COMPATIBILITY BETWEEN METAL-ENCLOSED SWITCHGEAR AND TYPICAL NETWORK CONDITIONS - FEEDBACK FROM BELGIAN DNO

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ABSTRACT

A tendency in Distribution Networks is to increasingly use SF6 insulated MS-switchgear almost exclusively of the sealed pressure system type. This is done in an attempt to avoid difficulties caused by tightness of the equipment and the need for pressure control towards the end of its lifetime. Experience shows a large dispersion in the tightness performance between manufacturers and between switchgears of the same manufacturer. This suggests that more attention should be paid to tightness performance and to available type and routine tests for switchgear. In particular, the standard is not specific enough concerning the tightness test method and the adequate measuring principles. Especially the temperature effect has to be taken into account. This paper describes studies recently carried out in Belgium, that do take into account typical environmental conditions. Based on these studies, most appropriate temperature conditions for performing the representative type tests are recommended (40°C and 80°C, respectively for the two tests) and sanctions for these tests are proposed. Further details concerning the best-adapted measuring principles will be provided during the CIRED 2007 conference.

INTRODUCTION

A general trend in Distribution Networks is the increased use of SF6 insulated MS-switchgear. This is due to three main factors:

- The smaller size of substations equipped with such devices. This is important, given to difficulty to find adequate space in countries with high population concentrations.
- The reduced sensitivity to environmental conditions of switchgears with active parts protected by a controlled gas composition: no oxygen and no humidity. In fact, most MV-switchgear in distribution networks are not installed in temperature and humidity controlled rooms. This can lead to frequent condensation effects and has an impact on the dielectric behavior of the equipments, reducing their lifetime.
- The relative ease of controlling the effect of internal arc fault in encloded volumes. The increase in pressure is reduced by the absence of oxygen-burning-metals phenomenon and as a result the external effects are easily controlled.

In Belgium, the control of SF6 pressure has been imposed by most utilities, since 1999, on RMU switchgears. The new technical specification imposes an automatic pressure control to prevent the risk of switching a circuit breaker in abnormal condition caused by SF6 leakage. However, most modular systems and existing RMUs are not equipped with such pressure control devices.

The distribution networks use almost exclusively sealed pressure system. This is based on the belief that, due to its construction principle, this type of switchgear does not need a control. Experience however shows that such belief is erroneous. The currently used type test and routine test, which abide by the IEC standard, are not sufficient to insure a 30 year lifetime in the typical field conditions.

The relevant number of cases in which switchgear has reached the atmospheric pressure inside the tank after a few years on the electrical network, lead us to investigate the cause of the SF6 leakages.

GENERAL CONSIDERATIONS

Typical conditions in the distribution network substations

Many MS-switchgear are installed in prefabricated substations with extensive ventilation but without special thermal insulation, and in some cases subject to heating due to transformer losses. Temperature extremes reached within the SF6 tank can be calculated by taking into account, on the one hand the extreme ambient temperatures in the substation in the winter or summer and in the sunlight or shadow and on the other hand the rise in temperature of the SF6 gas induced by a temperature rise of the active parts at rated current and itself causing a rise in temperature in the epoxy or steel body.

In Belgium, the extreme temperatures reached by the SF6 and the body typically fluctuate between –5°C in the winter, at night and with no current in the active parts for a substation in a section point of the network loop, and +80°C when the substation is in bright sunlight and when the rated current flows through the active parts.
A common operating temperature in the normal life of the SF6 body is 40°C. Such temperature is reached under an ambient temperature of 30°C when the substation is heated by sunlight and transformer losses, and under the thermal influence of half the rated current causing a 10K temperature-rise of the SF6 gas and body. The extreme temperature of 80°C is reached under a 40°C ambient temperature in the substation with a rated current flowing through the switchgear, leading to a 40 K rise in the temperature-of the SF6 gas and body.

Prefabricated substation in the winter sunlight

The temperature-rise value is estimated from the mean value of temperature-rise type test measurements in SF6 gas of various switchgear.

The mean switching frequency of the switchgears is very low and is mostly between once in five years and several times a year.

Requirements of the standard

The requirements are given in IEC 60694 and in the future CDV of IEC 62271-1 that is due to replace the former.

A tightness test is required before and after the mechanical type test at ambient temperature. The measured leakage must be less than the permissible temporary leakage rate "Fp". The latter is defined from the specified expected operating life. The preferred values are 20, 30 and 40 years. An example of lifetime calculation is given in the annex E of the IEC 62271-1 standard.
The standard proposes the test "Qm" (from IEC 60068-2-17) that represents an adequate method to determine leakages in gas systems. It is an accumulating method. The leakage is calculated from the measured concentration of SF6 molecules contained in a container volume.

An increased leakage rate at extreme temperatures is acceptable, if it then resets to a value not higher than the maximum permissible value at normal ambient air temperature. The increased temporary leakage rate should not exceed 3 times the values Fp for –5°C and +40°C for the basic temperature classes of equipment.

Routine tightness tests are to be performed at normal ambient air temperature with the assembly filled at the pressure (or density) corresponding to the manufacturer's test practice. For gas-filled systems sniffing may be used.

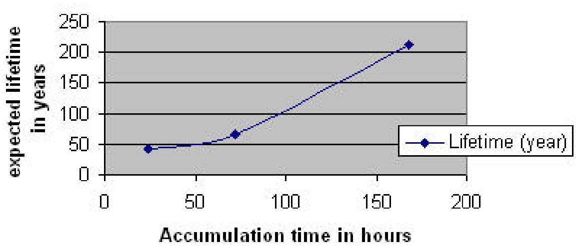
Interestingly, no indication is given in the standard about acceptable measuring principles.

INVESTIGATIONS

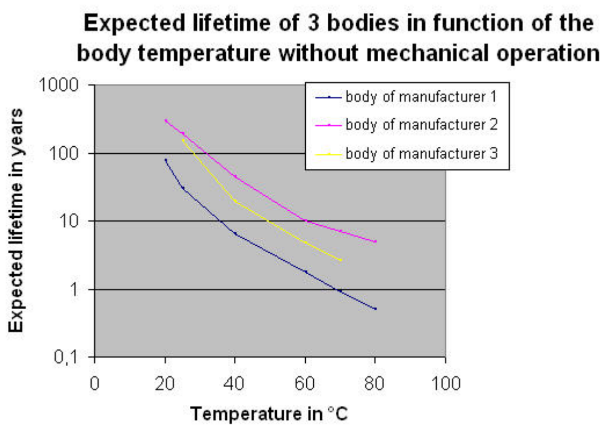
Test results

The standard does not specify the accumulation time nor the time between mechanical tests and tightness test. These times have a significant influence on the calculation of estimated leakage.
With the participation of some manufacturers, we have carried out a number of tests with various SF6 bodies, for various accumulation times and at different temperatures, before and after performing a 1000-operating-cycle mechanical test.

Expected lifetime at 20°C = f(accumulation time after mechanical test) of an averagely good body



When the test is carried out after mechanical test, the leakage rate appears to decrease exponentially as the accumulation time decreases. The leakage is located at the joints, especially around the joint of the operating axis.

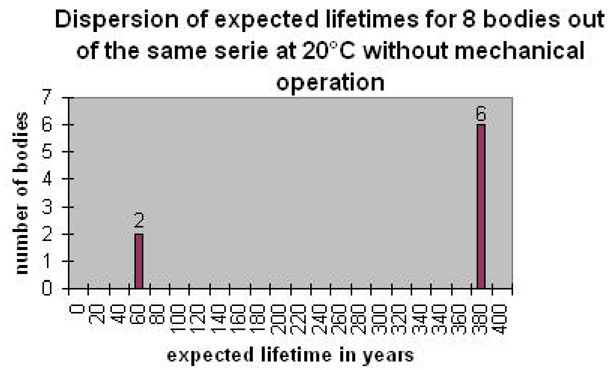


The figure here above shows the measurement results on a body with insufficient tightness and an acceptable body.

Following the requirement of the standard, a 3Fp leakage value is acceptable at 40°C for switchgear after mechanical test, but this is not the case for switchgear that have not operated for a long time. The leakage in this case should be much lower.

The most conventional routine test during manufacturing operations is performed by placing the empty body (vacuum, without any gas) in a helium environment in an autoclave during a few minutes. This test is carried out on every single body and hence cannot be made after heavy mechanical test. For flow type at very low leakage rates such as, say, 10^{-8} Pa.m³/s as is the case with sealed pressure system, the leakage ratio for helium is only 6 times higher than that for SF6 gas.
Regarding the duration of this test and its sensitivity, significant leakage could be detected only when the expected lifetime is lower than 6 months without any mechanical operation and at ambient temperature. This test does not give any indication concerning the achievement of the expected lifetime of 30 years after mechanical operations. It only allows the detection of particules or holes of a tenth of a millimeter or so in the joint glove, or hair or textile fibre across O-rings of joints.

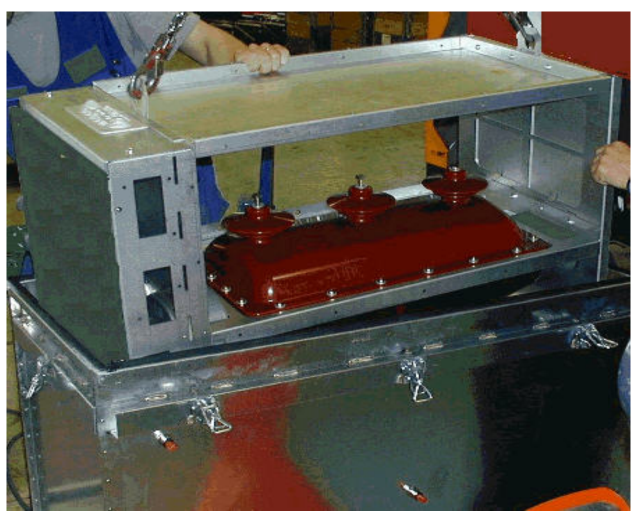
A study of tightness on a sample of eight bodies coming from the same production line, by the SF6 accumulation method, shows a large dispersion of the results.



This dispersion shows the need to perform the test on a large enough number of bodies to obtain statistically significant results.

Importance of the test procedure

The body is placed in a tight accumulating volume. The container can be rigid like a steel container closed with a cover equipped with joints. In such case, the pressure inside the measuring volume is reset to the atmospheric pressure at the moment of the temperature stabilization, before the start of the chronometer.



Tightness test: body to be tested in steel container equipped with measuring valves.

Tightness test: body to be tested in a plastic bag equipped with a measuring valve.

The accumulation time must be selected and held through all the tests. We propose 24h, which is a reasonable compromise between accuracy and lab occupation constraints. In case a tight soft bag is used, the volume has to be correctly evaluated. A valve is needed for the introduction of the test probe of the measuring apparatus. The accuracy of the measuring technique must compatible with the concentration to be measured (around one ppm or so).

Importance of the test device measuring principle

Some measurements were obtained with the collaboration of some manufacturers with devices using various measuring principles. The presence of organic or damp molecules can influence the result of the measurements. Devices using the electron capture principle and an IR-detection device were used to provide the measures. Experience suggests that such devices are not sensitive to the presence of organic molecules. The electron capture device can be influenced by air humidity because the mass of the water vapor is in the same range as the mass of SF6 and can create confusion. We are presently further studying these measuring principles and expect to give more details about them and to recommend a "best" choice during the CIRED 2007conference.

Proposed sanction of the tightness test

DNOs need switchgears with lifetimes compatible with the continuity of public service. This means the minimum expected lifetime has to be relevant for the large majority of the equipment. 97,5% (mean + 2s for a normal distribution) should be an acceptable ratio of equipment with a lifetime higher than a normal expected lifetime of equipment on a public electrical network (i.e. 30 years). It would not be economically realistic to try to achieve higher ratios. This shows the necessity to perform the tightness type test on a large number of specimens and to relate the minimum expected lifetime to the lifetime value obtained from the calculation of "mean leakage + 2 sample standard deviation"

This tightness test should be performed at a temperature of 40°C compatible with typical temperatures in prefabricated substations.

CONCLUSIONS

It is important for all Utilities that the standard IEC 62271-1 be revised, as far as specifications for switchgear tests are concerned. We feel the following requirements should be specified:

- Accumulation time: at least 24 h after temperature stabilization at 40°C.
- Accumulation time: at least 24 h after temperature stabilization at 80°C.
- Measuring principle which sufficient accuracy.
- The sanction of the test should not be based on only one body but on a sizeable sample of the population. The expected lifetime for 40°C should be based on the mean leakage + 2 sample standard deviation and should be at least 30 or 40 years.
- The expected lifetime at 80°C (extreme environment conditions of 40°C + temperature rise at rated current) should be required from the manufacturer.