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Monitoring and Control System For Mesh Type Grounding Resistance in Medium Voltage Portal Substations

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***Abstract*—Grounding is essential for the safety of people and electrical equipment. in general, the grounding system is only buried without any grounding resistance control system. Grounding resistance can change slightly according to the season, because during the rainy season the soil becomes moist, and vice versa, during the dry season the soil conditions become dry and cause an increase in grounding resistance. In this research, a device is designed that can monitor and control grounding resistance automatically, by injecting water into the grounding location. The control used is Hysteresis ON/OFF type. The device is designed with the specifications of resistance measuring area 0.1 - 500 W, and effective error < 1%. The resistance measurement method uses the 3-pole fall of potential method. The constant current source used is 10 sin ωt (mA) with a frequency of 128 Hz. The setpoint can be set to 3 - 500 W, with a hysteresis of ± 0.5 W. The data storage speed can be set to 1 - 60 data per minute and stored as a text file (DATALOG.txt). This tool was developed in the LabVIEW environment. The constant current source uses NI-9174 and NI-9265 cDAQ. The controller uses NI MyRIO-1900. As a result of realization and test, the device functions and can significantly control the grounding resistance with an effective resistance measurement error of ± 0.697%. The grounding resistance behavior can be monitored in the form of numerical and graphical data by time, via wireless on the host computer and client.**

Keywords*—control, grounding resistance, monitoring

I. Introduction

Grounding systems are designed to ensure the safety of people and equipment in an electrical installation [1]. Residential buildings, offices, and factories must be equipped with a good grounding system. There are several factors that affect the grounding resistance value, including earth resistivity (Ohm-meter), soil moisture (%), and electrode material or type (such as rod, mesh, and others) [2]–[4] .

The performance of any type of electrode is strongly influenced by weather conditions such as rain or not which will affect soil moisture [5], [6]. During the rainy season, with high soil moisture, the resistance value decreases. Another case when the dry season is generally the resistance value will increase along with the low soil moisture value [7], [8].

Efforts to reduce the grounding resistance value aim to maintain the safety of humans and electrical equipment, especially when exposed to surge waves [9], [10]. There are several methods that have been developed, one of which is the reconfiguration of the grounding electrode arrangement [11]. Generally, in areas with high soil resistivity values, increasing the electrode dimensions cannot significantly reduce the grounding resistance value. So that a parallel electrode arrangement is needed to overcome problems related to the dimensions of the grounding electrode. Decreasing the grounding resistance value can also be done by modifying the shape of the grounding electrode. The research [12] investigated electrodes with rod, plate, ball and mesh shapes. While the article describes the addition of bentonite chemicals to the grounding electrode planting process [13].

Another method that has been applied is to add Dead Sea water and chemical elements to reduce grounding resistance [14]. Dead Sea water is added to the hole around the electrode at a distance of about 10 cm to avoid corrosion layer on the electrode. Practical measurements are shown to demonstrate the efficiency of the approach.

The novelty of this research is the control of the grounding resistance value by automating the injection of water in the ground around the mesh-type grounding electrode. The advantages offered by this method include: lower investment cost compared to regular chemical addition and easier implementation compared to reconfiguration of the earthing electrode array. Mesh-type electrodes were chosen due to lower electrode embedment compared to rod-type electrodes to obtain the same resistance value.

II. Research Method

A. Mesh type grounding

Grounding resistance can be affected by climate, ambient temperature, and weather around the location. Wet soil has low resistance compared to dry soil. The main factors affecting earthing resistance are, type of soil (e.g. clay, ash, sand, stone, loam); soil moisture, and soil temperature.

Mesh type grounding system is a grounding system with horizontally buried conductors in the form of nets with electrodes connected to each other, as shown in Fig.1.

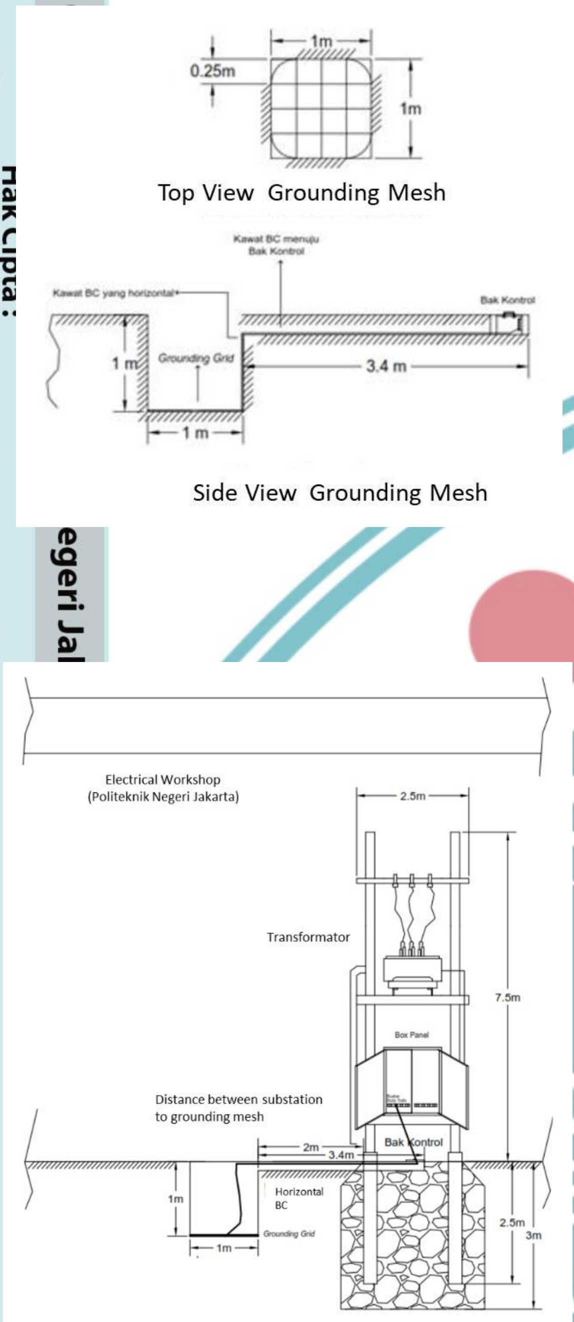

Fig. 1. Grounding Mesh Instalation for Substation

In this study, experimental research has been implemented in the grounding system of portal substation in Politeknik Negeri Jakarta. The grounding electrode is made by connecting a 10 mm diameter Bare conductor with mesh element dimensions of 25 cm x 25 cm each, and buried 1 m deep. A bentonite sand mixed with water was added to the grounding mesh. Water injection pipes are installed along with grounding electrode to control the grounding resistance value, especially during the dry season as shown in Fig.2.

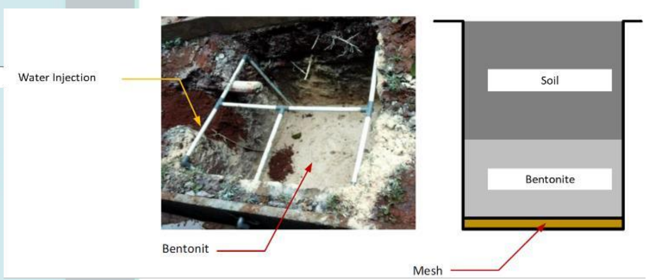

Fig. 2. Water injection instalation

The most common method used to measure grounding resistance is the Fall of Potential measurement technique. In this method three grounding contact points are used i.e., the measured grounding electrode (E), Voltage Probe (P) installed 5-10 meters from the grounding point, Current Probe (C) placed 10-20 meters from the grounding point, and, as shown in Fig.3. The formula for calculating mesh-type grounding resistance is shown.

$$Rm = \rho\left[\frac{1}{L_c} + \frac{1}{\sqrt{20A}}\left(1 + \frac{1}{1+h\sqrt{\frac{20}{A}}}\right)\right] \quad (1)$$

ρ : average grounding resistivity (ohm-m)
Rm : mesh grounding resistance (ohm)
Lc : total length of Mesh conductor (m)
A : Mesh Area (m^2)
h : depth of grounding electrode (m)

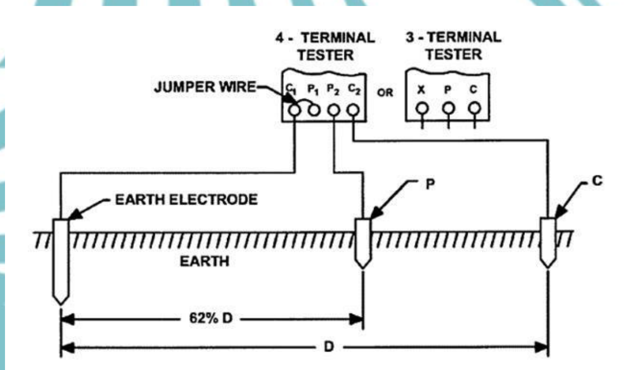

Fig. 3. 3 pole fall of potential Method

The constant current source injected into electrode C is I_{ext}=10 sin 804t mA. The calculation of grounding resistance as in.

$$Rm = \frac{V_{pe}}{I_{eks}} \quad (2)$$

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R_m : mesh grounding resistance (ohm) V_{pe} : leakage ground voltage (mV)

I_{ext} : excitation current (mA)

B. Hardware Configuration

A constant ac current source of 10 sin ωt mA with a frequency of 128 Hz was injected from electrodes E to C. The system specifications were designed as per Table 1.

TABLE I. COMPONENT SPESIFICATION

Parameter	Symbol	Value	Units
Excitation Current	Iext	10 sin ωt	mA
Frequency of I_{ext}	f	128	Hz
Resistance Measurement Range	Rg	0.1 to 560	Ω
Precision	U	1	*Digit of precision*
Hysteresis	H	± 0,5	Ω
Data Acquisition	NI 9174, NI 9265, NI MyRIO 1900		

In this research, the developed tool is laboratory scale. For commercial purposes the controller can be made from microcontroller, therefore the product can compete in the

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market, economically. The design consists of data acquisition design (hardware & software), grounding resistance measurement application program, and grounding sample testing. The system architecture is shown in Fig.4.

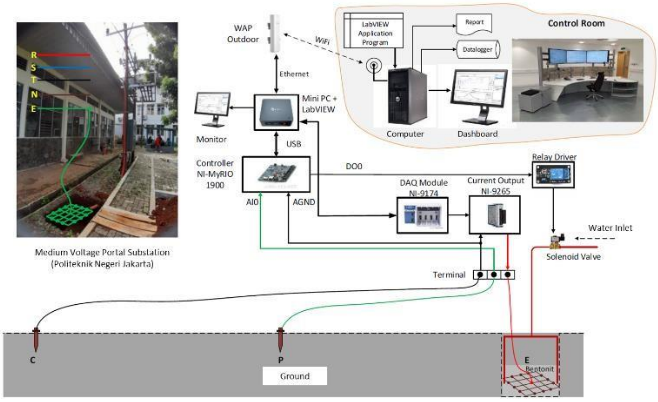

Fig. 4. System Architecture

The control hysteresis is designed to ±0.5W from the set-point value. For example, for a set-point value of 4W, when the earthing resistance is 4.6 W, the relay will be ON, the solenoid valve opens, and water enters the earthing ground so that the resistance drops. When the earthing resistance reaches 3.4 W, the relay is OFF, the valve closes, and the water stops flowing. This cycle continues as long as the appliance is operating, as shown in Fig. 5.

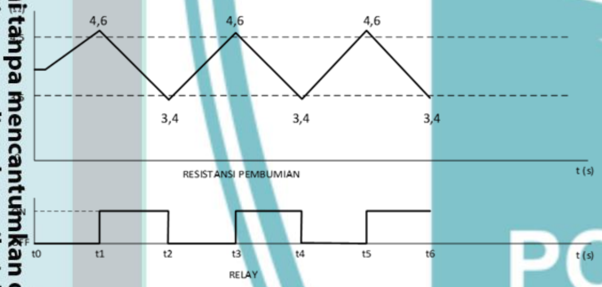

Fig. 5. Control mechanism (H=±0.5ohm, SP=4 ohm)

Excitation current and voltage measurement data need to be processed into grounding resistance (ohms). Information about measurement time, excitation current, frequency, and ground resistance is continuously stored in the Datalogger file in the form of a text file (Datalog.txt). Thus, an application program is required. The software used to create the application program is LabVIEW 2015. Program specification is shown in Table 2.

TABLE II. PROGRAM SPESIFICATION

Parameter	Symbol	Data Type	Remarks
Dashboard information			
Time	-	String	dd/mm/yy/hh/mm/ss
Excitation Current (mA)	I_{ext}	DBL	3 digits of precision
Frequency (Hz)	F	DBL	2 digits of precision
Eff. Voltage at C-P (V)	V_{cp}	DBL	2 digits of precision
Grounding Resistance (Ω)	R_G	DBL	2 digits of precision
Graph R_{pe} = f(t)	-	Graph	1 sample / second
Data Logger Information			
1st column	Time	String	hh/mm/ss
2nd column	R_G	DBL	1 digit of precision
3rd column	Valve	Boolean	TRUE / FALSE

III. Result and Discussion

Validation of the control system was performed at the Electrical Engineering Laboratory, Politeknik Negeri Jakarta. Grounding sample testing was held continuously for 8 days, with a measurement sampling rate of 1 sample per minute. The target of this test is to identify the control system performance, including the constant current source, control, monitoring, and data storage sub-sections.

Testing the capability of the resistance measuring area using a constant resistance: fixed metal-film resistors of 0.1 ohm, 10 ohm, 100 ohm, and 560 ohm ± 1% (1/2W), which were attached to the CE terminal. The test data is shown in Table 3, with the frequency measured by the Tektronix 1002B oscilloscope of 126.05 Hz ± 1%. From the analysis conducted, the following conclusions can be drawn:

$$I_{peak} = 9{,}966 \text{ mA} \pm 0{,}697\%;\ R = 0{,}1 – 560 \text{ ohm}$$

TABLE III. RESISTANCE MEASUREMENT RANGE MEASUREMENT TEST

No	R (Ω)	V_{peak} (mV)	I_{peak} (mA)
1	0.1	0.99	9.900
2	10	100.83	10.083
3	100	994.18	9.942
4	560	5566.29	9.940

Valve control testing aims to ensure that it performs as designed. The test procedure is as per the flowchart Fig.6. Fig. 7 shows the test display on the dashboard. The control type is ON-OFF Hysterisis. Set-point, SP, is set at 4 ohms. Hysterisis is designed to be ±0.5 ohm. R_G is simulated using a triangular shape, with a minimum value of 3.4 ohms and a maximum of 4.6 ohms. When the valve is ON the water flows into the earthing ground, while if the valve is OFF the water stops flowing. Based on Fig.7, for Rg(SP) 4 ohms, the control valve functions as designed:
Valve OFF when R_G rises from 3.5 W to 4.5 ohms
Valve ON so R_G drops from 4.5 W to 3.5 ohms.

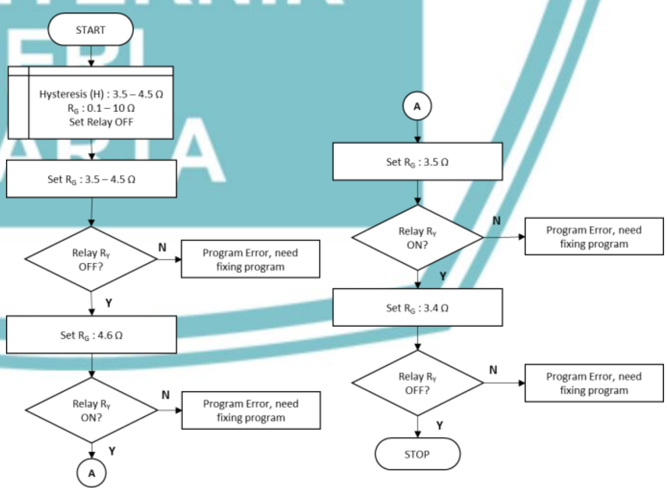

Fig. 6. Flowchart of Control System Testing

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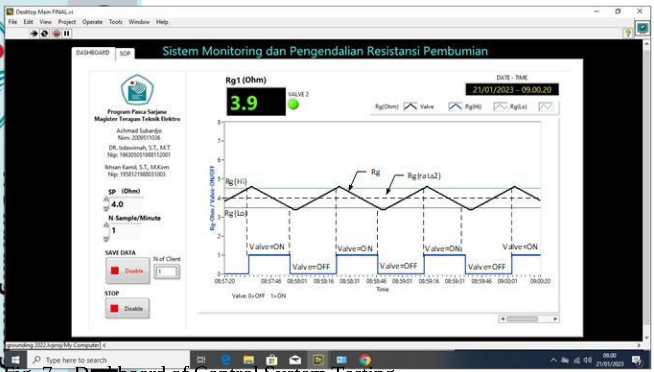

Fig. 7. Dashboard of Control System Testing

In the grounding sample test, the test result data in tabular form can be accessed in the DATALOG.xls file. While in the form of graphs shown in Fig. 8. Continuous testing with data stored in Datalogger as many as N = 12,379 samples for 8 days. Based on Fig.8 the grounding resistance measurement results: R_G (min): 1.8 Ω, R_G (max): 4.9 Ω, R_G (average): 2.6 Ω.

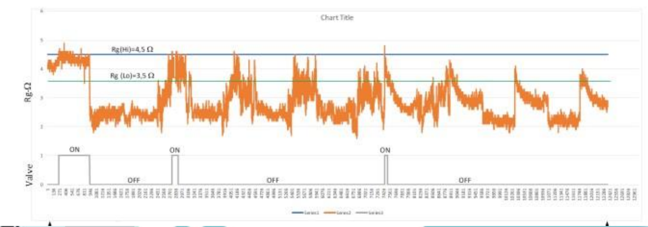

Fig. 8. Grounding Resistance Measurement Test

It can be observed that there is an increase in performance compared to no control, namely when the resistance $R_G > 4.5$ Ω, the valve is ON, so that water enters the grounding location which causes R_G to drop. When $R_G < 3.5$ Ω, the valve is OFF, so the water stops flowing. This condition lasts until R_G rises again and the valve turns ON again when $R_G > 4.5$ Ω. This cycle continues to repeat as long as the tool is on. It is validly stated that the system functions according to design.

IV. Conclusion

Based on the test data and analysis conducted, it can be concluded that the device functions according to the design, which can measure, monitor, and store data on the results of continuous earthing resistance measurements using the 3 pole fall of potential method. The performance of the constant current source of this tool is 9.966 mA (peak) with an effective error of ± 0.697% for the measuring area of 0.1 - 560 Ω, thus meeting the design requirements. The design frequency is 128 Hz ≤ ± 1%, measured 126.05 Hz ± 1%, resulting in an error of -1.95 Hz. Sample test results, mesh type earthing installed in the Electrical Engineering Lab has good quality, with resistance value < 5 Ω. Controlling grounding resistance using groundwater injection from this tool is very significant to maintain the desired range of grounding resistance values, so it is feasible to be used as an alternative choice, especially during the dry season. If the results of this research will be further developed into a prototype, then the author suggests focusing on the current acquisition and timing, so that the frequency is exactly 128 Hz ± 1%. In addition, in order to compete in the market the system can be developed in a microcontroller platform. dari sisi nilai ekonomi, pemilihan platform teknologi mikrokontroler untuk kontroler dan akuisisi data bisa dijadikan alternatif pilihan.

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