A Study on Electrical Sensors Applied to Conductive Media

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Abstract

The applicability of different electrical tomography sensors depends on the interrogating signal as well as the sensor itself. In all electrical tomography sensors, the electrical field distribution plays a major role on the measured boundary electrical property. The electrical field distribution is based on the electrical property distribution inside the imaging domain. In this study, the electrical capacitance tomography sensor is used to study the effect of conductivity value on the field distribution.

Keywords: Conductive, Electrical capacitance sensor; Multiphase flow; Particle;

1. Introduction

Electrical tomography has provided a means for process design, monitoring, and control of flow processes [1]. In particular, conductivity/permittivity imaging offers a tool to understand dynamics of multiphase flow systems such as fluidized beds. Recent research in tomography has reduced the costs and increased the potential of electrical tomography techniques for industrial applications.

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Different modalities of electrical tomography have been the subject of intensive research based on the sensed signal, sensor, and electrical property being interrogated [2]. Electrical capacitance tomography (ECT) has been favored in many cases over other imaging modalities due to its non-invasive nature, its ability to differentiate between different phases based on the dielectric constant of each phase, and its high-speed data acquisition for real-time applications. However, ECT sensors have been generally applied to nonconductive flows, and its applicability to conductive media or beds with metallic walls is yet to be investigated.

Similarly to other electrical tomography systems, electrostatic tomography systems (EST) are composed of three main parts: (1) sensor, (2) data acquisition hardware, and (3) reconstruction algorithm. In EST, a set of sensors is mounted around the boundary of the process vessel. The sensor plates are designed to measure voltages due to static charges introduced through process dynamics. The acquisition hardware is designed to measure the voltage difference (resulting from static charges in measurement domain) between each pair of sensors in the passive mode. The passive mode refers to the state in which the sensor is independent of any voltage or current source.

In this work, the effect of conductive media on ECT capacitance measurements is investigated. Metallic walls are used in some cases to separate the ECT sensor from the imaging domain, and their effect on the ECT measurements is studied in detail. This work is aimed at exploring the applicability of ECT technology to metallic wall beds and at optimizing its properties

2. Electrical Capacitance Tomography Sensor:

ECT sensors; similar to the sensor depicted in Figure (1); are usually non-invasive non-intrusive. An ECT sensor generally consists of a number *n* of electrodes placed around the region of interest providing $\frac{n(n-1)}{2}$ number of independent measurements used for image reconstruction. The potential distribution in an ECT sensor is governed by Poisson equation:

$\nabla\left(\varepsilon(x,y,z)\nabla\phi(x,y,z)\right) = -\rho(x,y,z)$	(1)

where, $\varepsilon(x,y,z)$ is permittivity distribution, $\phi(x,y,z)$ is potential distribution, and $\rho(x,y,z)$ is charge distribution. Including the conductivity and applying the quasi static approximation:

$\nabla\cdot\left(\sigma + j\omega\varepsilon(x,y,z)\right)\nabla\phi(x,y,z) = 0$	(2)

where σ is the conductivity.

3. Simulations

The electrical capacitance tomography (ECT) sensor response to conductive media is studied based on simulations performed using FEMLAB simulation software. A two opposite plate sensor around a process column has been used as the simulation model. The inner domain of the column has been filled with two different conductive and dielectric materials to study the effect of conductivity on the ECT sensor. The simulation where based on an oscillating excitation signal of 10 MHz frequency.

4. Results

In figure 2, the normalized electric field is depicted as a function of background conductivity for a pixel of 5 dielectric constant. It is clear from the figure that the electrical field value changes as a function of conductivity, and the maximum field value occurs at the resonance point for the values of permittivity and conductivity.

5. Conclusions

In this work, the ECT sensor has been used to study the effect of conductive media on electrical sensors. The conductivity of different phases in the imaging domain changes the value of electric field. The applicability of different electrical tomography modalities to regimes of conductive media is limited based on the interrogating signal and the frequency of the excitation signal. The ECT sensor is applicable in mediums where the electric field distribution is governed by the dielectric constant.

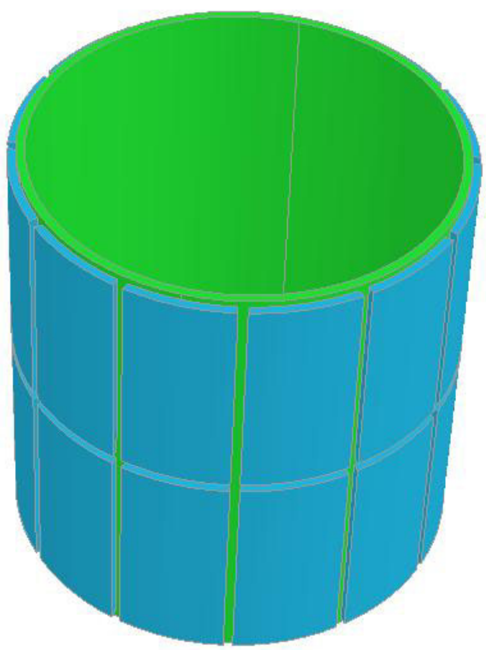

Figure 1, The ECT sensor system. A total of 12 rectangular double plane capacitor plates are used.

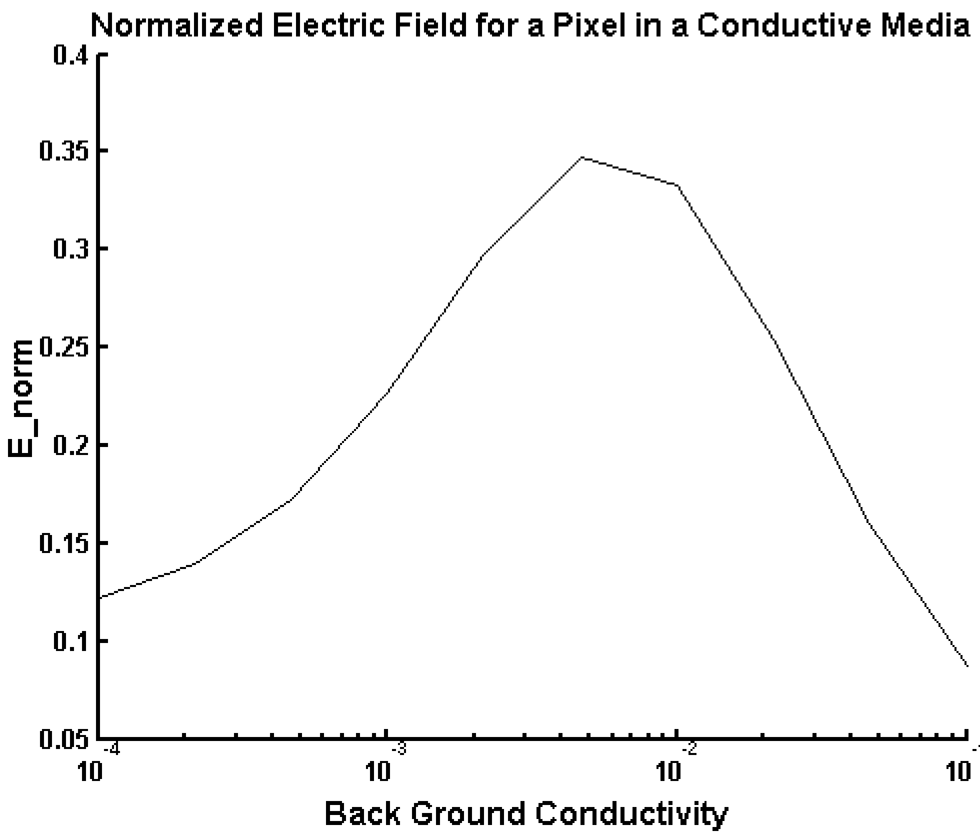

Figure 2, Normalized electric field for a pixel of 5 dielectric constant in a conductive background.

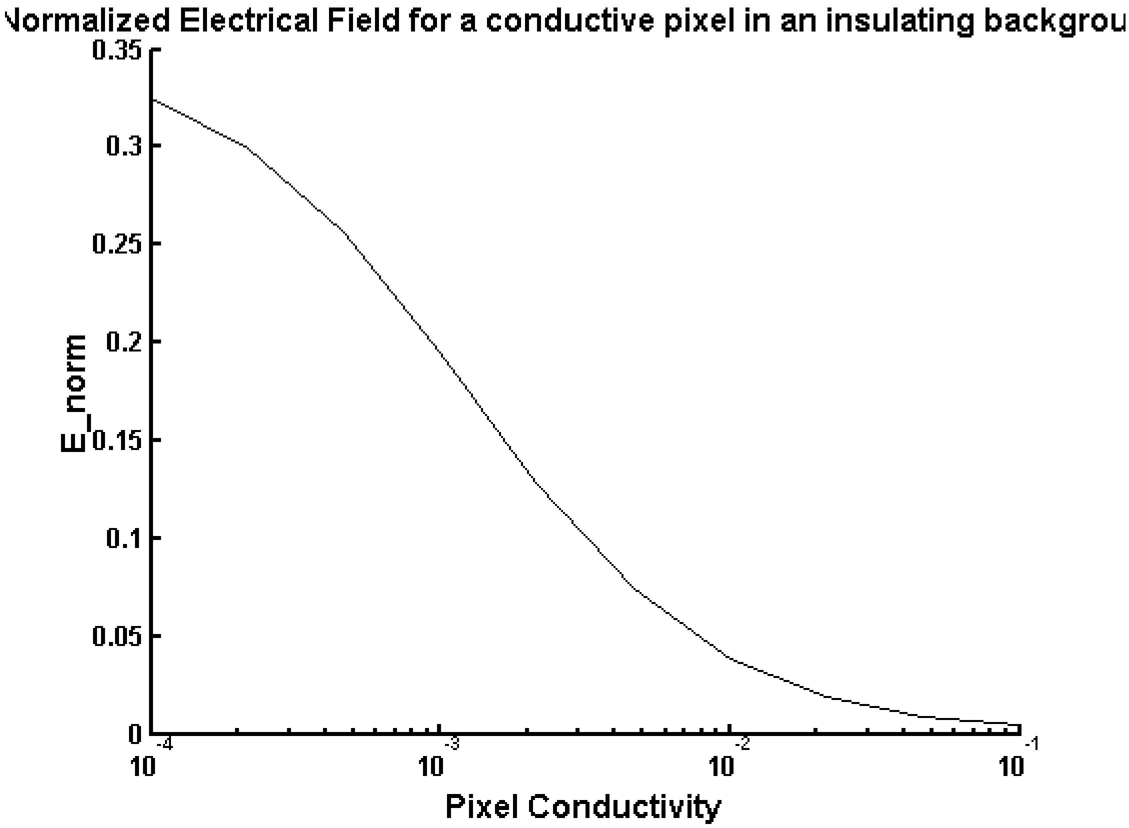

Figure 3, Normalized electric field for a conductive pixel in an insulating background.

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