Evolution in Electrical and Electronic Engineering Vol. 4 No. 1 (2023) 566-571

EEEE

Homepage: http://publisher.uthm.edu.my/periodicals/index.php/eeee
e-ISSN : 2756-8458

Development of a Remote Monitoring System for Voltage Measurements in Cathodic Protection

Muhammad Zahir Asyraf Omar[1], Khairul Anuar Mohamad[1]*, Afishah Alias[2], Muhammad Haziq Haslin[3], Mohammad Syahmi Nordin[3]

[1]Faculty of Electrical and Electronics Engineering, Universiti Tun Hussein Onn Malaysia, Parit Raja, Batu Pahat 86400 Johor, MALAYSIA

[2]Faculty of Applied Science and Technology, Universiti Tun Hussein Onn Malaysia, Campus Pagoh, Pagoh 84600 Johor, MALAYSIA

[3]MT Data Driven Sdn Bhd, Laurel Laman View, Cyberjaya 63000 Selangor, MALAYSIA

*Corresponding Author Designation

DOI: https://doi.org/10.30880/eeee.2023.04.01.068
Received 29 January 2023; Accepted 26 February 2023; Available online 30 April 2023

Abstract: Underground pipelines are one of the most important infrastructures in the world for transporting liquid or gas, such as natural gas, biofuels, and liquid petroleum. One major challenge in pipeline operation is a corrosion attack that significantly contributes to high-cost maintenance. Therefore, the monitoring system needs to be improved to provide an early warning to the operators or cathodic protection (CP) technicians for immediate mitigation planning and simultaneously speed up the maintenance work. The developed device is equipped with an integrated op-amp circuit as the voltage sensor and NEO-6M GPS Module as the positioning location. In addition, Blynk is used as an analytics platform to develop an interface to monitor voltage parameters. The findings indicate that the device could measure voltage readings as precisely as a multimeter with an accuracy of 98.8% maximum to 96.2% minimum. Based on the data collection, the voltage output of the op-amp circuit is reliable and can also measure the voltage reading of a corroded steel pipeline in a scale model of a cathodic protection system. Thus, the developed system enables remote monitoring and acknowledges the parameter in the cathodic protection system anywhere and anytime without frequent site visits.

Keywords: Sensor, Voltage, Remote Measurement, Cathodic Protection

1. Introduction

Malaysia is the second-largest oil and natural gas producer in Southeast Asia and is the fifth-largest exporter of liquefied natural gas (LNG) in the world as of 2019 [1]. Gas Malaysia Berhad (GMB)

**Corresponding author: author@organization.edu.co*

operated and maintained approximately 2040 km of a natural gas pipeline across Peninsular Malaysia, consuming 99.34% of the total gas supplied by GMB [2]. Sabah Sarawak Gas Pipeline (SSGP) has 512 km of a natural gas pipeline in East Malaysia that links from Kimanis in Sabah to Bintulu in Sarawak [3]. Pipeline corrosion occurs naturally on the deterioration of a material or properties because of a reaction by the environment. Corrosion can happen on the inside and outside surfaces of the pipeline. Cathodic Protection (CP) is a method to reduce corrosion reaction by minimizing the difference in potential between anode and cathode, which is applied by a current to the structure to be protected. When enough current is applied, the whole structure will be at one potential. CP is commonly used on many structures, such as pipelines, underground storage tanks, locks, and ship hulls. CP is the most suitable technique to limit metal corrosion in pipeline networks [4]. The system monitors the output voltage from transformer rectifiers (T/R) to ensure that the correct level of CP is applied.

Irannejad and M. Iraninejad (2014) have developed a device for remote sending CP information of pipelines consisting of measurement, controller, and data transmission. The measurement and controller use an AVR microcontroller for continuous voltage and current measurements in the CP system. Meanwhile, the data transmission part uses a global system for mobile communication (GSM) module integrated with the SCADA database system [5]. Abdulwahab et al. (2022) have also developed a real-time remote monitoring and control (RT-RMC) system to monitor the voltage and current measurements with different environments, disturbances and pipe coatings in the CP system. The RT-RMC system is implemented using GSM and web of things (WoT) techniques to facilitate monitoring and control tasks [6]. Thus, WoT and internet of things (IoT) are proposed as a replacement for conventional manual data logger systems. This work presents remotely measures and monitors the voltage parameter in the CP system using an integration op-amp circuit as the voltage sensor with a microcontroller. The remote monitoring system is connected with a global positioning system (GPS) module as the positioning location. In addition, for IoT applications, the Blynk platform is used to facilitate voltage value monitoring.

2. Materials and Methods

2.1 Integrated Op-amp Circuit for Sensor

Figure 1 shows the circuit diagram of the integrated op-amp circuit for voltage measurement. The circuit contains a voltage sensor using the voltage divider concept before any connection is made to the microcontroller to obtain voltage values.

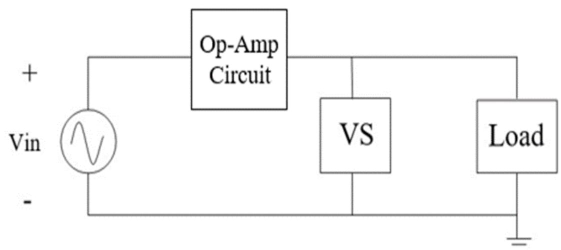

Figure 1: Circuit diagram of integrated op-amp circuit for voltage sensor

2.2 Remote Measurement and Monitoring System

Figure 2 shows the block diagram and schematic diagram of the remote voltage measurement and monitoring system. The input is a voltage measurement component using an integrated op-amp circuit with a voltage sensor. The sensor has two probes to measure the voltage value of the pipe in the CP system. The NodeMCU ESP 32 is used as a microcontroller, and the dashboard is developed using the Blynk platform to monitor the voltage value into the web or phone access.

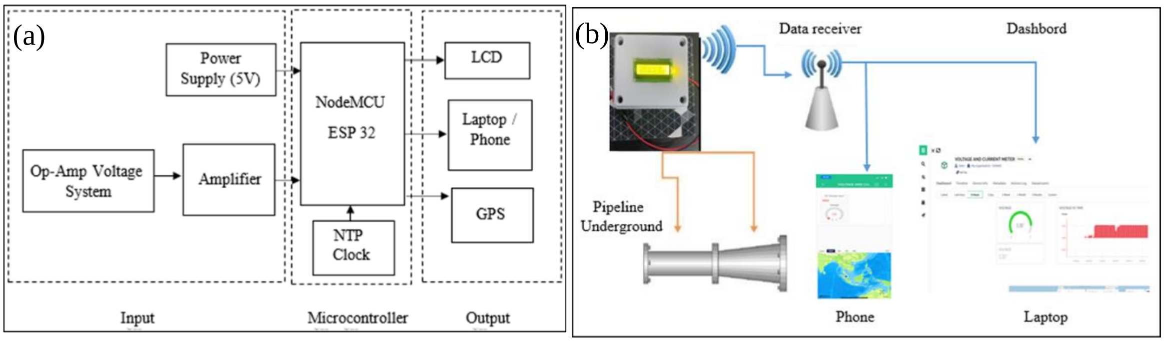

Figure 2: (a) Block diagram and (b) schematic diagram of remote measurement and monitoring for CP system

2.3 Measurement and Testing

Figure 3 shows the outside and inside views of the prototype remote measurement and monitoring system. The scale model of the CP system for an underground pipeline, as shown in Figure 4, is used to measure the voltage value remotely using the prototype system. The measurement is collected based on the value between the steel pipe (anode) and the permanent reference electrode (PRE). In comparison, all measurements by the prototype are compared to a multimeter.

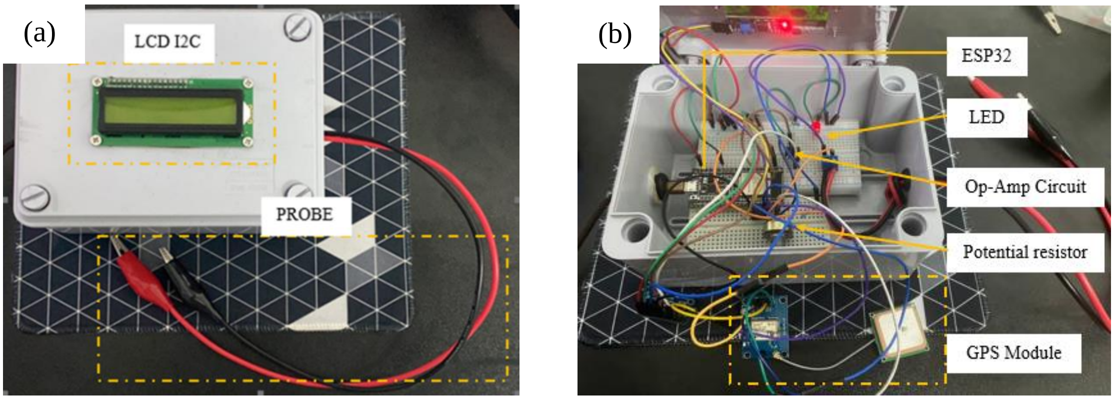

Figure 3: View of the remote measurement and monitoring prototype hardware (a) outside and (b) inside.

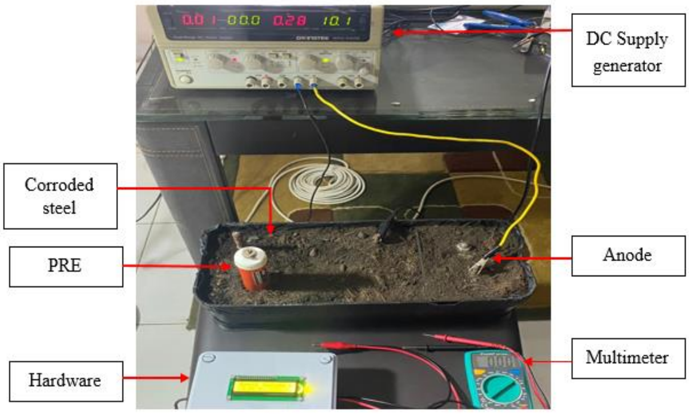

Figure 4: Scale model of Op-Amp circuit measurement

3. Results and Discussion

3.1 Measurement of voltage input and output of op-amp circuit

Table 1 summarizes the multimeter reading of the voltage input and voltage output of the op-amp circuit to identify the measurement accuracy. From the prototype reading, all measurements exhibited similar values to the multimeter reading with a small difference of approximately ±0.03 V. In addition. There is no voltage divider effect on the measurement.

Table 1: Multimeter reading of voltage input and voltage output

Multimeter Reading		Prototype Reading
Voltage Input (V)	Voltage Output (V)	Voltage Output Hardware (V)
1.50	1.50	1.51
1.80	1.80	1.81
2.10	2.10	2.08
2.50	2.50	2.51
3.30	3.30	3.28
3.90	3.90	3.92
4.20	4.20	4.18
5.00	5.00	4.98

3.2 Voltage measurement of CP system between steel pipe (anode) and PRE (cathode)

Figure 5 shows the voltage measurement setup in a scale model CP system for manual reading using a multimeter and prototype reading. Meanwhile, Table 2 shows the voltage measurement results using a prototype and multimeter. The accuracy of remote monitoring hardware compared to manual reading shows a range of 96.2% (minimum) and 98.8% (maximum), showing that the remote monitoring prototype exhibited reliable measurement data in the CP system.

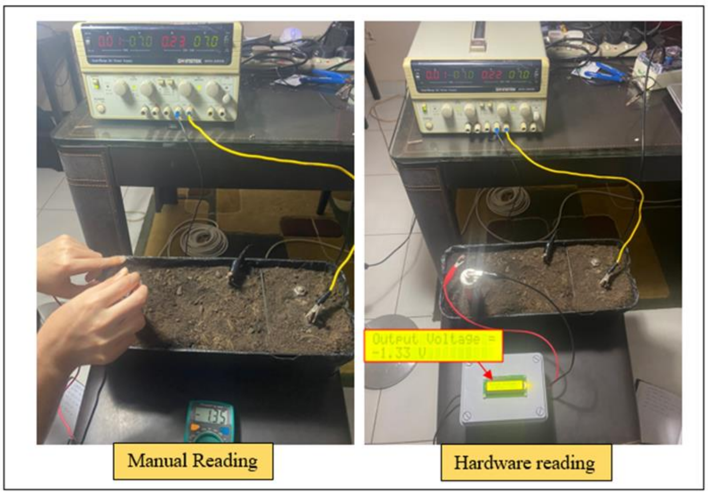

Figure 5: Measurement setup for manual reading (multimeter) and prototype reading

Table 2: Results of voltage measurement using the prototype (hardware) and multimeter.

Voltage input (V)	Output Voltage Hardware (V)	Output Voltage Multimeter (V)	Error Rate	Accuracy
3.00	-1.03	-1.05	1.942	98.1%
4.00	-1.07	-1.11	3.738	96.2%
5.00	-1.18	-1.2	1.695	98.3%
3.00	-1.03	-1.05	1.942	98.1%
4.00	-1.07	-1.11	3.738	96.2%
5.00	-1.18	-1.20	1.695	98.3%
6.00	-1.22	-1.26	3.279	96.7%
7.00	-1.33	-1.35	1.504	98.5%
8.00	-1.38	-1.42	2.898	97.1%
9.00	-1.46	-1.48	1.351	98.6%
10.00	-1.51	-1.53	1.325	98.7%
11.00	-1.54	-1.56	1.299	98.7%
12.00	-1.58	-1.62	2.531	97.5%
13.00	-1.65	-1.67	1.212	98.8%

4. Conclusion

A remote monitoring system for voltage measurements in the CP system was developed based on the IoT platform. The prototype was tested on a scale model of the CP system for buried steel pipe to prove the accuracy and efficiency of the voltage measurement values. The measurement values by an op-amp integrated voltage sensor are comparable to a conventional digital multimeter with a range accuracy of 96% to 98%. In addition, the IoT dashboard can display the collected data using the Blynk platform. In future work, a remote monitoring system integrated with IoT for the CP system may assist scheduling maintenance in the pipeline industry.

Acknowledgement

The authors would also like to thank the Faculty of Electrical and Electronic Engineering, Universiti Tun Hussein Onn Malaysia for its support.

References

[1] V. I. Merkulov, D. F. Skripnuk, and S. V. Kulik, "Analysis of world LNG production capacity," IOPConf. Ser. Earth Environ. Sci., vol. 539, no. 1, 2020.

[2] S. T. (Energy Commission), "Peninsular Malaysia Piped Gas Distribution Industry Outlook 2016," 2016, [Online]. Available:https://www.st.gov.my/en/contents/publications/outlook/PeninsularMalaysiaPiped GasDistribution Industry Outlook 2016.pdf

[3] A. Ferrari, “Pipeline Corridor Monitoring: The Sabah Sarawak Gas Pipeline In Malysia. Retrieved from TRE ALTAMIRA,” 2021. https://site.tre-altamira.com/pipelinecorridor-monitoring-in-malaysia/

[4] D. Eridani, E. D. Widianto, and A. R. Yulianto, “Analysis of Custom IoT Based Electricity Monitoring System,” IOP Conf. Ser. Mater. Sci. Eng., vol. 1071, no. 1, p. 012024, 2021.

[5] M. Irannejad and M. Iraninejad, “Remote Monitoring of Oil Pipelines Cathodic Protection System via GSM and Its Application to SCADA System,” vol. 3, no. 5, pp. 2012–2015, 2014.

[6] N. H. Abdulwahab, A. A. Abed, and M. A. Jaber, “Real-time Remote Monitoring and Control System for Underground Pipelines”, International Journal of Electrical and Computer Engineering, vol. 12, p. 4892-4902, 2022