IMPROVEMENT OF IMPULSE TEST SYSTEMS USING A SPACE SAVING DESIGN TOGETHER WITH A CORRECTION ALGORITHM OF A SYSTEMATICAL MEASUREMENT FAILURE

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Abstract: Impulse testing is a part of routine testing of power transformers. Due to the high investment cost for the building of a high voltage test laboratory a space saving arrangement is a major demand on the test system. The easy handling in order to save time during the preparation and the post preparation of the test circuit is another demand. To fulfill both requirements a new approach leads to integrate chopping gap, high voltage divider and overshoot compensation in one component, which is shown in the current paper with the new developed component "Connection Point". The Connection Point is able to measure chopped lightning impulses correctly after the chopping process. How the common practice shows another way is to simplify the test circuit by placing the voltage divider between the impulse generator and the test object. In this case the test field engineer has only to change the high voltage connections between divider and the test object. In contradiction to that the IEC standard 60060-2 defines the correct arrangement by placing the divider in parallel with separate high voltage connection to the test object in order to reduce the systematical measurement failure. In this case the test field engineer has to install more high voltage connections. The value of the peak voltage can differ up to 1% provoked by different arrangements of the voltage divider. However, the current paper shows how the systematical measurement failure of both circuit arrangements can be corrected. Practical measurement results demonstrate the suitability of the developed correction algorithm.

1 INTRODUCTION

Many manufactures of power transformer renew their production and their high volt laboratories. Those laboratories are integrated into the producing process of the factory. High investment cost of the building lead to the requirement of a space saving construction of the test equipment. An easy handling and a time saving test procedure is the other major requirement on the test systems. According to the common trend of increasing operation voltages of the transmission grids, most transformer producer will extend their product portfolio with the corresponding components. This leads to the consequence that the laboratories have to be dimensioned with the new voltage levels. The high voltage test for power transformers consists of the following test procedures:

- Induced voltage test
- Applied voltage test and
- Impulse voltage test.

The most relevant standards are the horizontal IEC standard 60060-1 and the component related IEC standard 60076-3. They refer apparatuses with an operation voltage levels only up to 800 kV. For ultra high voltage (UHV) equipment (above 800 kV) new testing voltage levels are under discussion. Some proposed reference data is summarized in table 1. In addition to the proposed data type and development tests will require test voltage levels for example for impulse voltage test up to U_{LI} = 3000 kV. Especially the impulse voltage test system requires more space because of the high switching impulse levels. With respect to the mentioned fact a space saving construction is highly requested.

Table 1: proposed testing voltage levels for UHV power transformer routine tests

Operation Voltage of Transformer in kV	Maximum Switching Impulse Voltage in kV (routine test)	Maximum Lightning Impulse Voltage in kV (routine test)
800	1700	2100
1100	1800	2250
1200	1800	2250

Especially the impulse voltage test system requires more space because of the high switching impulse levels. With respect to the mentioned fact a space saving construction is highly requested.

The entire organization of the test laboratory gets an important issue. The material flow in a transformer factory has to be considered. In order to provide an efficient testing process easy handling and time saving solution for the preparation and post preparation of the test set up is highly recommended.

The mentioned criterions have to be taken in account by planning all three test system but in the current paper the impulse test system shall be in the main focus.

2 STATE OF THE ART

Impulse test system consists of the components:

- Generator
- Chopping gap
- High Voltage divider

Especially in the UHV range an overshoot compensation is required as a fourth component. The layout of the common arrangement is shown in figure 1.

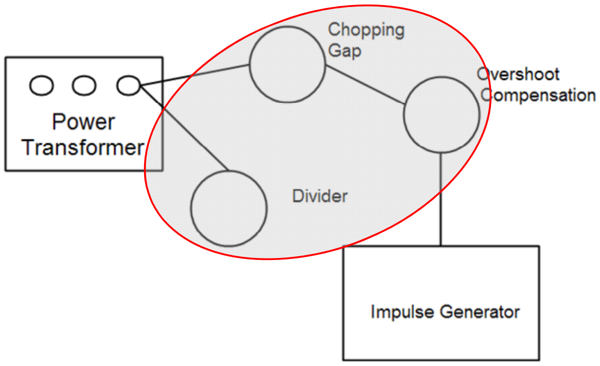

Figure 1: Common layout of an impulse test system containing divider, overshoot compensation and copping gap.

The distances between the individual components have to be taken in account. Therefore the entire test system reaches a remarkable dimension.

At the UHV range the distances increases. The increasing circuit leads to an increasing natural (physically given) parasitic inductance of the test circuit. Moreover, power transformers of the UHV range have higher winding capacitances, in some cases more than C_{Load} = 5 nF. Both mentioned facts lead to the problematic case to keep the permitted maximal front time of T_1 = 1.58 μs and the maximal permitted overshoot β = 10% [IEC60-1]. This topic was broadly discussed in [1].

As mentioned an overshoot compensation is recommended for testing of power transformers with high load at the UHV range. In [1] a comparison between serial and parallel compensation has been done. The main question of the development was how to match the requirements of time and space saving construction with the technical requirements of the IEC permitted parameters.

3 THE CONNECTION POINT

The basic idea of the connection point was to integrate the functions of wave shaping and measuring elements in one single component. Another idea was to omit one high voltage connection. In most cases they are realized by thin copper foils (200 mm bright) to reduce the parasite inductive influence. Because of the sharp edges they are not easy to install. Both ideas lead to the consequence to put the chopping gab and the high voltage divider on one single base frame and to give the one singe top electrode. But the smartest point was to integrate the overshoot compensation into the chopping gab. Its capacitors can be used as compensation capacitors. The resistors and a well chosen inductive component can be adapted to reach a high damping effect.

Figure 2: Picture of a Connection Point CO 1800 DOC (D => divider, O=> overshoot compensation C=> chopping gap).

Figure 2 shows an connection point CP 1800 DOC with the main parameters U_{LI} = 1800 kV and U_{SI} = 1200 kV what is a fairly right performance to test power transformers with a system voltage up to U = 420 kV. The layout of the testing circuit is shown in figure 3. Thereby the connection point is connected with separate HV connections to the test object. However one HV connection can be omitted. The dimension of the entire test system is reduced in comparison with the common layout.

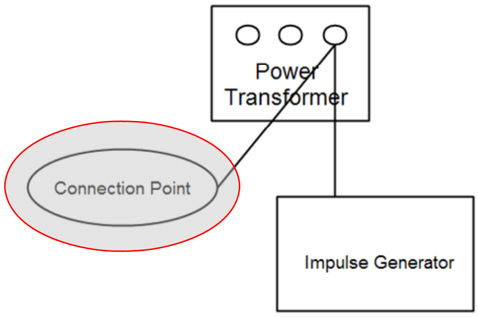

Figure 3: Layout of an impulse test system containing connection point.

The equivalent circuit is shown in figure 4. The generator consist of the discharging capacitor C_S the spark gap SG the damping resistor R_D tail resistor RE and the parasitic inductance of the generator L'_G. The other parasite elements of the testing circuit ar indicated with CP and L´S. The test object has the capacitance C_T. The Connection Point has the compensation elements R_C, L_C and C_{AFC}, C_U indicates the capacitor of the measurement divider.

In some cases the high voltage divider and the chopping gab shall be used as single components. For this purpose the connection point can be used as divisible construction.

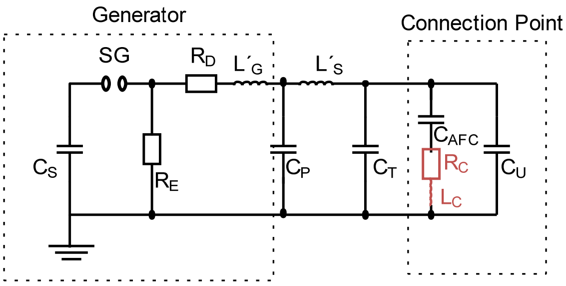

Figure 4: Equivalent circuit diagram of an impulse test system containing connection point.

The compensation can be installed near the test object. By this manner the inductance of the entire testing circuit can be compensated. If the compensation is installed in the generator, only the parasitic inductances of the generator will be compensated. The omitted copper foil reduces the parasite inductance of the testing circuit.

The damping effectiveness is shown with an example in figure 5. A load of C_{Load} = 7 nF is tested whereby the red line, uncompensated, has an overshoot of 10.7 % and a front time of T_1 = 1.62 µs. In contradiction to that the green line, compensated has an overshoot of 4.2 % and a front time of T_1 = 1.54 µs. A typical overshoot frequency which is round about f_{OV} = 450 kHz can be observed.

In any cases the overshoot frequency is between 250 kHz and 600 kHz. In relation to that R_C and L_C can be chosen to realize a smooth damping behaviour. The effect is that in a brought load range, what means in many test cases the configuration of the overshoot compensation does not need to be changed.

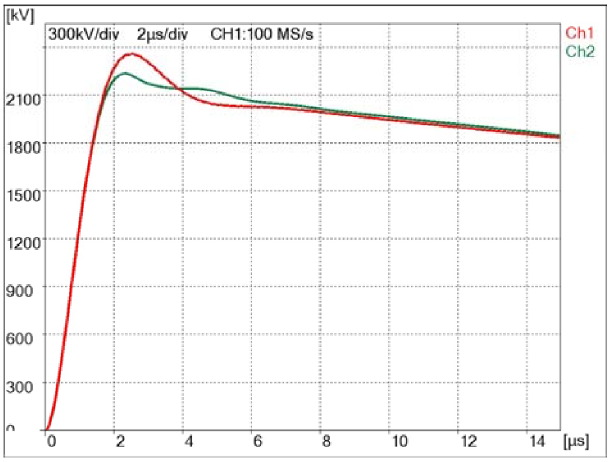

Figure 5: comparison between a compensated and uncompensated lightning impulse

4 POSSIBILITIES OF ARRANGEMENT

In principle the IEC standard 60060-2 [4] requires the installation of the high voltage divider in parallel to the test object with separate connections in order to minimize the measurement failure of the system as it is shown in figure 3. In contradiction to that the common praxis in many test laboratories is a serial arrangement with the divider between generator and the test object.

In order to investigate the influence of the positioning of the high voltage divider two test arrangements has been investigated and compared. Figure 6 (set-up 1) shows the IEC 60060-2 conform arrangement. The following components have been used:

- Generator IP 80/1600 M
- Load C_{Load} = 0.89 nF
- Divider SMC 560/1600 C = 560 pF
- HV connection copper foil 250 mm

In the second arrangement (set-up 2) the positioning of load and divider has been changed, see figure 7. The voltage difference between load and divider U_d is influenced by the high voltage connection between the components.

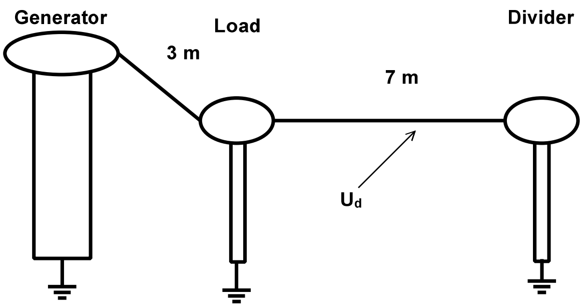

Figure 6: Test set-up 1

The distance between divider and load has been chosen with 7 meters longer usually required in order to provoke a remarkable voltage drop. The voltage signals of the dividers of both test setups are shown in figure 8. Due to the relative low impulse current and the high permeability of the copper foil a marginal difference concerning the peak voltage of 0.7 kV and a time difference of 0.01 μs could be observed. The connection point can be installed also between the generator and the test object. In that case the test field engineer has to install only one high voltage connection.

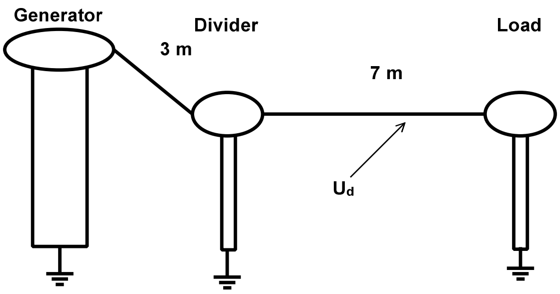

Figure 7: Test set-up 2

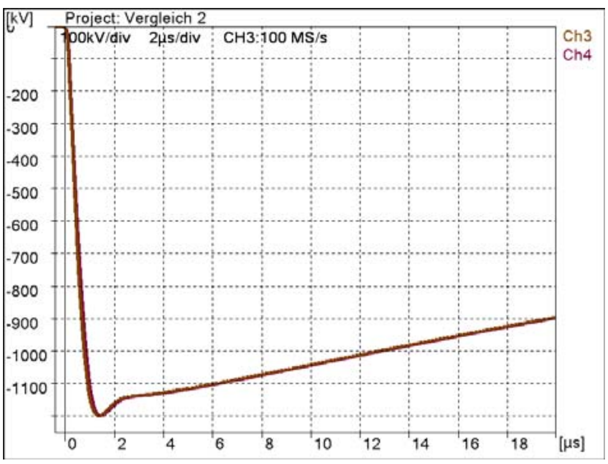

Figure 8: Comparison between the both measured voltage signals.

5 CONCLUSION

The connection point as an easy handling, space saving and overshoot reducing solution for impulse test systems has been introduced.

The positioning of the high voltage divider in the impulse test system has been investigated. A comparison between two test set-ups shows, that the high voltage divider (connection point) can be installed either between the generator and the test object or in parallel to the test object. The measured voltage signals differ marginal.

6 ACKNOWLEDGMENTS

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7 REFERENCES

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