International Conference on Large High Voltage Electric Systems

112, boulevard Haussmann – 75008 Paris

1982 Session – 1-9 September

23-07 **O**

EXPERIENCE OF AC VOLTAGE TESTS WITH VARIABLE FREQUENCY USING A LIGHTWEIGHT ON-SITE SERIES RESONANCE DEVICE

by

W. ZAENGL
Swiss Federal Institute of Technology, Zurich

F. BERNASCONI
Research Commission on High Voltage Technology of the Swiss Electrotechnical Association

B. BACHMANN, W. SCHMIDT, K. SPINNLER
BBC Brown, Boveri and Co., Ltd, Baden

(Switzerland)

Abstract

The construction of increasingly large GIS installations has resulted in unit capacities growing up and necessitated h.v. testing with transformers of ever increasing rates. The transport and the energy supply of such heavy transformers presents problems, today.

Resonance test sets with fixed or variable inductances of the reactors are a good alternative. In the first case, however, the test frequency is usually above the normal power frequency, that means 50 to about 300 Hz, depending on the testing capacity.

This paper provides a summary of the development of resonance test sets and shows their salient features. Further, it examines the question as to wheather and to what extent the frequency influences the breakdown values of a pure gas gap and one equipped with an insulator.

Referring to some practical assignments on site, the functional capability of the set is demonstrated, from which it would appear that particulary this method of testing is ideal for detecting faults.

Key words:

GIS installation; on-site testing; serie resonance test set; variable frequency; alternating voltage test.

I. Introduction

Single components of conventional indoor or outdoor switchgear installations are normally subjected to the stipulated type tests and routine tests in the factory. When the various components have been assembled on the customer's site there is no real need for an on-site test, since the proof of the specified insulation level can be guaranteed for the complete installation on the basis of the factory tests [1].

On the other hand, metal-enclosed gas-insulated switchgear (GIS) has to undergo a voltage test when it has been assembled on site, additionally. For the very compact SF_6 installations such a test serves a useful purpose for a number of reasons. Firstly, the live parts cannot be inspected visually when they have been assembled, on account of their enclosure. Secondly, owing to an oversight during assembly on site it is possible for foreign particles to enter the equipment and possibly result in the dielectric strength being reduced [2], and thirdly, damage suffered in transit cannot be altogether ruled out. By performing a voltage test on site at the conclusion of assembly, the customer is assured that the installation will operate properly and that the desired or specified insulation level is adhered to.

Present-day testing practice for the assurance of quality and proving the functional reliability is admittedly expensive, but it is selective. In addition to the normal material tests beginning with inspection of incoming materials received by the factory, tests are performed on the various components which are later assembled to form a high-voltage unit. A number of tested components are put together to form a shipping unit and subjected to the necessary electro-mechanical and dielectric tests laid down in IEC 517. A combined power-frequency voltage test together with measurement of partial discharge in a single test has been found to be very strict. With this test method the partial discharge onset and offset voltages are checked, which should be appreciably higher than 1.2 times the voltage between conductor and earth. On site the shipping units are then put together to form the complete installation and finally subjected to an on-site test, as proof of correct assembly.

If we now consider the various kinds of voltage which could possibly be used for such tests, it must be stated that a test with direct voltage is indeed a suitable means of detecting metal particles in particular after assembly. On the other hand, a direct voltage imposes different stresses on the insulation to the alternating voltage to which it is exposed in service.

Therefore, the test direct voltage, as commonly used for cables, although even there it is not without problems, should not be transferred to GIS installations because the SF_6 gas behaves quite differently to the oil/paper insulation systems of cables.

In contrast, the problem with tests employing alternating voltage is the large amount of reactive power that is required, especially in view of the relatively high capacitances of GIS installations. Apart from this high reactive power, the problem of power: weight ratio must also be mentioned. For an on-site test at only 400 kV, 1 A, employing conventional test methods, it is necessary to transport a total weight of up to 200 kN to the site.

The displacement of such weights rapidly leads to serious transport problems. As alternative, proposals have been made for an on-site test with oscillating switching impulse voltage [3], a method that has meanwhile been introduced. Oscillating switching impulse generators are relatively light in weight and can thus be transported easily. Experience has shown, though, that this method of testing is also able to detect certain faults in the installation reliably, although it has not been determined with certainty, whether foreign particles can also be reliably detected with this voltage form. Such a test is therefore particularly appropriate, because every switching operation in the network imposes similar stresses on the switchgear to those produced by the oscillating switching impulse.

On the other hand, for systems with lower rated voltages, testing with a power-frequency voltage of about 80% of the nominal test value, performed on site, is still the commonest and best accepted method of testing, and in this voltage range is the nearest equivalent to the stresses encountered in service.

In order to dispense with the heavy, conventional testing transformer, resonant circuits can be employed as a means of generating high alternating test voltages. Likewise, they are the sole on-site method of testing that is capable of detecting faults reliably.

II. Resonant Circuits for Generating High, Alternating Test Voltages

It is well known that – apart from a few exceptions – any electrical insulation system can be regarded as a capacitor with a high quality factor, i.e. a low active power in relation to the reactive power absorbed. Therefore, when testing equipment at high voltage with the system frequency or higher, the voltage generator is almost entirely loaded with reactive power. From this aspect test transformers are uneconomical and technically extravagant, because the reactive power gives rise to unnecessary losses in the various windings, and the voltage adjusting device, which is absolutely essential, has to be dimensioned for the full reactive power. Integral test installations, even when the test transformer is of very compact design [10], possess large dimensions and are very heavy. They are consequently far from ideal for on-site testing of SF_6 installations. It is therefore understandable that this method of generating the test voltage for high-grade insulating systems is often called the "brute-force" method.

The high reactive powers required for testing h.v. cables or capacitors provided the initial impetus at an early stage for the development of compensating circuits capable of relieving the load, at least on parts of the test voltage sources. The stages of this development are illustrated in Fig. 1, though only infinitely adjustable methods of compensation, possessing a resonance characteristic are taken into account.

In what is probably the oldest method (Fig. 1a), the variable or adjustable voltage source RT is indeed relieved of the greater part of the capacitive reactive power, but the test transformer has to be dimensioned for the full apparent power. The savings on the size and weight of the voltage adjustment elements are thus offset by the greater outlay for the reactors; however, the power consumption of the entire installation is appreciably reduced.

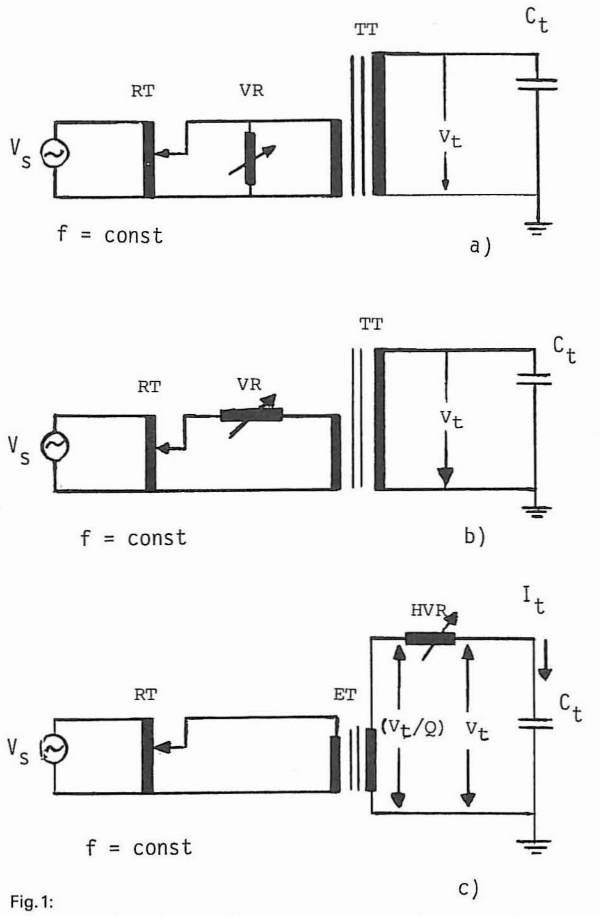

Fig. 1:

Different methods for capacitive load compensations for constant testing frequency

a. Low voltage parallel compensation
b. Low voltage series compensation
c. High voltage series resonant circuit

V_s AC input voltage
RT induction voltage regulator
VR variable reactor, low voltage
HVR variable reactor, high voltage

TT testing transformer
ET exciting transformer
C_t object under HV test
V_t test voltage
I_t load current

Often the arrangement in Fig. 1a results in the high test voltage V_t containing unwanted, strong harmonics because the leakage reactances of the test transformer and regulator RT form series resonance circuits together with the test object C_t. These circuits may be excited by harmonics in the system voltage V_t or current harmonics. This drawback is avoided in the arrangement shown in Fig. 1b, in which the variable compensating reactor VR is in series with the primary winding of the test transformer TT [4]. But the other advantages and disadvantages of the preceding arrangement are retained. This method is quite often used, sometimes in modified form [5]. But the overall weight of the equipment is not significantly reduced. A marked advance was, however, made when it became possible to construct reactors of variable inductance for high overall voltages [6], for which the principle of series resonance was primarily used (see Fig. 1c). This arrangement has rapidly found its way into practice in recent years [7, 8], the large, heavy test transformer having been replaced by the much lighter variable high-voltage reactor HVR. In this series resonance circuit the transformer is reduced to a mere excitation transformer ET of relatively low rating and voltage because it now has only to cover the active losses in the high-voltage components HVR and C_t. If Q is the quality factor of this series resonance circuit, the necessary secondary voltage of this excitation transformer is only V_t/Q, because it only has to provide the load current. It is quite evident that the capacitive reactive power of the test object is compensated in an ideal manner, thereby relieving optimally all the elements required for excitation. Even if, for reasons of insulation, the various h.v. reactors HVR can hardly be built for voltages higher than about 300–400 kV, it is nevertheless possible to obtain higher overall test voltages V_t by connecting several reactors in series.

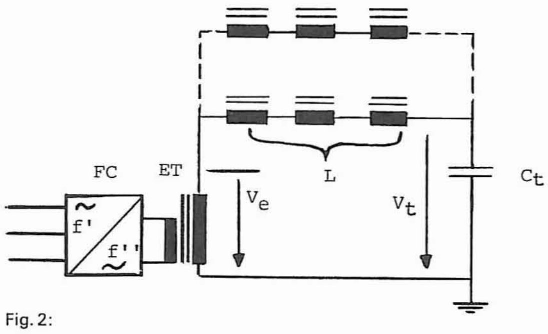

Fig. 2:
Schematic diagram of a HV-Series resonant circuit with variable frequency input voltage

From the power aspect the test transformers employed in the arrangements in Fig. 1a and 1b are directly comparable with the reactor in Fig. 1c. The simpler design of the reactor HVR, however, enables the weight per unit power to be reduced by a factor of about 3. Nevertheless, a weight of about 50 N per kVAr apparent output at test frequencies between 50 and 60 Hz must be reckoned with. This high specific value is caused by the rather complicated design, which is necessary for variation of the inductance over a sufficiently wide range. For this reason it has already been suggested that this kind of reactor be replaced by a combination of high-voltage transformer, low-voltage reactor and variable transformer [9], but this would once more increase the total weight of the equipment.

A further reduction in the size and weight of high-voltage test equipment can be achieved by operating the series resonance circuit as per Fig. 1c with a voltage V_s at variable frequency. Then there is no longer any need to vary the inductance of the reactor HVR in order to obtain the resonance conditions needed for generation of high output voltages. Moreover, the reactor can be built as a very small, compact unit with low weight. A circuit employing this principle is illustrated in Fig. 2 [11]. The voltage source with continuously variable frequency is a static frequency changer FC, which feeds the resonant circuit (L, C_t) through the exciter transformer ET. In [11] both the dimensions and the service characteristic were derived and it was shown that the high-voltage reactor L can conveniently by composed of a number of small elements if the frequency of the high test voltage V_t is to be maintained within close limits. The size of the reactor does not depend on the selected frequency. This means that it is not the reactive power $\omega C_t \cdot V_t^2$, increasing with the frequency, that governs its size, but rather the maximum energy $C_t \cdot V_t^2$ stored in capacitor C_t. A direct result of this is the major advantage that inductive voltage transformers, which would reach saturation at service frequency and high test voltages, are able to remain in the GIS installation. Therefore the series resonance circuit briefly described below was designed for a nominal frequency of about 100 Hz.

III. A Mobile 800 kV Series Resonance Circuit of High Output

The high-voltage reactors of this circuit were dimensioned in such a way that at a resonance frequency of 100 Hz and a voltage of 800 kV, it is possible to test a load capacitance of about 12 nF under short-time conditions for about 10 minutes. From the conditions for resonance

$$f_t = f_r = \frac{1}{2\pi\sqrt{L \cdot C_t}} \qquad (1)$$

the inductance L works out to about 200 H. Thus the rated current is 6 A. The total apparent power of the reactor, 4800 kVar was divided between four identical reactor units, each for 200 kV with an inductance of appr. 50 H, in order to enhance the flexibility of the equipment in application, thus resulting in the units being small and easily transportable. The weight of each reactor unit is only 3.75 kN, representing a ratio of weight to power of only about 3 N per kVA. The weight of this reactor makes it the heaviest single item in the test installation (the exciter transformer rated 50 kVA weighs 2 kN, the frequency changer rated 50 kW weighs 3 kN).

The complete installation is illustrated in Fig. 3, in which all four reactors are connected in series to provide a test assembly for 800 kV. The toroidal electrodes of conducting plastic material, which had to be very carefully dimensioned [12], are located between the reactor units; as separate elements they can also be easily transported and mounted on site. The frequency changer is a specially developed unit; the electronically controlled frequency variation in extremely fine steps at a constant output voltage of about 500 V enables the high voltage to be finely adjusted and kept stable, simply by utilizing the resonance curve.

According to eq. (1) the actual frequency f_t of the alternating test voltage with the series or parallel connection of the reactor units, as chosen in a particular case, is determined by the capacitance of the load C_t. During the on-site testing of SF_6 installations this value is given by the capacitance of the actual installation, but it is liable to fluctuate. At small values of C_t it is indeed possible to obtain a desired, tight frequency range by fixed additional capacitances of graduated values. But the fact remains that it is difficult to assure a given test frequency exactly. This drawback is offset by the advantage that by using a combination of reactors it is quite easy to keep within a narrow frequency range and, furthermore, it is possible to test quite high capacitances at reduced voltages. Since the range of application of a

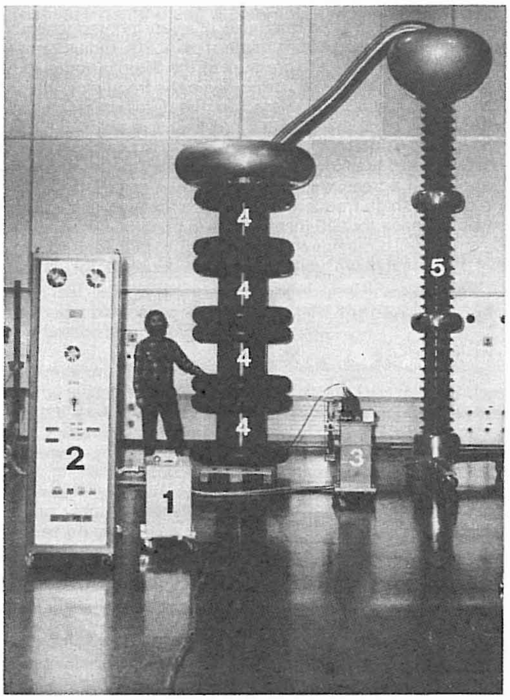

Fig. 3:

General view of the complete test set with 4 reactors in serie and the necessary components

1 isolating transformer
2 control unit, frequency converter
3 supply transformer
4 reactor
5 voltage divider

reactor is defined, on the one hand, by its nominal voltage, i.e. considerations of insulation, and on the other by the rated current (temperature rise and saturation of the iron circuit), but both quantities are independent of one another, the relationship between the maximum possible test voltage $V_{t\,max}$ of a series resonance circuit and the given load capacitance C_t for $C_t \geqq C_n$ is also given by

$$\frac{V_{t\,max}}{V_n} = \sqrt{\frac{C_n}{C_t}}\,, \text{ when } V_{t\,max} \leqq V_n. \qquad (2)$$

In this formula V_n and C_n are both nominal values, for which the rated current I_n is obtained at rated voltage V_n. From eq. (1) a similar relationship can be derived for the frequencies, i.e.

$$\frac{f_t}{f_n} = \sqrt{\frac{C_n}{C_t}}\,, \qquad (3)$$

in which f_n is the frequency occurring at the nominal values V_n and I_n (f_n = 100 Hz when U_n = 800 kV; I_n = 6 A, for the present dimensions of the reactors). Thus, according to eq. (2) it is possible to test insulation systems whose capacitance value C_t is considerably higher than the nominal value C_n. The lower frequency thereby derived from eq. (3) is however, mainly limited by the exciter transformer ET (Fig. 2), which may become saturated. If the frequency is too low, the quality factor of the reactors becomes also rather small. In the present case the installation was dimensioned so that test frequencies down to about 40 Hz can be generated, at which the quality factor Q is still at least 40.

Fig. 4 shows an evaluation of eq. (1), (2) and (3) for the installation illustrated in Fig. 3. The maximum test voltage $V_{t\,max}$ and the frequency f_t thereby obtained are shown for the following circuitry combinations:

1 : 1 reactor unit
2s: 2 reactor units in series
3s: 3 reactors in series
4s: 4 reactors in series

each in terms of C_t. Fig. 5 shows the same information for the combinations:

4p: 4 reactors in parallel
2p: 2 reactors in parallel
2s/2p: 2 pairs of reactors in series/parallel,

the conditions for a single reactor (1) being shown for comparison. For instance, if 300 Hz were specified as maximum permissible test frequency, it would be possible to use the 4s arrangement to test capacitances from 1.3 to 12 nF at the full voltage of 800 kV, during which the frequency would drop to 100 Hz. If the load capacitance were increased to 48 nF and the voltage reduced to 400 kV, the frequency would drop further to 50 Hz. But it is quite easy to restrict the frequency range to the selected dimensioning value of 100 Hz by employing the 3s, 2s or single-reactor arrangements at the maximum possible test voltages, as can easily be seen in the diagram. With parallel or series/parallel arrangements (Fig. 5) the field of application is, in principle, extended to very high test capacitances with correspondingly reduced voltages. With this equipment in the 4s arrangement it is thus possible to test a capacitance of 800 nF at a frequency of 50 Hz and a voltage of about 100 kV.

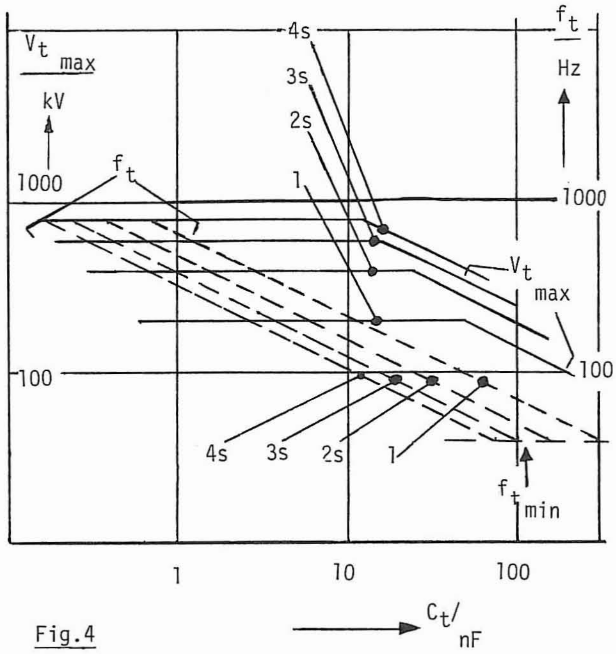

Fig.4

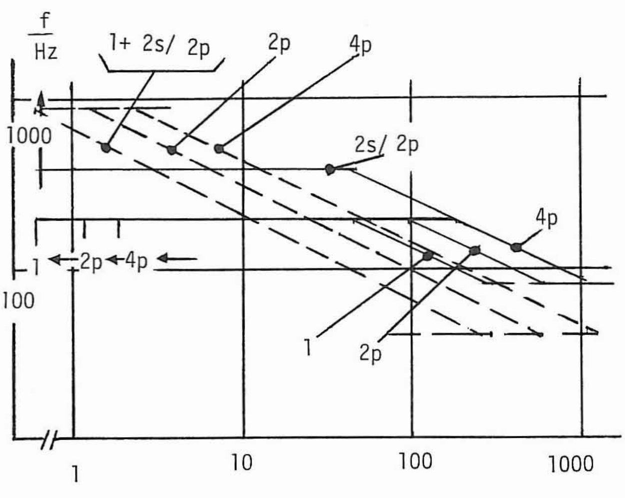

Fig.5

Fig. 4 and 5:

Diagram of voltage, frequency and capacity for various combinations of the reactor units

IV. Experiments

A series of practical experiments was carried out to determine the extent to which a test frequency differing from the industrial frequency affects the breakdown behaviour of GIS components when series resonance test circuits are used. The answer to this question is of importance, in that it has to be assured that a test voltage at elevated frequency of the order of 100 to 300 Hz enables equally clear and definite statements to be made as a test at the industrial power frequency.

1. Dependence on frequency

For the purposes of the test an experimental tank filled with SF_6 and containing a plate/plate configuration was used. In the middle of the plates there was a slight identation in which, for later tests, a cylindrical piece of insulation could be inserted. With a distance of 28 mm between plates and an SF_6 pressure of 350 kPa, this arrangement was tested with the series resonance equipment. The various frequency values were obtained by switching high-voltage capacitors in and out of circuit. In every case the voltage was raised until breakdown occurred. For the free gas gap (curve 1 in Fig. 6) the electric strength was found to remain constant up to above 300 Hz, following which a slight rise in the breakdown voltage was observed. For each test point about ten breakdowns were produced, from which the arithmetic mean was calculated. The diagram also shows the upper and lower measured maximum values.

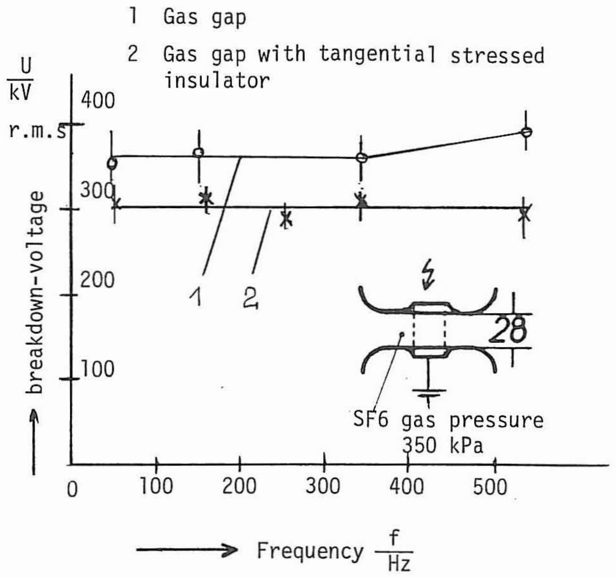

Fig. 6:

AC-Strength versus frequency for plate electrodes with and without insulator

Curve 2 also shows the relationship between the frequency and the breakdown voltage, but in this case when a supporting insulator was inserted. This epoxy insulator was loaded tangentially and reduced the breakdown voltage in the well known manner. For both of these basic arrangements the breakdown voltage was found to remain constant throughout the entire frequency range of interest. The 50 Hz points were obtained from measurements with a conventional test set and were obtained under otherwise identical conditions.

2. Dependence on pressure

Fig. 7 shows the familiar relationship between the breakdown voltage and pressure for the arrangement containing the supporting insulator. Here, too, the voltage was continuously raised with the series resonance test set and 3 to 5 breakdowns were produced per point.

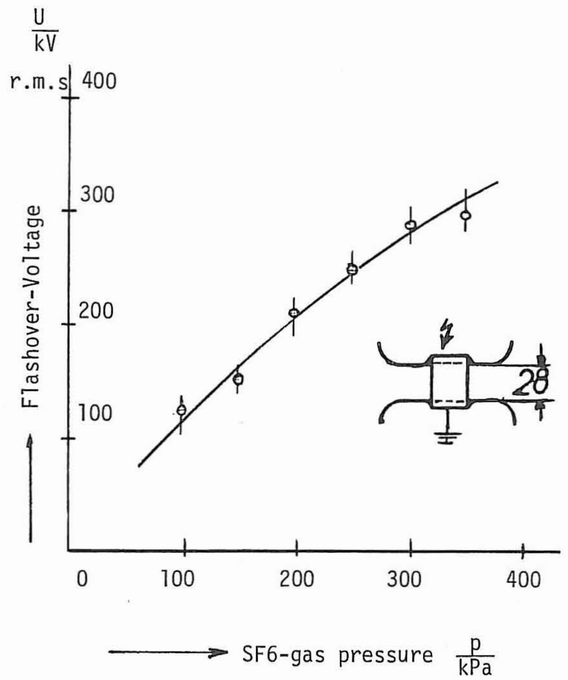

Fig. 7:

AC-flashover voltage as a function of SF_6-gas pressure at 330 Hz

3. Inhomogeneous arrangement

Also the relationship with pressure and frequency of a very inhomogeneous arrangement (point/plate, distance 40 mm, angle of point 30°, radius 2 mm) was investigated. Fig. 8 shows how the pressure of the SF_6 gas varies as a function of the breakdown voltage. The parameter is the frequency, which can be varied between 73 and 536 Hz. Here, too, the (familiar) result was obtained, the test voltage initial rising with increasing gas pressure. This maximum then changes to a minimum and finally begins to rise again. Here the relationship between the breakdown voltage and the frequency in the lower pressure range also agrees well with the known results [13]. This dependence on frequency (high frequencies also result in high breakdown voltages) is of no significance for GIS installations in practice because the pressure normally employed is outside this range. At 350 kPa, for instance, Fig. 8 shows that the breakdown voltage remains constant for all the measured frequencies.

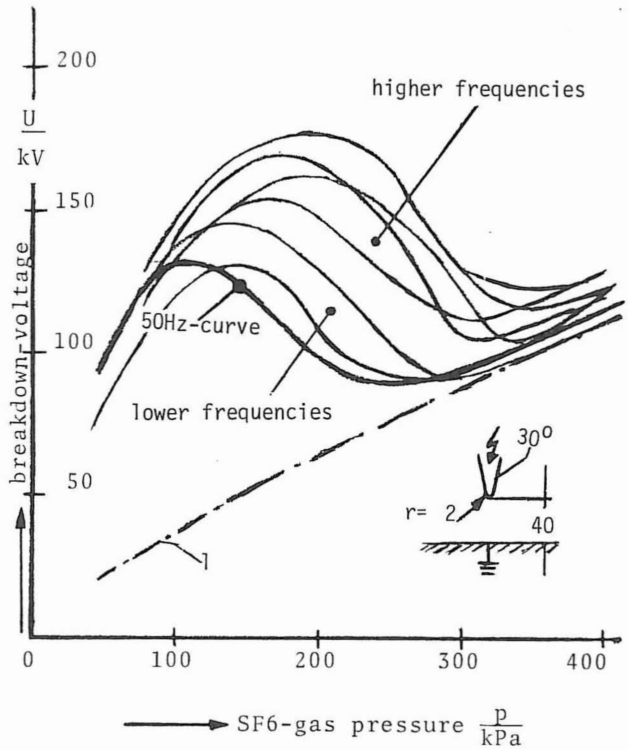

Fig. 8:

AC-breakdown voltage as a function of SF_6-gas pressure at frequencies Between 73 Hz and 536 Hz

1 Theoretical calculated minimal voltage (13)

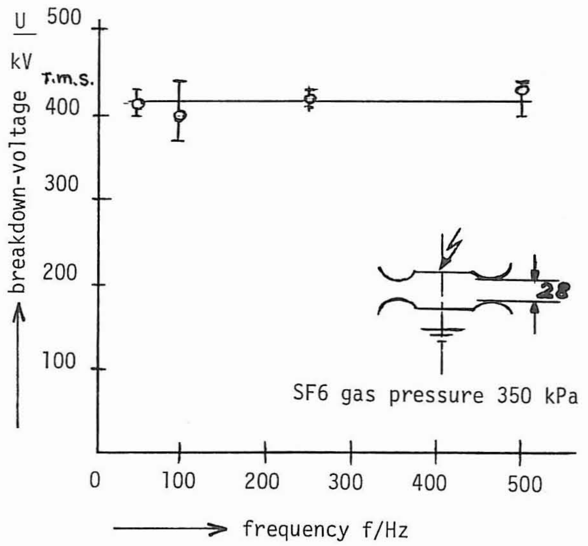

Fig. 9:

AC-breakdown voltage versus frequency, using a conventional test transformer

4. Measurements using a conventional test transformer

In addition to the measurements with the series resonance test set, the breakdown values were determined for a gap filled with SF_6 gas using a frequency different from 50 Hz, generated by a conventional converter. The frequency was set to 50, 100, 250 and 500 Hz. The test arrangement, as far as the geometry was concerned, was no different to that previously used, but the material used for the electrodes was. In this case they were specially hardened and chromium-plated. Fig. 9 also shows that the insulating gas behaves in the same manner at frequencies between 50 and 500 Hz, i.e. the breakdown voltage remains constant. The generally higher and more constant breakdown voltage compared with Fig. 6, curve 1, may be explained by the fact that the specially hardened electrodes were used. Owing to the resultant high quality factor of the electrode surface, the breakdown voltage rises by about 10% (compared with the previous simple aluminium electrodes) and, what is more, no formation effects are observed. Consequently in the upper part of the frequency range in the region of 500 Hz, no increase in the breakdown voltage was observed.

5. Discussion of results

From the measurements taken and illustrated it is quite evident that conventional test transformers and series resonance equipment, when employed under the same conditions, yield the same results. Both physical and practical results are equally attainable with both methods. This particularly applies to the frequency range investigated, ranging from the normal power frequency to several hundred Hz. This result is just as gratifying for the user of series resonance tests sets as it is for the customers, who can agree to their use on site without any hesitation.

V. On site experience

Meanwhile the series resonant test set was tested and used on-site by different customers of GIS-installations. The following table shows the listing of tested switchgears and gives the actual and characteristic datas resulting from test equipment, number of reactors, circuit, capacitance and so on:

Country	System voltage	Works-testing		On-site-testing			
		Type Test	Routine Test	Test voltage	Fre-quency	Number of reactors	Test duration
	U_m / kV	BIL / kV	AC-testv. / kV (r.m.s)	AC- / kV (r.m.s)	f / Hz		S
Switzerland	150	750	325	260	≈230	2 Series	60
Germany	150	750	325	260	100	2 Series	60
Norway	420	1425	630	504	115...230	3 Series 4 Series	60 to 120
Norway	420	1425	630	520	70...90	4 Series	60
Switzerland	420	1425	680	544*	110	4 Series	60
*additional test oscillating switching surge							

Table: Examples of on site high voltage tests conducted on complete assembled switchgear by means of the series resonant test set with variable frequency

All tests were done phase by phase. During the tests of installations with a rated voltage of 420 kV, in two cases remarkable faults were detected. Once, an insulator flashover occured because of pollution with metal particles and the other time a radius that was not carried out correctly caused a breakdown. After having finished and cleaned everything all tests were realized without any trouble and the behaviour of the GIS switchgear was correct. The tests were performed in open-air whereby particulary temperatures down to −15 °C, snow (see Fig. 10) and rain complicated the situation – but problems did not appear.

The duration of assembling the test set was less than half a day and included not only the transport of the device of some kilometers distance to the customer but also unloading of the components from the lorry, assembling of the reactors and shieldings to a complete cascade, the set up and the putting into service of the various service transformers and of the control unit. Once more it should be pointed out the real small weight of about 20 kN for the complete arrangement and the resulting high flexibility. Regarding the possibility to connect the reactors in any combination (serial, parallel or mixed up) to a cascade one is able to control current, voltage and frequency very individual, only according to conditions and own wishes.

VI. Conclusions

1. Resonance circuits are presented as an interesting method of testing objects with a high capacitance, such GIS installations or cables, especially when such tests have to be performed on site. It is found that series resonance circuits with constant inductance but variable frequency are well suited. For the metal-enclosed installations tested so far, the test frequency was between about 80 and 235 Hz, depending on the capacitance of the tested object. This range can be extended by dimensioning the reactors differently or by modifying the test circuit (additional capacitance, or other reactor arrangements), to suit the particular requirements.

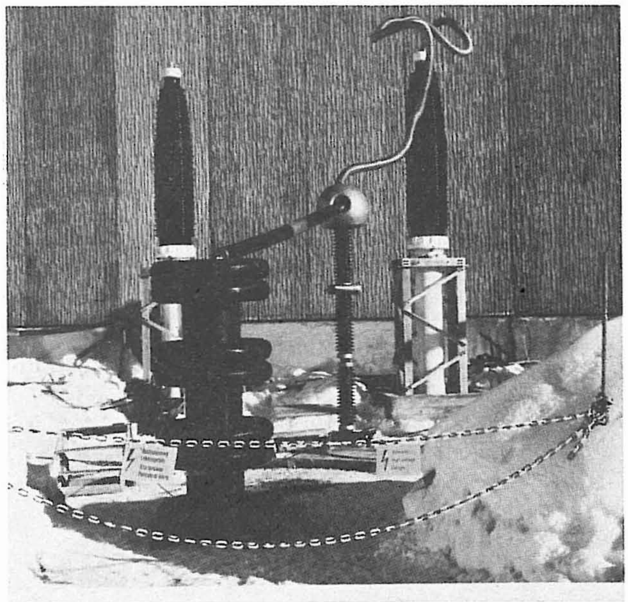

Fig. 10:
On site test in Norway.

2. A test at alternating voltage performed with a series resonance test set of the kind described in a frequency range extending from 50 to about 300 Hz has no influence on the breakdown values of the object tested.

3. The same applies to free gas gaps and gas gaps containing an insulator.

4. Experiments also carried out at different frequencies (between 50 and 500 Hz), but generated by conventional test transformers, also yielded constant breakdown voltages and exhibited no differences from breakdown at 50/60 Hz.

5. The IEC rules currently in force recognize the higher test frequency in this case.

6. An alternating voltage test performed at elevated frequency is therefore acceptable without hesitation. If the duration of the test is the same as before at 50/60 Hz, the test may prove advantageous for the customer because the object is subjected to a larger number of voltage peaks in the same time.

7. This is confirmed by on-site tests performed on GIS installations at rated voltages up to 420 kV, which have demonstrated the practical, flexible and easy handling of series resonance test sets with variable frequency as a means of performing alternating voltage tests.

References

[1] P. Högg, W. Schmidt, H. Strasser: Dimensioning of SF_6 Metalclad Switchgear to Ensure High Reliability. CIGRE paper No 23–10, 1972

[2] W. Schmidt, P. Högg, A. Eidinger: On-site High Voltage Testing of SF_6 Metalclad Switchgear Installations and Compressed Gas Insulated Cable. BROWN BOVERI Review, No 11, Nov. 1977, Vol 64

[3] K. Feser: High Voltage Testing of Metal-enclosed, Gas-insulated Substations on-Site with Oscillating Switching Impulse Voltages. Hadely E 1 – 44, 1. Edition

[4] A. Braaten: Improvements in or Relating to High Voltage Testing Equipment. Great Britain Patent No 646.756, Nov. 29, 1950

[5] E. Kuffel. M. Abdullah: High Voltage Engineering. Pergamon Press, 1970

[6] Peschel: United States Patent No 3.515.986, June 1970

[7] S. A. Boggs, P. Kirkby: A Resonant Surge Field Test for SF_6-Switchgear, IEEE – Trans. PAS Vol. PAS – 100 (1981), p. 1881–1884

[8] R. Reid: New Method for Power Frequency Testing of Metal Clad GIS and Larger Rotary Machines in the Field. Proceedings of World Electrotechnical Congress, Moscow, 1977, Rapport 29, Sect. 1

[9] Ch. H. Tutle: High Voltage Resonant Testing Circuit. United States Patent No 3.781.667, Dec. 25, 1973

[10] U. Brand, H. Dietz, H. Eberlein: A Metalclad Testing Set with Voltage Transformers for GIS. Proc. of 3. Intern. Symp. on HV Engg, Milan 1979, Report 43.16

[11] F. Bernasconi, W. S. Zaengl, K. Vonwiller: A new HV-Series Resonant Circuit for Dielectric Tests. Proc. of 3. Intern. Symp. on HV Engg, Milan 1979, Report 43.02

[12] B. Bachmann: Multitoroids for Controlling and Shielding. Proceedings of World Electrotechnical Congress, Moscow, 1977, Rapport 105, Sect. 2

[13] S. Sangkasaad: Dielectric strength of compressed SF_6 in nonuniform fields. Doctoral theses, ETH Zürich, Switzerland, 1976

Extrait de la *Conférence Internationale des Grands Réseaux Electriques*
Session de 1982
IMPRIMERIE LOUIS-JEAN – 05002 GAP

E R R A T A

to C I G R E P A P E R 23-07

Location	now reads	should read
equation (1)	$= \frac{1}{2\pi}\sqrt{LC_t}$	$= \frac{1}{2\pi\sqrt{LC_t}}$