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Cathodic Protection Online Monitoring Using a Low Power Wide Area Network Communication System

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A B S T R A C T

Cathodic protection is a corrosion control and prevention system that is applied to underground pipe structures by providing an electric charge to the structure to be protected. An online monitoring system for cathodic protection is urgently needed to save costs and ensure operator safety in the field in the care of the protected structure. This study aimed to evaluate cathodic protection online monitoring using a low power wide area network (LPWAN) communication system. Cathodic protection online monitoring in this study was applied using LPWAN with a radio frequency of 433 MHz. In this work, the type of communication with wireless technology has been chosen with low power consumption and can accommodate the distance between test stations in the distribution pipeline. From the results of testing the cathodic protection online monitoring system, it can be seen that measurement data that has been done manually can be replaced in real-time and monitored remotely. This system is highly recommended for areas that have so far not been covered by manual measurements, for example, remote areas prone to flooding, swamps, and interference areas that require denser data information to make handling easier to do early.

1. Introduction

The cathodic protection system is one of the most common methods of controlling metal corrosion.[1,2] Underground pipelines will generally experience corrosion due to interaction with the soil environment which contains aggressive ions. The popularity of this system is due to the system being simple, inexpensive, and suitable for many industrial applications.[3,4] The weakness of the cathodic protection system is that the monitoring process requires high costs because operators have to go to remote locations, especially in cross-city pipeline areas, and there are traffic hazards for urban areas and wild animal hazards for areas in the wilderness.[5] There are two systems of cathodic protection, namely, sacrificial anode cathodic protection (SACP) and impressed current cathodic protection (ICCP). In both systems, until now, the monitoring method is still using the conventional method, namely, the pipe operator manually measures the pipe protection by visiting a test station that is installed above the pipe, which is the cathodic protection measurement point.[6]

Non-conventional monitoring systems using wireless technology are still being researched to obtain remote monitoring methods with the hope that cathodic protection testing for underground pipelines can be carried out remotely. The development of cathodic protection online monitoring has been developed using the GSM network, but this system still requires financing to subscribe to credit.

This study uses a low power wide area network (LPWAN) system for designing a system monitoring cathodic protection remotely using radio frequency (RF) without incurring a pulse subscription fee in accordance with Indonesian regulations. LPWAN is a long-distance radio frequency wireless technology with a low-power consumption protocol that can transmit data with a license-free modulated radio spectrum. LPWAN is a battery-powered device equipped with supporting feature components to communicate with LPWAN gateways in LPWAN communication networks.[7]

LPWAN-based end devices are equipped with LPWAN transmitter circuit boards or PCBs, radio modules, and wireless signal antennas to communicate between point measurement locations and LPWAN gateways. The LPWAN node is also equipped with a low-power xmega series 32A microcontroller to process input data readings in the form of voltage and current detection, calculation of battery power usage, and simultaneous transmitter (real-time transceiver) processing.[8,9] This study aimed to evaluate cathodic protection online monitoring using a low power wide area network (LPWAN) communication system.

2. Methods

The principle of conventional cathodic protection measurement

The principle of cathodic protection is to provide a unidirectional electric charge to a pipe that is protected to become the cathode in an electrochemical cell (NACE SP0169-2018). The source of this electric charge comes from an embedded magnesium anode beside the pipe, and the connection is made through a test box.[10] The cathodic protection monitoring system is carried out by measuring the pipe-to-soil potential based on the NACE TM0497-2018 standard.[11-13] The tool used is a digital multimeter, reference electrode $Cu/CuSO_4$, and manual recording (Figure 1).

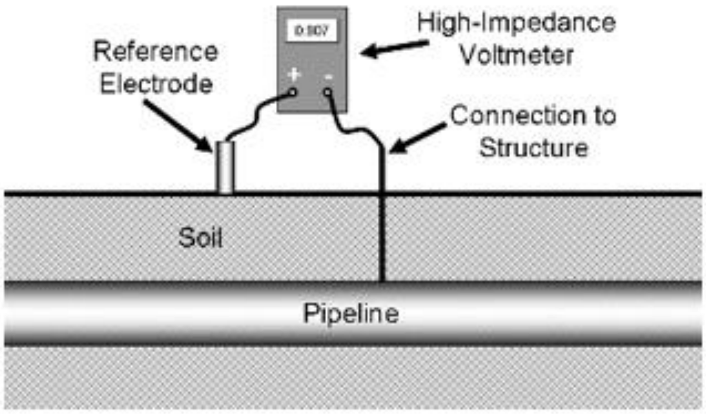

Figure 1. The principle of measuring cathodic protection (conventional) (NACE TM0497). Notes: Inspector cathodic protection brings a digital multimeter, portable reference cell ($CuCuSO_4$), toolkits, double cab 4x4 engine vehicles, and safety equipment. Data output; 1 data pipe to soil potential for each test point.

The principle of measuring online monitoring cathodic protection

The online monitoring system is a pipe to soil monitoring techniques potential without visiting the test station location.[12] This online monitoring system is carried out by installing $Cu/CuSO_4$ measuring electrodes permanently beside a pipe in the ground. This installation method is called permanent reference electrode $Cu/CuSO_4$.[13,14] The manual potential measuring tool, namely a voltmeter, is replaced by installing a measuring module in the test station so that in real-time, it can measure the pipe potential. After the system is installed, the pipe potential measurement data in the module is sent online via radio, wifi, and internet communication. In this study, data transfer was carried out through a low-power wireless area network (LPWAN). Data from the module installed at the test station will transmit data captured on the computer server. With the application built for this system, analysis and data processing can be carried out to evaluate the level of cathodic protection of pipes (Figure 2).

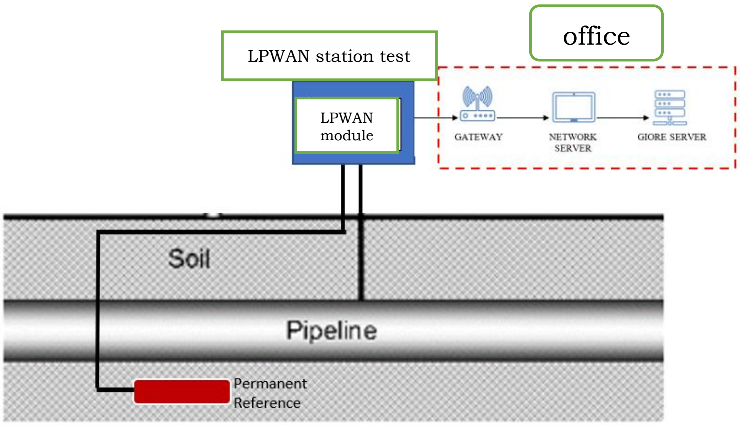

Figure 2. The principle of measuring cathodic protection online monitoring.

LPWAN cathodic protection monitoring

LPWAN technology is a powerhouse for IoT solutions, offering a cost-effective and power-efficient wireless option that leverages existing networks, global reach, and strong internal security and is purpose-built for M2M and IoT devices.[8] LPWAN technology enables low power consumption and long-distance wireless connectivity. LPWAN is a low-power wireless technology that uses the radio spectrum. This LPWAN technology is a distinct advantage in technological developments such as wireless sensor networks (WSN), which require data transmission that is resistant to noise, low power consumption, and can accommodate remote sensor nodes and gateways. The LPWAN cathodic protection monitoring trial method is to combine digital cathodic protection measurements. Then the measurement data will be sent via the network to the recipient (Figure 3).

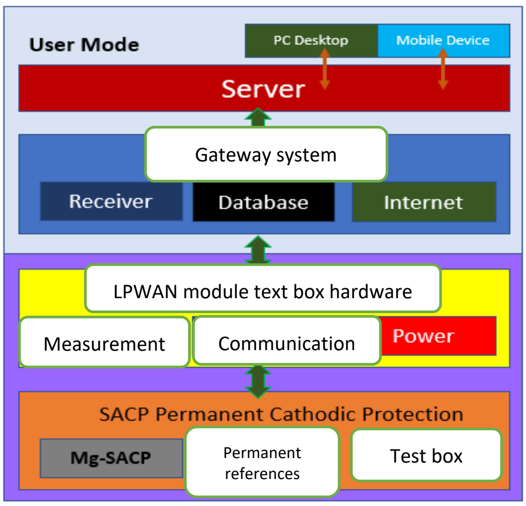

Figure 3. LPWAN SACP block diagram.

The work of this system requires a supporting device, namely a gateway or data receiving gate, that will send data to the server (Giore), and sending data requires a stable internet so that data does not occur delays in sending. LPWAN uses a network configuration in which a data center (gateway) receives and collects data from many distributed and remote nodes. The connection between the endpoint and the data center is non-TCP/IP. After receiving the data, the base station then passes it on to the server, for example, via Ethernet or cellular network. The working mechanism of sending analog data into digital data and sending it through the LPWAN system can be described schematically in Figure 4.

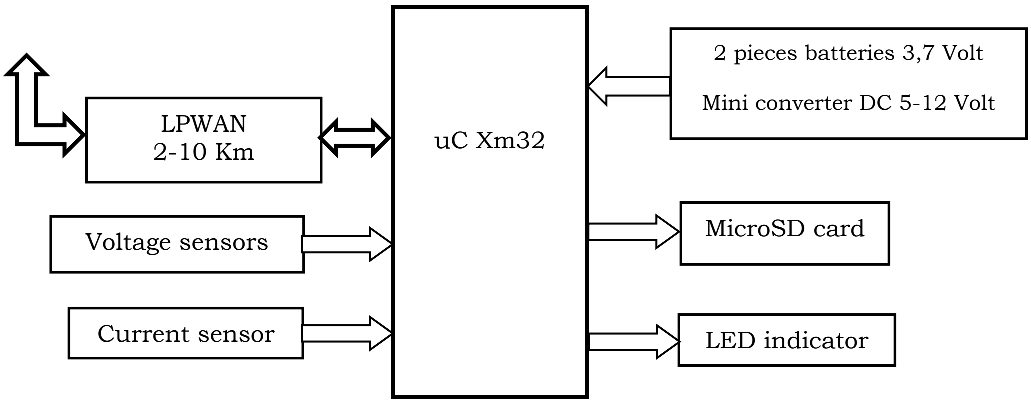

Figure 4. Block diagram of data acquisition.

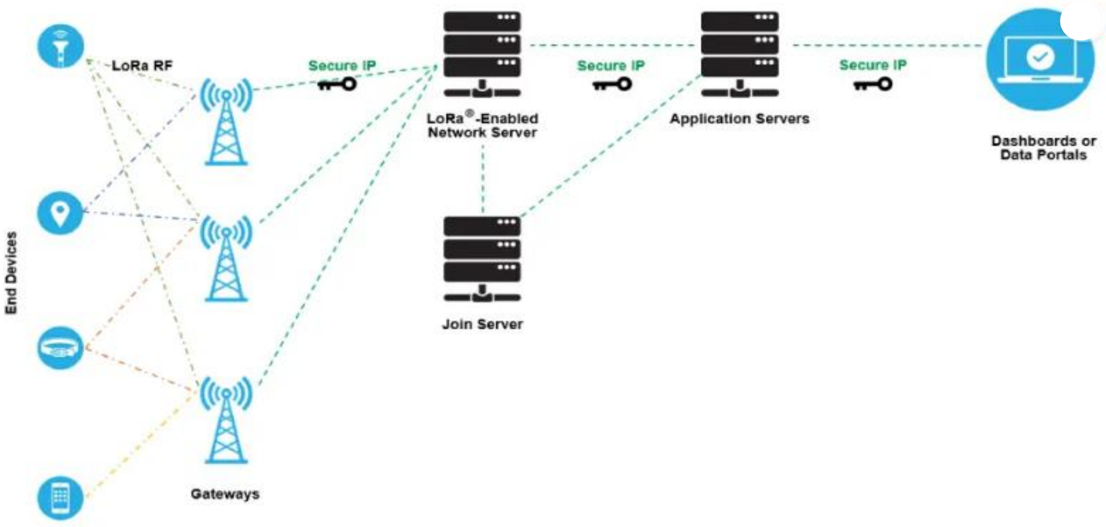

Figure 5. Data communication mechanism using LPWAN.

The data that has been acquired by each point (node) is processed or collected in a class group with a certain ID header, then entered into the plan according to Figure 5. Point LPWAN RF, which has been positioned for its data acquisition class group, is sent in a server network that can be monitored in a PC/smartphone software application by creating a data portal dashboard. LPWAN network works through the collective function of various elements. Some of these include licensed or license-free communication frequencies, end nodes, receiving and transmitting antennas, and application software. An end node is any device or object equipped with a frequency transmitter and other features capable of communicating at low power with an LPWAN gateway. Network servers control software that oversees the proper routing of all data that is communicated. In simple terms, the work of the LPWAN cathodic protection system can be described as follows; potential and current data from the cathodic protection system at each test station (TB-1, TB-2, and TB-3) will be sent to the gateway in the room, which will then be sent to the server via the internet network (Figure 6).

Figure 6. LPWAN cathodic protection scheme.

3. Results and Discussion

Cathodic protection testing location

The testing location for online monitoring of LPWAN cathodic protection is carried out at 3 installation locations on underground pipelines, each of which is located at the TB behind the PGN Bogor Mosque (TB-3), TB mall (TB-2) and TB Jln Sawojajar (TB- 1) (Figure 7).

Figure 7. Map of the location of the CP online monitoring test station.

Monitoring cathodic protection low power wide area network (CP-LPWAN)

The results of recording and mitigating the CP-LPWAN system at each location are presented in Figure 8. On TB-1, there was a delivery delay caused by an unstable internet connection, and an error occurred once in the measurement reading, which was caused by a bug in the program, so the measurement was inaccurate. For the test station 1 problem, a module connection change will be made so that the problem does not recur. Test station 2 can provide good record data to the Giore server stably. The findings at test station 3 show delivery delays caused by unstable internet connections in the office.

TB-01

device_date	device_time	voltage	current	battery	Receive Time	Difference (m)
2021-12-04	12:00	865.3	4.8	6019	2021-12-04 12:02	-2.622333333333333
2021-12-04	06:00	867.8	4.8	6029	2021-12-04 06:03	-3.1222833333333333
2021-12-04	00:00	874.2	4.6	6039	2021-12-04 00:03	-3.145366666666667
2021-12-03	18:00	886.4	4.6	6049	2021-12-03 18:03	-3.9261166666666667
2021-12-03	12:00	889.3	4.4	6059	2021-12-03 12:14	-14.112033333333333
2021-12-03	06:00	900.6	4.2	6069	2021-12-03 06:08	-8.7314
2021-12-03	00:00	906.8	4.1	6079	2021-12-03 00:06	-6.0620666666666665
2021-12-02	18:00	902.4	3.7	6089	2021-12-02 18:03	-3.647666666666667
2021-12-02	12:00	936.5	3.3	6099	2021-12-02 12:05	-5.653416666666667
2021-12-02	06:00	947.6	3.6	6109	2021-12-02 07:14	-74.05193333333334

TB-02

device_date	device_time	voltage	current	battery	Receive Time	Difference (m)
2021-12-07	00:00	854.7	5.8	5887	2021-12-07 00:01	-1.2379166666666668
2021-12-06	18:00	869.5	5.3	5897	2021-12-06 18:03	-3.6756333333333333
2021-12-06	12:00	867.2	5.1	5907	2021-12-06 12:07	-7.174033333333333
2021-12-06	06:00	857.3	5.3	5917	2021-12-06 06:45	-45.59265
2021-12-06	00:00	854.3	5.6	5927	2021-12-06 00:01	-1.2231333333333334
2021-12-05	18:00	867.2	5.9	5937	2021-12-05 18:11	-11.71395
2021-12-05	12:00	872.2	4.7	5947	2021-12-05 12:03	-3.3402666666666665
2021-12-05	06:00	877.4	4.5	5957	2021-12-05 06:04	-4.89685
2021-12-05	00:00	879.7	4.8	5967	2021-12-05 00:05	-5.475716666666667
2021-12-04	18:00	871.6	4.5	5977	2021-12-04 18:02	-2.6415333333333333

TB-03

device_date	device_time	voltage	current	battery	Receive Time	Difference (m)
2021-12-09	12:00	905.2	4.7	6049	2021-12-09 12:10	-10.2211
2021-12-09	06:00	919.3	4.8	6059	2021-12-09 06:44	-44.30858333333333
2021-12-09	00:00	924.7	4.6	6069	2021-12-09 00:02	-2.0657
2021-12-08	18:00	937.5	4.2	6079	2021-12-08 18:03	-3.1409166666666666
2021-12-08	12:00	932.1	4.6	6099	2021-12-08 12:02	-2.4884
2021-12-08	06:00	917.4	4.4	6109	2021-12-08 06:12	-12.579166666666667
2021-12-08	00:00	922.2	4.1	6119	2021-12-08 00:02	-2.6169333333333333
2021-12-07	18:00	912.3	4.4	6129	2021-12-07 18:05	-5.593616666666667
2021-12-07	12:00	905.2	4.6	6139	2021-12-07 12:03	-3.8865
2021-12-07	06:00	901.3	4.8	6149	2021-12-07 06:04	-4.314183333333333

Figure 8. Recording and mitigation of the CP-LPWAN system.

Based on the results of the LPWAN cathodic protection monitoring test, there are several analyzes and findings as follows; battery capacity in each module is 4 x 3400 mAH. Power consumption is around 40 mVoltper day, or spend 10mVolt each delivery. The location of the LPWAN node placement determines the range where TB-2 cannot provide a signal to the gateway/TB-LPWAN-3 because it is blocked by buildings. To overcome this problem, additional battery power was added from 2 sets to 4 sets.

Pipe protection potential data recording, anode current, and battery consumption can be properly monitored with a duration of 4 shipments in 24 hours (delivery every 6 hours). Based on online monitoring data, there are different levels of protection when the pipe environment is dry or in wet conditions. In addition, the environment around the module greatly influences the performance of the module with indications that the module is exposed to air only lasting for 2 weeks.[15,16] To overcome this, the protection of the module (PCB circuit) can be increased using electrical isolation, and the module can work properly without interruption.

4. Conclusion

Cathodic protection online monitoring has been carried out for 3 new test stations located on the gas pipeline under land for 3 months. The monitoring results show that the LPWAN system can be used to monitor potential, protection current, and module battery power properly with a delivery duration of 4 shipments per day. The LPWAN cathodic protection online monitoring system can be used as an alternative to replace system conventional online monitoring and can compensate for the use of conventional test station maintenance costs.

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