

CAPACITANCE TOMOGRAPHY TECHNIQUE FOR IMAGING MIXTURE OIL  
AND WATER

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*To my lovely husband, parent and supportive friends*

*Thank you for all your support, may god bless all of you.*

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## ABSTRACT

Electrical Capacitance Tomography (ECT) sensor is non-invasive device that used the Electrical Capacitance Tomography Techniques which is non – intrusive technique to measure the concentration of flow inside the pipeline. By develop 12 ECT sensors with MATLAB programming software, the distribution of fluids inside pipeline or vessel can be visualized easily. By design a simple 12 ECT sensor with portable electrodes may reduce the difficulties on sensor construction and configuration. Perhaps that, this project can give some idea to anyone out there to develop better ECT system in practice. This system also can be used to investigate volume ratio of mixture oil and water particularly in horizontal-stratified distribution inside a flowing pipeline. Data from hardware system can be computed using MATLAB software in order to visualize the cross-section image of pipeline. Linear Back projection algorithm is taken in to account as a projection method use in this project.

## ABSTRAK

Pengesan Tomografi Kapasitan Elektrik(ECT) merupakan alat yang tidak merbahaya yang menggunakan kaedah atau teknik tomografi kapasitan yang tidak intrusif untuk mengukur dan mengetahui taburan kandungan bahan dalam paip. Dengan membina 12 pengesan Tomografi Kapasitan Elektrik bersama dengan pengaturcaraan perisian MATLAB, pengagihan bendalir dalam sesuatu paip dapat diketahui dan dilihat dengan mudah. Rekabentuk yang ringkas dan mudah alih ini dapat masalah dalam pembinaan dan pengyelenggaraan pengesan ini. Diharapkan melalui projek ini, seseorang di luar sana dapat membina Sistem Tomografi Kapasitan yang lebih baik untuk kegunaan yang sebenar. Sistem ini juga boleh digunakan bagi mengetahui nisbah campuran air dan minyak terutamanya dalam pengaliran bendalir secara mendatar dan berlapis di dalam paip. Selain itu, data daripada sistem perkakasan boleh di analisa secara terus oleh perisian MATLAB dalam usaha untuk memaparkan gambar keratan rentas sesuatu paip. Unjuran belakang linear (Linear Back projection algorithm) diambil kira sebagai cara penayangan dalam projek ini.

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## LIST OF SYMBOLS

$A$	-	Total gain of measurement system
A/D	-	Analog to digital
$C$	-	Matrix of inter-electrode capacitance
CH	-	Capacitance measured at higher permittivity
CL	-	Capacitance measured at lower permittivity
CM	-	Measured capacitance
CN	-	Normalized capacitance
Coil	-	Relative capacitance of oil
Cr	-	Relative capacitance
$Cs1$	-	Stray capacitance of connecting lead
$Cs2$	-	Stray capacitance at Op-Amp feedback point
Cwater	-	Relative capacitance of water
$Cx$	-	unknown standing capacitance
$d$	-	Distance of 2 parallel plate
$D$	-	Sensor diameter
$\epsilon$	-	Effective permittivity
$\epsilon_0$	-	Permittivity of free space
$\epsilon_{oil}$	-	Relative permittivity of oil
$\epsilon_r$	-	Relative permittivity
$\epsilon_{water}$	-	Relative permittivity of water
$f$	-	Frequency

$f_{unitygain}$	-	Unity gain frequency
$\mathbf{K}$	-	Matrix of permittivity
$K_e$	-	Effective pixel permittivity
$K_{en}$	-	Normalized effective pixel permittivity
$K_H$	-	Pixel permittivity at lower permittivity
$K_L$	-	Pixel permittivity at higher permittivity
$L$	-	Length of electrode
$\mathbf{M}$	-	Number of individual standing capacitance
$M$	-	Total number of pixels
$N$	-	Total number of pixels
$N$	-	Number of measuring electrodes
$\mathbf{Q}$	-	Unknown matrix
$\mathbf{S}$	-	Sensitivity matrix
$\mathbf{S}^{-1}$	-	Inverse sensitivity matrix
SNR	-	Signal to Noise Ratio
$\mathbf{S}^T$	-	Transpose sensitivity matrix
$V_i$	-	Input voltage
$V_o$	-	Output voltage
VR	-	Volume ratio
$W$	-	Width of electrode
$X$	-	Volume ratio
$\Delta\mathbf{C}$	-	Error capacitance matrix
$\Delta\mathbf{K}$	-	Error pixel matrix
$\omega_o$	-	Corner frequency

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## CHAPTER 1

### INTRODUCTION

#### 1.5 An overview

An Electrical Capacitance Tomography (ECT) system has been developing to visualize the component or dielectric distribution in the flow processes since 1980's. This tomography technique is non-invasive, low cost, fast response, good safety performance and wide application in industries compare to other conventional tomography techniques. By definition tomography is define as:

*Radiography in which an image of a predetermined plane in the body or other object is obtained by rotating the detector and the source of radiation in such a way that pints outside the plane give blurred image. Also in extended use, any analogous technique using other form of radiation.*

*(William et al.,1995)*

Normally, Electrical Capacitance Tomography (ECT) is used for visualizing and measuring the permittivity distribution in a cross section by using a multi-electrode capacitance sensor. The measurement of the ECT is based on the capacitance of the permittivity ( $\epsilon$ ) of the medium between electrode plates over the entire sensing volume. For  $n$  electrodes, it must have  $(n(n-1)/2)$  measurements. This system consists of three main parts: a sensor array providing the projection information, signal transformation and adjusting circuit, and image reconstruction from projection and display unit.

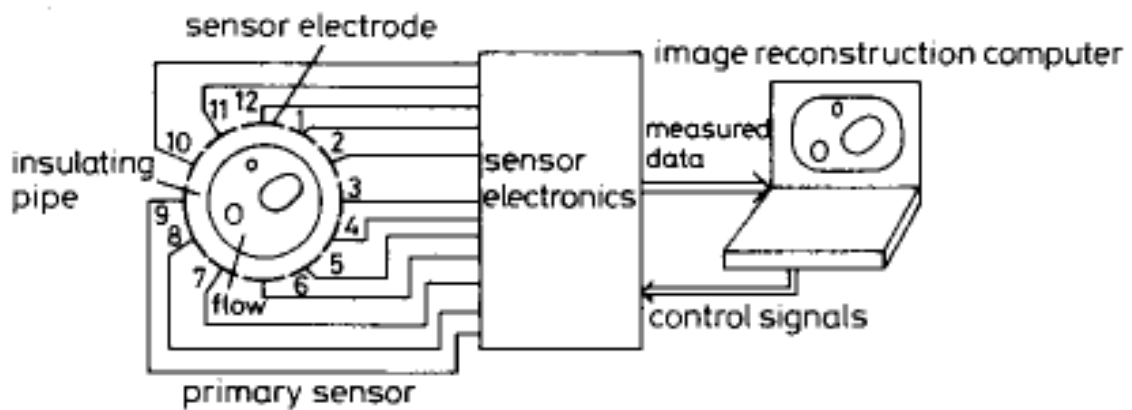


Figure 1: Capacitance tomography imaging system



## 1.6 Problem Statement

There some problem statements are listed by researchers during their task like data acquisition performances where the data transfer rate can't achieve the maximum rate due to pooling time, hardware and software processing time and data losses on the transmission line (cable). Problem regarding image reconstruction algorithm if we use Linear Back Projection (LBP) method because image produced are blurred. Another problem is how to visualize the cross-section image which it may take a long time to study and understand the program language.

## 1.7 Objective Project:

The main objective of this project is aims to visualize the image of two component fraction inside the pipeline (oil and water). However to achieve this main objective, there are some specific objectives need to consider:

- i. Familiarize with the concept of ECT system including the projection type and image reconstruction.
- ii. Designing the ECT sensors and develop the hardware and software.
- iii. Successful testing the system.

#### 1.4 Research Scope:

This project is consists of 2 stages which at the early stage is design the ECT sensors and next stage is development of hardware (implementation of ECT System). In order to achieve the main objective, there is several research scopes have been done for this project as listed below:

i) Designing of sensor electrodes and hardware system

The construction of ECT system can divide into 2 stages which is mechanical part and electrical part. The mechanical part also includes searching suitable materials for used as ECT capacitance sensor, radial and outer screen. Then for electrical part, we need implements the measurement system and digital controlling circuit on printed circuit board (PCB) and design of PCB. All the activities as material survey, sensor fabrication, coaxial cable connection technique and also budget cost of those materials needed to be consider..

ii) Study and design Software using MATLAB.

Study on how to use MATLAB software for ECT system image reconstruction. This part including investigation of data acquisition system, study on how image reconstruction can be done using MATLAB and how this software to acquired data from hardware.

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