

# Design and Development of Data Acquisition for Leakage Current at Electrical Tracking Test

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**Abstract**—In electrical power systems, the insulator is the material that determines whether the electrical energy can be supplied or delivered to a place of excellent quality and does not harm the human and the environment around such high voltage electrical conductor devices. In testing leakage current in the laboratory, current and voltage changes in input and current changes and output voltages change very quickly, making it difficult to detect with the usual measuring device. For that required software to simulate the test.

One method used to test the insulation resistance of the insulator material is the Inclined Plane Tracking (IPT) method. That is a method used to represent the leakage current on the surface of an insulation. The insulation and leakage resistance simulation in this test is performed by Multisim 14 software by simulating the insulation resistance with a potentiometer that changes resistance when a leak current occurs in the test. The resistance is increased step by step to know the parameters of current and voltage at the time of testing. In this simulation testing is done in stages, so it can be known Source Voltage, Input Voltage, Input Current, Leakage Current and Output Voltage.

Simulation using Multisim 14 software can represent insulation resistance, leakage current and output voltage that can be used to obtain replacement resistance ( $R_p$ ), leakage current ( $I_{out}$ ), output voltage ( $V_{out}$ ), alternating current ( $I_{loss}$ ) and replacement voltage ( $V_{loss}$ ). Simulation Software Proteus can simulate data received in the form of analog into digital data. Further processed according to the data required.

**Keywords**— *Inclined Plane Tracking (IPT), Leakage Current, Data Acquisition*

## I. INTRODUCTION

Electrical energy is a necessity that can be equated with basic needs. Electrical energy has penetrated almost all the wheels of human life. Business World, Industrial World, Educational Institutions and Households are the main users of electrical energy. Without electrical energy, the production process at the factory could not run. The business world and the industrial world as well as the offices will be overwhelmed [1].

The advancement of microcontroller system technology enables the creation of a tool that can translate the quantities of electricity it receives, into data that can be processed and displayed in accordance with the wishes of programmers using the software, whether appearing directly on PC computers,

laptops or through Liquid Crystal Display (LCD), dot matrix, and others [2].

The presence of leakage current is an initial event that can lead to flashover on the surface of insulation material that eventually lead to failure. Therefore, it is necessary to measure and analyze the leakage current for different surface roughness to know the effect of surface roughness on the surface performance of the material in the polluted area. One method of measuring leakage current to represent the situation in the field is the Inclined-Plane Tracking (IPT) method set out in International Electrotechnical Commission (IEC) 587: 1986. The waveform, magnitude and THD of leakage current or Leakage Current (LC) flowing from a voltage source to the ground side can provide useful information for the diagnosis and illustrate the state of contaminated insulation material [3].

## II. BASIC THEORY

### A. Incline-Plane Tracking Method

Abdul Syakur, Hamzah Berahim, Tumiran, Rochmadi, 2013 examine: Testing is done using high voltage AC 50 Hz. The 3.5 kV test voltage is applied to the top electrode while the contaminants flow along the bottom side of the sample. In this test, method 1: used constant tracking voltage, and the time to start tracking is also determined. High voltage AC 50 Hz with a 3.5 kV voltage is generated from a 5 kVA test transformer. The 22 k $\Omega$  resistor is used to hold the current flowing on the surface of the material in case of discharge. The peristaltic pump is used to drain the contaminant solution. The schematic diagram of the test is shown in Fig. 1.

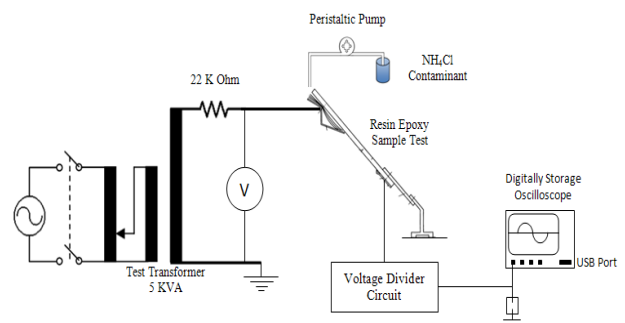


Fig. 1. Schematic diagram for testing

Electrical Tracking of epoxy resins coupled with silicone rubbers on various contaminants is investigated by analyzing leakage current and formation of Electrical Tracking with slanted tracker test method. The experimental results show that contaminants significantly affect the Electrical Tracking process. The effect of this contaminant can be analyzed by using current discharge parameters, ie discharge time and surface condition of the material. Based on the experimental results, found industrial contamination that occurs in Leak surface current leakage is 327.6 mA. It was also found that coastal contaminants (1420  $\mu\text{S} / \text{cm}$ ) showed the most severe damage to the surface of the test sample. Therefore special handling is required to test the samples based on the conditions of coastal contaminants and  $\text{NH}_4\text{Cl}$ , so that the performance of the material can be improved, especially on the discharge of electricity [4].

Rohmat Nugroho, Abdul Syakur, Hermawan, 2009 examines: HDPE samples such as Fig. 2 have dimensions of 120 mm in length, 50 mm in width and 6 mm thick (IEC 587: 1984).

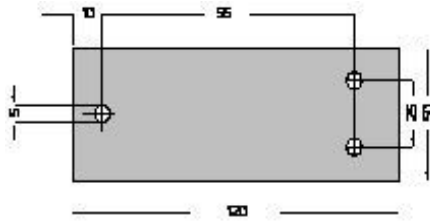


Fig. 2. Dimension of material used

The electrodes used are made of stainless with a thickness of 0.5 mm in accordance with IEC 587: 1984 standard. Can be seen in Fig.3

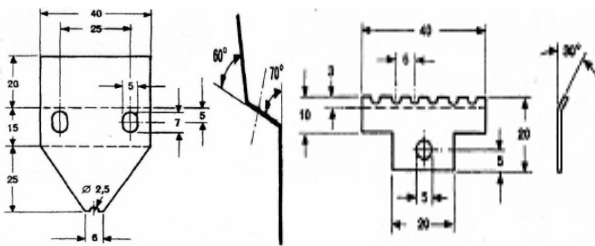


Fig. 3. Up and bottom electrode for testing

Installation of test and slope material, shown as Fig.4.

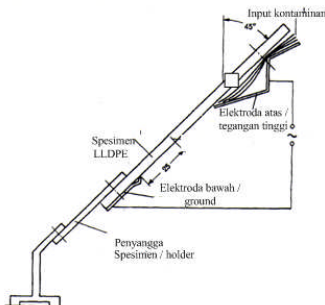


Fig. 4. Installation of electrode on the material

The conclusions can be obtained include :

1. The leakage current waveform that appears in the measurement is strongly influenced by the surface roughness conditions of the material and environmental conditions in the form of intensity of pollutant flow.
2. As a function of time the magnitude of the leak currents of the pulse shapes tends to oscillate while for the leaked current the distorted sine form tends to be constant [3].

### B. Electrical Tracking and Leakage Current

Based on several analysis of isolator performance that has been done, found that the most severe damage to the isolator structure is the result of Electrical Tracking on the surface of the insulator. The process of Electrical Tracking is a typical phenomenon that occurs on the surface of the insulator due to the release of spots that arise on the surface induced. All are the result of surface wetting and the level of contamination. Once the tracking starts, the debit will be accelerated further and the path grows. Also so tracking happens. The insulation surface properties will be reduced and can not be recovered. Electrical Tracking on the surface of the material sample is caused by heating on the surface of the material in the event of a leakage current. The leakage current on the surface of the material occurs due to the contaminants that flow on the surface material. Different contaminants show various forms of Electrical Tracking. When the flashover of the voltage of air critical ( $V_c$ ) is reached, the carbonization process occurs and the evaporation of water occurs. A permanent carbonization pathway is formed. This process is continuous and cumulative and eventually there is insulation damage. Surface discharge also occurs. Erosion on the surface of the sample is followed by the formation of filament pattern in which the resulting Electrical Tracking [4].

### C. Surface Discharge

When the condition is dry, the surface of the insulator has a high impedance and very small capacitive leakage current in the form of discharge occurs on the surface. When the surface conditions of the wet insulator cause the flow of electrolyte solution due to contaminants on the surface of the insulator. The resistive leakage current will flow on the conductive layer along the surface of the insulator. This leakage current is not uniform because the conduction layer is not evenly distributed on the surface of the insulator. At this stage, the surface equivalent circuit of the insulator is represented by a resistance  $R_w$ . Flowing of currents with considerable density causes increased temperature. Heat generated from leakage current can cause dryband to form. Equivalent circuit after dryband is represented by parallel resistor impedance ( $R_d$ ) and capacitor ( $C_d$ ). [3].

The leakage current (LC), which is driven by the source voltage and collected at the tip of the ground isolator, provides a lot of useful information about the contamination of the contaminated state. The LC analysis is investigated based on the LC waveform and the frequency spectrum characteristics.

It was found that the magnitude and content of LC harmonics, and discharge duration differ significantly during the test section where no visible degradation, as compared with its values at visible degradation onset. These findings can be used to detect early failure of high-voltage devices for outdoor insulation. When the insulator is wet, the resistive LC current flows, which is generally a lot of orders of magnitude higher than the capacitive current in the case of a dry insulator. LC produces a non-uniform heating of the contamination layer due to nonuniform resistivity of the conduction film. This eventually causes the dried band to form on the narrow part of the isolator where the LC surface density is highest. LC resistive insulator is then reduced or may even be lost due to high resistance of dry tape. Distribution of tension along the surface of contaminated wet insulators is not very uniform when dry bands are formed in series. Since almost all voltages applied in isolators appear in high resistive dry bands, this can result in air damage over dry bands. LCs along the isolator can be detected only when the power frequency energy voltage exceeds a certain positive or negative voltage threshold. LC becomes nonzero and follows the waveform of the power frequency wave as the energy voltage is above the threshold value. The release of electricity will cause high thermal spots developed on the root of the arc and thus lead to gradual erosion of the surface of the insulator. This repetitive discharge burns the surface of the insulator to create a carbonated area, and is called "surface tracking". Transition LC waveform, until flashover occurs grouped into different stages and there is a threshold where the flashover occurrence can be predicted. The possibility of flashover becoming higher when the quantity and harmonic content of the component stand out over a certain level [5].

#### D. Multisim

Multisim is an application software that serves to draw and simulate the behavior of electronic circuits both analog and digital. This software is developed by National Instrument Company engaged in the production of electronic components. Multisim is the development of electronic circuit simulation software previously known as Electronics Workbench. With this Multisim software, we can model the properties of analog and digital circuit parameters.

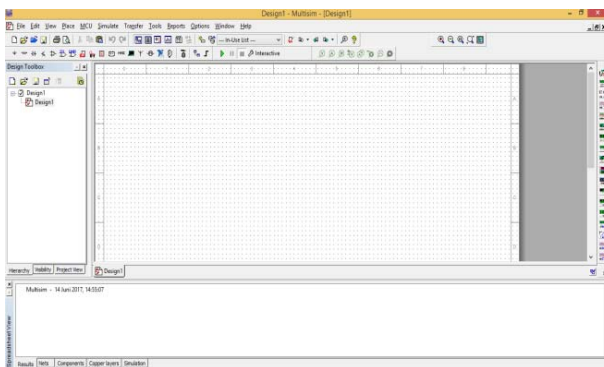


Fig. 5. Display Multisim Form

Multisim's ability is able to model various circuit designs, test a circuit with possible components, check the properties of the whole circuit by performing AC/DC or transient analysis. With the completeness of a number of existing components we can make a combination of almost unlimited circuit design [6]. Display the multisim form as shown in Fig.5.

#### E. Proteus Software

Proteus is a combination of ISIS and ARES programs. By merging these two programs the electronic circuit schematic can be designed and simulated and made into a PCB layout. ISIS stands for Intelligent Schematic Input System and is one of the integrated simulation programs with Proteus and is the main program. ISIS is designed as a medium for drawing electronic circuit schematics in accordance with international standards. In ISIS also included a program of ProSpice which is useful to simulate circuit schematic, so ISIS can be an interactive circuit simulator program. ProSpice is designed on the basis of the SPICE3F5 programming language standard, so it can simulate a mix of interactive analog and digital components known as Interactive Mixed Mode Circuit Simulator. ISIS can simulate various types of microprocessors and microcontrollers, including the AVR family microcontroller. It is expected that by using this simulation program, the design of microcontroller based circuit can be more easily done and reduce production cost and save time. ISIS comes with a compiler program, so it can compile source code files such as Assembly into Hex files so that later can be used by the actual microcontroller [7].

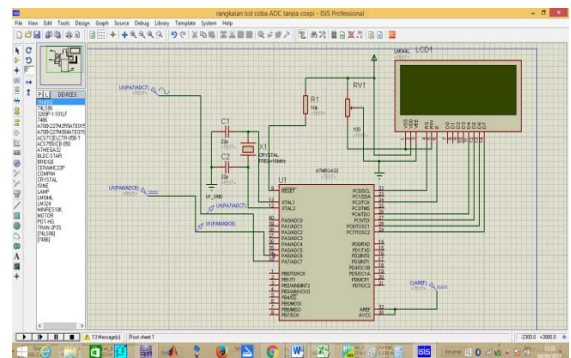


Fig. 6. Display of Proteus Form

### III. SIMULATION METHODOLOGY

#### A. Multisim Simulation

The method used to simulate the LC is to construct a circuit like Figure IV.1. Install a high voltage test source ie 3.5 kV<sub>rms</sub>, 22 kΩ front resistance. Ampere Meter and Volt Meter on the input side, 10Kohm Potentiometer is installed to present the change of resistance in insulation. Ampere Meter and Volt Meter on the output side. Added several resistors are arranged in series and parallel to secure the voltage to be inserted into the oscilloscope on the output side.

## IV. RESULTS AND DISCUSSION

### A. Simulation Measurement of Resistivity

Multisim provides source voltage in the form of peak voltage (Vpk). In the IPT testing performed a test with a voltage rms 3500 Volts. So to get the voltage Vpk done calculation as follows:

$$V_{pk} = V_{rms} \times \sqrt{2}$$

$$V_{pk} = 3500 \times 1.4142$$

$$V_{pk} = 4950 \text{ Vpk}$$

This Vpk voltage is input to the AC source voltage value for testing. The selection of potentiometers with 10 Mega Ohm prisoners to present insulation resistance was based on the analysis of experiments in the laboratory, that when no contaminant stream has caused leakage current, the Test Voltage (input) is 3514.8 Volt and the input Measured is 0.31 mA (0.00031 Ampere) as shown in Fig. 10



Fig. 10. Measurement of voltage and input current

Then a calculation can be performed to determine the approximate value of the resistance on the material being tested or the insulation resistance tested for modeling in multisim is as follows:

$$R = \frac{V}{I} \quad R = \frac{3514.8}{0.00031} \quad R = 11.338.064 \text{ Ohm}$$

Then chosen is close to the R with 10 Mega Ohm.

In the test simulation, when the multisim program is in Run, gradually the resistance in insulation is gradually reduced by 5%. It starts with a 100% test of prisoners.

TABLE I. RT 5% PER STEP TO GET A REPLACEMENT

No	Rtest	Vin	Iin	Rp
	%	Volt	Ampere	Ohm
1	100%	0,159	0,15900000	10.000.000,00
2	95%	3470	0,001388000	9.500.000,00
3	90%	3469	0,001402000	9.000.000,00
4	85%	3468	0,001445000	8.500.000,00
5	80%	3467	0,001524000	8.000.000,00
6	75%	3464	0,001649000	7.500.000,00
7	70%	3459	0,001845000	7.000.000,00
8	65%	3453	0,002158000	6.500.000,00
9	60%	3441	0,002699000	6.000.000,00
10	55%	3417	0,003796000	5.500.000,00
11	50%	3345	0,007042000	5.000.000,00

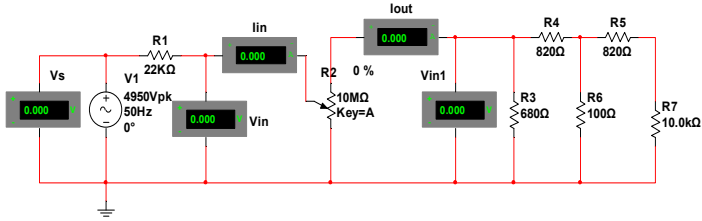


Fig. 7. LC test simulation circuit

Multisim provides many tools for measuring, the LC measurement method is used several tools include: 1 unit oscilloscope to see the input voltage and input current, Volt Meter to see the source voltage and input voltage on the insulation material installed before the Resistance. 1 ampere meter unit is needed to see the input current coming into insulation. After insulation resistance is installed 1 unit Amper meter to detect leakage current (LC) and 1 unit voltmeter to see the leakage voltage. 1 oscilloscope unit is required to see the LC wave and the leakage voltage that will be fed to the microcontroller for later on when data acquisition using microcontroller. The full range of simulated leakage current measurements can be seen in Fig. 8

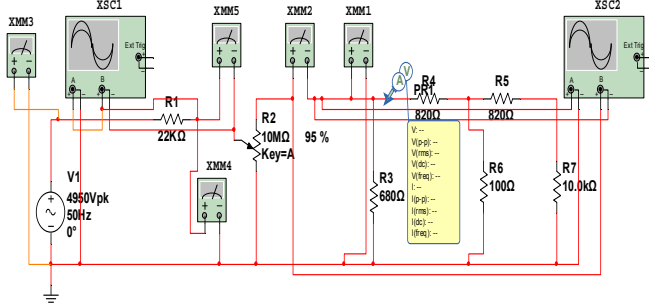


Fig. 8. Complete circuit of LC test of insulation

### B. Proteus Simulation

The method to simulate the output voltage and leakage current obtained in the multisim simulation, can be done by inputting the voltage and current in the microcontroller circuit created by using proteus software, as in Figure IV.3.

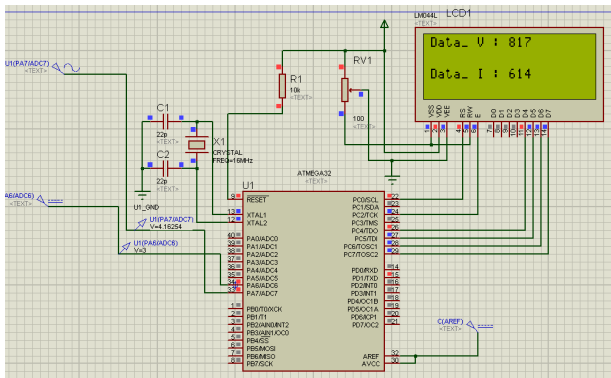
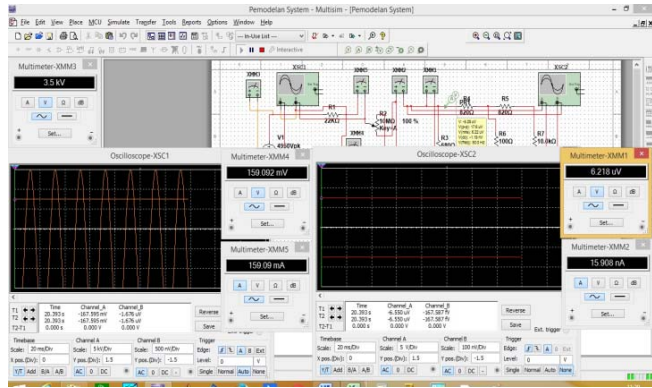
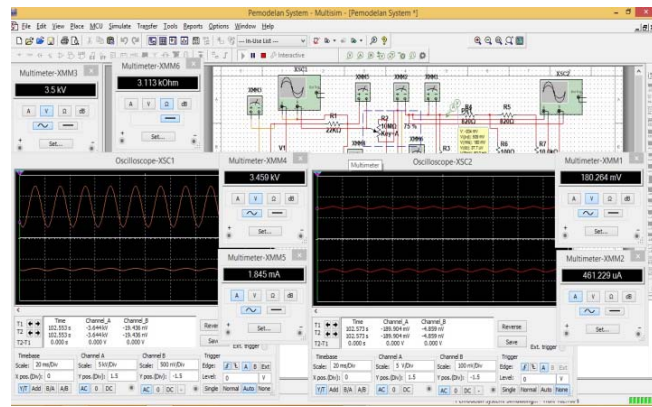


Fig. 9. Complete circuit data acquisition using Proteus

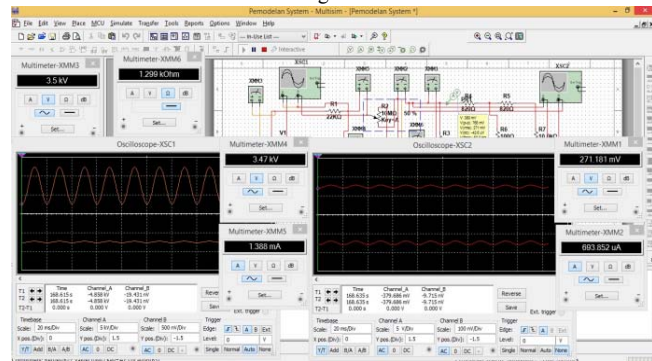
From table I it can be seen that, at the time of the insulation resistance tested 10 Mega Ohm, The voltage from the input side is considered short circuit, because the current is small and the resistance is large. When insulation resistance begins to shrink due to the contaminants flowing from phase to ground, the voltage detected decreases, the current becomes larger. The image of the simulation result on multisim is shown in Fig.11



a. Testing Simulation R 100%



b. Testing Simulation R 75%



c. Testing Simulation R 50%

Fig. 11. Simulation results with insulation (a) 100%, (b) 75% and (c) 50%

### B. Simulation Measurement of Leakage Current

This leakage current measurement simulation can represent the ratio between the input current and the output current and the lost current which will be the ratio between the

input and output currents in the experimental variation of 100% to 50% resistance. As shown in Table II

TABLE II. INPUT AND OUTPUT CURRENT DATA

No	Rtest	Iin	Iout (Ileak)	I loss
	%	Ampere	Ampere	Ampere
1	100%	0,159000	0,0000000159	0,1589999841
2	95%	0,001388	0,0003510500	0,0010369500
3	90%	0,001402	0,0003796000	0,0010224000
4	85%	0,001445	0,0004047690	0,0010402310
5	80%	0,001524	0,0004315530	0,0010924470
6	75%	0,001649	0,0004612390	0,0011877610
7	70%	0,001845	0,0004947980	0,0013502020
8	65%	0,002158	0,0005332820	0,0016247180
9	60%	0,002699	0,0005780060	0,0021209940
10	55%	0,003796	0,0006307240	0,0031652760
11	50%	0,007042	0,0006938520	-0,0006938520

From Table II a graph of the relationship between the input current and the output current, when testing the maximum resistance, the input current has not flowing. As the insulation resistance begins to shrink, then the output current or leakage current begins to flow. And this current will be fed to the microcontroller for further analysis. The graph is shown in Fig.12.

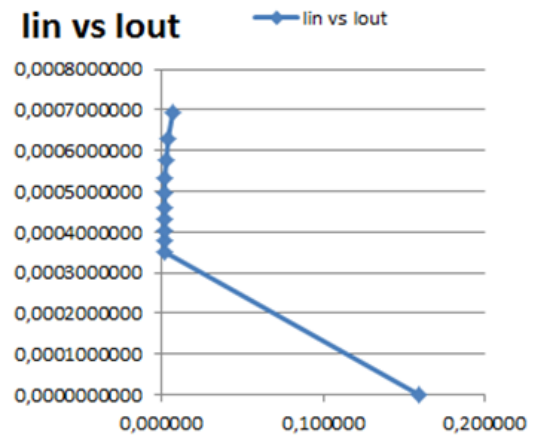


Fig. 12. Relationship input current between output current

The lost current can be searched with the following formula:  $I_{losses} = I_{input} - I_{output} (I_{leak})$ . Example calculation of current loss for resistance of 75%, known  $I_{input} = 0.001649$  A and  $I_{output} (I_{leak}) = 0.0004612390$ , then:  
 $I_{losses} = 0,001649 - 0,0004612390$   
 $I_{losses} = 0,0011877610$  Amper

### C. Simulation of Data Acquisition using Proteus

When the results of  $V_{out}$  and  $I_{out}$  (Ileak) are simulated with proteus, for example we take one of the experiments at  $R = 80\%$ , then we get the data:

$$V = 0.16866 \text{ Volt} = 168.66 \text{ milliVolt.}$$

$$I = 0.0004315530 \text{ (given } 100x \text{ reinforcement) then}$$

$$I = 0.004315530 = 43.15530 \text{ milliAmpere.}$$

The current 43.15530 is converted with a current sensor of  $1mV / 1mA$ , then the output voltage of the current sensor in milliVolt is  $V(I) = 43.15530 \times 1 = 43,16mV$ . Images and simulation results in ADC values can be seen in Fig.13.

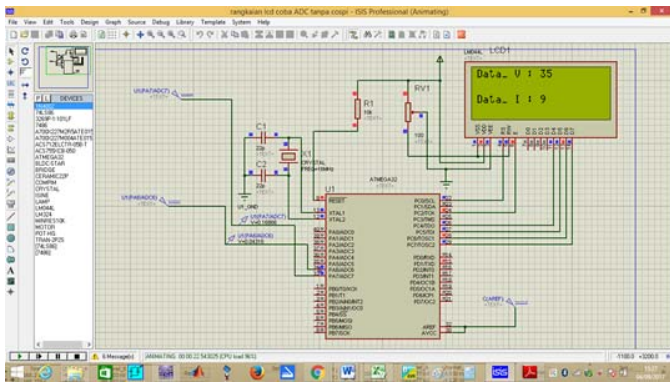


Fig. 13. Voltage and current value in decimal

Conversion to the voltage of the Decimal Data can be done in the following way:

Data Flow,  $Data_I = 9$ , ADC used 10 bits,  $V_{ref} = 5 \text{ Volt}$ , hence,

$$I = \text{Decimal Data} * (V_{ref} / 2^{10})$$

$$I = 9 * (5/1024)$$

$$I = 9 * 0.0048828125$$

$$I = 0.0439453125 \text{ A} = 43.95 \text{ mA}$$

Data Voltage:  $Data_V = 35$  ADC used 10 bits,  $V_{ref} = 5 \text{ Volt}$ , then,  $F_x = 3500/5 = 700$

$$V = V_{uji} - (\text{Decimal Data} * (V_{ref} / 2^{10}) * F_x)$$

$$V = 3500 - (35 * (5/1024) * 700)$$

$$V = 3500 - (35 * 0,0048828125 * 700)$$

$$V = 3500 - (0,1708984375 * 700)$$

$$V = 3500 - 119,62890625$$

$$V = 3380.37 \text{ Volts}$$

### V. CONCLUSION

From the simulation it can be concluded that the Resistance Insulation Value of the material under test can be determined, as the initial step can be simulated on multisim program. Leakage current and leakage voltage flow when there is contaminan causing leakage current and leakage voltage from phase to ground. The leakage current values and the measured leakage voltage can be used to further analyze the relationship between the leakage current and the leakage voltage with the insulating resistance of the material under test. The value of leakage current and leakage voltage can be further analyzed to determine the energy used when testing the electrical tracking of the insulating material. Simulation using Proteus can simulate data acquisition in electrical tracking test.

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