

An Universal Test Equipment for Metal-Oxide Surge Arresters without Gaps for AC Systems According IEC-Standard /1/

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AN UNIVERSAL TEST EQUIPMENT FOR METAL-OXIDE SURGE ARRESTERS WITHOUT GAPS FOR A.C. SYSTEMS ACCORDING IEC-STANDARD /1/

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Abstract

An universal test system for all tests of the metal-oxide arresters (MOA) according /1/ is presented. It consists of an impulse current generator for both exponential and long duration current impulses and a corresponding AC-test system. This installation is suitable for testing of all MOA-sections up to the rated voltage of $U_r \leq 12$ kV as well as for IEC line discharge classes 1 to 5. Also the high lightning duty-MOA can be tested with the prescribed high energy current impulse 30/80 μ s, 40 kA.

1. Introduction

When the earlier used Silicon Carbide (SiC) Arrester, which always had a series spark gap, were widely replaced by the gap-less Metal Oxide Arresters (MOA) a new International Standard for testing of MOA was introduced in 1991/1/. A fundamental point was the arrangement for testing "Long duration current impulse withstand test".

The earlier Standard /2/ which was valid also for the SiC Arrester with series spark gap. According to this the test circuit as well as the required charging voltage had to be dimensioned so as to achieve data according to Table 5 for "Long Duration Discharge Class" of the arrester and the "Rated Voltage of the test sample". This was understandable as the series spark gap, which was often equipped with magnetic blow, made is difficult to estimate accurately the amount of energy transferred in the non-linear resistance of the arrester. The disadvantage of this type of arrangement for the test circuit lies in the fact that for each rated voltage of the test object (U_r) which usually are in the range of 3 kV to 6 kV (often up to 12kV), a new test circuit with completely different circuit elements is necessary (see further "procedure a").

According to /1/ the purpose of the "Long duration current impulse withstand test" on MOA shall demonstrate the ability of the resistor elements to withstand possible dielectric and energy stresses without any damage. IEC 99-4 describes two possibilities to perform Line Discharge Tests on heavy duty arresters up to 20'000 A:

Procedure a)

A specific generator circuit is defined and a particular value of the charging voltage for all five line discharge classes of arresters, and this for every particular rated voltage U_r . If all classes of arresters must be tested the

user must have five different generator circuits for every value of rated voltage U_r to be tested. Such a generator would have, $5 \times 7 = 35$ different test circuits for 7 values of rated voltage between 3 kV and 12 kV. Testing of arresters with different rated voltages belonging to different line discharge classes requires every time a different generator configuration charged exactly to the charging voltage given in Table 4 to ensure that the correct energy

$$W = U_{res} \cdot (U_L - U_{res}) \cdot 1/Z \cdot T$$

is injected into the test sample (U_{res} : lowest value of the switching impulse residual voltage, U_L : charging voltage, Z : surge impedance of the test line, T : virtual duration of the long duration current impulse).

This design philosophy provides a straight forward test procedure. I.e. every type of arrester is tested exactly with the appropriate pre-defined test circuit. However, it results in a very inflexible test system and a complicated operating mode of the generator if many different types of arresters have to be tested and the circuit has to be changed for every type. "Procedure a" requires at least a large number of taps on the inductors as well as many single capacitors of the impulse shaping line in order to change the generator surge impedance Z defined in Table 4 for all classes and all rated voltages U_r . Nevertheless a test circuit for long duration (rectangular) pulses once matched for a particular class can in most cases not be adapted for different rated voltages U_r .

The following disadvantages of "procedure a" must be noted:

- Only a limited number of discrete values of rated voltages of arresters can be tested with a particular generator;
- at a later time the generator cannot be easily adapted to test arresters with other rated voltages;
- the energy injected into the arrester varies strongly from case to case since the residual voltage of an individual arrester can change up to 10 %
- with this "procedure a" it is not possible to test the energy effectively dissipated in the arrester during later operation (a detailed discussion of the mentioned disadvantage is given in the paper of Bargigia, Mazza, Carrara and de Nigris /3/).

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Procedure b)

As an alternative IEC 99-4 offers the possibility to utilise any impulse current generator fulfilling the required test characteristics (i.e. the virtual duration of the impulse shall be as specified in /1/, table 4, the oscillations or initial overshoot shall not exceed 10 % of the peak of the current value and the energy W for each impulse on each test sample shall be between 100 and 110 % of the above calculated value). This "procedure b" is described and explained in full detail also in /3/.

The impulse current generator described below follows this "procedure b" and allows to test arresters with every rated voltage comprised between 3 kV and 12 kV with one single generator and without any modification of the test circuit. With this "procedure b" the number of taps and generator modifications for long duration current impulses is reduced to only 4 different test circuits since changes of the test circuit are necessary only for adjustment of the 4 different pulse lengths involved with testing of the 5 different classes. All other parameters are set only by adjusting the charging voltage of the generator to a pre-defined value. As compared to "procedure a" a much higher flexibility of the operation is therefore achieved and testing of many different types of arresters in strict accordance with IEC 99-4 becomes much easier.

2. Concept of the Test system

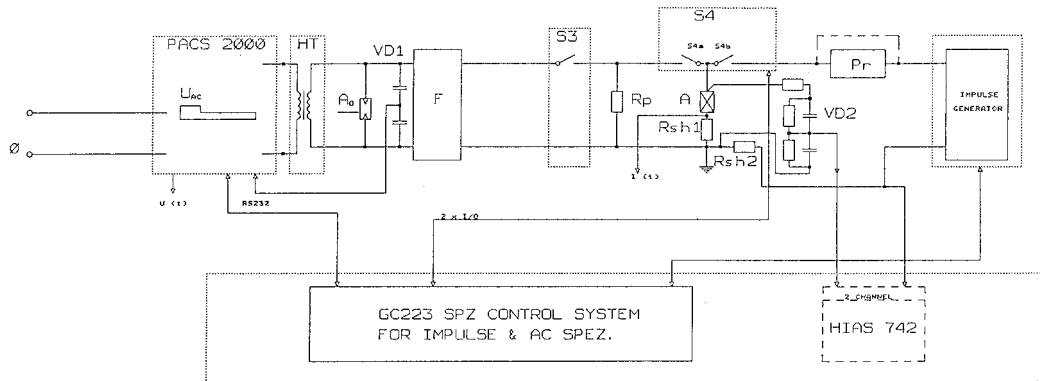
The arrester test system described here was designed to achieve all the current and energy tests (operating duty test equipment) respectively as foreseen in /1/. The only exception is "Power frequency voltage versus time characteristics of an arrester" according to Point 5.10, for which a much more powerful AC source would be necessary.

The overview of the presented test system is given in block diagram fig. 1. With this following individual tests are basically possible:

- a) Impulse Current test on MOA only (i.e. Exponential and rectangular wave respectively); Switch S4b "on"; S4a and S3 "off".
- b) Impulse Current Test of MOA with simultaneously applied AC voltage (UAC); Switch S3, S4a and S4 b "ON".
- c) Impulse current test of MOA and subsequently (within 100 ms) AC voltage test; first switch S3 and S4b "ON" and later S4a "ON", S4b "OFF".

Following is a short description of the individual tests.

Fig. 1
Diagram of the "Operating Duty Test"-equipment for MOA according /1/



COMPONENTS OF THE TEST EQUIPMENT
A = TEST OBJECT (ARRESTER)
Ao = PROTECTING ARRESTER
F = LOW-PASS FILTER
HT = HIGH VOLTAGE TRANSFORMER
Pr = GENERATOR PROTECTING COMPONENT
PACS = VOLTAGE REGULATING DEVICE

Rp = POTENTIAL RESISTOR
Rsh1 = AC CURRENT SHUNT
Rsh2 = IMPULSE CURRENT SHUNT

S3 = DISCONNECTING SWITCH (MANUAL OPERATION)
VD1 = AC DIVIDER
VD2 = IMPULSE VOLTAGE DIVIDER

SWITCH S4

POSITION OF SWITCH	S4a	S4b	TEST WITH	...	PROTECTIONS	
			ac	IMPULSE	F	Pr
OFF	ON	-	X	(X)	-	-
ON	ON	X	X	X	X	X
ON	OFF	X	-	X	(X)	-

(X) out of use

As further advantages of the design described below it is obvious that

- the energy dissipated in the arrester under test is much better reproducible than with "procedure a" and meets the calculated value much better since a measurement of the residual voltage on the test sample is made prior to the impulse current test;
- the same generator can be used for high current pulses and for rectangular long duration pulses, the time necessary for re-configuration is just 15 minutes;
- the very low inductance of the concentric generator design allows generation of all IEC pulse shapes down to $1/20 \mu s$.

2.1 Impulse current generator

As already mentioned in the "Introduction" the Generator is designed to perform all Impulse current tests (i.e. both exponential and long duration current impulses) on MOA sections with rated voltage up to $U_r = 12 \text{ kV}$.

2.1.1 Test circuits for exponential current impulses

The determining factor for the energy of the combined generator was the Impulse wave 30/80 μ s, 40 kA which is necessary for tests according to /1/ Annex C (i.e. for "High Lighting Duty Arresters"). The optimisation of generator parameters is described in /4/ and /5/ and will not be discussed here.

Due to a low inductance design of the generator, the current impulses 4/10 μ s, 120 kA and 8/20 μ s, 50 kA could be achieved with much higher amplitudes. For the realisation of the current impulse 1/<20 μ s special measures to reduce the circuit inductance were necessary. The measured two critical current impulses (i.e. 30/80 μ s, 40 kA and 1/<20 μ s, 20 kA) are given in fig. 2.

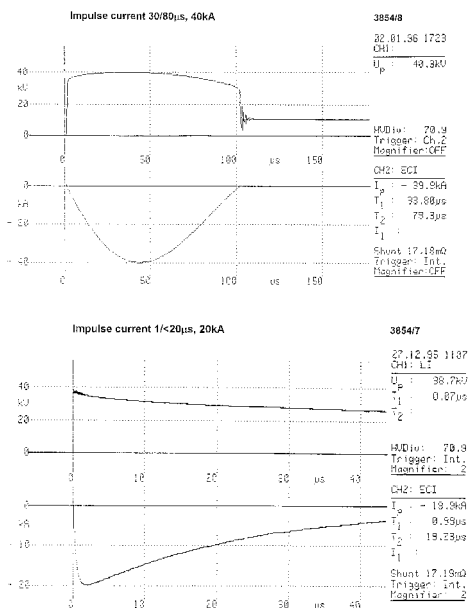


Fig. 2 Exponential current impulses.
a) Impulse 30/80 μ s, 40 kA;
b) Impulse 1/<20 μ s, 20 kA

2.1.2 Test circuit for long duration current impulses

The generator is designed for 5 IEC-long duration current impulses according to /1/, namely for

- IEC-Cl. 1 T = 2000 μ s, Wdes \leq 15 kJ
- IEC-Cl. 2 T = 2000 μ s, Wdes \leq 30 kJ
- IEC-Cl. 3 T = 2400 μ s, Wdes \leq 45 kJ
- IEC-Cl. 4 T = 2800 μ s, Wdes \leq 55 kJ
- IEC-Cl. 5 T = 3200 μ s, Wdes \leq 65 kJ

(Wdes = max. required energy losses in MOA for $U_r = 12$ kV)

For the realisation of the necessary Rectangular Impulses (see /1/ tab. 4) the required energy transfer in test object is decisive. The general design problems of the test line are described in /6/. The basis for the determination of the energy transfer is given in /1/ Annex E, fig E.1. These values of specific energy are summarised in the following table.

Tab 1 Specific energy for arresters 10 000 A and 20 000 A according to /1/

Line discharge class	Minimal switching residual voltage p.u.	Virtual duration of current peak T (μ s)	Specific energy W' (kJ/kV)	Test current (A)
1	2.0	2 000	1.0	200
2		2 000	2.0	400
3		2 400	3.0	500
4		2 800	4.2	600
5		3 200	5.0	625

The current values are estimated as $\approx W/(U_a T_{eff})$ with effective Impulse duration $T_{eff} \approx 1.25 T$.

The energy efficiency η_w of a real network test circuit must be taken in consideration (s. fig. 3). In fig. 4 are given the measured long duration impulses for IEC-classes 1 and 5.

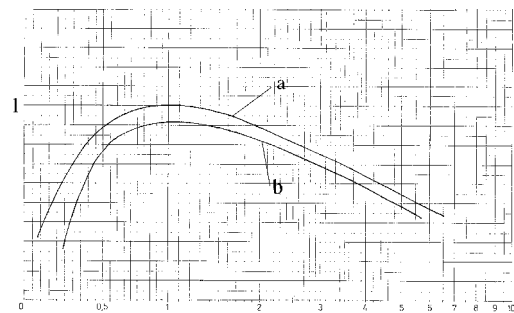


Fig. 3 Energy efficiency of the network η_w as function of the termination impedance $RA \approx U_{res}/I$
a) for loss-free network (see /5/)
b) for a real network with losses

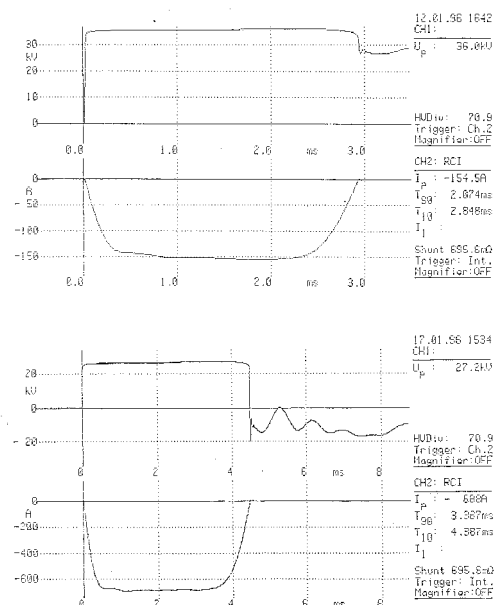


Fig. 4 Long duration current impulses
a) for IEC-class 1;
b) for IEC-class 5

In fig 5 is shown the arrangement of the combined generator for exponential-and rectangular impulse currents. It consist mainly of a 100 kV-capacitor bank of 12 units, which are distributed radial around the central spark gap in order to obtain a minimal self inductance of the concerning test circuits. The coils for the network are made as solenoids and are placed outside on the ground in vertical position.



Fig. 5 Test equipment for "Operating Duty Test" according /1/

2.2 A.C. test system

The A.C. test system consist of following parts (see fig. 1):

- A special developed AC-control unit PACS 2000, which makes possible to adjust in advance, as prescribed by /1/, both test voltage level and test duration.
- The one phase high voltage transformer (HT), which is designed to satisfy all IEC-requirements for "Operating Duty Test" of MOA with rated voltage up to $U_r \leq 12$ kV
- Protecting devices. The high voltage transformer is protected by a correspondingly designed voltage arrester Ao.

This is specially important, because the voltage level of the impulse current generator is much higher than the high voltage of the transformer. For the case if the generator would be discharged, by mistake, on a test sample with a very high impedance, the transformer is protected by Ao. The low pass filter F (see fig. 1) has in the first line the function to reduce the steepness of the voltage impulses on the transformer high voltage side, which could be dangerous for insulation between the turns of the high voltage coil.

d) The Disconnecting switch S3 serves only for visible separation of the AC supply from the other part of the test installation.

e) The multi contact commutation switch S4 is made of two parts, i.e. switch S4a and S4b (see fig.1). The first part of the switch with a fast contact S4a serves to connect respectively disconnect the AC-voltage from the test sample according to the IEC-standard for "Operating Duty Test" (i.e. in a time less than 100 ms). The second part, S4b serves in the same way to connect respectively disconnect the impulse current generator. The possible combinations in the positions "off" resp. "on" for both S4a and S4b is also given in fig. 1.

f) AC current measuring shunt Rsh1 (see fig.1), serves for measurement of AC-leakage current. It is made in such a mode, that at high current impulses its impedance becomes neglectible. Against that at the AC-leakage current of approximate 1 mA its impedance is high enough, which makes possible to perform the measurement.

3. Operating duty test (ODT)

According to IEC-standard IEC 99-4 the arresters must be stressed both with UAC and different impulse currents. For these tests the following two test procedures can be distinguished:

- The impulse current stress is applied at the same time with UAC (conditioning test, see IEC 99-4, fig. 1; 2 and C.1;)

For this test arrangement both contacts of the switch S4 (i.e. S4a and S4b s. fig. 1) are in position "on". The test circuit is in this case switched for the required rated impulse current 8/20 μ s. At this test procedure the generator protecting unit Pr must be always included in the test circuit. The function of Pr is to interrupt the connection between AC-supply and the impulse generator after its discharge (s. fig. 6).

- The impulse current stress is applied before the UAC is connected to the test sample (high current impulse-and switching surge ODT - see IEC 99-4, fig. 1÷4, C.1 and C.2)

The protecting unit Pr is not necessary here and must be removed. At the beinning of the test with any impulse current, the switch S4b is in position "on" and

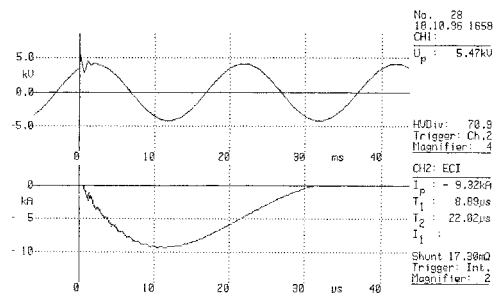


Fig. 6 Checking of the UAC-switching-on time ($t_{sw} < 100$ ms) after impulse test.

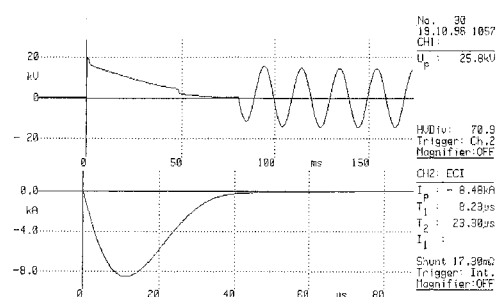


Fig. 7 Conditioning test of MOA according /1/ (discharge of the generator at 90°elec.)

the switch S4a is "off". Immediately after last discharge of the generator, but in a time less than 100 ms, the switches S4a and S4b will change the position (i.e. S4a in position "on" and S4b in position "off"). In this way the connection between AC-supply and the impulse generator will be prevented (s. fig. 7).

4. Summary

A multi purpose test equipment has been presented for metall oxide arrester sections with exponential current system, long duration current impulses and operating duty test.

5. References

- /1/ International standard IEC 99-4, 1991-11
Surge arresters. Part 4: Metal-oxide surge arresters without gaps for a.c. systems,
- /2/ International standard IEC 99-1, 1991-05
Non-linear resistor type gapped surge arresters for a.c. systems,
- /3/ A. Bargigia, G. Mazza, G. Carrara, M. de Nigris
Evolution of long duration current impulse withstand test on surge arresters for H.V.A.C. systems. IEEE Transactions on Power Delivery, Vol. PWRD-1, No 4, Oct. 1986
- /4/ M. Modrusan
Realisation of the prescribed exponential impulse currents for different kinds of test samples. International symposium on high voltage engineering, Zürich, 3.-9. Sept. 1975

- /5/ M. Modrusan
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