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REMOTE MONITORING OF OIL PIPELINES' CATHODIC PROTECTION SYSTEM VIA GSM/GPRS MODEM AND THE THINGSPEAK PLATFORM

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Abstract

With the advancement of technology and the implementation of contemporary techniques and system controls, conventional methods of on-site monitoring have been replaced by remote supervision, which offers a number of advantages. As a result, it appears that a suitable strategy utilizing these contemporary approaches and incorporating information technology into the industry is required. The author's goal in this work is to describe a device for remotely transferring cathodic protection information from oil and gas pipelines to a platform server through the internet and sending alerts by SMS and e-mail. This system was developed and tested in Iraq's Al-Ahdab oil field. The system provides real-time, 24/7 assessment data with an accuracy of 99.7%.

Keywords: remote monitoring, GSM, GPRS, cathodic protection.

1. INTRODUCTION

Iraq's oil sector is one of the country's largest and most vital industries. Some of its subordinate or contracting enterprises' operating areas span the entire country. These enterprises' pipelines are extremely lengthy and expensive, and their ongoing, uninterrupted use for transportation makes them extremely vital. As a result, their safety is critical. Protection mechanisms have been used in industries, particularly pipelines, since the commencement of their production, and monitoring continues during operation, with personnel staying at the site.

Pipeline operators reduce the interaction between the pipe and the surrounding soil by applying high-quality coatings to prevent long-term corrosion impacts. The coating, on the other hand, can have flaws. As a result, a supplementary technique of corrosion protection for the pipe metal is necessary [1, 2]. When a metal is exposed to its environment, it undergoes corrosion, which is an electrochemical process. Corrosion normally occurs at the circuit's anode, but not at the cathode. Cathodic protection (CP) works by transferring a positive DC current between an external anode and the metal to be protected, causing the metal to become cathodic and not corrode. On their transmission pipes, all pipeline operators employ CP extensively. CP has a significant benefit over other types of corrosion treatment in that it can be applied quickly and easily by maintaining a DC circuit, and its effectiveness can be continuously checked [1]. Figure (1) shows the two types of CP systems. Routine measurements of CP levels are essential to meet regulatory safety limits. Apart from their high costs, manual measurements may only detect problems after they have happened, leaving pipelines vulnerable until the malfunction is detected [2].

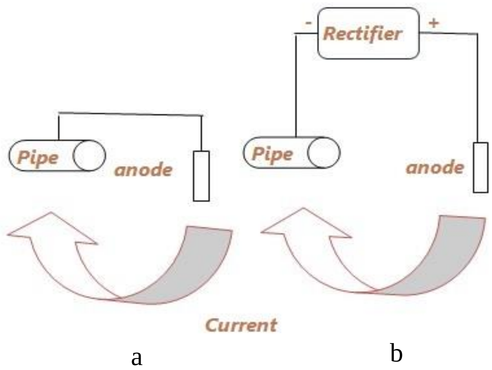

Fig. 1. Two types of cathodic protection systems a) Galvanic (L) CP. b) Impressed current (R) cathodic protection

With the advancement of information technology, surveillance technology has grown increasingly widespread, particularly in the sphere of the Internet of Things (IoT). Wireless Sensor Networks (WSNs) are one of the important components of the networking field for remote monitoring sensors. They are gaining importance in numerous applications due to their low cost, high efficiency, and tiny size. WSNs continue to have problems with memory, energy utilization, security, and processing despite the fact that they are used in a wide range of applications. Some researchers have relied on WSNs to monitor the environment, such as remote monitoring of Post-Eruption Volcano environments in [3] or rainfall monitoring networks in urban areas in [4]. On the other hand, all of the sensors in an IoT system send data straight to the internet. In this instance, the data will be instantly or repeatedly delivered directly to the internet, where a server can process it and allow for front-end interface interpretation, but sensors will need internet access. IoT offers to be more effective in tasks that could be time-consuming and can help many businesses reassess how they provide their services. You can anticipate more cutting-edge sensor applications transforming sectors for the better as IoT expands. Therefore, researchers are focusing on the application of IoT to almost all aspects of life because many of the WANs problems have been solved since there are many free and low-cost servers for IoT applications. In [5, 6], the authors have provided techniques for tracking river speed and water levels in real time by sending the data via GPRS modem or WiFi modem. Also, authors have developed an algorithm for multiple cloud-based IoT applications in an energy-aware service composition in [7]. In [8], Authors have proposed a real-time energy consumption monitoring technique in IoT-based Smart Cities. The following are some of the other benefits of using remote monitoring: protecting people's health and lives on the roads, lowering transportation costs, and collecting extensive real-time data from a number of sources.

Remote CP monitoring is a recent advancement that automates the data collection procedure and gives operators a proactive surveillance system. To guarantee that the correct level of CP is applied, the system should monitor the output voltage and current from transformer rectifiers (T/R) that is shown in figure (2). The T/AC R's supply is also monitored so that power failures can be reported as soon as possible. A system like this will extend the lifetime of pipes and tanks, lower maintenance and inspection costs, save testers time, save lives, and ensure that they are fully aware of the state of CP in the fields. As a result, various authors have suggested multiple techniques for remotely monitoring the CP's system.

In [9], this paper's cathodic protection monitoring system offers a long-term method for protecting long-distance transportation pipelines. The pipeline's electric potential is monitored by the Wireless Sensor Network (WSN). The General Packet Radio Service (GPRS) network is in charge of long-distance transmission, and the Internet is in charge of issuing and evaluating monitoring information. The monitoring system can satisfy the demand for tracking the state of the cathodic protection system in the station. This system has been optimized using a dependable communication protocol and an energy-saving mechanism based on real-world data.

Fig. 2. The Transformer Rectifier.

The suggested system in [10] incorporates WSN technology to capture potential data and enable remote data transmission. The researchers looked into three scenarios: a regular circumstance in which no difficulties with the oil pipeline were detected; a malfunction in the voltage values caused by a simple increase or reduction; and a significant flaw in the pipe that resulted in either smuggling or anode malfunction. Nine WSs (MDA100CB mote with IRIS mote), three Remote Terminal Units (RTUs) (MIB 520 mote with IRIS mod), and one Base Station (BS) personal computer are used in each of the three situations investigated (PC). The LabVIEW 2010 program was used to create the simulation environment. According to modeling results, this system has the shortest time delay, quickest speed, and uses the least amount of power, as well as proper WS and corrosion placement in the pipeline. The system, on the other hand, is complicated and expensive.

ICCP technology is a common kind of corrosion prevention for ships and bridges, according to [11]. The ICCP master control panel's ARM LPC2138 is linked to a color touch screen via serial ports. The 12 mod-bus protocol is used to communicate between the ICCP systems and the ARM processors of remote terminals. The touch screen is utilized for real-time online monitoring, and the RS485 communication interface is used to build a real-time database for user convenience. Predictions are double-checked with the frames received when receiving the response frames to avoid any mistakes. The result confirms the system's efficacy.

The goal of this study is to develop an embedded low-cost remote monitoring CP system to safeguard pipes from corrosion and to protect the facility from a sudden shutdown caused by corrosion. An ATMEGA 328 acts as the control center, with a

GSM module and user terminals. This paper's information can be summarized as follows: System structures are the topic of the second section. The third section provides and examines the main findings. The fourth section summarizes the study's major conclusion.

2. METHODOLOGY

2.1. The system structure

The following materials make up the system:

- A microcontroller board based on ATmega328 (Arduino Uno) [12].
- A GSM/GPRS Modem (SIM900) [13].
- Liquid Crystal Display (LCD).
- Two resistances 10 KΩ and 100 KΩ.
- PCF8574A.
- ThingSpeak platform [14,15].

2.2. Hardware design

It's a basic digital voltmeter (DVM) that can securely detect input DC voltages in the range of 0 to 30V. A regular 9V battery pack can be used to power the Arduino board, which has 14 digital input/output pins, 6 analogue inputs, a 16 MHz crystal oscillator, a USB port, and a power jack on this board. The Arduino's analog inputs measure DC voltages between 0 and 5 volts when using the normal 5-volt analog reference voltage, and this range is extended if we use two resistors to produce a voltage divider if the applied voltage exceeds 5 volts. The Arduino board's analog sensor detects the voltage on the analog pin and converts it into a digital format so that the microcontroller can process it. Here, we are utilizing a straightforward voltage divider circuit made up of resistors R1 (100K) and R2 to supply the input voltage to the analog pin (A0) (10K). It is feasible to supply the Arduino board with a voltage ranging from 0V to 55V according to the values used in the voltage divider. When the input voltage is divided by 11, 55/11 = 5V, it equals the junction on the voltage divider network connected to the analog pin on the Arduino board. In other words, while measuring 55V, the Arduino analog pin will be at its maximum voltage of 5V. In order to add a margin of safety, it is therefore preferable to designate this voltmeter as "0-30V DVM" in practice. Thus, the voltage divider reduces the measured voltage to fit inside the analog input range of the Arduino. The SIM900 wireless module, PCF8574A, and a 16x2 LCD, which have been used to show the DC voltage value on the site, were both linked.

The ATmega 328 on the mainboard of the system, as indicated in figure (3), which is in charge of all of the other components. The voltage divider is attached to ATmega pin 23. The GSM/GPRS modem's TXD and RXD pins are connected to the ATmega's second and third pins, respectively. We can connect to the internet using the General Packet Radio Service by using the GSM/GPRSRS232 shield that has a built-in TCP/IP stack (GPRS).

The LCD screen was connected using the PCF8574A I2C port expander, which is an IC chip having an 8-bit input/output (I/O) port expander. We may use this IC chip to add another 8-bit bi-directional port to the microcontroller if we wish to increase the precision and reliability of the present system [16].

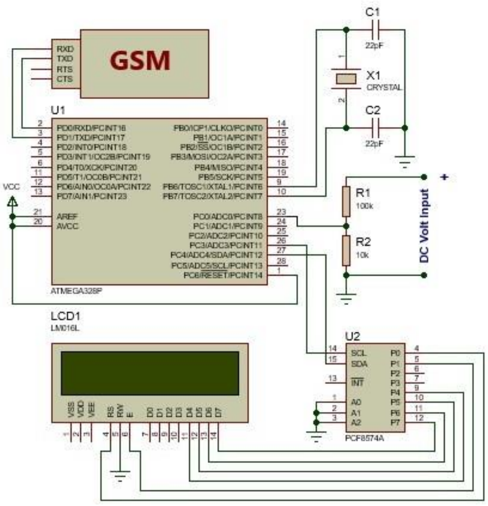

Fig. 3. The schematic diagram of the proposed CP monitoring system.

The Arduino microcontroller will process the detected potential voltage and show it on an LCD screen. Additionally, Arduino uses GPRS to send the measured data to a free web server. The recorded data of the voltage level is updated on the platform every 10 minutes. The recoded data could be customized to meet your specific requirements.

2.3. Softwaer design application

Many strategies are employed to construct a system's GUI, according to previous related procedures. To save money on implementation, freeware software is used. The system is based on "ThingSpeak," a web-based IoT platform with an open API service. It's a cloud-based IoT analytics platform for collecting, displaying, and analyzing real-time data from a variety of sensors, including air quality, temperature, heat, humidity, rain sensing, light intensity, barometric pressure, and sea level pressure. There are also apps that can alter and visualize data or initiate an action. The designed website for data collection is shown in figure (4).

2.4. Mechanism of the work

The terminals of the voltage divider must be connected between the pipeline and the reference where the reference should be away from the pipeline. The control unit that has measured the potential voltage value between the pipeline and the reference will display the DC voltage on the LCD screen. However, if the potential voltage has been exceeded or underrated, an SMS alert will be created and sent to a specific phone number. To transport data outdoors in telecommunication systems, we

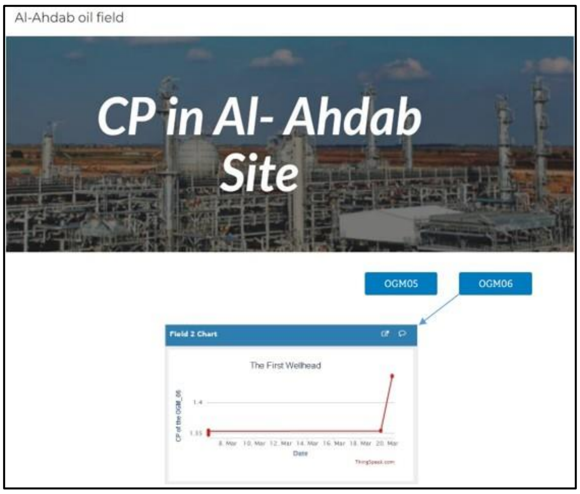

Fig. 4. For data gathering and viewing, a website and the ThingSpeak platform were created.

require radio frequency permits from the Regulatory Authority, and creating communication circuits at a specific frequency has its own set of issues. However, this device, which uses GPRS technology, entirely overcomes all of these issues because it not only does not require a dedicated communication channel, but it can also link an unlimited number of locations and devices, and there are no security issues when sending data. As a consequence, the data is sent through GPRS to the newly created channel on the ThingSpeak platform. The data from this base station is sent to the cloud. The central command center may look at real-time voltage data to see if the transformer rectifier needs to be corrected. In addition, an email notice will be sent. The method is depicted in figure (5) as a flowchart. Figures (6) and (7) depict the actual designed system as well as the reference that was used, respectively.

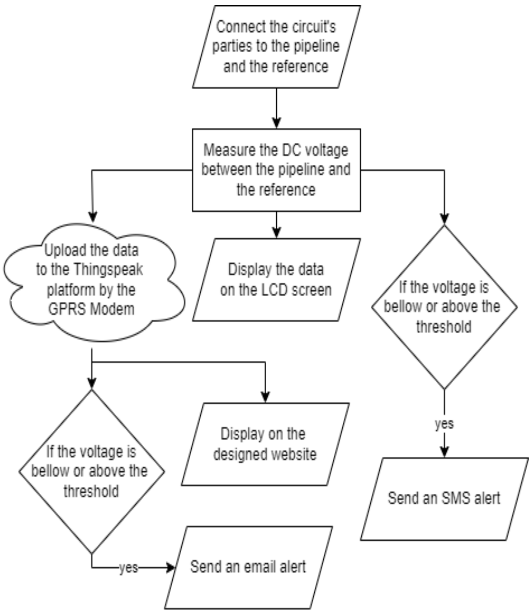

Fig. 5. A flowchart depicting the procedures involved in data processing

Fig. 6. The intended system's mainboard.

Fig. 7. The references utilized

In the manual reading approach, an inspector uses the DVM to measure the potential voltage, which is applied by the rectifier, between the pipeline and the reference. Figure (8) illustrates the differences between the manual reading approach by using the DVM and the real-time recoding technology by the system, as displayed on the LCD panel. The percentage error was calculated using equation No. 1, and it was 0.002 percent. To test the effectiveness of alarm strategies, the transformer rectifier is turned off in one of the oil gathering manifolds. Two types of alarms (SMS and email) would be sent to the operator as shown in figures (9) and (10).

$$\text{Percent Error} = |\text{measured} - \text{real}|/\text{real} \quad (1)$$

According to the CP team's recommendation, the proposed system has been installed on a pipeline for more than one month, and it has been programmed to send the potential voltage every hour. On the other hand, the CP team checks this pipeline once

Fig. 8. The difference between the traditional method and the proposed method.

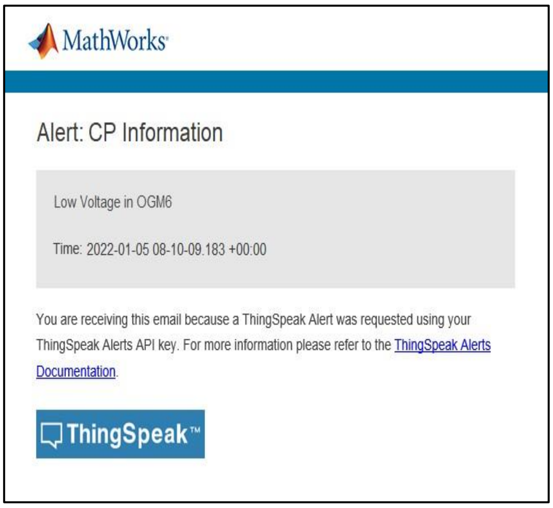

Fig .9 . The method that have been used to alert if the CP system is fail (by an email).

every week. Figure (11) depicts the mathematical model of the data acquired by hand and the interpolated data, which was calculated using equation No. 2 [17].

$$y = yi + (x - xi)(y_{i+1} - yi)/(x_{i+1} - xi) \qquad (2)$$

Since:

- The needed data point is represented by y.
- x characterizes a well-known metric.
- xi and yi characterize the first known point's coordinates.
- xi+1 and yi+1 characterize the second known point's coordinates.

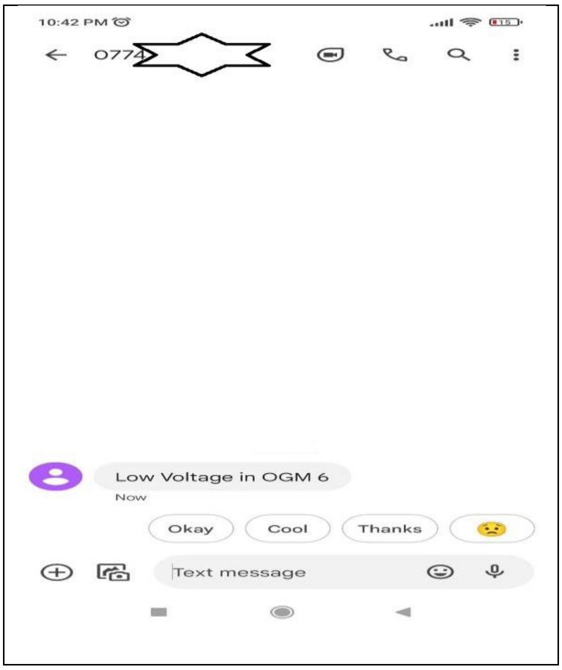

Fig. 10 . The method that have been used to alert if the CP system is fail (by SMS).

The absolute error between the readings of the two techniques is calculated using the interpolation procedure, as indicated in black in figure (11) The root mean square error (RMSE) for this experiment was 0.0287. This term is calculated using Equations 3 [18].

$$\text{RMSE} = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(Measured_I - Interpolated_I)^2} \qquad (3)$$

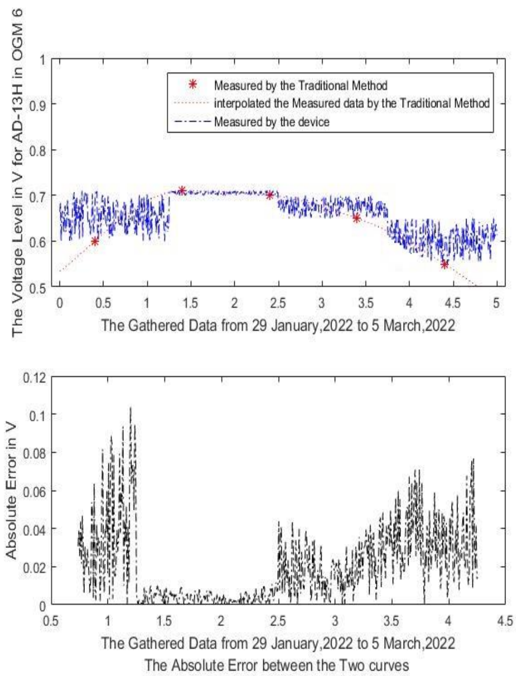

Fig. 11. The voltage level for a pipeline that calculated by using interpolation to fit the measured data by the worker once every week with the measured data by the proposed system every hour

The suggested system's key features include the ability to record a large amount of real-time data, which might aid in the production of useful statistical characteristics of CP status at different periods of the year. Furthermore, the combined web server allows multiple authorities to quickly access the recorded data using the designed GUI. Additionally, increasing the safety of the working team when traveling to the site and during the measurement procedure as well as lowering indirect costs are additional benefits. The system is also straightforward to maintain because it is built using low-cost hardware and a user-friendly platform. The linked LCD panel can also let the worker compare potential voltage readings.

Other advantages might include the utilization of commonly available, low-cost, and easily replaceable hardware. Low-power, high-precision, and anti-interference capabilities are all features of the proposed system., as well as capable of operating in a range of harsh weather situations. All the components are mounted in a plastic weather-proof box. Another interesting advantage is that the system could send a phone call or SMS when no data is available to send, which can indicate an instantaneous problem that may occur.

The system's main flaw is that it needs payment of a specific credit amount each time the credit validity expires. This problem can be prevented by selecting a suitable prepaid SIM package or lengthening the duration between sending data and receiving notifications.

Some over-voltage protection is also provided by the resistor values (R1 & R2) in the circuit design. To determine the precise values of the resistances (R1 and R2), as well as the 5V supply pins of the Arduino board, we must use a precision digital multimeter. We must pay attention to these values in writing the code.

3. CONCLUSION

A low-cost real-time monitoring system is what this study aims to develop and evaluate. Using this method, the cathodic protection effectiveness in the Al-Ahdab field in the Wasit province is evaluated. The developed system can record the instantaneous potential voltage level with a high rate of accuracy and collect real-time 24/7 data with less time, effort, and expense than existing traditional methodologies. The proposed system has been used for almost 3 months and has been sending data hourly. When we compare the system's reading, potential voltage, with the regular method—used every week by an inspector—we can determine the reliability of the system. It was discovered that a remarkable accuracy rate of up to 99.7 percent could be achieved. This makes it possible for local governments to regularly rely on the system to get a full profile of the transformer rectifier status in their region and to get alerts in the event of a breakdown.

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