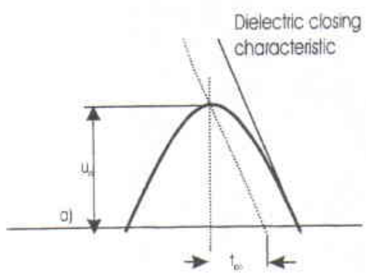
Fig. 2. Making process, basic time intervals

a) Symmetrical making current
b) Asymmetrical making current

i — current
i_p — making current peak
u — power frequency voltage
u_d — dielectric closing characteristic
u_a — arc voltage

Time intervals:

t_0 — high voltage interval
t_0 - t_1 — pre arcing interval
t_1 - t_2 — latching interval
t_2 — fully closed position



$$\left(\frac{du}{dt}\right)_{\max} = \omega . u_p$$

$$\left(t_{pa}\right)_{\max} = \frac{u_p}{\omega u_p} = \frac{1}{\omega}$$

Fig. 3. Maximum allowable pre arcing time for valid making test at reduced voltage

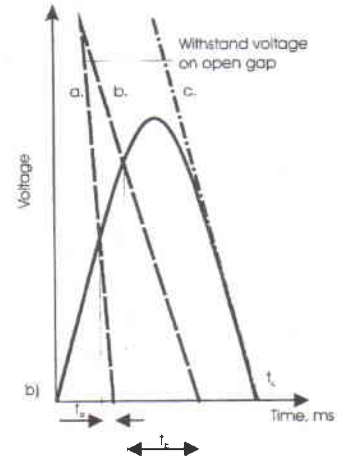


Fig. 4. Maximum pre arcing time for making test at reduced voltage, setting the switch to the proper speed

Pre arcing interval

The pre arcing interval is the time, during the closing stroke of the HSES, from the moment of breakdown across the contact gap to the touching of the contacts.

During pre arcing the HSES is subjected to electrodynamics forces due to the current and to deteriorating effects due to arc energy. In general the current is composed of three components:

- the initial transient making current, ITMC,
- the d.c. and a.c. components of the short circuit current.

Two typical cases may occur depending on the moment of closing and on the HSES design:

- Breakdown occurs near the crest of the applied voltage, an almost symmetrical current is established. Pre arc energy and ITMC are relatively high, Fig. 2a,
- Breakdown occurs near zero of the applied voltage, an asymmetrical current is established. Pre arcing energy and ITMC are negligible, Fig. 2b.

ITMC is not defined in [5], a value sufficient to maintain pre arcing is adequate.

The short circuit making current shall be expressed as the maximum value of the peak test current for three phase tests, or the peak test current for a single phase test, and shall be at least 100% of the rated short circuit making current in at least one test of the two tests required [6].

The tests are considered valid if the peak current in the other test is at least 90% of the rated value or of the specified test current. The symmetrical r.m.s. value of current in each pole during the tenth cycle of current shall be at least 80% of the rated short time withstand current.

The duration of the short circuit current shall be at least 10 cycles.

Due to pre arcing, it is not always possible to achieve the required rated short circuit making current even though tests are made at the rated voltage of the switch. For this case, evidence shall be given that the making currents attained are representative of the currents which will be achieved upon application of the switch at rated voltage in a circuit wherein the maximum prospective peak current is equal to the rated short circuit making current.

Latching interval

The latching interval is the time, during the closing stroke of the HSES, from the touching of the contacts to the moment when the contacts reach the fully closed (latched) position.

During these intervals the HSES has to be closed in presence of the electrodynamic forces due to the current and contact friction forces. Therefore during these intervals the making current shall comply with [5].

III. TEST PROCEDURE AND RESULTS

High speed earthing switch (HSES) being installed on the entering point in the bay, pos. 9 on Figure 1, has been taken as tested apparatus [7].

By releasing pre charged spring at closing operation high speed earthing switch is the fast acting apparatus with closing time of about 80 ms (from spring realizing moment to the touching of contacts).

During a closing operation and as the contacts approach each other, a point is reached where the gap equals the maximum flashover distance and therefore electric arc is initiated. As the distance between the contacts continues to diminish the arc gradually shortens until finally engage and arc disappears.

Depending upon the voltages, conditions of interrupting medium and the design of each particular part of the switch, the contact flashover characteristic or dielectric closing characteristics vary very widely. As we can see on Fig. 4, three characteristics slopes was settled and checked. When these slopes are superimposed on the plot of the absolute values of a sinusoidal wave that represent the system voltage, it shows, that depending on the instantaneous relation between the contact gap and the system voltage the arc is initiated at the point of intersection of the two curves.

The elapsed time between the flashover point and the time where the contacts engage represents the total arcing time which is shown as t_a, t_b and t_c corresponding to slopes a, b and c respectively. It also can be seen in this figure that the arcing time decreases as the slope of the flashover characteristics increases which suggests what should be obvious that increasing the closing velocity decreases the arc duration.

Increasing the closing velocity not only decreases the arcing time but it also decreases the magnitude of the current at the instant of the contact engagement.

The benefits of a high closing speed are then a reduction in the mechanism energy requirements and a reduction of the contact erosion. But higher speed has reverse impact on the damping system and life time of all parts of mechanism. Some optimum has been found between these two opposite requirements without using additional system for arc quenching.

Opening operation has been performed with low speed and opening time of 1.0 sec. based on the action of motor drive only.

Apart from fast action at closing operation high speed earthing switch is submitted with arc resistant contacts, Fig. 5. No any additional arc quenching system has been applied. These provide its ability to withstand two closing operation on the peak value of the specified short time current, 100 kA peak and 40 kA r.m.s at latching position.

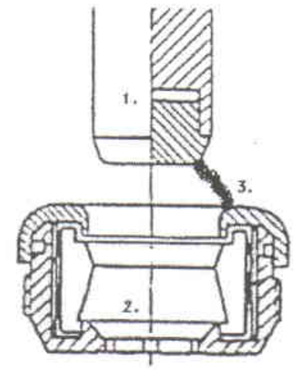


Fig. 5. HSES contact system

1. Moving contact, 2. Fixed contact, 3. Pre arc

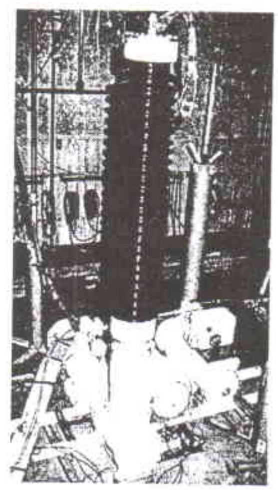


Fig. 6. HSES Test unit

Test unit consisting of three poles of one phase enclosed HSES connected mechanically together on common spring motor drive is shown on Fig. 6.

Single phase test on HSES in synthetic test circuit was performed at lockout, minimum working SF6 gas density and minimum value of the drive supply voltage.

On order to obtain in chapter II. mentioned requirements combined from many different standards, the next test procedure for making test of high speed earthing switch has been established:

a) The phase of HSES under test, phase opposite to the driven pole, has been tested by phase to earth rated voltage value, 15 min. as preconditioning test.
b) In order to measure non simultaneity between poles certain number of no load operation was performed. Because of mechanical connection between poles, very low and less than 0.5 cycles time of non simultaneity has been found. According to Table I, at single phase test and this value of non simultaneity test can be performed at phase to earth test voltage i.e. $300/\sqrt{3} = 173$ kV.
c) In the next step pre arcing times values were measured five times and test results are given on the Fig. 7. As it can be seen minimum, maximum and average values of pre arcing time is higher than $1/\omega = 3.18$ ms.
d) Based on these input results test has been performed consisting of:
- one three phase making operation on $i_p = 107$ kA, r.m.s. values in three phases 38.3, 41.1 and 37.8 kA and reduced test voltage of 4.6 kV,
- two single phase making in synthetic test circuit of $i_p = 100$ and 98 kA with r.m.s. value of 39.5 kA at test voltage of 173 kV and pre arcing time about average value. Testing time was 0.22 sec.

e) Very wide additional tests after main tests were performed:
- To check insulation conditions after test, dielectric test by power frequency test voltage of 370 kV and 425 kV, 1 min. between phase and earth has been carried out. No discharge was occurred during the test.
- Certain number of no load operations have been done. HSES closed and open firmly. No any change in opening and closing time measured before and after test has been found.
- Resistance of the switch in closed position was measured. No any change in results before and after test have been found.

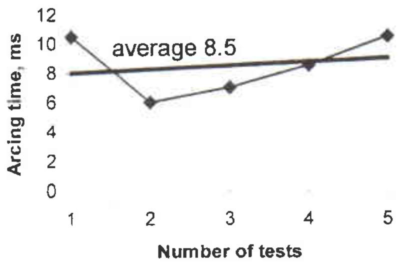


Fig. 7. Pre arcing time values at 170 kV

IV. CONCLUSION

In each point of the gas insulated metal enclosed switchgear where earthing by mistake on the supply side is very probably, instead ordinary maintenance arthing device, switch with making capability on short circuit current has to be used. This device, with usual name high speed earthing switch is not defines until now in any standard regarding application aim and testing procedures.

In this article GIS high speed arthing switch for rated voltage 300 kV, rated making short circuit current of 100 kA peak has been introduced.

Single phase test at full value of tested voltage combined with three phase test at reduced test voltage performed in synthetic test circuit was explained.

This approach was based on the interpretation a few standards dealing with the making capability of different sort of switching apparatus in general [3,4,5,6].

To proof service condition of the tested apparatus, very wide tests after making test have been performed. No any irregularities at these tests were found.

V. REFERNCES

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VI. BIOGRAPHY

Predrag Bojić received the BS and Ph.D. degrees from University of Sarajevo in 1968 and 1983 respectively.
From 1968 to 1988 he was chief designer in development of SF6 gas insulated metal enclosed switchgears with Company Energoinvest, Sarajevo. From 1988 to 1993 he worked as professor at University of Sarajevo and as Consultant at Company Energoinvest. Since 1993 he has been engaged on development of high voltage gas insulated metal enclosed switchgears and circuit breakers with Ansaldo T&D, Genoa and Ganz-Ansaldo, Budapest.