Development of Cloud-Based Monitoring System for Underground Resistivity and Soil Measurement

Khairunnisa Nabilah Juhari, Akmal Hafiz Mohamed, Mohamad Huzaimy Jusoh*, Norazam Aziz

Abstract—**Geo-electrical resistivity measurement is one of the established geophysical methods for evaluating the underground profile. It provides the detail of electrical resistivity under the ground which can be utilised to study various application in engineering, geology and environmental problems. This paper presents an approach to integrate a normal operating system of a resistivity meter and soil sensor with the cloud-based monitoring system. The conventional method used in the monitoring system is somehow not applicable to all operating devices such as the need to monitor real-time data that can be accessed over the internet. Thus, this project proposes the implementation of Internet of Things (IoT) development tools to develop data acquisition system (DAQ) for real-time underground resistivity and soil condition monitoring system. The system was developed using an open development board that is supported by OpenWrt Linux distribution which allows the user to fully customise the system. The real-time data can be monitored from the open source database platform where the data are displayed and stored. The development of this system has particularly improved the feasibility of data monitoring and thus shows the practicality of the developed system.**

Index Terms—**DAQ, cloud-based, monitoring system, real-time, underground resistivity.**

I. INTRODUCTION

THE ubiquitous of the Internet of Things (IoT) based devices in the present day have subsequently improved the performance of technologies in our daily life. In general, IoT refers to the interconnection of devices, either physically or virtually, that enable them to interact with each other [1]. Based on a survey conducted by authors [2], they stated that the most significant contributions of IoT include the identification and tracking technologies, wired and wireless sensor and actuator networks, enhanced communication protocols and distributed intelligence for smart objects.

The main objective of the current work is to propose an alternative method in devising sensors for real-time monitoring purpose. In some cases, the typical method of storing the data inside the storage does not provide the capability for the end user to monitor the data wirelessly. Therefore, the focus of this project is to develop a cloud-based monitoring system that involved two sensors which are: i) C.A 6471 Earth and Resistivity Tester and ii) Hydra Probe. Both types of equipment are used in measuring underground resistivity and soil condition respectively.

One of the benefits of real-time monitoring is that it enables the user to respond immediately whenever any problem arises. This helps the user to ensure the functionality of the system and data availability.

II. METHODOLOGY

The methodology of this study encompasses three main parts which are: i) instrumentation, ii) architecture of the proposed system, and ii) underground resistivity and soil measurement. In order to get a comprehensive idea for this study, an initial investigation and background of the project were studied thoroughly.

A. Instrumentation

In this project, there are two instrumentations involved that are used to measure underground resistivity and soil condition. The C.A 6471 Earth and Resistivity Tester is used in determining soil resistivity, ρ while Hydra Probe provides secondary data of soil condition.

The resistivity meter is a portable sensor that measures underground resistivity. It is equipped with four terminals where H and E are terminal for current electrode while S and ES are terminal for potential electrode [3]. These terminals are connected to the electrodes and placed into the ground. Table I presents the specifications of the C. A 6471 Earth and Resistivity Tester.

This paper was submitted for review on November 2017. This research work was financially supported by Yayasan Penyelidikan Antartika Sultan Mizan, YPASM (Code No. YPASM/Grant/12-2014/JLD.1 (23)). Accepted on 10th April 2018.

Khairunnisa Nabilah Juhari, Norazam Aziz and Mohamad Huzaimy Jusoh are with Applied Electromagnetic Research Group (AERG), Advance Computing and Communication Communities of Research, Universiti Teknologi MARA, Malaysia (e-mail: khairunnisanabilah93@gmail.com, norazamzz1@gmail.com & huzaimy@salam.uitm.edu.my).

Akmal Hafiz Mohamed is with Faculty of Electrical Engineering, Universiti Teknologi MARA, Malaysia (e-mail: akmalhafiz.mohamed@yahoo.com).

TABLE I
SPECIFICATIONS OF THE C. A 6471 EARTH AND RESISTIVITY TESTER [3]

Parameter	Details
Power source	Rechargeable 9.6 V, 3.5 Ah, NiMH Battery Pack
Maximum value for R_H, R_S, R_{ES}, R_E	100 kΩ
Maximum value of ρ	999 kΩ
Resolution	0.01 Ω – 100 Ω
Memory capacity	512 test result (64 kB)
Communication	Optically isolated USB

The second instrument is Hydra Probe which is a soil sensor that measures parameters of the soil such as temperature, moisture content and dielectric permittivity. The Hydra Probe is specifically designed for robust applications where the probes are made up of marine grade stainless steel to prevent corrosion. The internal electrical components of the sensor are protected by the Acrylonitrile Butadiene Styrene (ABS) material and high-grade epoxy potting that made up the housing for the sensor [4]. Table II provides detailed information on accuracy and precision of the Hydra Probe.

TABLE II
SPECIFICATIONS OF THE HYDRA PROBE [4]

Parameter	Accuracy/Precision
Temperature	± 0.6 ℃ (from -30℃ to 36 ℃)
Soil moisture wfv (m^3 m^{-3})	± 0.003 wfv (m^3 m^{-3}) Accuracy
Soil moisture wfv (m^3 m^{-3})	± 0.0003 wfv (m^3 m^{-3}) Precision
Electrical conductivity (S/m) (Temperature uncoreccted)	± 0.0014 S/m or ± 1%
Electrical conductivity (S/m) (Temperature coreccted)	± 0.0014 S/m or ± 5%
Real/Imaginary dielectric constant (Temperature uncorrected)	± 0.5 or ± 1%
Real/Imaginary dielectric constant (Temperature corrected)	± 0.5 or ± 5%

B. *Architecture of the Proposed System*

In general, the main idea of this system is to provide wireless monitoring of the data from the primary sources which are the resistivity meter and soil sensor. A microcontroller is used to govern the system's operation for the supplied data and organise into a relevant distribution in the database before being uploaded into the cloud storage. Fig. 1 presents the basic structure of the proposed system.

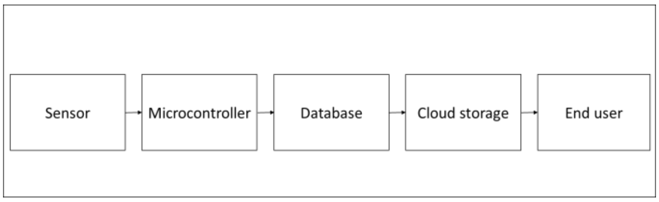


Fig. 1.Block diagram of a general architecture of the system.

The approach of this project utilised the Linkit Smart 7688 Duo as a development board for its ability to communicate with another technology systems and software applications. It incorporates both microcontroller (MCU) and a microprocessor (MPU) which are ATmega 32U4 and MT7688 respectively. Plus, its operating system that is based on the OpenWrt Linux distribution allows full customisation for users to design a system that suits any application [5]. Furthermore, this board is compatible with Arduino features and several programming languages such as Python, Node.js and C that provides various options to create device applications [6].

The analogy for the Linkit Smart 7688 Duo can be explained as a Central Processing Unit (CPU) as it performs the instructions received from both hardware and software of the system. In this project, a resistivity meter and soil sensor were connected to the computer using Universal Serial Bus (USB) cable. In order for the board to access the computer, its Wireless-Fidelity (Wi-Fi) was configured to the same Wi-Fi network as connected to the computer.

The memory card folder which located on the computer was mounted on the board by using Putty software as a terminal emulator. This allows network file transfer (NFT) where the data can be transferred or shared over the Wi-Fi using the Secure Shell (SSH) protocol. A Python script was created to read the output data from both sensors before being injected into the Sqlite3 database. From there, the data were uploaded to the ThingSpeak platform that provides cloud storage application and displays real-time data for monitoring purpose. Fig. 2 demonstrates the conceptual framework of the system.

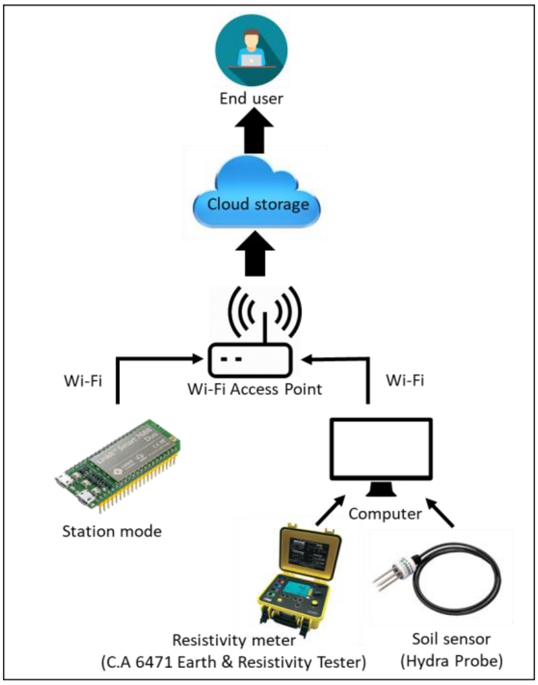


Fig. 2.The proposed model framework of the system.

C. Underground Resistivity and Soil Measurement

The final stage of this project is to test the functionality of the developed system. For this part, we conducted a continuous measurement of underground resistivity and soil condition where the reading for both instruments was recorded simultaneously. The Hydra Probe sensors were buried beneath the soil at depth of 0.75 meters. In measuring underground resistivity, there are several electrode configurations that can be applied such as Wenner, Schlumberger, Pole-Pole and Dipole-Dipole. Each of these arrays has their own advantageous depending on the purpose of the measurement [7].

In this work, we applied a four-point resistivity method of Wenner array to measure the underground resistivity as outlined in the IEEE Guide for Measuring Earth Resistivity, Ground Impedance and Earth Surface Potential of a Grounding System (IEEE Std. 81-2012) [8]. This array was chosen as the purpose of the measurement was to measure a single-depth underground resistivity. The distance between each electrode, α was maintained at 3 meters as illustrated in Fig. 3.

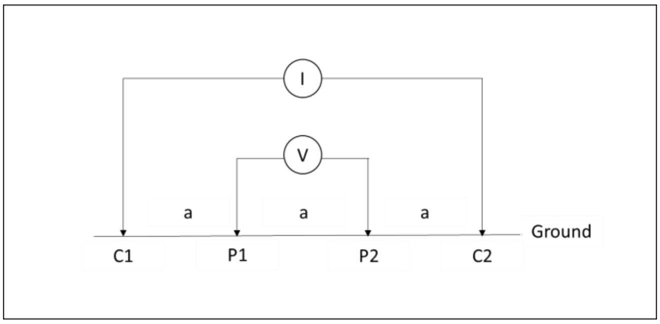


Fig. 3.The electrodes arrangement of Wenner configuration.

Theoretically, the underground resistivity is obtained based on the fundamental of Ohm's Law. In Wenner array, the two outer electrodes (C1 and C2) behave as current electrode where the current is injected through it and the resulting voltage is measured between the two inner electrodes (P1 and P2) which are also known as a potential electrode. Thus, the ground resistance, R can be calculated as below

$$R = \frac{V}{I} \tag{1}$$

where V is the potential difference between the potential electrodes and I is the electrical current. Then, the underground resistivity for Wenner array, ρ_w can be obtained from

$$\rho_w = 2\pi a R \tag{2}$$

where α is the electrode spacing and R is a measured resistance [9]. Fig. 4 shows the site view of underground resistivity measurement.

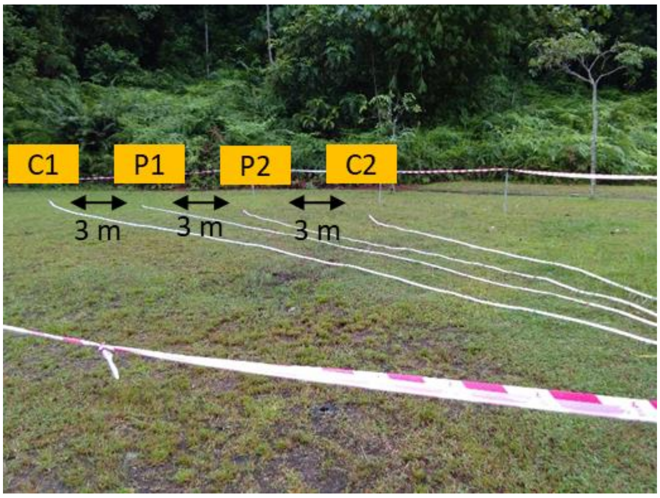
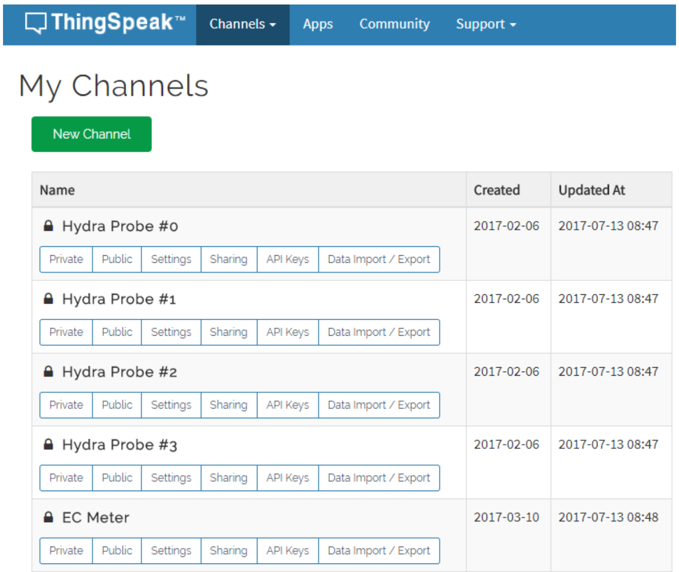


Fig. 4.Electrodes arrangement of Wenner configuration with the distance is set to 3 meters.

III. RESULTS AND DISCUSSION

The discussion of the results begins with the analysis of the developed system. As mentioned before, the output data from the measurement will be uploaded into the cloud storage for monitoring and storing purposes using an open source IoT platform tool. The dashboard of the ThingSpeak platform that stores and displays the underground resistivity and soil parameters data are shown as in Fig. 5 and Fig. 6.



My Channels

Name	Created	Updated At
Hydra Probe #0	2017-02-06	2017-07-13 08:47
Hydra Probe #1	2017-02-06	2017-07-13 08:47
Hydra Probe #2	2017-02-06	2017-07-13 08:47
Hydra Probe #3	2017-02-06	2017-07-13 08:47
EC Meter	2017-03-10	2017-07-13 08:48

Fig. 5.The main interface of the open source database platform displaying all available channel for all sensors.

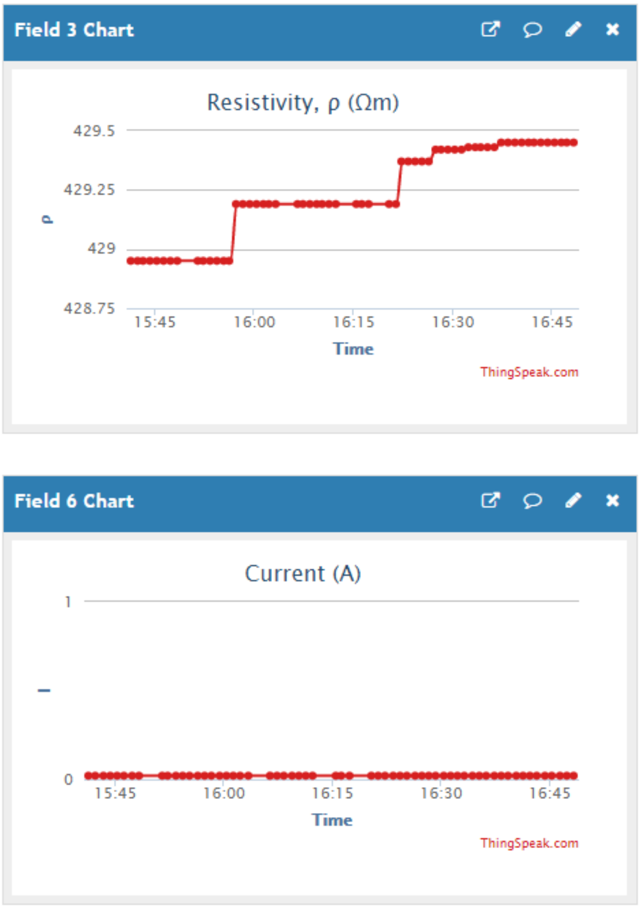


Fig. 6.Real-time data from the sensor as displayed in the channel.

From the cloud storage, the data can also be downloaded into the Microsoft Excel format for further analysis process. Fig. 7 and Fig. 8 present the graph of five-minute intervals of underground resistivity and soil temperature variations as measured by the resistivity meter and soil sensor respectively.

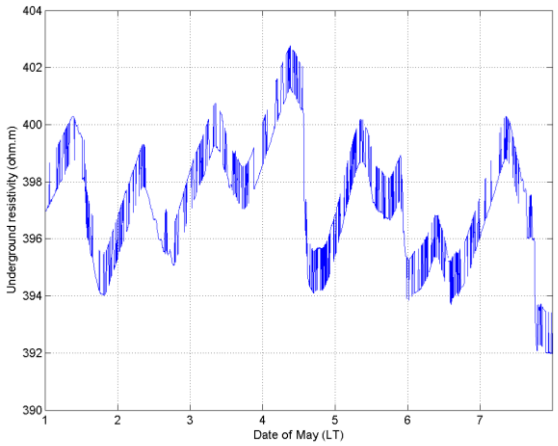


Fig. 7.Five minutes interval of underground resistivity variation.

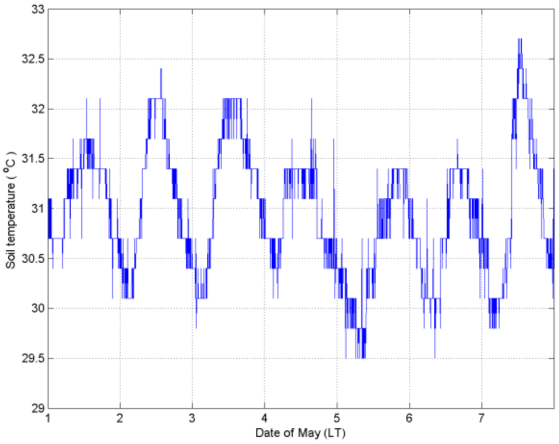


Fig. 8.Five minutes interval of soil temperature variation.

Based on the graphs, it is shown that the underground resistivity variation exhibits distinct pattern where it peaked during noon time and reached a minimum at night time. Similarly, the changes in soil temperature show the highest reading during noon time and lowest reading during night time. Theoretically, an increase in the temperature causes more vibration and collision between the atoms and thus, leads to an increase in resistance due to the vibrating and colliding atoms [10]. Soil temperature is significantly affected by the air temperature due to the exposure of solar radiation which causes the changes in underground resistivity. In essence to the above details, it can be inferred that soil temperature affects the underground resistivity.

IV. CONCLUSION

The proposed cloud-based monitoring system for underground resistivity and soil measurement was successfully developed and tested for several periods of observation. The implementation of the developed system gives an advantage for the end user in monitoring the data wirelessly and thus, proved its functionality for a continuous measurement. Furthermore, the information on the underground resistivity and soil conditions can be used in designing electrical grounding system where soil resistivity is the key factor in determining an effective and safe grounding system.

ACKNOWLEDGMENT

We acknowledge engineers from Luimewah (M) Sdn. Bhd. for their guidance throughout this project. We also would like to express our gratitude to Universiti Pendidikan Sultan Idris (UPSI) for providing us place to conduct the experiment. This project is financially supported by Sultan Mizan Antarctic Research Foundation, YPASM (Code No. YPASM/Grant/12-2014/JLD.1 (23)). We also thank Universiti Teknologi MARA for the management support and consideration during the period of the project.

REFERENCES

[1] Gubbi, J., Buyya, R., Marusic, S., & Palaniswami, M. (2013). Internet of Things (IoT): A vision, architectural elements, and future directions. *Future generation computer systems*, *29*(7), pp. 1645-1660.

[2] Kelly, S. D. T., Suryadevara, N. K., & Mukhopadhyay, S. C. (2013). Towards the implementation of IoT for environmental condition monitoring in homes. *IEEE Sensors Journal*, *13*(10), pp. 3846-3853.

[3] Earth and Resistivity Tester. [Online]. Available: https://chauvin-arnoux.fi/wp-content/uploads/2014/09/CA_6471-eng-manual.pdf

[4] The Hydra Probe Soil Sensor. [Online]. Available: http://www.stevenswater.com/resources/documentation/hydraprobe/HydraProbe_Manual_92915_Jan_2015.pdf

[5] OpenWrt. [Online]. Available: https://openwrt.org/

[6] Linkit Smart 7688. [Online]. Available: https://labs.mediatek.com/en/platform/linkit-smart-7688

[7] Aizebeokhai, A. P. (2010). 2D and 3D geoelectrical resistivity imaging: Theory and field design. *Scientific Research and Essays*, *5*(23), pp. 3592-3605.

[8] *IEEE Guide for Measuring Earth Resistivity, Ground Impedance and Earth Surface Potential of A Grounding System*, IEEE Standard Association, 2012, pp. 12.

[9] Loke, M. H., Chambers, J. E., Rucker, D. F., Kuras, O., & Wilkinson, P. B. (2013). Recent developments in the direct-current geoelectrical imaging method. *Journal of Applied Geophysics*, *95*, pp. 135-156.

[10] Learnabout Electronics. [Online]. Available: http://www.learnabout-electronics.org/Resistors/resistors_01a.ph

Khairunnisa Nabilah Juhari received the BSc in Physics with Electronics from Universiti Malaysia Sabah (UMS), Malaysia in 2015. She is currently pursuing her master's degree in Electrical Engineering at Universiti Teknologi MARA (UiTM). Her research interests involved the studies in Space and Earth's Electromagnetism and Electromagnetic Applications.

Akmal Hafiz Mohamed received the Diploma in Electrical Engineering in 2012 and BSc in Electrical Engineering (Communication) from Universiti Teknologi MARA (UiTM), Malaysia in 2017. His final year project area is in the embedded design of Internet of Things (IoT) instrumentation.

Mohamad Huzaimy Jusoh is a senior lecturer at Faculty of Electrical Engineering, Universiti Teknologi MARA, Shah Alam, Malaysia. He received his bachelor's degree in Electronic Engineering (Communication) from Universiti Teknologi MARA in 2004 and MSc in Communication and Computer from Universiti Kebangsaan Malaysia (UKM) in 2007. He later continued his PhD in Satellite Communication and Space Science at Kyushu University, Japan and graduated in 2013. His main research areas are Space and Earth's Electromagnetism, Wireless Instrumentation and Communication System, Polar Exploration, Energy Efficiency Management System and Occupational Safety and Health.

Norazam Aziz received the BSc in Electronic Engineering (Instrumentation) from Universiti Teknologi MARA (UiTM), Malaysia in 2011. He has vast experiences in national projects that involved in Wireless Sensor Network, Terminal Node Controller, ARPS Design and Solar System Design. His area of expertise is mainly in the embedded design for the Internet of Things (IoT) instrumentation. He is currently undergoing his master's degree in Electrical Engineering at Universiti Teknologi MARA (UiTM).