Perturbation Measurements on HV Overhead Lines using Electric Field Sensors

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Abstract— It is widely known that in most countries there are severe Power Quality rules that Utilities as well as customers have to comply with. Therefore, it is necessary to assess carefully the levels of disturbances.

The traditional procedure to determine the origin of such disturbances is to perform field measurements in all the plants containing power electronic equipment, electric arc furnaces, etc., located near the point in which high levels of disturbances have been detected. Nevertheless, in most cases field engineers find it difficult to have access to the plants belonging to Utilities and also to the different industries settled nearby, which are also likely to emit disturbances. In addition, the task of installing the PQ recorder in the electrical cabinets inside the plant demands a considerable time, as well.

With the intention of avoiding all the difficulties that can arise when field engineers are searching for a disturbing load, it was considered a great challenge to design a novel device to make the field work simpler. Such a challenge was based on designing a measuring system capable of recording voltage waveforms with no physical contact with the installations and without the assistance of Utilities personnel. In order to achieve this goal an Electric Field Sensor (EFS) was employed in the design of the measuring system.

This paper deals with the results of testing an electric field measurement system – completely designed by the authors – for monitoring voltage Flicker and harmonics in overhead power systems [1]-[3]. Some results of field measurements performed in plants containing disturbing loads are shown.

Index Terms— Disturbing Load. Electric Field Sensor (EFS). Flicker. Harmonics. Total Harmonic Distortion.

I. INTRODUCTION

The public electricity service in Argentina, which was privatized in the early nineties, is carried out by different Agents and the control is performed by a Regulatory Agency (ENRE). The IITREE of La Plata University provides technical assistance to the Utilities and the Authorities.

Nowadays, after almost twenty years of experience, it is possible to conclude that when it is necessary to find a disturbing source, traditional measurements through voltage transformers in many places could be impractical, time consuming, and expensive.

In this article, an alternative way of measuring voltage perturbations based on sensing the Electric Field is described in detail. Experimental and field measurements results validate the proposed method.

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II. FUNCTIONING PRINCIPLE OF EFS

Unshielded electrical power systems generate electric fields, which can be measured accurately at distances from the conductors that are one order of magnitude larger than typical system dimensions. The field at a particular location and time is a function of the instantaneous voltage on all conductors and depends on the geometry of both the power system and its environment.

The electric current that flows between the plates of a parallel-plate capacitor immersed in an electric field – as shown in Fig. 1 – is given by:

$$i_C(t) = \omega \cdot \varepsilon_0 \cdot A \cdot E \cdot \cos(\omega t) \quad (1)$$

Where:

ε_0: Permittivity of free space = 8,854x10-12 [F/m]
A: Surface area [m^2]
E: Electric field magnitude [V/m]

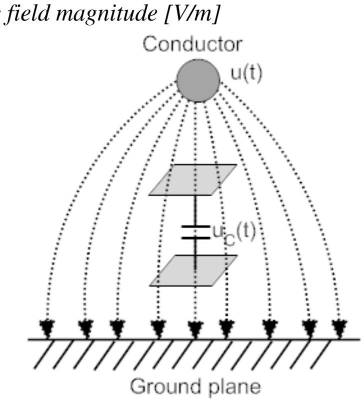

Fig. 1: Measuring electric field between two electrodes.

If an external capacitor C_B is connected between the parallel plates, and if this capacitor is not influenced by the electric field E – as shown in Fig. 1 – the capacitor potential magnitude is given by:

$$\dot{U}_C = -j \cdot \dot{I}_C \cdot X_C = \frac{-j \cdot \dot{I}_C}{\omega \cdot C_B} = -j \cdot \left(\varepsilon_0 \cdot A / C_B\right) \cdot E \quad (2)$$

It can be deduced that the potential in the capacitor C_B is proportional to the electric field E through a transduction constant:

$$k_E = \left(\varepsilon_0 \cdot A / C_B\right) \text{ [m]} \quad (3)$$

This relationship is independent of frequency, and therefore, if the electric field varies randomly, also the electric potential will follow the same rule. In general:

$$u_C(t) = k_E \cdot e(t) \quad (4)$$

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