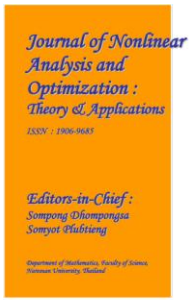
Journal of **N**onlinear **A**nalysis and **O**ptimization
Vol. 15, Issue. 1 : 2024
ISSN : **1906-9685**



WIRELESS MONITORING OF INSULATOR POLLUTION LEVELS VIA LEAKAGE CURRENT BURSTS

Dr. S. V. Rama Rao, Associate Professor in Department of ECE, NRI Institute of Technology, Agiripalli, Vijayawada.
T. Pranathi, Student, Department of ECE, NRI Institute of Technology, Agiripalli, Vijayawada
V. Ruchitha, Student, Department of ECE, NRI Institute of Technology, Agiripalli, Vijayawada
S. Venkat Sai, Student, Department of ECE, NRI Institute of Technology, Agiripalli, Vijayawada
Y. Siva Sai Kumar, Student, Department of ECE, NRI Institute of Technology, Agiripalli, Vijayawada

ABSTRACT:
This article introduces an innovative wireless monitoring device designed to assess the severity of contamination on high voltage transmission network insulators. The device operates by continuously detecting leakage current bursts and calculating their average Root Mean Square (RMS) values within customizable time intervals. Once calibrated, if the RMS value surpasses a predefined threshold indicating a potential power outage, the device triggers an alarm and promptly notifies maintenance personnel to clean the insulators before a network outage occurs unexpectedly. Comprising essential components such as a current transformer with a burden resistor, Node MCU (ESP8266), AC Load, cloud-based data storage, and a smart device (like a mobile phone), this monitoring system can be assembled and operated without requiring an external power source. Its simplicity, low cost, ease of calibration, and high safety standards distinguish it from other monitoring devices. Moreover, being an online system, it offers real-time monitoring capabilities, ensuring timely intervention to prevent network disruptions

Index Terms –
Contaminated insulators, Internet of Things, leakage currents, sensors, smart monitor system.

1. INTRODUCTION

High voltage transmission lines play a pivotal role in the efficient distribution of electrical power. However, their reliability can be compromised by pollution-induced insulator contamination, leading to flashovers and service interruptions. Traditional methods of assessing pollution severity, while effective, often lack real-time monitoring capabilities, hindering timely intervention. Recent research has shown that analyzing leakage currents of insulators offers valuable insights into pollution levels and the likelihood of flashovers. To address these challenges, this paper proposes a novel approach to pollution severity monitoring using high voltage transmission line insulators. Leveraging wireless devices based on leakage current bursts, the system aims to provide real-time data on pollution levels, enabling proactive maintenance strategies. By integrating IoT technologies and advanced analytics, the proposed system offers a comprehensive solution for monitoring insulator conditions remotely and continuously [1].

Moreover, these methods often require significant human resources and may not be practical for large-scale transmission networks spanning vast geographic areas [4]. Recent advancements in sensor technology and wireless communication have opened up new possibilities for real-time monitoring of pollution levels on high voltage transmission line insulators. By leveraging these technologies, it becomes feasible to continuously collect data on leakage currents, which serve as indicators of pollution severity [6]. Wireless devices based on leakage current bursts offer the advantage of remote monitoring, enabling utilities to monitor insulator conditions across their entire network without the need for manual intervention [8]. The integration of IoT technologies further enhances the capabilities of the monitoring system by enabling data analytics and predictive maintenance strategies [7]. By analyzing historical data and identifying trends in pollution levels, utilities can anticipate potential issues and take proactive measures to mitigate risks. This paper proposes a comprehensive approach to pollution severity monitoring using high voltage transmission line insulators. The proposed system combines advanced sensor technology, wireless communication, and data analytics to enable real-time, remote monitoring of insulator conditions. Through experimental validation and case studies, the effectiveness and practicality of the proposed monitoring system will be demonstrated, paving the way for enhanced reliability and resilience of power transmission networks

2. REVIEW OF LITERATURE

The assessment of pollution severity on high voltage transmission line insulators has been a topic of significant interest in the field of electrical engineering. Various studies have investigated different approaches for monitoring insulator conditions and predicting flashover events induced by pollution contamination.

Salem et al. [1] conducted a systematic review of experimental works focusing on the pollution flashover voltage of transmission line insulators. Their study provides valuable insights into the factors influencing insulator performance under polluted conditions, highlighting the importance of continuous monitoring. Artificial pollution tests, as outlined in IEC Standard 60 507 [2], have long been used to evaluate the performance of insulators under controlled laboratory conditions. These tests provide a standardized method for assessing pollution severity and are widely recognized in the industry.

Li et al. [5] proposed the use of leakage currents of insulators to determine the stage characteristics of the flashover process and predict contamination levels. Their research demonstrated the potential of leakage current analysis as a reliable indicator of pollution severity and insulator performance.

This paper proposes a new approach to monitoring pollution severity using high voltage transmission line insulators. It uses advanced sensor technology, wireless communication, and data analytics to enable real-time monitoring of insulator conditions. The assessment considers factors such as Current Leakage Bursts (CLB), Environmental Conditions (EC), and Insulator Conditions (IC). The system captures leakage current bursts as indicators of pollution severity and insulator performance. Real-time analysis provides insights into pollution trends and proactive maintenance strategies. The method will be tested for reliability and resilience of power transmission networks.

3. ENHANCED WIRELESS MONITORING SOLUTION PROPOSAL

The proposed pollution severity monitoring system for high voltage transmission line insulators involves careful configuration of hardware components, calibration and optimization of sensor parameters, wireless communication with a GSM module, and integration with an IoT cloud platform. This system provides real-time data storage, analysis, and visualization, enabling informed decision-making and proactive maintenance strategies. An alert mechanism detects abnormal pollution levels, and rigorous testing and validation ensure its reliability and accuracy. The system empowers utilities to manage insulator contamination, optimize maintenance, and safeguard high voltage transmission line operations. The basic block diagram proposed system as shown in Fig 3.1.

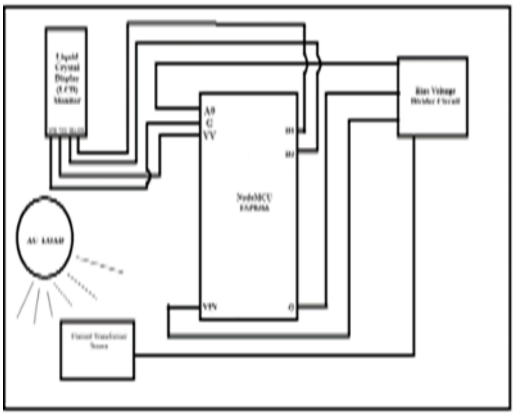


Fig 3.1 Block Diagram of Wireless Monitoring System

CT SENSOR

CT sensors measure Alternating Current in high-voltage power systems using a primary winding and a secondary winding. They are used for pollution severity monitoring in high-voltage transmission line insulators to detect leakage current bursts caused by pollution buildup or contamination on insulator surfaces. CT sensors monitor Alternating Current in high-voltage power systems, detecting leakage current bursts caused by pollution buildup or contamination on insulator surfaces using primary and secondary windings as shown in Fig 3.2.

Fig 3.2 Split Core Current Transformer

NODE MCU(ESP8266)

The NodeMCU is a low-cost IoT platform that monitors pollution severity in high-voltage transmission line insulators using leakage current bursts. It interfaces with CT sensors, converts data into digital form, and transmits it wirelessly to a central station. It can integrate with cloud services for real-time decision-making. AC Supply Provides power to the CT sensor, Node MCU ESP8266, and other electronic components in the system. It ensures continuous operation of the monitoring system. A Node MCU(ESP8266) as shown in Fig 3.3

Fig 3.3 NodeMCU ESP8266

LCD MONITOR

The project uses an I2C LCD module for real-time visual feedback as shown in Fig 3.4, enabling communication via the I2C protocol. The module manages LCD initialization, cursor positioning, character display, and backlight control, simplifying wiring and enhancing user interaction. As the data receive from NodeMCU ESP8266 the data will be display on the screen as Current values and Power values

Fig 3.4 I2C LCD Monitor

4.SOFTWARE IMPLEMENTATION

ARDUINO IDE

Arduino is a versatile device that collects data from leakage current burst sensors, identifies patterns in real-time, communicates wirelessly with central monitoring systems, logs data for historical analysis, aids in predictive maintenance, and can be integrated with IoT platforms for scalability.

IOT CLOUD BASED DATA STORAGE:

ThingSpeak is an IoT platform that provides cloud-based data storage and visualization capabilities. It allows users to collect data from various devices and sensors, organize it into channels, and upload it using the ThingSpeak API. The data is stored in a time-series format for analysis over time. ThingSpeak can be integrated with other IoT platforms, services, and applications for actions, notifications, and data analysis.

5.RESULTS AND OBSERVATION

The system measures leakage current bursts on high-voltage transmission line insulators without an AC load as shown in Fig 5.1, resulting in baseline measurements and variations over time. The system monitors insulator condition under normal operating conditions, obtaining overall measurements of Current(A):0.003 and Power(W):0.00.

When an AC load is introduced, the system simulates actual operating conditions, measuring leakage current bursts under the load's influence and assessing its impact on insulator pollution severity. Obtaining overall measurements of Current(A):27.33 and Power(W):6286.4 as shown in Fig 5.2 as the LCD Monitor Display.

These results underscore the importance of continuous monitoring and the potential of wireless devices in enhancing the resilience of HVTL systems against pollution-related challenges.

5.1 Wireless Monitoring System

5.2 I2C LCD Monitor

REAL-TIME MONITORING OF ELECTRICAL PARAMETERS IN HVTL INSULATORS

The system logs and displays the top 10 observations or events related to leakage current bursts on the LCD screen as sown in Table 5.1. Observations may include the magnitude, frequency, and duration of bursts, as well as any notable variations or anomalies

Table 5.1 I2C LCD Monitor Readings

	
Fig:5.3 LCD Reading 1	Fig:5.8 LCD Reading 6
	
Fig:5.4 LCD Reading 2	Fig:5.9 LCD Reading 7
	
Fig:5.5 LCD Reading 3	Fig:5.10 LCD Reading 8
	
Fig:5.6 LCD Reading 4	Fig:5.11 LCD Reading 9
	
Fig:5.7 LCD Reading 5	Fig:5.12 LCD Reading 10

Equations:

The line double Irms = emon1.calcIrms(1480);

Calculates the Root Mean Square (RMS) value of the current.

RMS CALCULATION STEPS:

$$I_{rms} = \sqrt{\frac{\sum_{n=0}^{N-1} i^2(n)}{N}} \quad \text{-----(1)}$$

Sampling(N): The energy monitor takes multiple samples of the current waveform over a specified period.

In this case, it takes 1480 samples.

Square the Values: Each sampled value of the waveform is squared.

Average of Squares: The squared values are averaged.

Square Root: Finally, the square root of the average of the squares is taken to obtain the RMS value.

RMS Calculation: Let's say we have sampled 1480 values of the current waveform and after processing,

we obtain the following:

Squared values:$2.3^2 + 2.5^2 + 2.4^2 + \ldots\ldots$ (1480 values)

Average of squared values: $(2.\ 3^2 + 2.\ 5^2 + 2.\ 4^2 + \ldots) / 1480$

RMS Current (Irms) = Average of squared values

This value is obtained from the energy monitor (EmonLib library).

The argument 1480 represents the number of samples taken over a period of time.

The value obtained by the Energy monitor is 27.33 A

POWER CALCULATION

Power is calculated using the formula:

Power (W) = Current (A) * Voltage (V) * COS(θ) -----(2)

Where:

θ is the phase angle between voltage and current (power factor).

The line double power = Irms * voltage; calculates the power consumption in watts.

Power(W) = 27.33*230*1 =6286.6

LEAKAGE SEVERITY CALCULATION

Suppose after measuring, Irms and power consumption is measured in Watts. Assume the weighting factors are:

clbWeight = 0.4,

ecWeight = 0.3,

icWeight = 0.3.

Using the measured values and the provided weighting factors, we can calculate the overall leakage severity as follows:

Overall Leakage Severity = (0.4 x Current(A) + (0.3 x calculateEC ()) + (0.3 ×calculateIC ())

Overall Leakage Severity = (0.4 x Current(A)) + (0.3 x calculateEC ()) + (0.3 x calculateIC ())

Let's assume calculateEC () returns a value of 6 and calculateIC () returns a value of 5.

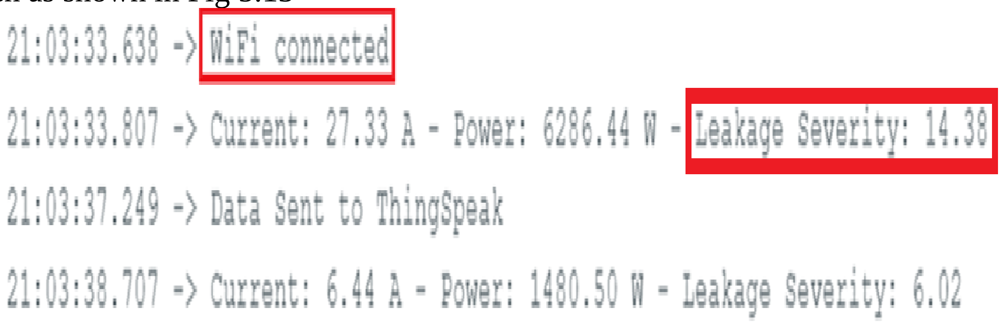
Overall Leakage Severity = (0.4 x Current(A)) + (0.3×6) + (0.3×5)

Overall Leakage Severity = (0.4 x 27.33A) + (0.3×6) + (0.3×5)

Overall Leakage Severity = 14.23

SERIAL MONITOR OUTPUT

The serial monitor is a crucial tool in the pollution severity monitoring project for High Voltage Transmission Line (HVTL) insulators. It collects data on key parameters like current flow, power consumption, and leakage severity, providing real-time monitoring. The Arduino serial monitor executes commands for calculating leakage severity, power, and RMS values, displaying the results on the screen as shown in Fig 5.13



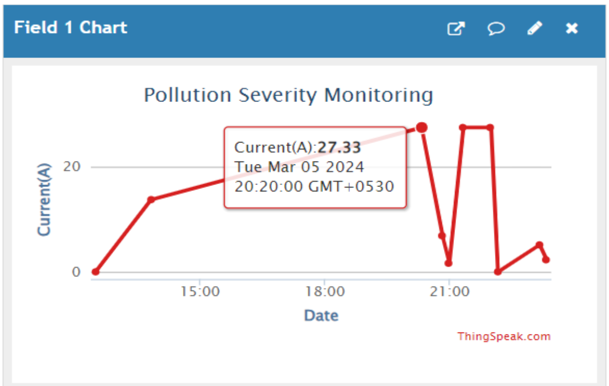
5.13 Serial Monitor Output

DATA VISUALIZATION IN THING SPEAK

ThingSpeak offers data visualization tools for monitoring pollution severity, enabling the identification of sources and implementation of targeted interventions time to improve air quality and public health.

CURRENT(A)

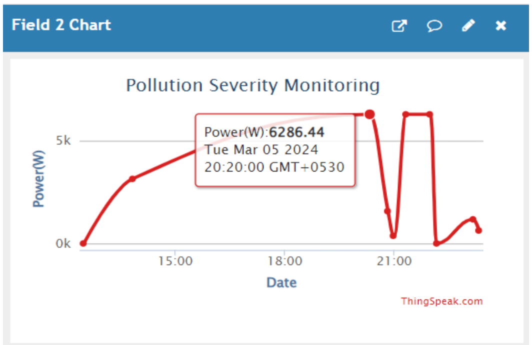
ThingSpeak is a tool used to monitor high current values, enabling users to manage risks and enhance safety. It uses key steps to visualize data and respond promptly. The highest current recorded on a power transmission exceeds the 20A limit, indicating high voltage measurement of 27. 33A.This precision captures the intensity of electrical activity, enhancing operational efficiency as shown in Fig 5.14



5.14 Obtained RMS Current

POWER(W) RATINGS

A spline area graph is a useful tool for monitoring power ratings in watts. It captures both active and reactive power components over time, allowing for better decision-making and performance optimization. Data is collected from a power monitoring system, such as sensors or smart meters In Fig 5.15 it shows the reading of power 6286.44W where it reaches the maximum point in linear with current and input voltage



5.15 Obtained Power in Watts

LEAKAGE SEVERITY(A):

ThingSpeak's Leakage Severity graph is a crucial tool for monitoring HVTL insulator integrity, providing real-time data points, trends, and anomalies. The Leakage Severity graph indicating high level of leakage severity is noted as 14.38A.Its interactive features enable quick identification of potential issues, enhance pollution severity monitoring efficiency, and enable customizable alerts as shown in Fig 5.16

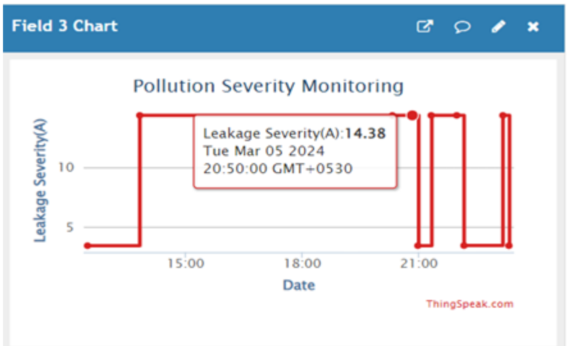


Fig 5.16 Leakage Severity Calibrated

MONITORING ELECTRICAL PARAMETERS: CURRENT, POWER, AND LEAKAGE SEVERITY

Recordings of current, power, and leakage severity is shown in Table 5.2. It meticulously documents the fluctuating currents, varying power values, and the severity of leakage in precise measurements. These recordings offer crucial insights into the operational dynamics, facilitating informed decisions for optimizing efficiency and safety protocol

Table 5.2 Electrical Parameters Recording

S. No.	Current (A)	Power (W)	Leakage Severity (A)
1	27.33	6286.44	14.38
2	6.44	1480.50	6.03
3	1.52	348.67	4.06
4	0.36	82.11	3.59
5	0.08	19.34	3.48
6	0.02	4.55	3.46
7	0.00	1.07	3.45
8	0.20	45.33	3.53
9	0.06	14.71	3.48
10	0.02	3.47	2.46

6.CONCLUSION

The development and implementation of a pollution severity monitoring system for high voltage transmission line insulators using wireless devices based on current leakage bursts is a significant advancement in power transmission infrastructure management. The system enables real-time monitoring of pollution severity, enabling early detection of contamination and timely intervention to prevent grid disruptions. Key findings include enhanced reliability, cost-effectiveness, data-driven insights, and scalability and flexibility. The monitoring system offers continuous monitoring of insulator conditions, enabling utilities to detect and mitigate pollution-related issues before they escalate into major failures. It also provides data-driven decision-making capabilities for optimizing grid performance. The modular design allows for seamless 56 integration with existing infrastructure and adaptation to evolving needs and requirements. Future research and development efforts should focus on enhancing sensor accuracy, improving data analytics capabilities, and integrating advanced technologies like machine learning for predictive maintenance and anomaly detection. The pollution severity monitoring system represents a significant step towards ensuring the reliability, resilience, and sustainability of power transmission networks in the face of evolving environmental challenges.

REFERENCES:

[1] A. A. Salem, K. Y. Lau, W. Rahiman, Z. Abdul-Malek, S. A. Al-Gailani, N. Mohammed, R. A. Rahman, and S. M. Al- Ameri, ‘‘Pollution flashover voltage of transmission line insulators: Systematic review of experimental works,’’ IEEE Access, vol. 10, pp. 10416–10444, 2022.

[2] Artificial Pollution Tests on HV Insulators to be Used on AC Systems, IEC Standard 60 507, 1991.

[3] O. E. Gouda, S. H. El-Hoshy, and S. S. M. Ghoneim, ‘‘Enhancing the diagnostic accuracy of DGA techniques based on IEC-TC10 and related databases,’’ IEEE Access, vol. 9, pp. 118031–118041, 2021

[4] Monthly Faults Reports on Unified Egyptian Network, Egyptian Electricity Holding Company Annual Report, Cairo, 2021. Accessed: Feb. 14, 2022. [Online]. Available: http://www.moee.gov.eg/english_new/ EEHC_Rep/REP2021-2022en.pdf

[5] J. Li, W. Sima, C. Sun, and S. Sebo, ‘‘Use of leakage currents of insulators to determine the stage characteristics of the flashover process and contamination level prediction,’’ IEEE Trans. Dielectr. Electr. Insul., vol. 17, no. 2, pp. 490–501, Apr. 2010,

[6] R. Castillo-Sierra, O. Oviedo-Trespalacios, J. E. Candelo, and J. D. Soto-Ortíz, ‘‘Modeling leakage current of ceramic insulators subject to high pollution levels for improving maintenance activities,’’ DYNA, vol. 85, no. 204, pp. 364–371, Jan. 2018. [7] J. Li, C. Sun, W. Sima, Q. Yang,

and J. Hu, ‘‘Contamination level prediction of insulators based on the characteristics of leakage current,’’ IEEE Trans. Power Del., vol. 25, no. 1, pp. 417–424, Jan. 2010.

[7] I. Ramirez, R. Hernandez, and G. Montoya, ‘‘Measurement of leakage current for monitoring the performance of outdoor insulators in polluted environments,’’ IEEE Elect. Insul. Mag., vol. 28, no. 4, pp. 29–34, Jul. 2012.

[8] M. M. Werneck, D. M. Santos, F. V. B. de Nazare, J. L. da Silva Neto, R. C. Allil, B. A. Ribeiro, C. C. Carvalho, and F. Lancelotti, ‘‘Detection and monitoring of leakage currents in distribution line insulators,’’ in Proc. IEEE Int. Instrum. Meas. Technol. Conf. (I2MTC), May 2014, pp. 468–482.

[9] M.-Q. Tran, M. Elsisi, M.-K. Liu, V. Q. Vu, K. Mahmoud, M. M. F. Darwish, A. Y. Abdelaziz, and M. Lehtonen, ‘‘Reliable deep learning and IoT-based monitoring system for secure computer numerical control machines against cyber-attacks with experimental verification,’’ IEEE Access, vol. 10, pp. 23186–23197, 2022

[10] S. Ganurkar and P. Gour, ‘‘Prepaid energy meter for billing system using microcontroller and recharge card,’’ Int. J. Core Eng. Manage., vol. 1, no. 1, pp. 1–7, Apr. 2014.

[11] M. Elsisi, M. Q. Tran, K. Mahmoud, and D. E. A. Mansour, ‘‘Towards secured online monitoring for digitalized GIS against cyber-attacks based on IoT and machine learning,’’ IEEE Access, vol. 9, pp.