IEC/TR 62836

Edition 1.0 2013-09

TECHNICAL REPORT

colour inside

Measurement of internal electric field in insulating materials – Pressure wave propagation method

IEC/TR 62836:2013(E)

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

PRICE CODE M

ICS 17.220.99; 29.035.01

ISBN 978-2-8322-1102-1

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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FOREWORD

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IEC/TR 63836, which is a technical report, has been prepared by IEC technical committee 112: Evaluation and qualification of electrical insulating materials and systems.

The text of this technical report is based on the following documents:

Enquiry draft	Report on voting
112/258/DTR	112/263/RVC

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

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

A bilingual version of this publication may be issued at a later date.

INTRODUCTION

High-voltage insulating cables, especially high-voltage d.c. cables, are subject to charge accumulation and thus to electrical breakdown if the electric field produced by the charges exceeds the electrical breakdown threshold. With the trend to multiply power plants, especially green power plants such as wind or solar generators, more cables will be used for connecting these power plants to the grid and share the electric energy between countries. Therefore the materials for the cables, and even the structure of these cables when considering electrodes or the junction between cables, need a standardized procedure for testing how the internal electric field can be characterized. The measurement of the internal electric field would give a tool for comparing materials and help to establish thresholds on the internal electric field for high voltage applications in order to limit as much as possible breakdown risks. The pressure wave propagation (PWP) method has been used by several researchers to measure the space charge distribution and the internal electric field distribution in insulators. However, since experimental equipment, with slight differences, is developed independently by researchers over the world, it is difficult to compare the measuring results between the different researchers.

The procedure outlined in this technical report would give a reliable point of comparison between different test results carried out by different laboratories and avoid interpretation errors. The IEC has established a project team to develop a procedure to evaluate PWP measurement. The method will be verified in a Round Robin test. Once, having received reliable experience, this report is intended later to be upgraded to a technical specification in order to establish a specified way to estimate fairly the performance of a PWP measurement.

MEASUREMENT OF INTERNAL ELECTRIC FIELD IN INSULATING MATERIALS – PRESSURE WAVE PROPAGATION METHOD

1 Scope

IEC/TR 62836, which is a technical report, contains an efficient and reliable procedure to test the internal electric field in the insulating materials used for high-voltage applications using the pressure wave propagation (PWP) method. It is suitable for a sample with homogeneous insulating materials and an electric field higher than 1 kV/mm, but it is also depended on the thickness of sample and the pressure wave generator.

2 Terms, definitions and abbreviations

For the purposes of this document, the following terms, definitions and abbreviations apply.

2.1 Terms and definitions

2.1.1
pressure wave propagation
PWP
propagation of wave generated by the action of a pressure pulse

2.2 Abbreviations

LIPP laser induced pressure pulse

PIPP piezoelectric induced pressure pulse

3 Principle of the method

The principle of the PWP method is shown schematically in Figure 1.

The space charge in the dielectric and the interface charge are forced to move by the action of a pressure pulse wave. The charge displacement then induces an electrical signal in the measuring circuit which is an image of the charge distribution in the short-circuit current measurement condition. The expression for the short-circuit signal is

$$i(t) = C_0 \int_0^d \mathrm{B}\, E(x) \frac{\partial p(x,t)}{\partial t} dx \qquad (1)$$

where

$E(x)$ is the electric field distribution in the sample;

d is the thickness of sample;

$p(x, t)$ is the pressure pulse wave in the sample, which depends on the electrode materials, dielectric sample material, the condition of coupling on the interface, etc.;

C_0 is the sample capacitance without the action of pressure pulse wave.

C_0 depends on the thickness of sample, and its surface area which is equal to the area of action of pressure pulse wave. The constant $\mathrm{B} = x\ (1 - \mathrm{a}/\varepsilon)$ only depends on the characteristics of the dielectric materials. For heterogeneous dielectric materials, B is a function of space. For homogeneous dielectric materials, B is not a function of space and can be put in front of the integral. In this proposition, only homogeneous dielectric materials are considered, B is a constant.

In Equation (1), the electric field distribution can be obtained if it is deconvolved.

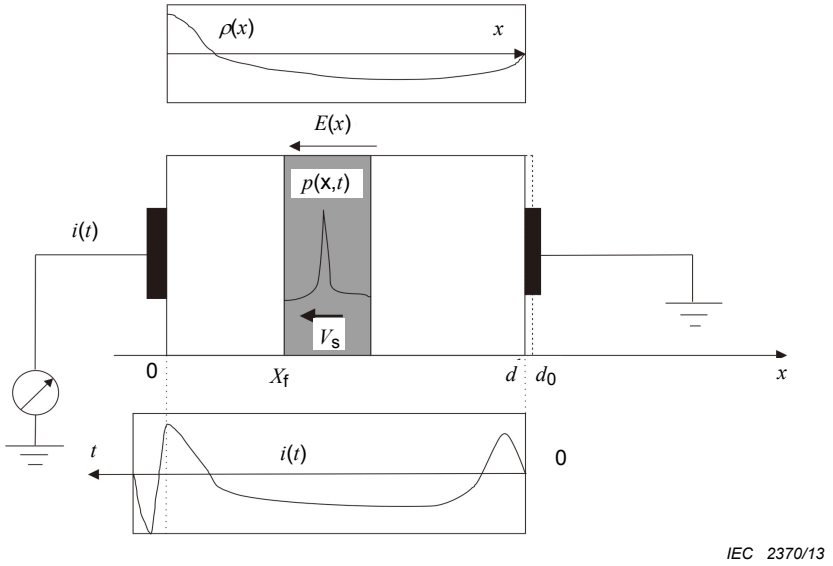

Figure 1a – Applied pressure pulse and measured short-circuit current signal

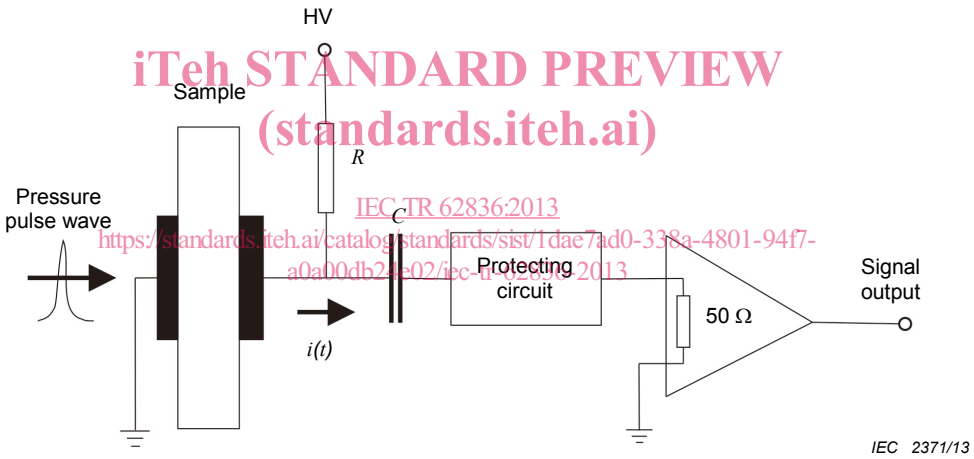

Figure 1b – Measuring schematics

Figure 1 – Principle of the PWP method

The applied pressure pulses can be generated by different techniques, but the same kind of analysis can be done for any of these techniques. The main practical PWP method can be divided into two ways: a pressure pulse is induced by a powerful pulse laser, a technique called LIPP method, and a pressure pulse generated by a piezoelectric device, a technique called PIPP. The sensibility and resolution of PWP method depends mainly on the amplitude and width of pressure pulse. The advantage of the LIPP method is to produce high sensitive measurements. The advantage of the PIPP is to obtain a better spatial resolution.

In the case of a narrow pulse, e.g., the width of the pressure pulse is much less than the thickness of sample

$$\int_0^t \mathrm{i}(t')\,\mathrm{d}t' = C_0 \mathrm{B}\overline{E(x = v_s t)} \int_0^d p(x,t)\,\mathrm{d}x \qquad (2)$$

where

$\tau \ll [min(d_0, d_x)]/v_s$ is the pressure pulse duration;

v_s is the sound speed in the sample;

$\overline{E(x = v_s t)}$ is the mean electric field during the pressure pulse width.