Multistage Scanning Method on 64-Channels ECVT Sensor

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Multistage Scanning Method on 64-Channels ECVT Sensor

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Abstract**—** This research proposes a scanning method on capacitance tomography known as Electrical Capacitance Volume Tomography (ECVT). This study discusses a new scanning method i.e. multistage scanning used to retrieve data from 64-channel capacitive sensor. The scanning process is divided into six groups which is each group can handle up to 24 electrodes. The experimental result were performed at each sensor level, followed by the first group on a multistage scanning, and finally for all 64-channel electrodes. The pattern of capacitance data in each group has a similar however its value is different. The amount of data in the first scanning group was 276 data, hence the total data for all 64 channels as much as 1656 data. An adjacent of electrodes pair produce a capacitance value of about 0.8 pF to 1.5 pF, while the opposite of electrodes pair produce a capacitance value of about 0.2 pF.

Keywords—ECVT; capacitive sensor; multistage scanning; stray capacitance.

I. INTRODUCTION

The three-dimensional (3D) tomography based on capacitance measurement known as Electrical Capacitance Volume Tomography (ECVT). The ECVT is one of the volumetric image visualization methods that produces 3D images directly. The principle of capacitance tomography is by injecting a sinusoidal or square wave signal into one of the active electrode pairs as shown in Fig. 1. As a result, will cause a fringing electric field inside the sensor [1]. The electric field will affect the object within the sensor and then the signal is detected by another electrode and controlled by the electronic circuitry to be further processed into the image using an image reconstruction algorithm.

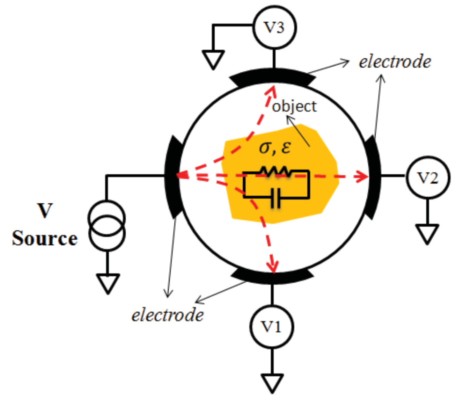

Fig 1. Principle of capacitance tomography

The applications of ECVT are numerous, for example multiphase flow scanning [2], [3], gas and liquid imaging [4], and other applications requiring a long experimental vessel. To accommodate these requirements a long capacitive sensor and a large number of electrodes are required. Hence, this study propose a 64 channel cylindrical capacitive sensor. The process of capturing data from capacitive sensors is called scanning. Scanning in ECVT is produces capacitance data that used as input of image reconstruction algorithm. Generally, the ECVT system uses conventional scanning method i.e. activating an electrode pair and measuring the capacitance signal.

In the design of the cylinder sensor, the maximum number of electrodes that can be handled is up to 24 electrodes which are divided into 3 levels with each level containing 8 electrodes. According to the previous research, it is known that the electric field flowing in the capacitance sensor can still be detected by the electronic circuit is only up to level 3. At the electrode level 4, 5, 6, etc. obtained very small SNR, making it very inconvenient to measure the capacitance [5], [6]. According to the above issue, this study is proposed a new scanning method namely multistage scanning to accommodate 64 channel cylindrical ECVT sensor.

II. 64-CHANNELS ECVT SENSOR

In this study designed cylinder-shaped sensor consisting of 64 electrodes with 8 levels, where each level has 8 electrodes as shown in Fig. 2. The sensor has a height of 24 cm, a diameter of 9 cm, a sensor material made from pvc (polyvinyl chloride), and 3x3 cm electrode size. The electrostatic can breakage the electronic circuitry that used to measure capacitance in data acquisition systems. To overcome the matter, each electrode added 1 Mohm resistor which is connected with earth guard [7].

The measurement of the capacitance in the cylinder sensor is by activating a pair of electrodes, where one electrode is connected to the excitation signal source and one electrode connected to the detection circuit. The voltage injected into the electrode will create an electric field flowing through the sensor, for example the first electrode as the excitation voltage source and the second electrode as the source of the detection. Sensors are simulated to know the radiation pattern of signals by using special software. In the electric field simulation, the value of the electric field voltage flowing in the sensor is 0.025 V / m to 0.975 V / m.

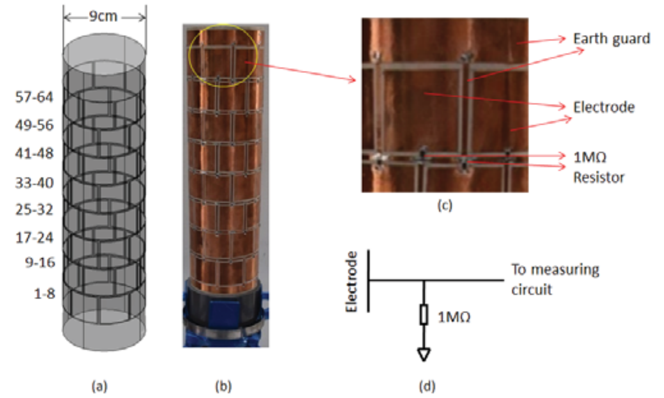

Fig 2. 64-channels cylindrical ECVT sensor; (a) design of sensor, (b) the sensor photograph, (c) electrode connection, (d) circuit diagram

In accordance with the principle of measuring capacitance, two parallel and opposite electrodes will have capacitance values. The value depend on the shape of geometry of the electrode, area of the electrode, distance between the electrodes, and the insulating material (dielectric) between the two electrodes. Analysis of the sensor design shows that among the electrode and the earth guard will give a capacitance value, where in tomography namely stray capacitance. Ideally, the stray capacitance of the sensor can be expressed as follows:

$$C_s = NS\frac{\varepsilon_0 \varepsilon_r A}{d} \qquad (1)$$

Where, C_s is stray capacitance in the sensor, N is number of electrodes, S is number of sides in a single electrode, ε_0 is dielectric constant in a vacuum of 8.85 pFm^{-1}, ε_r is the relative permittivity of the dielectric material, A is area of electrode, and d is the distance among electrode and earth guard. If the parameters mentioned above are fed to Eq. (1), the stray capacitance of the sensor is 0.0177 pF for one electrode and 4.53 pF for 64 electrodes.

III. Multistage Scanning Method

Scanning is a way of obtaining data from the capacitive sensor, where the number of data depends on the number of electrodes and the scanning method. There are several methods in the ECVT scanning, such as conventional scanning which is a common method. Another method is to arrange the electrode configuration, which combines two electrodes into one excitation and detection electrode [8], [9], rotary electrode [10], [11], and multi excitation [12]. In this study described conventional multistage scanning applied to the 64-channel ECVT systems.

A. Conventional Scanning Method

Generally the scanning method used in the ECVT system is conventional method, viz. activating electrode pair and measure the capacitance signal, hence the amount of data can be known by Eq. (2).

$$N = n(n-1)/2 \qquad (2)$$

Where, N is number of capacitance data, n is number of electrode. For example, the sensor has 8 electrodes then the total capacitance data is 28 data. Table 1 describes the data acquisition of the scanning process in the ECVT system.

TABLE I. Data acquisition of the scanning process

Detection Electrode / Excitation Electrode	1	2	3	4	5	n
1	-	$C_{1,2}$	$C_{1,3}$	$C_{1,4}$	$C_{1,5}$	$C_{1,n}$
2	-	-	$C_{2,3}$	$C_{2,4}$	$C_{2,5}$	$C_{2,n}$
3	-	-	-	$C_{3,4}$	$C_{3,5}$	$C_{3,n}$
4	-	-	-	-	$C_{4,5}$	$C_{4,n}$
5	-	-	-	-	-	$C_{5,n}$
n	-	-	-	-	-	-

According to the Table 1, for example the number of electrodes is known to be 8 pieces, the capacitance readings are obtained from electrode pairs 1-2, 1-3, .., 1-8, 2-3, 2-4, .., 2-8, 3 -4, 3-5, 3-6, .., 3-8, and so on until the pair of 7-8 electrodes. If there are a number of n electrode, then the data acquisition of the capacitance corresponds to Eq. (2).

B. Multistage Scanning Method for 64-Channels ECVT Sensor

As previously described above, the electric field is flowing inside the sensor from the excitation electrode to the detection electrode. The closer of pair of electrodes is, the more electric current flows and the easier it to measure. Nevertheless, the farther pair of electrodes is, the less the electric field flows, and the more difficult it to measure the signal. For cylindrical sensors the electric field measured by the detection circuit is only up to level 3 or only up to the 24th electrode [5], [6].

To accommodate the long cylinder sensor with the number of electrodes as much as 64 pieces, it is necessary multistage scanning process. The scanning process was divided into six groups where the first group scanning process started from electrode 1 to 24, second group of electrode 9 through 32, third group of electrode 17 to 40, fourth group from electrode 25 to 48, scanning the fifth group from electrode 33 to 56, and the last scanning of the sixth group from 41 to 64 electrodes. The amount of data in the first scanning group was 276 data. The process is repeated for the next group so that the total data obtained as much as 1656 data.

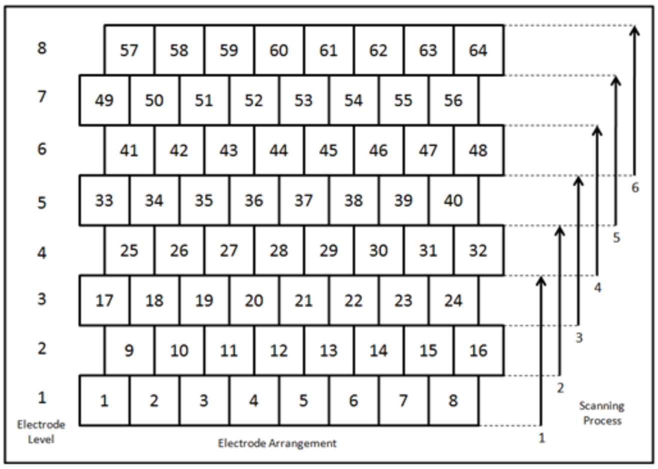

Fig 3. Electrode arrangement and multistage scanning process on 64-channels ECVT sensor

Electrode arrangement and multistage scanning processes are shown in Fig. 3. Electrodes are arranged into eight levels where each level contains eight electrodes. The numbering electrode is starts from the bottom electrode from left to right and then up to the next level. The scanning process is divided into six groups as described above.

IV. Results and Analisys

The scanning method is applied to the 64-channel ECVT sensors requires six stages as described above. The 64-channel sensor should be able to be measure the capacitance signal with the scanning method, therefore the performance testing is necessary. The experiment were performed at each level of the sensor from level one to level eight, this was done to know that the sensor and electronic circuit nothing is error. The shape of the signal pattern should be as shown in Fig. 4 which resembles the letter 'U', if the signal pattern is not the similar there is a problem in the design. And then followed by experiment in the first group on a multistage scanning, and finally for all 64-channel electrodes. In the first group scanning there are 24 electrodes so that 276 data will be generated. The shape of the signal pattern is similar to the pattern on the previous scan but more in number. Likewise the signal pattern on multistage scanning will produce data pattern with data as much as 1656 data. The results of the capacitance signal measurement are shown in Fig. 4 through 6. The signal measurement shows the pattern of the capacitance data of the cylinder sensor, the adjacent of electrodes pair give a large value and the opposite of electrodes pair give a small value.

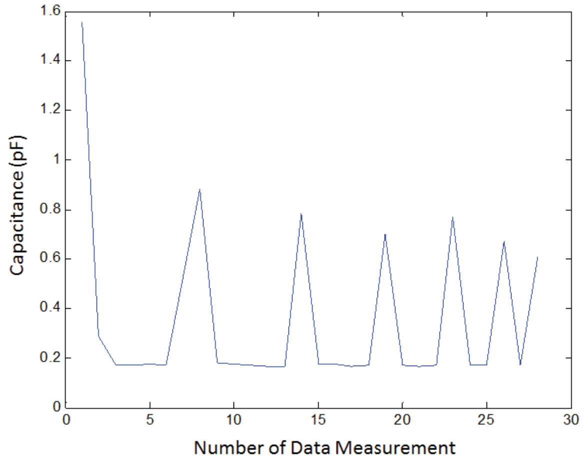

Fig 4. Capacitance signal in the first level (8 electrode)

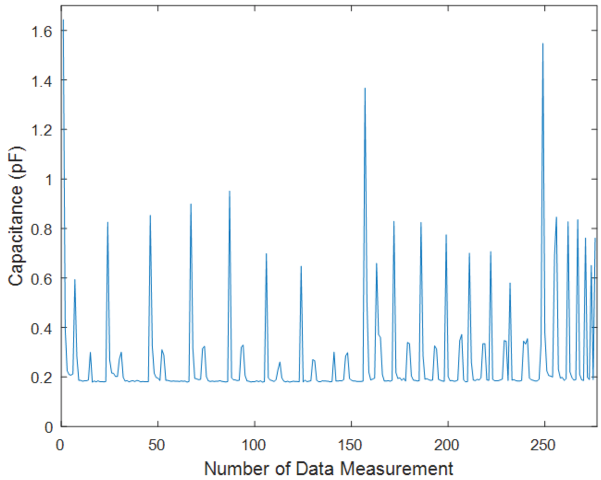

Fig 5. Capacitance signal in the first group (24 electrode)

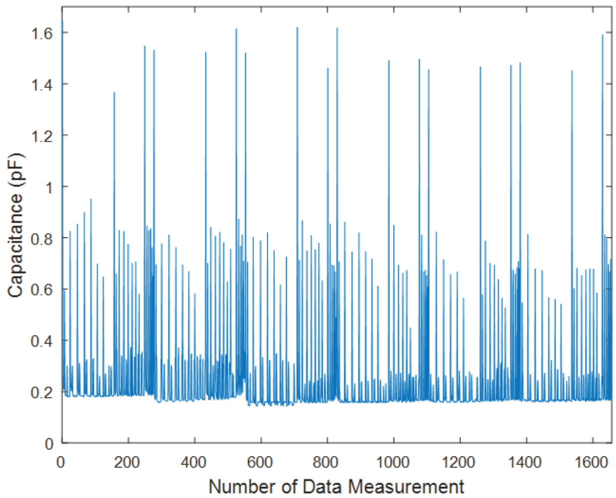

Fig 6. Capacitance signal for all channel (64 electrode)

The pattern of capacitance signal of the 64-cylinder sensor is shown in Fig. 4 which is measured at the first-level of 8 electrode. According to the Eq. (1) the amount of data obtained is 28 data. An adjacent of electrode pair produce a large capacitance value of about 0.8 pF to 1.5 pF as in the electrode pair 1-2, 1-8, 2-3, 3-4, 4-5, 5-6, 6-7, and 7-8. While the opposite of electrode pair produce a smaller capacitance value of about 0.2 pF as in electrode pairs 1-3, 1-4, 1-5, 2-4, 2-5, 2-6, 3-5, 3-6, etc.

The pattern of the capacitance signal of the 64-channel cylinder sensor on the first group of multistage scanning is shown in Fig. 5 in which are 24 electrodes in the group. The data other group such as group two to six show similar patterns but different capacitance values. Besides, the pattern of capacitance signal of all scanning groups for all channels (64 electrodes) is shown in Fig. 6. The pattern of capacitance signal in each group has a similar shape because all electrodes have the same geometry and the shape of the sensor is a cylindrical vessel having the same diameter between the lower and upper ends.

V. CONCLUSION

The 64-channel capacitive sensors used for ECVT tomographic applications have been designed. To measure the capacitance signal on each pair of electrodes requires a multistage scanning, which are divided into six groups. The resulting of the scanning indicate that an adjacent of electrode pair produce a large capacitance value, and vice versa for an opposite of electrode pair resulting a small capacitance value. The amount of data in the first scanning group was 276 data, hence the total data for all 64 channels as much as 1656 data.

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