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Cloud-base monitoring of Lease Automatic Custody Transfer (LACT) parameters in Nigeria

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ABSTRACT: This paper presents an improvement to the existing method of monitoring LACT unit parameters in the Nigerian oil and gas industry. It implemented a low cost near real-time cloud-based monitoring system using MATLAB, proteus software, Arduino integrated development environment (IDE) and sim-808 to perfect the simulation and transmission of the line temperature, line pressure, line flow rates, line BS & W and line density of the Lease Automatic Custody Transfer (LACT) unit. A secured ThingSpeak IoT cloud-based platform was used to receive the transmitted line parameters remotely and the graphical result obtained from the ThingSpeak platform replicated that of the line/field parameters. The parameters used for this study was collected from Rumuekpe LACT-unit in Port Harcourt, Rivers state, Nigeria.

KEYWORDS: LACT-unit, Cloud-based, Arduino integrated environment, Thing Speak, Measurement, MATLab, Proteus, Oil and gas.

I. INTRODUCTION

The determination of the quantity and the quality of petroleum and petroleum products is of great important to the oil and gas industry. Several measures have been put in place by the interested parties in the industry to ensure accountability and reliability of metering systems. These measures includes but, not limited to constant monitoring and periodic maintenance of hydrocarbon measuring devices. The devices monitored are temperature transmitters, pressure transmitters, differential pressure switches and transmitters, flow meters, valve limits switches, pipe provers and auto-sampler systems. Because of the importance of the monitoring system, lease automatic custody transfer (LACT) unit and control room operators from indigenous oil producing companies, third party companies and government regulatory agencies are deployed to work in a hazardous environment in an offshore location for monitoring on regular basis, the actual readings and behaviors of these measurement instruments. At several occasions, accommodation, feeding, transportation and wellbeing of these operational personnel have created unsurmountable challenges to the stakeholders and have been responsible among other thing, for the high cost of production of petroleum and petroleum products. According to business newspaper energy review of September 15th, 2020, oil and gas company operators have blamed the high cost of production on obsolete systems and technologies. To attain optimal performance and bring down the high cost of production of crude oil in Nigeria, more sensors are needed to be deployed to transmit data to people at remote locations to monitor and this cannot be achieved without the involvement of the embedded information technology in every process including measurement (Onyekwelu, 2020). Because of the inadequate utilization of sensor, communication and information technology in the oil industry in the country, Nigeria has become the world's second most expensive country to produce oil in 2024 (Oladipo, 2024).

However, industry 4.0 which was first coined by German government at a fair in Hannover could offer a solution (Lu, 2017). It can be defined as "utilizing the power of the communication technology and innovative inventions to boost the development of the manufacturing and processing industries". The application of industry 4.0 in the manufacturing industry is characterized by cyber physical production system (CPPS) with the integration of

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heterogenous data and knowledge whose aim is to improve effectiveness and efficiency in operations as well as realizing the rapidly changing production requirement (Costa, et al 2020). According to (Oztemel and Guserv, 2020), industry 4.0 consist of the following base technologies: Big data Analysis, Internet of things, Cloud computing, Additive Manufacturing, Machine Learning, Autonomous Robotics and Block Chain (Frank et al, 2019; Oztemel and Gursev, 2020). Industry 4.0 makes it easy for vertical integration allowing uninterrupted communication to the factory assets beginning from the lowest level to the enterprise level. It represents a paradigm shift from the computer integrated manufacturing (CIM) which is an industry 3.0 concept to smart factory. Horizontal integration which is another evolutionary framework has been made possible by industry 4.0, and it makes the actors in the supply chain to be interconnected, becoming a hybrid of products and services (Nakayama, et al, 2020).

Cloud-based monitoring of lease automatic custody transfer (LACT) unit parameters is a system that will develop visual sensors for emulationand transmission of data through visual nodes, demonstrate an algorithm or regression for transmitting the data to the cloud and configure a Thinkspeak interface for receiving the data at the cloud. These will enable stakeholders to view LACT unit parameters in real time from their different locations and make decisions based on their observations.

II. LITERATURE REVIEW

2.1 Conceptual framework

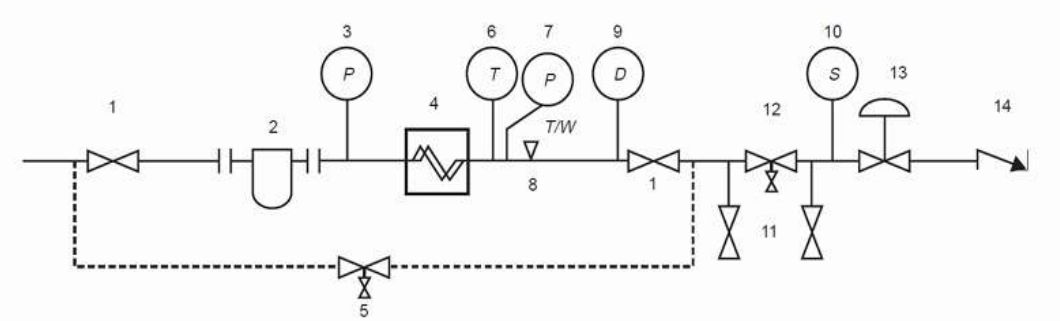

Figure 2.1: Line diagram of a typical LACT-unit

Lease Automatic Custody Transfer (LACT) units are essential in the oil and gas industry, acting as the benchmark for the precise measurement and transfer of hydrocarbons between entities. These units are crucial in ensuring that the quantities and quality of oil and gas exchanged are meticulously documented, thereby becoming vital for financial dealings, adherence to regulations, and overall operational effectiveness (Naslednikov and Petrov, 2022). LACT units are indispensable for accurate measurement, regulatory compliance, operational efficiency, and quality control in the oil and gas industry. However, they face several operational challenges. These challenges centers on data accuracy, connectivity, security, integration, compliance, maintenance, cost, and human factors. Overcoming these challenges requires the integration of advanced technology such as cloud monitoring to ensure the effective and reliable operation of LACT units.

2.2Review of Related Literatures

Through their studies, Abdelgawad, Lewis, Elgamel, Issa, Teng, and Bayoumi (2006) developed a fresh approach for monitoring and evaluating oil and gas fluids. Research by Abdelgawad et al. (2006) included creating a prototype for consistently accurate flow rate measurement from an oil industry distance. Data was sent across a Wireless Sensor Network (WSN) using a Crossbow Technology MICA2 mote and the NuFloat Measurement System Model MC-II Flow Analyzer. The primary goal of the research was to provide a means for the oil and gas sector to

consistently, continuously, and precisely monitor flow rates and total fluid flow free from human mistake.According to the prototype, the battery should run 1.5 to 2.5 years and the flow meter and host computer could interact up to 55 feet away only. It should be mentioned thatthe prototype didn't meet the difficulties surrounding remote monitoring yet, it played a significant role to mixing modern wireless technology withhold analog sensors.

John and Igimoh (2015) developed a real-time system tracking oil and gas flow rate in order to increase openness and responsibility in the sector. The system allows users of several locations monitor daily production from a distance.The system employs architecture based on wireless sensor networks. A wireless network feeds data to a database server; flow rate sensors, an LCD, and a microcontroller display data. Working with IEEE 802.11 criteria, the scheme comprises a WiFi module (MRF24WBOMA). This allows people to quickly communicate without running the microcontroller too much memory consumption.

This study aimed to find a means to reduce the high expenses of manually monitoring oil and gas flow by means of remote site sending of technicians. Lack of metering infrastructure in Nigeria's oil and gas industry was seen as a major issue requiring a consistent and reasonably priced means of monitoring affairs. The system developed, allowed one to evaluate oil from wellheads to export terminals more precisely. This increases openness and responsibility in oil lifting activities. It also lessens the expenses of hand monitoring.

According to John and Igimoh, 2015, the system satisfies the demand for real-time monitoring and data access; nevertheless, the security of the wireless sensor network might not be flawless.

In a 2016 study by Priyanka, Krishnamurthy, and Maheswari, a PLC-based controller's ability to regulate flow and pressure in a liquid transmission system was underlined by an experiment. A PLC running RS Logix 500, a pump, pressure sensors, and control valves created a lab-sized experiment set-up. The control valve opening was adjusted depending on pressure signals from sensors positioned at several pipeline points in order to test the system. Examining the open loop response helped us to understand how pressure alters flow rate.

(Priyanka, et al., 2016) investigation targeted to replace manual control of valve openings with an automated PLC-based system to maintain desired pressure ranges and flow rates during the transmission of petroleum through pipelines, thereby preventing back pressure that could damage the pipelines.

However, (Priyanka, et al., 2016) study does not address the real-time system requirements that were ignored in the experimental setup, which may affect the applicability of the results in actual industrial conditions.

Again, investigation by (Gosavi, Gawade and Gautam, 2017) explored the development of a system to monitor and forecast water consumption through domestic pipelines, utilizing advanced data analytics and various prediction techniques. The proposed system consists of a flow meter, microcontroller (Arduino), microcomputer (Raspberry Pi), and cloud infrastructure. The flow meter measures water flow using a Hall effect sensor, and the data is processed and uploaded to a web server for user access.According to Gosavi et al. (2017), water use monitoring and prediction turned out successful. With among the several techniques applied, SVM regression had the lowest mean squared root error. The system shows users how much water they are using over a web interface. Gosavi et al., 2017 discussed data security, power management, and sensor accuracy among physical concerns. They also discussed how better data prediction models might raise consumer satisfaction andoutcomes.

Examining how to build and set up a cloud-based monitoring and control system for industrial processes, the paper by (Egwurube, Kamalu, and Nwazor, 2018)demonstrated simultaneously how cloud computing might support management and security. It covers how to set up and use data dictionaries for tracking tables including voltage, temperature, and pressure as well as how to run MySQL to handle databases. Designed on PHP, the system records past data and responds to issues while also allowing you real-time data and control to monitor equipment from a distance.The last section discusses how effectively the system performs for remote monitoring and offers some recommendations for enhancements—such as including more intelligent control measures—that would help to make it still better.

In another development, (Lawan, Oduoza, and Buckley 2021) x-rayed in their paper the adoption of cloud computing in the upstream oil and gas industry, highlighting the current state of adoption, the factors influencing this adoption, and presenting a conceptual model to facilitate decision-making. A literature review was conducted to gather existing knowledge and identify the crucial factors that impact cloud adoption. To develop a whole model that separates

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elements into three main groups, several theories—including the Technology-Organization-Environment (TOE) framework, institutional theory, and the diffusion of innovation—are applied in this paper.

The research was started because it is known that cloud computing has many benefits, including the ability to grow, be flexible, and lower costs. However, the upstream oil and gas sector is still hesitant to fully adopt this technology because they are worried about security, trust, privacy, data integrity, and reliability.

results.

But (Kukreja and Kernawat, 2022) also found some gaps that need to be looked into further. One big worry is that some businesses aren't fully adopting cloud solutions because they're afraid of security risks and the difficulty of moving old systems to the cloud. More in-depth research is also needed to find out how using the cloud will change the culture of an organization and the way employees work in the long term. For implementation to go smoothly, it's important to know how cloud technologies can be added to current processes without causing problems.

In general, looking into cloud computing in the oil and gas industry has led to useful discoveries and big steps forward. However, more research is needed to solve the problems and fill in the gaps that have been found. As the industry changes, incorporating cloud technologies will be very important in determining its future.

III METHODOLOGY

3.1 Materials and Software Tools Used in the Work.

The following materials and software tools are used in the development of the cloud-based monitoring of Lease Automatic Custody Transfer (LACT) unit parameters.

i. LACT data from the existing plant
ii. MATLAB software
iii. Excel Software
iv. Arduino Integrated Development Environment (IDE)
v. Proteus professional software
vi. ThingSpeak Cloud Resource
vii. IoT data transmission gateway, SIM 808.

3.2 High level block diagram.

The figure below, shows the high-levelblock diagram of the method adopted to achieve the objectives of this research.

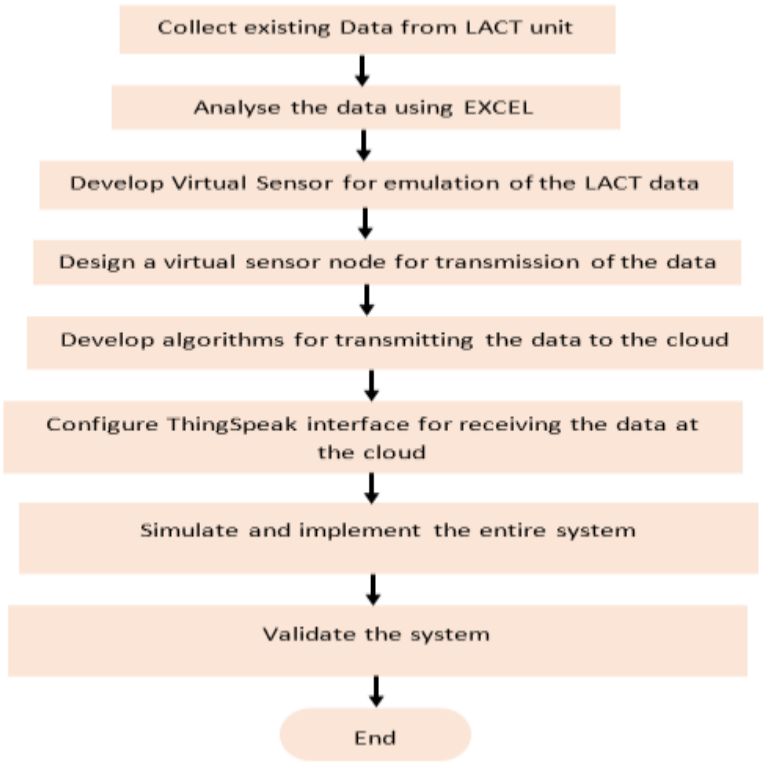

Figure 3.1: System Methodology

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3.2.1 Description and Analysis of LACT Data Collected from LACT Unit, Port Harcourt

Table 3.1 shows the summary of data collected from LACT Unit, Port Harcourt Rivers State Nigeria.

Let the minimum flow rate be MinFR. From table 3.1, MinFR is a constant. So

$$MFR = 100 \quad (3.1)$$

Similarly, the maximum flow rate, $MaxFR = 1000$ (3.2)

The minimum value of the current operating flow rate is 549 bbl/hr while the maximum value is 680 bbl/hr. The average flow rate is 596.205 bbl/hr. Figure 3.2 shows the scatter plot of current operating flow rate.

The minimum pressure MinP is 0 psi while the maximum pressure MaxP is 300psi. Thus

$$MinP = 0 \quad (3.3)$$

$$MinP = 300 \quad (3.4)$$

The minimum value of the current operating pressure r is 75.2 psi while the maximum value is 76.8 psi. The average pressure is 76.0695 psi. Figure 3.3 shows the scatter plot of current operating pressure.

The minimum temperature MinT is 0 °F while the maximum temperature MaxT is 300 °F. Thus

$$MinT = 0 \quad (3.5)$$

$$MinT = 300 \quad (3.6)$$

The minimum value of the current operating Temperature is 91.2 °F while the maximum value is 93.5.2 °F. The average temperature is 92.322°F. Figure 3.4 shows the scatter plot of current operating temperature.

The minimum API gravity at 60 °F is 43.5 while the maximum value is 45.8. The average value is 43.788. Figure 3.5 shows the line plot of API gravity at 60 °F.

Percentage of sediment and water (S&W) is a constant, and is equal to 0.05. Figure 3.6 shows the scatter plot of S&W

Table 3.1 Summary of data collected from LACT Unit, Port Harcourt

Sr. No.	Min. Flowrate BBL/HR	Current operating Flowrate BBL/HR	Max. Flowrate BBL/HR	Min Pressure Psi	Current operating Pressure Psi	Max Pressure Psi	Min Temperature Deg F	Current operating Temperature Deg F	Max Temperature Deg F	API gravity @60 Deg F	% of S&W
1	100	596	1,000.00	0	75.2	300	0	91.2	300	43.5	0.05
2	100	580	1,000.00	0	76.3	300	0	92.1	300	43.5	0.05
3	100	680	1,000.00	0	75.3	300	0	91.6	300	43.5	0.05
4	100	655	1,000.00	0	75.2	300	0	91.5	300	45.8	0.05
5	100	652	1,000.00	0	75.6	300	0	91.6	300	43.8	0.05
6	100	632	1,000.00	0	76.1	300	0	91.5	300	43.6	0.05
7	100	623	1,000.00	0	76.3	300	0	91.8	300	43.5	0.05
8	100	598	1,000.00	0	76.2	300	0	91.9	300	43.6	0.05
9	100	569	1,000.00	0	76.5	300	0	92.1	300	43.8	0.05
10	100	578	1,000.00	0	76.1	300	0	93.2	300	43.8	0.05
11	100	600	1,000.00	0	76.5	300	0	93.1	300	43.8	0.05

12	100	598	1,000.00	0	76.1	300	0	93.4	300	43.8	0.05
13	100	586	1,000.00	0	75.9	300	0	92.4	300	43.6	0.05
14	100	568	1,000.00	0	75.8	300	0	92.8	300	43.5	0.05
15	100	612	1,000.00	0	75.6	300	0	93.2	300	43.6	0.05
16	100	586	1,000.00	0	75.7	300	0	92.4	300	43.8	0.05
17	100	628	1,000.00	0	75.9	300	0	92.8	300	43.5	0.05
18	100	576	1,000.00	0	76.2	300	0	93.2	300	43.5	0.05
19	100	575	1,000.00	0	76.1	300	0	92.1	300	45.8	0.05
20	100	574	1,000.00	0	76.5	300	0	91.6	300	43.8	0.05
21	100	582	1,000.00	0	75.5	300	0	91.5	300	43.6	0.05
22	100	562	1,000.00	0	76.8	300	0	91.6	300	43.5	0.05
23	100	586	1,000.00	0	75.9	300	0	91.5	300	43.6	0.05
24	100	581	1,000.00	0	76.3	300	0	91.8	300	43.8	0.05
25	100	583	1,000.00	0	76.2	300	0	91.9	300	43.8	0.05
26	100	549	1,000.00	0	76.5	300	0	92.1	300	43.8	0.05
27	100	612	1,000.00	0	76.1	300	0	93.2	300	43.6	0.05
28	100	632	1,000.00	0	76.5	300	0	93.1	300	43.5	0.05
29	100	614	1,000.00	0	76.1	300	0	93.4	300	45.8	0.05
30	100	628	1,000.00	0	75.9	300	0	92.4	300	43.8	0.05
31	100	612	1,000.00	0	75.8	300	0	92.8	300	43.6	0.05
32	100	586	1,000.00	0	75.6	300	0	93.2	300	43.5	0.05
33	100	628	1,000.00	0	75.7	300	0	91.6	300	43.6	0.05
34	100	576	1,000.00	0	76.3	300	0	91.5	300	43.8	0.05
35	100	575	1,000.00	0	76.2	300	0	91.2	300	43.8	0.05
36	100	574	1,000.00	0	76.5	300	0	91.3	300	43.8	0.05
37	100	582	1,000.00	0	76.1	300	0	91.8	300	43.8	0.05
38	100	562	1,000.00	0	76.5	300	0	93.5	300	43.6	0.05
39	100	586	1,000.0	0	76.1	300	0	92.5	300	43.5	0.0

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			0								5
40	100	581	1,000.00	0	75.9	300	0	92.4	300	43.6	0.05
41	100	623	1,000.00	0	75.8	300	0	92.3	300	43.8	0.05
42	100	598	1,000.00	0	75.6	300	0	92.8	300	43.8	0.05
43	100	569	1,000.00	0	75.7	300	0	92.6	300	43.8	0.05
44	100	578	1,000.00	0	75.9	300	0	92.5	300	43.8	0.05
45	100	600	1,000.00	0	76.2	300	0	93.2	300	43.6	0.05
46	100	598	1,000.00	0	76.1	300	0	93.1	300	43.5	0.05
47	100	586	1,000.00	0	76.5	300	0	93.4	300	43.6	0.05
48	100	568	1,000.00	0	75.5	300	0	92.4	300	43.8	0.05
49	100	612	1,000.00	0	76.8	300	0	92.8	300	43.5	0.05
50	100	586	1,000.00	0	75.9	300	0	93.2	300	43.5	0.05

Figure 3.2: scatter plot of current operating flowrate

Figure 3.3: scatter plot of current operating pressure

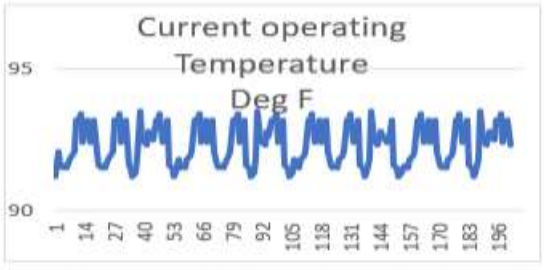

Figure 3.4: scatter plot of current operating Temperature

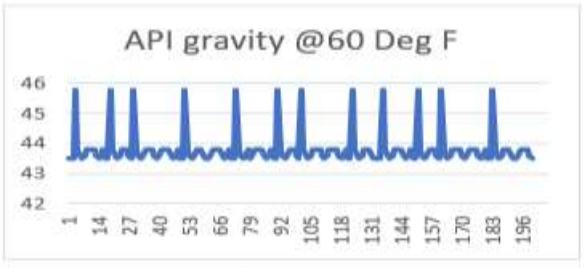

Figure 3.5: scatter plot of current operating API gravity

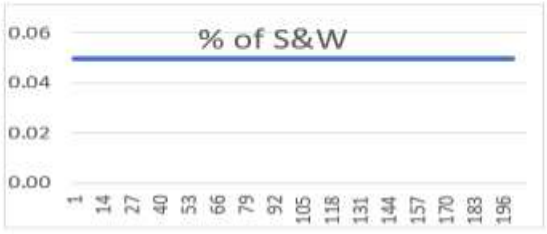

Figure 3.6: scatter plot of current operating % S & W

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3.2.2 The Key Intelligence Elicitation from the LACT Data Analysis

Examination of the scatter plots and line plot of the LACT unit parameters reveal that each set of data follow a definite pattern that is almost periodic. It means a faulty LACT unit can be easily detected by observing the graphic display of data extracted from the unit. If these data are transmitted online in real time using IoT cloud technology, it means this plant can be monitored online in real time. Abnormal flow rate for example could mean that the flow valve needs maintenance or that the flow control loop and its algorithm require maintenance.

3.3 Design of Virtual Sensors for Emulation of LACT Data Parameters.

In order to develop and deploy a cloud-based monitoring LACT unit, there is need to develop virtual sensors that would emulate the data parameters of table 3.1. These sensors would help in carrying out factory acceptance test (FACT) before the physical deployment of the cloud solution.

3.3.1 Industry Standard for Sensors

The basic requirement for calibration of industrial sensors is that it must be within the scale of 4mA to 20mA. Basically, the sensors are designed to have output of 4mA as the minimum value and 20mA as the maximum value (Keyence, 2023). It means that virtually, industrial sensors can be characterised as current source with output range of 4mA to 20mA.

Now the microcontroller to be used in the simulation accepts maximum analog input of 5v dc. Given that V=IR by ohm's law where R is the input impedance to the controller and I is the current from the sensor, it means that at constant R,

$$\frac{V}{I} = R \qquad 3.7$$

At 5v and current of 20mA,

$R = 5/0.02 = 250$ ohms.

the voltage equivalent of 4mA is $0.004 * 250 = 1V$

so, the equivalent standard reading of the emulated sensor should be 1V to 5V. Table 3.2 represents the characterisation of sensors to be used in the emulation of sensors that generated the LACT data parameters.

The analog to digital converter (ADC) resident in the microcontroller is 10bits. It means it has a resolution of 10 bits which implies that the smallest increment that can be detected by the controller is $1/2^{10} = 0.00098$V. This is approximately 0.001v

Matlab file (mfile) shown in figure 3.7 was created to discretise the range of values of the sensors characterised in table 3.2. Matlab curve fitting tool was used to generate the corresponding linear regression models of the graphs resulting from figure 3.7 as shown in figures 3.8 to 3.11

```
1   V = 1:0.001:5
2   n = length(V)
3   Pressure =linspace(0,300,n );
4   plot(V,Pressure)
5   xlabel("Sensor Output in Volt")
6   ylabel("Pressure in Psi")
7   figure
8   Flowrate =linspace(100,1000,n);
9   plot(V,Flowrate)
10  xlabel("Sensor Output in Volt")
11  ylabel("Flow rate in bbl/hr")
12  figure
13  Temperature =linspace(0,300,n);
14  plot(V,Temperature)
15  xlabel("Sensor Output in Volt")
16  ylabel("Temperature in deg.F")
17  figure
18  APIgravity =linspace(43.5,45.8,n);
19  plot(V,Temperature)
20  xlabel("Sensor Output in Volt")
21  ylabel("APIgravity")
```

Figure 3.7: Mfile for discretization of the sensor values

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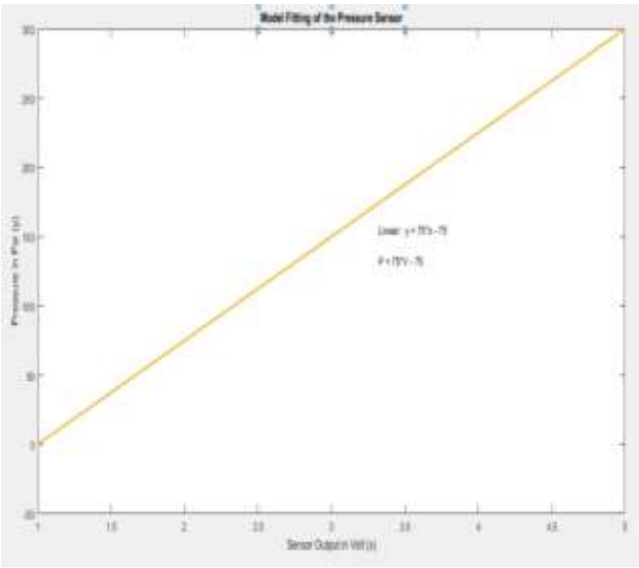

Figure 3.8: linear regression model for the pressure sensor

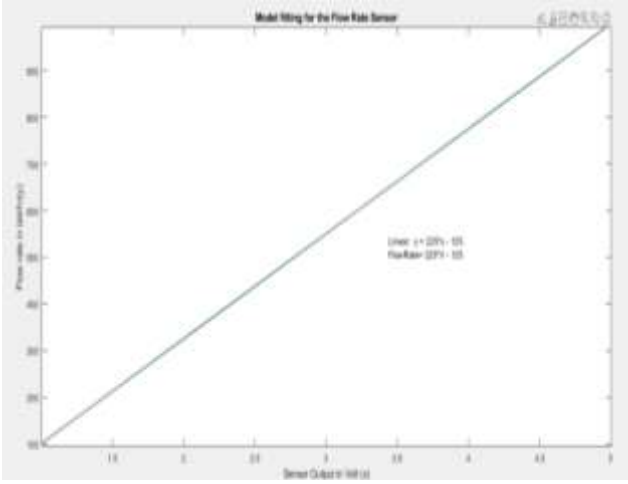

Figure 3.9: linear regression model for the flow rate sensor

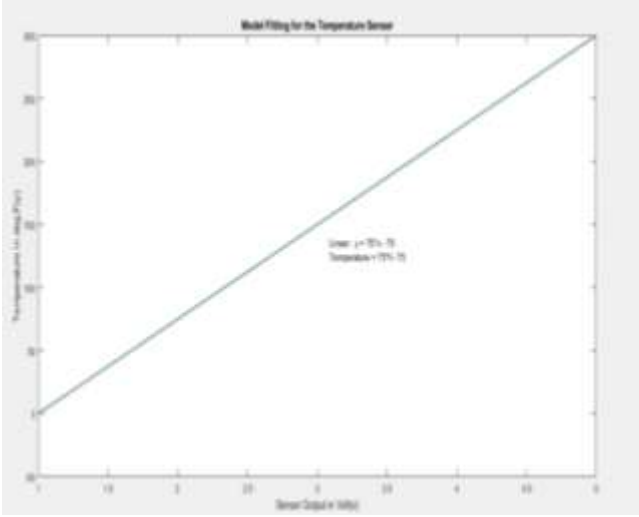

Figure 3.10: linear regression model for the temperature sensor

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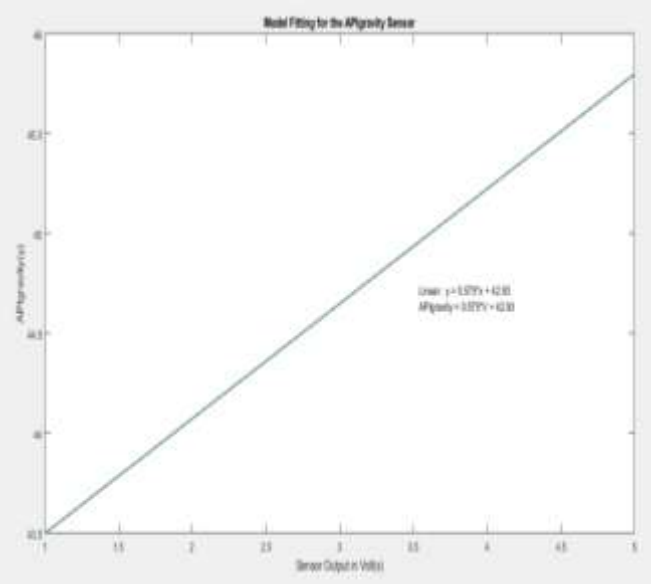

Figure 3.11: linear regression model for the API gravity sensor

Table 3.2: characterisation of virtual sensors

Parameter	Standard Current Range	Required Parameter Range	Designed Voltage output range
Flow rate sensor	4mA – 20 mA	100bbl/hr – 1000bbl/hr	1v – 5v
Pressure sensor	4mA – 20 mA	0 psi – 300 psi	1v -5v
Temperature sensor	4mA – 20 mA	0 °F – 300 °F	1v -5v
API gravity sensor	4mA – 20 mA	43.5 – 45.8	1v -5v

3.3.2 Linear Regression Models for the Selected LACT Unit Parameters

From the analysis done in section 3.3.1, the following equations represent the regression models of virtual sensors for the selected LACT unit parameters.

$$\text{Pressure} = 75 * V - 75 + e \quad 1 \quad 3.7$$
$$\text{FlowRate} = 225 * V - 125 \quad + e2 \quad 3.8$$

$$\text{Temperature} = 75 * V - 75 + e3 \quad 3.9$$

$$\text{APIgravity} = 75 * V - 75 + e4 \quad 3.10$$

V is the voltage output of the sensors while e is the regression error

3.4 Design of the Virtual Physical-Perception-Network PPN Layer for the LACT unit Transmission to the Cloud

3.4.1 The Architecture of the PPN layer

IoT architecture essentially contains the physical layer, the perception layer, the network layer and the cloud layer as shown in figure 3.12

The physical layer represents the physical infrastructure (PI) under monitoring, in this case LACT unit. Sensors are usually mounted on the PI. So, in this work, the virtual sensors shall represent the PI.

The perception layer represents the sensor node used to acquire and process sensor data from the PI. Atmega 328 microcontroller resident in Arduino board shall be used to represent the perception layer in this work. This is because it contains internal ADCs that can be used to process analog signals into digital equivalent before transmitting them to the network layer.

The network layer is the bridge between the perception layer and the cloud layer. Any device that has capability of transmitting data can be used provided it is compatible with the chosen microcontroller. SIM 808 is used in this work as the network layer because it is compatible with the chosen microcontroller. Figure 3.13 shows the picture of sim808 used in this work.

The cloud layer displays the transmitted data. ThingSpeak is used in this work because it is purely designed for prototyping of IoT concept, so it is cost effective. ThingSpeak is a third-partycloud

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resourcedeveloped by MATHWORKS for prototyping of IoT concepts.

Figure 3.14 shows the virtual PPN layer designed for cloud-based transmission of the LACT unit parameters. The design was done using proteus professional software

Figure 3.12: High level description of IoT layer

Figure 3.13: sim 808

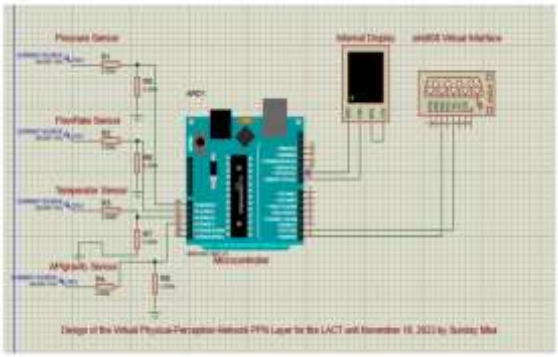

Figure 3.14: Design of PPN layer for the LACT unit

3.4.2 Characterization of the PPN Layer for LACT Unit

Table 3.3 shows the pin mapping of the input and output devices connected to the virtual LACT unit.

Equation 3.7 and table 3.2 were used to characterise the sensors as shown in figures 3.15a and 3.15b. Figure 3.16a shows the characterisation of the internal display while figure 3.16b shows that of the virtual sim808

Table 3.3: Pin mapping of the LACT unit

INPUT DEVICES	
DEVICE	MICROCONTROLLER PIN
Pressure sensor	A0 (Analog input 0)
Flowrate Sensor	A1 (Analog input 1)
Temperature Sensor	A2 (Analog input 2)
APIGravity	A3 (Analog input 3)
OUTPUT DEVICES	
Internal Display(RXD)	D9 (Digital Output 9)
Internal Display(TXD)	D9 (Digital Output 8)
Virtual sim808(RXD)	D0 (Digital Output 0)
Virtual sim808(TXD)	D1 (Digital Output 1)

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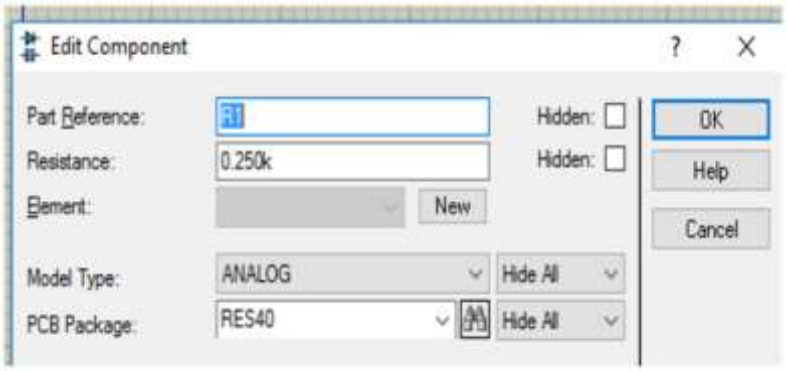

Figure 3.15a: Characterisation of Resistor values of the virtual sensor

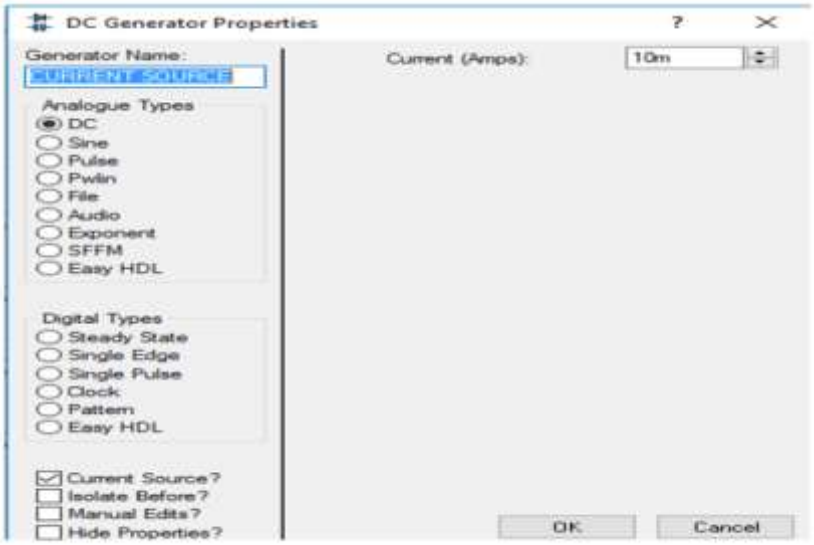

Figure 3.15b: Initial characterisation of current sources of the virtual sensor

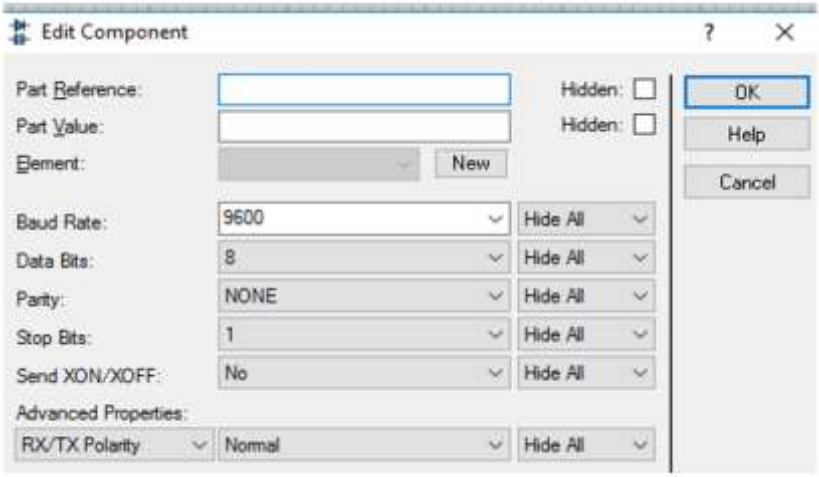

Figure 3.16a: Characterisation of the internal display

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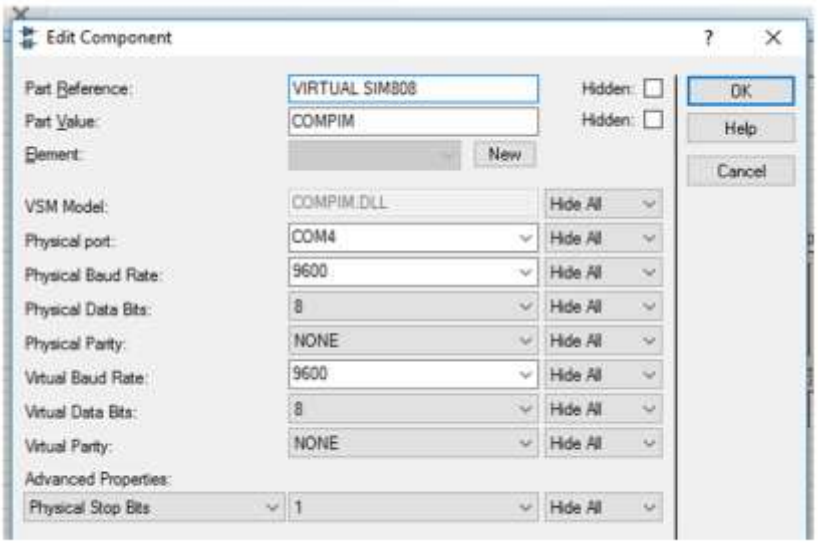

Figure 3.15a: Characterisation the virtual sim 808

3.5 Design of ThingSpeak Server for online Logging of LACT Unit Data

Third party cloud resource server, ThingSpeak, was used to logged the data transmitted from the virtual LACT unit. The graphical user interface of the server was designed to be suitable for this work. Figure 3.17 shows the blank page of the user interface as opened on the ThingSpeak cloud platform. Figure 3.18 shows the creation of data fields for data collection and logging. The fields were created according to the parameters of the LACT unit. Figure 3.19 is the output graphical user interface before sending data to the server.

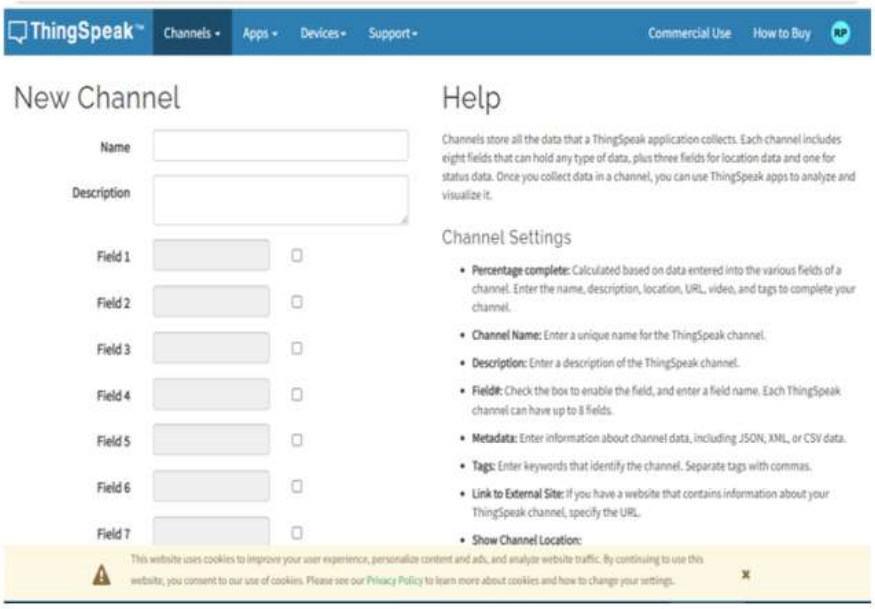

Fig. 3.17: blank channel at ThingSpeak platform

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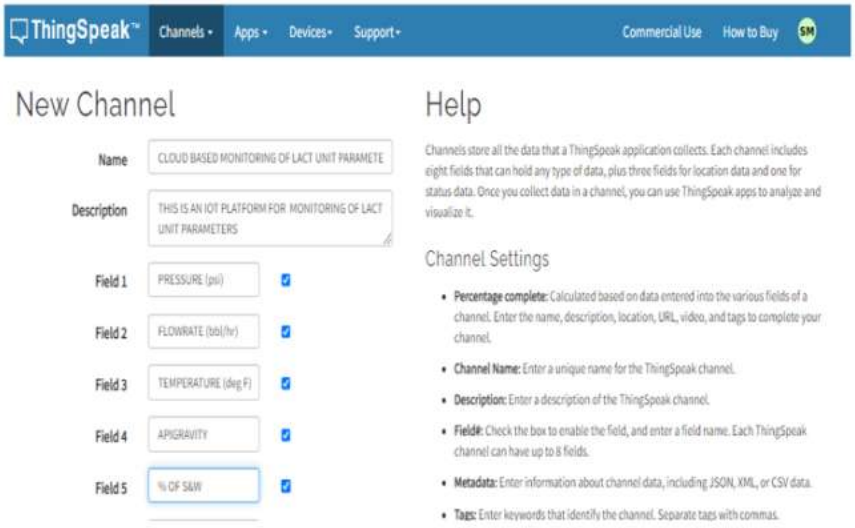

Fig. 3.18: Data base fields for data collection

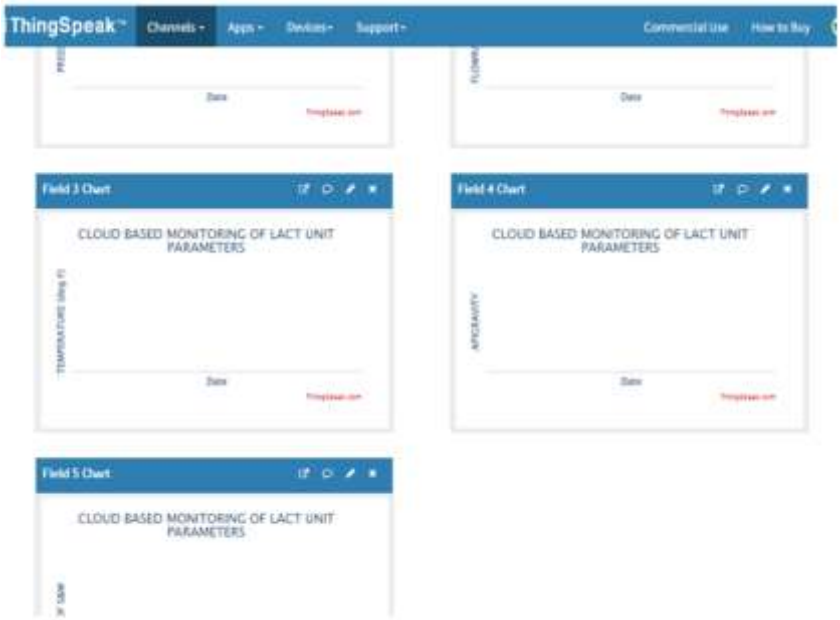

Fig. 3.19: The ThingSpeak GUI for the LACT unit data monitoring

3.6 Software Development

Three algorithms are considered here: Virtual PPN Layer Characterisation Algorithm; Sensor Algorithm and Data transmission to Remote Server Algorithm

3.6.1 Virtual PPN Layer Characterization Algorithm

This is used to map the physical devices connected to the microcontrollers to the internal software.

Input: Virtual PPN layer physical addresses, pin numbers, and data type

Output: mode classification ofVirtual PPN layer physical addresses, pin numbers, range of data

SoftwareSerialgprsSerial (physical address of sim808 modem);

Data_typePressureSensor_route_address = address _number;

Data_typeFlowRate_route_address = address _number;

Data_typeTemperatureSensor_route_address = address _number;

Data_typeAPIgravity_route_address = address _number;

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```
Data_type SIM808_route_address = address _number;;
void setup()
{ pinMode(PressureSenso_route_address, state_mode);
pinMode(FlowRate _route_address, state_mode);
pinMode(TemperatureSensor _route_address, state_mode);
pinMode(APIgravityr_route_addressstate_mode);
gprsSerial.begin(data_baudrate);
}
```

3.6.2 Sensor Reading Algorithm
Input: Sensor Physical address
Output: sensor real data value

3.6.3 Data transmission to Remote Server Algorithm
Input: AT command of SIM80/GPRS modem, APN, and API address of the remote server, measured LACT unit parameters
Output: concatenated data comprising pressure, flow rate, temperature, APIgravity and % S&W

```
gprsSerial.println("set of AT_Commands for GPRS configuration");
gprsSerial.println("AT+CSTT=\"APN_address of GPRS modem\"");
gprsSerial.println("AT+CIPSTART=\"TCP\",\" APN_address of remote server\",\"port_number of the server\"");
String str="GET https://api.thingspeak.com/update?api_key=API_adres_of_the_server&field1="+String(pressure_level)+"&field2="+String(flowrate_level)
+"&field3="+String(temperature_level)+"&field4="+String(APIgravity_level)+"&field5="+String(%S&W_level;
Serial.println(str);
gprsSerial.println(str);
```

The algorithms of 3.6.1 to 3.6.3 were developed using embedded c language in Arduino IDE. The full software is shown in appendix A

3.7 System Testing
The following steps were taking to test the entire system:

1. Connect the external sim808 device to the USB port of the computer
2. Select the comport assign to the sim808 by the computer and make it the comport of the virtual sim808
3. Compile the software of appendix and upload it to the microcontroller
4. Run the system and record the test results according to table 3.4

Figures 3.20 to 3.22 shows the selected snap shots of the system during testing. From table 3.4, the average errors between the regression models of equations 3.7 to 3.10 and the practical test results with respect to pressure, flow rate, temperature and APIgravity are 0.183psi, 0.55 bbl/hr, 0.183 °F and 0 @ 60 °F respectively. It means that equations 3.7 to 3.10 can now be written as

$$\text{Pressure} = 75 * V - 75 - 0.183 \quad 3.11$$
$$\text{FlowRate} = 225 * V - 125 \quad - 0.55 \quad 3.12$$
$$\text{Temperature} = 75 * V - 75 - 0.183 \quad 3.13$$
$$\text{APIgravity} = 75 * V - 75 + 0 \quad 3.14$$

Rearranging, it implies
That

$$V = (\text{Pressure} + 75.183)/75 \quad 3.15$$
$$V = (\text{FlowRate} + 125.55)/225 \quad 3.16$$
$$V = (\text{Temperature} + 75.183)/75 \quad 3.17$$
$$V = (\text{APIgravity} + 75)/75 \quad 3.18$$

By implication also

Current I

$$I = \frac{\text{Pressure} + 75.183}{75*250} \quad 3.19$$
$$I = \frac{\text{FlowRate} + 125.55}{225*250} \quad 3.20$$
$$I = \frac{\text{Temperature} + 75.183}{75*250} \quad 3.21$$
$$I = \frac{\text{APIgravity} + 75}{75*250} \quad 3.22$$

3.8 Validation of Data
By substituting the values of the unit parameters provided from the physical LACT unit as shown in table 3.1, the equivalent values of source currents needed to validate the cloud based LACT monitoring system shall be generated. Table 3.5 shows the validation data generated.

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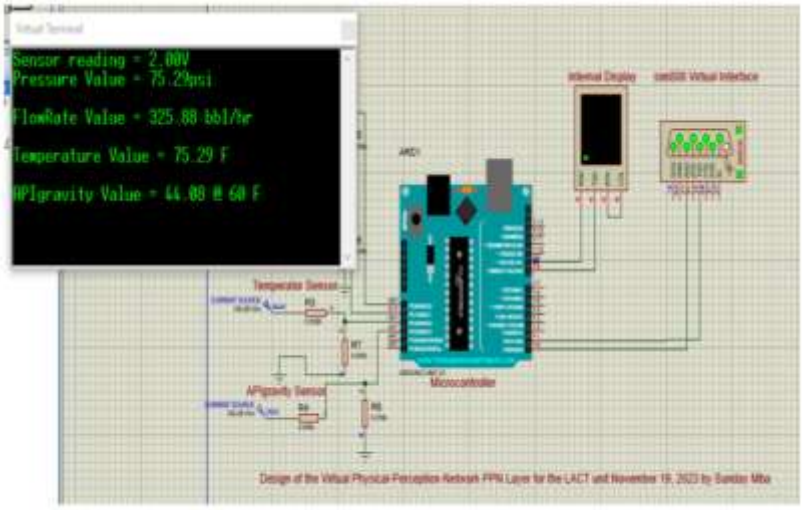

Figure 3.21: System testing at current source = 8mA

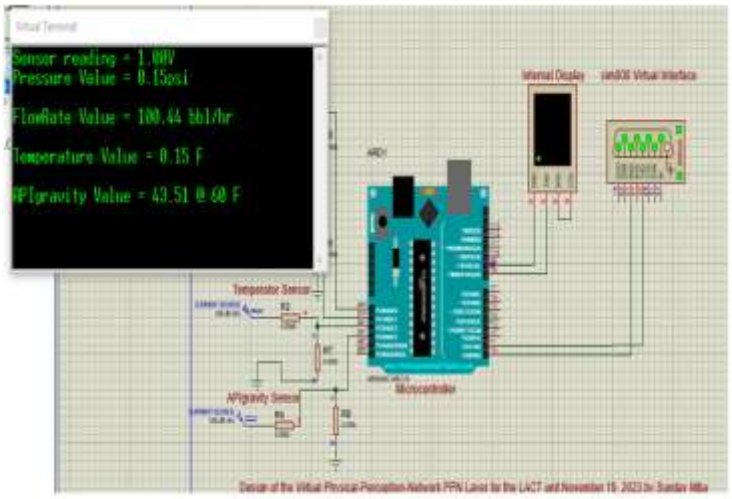

Figure 3.20: System testing at current source = 4mA

Table 3.4: System test results

Current Source Value	Expected voltage Sensor reading	Real Sensor reading	Expected Reading using regression model equation	Real Reading from the running software	Errors in Readings	Expected data to be transmitted to the cloud	Real data transmitted to the cloud
4mA	1V	1V	0 psi 100 bbl/hr 0 °F 43.51 @ 60 °F	0.15 psi 100.44 bbl/hr 0.15 °F 43.51 @ 60 °F	0.15 psi 0.44 bbl/hr 0.15 °F 0 @ 60 °F	0.15 psi 100.44 bbl/hr 0.15 °F 43.51 @ 60 °F	0.15 psi 100.44 bbl/hr 0.15 °F 43.51 @ 60 °F
8mA	2V	2V	75psi 325 bbl/hr 75 °F 44.08 @ 60 °F	75.29 psi 325.88 bbl/hr 75.29 °F 44.08 @ 60 °F	0.29 psi 0.88 bbl/hr 0.29 °F 0 @ 60 °F	75.29 psi 325.88 bbl/hr 75.29 °F 44.08 @ 60 °F	75.29 psi 325.88 bbl/hr 75.29 °F 44.08 @ 60 °F
12mA	3V	3V	150 psi 550 bbl/hr 150 °F 44.66 @ 60 °F	150.07 psi 550.22 bbl/hr 150.07 °F 44.66 @ 60 °F	0.07 psi 0.22 bbl/hr 0.07 °F 0 @ 60 °F	150.07 psi 550.22 bbl/hr 150.07 °F 44.66 @ 60 °F	150.07 psi 550.22 bbl/hr 150.07 °F 44.66 @ 60 °F
16mA	4V	4V	225 psi 775 bbl/hr 225 °F 45.23 @ 60 °F	225.22 psi 775.66 bbl/hr 225.22 °F 45.23 @ 60 °F	0.22 psi 0.66 bbl/hr 0.22 °F 0 @ 60 °F	225.22 psi 775.66 bbl/hr 225.22 °F 45.23 @ 60 °F	225.22 psi 775.66 bbl/hr 225.22 °F 45.23 @ 60 °F

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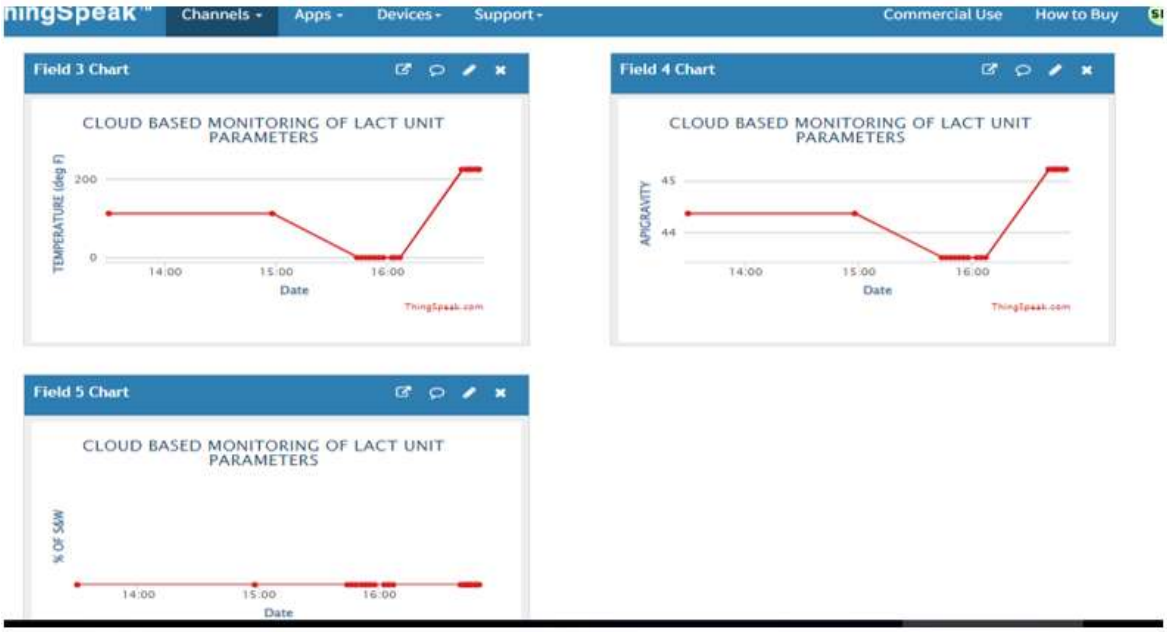

Figure 3.22: Data received at the cloud during system

Table 3.5: The validation Data

Sr. No.	Current operating Pressure Psi	Sensor Current due to Pressure (A)	Current operating Flowrate BBL/HR	Sensor Current due to Flowrate (A)	Current operating Temperature Deg F	Sensor Current due to Temperature (A)	API gravity @60 Deg F	Sensor Current due to APIgravity (A)	% of S&W
1	75.2	0.008020 43	596	0.012827556	91.2	0.008873 76	43.5	0.00632	0.05
2	76.3	0.008079 09	580	0.012543111	92.1	0.008921 76	43.5	0.00632	0.05
3	75.3	0.008025 76	680	0.014320889	91.6	0.008895 093	43.5	0.00632	0.05
4	75.2	0.008020 43	655	0.013876444	91.5	0.008889 76	45.8	0.0064426 67	0.05
5	75.6	0.008041 76	652	0.013823111	91.6	0.008895 093	43.8	0.006336	0.05
6	76.1	0.008068 43	632	0.013467556	91.5	0.008889 76	43.6	0.0063253 33	0.05
7	76.3	0.008079 09	623	0.013307556	91.8	0.008905 76	43.5	0.00632	0.05
8	76.2	0.008073 76	598	0.012863111	91.9	0.008911 093	43.6	0.0063253 33	0.05
9	76.5	0.008089 76	569	0.012347556	92.1	0.008921 76	43.8	0.006336	0.05
10	76.1	0.008068 43	578	0.012507556	93.2	0.008980 427	43.8	0.006336	0.05
1	76.5	0.008089	600	0.012898667	93.1	0.008975	43.8	0.006336	0.05

1		76				093			
12	76.1	0.00806843	598	0.012863111	93.4	0.008991093	43.8	0.006336	0.05
13	75.9	0.00805776	586	0.012649778	92.4	0.00893776	43.6	0.006325333	0.05
14	75.8	0.00805243	568	0.012329778	92.8	0.008959093	43.5	0.00632	0.05
15	75.6	0.00804176	612	0.013112	93.2	0.008980427	43.6	0.006325333	0.05
16	75.7	0.00804709	586	0.012649778	92.4	0.00893776	43.8	0.006336	0.05
17	75.9	0.00805776	628	0.013396444	92.8	0.008959093	43.5	0.00632	0.05
18	76.2	0.00807376	576	0.012472	93.2	0.008980427	43.5	0.00632	0.05
19	76.1	0.00806843	575	0.012454222	92.1	0.00892176	45.8	0.006442667	0.05
20	76.5	0.00808976	574	0.012436444	91.6	0.008895093	43.8	0.006336	0.05
21	75.5	0.00803643	582	0.012578667	91.5	0.00888976	43.6	0.006325333	0.05
22	76.8	0.00810576	562	0.012223111	91.6	0.008895093	43.5	0.00632	0.05
23	75.9	0.00805776	586	0.012649778	91.5	0.00888976	43.6	0.006325333	0.05
24	76.3	0.00807909	581	0.012560889	91.8	0.00890576	43.8	0.006336	0.05
25	76.2	0.00807376	583	0.012596444	91.9	0.008911093	43.8	0.006336	0.05
26	76.5	0.00808976	549	0.011992	92.1	0.00892176	43.8	0.006336	0.05
27	76.1	0.00806843	612	0.013112	93.2	0.008980427	43.6	0.006325333	0.05
28	76.5	0.00808976	632	0.013467556	93.1	0.008975093	43.5	0.00632	0.05
29	76.1	0.00806843	614	0.013147556	93.4	0.008991093	45.8	0.006442667	0.05
30	75.9	0.00805776	628	0.013396444	92.4	0.00893776	43.8	0.006336	0.05
31	75.8	0.00805243	612	0.013112	92.8	0.008959093	43.6	0.006325333	0.05
32	75.6	0.00804176	586	0.012649778	93.2	0.008980427	43.5	0.00632	0.05
33	75.7	0.00804709	628	0.013396444	91.6	0.008895093	43.6	0.006325333	0.05
34	76.3	0.00807909	576	0.012472	91.5	0.00888976	43.8	0.006336	0.05
35	76.2	0.00807376	575	0.012454222	91.2	0.00887376	43.8	0.006336	0.05
36	76.5	0.00808976	574	0.012436444	91.3	0.008879093	43.8	0.006336	0.05
37	76.1	0.00806843	582	0.012578667	91.8	0.00890576	43.8	0.006336	0.05
38	76.5	0.00808976	562	0.012223111	93.5	0.008996427	43.6	0.006325333	0.05

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39	76.1	0.00806843	586	0.012649778	92.5	0.008943093	43.5	0.00632	0.05
40	75.9	0.00805776	581	0.012560889	92.4	0.00893776	43.6	0.006325333	0.05
41	75.8	0.00805243	623	0.013307556	92.3	0.008932427	43.8	0.006336	0.05
42	75.6	0.00804176	598	0.012863111	92.8	0.008959093	43.8	0.006336	0.05
43	75.7	0.00804709	569	0.012347556	92.6	0.008948427	43.8	0.006336	0.05
44	75.9	0.00805776	578	0.012507556	92.5	0.008943093	43.8	0.006336	0.05
45	76.2	0.00807376	600	0.012898667	93.2	0.008980427	43.6	0.006325333	0.05
46	76.1	0.00806843	598	0.012863111	93.1	0.008975093	43.5	0.00632	0.05
47	76.5	0.00808976	586	0.012649778	93.4	0.008991093	43.6	0.006325333	0.05
48	75.5	0.00803643	568	0.012329778	92.4	0.00893776	43.8	0.006336	0.05
49	76.8	0.00810576	612	0.013112	92.8	0.008959093	43.5	0.00632	0.05
50	75.9	0.00805776	586	0.012649778	93.2	0.008980427	43.5	0.00632	0.05

IV RESULT

After system testing was carried out and the errors of the modelled equation were substituted, the current sensor values of table 3.5 were used to characterized figure 3.14 while simulating the system to send data to the cloud

Figure 4.1 shows the ThingSpeak cloud interface after sending the data. Figure 4.1a shows the pressure and flow rate data while figure 4.1b shows temperature and API gravity data. %SW data is shown in figure 4.1c. Table 4.1 in Appendix D shows the stored excel data downloaded from the ThingSpeak server while figures 4.2 to 4.6 shows the plots of the downloaded data.

Figure 4.1a: Pressure and Flow rate cloud data

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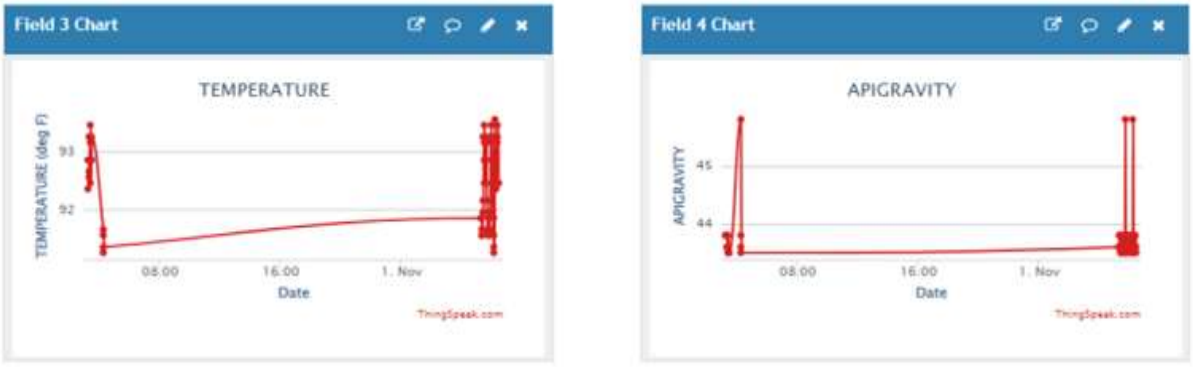

Figure 4.1b: Temperature and APIgravity data

Figure 4.1 c: % SW

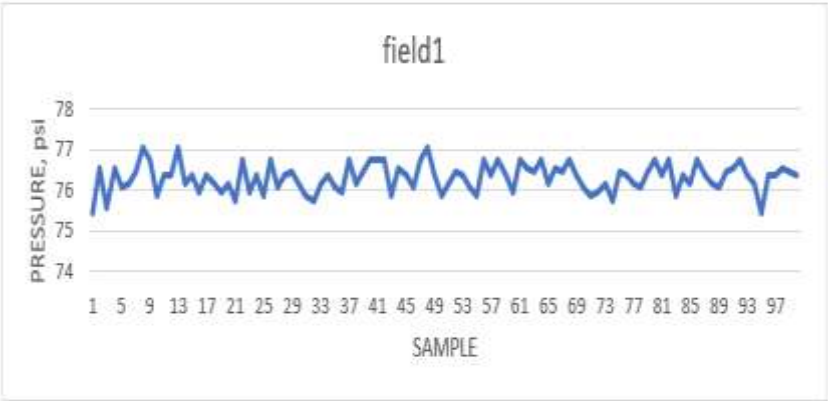

Figure 4.2: Plot of LACT pressure data received at the cloud

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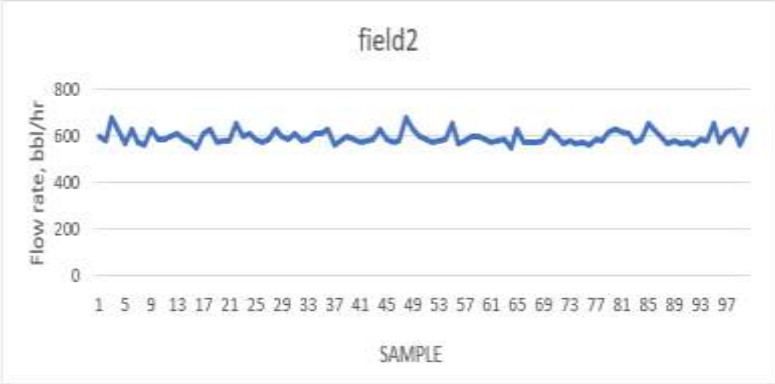

Figure 4.3: Plot of LACT flow rate data received at the cloud

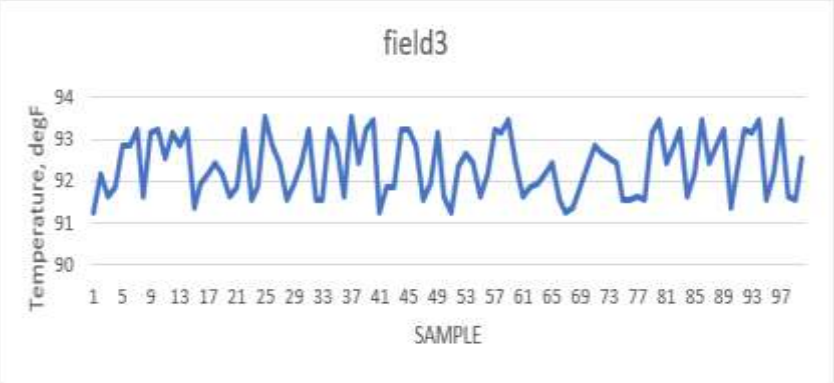

Figure 4.4: Plot of LACT temperature data received at the cloud

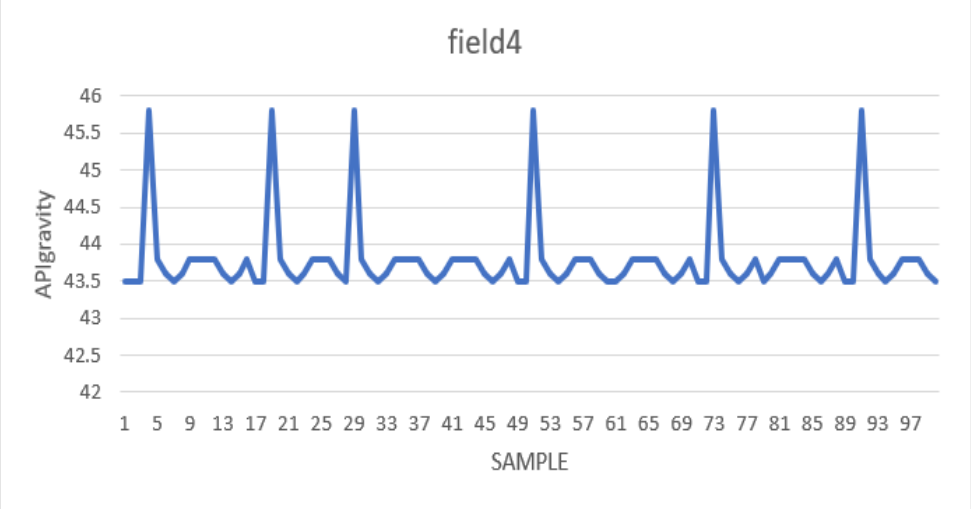

Figure 4.5: Plot of LACT API gravity data received at the cloud

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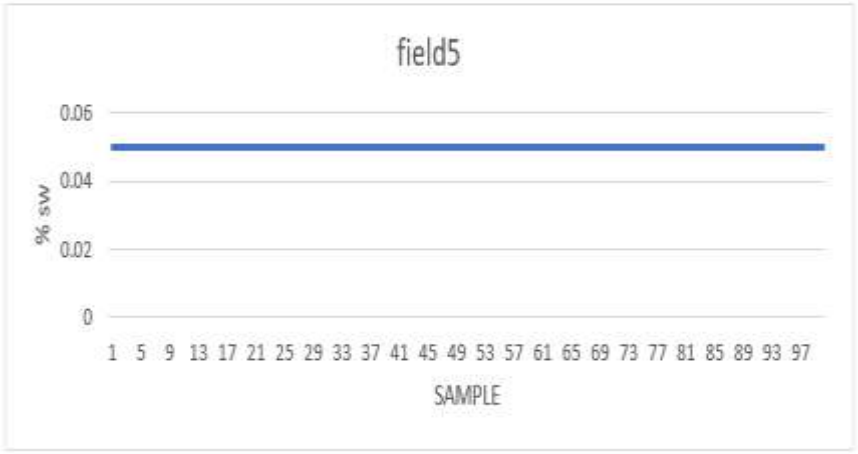

Figure 4.6: Plot of LACT %S & W data received at the cloud

Figure 4.7: Specific chart shows the details of the datum selected

From the charts, it can be observed that the time stamp of the data collected uploaded from the system design of figure 3.14 is recorded by the cloud server. The time stamp of each data can also be seen online by pointing computer mouse at the specific data shown in figure 4.7. It means that the time of any abnormality that took place in the LACT unit can be estimated if the network transmission delay time is known. By observing the pattern of the graph, trained maintenance personnel can always detect unusual data pattern.

V. CONCLUSION

The objective of this work was to implement a low cost near real-time cloud-based monitoring of Lease Automatic Custody Transfer (LACT) unit parameter through five defined research objectives. The proposed solution has been able to meet the five defined objectives though, further studies may review some challenges like network security treat, cloud cost and ability to track workload performance.

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