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Development of Remote Cathodic Protection Potential Measuring System

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Abstract: Underground pipelines are one of the most critical infrastructures in the world for transporting a liquid or gas. One major challenge in the pipeline operation is a corrosion attack that significantly contributes to high-cost maintenance. Therefore, the monitoring system needs to be improved to provide early warning to the operators and cathodic protection (CP) technicians for immediate mitigation planning and, at the same time, speed up the maintenance work. The developed device is equipped with a voltage sensor, humidity sensor and battery capacity sensor. Node-RED will be used to develop an interface to monitor all the parameters collected from the device. The findings indicate that the device could measure potential readings as precisely as a multimeter after the experiment setup was conducted. Based on the data collection, the potential readings for corrosion-free is higher than corroded steel, and the observation is conducted to study the behaviour of steel in terms of cathodic protection. To conclude, the objectives are successfully achieved in this project.

Keywords: Corrosion, Cathodic Protection, Node-RED

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1. Introduction

Cathodic protection is a corrosion prevention method of metals by applying electrical DC current in electrolytes such as soil or water and stopping the corrosion reaction. This system aims to stop the energy from leaking out by applying current to the surface of the pipeline structure [1]. Manual measurements are normally difficult due to the long distances and wide distribution of pipelines [2]. This is due to the difficulty of the CP technicians to access the location of test points such as busy roads or difficulty to access such as private land.

Although cathodic protection systems are used widely nowadays and the durability and effectiveness of this system are at their best, there are weaknesses in this system that is in speed in the maintenance process to handle any failure [3]. Therefore, changing the monitoring system from manual monitoring to real-time automated monitoring will increase the effectiveness of this cathodic protection. The crucial part of this system is to monitor the voltage and current output from supplying not enough or excessive potential. If the pipeline is under-protected, corrosion of the protected structure will occur. Otherwise, if the pipeline is overprotected, it can cause the disbandment of protective coatings and can cause hydrogen embrittlement [4]. Thus, an interface is being developed using the Node-RED dashboard to overcome these limitations. By this interface, all data will automatically be transmitted via wifi from the device to the user device.

The objectives that need to be achieved in this project are to develop a remotely high impedance DC potential measurement for underground pipeline corrosion. Second, to investigate the corrosion measurement based on DC potential measurement for steel pipelines. Third, to develop an interface system for DC potential measurement. Therefore, this project focused on producing a device that is capable to measure various parameters and using all the data collected from the dashboard to observe and investigate the steel behavior in terms of corrosion

2. Overall Project for Cathodic Protection System

The CP system device will be controlled by ESP32. Then, ADS1115 will be used since it can serve as a low-consumption, robust and accurate analog-to-digital converter adapted to perform different conversions [5]. An additional sensor, a humidity sensor, will be equipped to maximize the prevention of corrosion. A Lithium Battery Fuel Gauge will be connected to the lithium-ion battery as its function is to monitor the battery's capacity. The hardware must be tested to whether it works well and according to the plan or not. If it works successfully, the error must be identified and fixed. Node-RED will be used to develop the interface and the dashboard, also used by the Node-RED dashboard itself. Figure 1 shows the system design of the remote cathodic protection potential measuring system using the Internet of Things (IoT).

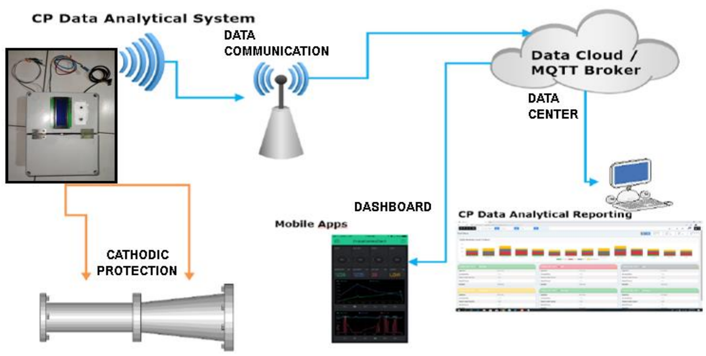

Figure 1: Overall block diagram of the cathodic protection system

2.1 Hardware Development

Figure 2 shows the complete hardware for the CP system meanwhile Figure 3 shows the inside part of the hardware. The battery and board were placed side by side in the junction box. The DHT11 will be buried in the same place as the pipe, while the voltage cable will be connected to the pipe and half-cell. The function of the two pushbuttons is to control the LCD since there are three pages for displaying all the parameters.

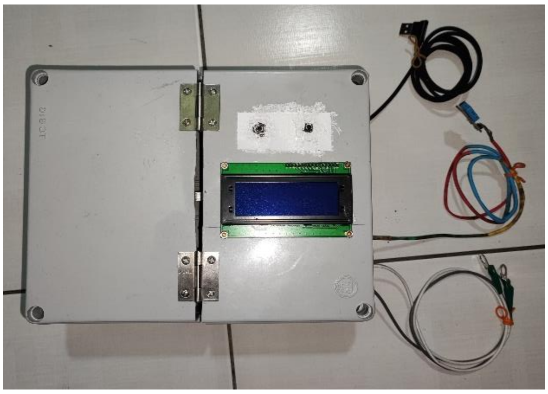

Figure 2: The complete hardware

Figure 3: The inside part of the hardware

2.2 Experimental Setup

The experimental setup will follow based on Figure 4. The negative terminal from the DC Power Supply will be connected to the steel pipe meanwhile the positive terminal will be connected to the anode [6].

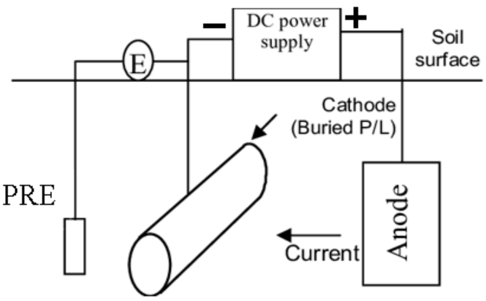

Figure 4: Layout of CP system

Figure 5 shows the experimental setup for the cathodic protection system. The first case study is to observe the potential value between Permanent Reference Electrode (PRE) and the corrosion-free steel. Meanwhile, the second case study is to observe the potential reading between corroded steel and the PRE. The length of corrosion steel free and corroded steel is the same is 85cm and the diameter is 5cm. Meanwhile, the weight is 10kg and the shape is a cylinder.

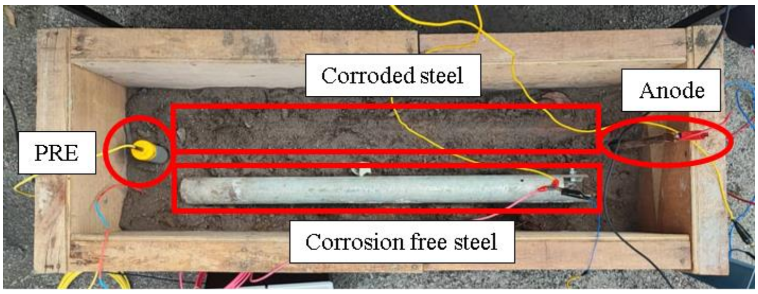

Figure 5: Experimental setup

2.3 Parameter of Transformer Rectifier Unit (TRU)

Figure 6 shows the parameter of voltage and current in TRU injected to the pipeline at Petronas Block Valve Station at Putrajaya. To justify this paper, the same parameter value applied to the Petronas Gas Pipeline will be used by using DC Power Supply. Figure 7 shows the value of voltage and current injected into the steel. Table 1 shows the parameter of TRU and DC Power Supply.

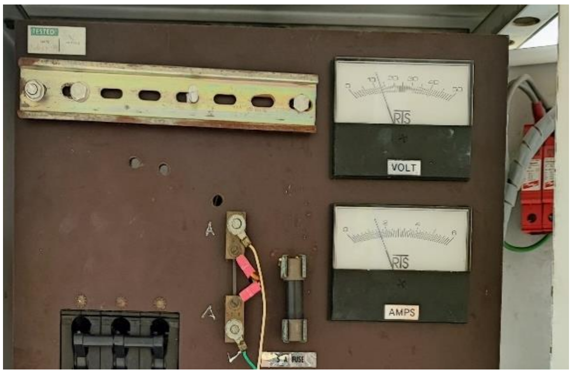

Figure 6: Parameter of TRU

Figure 7: Parameter of DC Supply

Table 1: The parameter of the TRU and the DC Power Supply

	TRU	DC Power Supply
Voltage	13.0V	13.0V
Current	1.58A	1.58A

3. Results and Discussion

3.1 Case Study 1 – Corrosion Free Steel to PRE

Case study 1 will observe the potential measurement taken between PRE and corrosion-free steel. Table 2 shows the comparison of measurement taken between manual measurement using a multimeter and device measurement. The measurement was taken within 15 seconds.

Table 2: Measurement of PRE to the corrosion-free steel

Multimeter Measurement (mV)	Device Measurement (mV)	Accuracy
-1050	-1048	99.8%
-1046	-1051	99.5%
-1048	-1044	99.6%
-1039	-1042	99.7%
-1036	-1038	99.8%
-1042	-1047	99.5%
-1049	-1045	99.6%
-1037	-1039	99.8%
-1039	-1040	99.9%
-1047	-1048	99.9%

3.2 Case Study 2 – Corroded Steel to PRE

Case study 2 will observe the measurement taken between PRE and the corroded steel. Table 3 shows the comparison of measurements taken between manual measurement using a multimeter and device measurement. The measurement was taken within 15 seconds.

Table 3: Measurement of PRE to the corroded steel

Multimeter Measurement (mV)	Device Measurement (mV)	Accuracy
-3152	-3151	99.9%
-3149	-3149	100%
-3150	-3148	99.8%
-3177	-3175	99.8%
-3163	-3162	99.9%
-3157	-3158	99.9%
-3159	-3160	99.9%
-3149	-3151	99.8%
-3185	-3187	99.8%
-3179	-3176	99.9%

3.3 Discussions

Based on the potential measurement taken from case study 1 and case study 2, it can be concluded that the voltage for corroded steel is much higher than the corrosion-free steel. The corrosion-free steel consumes more current than corroded steel. If the current increases, the voltage will decrease. So, the voltage of corroded steel is much higher due to the small amount of current consumed. The voltage sensor (ADS1115) used in this project has a stated typical accuracy of 0.01% to 0.015% which means it is incredibly precise and capable to measure the potential value same as a multimeter.

3.4 Dashboard for Cathodic Protection System

The interface has been developed to improve the effectiveness of monitoring the potential value and other essential parameters. Figure 8 shows the data of humidity, temperature and battery capacity collected from the microcontroller and published on the first page of the dashboard. Figure 9 and Figure 10 shows the data collected from the microcontroller and display it on the LCD. So, it can be justified that the dashboard was successfully operated since the actual data displayed on the LCD are tally with the data displayed on the dashboard.

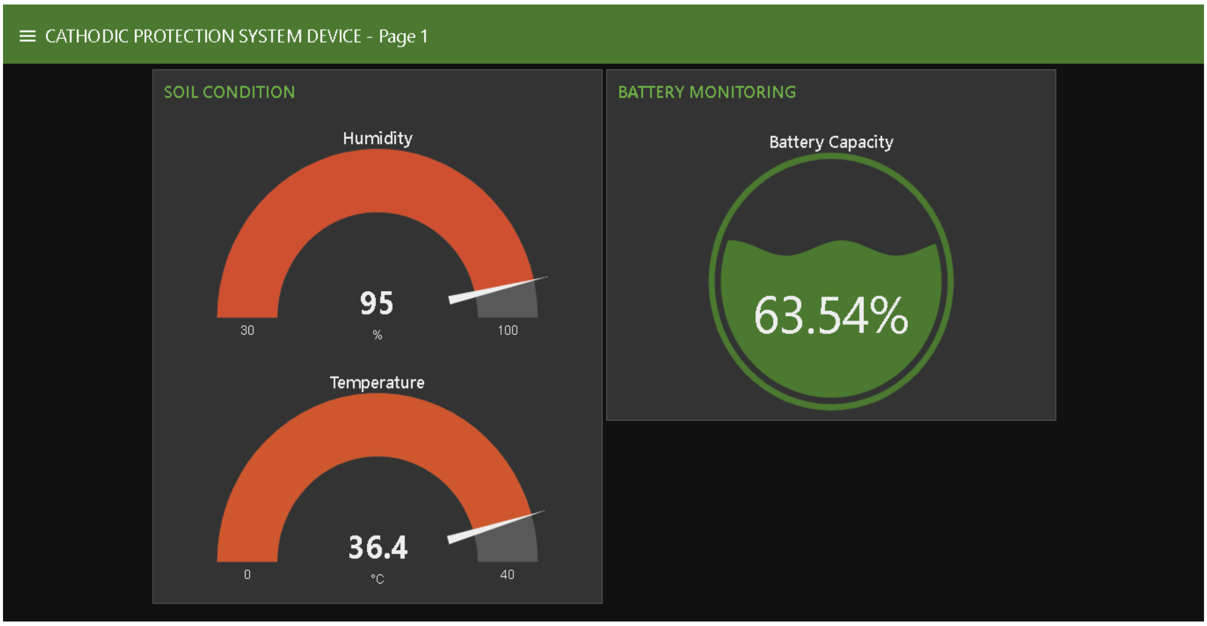

Figure 8: Important parameters displayed in the dashboard

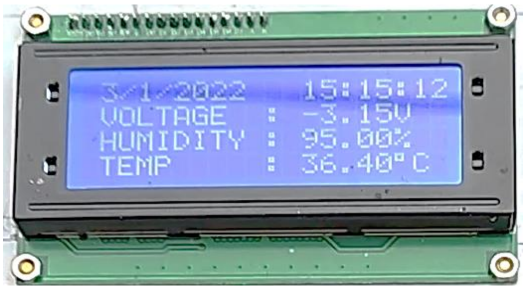

Figure 9: Important parameter displayed on the second page of the LCD

Figure 10: Important parameter displayed on the third page of the LCD

Figure 11 and Figure 12 show the voltage graph on the second page of the dashboard for 2 case studies. Based on the graph in Figure 11, the potential measurement is fluctuating between -1036mV to -1050mV for case study 1. Meanwhile, Figure 12 shows the potential measurement graph is fluctuating between -3148mV to -3185mV for case study 2.

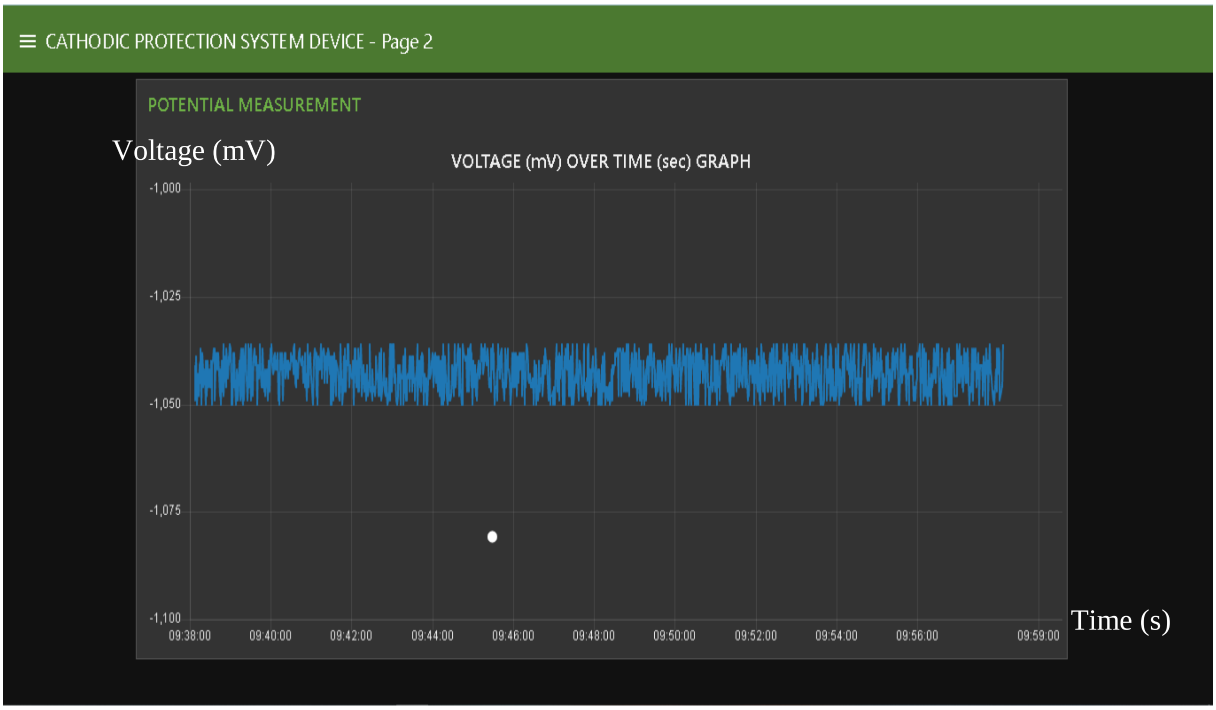

Figure 11: Voltage graph for case study 1

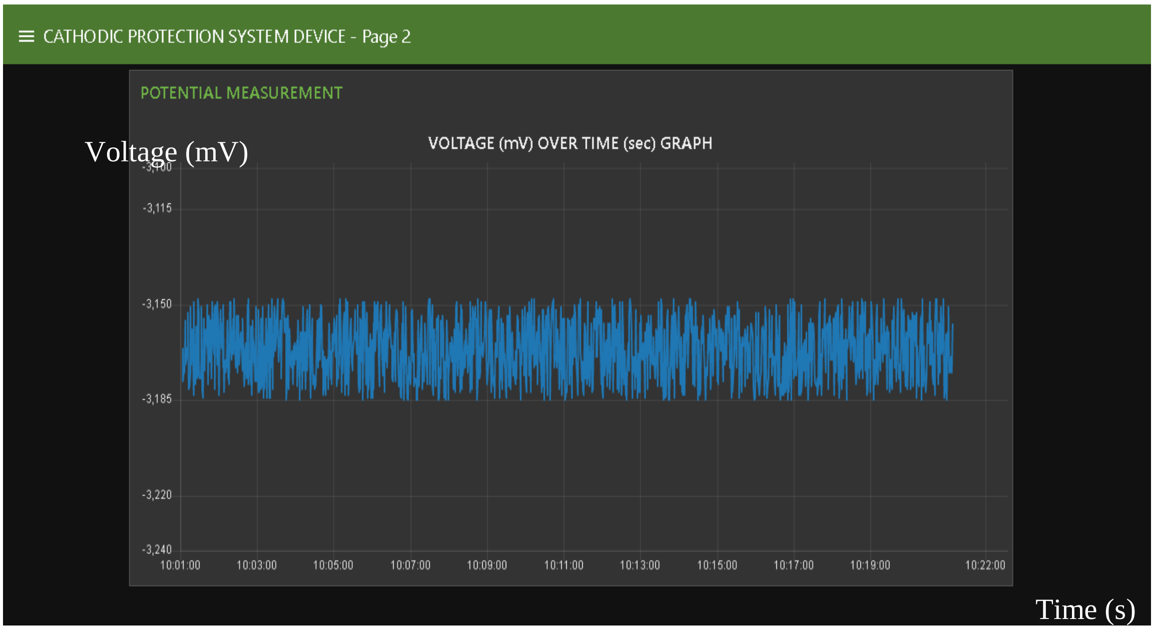

Figure 12: Voltage graph for case study 2

4. Conclusion

The objectives are successfully achieved in this project. A high impedance DC potential measurement measured DC potential using the cathodic protection concept. The measurement values by voltage sensor of the developed system are comparable to a conventional digital multimeter with an accuracy of 99%. In addition, the humidity sensor and lithium battery fuel gauge also provided a valid measurement. A developed DC potential measurement remotely was set up in a cathodic protection environment for corrosion measurement of steel pipeline. An observation can be made based on the data collected from the measurement setup. The dashboard developed using Node-RED can also receive all the data collected from the microcontroller and publish it to Node-RED via MQTT. It can be said that the developed dashboard is very effective and user-friendly.

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