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INSTRUMENTATION USED FOR DIKES MONITORING

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Abstract – Instrumentation technique and processing of analog and digital signals in specially designed equipments are described. Parameters of instruments that have been built for purposes of the thermal scalar field monitoring and for electrical impedance spectroscopy are discussed.

Keywords: signal processing, thermistor, electrical impedance.

1. INTRODUCTION

Environmental changes caused by human activities lead to weather changes in the last time. Growing frequency of floods in Europe turns human attention to the building of robust protective dikes that eliminate effects of floods. Unfortunately, the status of dikes changes in time because of rush water, water erosion, weather influence, and incidence of living organisms (trees, bush, small animals, etc.). All of these effects cause decrease of protective capability of dikes, but the worst is the influence of the rush water. To be able to minimize probability of the dike damage, the effects of factors that degrade dike properties must be studied. For these purposes, the physical models of dikes are carried out. They make possible to test dikes, made from different materials, in laboratory conditions. The goal of such laboratory experiments is observation and quantification of surface and internal changes of the dike structure. While the surface changes can be evaluated by visual observation (photography, camera, etc.), the measurement of internal changes must use different approaches. Therefore, physical magnitudes that sensitively indicate these changes were studied. This effort led to the measurements of the scalar thermal field and electrical impedance in the space of the dike body during rush water incidence. The first method is based on observing of temperature changes in internal space of the dike caused by water infiltration, and, in the case of the water tint over the top of the dike, temperature changes caused by denudation of sensors after the dike material has been washed away. The second method takes advantage of electrical conductivity changes of the dike material because of water infiltration. The instruments needed for these measurements have been carried out and their principles using modern instrumentation technique are described.

General problems of the design of the apparatus for measurements in dikes can be divided to two groups:

- Election of suitable sensors,
- Electronic and mechanic design of measurement instruments.

The measurement inside of the dike asks for the application of sensors that have their physical dimensions comparable with grain of the dike material. This requirement minimizes affects of sensors on dike parameters.

2. THERMAL DATA LOGGER

For measurement of the thermal field, small thermistor pearls (diameter of approximately 1 mm) have been used. They were coated by a water resistant paint after soldering to a cable. Besides, a thin insulating tube protected the connection sensor – cable [1]. For purposes of the experiment, the thermistors have been placed to pre-defined positions creating a spatial matrix, which samples internal space of the dike.

The electronic circuitry of the designed data logger ensures supplying of 128 sensors by a constant current, multiplexing of all 128 measuring channels containing sensors, sampling and digitization of voltage drops measured on sensors and packing measured data and sending them via the serial link to the PC. The core of the data logger consists of the digital signal processor Analog Devices ADSP 2101. It controls sampling rate that is programmable from the PC, switching of multiplexers selecting measuring channel, mode of operation of the 12-bit analog-to-digital converter, data transfer from the analog-to-digital converter, data processing and their transport to the PC (see “Fig.1”) via asynchronous serial link RS 232.

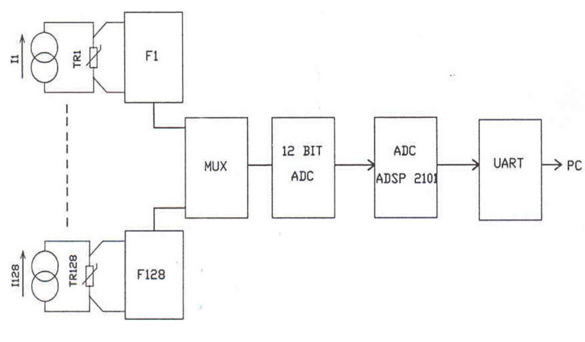

Fig.1. Principal block diagram of the thermal data logger

When received, data are stored to the data file on the PC's hard disk. Size of this file is given by time of the experiment. The DSP software is written in the assembler of the 21xx DSP family, the PC software is supported by Windows 98, and from the point of view of the operator, creates a window that makes possible to control the experiment.

The series of experiments that have been worked out showed possibilities of this measuring method. Sensitivity and sufficient density of probes inside of the dike model ensured reliable monitoring of infiltration and deforming processes inside of the dike during process of the rise of rush water. Disadvantage of the method is lower sensitivity in the case of small thermal difference between dike material and water temperatures, and after reaching of thermal equilibrium between both materials after saturation of the dike by infiltrating water. Therefore, transients caused by the decrease of the water level cannot be observed.

3. IMPEDANCE SPECTROMETER

During the last decade, the method of the impedance spectroscopy became very popular in many branches of the scientific research, in material science, analytical chemistry, medicine, etc. Electrical conductance and dielectric or ferromagnetic features are the basic characteristics of the material. Information quantity offered by impedance measurements led us to the use of this method for observing of transients inside of the dike body caused by rush water infiltration, and observing of structural changes caused by deformations of dike construction because of influences of weather and environment. For purposes of the research, the impedance spectrometer capable of the measurement of complex impedance in wide range of impedance, frequency and signal strength (see later) has been built. The instrument makes possible to use both, the two and four terminals impedance measurements.

For measurements of rush water effects on dikes [2], the stainless electrode system has been used. It has been consisted of five pairs of electrodes, which have been placed equidistantly in the dike to sample the dike space (see "Fig. 2"). As can be seen, the two-terminal method has been used for this purpose. In this type of experiment, humidity of material is high enough so that the transition resistance between electrodes and material is small and causes negligible errors.

The electronic circuitry of the instrument allows the measurement of both real and imaginary parts of measured impedance. For the impedance determination, the method of three voltmeters has been used (see "Fig. 3").

The basic circuitry consists of a generator that supplies the circuit of two impedances, the standard resistor and measured impedance, connected in series. If voltages of the generator and voltage drops on both impedances are measured, it is possible to create the vector diagram of the circuit and to determine impedance, if the resistance of the standard resistor is known and stable in wide range of frequencies. This makes possible to study material structure (dielectric constant) and affects of infiltrating water.

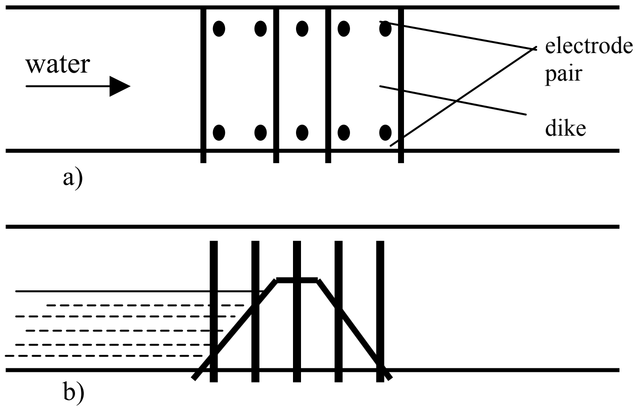

Fig. 2. The basic impedance measurement of rush water effect. The top view (a), the side view (b)

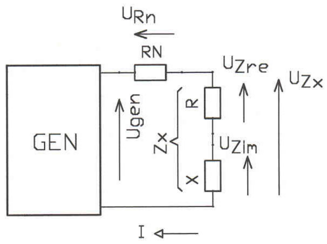

Fig 3. Basic principle of the impedance measurement

To be able to determine both impedance components, the method of quadrature detection must be used. This method of the signal detection is a special type of the synchronous detection based on the multiplication of measured signals by the reference signal, the frequency of which is the same as of measured signal, and its phase is shifted between 0° and 90°. In fact, it is the multiplication of the measured signals by sinus and cosinus parts of the reference signal, so that the real and imaginary parts of the measured signals are detected.

As can be seen, the instrument for the impedance spectroscopy has to solve several tasks:

- generation of reference and measurement a.c., and, if necessary, d.c. signals of asked frequencies and amplitudes,
- switching of measuring ranges of impedance,
- analog signal processing involving four terminal impedance measurement, quadrature detection, filtering, and analog-to-digital conversion,
- digital signal processing, including digital filtering of data, impedance vector diagram calculation and transfer of data to the PC,
- experiment parameters adjustment and experiment control and automation.

The block diagram of the impedance spectrometer built for measurements on dikes is shown in "Fig. 4".

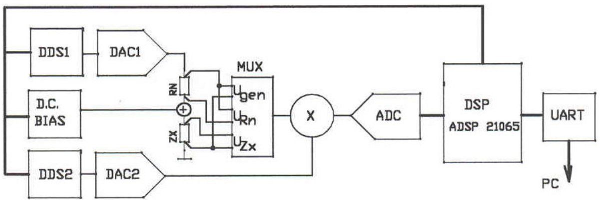

Fig.4. Principal block diagram of the impedance spectrometer

There are several basic parts of the instrument. The first ensures measurement and reference signal generators. For this, two direct digital synthesizers are used to generate needed a.c. signals – DDS1 generates digital equivalent of the measuring signal that supplies measured circuitry. This digital signal is converted to the analog one in the analog-to-digital converter DAC1. The signal amplitude is controlled by the change of the DAC1 reference voltage level. DDS2 generates the reference signal of the constant amplitude and the same frequency as the DDS1. During measurement, its phase, related to the measuring signal, is switched between 0° and 90° for quadrature multiplication. For cases, in which parasitic d.c. electrode potentials occur, the additional d.c. signal power supply is connected to compensate this parasit, and, thus, to prevent overriding of measuring circuitry by this parasitic signal. The next part of the instrument circuitry ensures switching of reference resistors that determine the range of measured impedances. Switching of ranges can be worked out automatically, or, if necessary, the measurement can be carried out on the fixed range. The circuits of the analog signal processing measure voltage on potential terminals. Measured voltages are multiplexed between all three sources of measured voltages. The terminals are connected to the input of the wide range, high input impedance buffer, which minimizes leakage currents and load of the tested impedance. The signal is then led to the precise wide range analog multiplier providing the quadrature multiplication. After the quadrature multiplication, the detected signal contains, besides the information carrying d.c. component, parasitic a.c. components that must be filtered out. Therefore, the analog low-pass filter follows the multiplier. The filter output is connected to the 16-bit analog-to-digital converter, which digitizes detected signals.

Digital data are led to the floating-point signal processor Analog Devices ADSP21065. Additional digital filtering of received data is, worked out using the 6th order FIR digital filter carried out by the software. Further, the software calculates all needed components of the impedance vector diagram, and equivalent parallel circuit of the resistance and reactance. The DSP provides the experiment control, e.g. programs both of synthesizers, magnitude of signal level, switching of the reference signal phase, range adjustment, ADC control, etc., and communication with the PC via the asynchronous serial link. The PC software archives measured data to the file, and ensures visualization of the experiment programming and results.

The instrument is capable of the impedance measurement (10 Ω – 10 MΩ) within the frequency range of 10 Hz – 8 MHz in two modes, at a single frequency or within elected frequency range. The measuring signal amplitude can be varied from 0 to 700 mV in 1 mV steps.

When compared with the method of thermal field measurement, the method of the impedance spectroscopy brings new quality to the knowledge of mechanisms in the dike. The method is sensitive, makes possible to monitor transients of water level increase and decrease, structural changes, and in small volumes is able to recognize material differences. But, at present, density of electrodes and manual switching of electrode pairs cause time and spatial undersamplings that degrade information gain of the measurement. Combination of both method improves results of monitoring.

4. CONCLUSIONS

Both instruments have been carried out and made possible to work out the experiments that contributed to the study of mechanisms of the process of water infiltration inside of the piled up dikes. The results are shown in the separate conference contribution [3]. The instrument building has been supported by the grant project 103/01/0057 GAČR (Czech Grant Agency).

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