DIAGNOSTIC METHODOLOGY TO ENHANCE OPERATIONAL PERFORMANCE OF SF6 INSULATED CIRCUIT BREAKERS

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ABSTRACT

Due to the growing importance of service quality offered, Utilities and Distribution companies are constantly investing in R&D asset performance improvements.

The AEEG (Italian National Energy Authority) indicates as one of the main performance key indicator, the average number of customer outages lasting less than 180 sec.
To minimize as much as possible duration of supply interruptions , Enel Distribuzione has planned to shorten MV circuit breakers re-closing cycle on either installed and to be installed devices.

Estimation of cb's future capabilities under heavy duty work load (short re-closing cycle) required an initial evaluation of installed cb's actual functional life time span.
A series of tests on SF6 circuit breakers with an average ageing of fifteen years was carried out in cooperation with ABB PT (Dalmine) and CESI (Centro Elettrotecnico Sperimentale Italiano).
Tests included an accurate record and measurements of the voltage drop shape across the main contacts using a breaker test instrument.
Also a review of the arc contact wear was executed by trained operators which analyzed and compared the wave shape with a range of standard defined characteristics.

Nowadays the springs operating mechanism functionality diagnostic analysis of the trip coil current shape is a well consolidated methodological approach, but our proposal provides additional range of cb's functional data (i.e. interruption chamber operational state, cb's performance enhancement, etc.).

INTRODUCTION

The short re-closing cycle can be applied revamping (if needed) or substituting existing cb's with new SF6 or vacuum breakers .

As already mentioned, the need for a renewal maintenance is established according a preliminary arc extinction functional evaluation and because it requires specialised personnel can only feasibly be performed by manufacturers.

Our method focuses on cb's contacts wearing, assessed by measuring the voltage drop across both main and arcing contacts; comparing the resulting characteristic with those relative to a new device is then possible to rank the capability of the c.b under examination to sustain the standard rated duty cycle fixed in O-0,3sec-CO-30sec-CO at a rated short circuit current of 12,5 kA.
Once the rated standard condition is verified, protections are set out according the new shorter re-closing cycle: O-0,3sec-CO-30sec-CO-70sec-CO-70sec-C (note that the last two closing operation has been shorted from 120 sec to 70 sec).

This paper has been divided into four sections: the first describes the working principle of SF6 insulated c.b. type SFA/U (manufactured by ABB), the second illustrates St. Ilario (Reggio Emilia) Primary Substation tests data and records, the third section concentrates on the results obtained testing a selection of three of the seven c.b. selected samples.
Final conclusive considerations are summarised in the last section.

1. SF6 CIRCUIT BREAKER MAIN FEATURES

This type of c.b. is widely employed by Enel: currently there are about 5500 ABB SFA/U units in service aged in average fifteen years.

Fig. 1 –ABB -SFA/U SF6 circuit breaker -

Each cb's pole consists in a cylindrical chamber embedding the interruption device and having airtight vertical axis,

filled with sulphur hexafluoride.
During the opening operation procedure the main contacts (see Fig. 2) are firstly involved: after a race of 10 mm by the time the main contacts open, the arcing contacts stood, with a race of 35mm, begin to operate.
The blasting conical shape nozzle made with teflon (Venturi tube) permits the arc cooling extinction by means of the SF6 gas injected through the mobile contact movement.

The voltage drop occurring across the main contacts during the first phase and, across the arcing contacts during the second phase, is measured and used to estimate the contacts wear, comparing the above measured values with those relative to a new sample of the same kind.

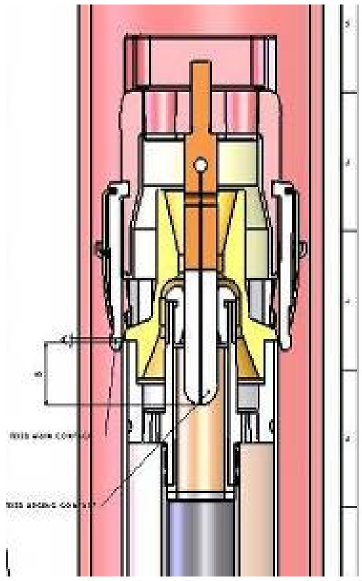

Fig. 2 - SF6 isolated interruption chamber -

2. PRIMARY SUBSTATION CB'S MEASUREMENTS

St. Ilario Primary Substation has been selected because the age of its cb's is similar to those of the same kind, widely installed on Enel Electrical Grid (see Fig.3).

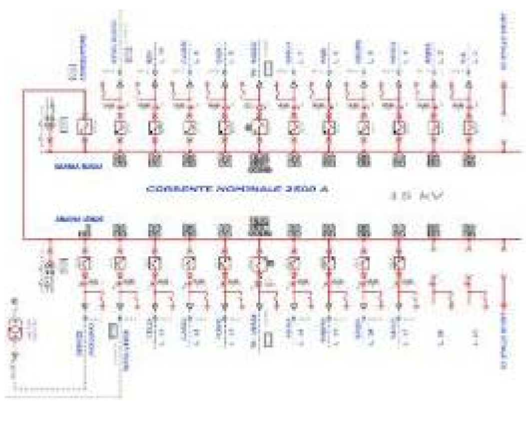

Fig. 3 - St.Ilario Primary Substation MV section scheme layout -

A meeting between the authors was held on the 11th of April 2006 in St. Ilario (Reggio Emilia).

A preliminary contact wear condition was scheduled and an undirect measurement was executed.
The three out of seven c.b. samples were chosen comparing the drop voltage recorded across the contacts and the rated standard values.

The standard rated values were provided by ABB Factory of Dalmine by testing a refurbished cb's of the SFA/U type.
Devices has to be renovated because currently out of production.
In particular the renewal consisted in the replacement of the contacts so that initial standard rate factory values were restored.

Fig.4 indicates circuit breaker n. LM062900 opening data: the decreasing characteristic curve shows each cb's phase imposed test current.
DC current value applied was 800A.
The rising characteristic curve depicts the voltage drop across phase S' contacts.

The characteristic curve located lower in the picture, shows the trip coil current absorbed during the opening operation. This last curve outlines the mechanical device tripping efficiency of the opening spring which controls the moving contacts.

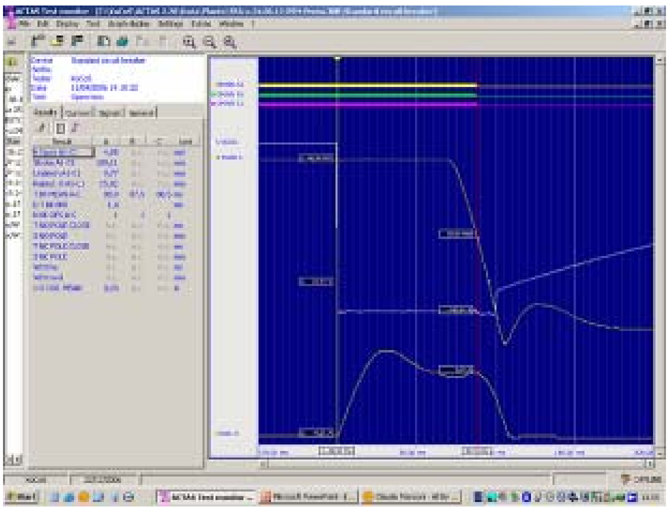

Fig.4 - Opening operation records -

In fig.5 the magnitude of both axis has been changed for visual purposes and in particular during cb's phase contacts opening.

Here, the decreasing characteristic curve shows the contacts movement recorded by a transducer installed on the poles shaft.

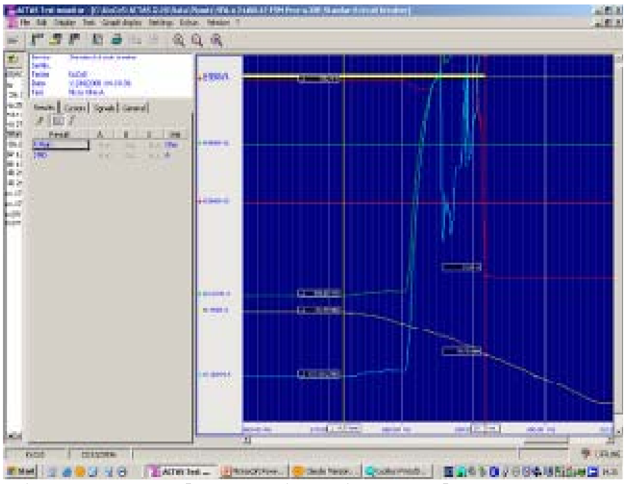

Fig. 5 - Drop voltage registration on phase S contact -

In Fig.6 the same characteristics of fig.5 are illustrated.

In addition, on the abscissas axis (Time), the start race of both main and arcing contacts from where is possible to visualize the arc extinction length, are reported.

During the first part of the voltage drop characteristic (lasting 10msec) the curve keeps steady; then during the following 35msec when arcing contacts start to operate, the drop voltage rises (see Fig.6).

In the same last picture is also represented the phase S resistance which is similar in shape to the drop voltage.
Either the first and the second part of the voltage drop characteristic gives useful information about the main and the arcing contacts wear: to drawn information from this characteristic is necessary to compare the curve with that of a new circuit breaker of the same kind.

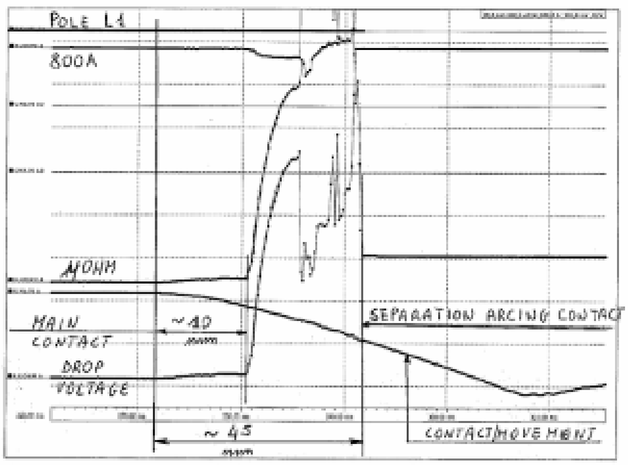

Fig.6 - Explanation of Fig.5 parameters -

3. CB'S SHORT CIRCUIT TESTS

Tests have been carried out by CESI (Centro Elettrotecnico Sperimentale Italiano, Milano).

Three samples of ABB manufactured SF**6** circuit breakers, selected with care among the same type of apparatus, in service in the primary distribution substation of St.Ilario (Reggio Emilia) – Italy, have been submitted to the short circuit tests.

The selected circuit breakers have an electrical life of 15 years of service.
For the purpose of the investigation, the less stressed ones have been chosen and precisely: ABB SFA/U serial number LM062885, LM062900 and LM062901 all manufactured in the 1989.

Due to the heavy operating sequence, the supply circuit used was not from the own short circuit power generator but directly connected to the network.
The interval of 70 sec. between each closing-opening operation, would have required the same short circuit power maintained approx for 3 minutes.

The decision to use a real network supply was taken to maintain the ether the short circuit current or the frequency at the same requested values (12,5kA and 50 Hz respectively), with a tested voltage of 24 kV.
Being CESI – Milano testing plants supplied either by short circuit power generator or by network, the network supply has finally used.

Particular attention has been given to the TRV parameters, as per IEC Standard requirements.
The following operating sequence has been used.
O – 0,3s – CO – 30 s – CO - 70 s – CO – 70 s – CO.
The tested circuit breaker passed all the short circuit tests.

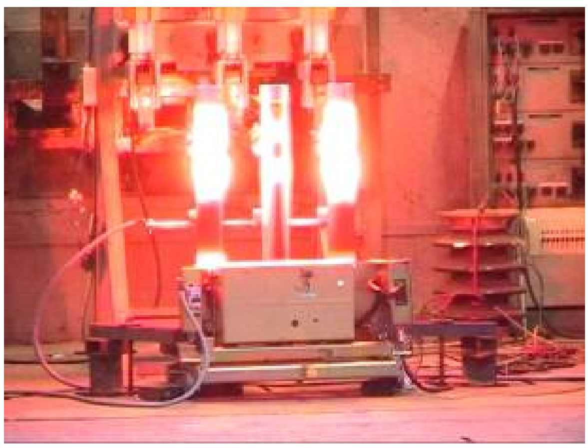

Fig.7 - Test station at Cesi labour -

The following circuit diagram represents the circuit used.

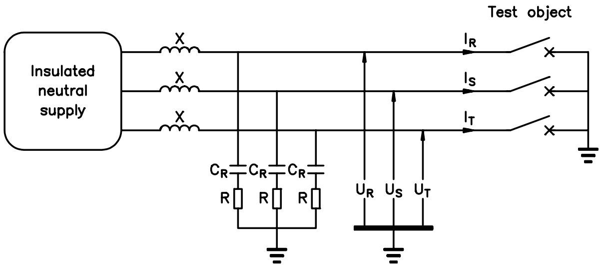

Fig.8 Test circuit layout

4. CONCLUSION

Scope of the diagnostic method presented in this paper was the evaluation of existing SF6 insulated circuit breakers.

In particular tests outlined both main and arcing contacts wear which together with the mechanical state condition of the control mechanism, allows to establish whether the cb's at the time of testing, is still able to operate at rated duty cycle and rated short circuit current.

Once this potential is verified is then possible to set c.b. protections to a shorter re-closing cycle allowing the three interruption cb's chambers overload.

Final method outcomes can be summarised into the following benefices:

- To monitor realistically the device general operational and functional conditions
- To Enhance SF6 cb's performance
- To reduce customer outages

Method validation was confirmed by the short circuit tests carried out by CESI: all three c.b.'s samples fulfilled twice the re-closing cycle at the rated short circuit current and passed the final interruption chambers visual inspection (see Fig.9 e Fig.10).

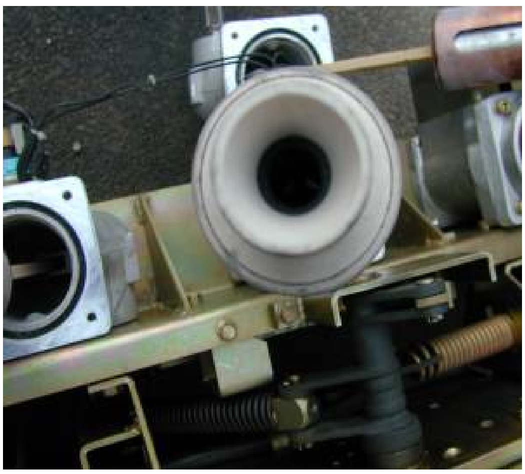

Fig.9 - Phase S moving contact -

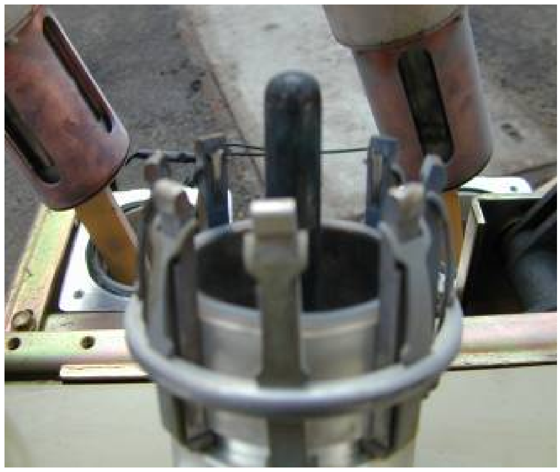

Fig.10 - Phase S fixed contact: note the arcing contact (stood) and t the circular main contact around it -

Acknowledgments

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