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Electrode Systems and Their Switching Used in Monitoring of Dike Status

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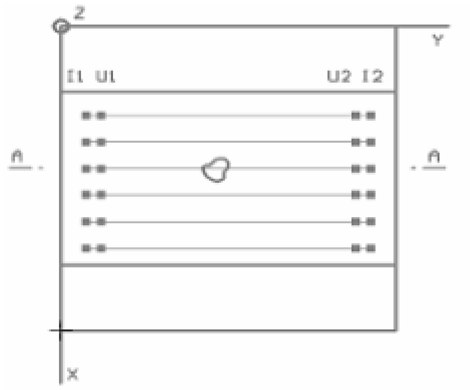
Abstract – Diversity of applications of the electrical impedance method in the dike monitoring requires new approach to the construction of sensors – the electrode systems. Laboratory experiments show possibilities of the method that can contribute to the description of effects causing changes of stability of protective dikes, and can quantificate and localize these changes. Besides, the method makes possible to observe water pollution methods measuring changes of its conductivity. Different types of electrodes are required to reach optimal results of different classes of application. Problem of spatial undersampling is discussed.

Keywords: Electrode systems, multiplexer.

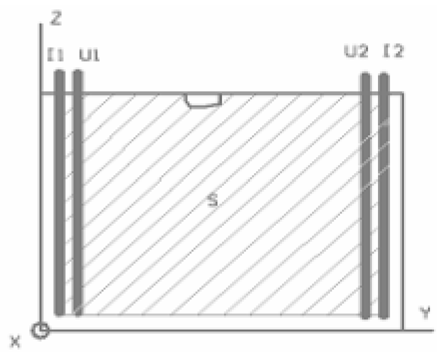
1. INTRODUCTION

Impedance (or admittance) measurements carried out during laboratory experiments on dikes or in polluted water differ in the state of material in which the experiment is performed. The study of the dike stability changes and their localization is taken at different degrees of the solid-state material saturation by water. Thus, the wide range of measured impedances is awaited, from 10^1 to $10^4\,\Omega$. Moreover, high sensitivity and resolution of measurement is required, if structure deformations are to be measured and localized, because visible deformations cause only small effective cross-section changes, and, thus, small impedance changes (Fig. 1). To be able to determine these small changes, the influence of all parasitic impedances (transition resistance electrode – tested material, and lead-in wires' resistance) must be eliminated. Therefore, the instrument is equipped with four terminals divided in two pairs, in current and voltage (high input impedance) terminals. Two pairs of electrodes, current and voltage are connected to these terminals. This arrangement allows for the measurement of the voltage drop on measured impedance without any current loading of the measuring circuit.

Free water level movement inside of the dike body creates sharp boarder between high and low saturation of material by water. It means, there is a precipitate gradient in material impedance at this boarder, so that a binary criterion can be used to determine the free water level position. The need of the high resolution and sensitivity is not critical,



a)



b)

Fig.1 The basic four – electrodes arrangement of the experiment investigating dike deformations (a), section A – A showing the change of the effective cross-section (b).

and simple two electrodes arrangement can be used. In this case, the current and voltage terminals are connected.

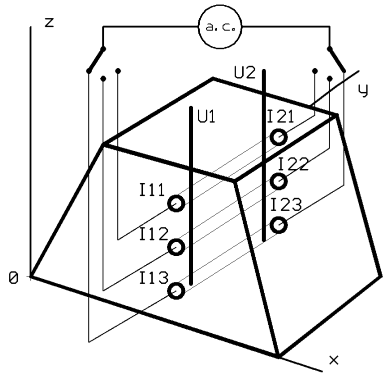
The measurement of water pollution is carried out in a liquid environment, and, to reach useful results, severe requirements on electrode geometry must be respected [1] and the entire effective surface of electrodes must be dived into the tested liquid. The goal of the measurement is the monitoring of time and space distributions of the pollution.
The previous use of the universal rod electrodes in two or four terminals configurations [2] showed possibilities of the method and provided promising results in all types of experiments. Nevertheless, result evaluations and their discussions discovered imperfections and limitations caused

by non-optimal electrode shape, geometry and dimensions. Therefore, the design of new types of electrodes for different type of experiments became substantial topic of our effort.

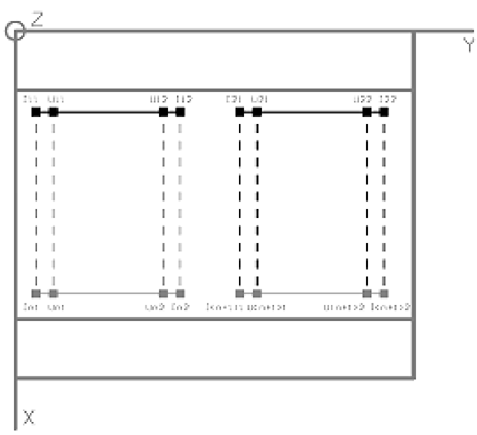
2. CLASSIFICATION OF ELECTRODES

As shown, different types of experiments require different type of electrodes or electrode systems to achieve optimal results so that their construction can be divided to three basic groups.

Experiments, recently carried out with the aim of deformation localization, used rod electrodes in four terminal configuration, as shown in Fig. 1. As can be seen, only the lengthwise, *x*, coordinate of the deformation has been determined, because the current field produced by current rod electrodes has created the cross-section s in *y-z* plane. To be able to determine the other coordinates, spot current sources should be used to produce narrow current streamlines capable of the resolving z coordinate of the deformation (see Fig. 2a). In this case, each electrode is created by the basic body of the voltage electrode, which ensures mechanical sturdy. There are several insulating islands of defined dimensions placed on this body equidistantly. These islands create required current spot electrodes.



a)



b)

Fig. 2. The use of divided current electrodes makes possible to sample the dike space in *z* – direction (a), and higher density of electrodes in *y* – direction allows for the sampling of the space in *y* – coordinate.

y – coordinate of the deformation can be determined if the dike space is sampled if higher density of electrodes is applied (Fig. 2b) in that direction. In all cases, the base of the electrode creates the voltage electrode, on which small current electrodes are placed. As an example, the divided electrode construction that is used in laboratory experiments is shown in Fig.3.

For the free water level monitoring inside of the dike body, simple small twin electrodes in two terminals configuration can be used, because infiltrating, water causes dramatic change of material conductivity, and, thus, the classification of the infiltration (material saturation by water) is easy. Besides, high density of simple electrode pairs in the space of the dike avoids problem of spatial undersampling. The example of the electrode system with divided electrodes determined for two terminals measurement is shown in Fig. 4. Division of electrodes makes possible to determine the height of the infiltrating water level (*z* – coordinate).

Measurement of water pollution and its spatial distribution differs from previous types of experiments in the pure liquid state of measured medium. In principle, the same rules as in conductometric measurements used in analytical chemistry should be kept. Two terminal electrode configuration (negligible transient resistance) and equal dimensions of all pairs of electrodes placed in the tested space are substantial to achieve reliable comparison of results. The use of small conductometric cells [3] fully immersed to measured plant is recommended.

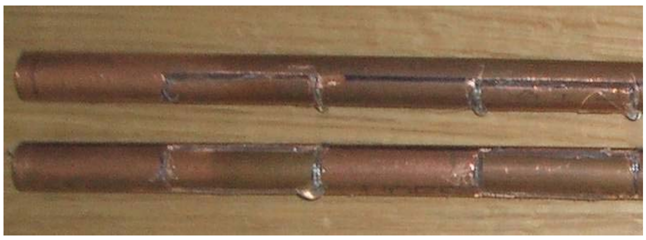


Fig. 3. The example of the electrode with common voltage and divided current electrode.

Fig. 4. Divided electrodes for the free water level measurement using simple two terminals experiment arrangement.

3. SWITCHING OF ELECTRODES

All types of experiments measure spatial distribution of material impedance. When monitoring the dike space, the problem of spatial undersampling becomes substantial. It means, the density of sensors must response to required resolution of monitored phenomena, to map this space worthfully. The electrodes must be placed in defined stable positions to create the space matrix that makes possible to determine impedance distribution within the structure space and to reconstruct its image that represents the shape and/or free water level position progress. To be able to observe these effects accurately, strong requirements on electrodes' time switching, as well as their time consequence of connection to the impedance spectrometer during measurement must be carried out. Joining of individual electrode couples (quartets) – electrode systems - and its timing is insured by the digital signal processor that controls the entire experiment [4], and apart from these things, ensures the handling of a complicated multiplexer that connects defined electrodes in defined time intervals to the impedance spectrometer. The multiplexer consists of eight PCB cards. Each card is capable of the switching of sixteen electrode systems (in two or four terminals arrangement), so that the apparatus is able to sample the space of observed construction at 128 places. Each PCB card has its own, switch-selectable address, and its presence can be checked before its use. The principal block diagram is shown in Fig. 5.

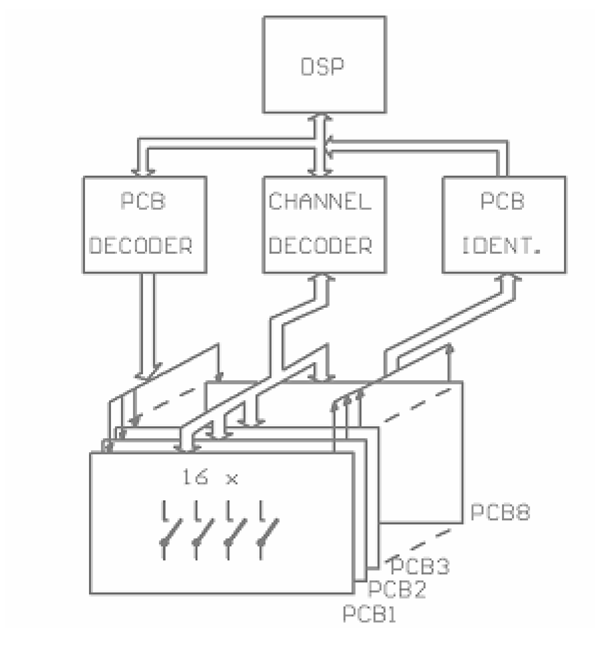


Fig. 5. Principal block diagram of the channel multiplexer.

The picture shows the system of the measuring channel selection. Each switch of the multiplexer consists of four independent contacts that are able to join up to four electrodes to the instrument terminals. The system involves two decoders that select one of eight multiplexer boards and one of sixteen channel switches respectively. PCB identifier helps the DSP to test the PCB presence in the rack and, thus, optimising of switching cycles.

4. CONCLUSIONS

The experience from experiments that have been carried out, shows the need of different approaches to the application of the electrical impedance spectroscopy in different tasks of the monitoring internal phenomena in the dike construction. These requirements ask for the building of new sensing probes and probe systems that improve quality and quantity of information offered by the method of the electrical impedance spectroscopy. At present, new types of electrode systems are designed and produced, as shown in Fig 3. The research is worked out within projects 103/01/0057 and 103/04/0741 granted by the Grant Agency of Czech Republic (GAČR).

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