International Journal of Applied Engineering Research
ISSN 0973-4562 Volume 21, Number 2 (2026) pp. 169-181

http://www.ripublication.com

# Development of a Real-Time Partial Discharge Monitoring System Using an Augmented Design Rogowski Coil

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**Abstract**

This study presents the development of a real-time partial discharge (PD) monitoring system using a Rogowski coil, aimed at enhancing early fault detection in power cables. The main objectives include reviewing current research on PD detection using Rogowski coils, designing a coil-based system to sense high-frequency current transients associated with PD events, and implementing a signal conditioning circuit with an active integrator for accurate signal processing. A custom augemented Rogowski coil was developed to capture transient current signals produced by PD events, and the output was processed using an op-amp-based active integrator circuit to reconstruct the original current waveform for better analysis. The processed signal was then analysed by an Arduino microcontroller, which activated real-time indicators such as an LED and buzzer when PD activity was detected. Testing with simulated PD sources confirmed that the system effectively detected and responded to discharge signals. This project demonstrates a low-cost, portable solution for real-time PD monitoring and lays the groundwork for future improvements, including wireless communication and advanced signals.

**Keywords:** Partial Discharge (PD), Rogowski Coil (RC), Real-Time Monitoring, Active Integrator, Arduino

## Introduction

Partial discharge (PD) is a localized dielectric breakdown in high-voltage insulation systems that do not completely bridge the gap between conductors. It is a critical indicator of insulation degradation and is widely recognized as an early sign of potential failure in electrical equipment such as power transformers, cables, and switchgear. Detecting PD at an early stage is essential to prevent catastrophic failures, enhance system reliability, and reduce maintenance costs. As such, PD monitoring has become a key area of focus in power system diagnostics, both industrially and academically. In recent years, the demand for real-time, portable, and cost-effective PD detection systems has increased, especially with the aging of power infrastructure and the expansion of renewable energy networks. Conventional PD detection methods often rely on bulky, expensive instruments that are not suitable for in-situ or continuous monitoring. This has driven research towards the development of compact and flexible sensing solutions.The RC has emerged as a promising alternative due to its non-intrusive, flexible, and wideband nature, making it ideal for capturing the high-frequency current pulses associated with PD. However, the raw output of a Rogowski coil is not directly usable for analysis as it provides a voltage proportional to the rate of change of current (di/dt), necessitating the use of an integrator circuit to reconstruct the actual current waveform.This project addresses the existing gap by developing a real-time PD monitoring system using a custom-made Rogowski coil integrated with an active signal conditioning circuit. The system aims to provide an affordable and portable solution for real-time detection of PD in power cables. Recent advancements in microcontroller technology and low-cost analog circuitry make it feasible to implement such a system for field deployment, especially in remote or resource-constrained environments. This work contributes to the ongoing development of smart monitoring systems and supports the broader goal of improving the resilience and efficiency of electrical power networks.

PD is a major cause of insulation failure in high-voltage equipment, particularly in aging underground power cables and transformers that are critical to urban and industrial energy distribution. Despite its serious implications, PD often goes undetected until it leads to equipment breakdowns, resulting in costly repairs, unplanned power outages, and potential safety hazards. Traditional PD detection systems are often expensive, bulky, and require skilled personnel to operate, limiting their use in on-site or continuous monitoring, especially in developing regions or rural areas where resource availability is constrained.This problem affects utility companies, industrial facilities, and society at large. Unreliable power systems can disrupt daily life, economic activities, and access to essential services such as hospitals, schools, and communication networks.

In developing countries, where infrastructure is often overstressed or outdated, undetected PD can further degrade energy reliability and worsen energy poverty. Furthermore, frequent equipment failures due to undetected PD contribute to environmental issues, including electronic waste from damaged components and increased carbon emissions from emergency repairs and system inefficiencies. These outcomes go against global efforts to promote cleaner energy, build more resilient infrastructure, and create safer, more sustainable communities for everyone. By failing to address PD early, we indirectly contribute to increased environmental degradation, economic loss, and social inequity. Therefore, there is a significant need for a low-cost, portable, and reliable PD monitoring system that can be widely deployed for early fault detection. The development of a real-time monitoring system using a Rogowski coil with an integrated active signal conditioning circuit represents a feasible and sustainable solution. Such a system can enhance the resilience of power infrastructure, reduce environmental impact, and support the equitable delivery of clean energy to all sectors of societ.

**2. Modeling Approach**

The RC operates on the fundamental pricinple of Faraday's law, an electromotive force (EMF) is induced in a surrounding closed loop by a time varying magnetic field. When a magnetic field due to an alternating current flowing through the measurement conductor is chained with the coil, an induced voltage is generated in the coil as shown in figure 1[1].The coil, perpendicular to the magnetic field, enables flux lines, and lines are cut by coil, thereby inducing an electromotive force (EMF) in accordance with Faraday's law. The Rogowski coil, which is usually built as an air-core toroidal winding around a conductor, uses this principle to detect the flow of current. The pace at which the current change through the conductor has a direct relationship with the voltage that is induced in the coil; V_ouT (T)=M·dI(t)/dt in this equation M is the mutual inductance between the coil and the conductor, V_ouT (T) is the coil's output voltage and dI(t)/dt is the rate at which current changes. The original current waveform is usually recovered using an integrator circuit as the output reflects the derivative of the current. The Rogowski coil's broad bandwidth, linear response, and resistance to magnetic saturation make it especially suitable for recording high-frequency or pulsed currents.

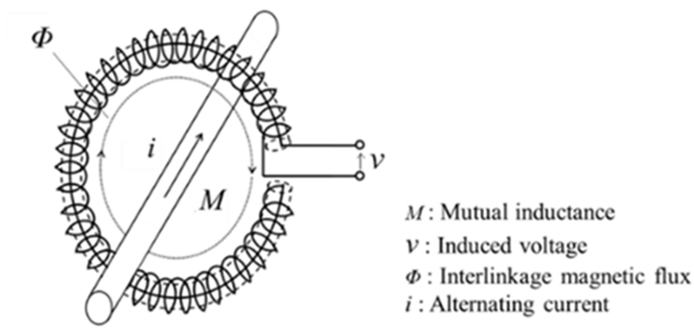


**Figure 1.** Internal Structure of Rogowski Coil

**3. Easy Calibration and Integration**

RC are very simple to calibrate and integrate into electronic measuring systems. They may monitor and analyze current waveforms in real time by integrating their output signal with microcontrollers or digital signal processors.The embedded Rogowski coil for wide bandwidth switch current monitoring. The proposed increasing switching speed of wide-band semiconductors requires a high bandwidth current sensing solution and discusses real time monitoring and embedded integration. Rogowski coil sensor embedded in the power stage is one of the promising concepts in increasing the system reliability [2]. The RC with a comparator circuit can be used as a fast-acting short circuit protection in addition to current sensing. This work investigates the possibility to use the PCB-embedded Rogowski coil for current sensing and the achievable bandwidth of such current sensing solution. A pulse compound integrator designed for use with RC, demonstrating how active integration techniques can enhance signal quality and make calibration easier as shown in figure 2. In contrast to passive integrators, which are dependent on limited low-frequency responsiveness and long-term signal instability, the suggested active integrator ensures greater accuracy and consistent performance [3]. This highlights RC's advantages in easy integration with microcontrollers, such as the Arduino Uno, which is essential to the design of the present project for monitoring discharge in real-time.

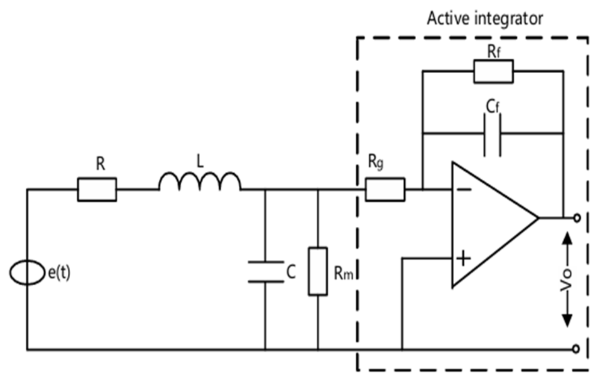


**Figure 2.** Active Integrator Circuit Diagram

## 4. Theoretical Framework of PD Phenomena

A complete understanding of insulation failure, especially with respect to high voltage usage, requires study of partial discharge phenomena. Enhancing the reliability and lifespan of insulating systems in high voltage equipment requires effective tracking of partial discharge activity. Partial discharge (PD) poses a critical risk in high voltage (HV) power equipment due to insulation imperfections, such as air bubbles, which can result in device failures and safety hazards[4][5]. External PD occurs on insulation surfaces where the electric field is sufficiently high to cause breakdown [6]. This form of discharge is usually started in air gaps or at points where external damage or problems are present on the surface of insulation. These discharges do not cause a primary failure of the insulation, but rather they suggest some form of damage and stress within the insulation system whereby if not addressed it will gradually result in long-lasting damage.

## 5. Overview of IEC 60270: PD Measurement International Standards

The IEC 60270 standard for measuring partial discharge in high-voltage electrical equipment was set by the IEC, an international electrotechnical commission [7]. This guide describes the test procedures, instruments, and interpretation methods for evaluating partial discharge activity and is specifically applicable to insulation systems and its scope was defined in the 2000 edition. IEC 60270 is important for the condition monitoring of high-voltage equipment, including transformers, cables, and switch gear, to promote operational reliability and safety. It is however within the international standard, but also a common national standard in many countries including India (as IS/IEC 60270), suggesting its overall importance and focus on high voltage testing. This guide provides the scholarly and industrial basis to evaluate insulation integrity and prevent dielectric failure.

## 6. Application For Rogowski Coil

The application for Rogowski coils is important to develop because the Rogowski coil is frequently used to measure electric current without breaking or touching the wire. It has a flexible shape and can easily place it around a wire. This makes it useful for checking fast or changing currents, like a partial discharge test. This coil gives a small voltage signal that can be used to find out how much current is flowing. The Rogowski coils are key measurements instruments in several applications due to flexibility, large bandwidth, linearity, and so on [8]. Rogowski coils are systematic, and their use is regulated almost for every application ensures greater accuracy and consistent performance [3]. This highlights RC's advantages in easy integration with microcontrollers, such as the Arduino Uno, which is essential to the design of the present project for monitoring discharge in real-time.

## 7. Power System Monitoring and Protection

The analysis of the partial discharge is challenged in low and medium voltage, and it requires new methods and tools to solve this with power system monitoring[9]. Even in the present day, in many cases, energy loss in generated due to insulation ageing of the transmitter and for or against the user. For is problem, a measurement and monitoring system for electrical energy is proposed for cost effective to achieve energy savings and with it, a lower environmental impact by using low-cost monitoring systems and partial discharge detection. Based on these studies, an Arduino uno microcontroller, and programmed in the Arduino software, the Rogowski coil, besides it creates a voltage signal, and it will have to be converted by programming into the appropriate signal for current analysis in graphical interface design.

## 8. Methodology

The methodology used to design and develop a real-time partial discharge (PD) monitoring system using a Rogowski coil and Arduino Uno. The methodology includes the stages of project planning, hardware development, software implementation, system integration and simulation. Each stage is carefully structured to achieve the main objective of detecting partial discharge activity. This research presents several challenges, including the need for specialized techniques or methods and analysis of information. By detecting and monitoring partial discharge (PD) this research applies an experimental methodology relating to sensor development signal processing, and data visualization. The use of Rogowski coil and Arduino Uno forms the foundation for real-time data acquisition. Besides that, simulation steps are included to ensure system reliability and accuracy in detecting partial discharge events. The complete architecture of the project is depicted with a flowchart in a systematic, step-by-step logic. It offers a graphical view to all three development phases: research, simulation and hardware development. This flowchart presents each of the major stages of the development of the real-time partial discharge (PD) monitoring system as shows in figure 3. The remaining of the architecture starts with the research and data gathering that focused on partial discharges detection, and the applications of the Rogowski Coil.

Next was pre-development, during which it was familiarized with the programming environment (the Arduino IDE) and planned the functional form of the system. The following steps are, DIY Rogowski coil prototype construction, active integrator circuit simulation, Arduino code writing, and proteus system implementation. The final phase focuses on testing and performance evaluation.

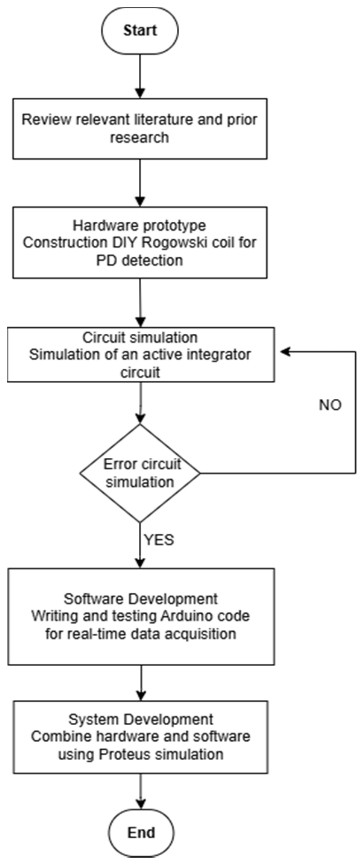


**Figure 3.** Flowchart of Project Overview

## 9. Design and Construction

The proposed system to detect partial discharge (PD) which senses high frequency current pulses during the time of discharging. The flowchart of the Rogowski coil construction process is shown in figure 4. Primary sensor, a custom-built Rogowski coil to sense these high frequency transients and high frequency currents are sampled by a Rogowski coil, output signal is feed to active integrator operating-connected. This circuit then takes the signal and shapes it into a current waveform that syncs almost one to one with actual discharge current. Then the analog input pin of Arduino Uno microcontroller take signal as processed by it. Arduino reads the voltage level and figure out whether partial discharge taking place or not. Using a set threshold, it shows "PD: Detected" or "PD: No Detected" on the screen of 16x2 LCD (Gor Arlet) independently. The Rogowski coil utilized for this project was constructed manually as cost-effective and customizable solution to detect high-frequency current pulses related to PD events as shown in figure 5.

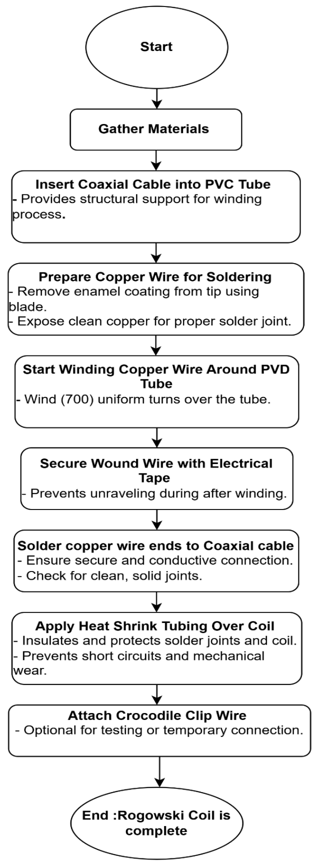


**Figure 4.** Flowchart of DIY RC Construction

**Figure 5.** DIY Rogowski Coil

**10. Software Flow Chart**

The flowchart illustrates the operational process of a real-time PD monitoring system that employs a Rogowski coil and Arduino microcontroller. The system starts by continuously checking for PD occurrences within the transformer or high-voltage equipment. When a PD event occurs, the Rogowski coil senses the transient current pulses and converts them into a corresponding differential voltage. This voltage signal is then processed by an active integrator circuit, which converts the rate-of-change signal from the Rogowski coil into a proportional voltage waveform. The output waveform accurately represents the magnitude and shape of the PD pulse, enabling further digital analysis. Afterwards, the Arduino Uno would read the filtered current signal and measure its duration and amplitude. It will compare the signal to a predetermined threshold level, establishing whether the event constitutes a PD. When PD is detected, the Arduino will activate the LED indicator and the buzzer alarm to notify the user of the event. Additionally, the Arduino will display the current PD percentage measured on the LCD when a PD takes place. If no PD is detected, the indicator will remain off and continue to monitor the current in a perpetual loop. The real-time monitoring process would result in early detection and improved reliability and safety of electrical insulation systems as shown in figure 6.

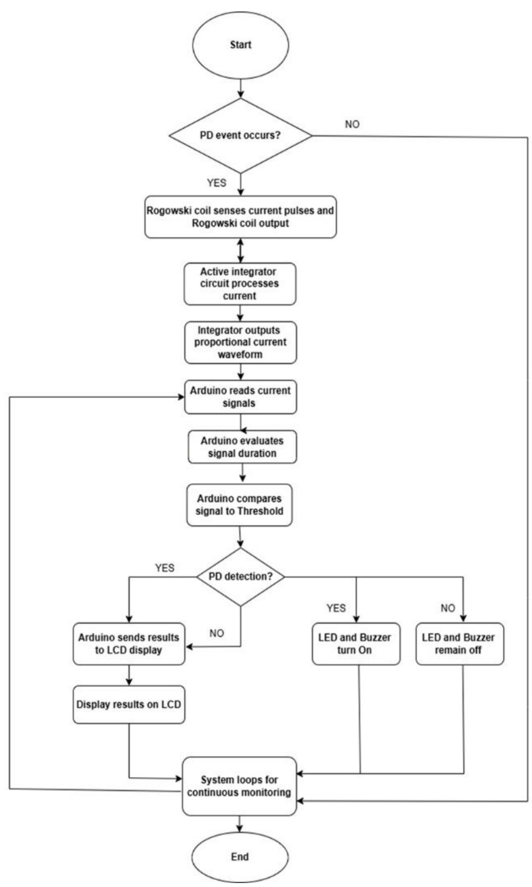


**Figure 6.** Flowchart of Software

The software used in this project plays a vital role in ensuring the proper functioning and validation of the entire system. Without these applications, it would be impossible to design the connecting circuit, simulate its operation, and verify its performance before hardware implementation. Proteus 8 serves as the primary simulation platform, widely utilized in electrical and electronic engineering for circuit design, analysis, and verification. It enables schematic capture, virtual prototyping, PCB layout design, and embedded system simulation. Through its comprehensive tools and user-friendly interface, designers can easily construct and test circuits, identify faults, and validate the system's response before physical assembly. Proteus also supports microcontroller integration, allowing the programmed Arduino to be tested alongside the electronic components virtually.

The Arduino IDE is another essential software tool used in this project for programming the Arduino Uno microcontroller. It provides an intuitive environment for writing, compiling, and uploading codes using a simplified version of the C++ programming language. The IDE includes a built-in compiler, serial monitor, and extensive library support, which streamline the development process. Through the Arduino IDE, control algorithms for partial discharge detection, signal processing, and display output were developed and tested. The integration between the Arduino IDE and Proteus ensures that both the hardware and software components function cohesively, enabling accurate real-time monitoring and reliable performance of the partial discharge detection system.

## 11. Results

The results include the performance of the Rogowski coil, active integrator circuit, Arduino signal processing, and the output display on the LCD. The aim is to verify the system's ability to detect PD signals accurately and provide real-time indication through visual and audible alerts. The experimental results and performance evaluation of the development of real-time partial discharge monitoring system using RC. The hardware testing starts by placing the DIY Rogowski coil around the live wire of an extension cable to measure the current flowing through the load. This method allowed the coil to pick up the magnetic field generated by the AC current without making any direct electrical contact, ensuring safe and non- intrusive measurement. The Rogowski coil was connected to the active integrator using a shielded audio cable to maintain signal quality and reduce noise during the test as shows in figure 7.

**Figure 7.** Hardware testing setup with Rogowski coil placed around the extension cable

The Arduino then received the signal from the active integrator, analysed the waveform, and showed the current reading in real time on the LCD display. Additionally, the system had buzzer and led indicators to display the partial discharge (PD) detection status as shows in figure 8. During the test, the hardware responded accurately, where higher current levels or sudden spikes caused the display to show "PD DETECT", while normal or low current readings showed "NO DETECT". The Indication lights worked just as intended, and the LCD updated smoothly.

**Figure 8.** Real-time current reading and PD status displayed on the Arduino monitoring unit

The system's overall performance was measured by examining the measurements consistency and signal stability. Variations in current from various loads attached to the extension cable were successfully detected by the Rogowski coil. Furthermore, the Arduino and active integrator showed high sensitivity, enabling the early detection of abnormal waveforms that point to partial discharge activity. Overall, the test confirmed that the hardware system is functioning for real-time monitoring applications and is operating as designed.

## 12. Experimental Pulse Testing Configuration

The experimental setup for partial discharge testing using the Rogowski coil and oscilloscope is illustrated in figure 9. To record high-frequency current pulse produced during discharge events, the Rogowski coil is positioned around the spark source. After the active integrator and signal conditioning circuit receive the induced signal from the coil, the processed output is transferred to the oscilloscope for waveform analysis and inspection. During testing, the electric mosquito bat is utilized as an energy spark source to simulate discharge like events. To verify the system's response and overall performance under realistic testing settings, the oscilloscope is used to monitor the signal amplitude, waveform shape, and transient behavior.

The system was implemented and tested using actual hardware, where partial discharge signals were effectively recorded and analysed using an oscilloscope. To evaluate their impact on signal sensitivity and response during PD detection under realistic working conditions, two types of DIY Rogowski coils made with 0.5 mm. The capability of the main hardware components, including the Rogowski coil, active integrator and signal conditioning circuit, and Arduino-based processing unit, is evaluated based on measured waveform characteristics, signal stability, and real-time response. The accuracy and dependability of the system are assessed by looking at the LCD output that displays current levels and PD detection status, while oscilloscope measurements are used and verify signal integrity and conformity with theoretical predictions.

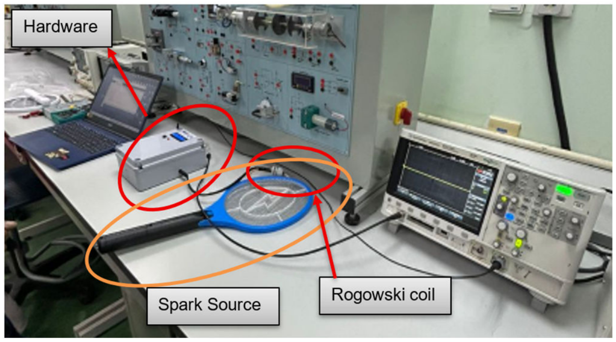


**Figure 9.** Experimental setup for PD testing using RC and oscilloscope

The effectiveness of the system and possible areas for improvement are discussed after a comparison of the output response of the 0.5 mm. The 0.5 mm Rogowski coils were tested to pulse testing to evaluate their transient response and signal detection ability. Spark source pulses were applied to simulate partial discharge events, and the Rogowski coil outputs were recorded using an oscilloscope. The results show that both RCs can capture rapid changes in current and produce different waveforms. This test shows the Rogowski coils aptitude to identify quick transient events, which are necessary for accurate partial discharge monitoring in real time applications as shows in figure 10.


**Figure 10.** Output waveform of the 0.5 mm Rogowski Coil during pulse testing

**Conclusion**

The DIY Rogowski coil with an active filter successfully enhances the detection of partial discharge (PD) signals in high-voltage insulation systems. The designed system effectively senses high-frequency transient pulses and provides accurate signal conversion through the active filter circuit. Compared to a conventional active integrator setup, this configuration offers improved signal clarity, higher sensitivity, and more stable pulse detection. The Rogowski coil's air-core structure eliminates magnetic saturation, ensuring linearity and consistent response even under varying current conditions. The integration with an Arduino microcontroller allows real-time processing and digital display of PD activity, voltage, and current values. Visual and audible alerts through LED and buzzer further strengthen the system's functionality in identifying abnormal discharge events. The Proteus simulation results validate the overall performance and confirm reliable PD detection capability. The system's compact, portable, and low-cost design provides an efficient alternative to traditional PD monitoring instruments. It is suitable for both laboratory testing and on-site field applications.

**Acknowledgments**
The authors would like to express their sincere appreciation to Universiti Teknikal Malaysia Melaka (UTeM) for the financial support and provision of research facilities that made this publication possible.

## References

[1] Tanaka, R., & Yamamoto, K. (2023). Development of Lightning Detection System Using Large-diameter Rogowski Coil and its Performance Evaluation Results. APL 2023 - 12th Asia-Pacific International Conference on Lightning. https://doi.org/10.1109/APL57308.2023.10181542

[2] Minarik, M., Marek, J., & Satka, A. (2022). Embedded Rogowski coil for wide bandwidth switch current monitoring. ASDAM 2022 - Proceedings: 14th International Conference on Advanced Semiconductor Devices and Microsystems. https://doi.org/10.1109/ASDAM55965.2022.9966761

[3] Yang, H., Wang, M., & Wei, R. (2024). Design and Simulation of Rogowski Coil with Pulse Compound Integrator. 2024 5th International Conference on Mechatronics Technology and Intelligent Manufacturing, ICMTIM 2024, 75–79. https://doi.org/10.1109/ICMTIM62047.2024.10629230

[4] Baghelkar, N., & Dubey, A. (2021). A REVIEW OF STUDY AND ANALYSIS OF PARTIAL DISCHARGE FOR DIFFERENT INSULATION MATERIALS WITH CAPACITANCE VALUE. International Journal of Engineering Technologies and Management Research, 7(12), 64–66. https://doi.org/10.29121/ijetmr.v7.i12.2020.844

[5] Kuan, J. X., Chai, C. Y., Chin, K. F., Stephen, A., Yoong, H. P., Afnan, M. N., & Ibrahim, P. (2024). Investigating the Impact of Coil Turns in Flexible Rogowski Coil Sensor for Partial Discharge Detection. 2024 IEEE Sustainable Power and Energy Conference, ISPEC 2024, 618–623. https://doi.org/10.1109/iSPEC59716.2024.10892603.

[6] Awan, H. A., Amin, S., Rahman, T. U., Asad, U., & Awais, M. (2020). Effect of regular and core shell nano fillers on the partial discharge and tracking performance of low-density polyethylene. Materials Research Express, 7(1). https://doi.org/10.1088/2053-1591/ab66ed

[7] Mingotti, A., Peretto, L., & Tinarelli, R. (2020). A Smart Frequency Domain-Based Modeling Procedure of Rogowski Coil for Power Systems Applications. IEEE Transactions on Instrumentation and Measurement, 69(9), 6748–6755. https://doi.org/10.1109/TIM.2020.2986864.

[8] Velásquez, R. M. A. (2022). Low-cost monitoring system and partial

discharge detection in cables. Proceedings of the 2022 IEEE 29th International Conference on Electronics, Electrical Engineering and Computing, INTERCON 2022. https://doi.org/10.1109/INTERCON55795.2022.9870045.

[9] Gong, J., Wang, Y., Wang, L., Zou, M., Sun, P., Liang, Y., Gong, Y., Zheng, H., & Zeng, Z. (2025). Overcurrent Protection Enabled by Broadband Rogowski Coil Current Sensor for Medium Voltage SiC MOSFET. IEEE Transactions on Power Electronics. https://doi.org/10.1109/TPEL.2024.3525298.

[10] Chin, K. F., Chai, C. Y., Saad, I., Bakar, A. A., Ikhsan Megat, M. M., & Yong, L. (2023). Development of a Flexible Rogowski Coil Sensor for Partial Discharge Detection in Power Cables. 5th IEEE International Conference on Artificial Intelligence in Engineering and Technology, IICAIET 2023, 387–392. https://doi.org/10.1109/IICAIET59451.2023.1029169