Measurements and calculations of electromagnetic fields under overhead lines and possible measures to reduce EMF

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Abstract— **The transmission of electrical energy through extra-high-voltage (EHV) power lines is an integral part of modern power systems. However, the operation of these lines is accompanied by the generation of electric and magnetic fields at a frequency of 50 Hz, which represent a significant physical factor in their vicinity. In recent years, electromagnetic fields (EMFs) have received increasing attention due to the expansion of residential and recreational areas, the development of cycling infrastructure, growing requirements for public health protection, and the need for objective assessment of the environmental impacts of power system facilities. For these reasons, reliable methods for the measurement and numerical modelling of electromagnetic fields are essential to accurately determine EMF levels and subsequently design appropriate technical or mitigation measures.**

Keywords— electromagnetic field, overhead lines, EMF exposure, mathematical modelling

I. INTRODUCTION

This paper addresses the measurement and numerical modelling of electric and magnetic fields in the vicinity of extra-high-voltage (EHV) power lines. The first area of focus concerns methods for determining electric field strength and magnetic flux density beneath EHV power lines, which are the fundamental quantities used in the assessment of public exposure. The accuracy and reproducibility of electromagnetic field (EMF) measurements depend on measurements being performed under suitable meteorological conditions that limit the influence of interfering factors and eliminate potential sources of systematic errors. Field measurements provide a realistic representation of the EMF distribution at a specific location and also serve as a basis for the validation of numerical models [1].

The second area of focus is the numerical modelling of electromagnetic fields. Modern computational tools enable the distribution of electric and magnetic fields in the vicinity of EHV power lines to be simulated with an adequate level of accuracy and various operating conditions to be analysed without the need for extensive measurement campaigns. Electric field modelling employs methods based on the solution of electrostatic problems, such as the method of image charges or the finite element method (FEM). Magnetic flux density calculations are based on the Biot–Savart law and take into account the actual current loading of the power line. The modelling results are presented as spatial maps of electromagnetic field distribution, which enable the identification of areas with the highest exposure levels and the assessment of compliance with applicable regulatory requirements.

Particular attention is given to methods for reducing electromagnetic field levels without modifications to the power line itself. In many cases, changing the conductor configuration, tower height, or operating conditions of the line is neither technically nor economically feasible. Therefore, measures that can be implemented directly within the transmission line right-of-way or in its immediate vicinity are analysed. The proposed solutions include appropriate spatial and vertical arrangement of the affected area, terrain modifications, vegetation barriers, and grounded metallic shielding structures. These measures can be used primarily to achieve a local reduction in electric field strength. In the case of magnetic fields, the possibilities for reducing field levels without modifications to the power line itself are more limited; passive compensation loops or active compensation systems may be considered as potential solutions.

II. MEASUREMENT AND CALCULATION OF ELECTROMAGNETIC FIELDS

Electromagnetic field measurements in the vicinity of transmission lines are performed in accordance with the relevant technical standards [2], [3] and applicable regulatory requirements [4] specifying permissible electromagnetic field levels. Measurements are initially carried out along the longitudinal profile of the transmission line, i.e., beneath the outermost phase conductor, over the entire length of the span under assessment. At the location where the highest value of the measured quantity is recorded, additional measurements are subsequently performed along the transverse profile, i.e., in a direction perpendicular to the transmission line axis.

To ensure that the measured electric field strength values are representative, the influence of objects capable of disturbing the spatial distribution of the electric field should be minimized. Therefore, during measurements, moving persons, vehicles, and other large objects that may affect the measurement results should not be present in the immediate