IoT for Cathodic Protection System as Iron Concrete's Corrosion Protection

by A Referensi

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Abstract: **-** Iron concrete or reinforcement steel is steel used for reinforcement of concrete construction or known as reinforced concrete. Iron concrete can undergo a corrosion process caused by chemical or electrochemical reactions between reinforcement steel and its environment. One way to protect concrete from corrosion is cathodic protection. There are two types of cathodic protection, namely sacrificial anodes and impressed current cathodic protection (ICCP). ICCP is more commonly used for protection in reinforced concrete structures. In ICCP, negative current flows to the iron concrete and positive current flows to the anode. This is to protect the concrete from corrosion. In addition to the corrosion protection system, there is also a half-cell potential test to measure the chance of corrosion of the concrete. The project used IoT to monitor and control the ICCP. Measurements are made by reading the potential difference between the reference electrode and the iron concrete. The probability of corrosion can be determined by reading the corrosion probability table with ASTM C879-09 standard. The ICCP system in general still uses the manual method so that there are time efficiency problems in controlling the voltage and current for ICCP purposes, cannot schedule the provision of electric current and monitor it at any time, especially if the electric current flowing in the concrete is higher than the standard it should be. Based on the results of the tests carried out, the IoT system can regulate the power supply by setting the voltage and current and can schedule the power supply to provide electric current to the iron concrete and can provide notifications if the electric current flowing in the concrete is more than or less than ICCP standard.

Keywords: Internet of Things, Impressed Current Cathodic Protection, Half-Cell Potential Test

I. Introduction

Iron concrete or reinforcement steel is steel used for reinforcement of concrete construction or known as reinforced concrete. This reinforcement steel has a shape like a circle cross section which produced from billet raw material by hot rolling. (Kenny and Iwan Santoso, 2018). Iron concrete can experience corrosion process. Iron concrete corrosion is a chemical reaction or electro chemical between the reinforcement steel and the environment. Reinforcement steel corrosion process inside the concrete occur in a manner of carbonation, degradation by sulphate, chloride and leaching (Fahirah, 2007).

Cathodic Protection (CP) is one way to maintain as well as protecting the reinforcement steel in a iron concrete from corrosion. There are two kind of cathodic protection that could be used to protect the concrete from corrosion that is sacrificial anodes and impressed current cathodic protection (ICCP). However, ICCP commonly used for

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reinforced concrete protection (Yehia & Host, 2010). ICCP system conducted by connecting the metal which later be protected with an external anode and flowed by the direct current (DC) from a power supply so the metal become cathodic and the corrosion can be avoided (Bahekar & Grave, 2017).

ICCP system in general still using the manual way so there's a time efficiency problem in controlling the voltage and the current, can't schedule the electric current administration, and monitor at all times especially if the electric current that flows in a iron concrete is higher than the predetermined standard. People who responsible for the ICCP system must always arrive at the location to handle the problem. This thing causes the lack of time efficiency because people always need to arrive to the location to monitor the ICCP system in the iron concrete/reinforcement steel.

At the moment, technology has grown rapidly and more advanced. Human is using technology when doing any activity, so it has become a daily necessity. Even with technology, human can create many things like a parking lot that can shows how many empty lot there is. That matter can be done because of the sensor. Internet of Things has a concept which aim to broaden the benefit of connecting to internet continuously. Method that being used is the long-ranged automatic control.

ICCP system indeed very effective to protecting the iron concrete from corrosion, however in general IoT system which implemented in the ICCP doesn't equipped with the half-cell potential test method to measure the chance of corrosion, notification system when the electrical source goes out and current administration scheduling.

To answer the problem above, in this research, will be using Internet of Things system that can give & monitor the electrical current administration, ICCP system scheduling, looking for the chance of iron concrete corrosion and can give notification if the power supply and Raspberry Pi doesn't flowed by electricity.

Tools that used as a controller is the Raspberry Pi and the other DC source is the RD6006 power supply. Raspberry Pi is going to control the voltage from the RD6006 power supply that flowed to the iron concrete and to the anode. Voltage sensor used to measure the potential difference, therefore, can be known the corrosion level of the iron concrete..

II. LITERATURE REVIEW

A. *Corrosion in Iron concrete/ Reinforcement Steel*

Reinforcement steel corrosion is a chemical reaction or electro chemical between reinforcement steel with it's environtment. (Fahirah F., n.d.) as depicted on Fig 1 & 2.

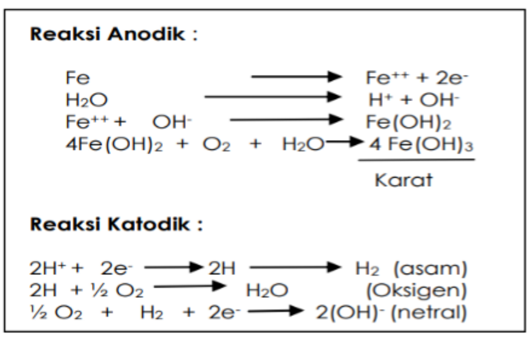

Figure 1 Anodic reaction and cathodic in a iron concrete
Source: SMARTek University Tadulako Journal

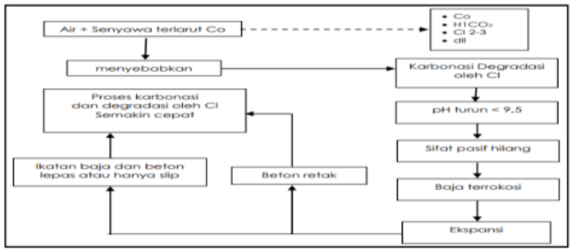

Figure 2 Flow diagram of the corrosion occurrence
Source: SMARTek University Tadulako Journal

B. Impressed Current Cathodic Protection

Siti Codijah (2008) explains Impressed Current Cathodic Protection as follows:

ICCP is one of the method from the cathodic protection system to minimize the corrosion occurrence. Current source in the counter current system comes from the outside, usually comes from DC and AC that equipped with current rectifier. Where the negative pole is connected to the anode. The current flows from the anode through electrolyte to the structure surface, then flows along the structure and comes back to the rectifier through the electric conductor. Because the structure receives the current from the electrolyte, then the structure becomes protected. The current output of the rectifier arranged to flows enough current so it could prevent the current corrosion that'll leaves the anode area to the protected structure. With the output current from this anode , then this anode consumed. Therefore, should be better to to use material that has lower consuming speed than magnesium, zinc, and alumunium commonly used to the system mentioned. Counter current system used to protect the big structure or the one that needs a bigger current protection and regarded less economical if using the sacrifice anode system. This system can be used to protect coated & uncoated structure, whether the coating is in a good condition or not. British Standart European Norm (BSEN) 12696 suggest the current density ICCP in the amount of 2-20 mA/m2. (Kennedy & Samuel Eric, 2019).

C. Half-Cell Potential Test

Nathaniel & Calvin (2020:9) explains Half Cell Potential Test as follows: Half cell potential test is a method used to measure the difference potential between reinforcement steel with the reference electrode. The value difference potential mentioned also used to measure the effectiveness from the cathodic protection that be given to the reinforcement steel. Corrosion measurement with the half cell potential test method conducted using ASTM C879-09 "Standart Test Method for Half Cell Potentials of Uncoated Reinforcing Stell in Concrete". Half-cell potential test conducted by connecting the positive pole with the reinforcement located in the concrete. Whereas the negative pole is connected to a reference electrode. After that, the reference node is pasted to the concrete surface to measure the potential value difference between the reinforcement against the reference electrode.

Potential value difference read by the voltage sensor shows the chance of corrosion of the reinforcement steel. The more positive the potential value difference that read by the voltage sensor, then the chance of corrosion gets smaller and vice versa. The magnitude of the potential difference can be used to know the effectiveness of the ICCP.

Nilai Pembacaan Potensial (mV) terhadap elektrode acuan (Tembaga Sulfat-CuSO4)	Peluang Terjadinya Korosi (%)
< -350	90
-200 s.d -350	50
> -200	10

Figure 3 Corrosion Occurrence Chance Classification

Source: Petra Digital Collection

Corrosion measurement that conducted based on the potential difference at the concrete against the reference electrode that placed at the concrete surface. Reference electrode that generally used as a reference is copper/ copper sulphate (Cu/CuSO4), calomel (Hg/Hg2Cl2), and silver / silver chloride (Ag/AgCl). The type difference of the reference electrode that used will resulted the value difference potential of the surface. Correction against the reading results which suitable with the reference electrode is needed during interpretation for the check up result. (Kennedy & Samuel Eric, 2019).

Konversi ke / Menggunakan	Copper/ Copper Sulfate ($Cu/CuSO_4$)	Silver/ Silver Chloride (Ag/AgCl)
Copper/Copper Sulfate ($Cu/CuSO_4$)		-54 mV
Silver/Silver Chloride (Ag/AgCl)	+54 mV	

Figure 4 Value difference conversion potential between Reference Electrode

III. SYSTEM DESIGN

System diagram (Fig. 5) that used in this research is the merger between microcontroller, power supply, voltage sensor, internet, and website that can monitor the administration of the electrical current in the ICCP system and can control the magnitude of the current and voltage that flows in the iron concrete/reinforcement steel.

Power supply that used is the RD6006 power supply that can directly controlled & long-ranged controlled using the internet through the provided software. Power supply mentioned can also be controlled with the microcontroller such as Raspberry Pi or Arduino through USB cable. Voltage sensor used to measure the voltage in the iron concrete and measure the corrosion potential in a iron concrete by connecting the iron concrete and reference electrode.

The system controlled by Raspberry Pi that can read the value of the voltage sensor and can control the RD6006 power supply through USB cable. Raspberry Pi controls the power supply on the user's order through website. Internet used to connect between the computer server with Raspberry Pi with the intention so the Raspberry Pi can send the data to the web server and web server can send the order to the Raspberry Pi. Therefore, all devices can be connected and the user can see the realtime data.

For the design of this research divided into two parts which is internet of things design for the impressed current cathodic protection system and web design so the user can control the voltage & current value, scheduling the electrical current administration, getting the notification if the raspberry pi or the electrical source don't flows and to monitor the voltage & current value that flows through the iron concrete / reinforcement steel.

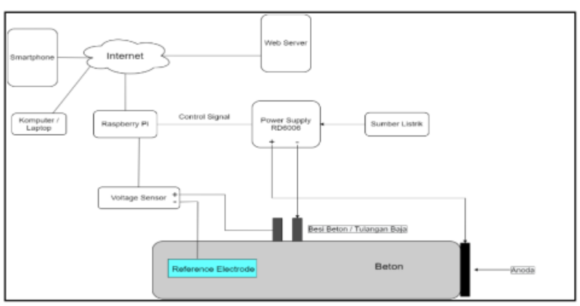

Figure 5 System Diagram

Figure 5 is the internet of things scheme that explains the overall system for the impressed current cathodic protection. User will using the internet of things feature through internet & website. Web server that'll be used is from Universitas Kristen Petra. Web server will be connected to the raspberry pi through internet network for data communication. Raspberry Pi will send the signal to the RD6006 power supply through USB cable.

In the ICCP system, the positive pole of the power supply is to the anode and the negative pole is connected to the rebar. For the half-cell potential test, use a voltage sensor. The positive pole is connected to the rebar and the negative pole is connected to the reference electrode. Data from the sensor will be sent to the raspberry pi, after which it will be entered into the database. The data in the database will be displayed to the user in the form of numbers and graphics for monitoring purposes.

IV. SYSTEM TESTING

After the text edit has been completed, the paper is ready for the template. Duplicate the template file by using the Save As command, and use the naming convention prescribed by your conference for the name of your paper. In this newly created file, highlight all of the contents and import your prepared text file. You are now ready to style your paper; use the scroll down window on the left of the MS Word Formatting toolbar.

A. Monitoring and Controlling The Power Supply

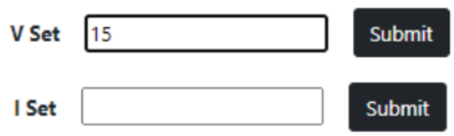

Fig. 6 Controlling V Set

Figure 6 is a v set charging value to set the value of the v set in the RD6006 power supply

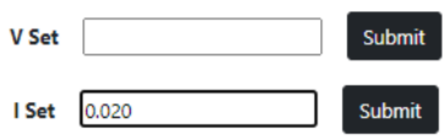

Fig. 7 Managing I Set

Figure 7 is a i set charging value to set the value of the i set in the RD6006 power supply

Fig. 8 V set and I set has been successfully set

Figure 8 shows that the power supply succeed to be set and the web system can shows the data of the power supply.

Fig. 9 V Out and I Out chart

Figure 9 shows the chart that resulted from the voltage & current data that went out from the power supply to the iron concrete and the anode.

Fig. 10 Half-Cell Potential Test

Voltage sensor read the potential value difference between the iron concrete and the probe that has been filled with the copper sulphate and distilled water.

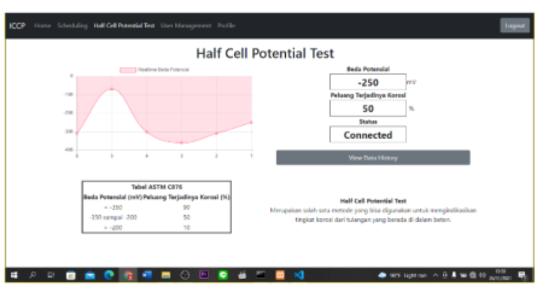

Fig. 11 Data reading of the Half-Cell Potential Test between Iron concrete and the reference electrode

In this testing conducted the reading of the potential value difference between the iron concrete and reference electrode using the voltage sensor.

Table 1 Voltage sensor reading

Minute	Average value of the Voltage Sensor reading (mV)	Average value of the Multimeter reading (mV)	Difference (mV)
1	-212.9	-237.5	24.6
2	-219.4	-237.2	17.8
3	-198.7	-236.8	38.1
4	-235.1	-236.4	1.3
5	-208.9	-237.3	28.4
6	-212.9	-237.2	24.3
7	-204.6	-237.5	32.9
8	-226.6	-238,1	11.5
9	-236.6	-236,9	0.3
10	-205.8	-237,3	31.5
Average difference between the voltage sensor & multimeter reading			21.07

V. CONCLUSION

From the result of this system testing can be pulled some conclusion as follows:

1) System can arrange Voltage set and I (Current) set in the power supply according to the user's request.

2) System can schedule the activation & deactivation of the power output in the power supply

3) System can gives notification if the power supply didn't connected (turned off)

4) System can gives notification if the output current to the iron concrete didn't suitable to the ICCP standard

5) System can shows, add, edit, and delete the user's data in accordance of user's position / status

6) System can read the potential value difference between iron concrete and reference electrode and can classify the potential corrosion in the iron concrete with ASTM C879-09 standard.

7) System can gives notification if there's a change in the value of the potential corrosion of the iron concrete.

8) Average difference reading between the voltage sensor and multimeter is 21.07 mV and the reading from the voltage sensor is less stable than the reading from the multimeter.

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