

INVESTIGATIONS ON ELECTRICAL FIELDS AND CURRENT FLOW THROUGH ELECTRODE SYSTEM WITHIN ELECTRODE

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Abstract: An isolated system of two electrodes with autonomous power supply has been investigated. When electrodes are far away from each other, the system can be described by equivalent single wire setup. But in case when the generator and the smallest electrode are enclosed within a large one, even when charging and discharging currents are detected, no electrical field or potential is detected on the outer electrode.

Keywords: electrical field, spatial electrodes, self-capacity.

Introduction

The following work describes an electrical system similarly as it was introduced in previous works [1, 2], where system for energy transfer through single wire was developed. The principal scheme is shown in Fig. 1.

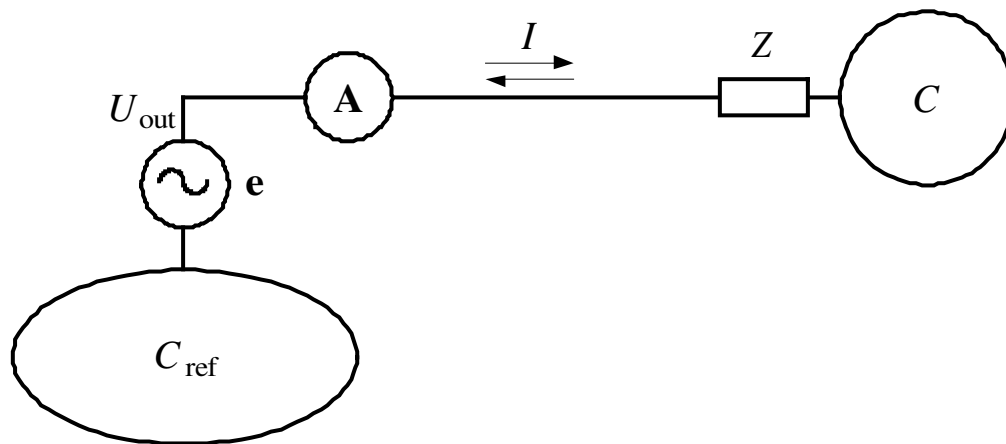


Fig. 1. Schematic of single wire energy transfer system

One output of AC generator e is connected to isolated electro conducting body C . Second output is connected to reference body C_{ref} . Output voltage U_{out} generates potential φ changes with respect to free space, for example, if C_{ref} is Earth than $U_{out} = \varphi$. Changes within potential φ induces charging of self-capacity of body C , thus through connecting wire flows current I which is measured by an ammeter A . In the result, the electrical energy or information by the help of only one wire can be transferred to consumer Z .

Due to the fact that the same current flows from e to C_{ref} , it is shown that electrical displacement of the current flowing from the body C binds with C_{ref} and vice versa forming a virtual wire [2].

Aim of the work

In the following work, the system where conducting body C is stepwise inserted within C_{ref} has been studied. The changes in flowing current I and electrical field around C_{ref} have been monitored in respect to the level of insertion.

Experiments and results

The experimental setup is show in the following image (Fig. 2). It consists of two conducting hollow cylinders 1 and 2, with inner diameters of 150 mm and 100 mm. The thickness of outer walls does not exceed 1 mm. For each cylinder the top part can be sealed by a lid. An autonomous square

waveform generator e with output peak amplitude voltage of $\hat{U} \approx 50V$ and frequency of 10 kHz is placed within the smaller cylinder 2.

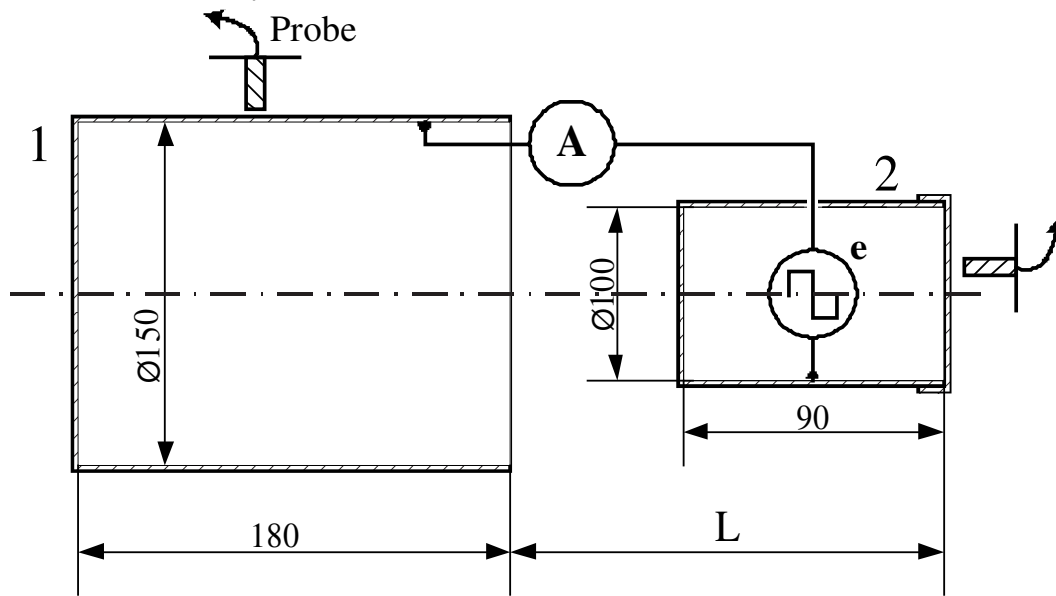


Fig. 2. Experimental system

One output of the generator is connected to the smaller cylinder 2 and the other – through the ammeter A , to the bigger cylinder 1. The ammeter measures the current similarly as in the previous system (c.f. Fig. 1). Simultaneously, the electrical field at the side of the largest electrode and at the top of the smallest electrode has been measured by a probe. The probe is made from conductive metal with dimensions of 2×2 cm, and is fixed at a constant distance of 2 cm from the cylinder 1 by a dielectric rubber. The voltage U_s induced within the probe by changing electrical field, is measured by an oscilloscope. Depending on the distance between electrodes L , the amplitude of U_s and the current I have been recorded. The results are summarized in the following graph (Fig. 3). It is assumed that U_s is linearly dependant on the intensity of the electrical field, thus the intensity is represented by normalized U_s values.

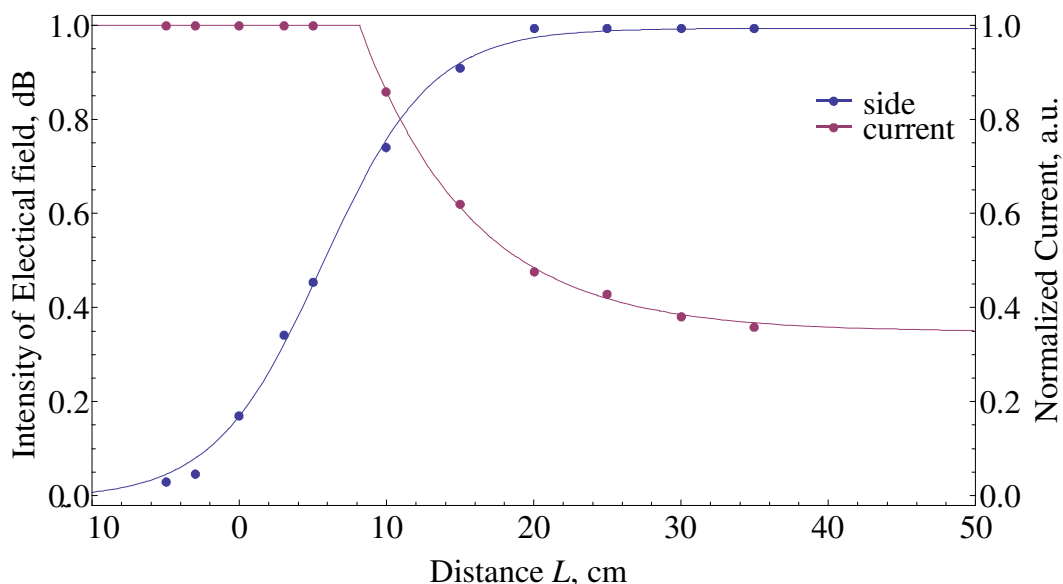


Fig. 3. Electric current I and strength of Electric field depending on the distance between two electrodes L , where L represents an insertion level of smaller electrode

When electrodes are far away, the smallest electrode 2 emits twice as strong electrical field of 2 dB compared to the large electrode, as detected by the probe (Fig. 3). The difference is described proportionally to self-capacitance of both bodies [2]. If the distance between electrodes is reduced the

current increases, but the strength of electrical field outside the biggest electrode diminishes. The current reaches its saturation level already at the distance of 8.2 mm. The sharp change for the exponential increase is due to fact that the distances between the electrodes do not change at any point and the capacitance between both of the electrodes remains approximately constant. In contrast, the electrical field intensity is reduced almost to zero when the smallest electrode is completely inserted inside the larger electrode. When the lid is closed, neither the electrical field with probe, nor any potential on the outer electrode can be detected. If the small electrode is moved closer to the large one, measurements of the electrical field are disturbed and can't be measured, but it is possible to see that the peak amplitude of the potential on the small electrode is growing and reaches full potential of $\hat{U} \approx 50V$ as given by generator *e* output.

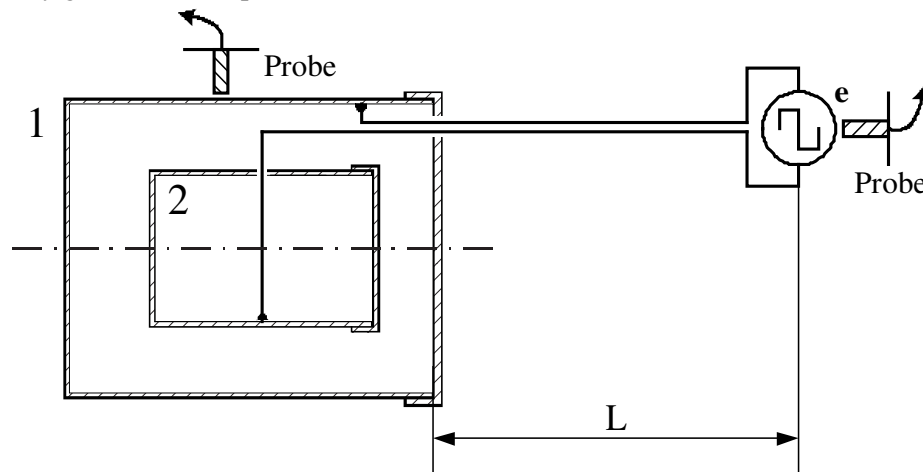


Fig. 4. Closed system when generator is outside electrodes

Further more, the generator *e* is placed outside the electrode system at a distance of, $L = 15\text{ cm}$ in case when the smallest electrode 2 is completely inserted within the biggest one (Fig. 4). By increasing the distance, the electric field intensities of the big electrode and power supply construction do not change. The measurements of the strength of the electrical field have been conducted for three cases: 1) outside the large electrode (as shown in Fig. 4); 2) at the top of the small electrode in the case when the lid is taken off; 3) near the generator setup. All results are summarized in Table 1.

Table 1

Strength of electrical field in case when generator is placed outside the system

Big electrode (dB)	Small electrode (dB) (lid opened)	Near generator (dB)
0.17	1.76	0.85

Measurements on the big electrode and near the generator are not affected by the opened lid.

Discussions

The conservation of electric charge, as expressed by the continuity equation, gives the relation between current and charge

$$Q(t) = \int_t I(t) dt \tag{1}$$

- where *I* – the net outward current through a closed surface, A;
- Q* – the electric charge contained within the volume defined by the surface, C;
- t* – time, s;

In electromagnetism and electronics, capacitance is the ability of a body to store an electrical charge. Capacitance is also a defined by the amount of electric charge stored for a given electric potential.

$$C = \frac{Q}{\varphi} \quad (2)$$

where

C – capacity, F;
 Q – charge, C;
 φ – potential, V;

Here the capacitance C is considered to be a self-capacitance of an electrode, which is the amount of electrical charge that must be added to a conductor to raise its electrical potential by one volt. The reference point for this potential is a theoretical hollow conducting sphere, of infinite radius, centred on the conductor.

Due to full current law it is expected for electrical field to be zero in case when setup is completely closed (Fig.2). But in the mean time detected current that flows between electrodes indicates that the electrical charges Q are stored and extracted periodically from the large electrode 1 (1). But potential φ of the electrode 1 remains zero regardless of the quantity or polarity of charge. This indicates that the inner electrode 2 of the system feels the outer electrode 1 as an electrode infinitely far away with infinite radius, thus the reference electrode 1 with respect to electrode 2 by definition has an infinitely large capacitance C (2). If the system is broken and the outer electrode is incomplete (opened lid or taken out generator), the capacitance of the larger electrode can't be infinite, and is decreased respectively.

The other conclusion is that the electrical field strength lines have to be closed and can not be broken. For a case when the electrode system is enclosed, the strength lines would not have a second point to flow to, and thus the electrical field cannot be created. Only when the generator is taken out or the lid is open, the field lines have a clear path for enclosure thus the electrical field appears.

Conclusions

1. If electrode system is closed, no electrical field can or is created outside the outer electrode, as required by full current law, even when the capacitance charging currents flow between electrodes;
2. For closed electrode system, the inner electrode feels the outer one as to be with infinitely large self-capacitance, in this case it has a full peak amplitude of potential change, as defined by the generator, when the outer electrode stays with zero potential regardless of stored charge;
3. As the opening of the system does not influence the system significantly, the current setup can be studied more intensively to find the best use of exhibited behaviour.

References

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2. J. Voitkāns, J. Greivulis, A. Voitkāns. Single Wire and Respective Double Wire Scheme Equivalence Principle. 7th International Scientific Conference „Engineering for Rural development”, Jelgava, 2008.