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Leakage Current Monitoring System for High Voltage Insulator using LabVIEW

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Abstract: This paper describes a leakage current monitoring system designed to analyse the efficacy of high-voltage insulators. Establishing monitoring parameters, constructing a graphical user interface (GUI) based on these parameters, and analysing the monitoring system are the objectives of the study. The system employs the LabVIEW methodology, which provides a customizable and dependable GUI solution. Data acquisition (DAQ) captures and processes pertinent insulator data for accurate monitoring of leakage current. The system is also equipped with overvoltage and overcurrent protection mechanisms. In the FKEE High Voltage Laboratory, the designed leakage current monitoring system is assessed. The system provides effective user input, data visualization, recording, and alerts. The numerical results demonstrate the accuracy and dependability of the system in identifying and measuring leakage current in high-voltage insulators.

Keywords: Leakage Current, Monitoring System, Labview, DAQ

1. Introduction

High-voltage insulators are essential components in the power industry. The performance of these components is highly dependent on environmental factors, which can affect insulation capabilities and thus cause flashovers. Because flashovers are extremely dangerous in any power system, it is critical to understand how environmental factors affect electrical insulators. The leakage current is the current that flows through the insulation of a conductor, or an insulator and it can cause damage to the equipment or cause power outages. The occurrence of the surface discharge phenomenon, as depicted in the waveform of leakage current, is correlated with the deposition of contaminants, the degradation of polymer insulators, and the progression towards flashover [1-3].

Apart from that, higher leakage current values might indicate poor performance of the insulator, potentially resulting in faults like insulator string flashover. The magnitude of insulator leakage current (LC) serves as a measure of its operational efficacy. This paper basically describes the leakage current

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monitoring approach to predict the performance of high voltage insulators in the transmission line or distribution system. A number of studies have proposed methods of measuring leakage current in high-voltage applications. There are techniques for measuring leakage current using data acquisition approaches connected through the glass insulator, in series with the device [4]. Also, using the current sensor as an analogue input to convert the signal transmitted through the DAQ device using Wireless Local Area Network (WLAN) for leakage current measurement [5].

1.1 Leakage Current Monitoring

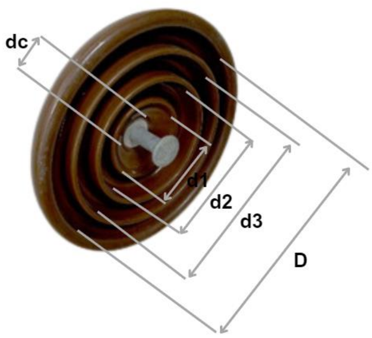
Insulators may fail due to discharges or flashovers. High voltage insulators in electrical transmission systems require a leakage current monitoring system to assess their efficacy. This system should be commercially viable and customised to monitor and record real-time leakage current. Problems such as surface contamination, moisture ingress, and ageing can be detected early by continuously monitoring leakage currents. The system should include real-time data logging, alerts for current thresholds, and user input. It should also record and capture leakage current data automatically for 24 hours, protecting against overvoltage for the data acquisition device using certain methods.

According to the datasheet provided by National Instrument [6], the DAQ device's analogue input limit is approximately 11V. Therefore, the protection criteria should be able to limit the input voltage within the specified range. There are a variety of methods that can be used to protect the DAQ device. A simple circuit can be designed consisting of a gas spark gap, ZnO Varistor, TVS, and resistor will effectively protect the system from overvoltage or overcurrent [7]. Besides, other alternatives exist to using the voltage divider principle to protect the DAQ device [8]. In the event of overvoltage circumstances, wherein the input voltage surpasses the permissible operational threshold, the voltage divider attenuates the voltage proportionally supplied to the DAQ apparatus.

2. Methodology

2.1 Test Samples

The insulator that has been proposed to be tested is porcelain type, as the material is widely used in Malaysia transmission lines. Besides, the paper [2] showed that electric porcelain insulators with good properties can be produced from available local raw materials in some developing countries using appropriate formulations. Porcelain insulators are mostly made from feldspar, quartz/silica, and kaolin. For this paper, the test samples will be single disks of porcelain insulators as shown in Figure 1 and the characteristics of the sample in Table 1.



(a) **(b)**

Figure 1: Porcelain insulator: (a) Insulator dimension (b) Insulator pin

Table 1: Porcelain Insulator Specification

Parameter	Symbol	Length (cm)
Creepage distance	L	32
Insulator height	H	14.6
Insulator diameter	D	25.5
Rib diameter	d_1	19.5
	d_2	14.5
	d_3	10.5
	d_c	5

2.2 LabVIEW Monitoring System

To effectively analyse and visualise the recorded leakage current and voltage waveforms, it is crucial to create interfaces that use the DAQ tools available in LabVIEW. These interfaces are the intermediary between the electrical hardware and the LabVIEW software, facilitating continuous data collection and analysis. The system design showcases the incorporation of measurement block instruments in the monitoring system as shown in Figure 2. These instruments facilitate accurate measurement and analysis of leakage current and voltage signals. The DAQ module, a crucial component of LabVIEW, is utilised for signal acquisition from a leakage current input linked to the physical input of a NI-DAQ 6361 device. To provide a graphical representation of the acquired data from the system, the interfaces were developed to exhibit the voltage output and leakage current waveforms. These interfaces make it possible to instantly see the acquired signals, making it easier to see any patterns or changes. Moreover, the system integrates an automated data logging functionality, guaranteeing that the obtained data is recorded into a CSV file.

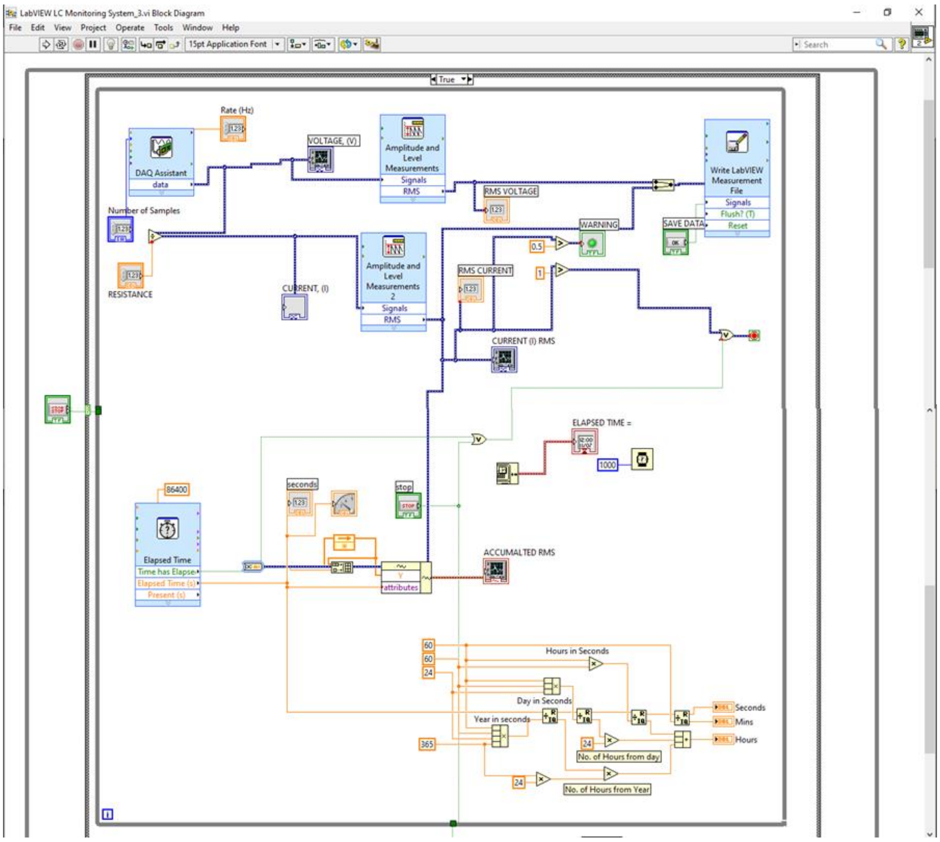


Figure 2: Architecture Structure of the Monitoring System

2.3 Experimental Setup

In order to perform a test on the insulator samples, it is necessary to utilise a fog chamber test. This particular test is capable of replicating extreme natural contamination conditions on the artificially contaminated insulators. To conduct this test, a fog chamber having dimensions of 50 cm × 50 cm × 75 cm was custom-built. The fog chamber was fabricated utilising polycarbonate sheets for robustness and optical clarity. As shown in Figure 3, the schematic represents the intended experimental arrangement for the project. The fog chamber test setup is linked to a transformer rated at 220V/100kV, 5kVA, and a frequency of 50 Hz. Furthermore, an inclusion of capacitive voltage divider is integrated into the arrangement for precise measurement and monitoring of voltage levels.

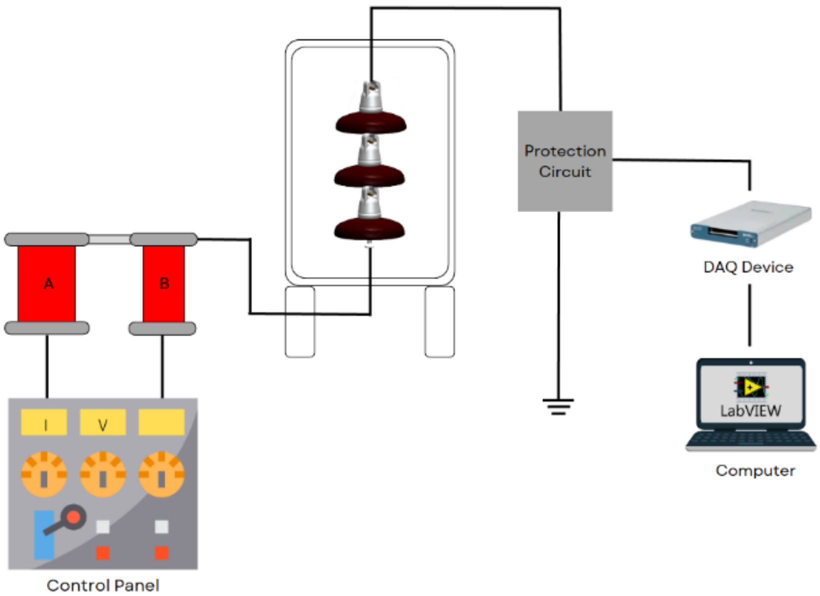


Figure 3: Leakage current monitoring testing setup

2.4 Artificial Pollution Analysis

Important to the study of high-voltage insulators are the phenomena of moisture and contamination. Wetting refers to the deposition of liquid on the surfaces of insulators, which can impair their electrical insulation properties and performance. The presence of moisture or conductive liquids can increase surface conductivity, leading to an increase in leakage currents and the potential for flashovers. Prior to the deposition of the contamination onto the surface, the insulator materials must be cleaned with alcohol. According to [8], the insulator surface was subsequently contaminated using the solid layer technique. There are two categories of deposited pollutants: soluble deposit density (SDD) and insoluble deposit density (NSDD). These are represented by sodium chloride salt (NaCl) and Kaolin.

Based on both IEC 60507 and IEC 60815 standards, the SDD can be calculated using Equation (1):

$$\mathrm{SDD} = \frac{(5.7 \times \sigma^{20})^{1.03} \times \mathrm{V}}{S} \qquad (1)$$

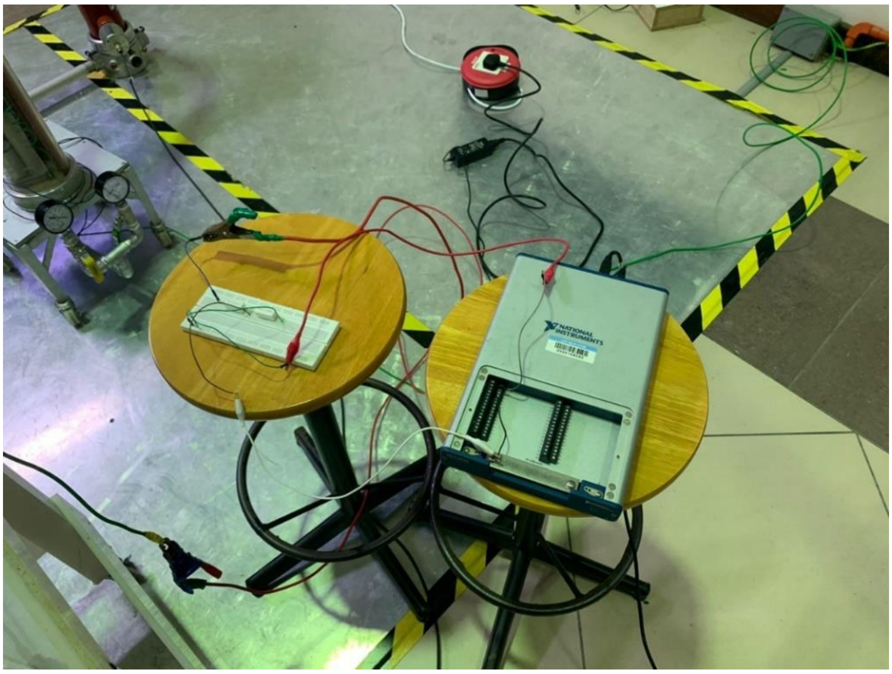
In this Equation (2), V and S denote the pollution solution volume and the insulator surface area, respectively. The NSSD according to the IEC 507 standard:

$$\mathrm{NSDD} = \frac{(\omega_s - \omega_i) \times 10^3}{S} \qquad (2)$$

where ω_S and ω_i are the mass of the filter paper under contamination and under dry conditions, respectively.

The insulator was wetted using the spray technique by applying the material onto the surface of the insulator in the pollution chamber. Figure 4 depicts the pollution testing that been done in the HV Laboratory in FKEE along with monitoring system setup.

(a)



(b)

Figure 4: Monitoring system for high voltage insulator testing under pollution chamber: (a) Pollution chamber (b) DAQ and Protection circuit

The pollution testing was set once to analyse the leakage current behaviour under different conditions. By conducting pollution tests, the main focus of the study, which is the leakage current monitoring system, can be thoroughly evaluated in terms of system response changes during the experiment. Then, modifications can be made to improve the system's ability to capture leakage current data from the high-voltage insulator.

3. Results and Discussion

3.1 Leakage Current Monitoring System GUI

The validation process generally includes comparing measurements acquired from the LabVIEW monitoring setup with a reference or pre-existing standard. Regarding high voltage insulator monitoring, an oscilloscope is a frequently utilised tool that delivers accurate and dependable readings of diverse electrical characteristics. In the process, known input voltages or currents will be applied to the DAQ device and measure the corresponding output values using both the LabVIEW system and the oscilloscope. The LabVIEW interface for the monitoring system that been designed consist of the features that has been discussed in the previous chapter as resulted in Figure 5.

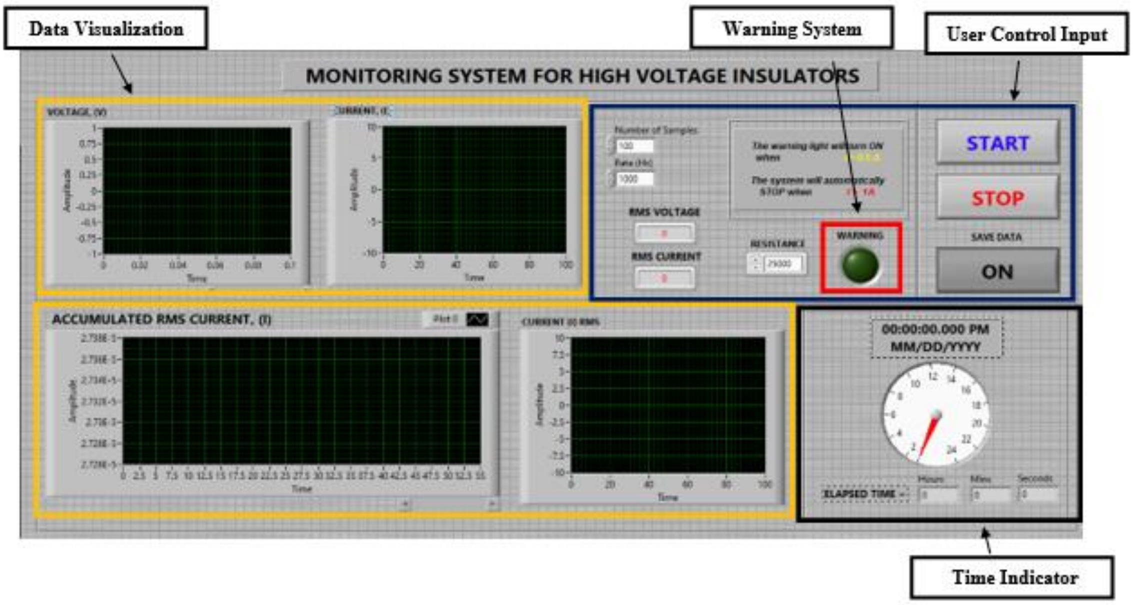


Figure 5. Leakage current monitoring system for high voltage insulator GUI

3.2 Leakage Current Result

As for leakage current, the monitoring system is capable of measuring the magnitude of the leakage current, which can serve as an indicator of the insulation's overall condition. An increase in leakage current above normal levels which about 150mA may indicate insulation deterioration, contamination accumulation, or other potential problems. The monitoring system captures the waveform depicted in Figure 6 for the leakage current over time, enabling the examination of variations and patterns. Variations or continuous trends in the output of leakage current may indicate transient faults, insulation irregularities, or changes in environmental conditions.

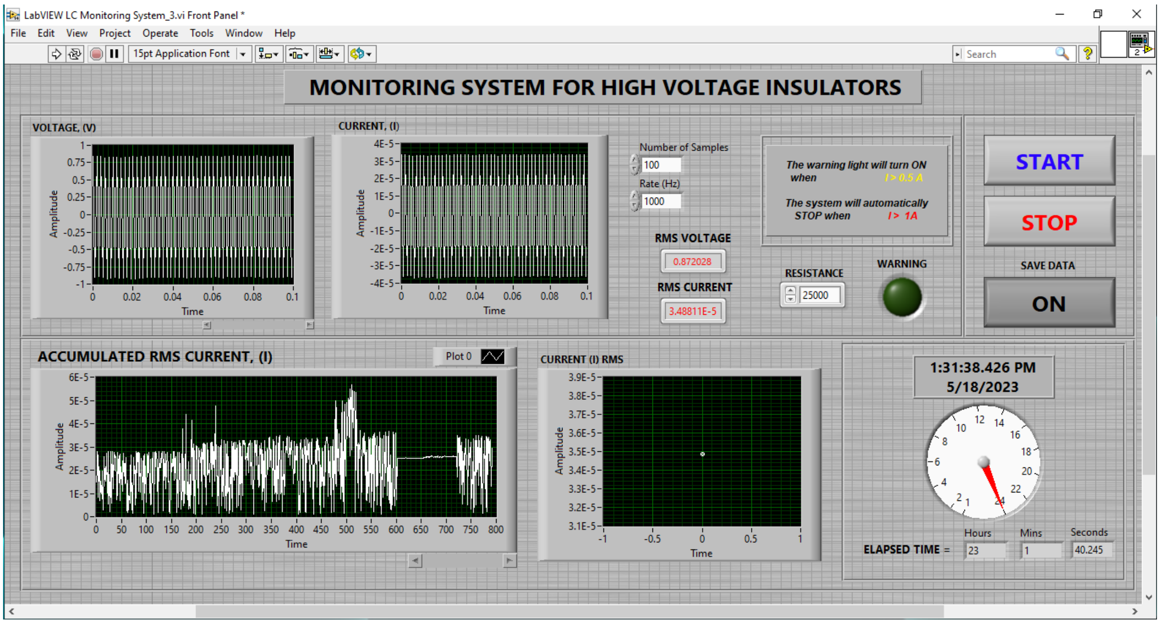


Figure 6: Leakage current waveform from LabVIEW

For the purpose of evaluating the performance of a high-voltage insulator, it is necessary to acquire leakage current data over a specific amount of time. In the evaluation, the data would be analysed over the course of 24 hours. The monitoring system is able to record leakage current trends continuously over time. Figure 7 represents the outcome of continuous monitoring, wherein the leakage current is marginally stable in a clean setting. The durations permit a more comprehensive evaluation of leakage current under different situations or conditions. Change in humidity, temperature, and other factors, for instance.

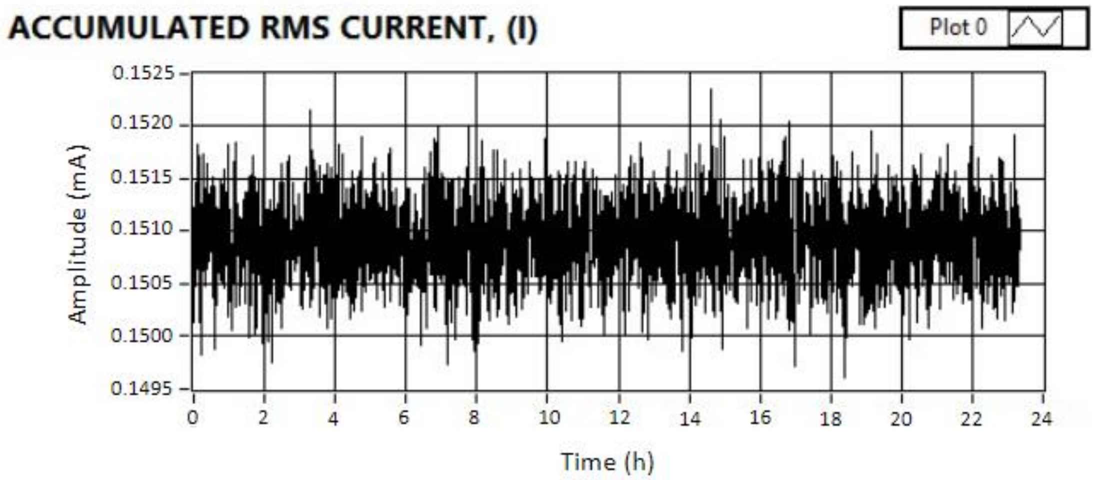


Figure 7: Leakage current output over 24 hours of monitoring

4. Conclusion

LabVIEW monitoring of leakage current in high-voltage insulators was successful in achieving the three objectives of the study. The first objective was to establish the monitoring system's fundamental parameters, such as the front panel display, user control, real-time monitoring, warning systems, and data visualisation. To assure the functionality of these features, the LabVIEW software was configured with block tools. The second objective was to design and implement an application for monitoring and displaying leakage current data effectively. Through extensive testing and validation, the LabVIEW software demonstrated its ability to accurately synchronise and display data. The system demonstrated its ability to provide data in real-time, allowing for the evaluation and analysis of leakage current behaviour. The integrated warning system worked as intended, alerting users of excessive current flow without delay. The third objective was to evaluate the efficacy of the leakage current monitoring system. Together with time-stamped data, the generated leakage current output was analysed to determine the factors influencing leakage current behaviour under high voltage conditions. The outcomes validated the system's suitability for high voltage applications. The LabVIEW-based monitoring system offers an effective and user-friendly approach for real-world applications, allowing for timely intervention and proactive maintenance to prevent insulator failures.

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