INTERNATIONAL ELECTROTECHNICAL COMMISSION

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IEC 61869-11
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INSTRUMENT TRANSFORMERS –

Part 11: Additional requirements for low-power passive voltage transformers

INTERPRETATION SHEET 1

This interpretation sheet has been prepared by IEC technical committee 38: Instrument transformers.

The text of this interpretation sheet is based on the following documents:

DISH	Report on voting
38/663/DISH	38/672/RVDISH

Full information on the voting for the approval of this interpretation sheet can be found in the report on voting indicated in the above table.

IMPORTANT – The "colour inside" logo on the cover page of this document indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

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1 Introduction

IEC 61869-11 was published in 12-2017 and since then experience with the application of the document has been gained. During this period, it became visible that the type test "Test for impact of electric field from other phases" as required in 7.2.6.1101 and outlined in Annex 11A creates ambiguities in the execution of the test and the interpretation of its results.

IEC 61869-11:2017-12/ISH1:2021-09(en-fr)

ICS 17.220.20

7.2.6.1101 Test for impact of electric field from other phases

The purpose of this test is to verify the influence of the electric fields at rated frequency emitted by other phases.

The test shall be performed in a configuration representing the real installation. The test can be performed in three-phase or single-phase. Test arrangement and procedure are given in Annex 11A.

Annex 11A (normative)
Tests for impact of electric field from other phases

11A.1 General

Adjacent phases in a three-phase power system can influence the accuracy of passive LPVT. To evaluate the impact of electric fields effects at rated frequency generated by adjacent phases in the power system the following test shall be performed.

2 Background

2.1 General

The type test is intended to evaluate the impact of horizontal and vertical stray capacitances that the equipment is exposed to in service, which is typically different to the situation in the laboratory. In order to estimate this impact on the ratio of the LPVT, Annex 11A describes a test layout and procedure where:

Figure 1 (Figure 11A.1 from IEC 61869-11, annotated, with stray capacitances when busbar is grounded) shows the general layout of the test setup in which the influence of stray capacitances is evaluated through a two-step test process. The setup consists of the equipment under test (EUT, coded 1 in Figure 1 and Figure 3 (Figure 11A.1 from IEC 61869-11, annotated, with stray capacitances if busbar is energized), a second LPVT (coded 2 in Figure 1 and Figure 3), a metallic busbar with a length equal to twice the distance between the second LPVT and EUT, a switch to connect the busbar to either ground or high voltage, a grounded metallic wall with 1,5 times the height of the EUT, a reference VT, measuring equipment and an HV generator, see Figure 1 and Figure 3. The distance D between the EUT to the metallic wall as well as between the EUT to the second LPVT is equal to the distance between phases of a power system operating at U_m of the EUT.

The stray capacitances of the setup originate from the horizontal capacitance between the two LPVTs as well as to the metallic wall and the vertical stray capacitances of the LPVTs to ground. The horizontal stray capacitances depend on the height of the LPVT and the distance to parallel objects. The vertical stray capacitances depend on the height of the LPVT over ground potential, i.e., height of a pedestal, specified by the system design supplier. Depending on the dimensions of the test laboratory hall, the distance between the top of the EUT to the laboratory roof may pose restrictions due to necessary insulation clearances and add additional stray capacitances to the grounded roof.

2.2 First step

In the first step of the evaluation the busbar is grounded, and the following stray capacitances are effective:

C_{E1_E}: Stray capacitance between EUT and ground

C_{E1_MW}: Stray capacitance between EUT and grounded metallic wall

$C_{E1\_E'}$: Stray capacitance between EUT and grounded busbar

C_{E1_2}: Stray capacitance between EUT and second LPVT

C_{E2_E}: Stray capacitance between second LPVT and ground (can be disregarded, only shown for completeness)

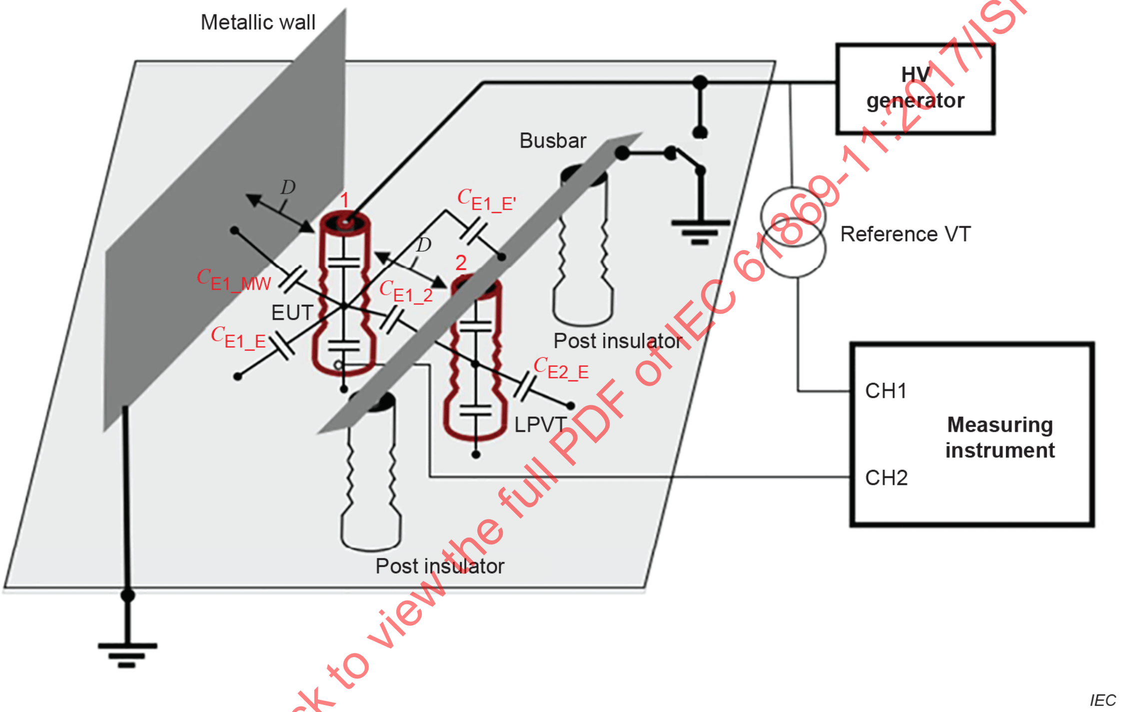

Figure 1 – Test setup with stray capacitances when busbar is grounded (Figure 11A.1, annotated)

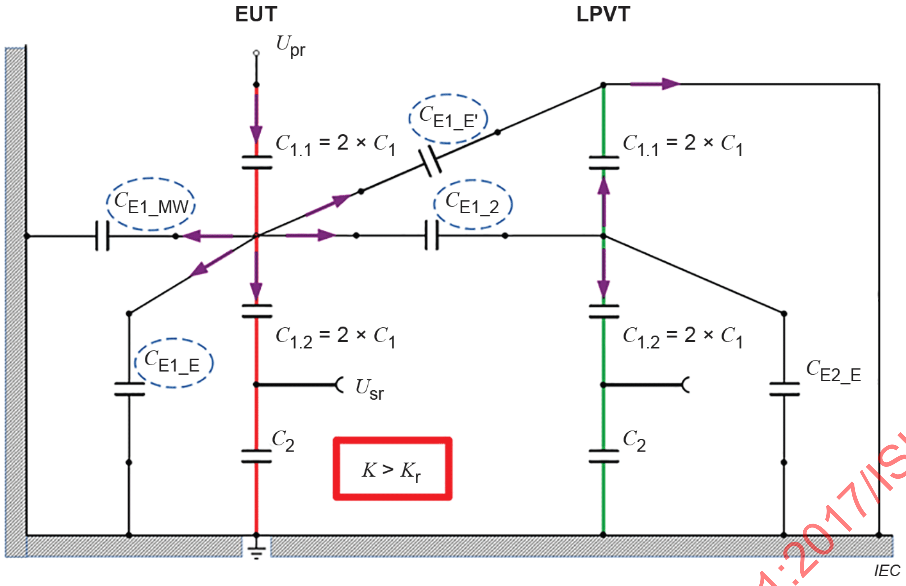

Figure 2 – Equivalent circuit of the test setup in Figure 1 with current flow direction

In this test configuration, the stray capacitances act to decrease the primary capacitance C_1 of the EUT leading to an increase of the transformation ratio, $K > K_r$. The stray capacitances with the largest impact on the ratio are marked with dotted blue circles. The red marked path represents the EUT, the green marked path represents the second LPVT shown in Figure 2.

2.3 Second step

In the second step of the evaluation, the busbar and hence the second LPVT are energized to the same high voltage source as the EUT and the following stray capacitances are effective:

C_{E1_E}: Stray capacitance between EUT and ground;

C_{E1_MW}: Stray capacitance between EUT and grounded metallic wall;

C_{E1_HV}: Stray capacitance between EUT and energized busbar;

C_{E1_2}: Stray capacitance between EUT and second LPVT (0 pF if identical units);

C_{E2_E}: Stray capacitance between second LPVT and ground (can be disregarded, only shown for completeness).

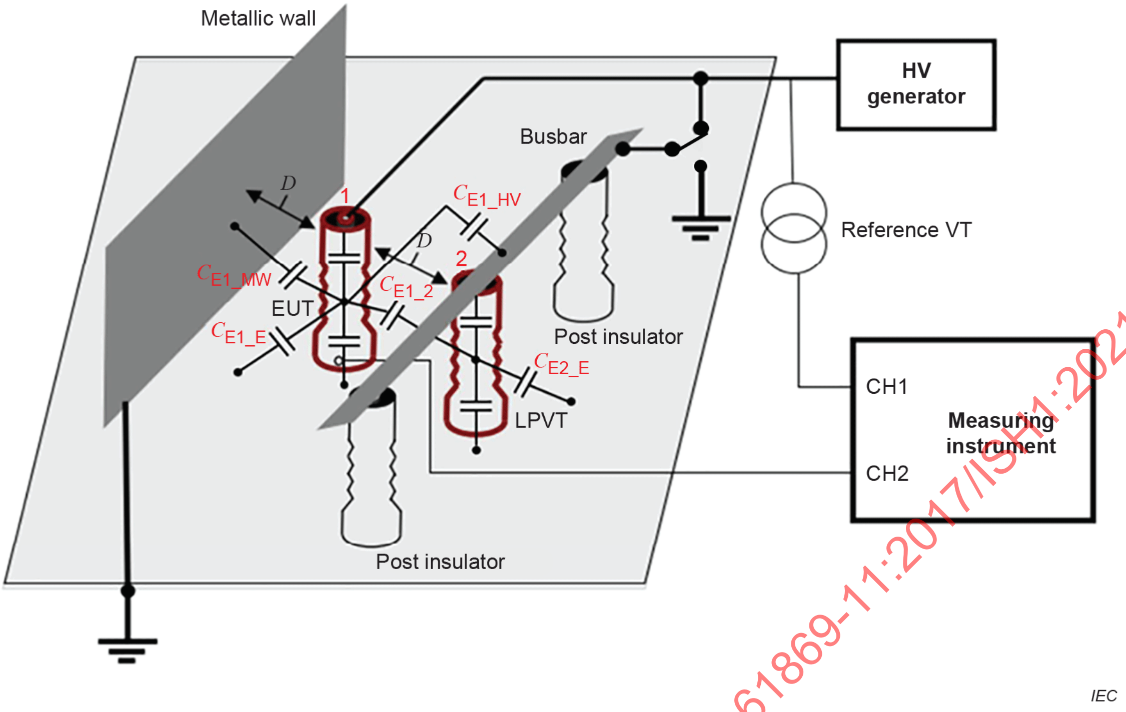

Figure 3 – Test setup with stray capacitances when busbar and second LPVT are energized (Figure 11A.1, annotated)

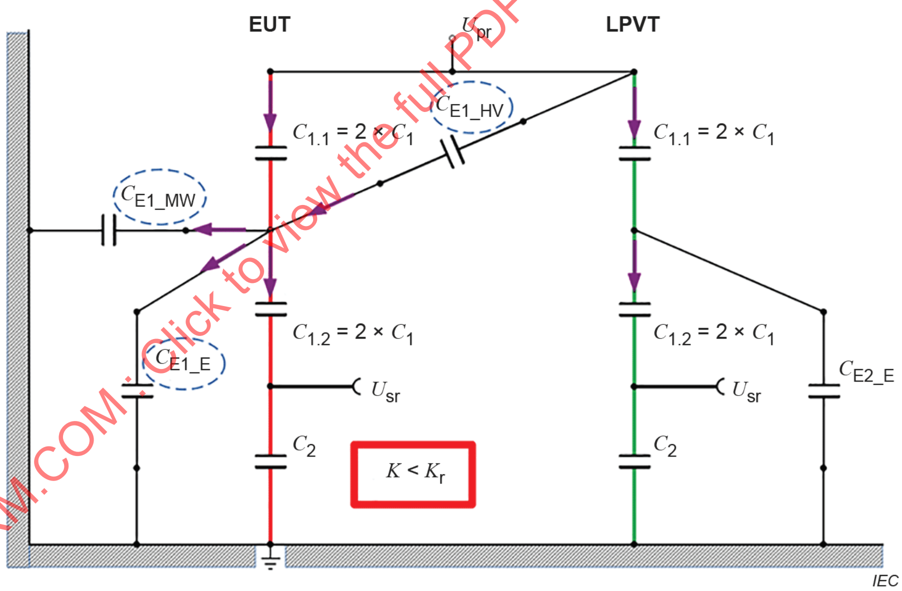

Figure 4 – Equivalent circuit of the test setup in Figure 2 with current flow direction

In this test configuration, the stray capacitances act to increase the primary capacitance of the EUT leading to a decrease of the transformation ratio, $K < K_r$. The colour coding is the same as described for Figure 2.

2.4 Result of the two steps

IEC 61869-11, Annex 11A requires the following limits:

The transformation ratios as well as the phase displacements evaluated in step 1 and in step 2 are then compared. The difference between the actual transformation ratios, evaluated in step 1 and step 2 divided by the actual transformation ratio evaluated in step 1, shall be lower than or equal to 1/5 of the ratio error associated with the specified accuracy class. The difference between the phase displacements shall be below 1/3 of the phase displacement associated with the specified accuracy class.

2.5 Open topics – Analysis of the test

This two-step test procedure suffers from the following issues:

a) The first step in the process is not representative of service conditions since it measures the impact of stray capacitances to a grounded parallel busbar. In three-phase system all 3 busbars are either grounded or energized.

b) The test layout needs a lot of space especially for HV and UHV LPVTs and available test laboratories are of limited size with varying dimensions. This leads to different spacing to other grounded objects and walls in different laboratories. These spacing differences and the influence of the additional stray capacitances may lead to different test results from one laboratory to another making the comparison of results and their reproducibility difficult.

c) HV and UHV LPVTs are typically installed in a substation on a pedestal. This elevation has an influence on the stray capacitance to ground which can vary by more than 10 % depending on voltage class. No pedestal is foreseen in the test setup. However, if included, the overall geometric structure would then exacerbate the spacing situation and in some cases test may not be possible.

d) The test evaluates in-phase contributions to the ratio accuracy whereas in typical three-phase applications the influence of the other two phases is 120° out of phase.

These issues, combined, lead to an overestimation of the influence of the stray capacitances.

Besides the ambiguities in the execution of the test, the interpretation of the results gives rise to difficulties as to how these are to be implemented in the overall ratio accuracy. LPVTs, contrary to conventional instrument transformers, can be adjusted to accommodate influencing factors in order to achieve a ratio as close as possible to nominal. This fact is reflected in the introduction of a ratio correction factor (3.4.1101) and a corrected transformation ratio (3.4.1102, Annex 11B).

The specified limit of the effect from other phases of 1/5 of the specified accuracy class as defined in Annex 11A is interpreted as a fixed value in case a ratio correction is not applied because the impact of electric field from other phases is considered negligible. An LPVT of class 0.2 with a ratio error of 0,19 % can have a ratio error of 0,23 % with the influence of the external field included.

3 Interpretation

3.1 Description of the test circuit

The following description is related to a single-phase LPVT for air-insulated applications. Figure 5 shows the test setup and illustrates how the surrounded components shall be arranged. For both LPVT, all the original external grading electrodes or additional components (e.g., gas density monitor) shall be attached.

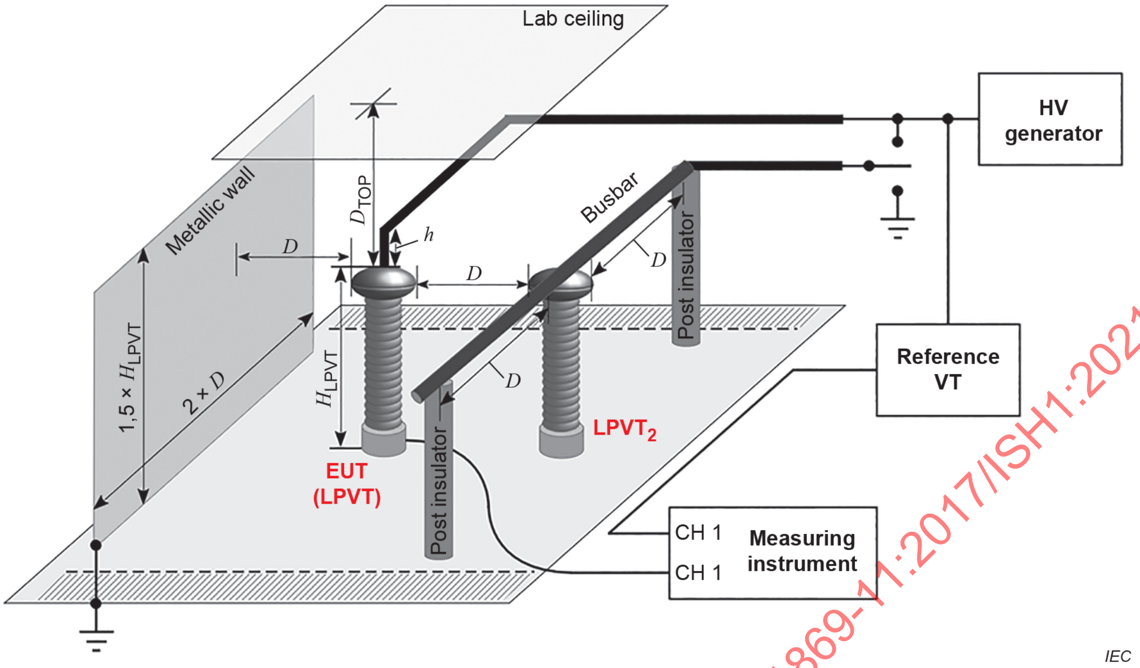

Figure 5 – Test setup for LPVT used in air-insulated substations (Figure 11A.1, improved)

The EUT shall be placed in the test field with a distance D equal to the clearance (according to IEC 61936-1:2021, 3.5 "Definitions concerning clearances") between phases to all other equipment, based on the highest voltage for equipment U_m. If not otherwise defined, the distance D is based on IEC 61936-1:2021, Table 2 or Table 3, depending on U_m. The grounded metallic wall shall have the length of 2 × D and the height of the metallic wall shall be at least 1,5 times the total height H_{LPVT} of the EUT. The EUT shall be placed directly at the ground level since this is the worst case with the largest influence of the ground plane. The distance D_{TOP} between the top of the EUT and the lab ceiling, if present, shall be at least 0,75 × D since the ceiling can have an influence for LPVTs 72,5 kV and above.

A second LPVT ($LPVT_2$) of the same type or a similar one, with a tolerance of ±10 % of the total height H_{LPVT} of the EUT, shall be placed with the distance D to the test object. The position is opposite to the grounded metallic wall and with the EUT in between. The base frame shall be placed at the same level as the EUT. A metallic busbar with a length twice the distance D is mounted on top of the $LPVT_2$. The outer diameter of the busbar should be designed to be corona free; a circular cross section is recommended.

The electrical connection on the high voltage terminal of the EUT should start with h = 0,15 × H_{LPVT} in the vertical direction and then in the horizontal direction to the HV generator.

For the electric field impact test, the original transmission cable and the rated burden shall be used as it is in the accuracy test. The ground terminal of each device should be connected to a ground star point to prevent any loops. The type of the ground connection shall be a flat copper band as it is used in impulse voltage tests.

All other equipment within the test lab shall be grounded and placed outside the area of the test arrangement, see dotted line in Figure 5.