



Design of ERT system*

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Abstract: A new electrical resistance tomography (ERT) system, based on the bi-directional current pulse technique, is developed. Polarization effects at the electrodes are eliminated. During each half cycle of the excitation process, direct current (DC) is used as the excitation source and filtering is not needed. Moreover, using optimized data collection protocol, the number of current injections for a 16-electrode system is reduced to 14 for 104 independent readings of an image. Experimental results showed that the system is effective using the sensitivity coefficient algorithm for image reconstruction.

Key words: Electrical resistance tomography (ERT), Direct current (DC), Excitation, Reconstruction

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INTRODUCTION

Electrical resistance tomography (ERT) is a technique producing images based upon variations in conductivity, and has great potential in process applications (Tapp *et al.*, 2003). In an ERT system, current is injected to a pair of drive electrodes and voltage measurements are taken between sense electrode pairs, yielding resistance information for image reconstruction (Cilliers *et al.*, 2001).

Traditional ERT systems usually use high frequency sinusoidal waveforms as the excitation source, inevitably introducing extra signal demodulation circuits, such as filters, which are time-consuming and become the bottleneck for improving measurement speed (Huang *et al.*, 2003).

This paper describes a new ERT system in which bi-directional current pulse is used to excite the electrodes. During each half cycle, the current is kept constant, and similar to a square wave. It was proved that the difference of voltage measured between the sense electrode pair is nearly a perfect square wave proportional to the drive current and the conductivity

distribution in the medium (Cilliers *et al.*, 2001). Therefore, signal demodulation is not needed and high measurement speed can be obtained.

SYSTEM CONFIGURATION

The system proposed is shown in Fig.1. In this system, a current pulse can be applied to any required pair of drive electrodes by multiplexing. The same is true for the measurement of the voltage difference between any required pair of sense electrodes. Thirty-two samples and holders (S/Hs) are adopted so that all the voltages on the 16 electrodes can be sampled and held simultaneously during each half cycle of the current pulse. Using this data collection protocol, the number of current injections using the adjacent pair measurement sequence is reduced to 14 for 104 independent readings of an image. Much time is saved compared to other systems, in which a separate current pulse is injected for each voltage measurement (Cilliers *et al.*, 2001).

The resistance measurement circuit for the ERT system is shown in Fig.2. The voltage signal on each electrode is buffered by an operational amplifier, which is configured as a voltage follower to take

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advantage of its high input impedance to correctly measure the voltage generated by the constant current, before being sampled by two S/Hs during the positive and negative half cycles of the current pulse respectively. The 32 outputs of the S/Hs are fed into two differential amplifiers via four 16-channel multiplexers to get two measurements of voltage difference between a certain pair of electrodes, one for the positive half cycle and the other for the negative half cycle. Because a voltage measurement is made during both half cycles, and the absolute values of the current are the same, the offset voltage between electrode and solution which exists in every electrochemical interface can be removed in the subtraction (van Weereld *et al.*, 2001). Before being converted by an A/D converter (ADC), the output of the third differential amplifier is subtracted by a baseline voltage given out by a D/A converter (DAC) and amplified by a software programmable gain amplifier (PGA). This operation can improve the resolution of the system under a certain input range of the ADC. When measur-

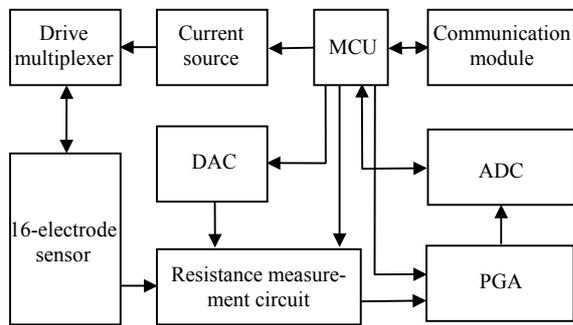


Fig.1 system block diagram

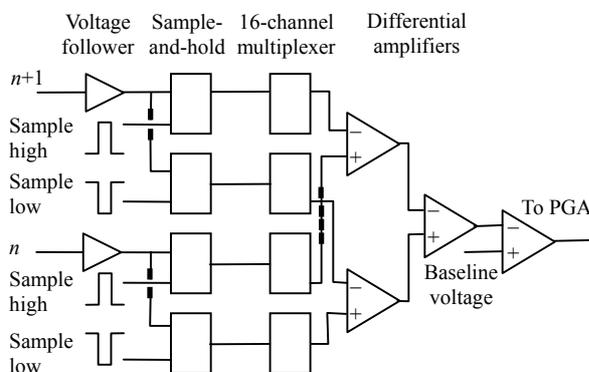


Fig.2 Schematic diagram of resistance measurement circuit

ing the baseline voltage, the output of the DAC is set to zero. Due to the differential structure, the measured result is nearly not affected by the offset voltages of the amplifiers (Wang *et al.*, 2005) and the influence of low frequency noise usually present in DC systems is also eliminated (Cilliers *et al.*, 2001). All the control signals are outputted by the Microcontroller unit (MCU) W77E58.

The bi-directional current pulse is generated by the circuit consisting of a constant current source and 4 switches (Fig.3). In the positive half cycle, switches S_1 and S_3 are closed, while switches S_2 and S_4 are open. The current flows from electrode A to electrode B. In the negative half cycle, S_1 and S_3 are open while S_2 and S_4 are closed. As a result, the current is reversed, flowing from electrode B to electrode A.

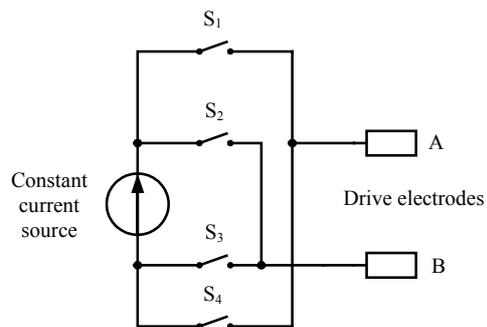


Fig.3 Bi-directional current pulse generation circuit

A communication module which can receive commands from an image reconstruction computer or send measured results to the computer for further analysis, is also designed for this ERT system. Data transmission can be implemented under the protocol of RS232 or RS422. The former is suitable for short distance and low speed communication (not higher than 115.2 kbps) while the latter is preferred for long distance and high speed transmission (up to 921.6 kbps). In the software, the CRC-CCITT polynomial is adopted to ensure the reliability of the data communication. In order to reduce circuit noise, an isolated power supply is used for the serial port.

EXPERIMENTAL RESULTS

Experiments were carried out based on a proto-

type system shown in Fig.4, in which sixteen 50 mm×5 mm×1 mm copper electrodes are mounted vertically around the circumference of an 80-diameter test pipe filled with tap water. Non-conducting plastic rods are placed at various positions of the pipe and corresponding data is collected for image reconstruction.

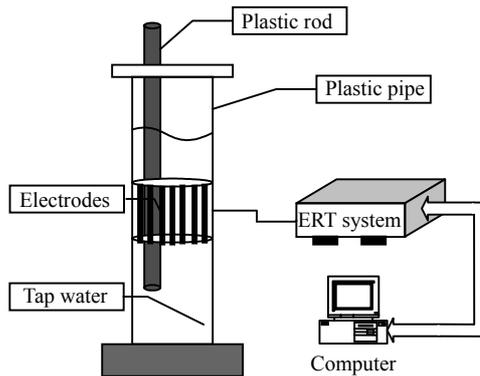


Fig.4 ERT experimental system

The excitation current is set to 10 mA, and the MCU runs at the clock of 24 MHz. RS232 is selected to be the communication protocol and the data transmission speed is set to 115.2 kbps.

Some images reconstructed by sensitivity coefficient algorithm are shown in Fig.5. The upper images in Fig.5 show the actual positions of the rods in the test pipe, while the lower ones are the corresponding reconstructions from the measurements. The results showed that the image quality is satisfactory except for the image of a rod in the center of

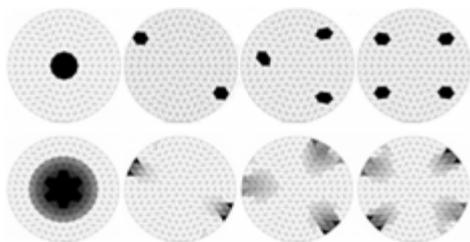


Fig.5 Images of the rod in the test pipe

the pipe, which seems too large according to the size of the rod relative to the diameter of the pipe. However, it is still reasonable considering that it is inherently difficult to image the center area.

Tests showed that the online imaging speed can be 20 frames per second and that the off-line data capture rate without imaging is about 65 frames per second. However, the measurement speed of the proposed system can be further improved by using higher speed components and networks with faster processors and peripherals.

CONCLUSION

A prototype ERT system based on the bi-directional current pulse technique is developed. Polarization effects at the electrodes are eliminated and the measurement process is simplified. High data capture rate can be achieved due to the new measurement principle and the optimized data collection protocol. Experimental results showed that the ERT system is effective for two-phase flow measurement.

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