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Measurement Uncertainty Consideration of Electric Field Meters

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Summary:
The capability of electric field meters as traceable measuring devices in a static electrical field is investigated. For this purpose, the measuring method of the electric field meter is examined based on the influencing variables and possible conditions for application are derived. Based on the results, a model for the identification of measurement uncertainty according to the "Guide to the Expression of Uncertainty in Measurement" is developed.

Keywords: measurement uncertainty, electric field meter, traceability, electrostatics, surface charge

Introduction

In order to measure electrostatic charges on surfaces by means of an electric field meter (FM) with corresponding indication of the measuring accuracy, it is necessary to characterize metrologically the measuring method of a FM to obtain a traceable measuring instrument. By using a FM to determine the electrostatic field of the surface charges, a measurement without discharge can be obtained. This is possible due to the non-contact and discharge-free measuring method of a FM. The measuring method is based on the principle of electrostatic induction [1]. The FM used here [1, 2, 3] consists of a grounded measuring head and electronic measuring equipment in a grounded enclosure. With this measurement method, the FM does not directly influence the electrostatic charge. However, it is necessary to consider that the FM changes the shape of the E-field distribution. This is caused due to the characteristics of the FM, in particular, the edge of the grounded measuring head, which is not homogeneous (Fig. 1 left) [1]. This kind of distortion can be prevented by placing the measuring head into a grounded electrode. As a result of the homogenization, the measuring head causes no significant influence on the distribution of the E-field, see Fig. 1 right. That optimization is used by manufactures to indicate the measurement deviation of their FM. Hereby is the problem that the indication of the deviation applies for just one particular case, the so-called "one point calibration". For this one homogenous E-field configuration: Measuring head placed centered in a ground electrode, a plate electrode as measuring object, both electrodes with the same diameter and are also placed centered and parallel to each other in a set distance [2].

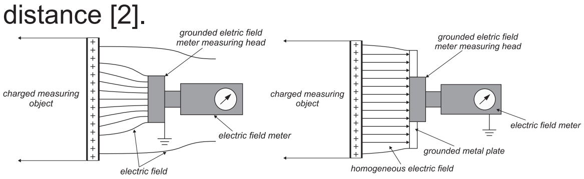

Fig. 1. Left: E-field distortion due to measuring head; Right: E-field homogenization by a grounded electrode (according to [1]).

However, no further indications on the measurement deviations for applications without a ground electrode, other measuring object sizes or shapes (homogenous and inhomogeneous E-field configurations) and measuring distances are provided. Establishing the FM as a measuring instrument requires precise knowledge of the measuring method, the characterization of influencing parameters and the traceability of the measured values to national standards. Therefore, a test setup was developed, which ensures correct and reproducible measurements [4]. Due to the investigation results [4], and additional considerations on the mode of operation of the FM within the E-field, it could be determined that measuring objects are detected by means of a measuring cone defined by a measuring angle (depending on the diameter of the measuring head) [5]. Thus, the influencing variables and conditions for the correct application of an FM could be identified [6]. Based on these results it is possible to develop a model for the indication of the measurement uncertainty according to GUM [7].

Modelling and Results

The GUM provides a consistent method for the determination and indication of the measure-

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ment uncertainty. The determination of the influencing variables, the application conditions and the modelling are the main challenges and are discussed here for the measuring method FM. The influencing variables and conditions for the correct application of FM measurement are identified [6]. All other influences are considered as not relevant.

Conditions:

- Environmental conditions (temperature *T*, relative humidity *rh*)
- Optimal measuring distance depends on measuring object size, measuring angle and measuring range of FM.
- Tilting of FM to measuring object, indicated by tilt angle δ. Depends on optimal measuring distance and volume of measuring cone.

Influencing variables:

- Measuring distance (set distance, deviation according to calibration certificate, handling).
- FM measured value recording (accuracy recorder output, display output voltage FM).
- Voltage generation and measuring system (HV-divider, display voltage standard, nominal voltage deviation).
- Inhomogeneity of FM (correction factor of field distortion by measuring head for measurements without ground electrode).
- Inhomogeneity of the measuring objects (correction factor of field distortion by measuring real objects).

Fig. 2 shows the influencing variables for the measurement of the E-field caused by the measuring object and the symbol of the equation for the following consideration.

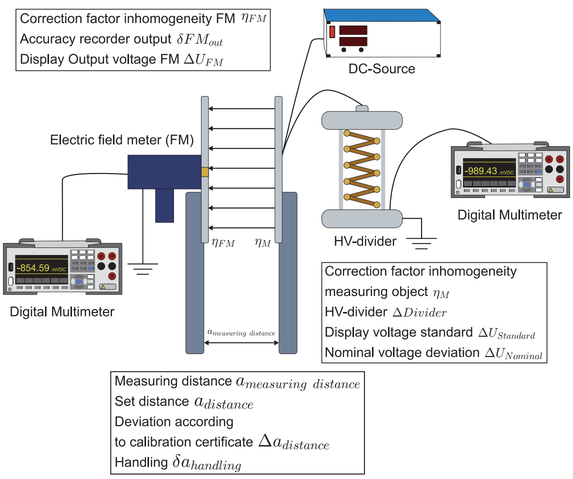

Fig. 2. Influences on the measuring method electric field meter by means of the schematic test setup.

The model equation is based on several analytical terms. In the equations, all quantifiable influences are indicated by Δ. The measurement result is corrected by these terms. All influences which cannot be quantified are indicated with δ. These do not change the measurement result, but only contribute to the measurement uncertainty.

As a result, the model provides the value $\Delta E_{\%}$, which is the difference between the expected E-field E_h and the determined E-field $E_{h,\ measure}$ in percent. Here, the influence variables and the conditions on the measurement method as such, as well as the influences resulting from the specific measurement and measurement object after the measurement are considered according to the correction factors in the measurement uncertainty. With the measurement method, it is therefore possible to indicate the measurement deviation with extended uncertainty of the measurements with the extension factor $k = 2$ and a coverage probability of 95% (normal distribution), if the following applies:

- Environmental conditions: T = 15 °C to 31 °C and rh = 25% to 65%
- Measurements with or without homogenizing electrode (η_{FM})
- Homogeneous measuring objects with a diameter d_{HVe} = 100 mm to 400 mm
- Inhomogeneous measuring objects with round-, angle- or corner geometries (η_M)
- Depending on the respective optimal measuring distance $a_{optimal}$ and the acceptable tilt angle δ of FM

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