

Conceptual Development of a Portable Partial Discharge Diagnostic Device for Domestic Wiring Systems

M.F. Endrizal¹, N.A. Othman^{1*}, M.H.M. Mazhanafi¹, H. Kamarden², M.A.N.A.M. Nadzir³ and Z. Adzis⁴

¹*Faculty of Electrical and Electronic Engineering, Universiti Tun Hussein Onn Malaysia,
86400 Batu Pahat, Johor, Malaysia*

²*AAF Bioscience PLT, G11-B, Bangunan PIJ, Jalan Rebana, 80250 Johor Bahru, Johor, Malaysia*

³*APD Global Sdn Bhd, Level 23, Ilham Tower, No.8, Jalan Binjai, 50450 Kuala Lumpur, Malaysia*

⁴*Institute of High Voltage and High Current, Universiti Teknologi Malaysia, Johor Bahru, Malaysia*

This study presents the conceptual development of a portable, non-intrusive partial discharge (PD) diagnostic device for domestic wiring systems. The proposed system integrates an acoustic emission sensor (MAX4466), an ultrasonic distance sensor (HC-SR04), and an ESP32 microcontroller for real-time PD detection without direct electrical contact or external power injection. The system operates by passively capturing acoustic emissions from PD events, which are processed into ADC values for analysis. An ADC-based classification framework is used, where low values indicate normal conditions, intermediate values represent transient disturbances, and high values (above 3000) indicate significant PD activity. Experimental results show that the system can effectively distinguish between normal, minor defect, and severe defect conditions based on signal magnitude and patterns. The addition of distance verification enhances measurement reliability. Overall, the proposed device offers a cost-effective and portable solution for early insulation fault detection in low-voltage wiring systems.

Keywords: partial discharge detection; portable diagnostic device; domestic wiring system; acoustic emission sensor; ultrasonic sensor; ESP32 microcontroller; signal processing

I. INTRODUCTION

The electricity demand has grown exponentially since its discovery, establishing domestic wiring systems as the backbone of residential infrastructure. These systems distribute power safely to appliances, lighting, and outlets; however, poor insulation or ageing components can compromise safety. Electrical fires, short circuits, and shocks are often linked to insulation defects, equipment malfunctions, or lightning (V. Babrauskas, 2008; M. Ahrens, 2013). Preventing such hazards requires reliable methods to identify early signs of wiring deterioration before catastrophic failures occur.

Partial discharge (PD) is a critical early indicator of insulation degradation. According to IEC 60270 and British

Standard EN60270, PD is defined as a localised electrical discharge that partially bridges the insulation between conductors and may or may not occur near a conductor (I. Standard, 2000). In simpler terms, PD occurs when localised voltage stress is sufficient to cause partial insulation breakdown without complete failure. Early PD detection enables preventive maintenance, reducing the likelihood of equipment damage, electrical faults, and fire hazards (M. Yaacob *et al.*, 2014; Pattanadech, 2023).

In domestic systems, exposed conductors, poor installation practices, ageing insulation, and environmental factors are common triggers for PD. High electric field concentrations at defects or gaps can lead to localised discharges, surface breakdown, and corona effects. Over time, such activity

*Corresponding author's e-mail: ndiana@uthm.edu.my

accelerates insulation deterioration, increasing the risk of faults (M. Yaacob *et al.*, 2014; Z. Weixia *et al.*, 2012). Research on 10 kV cables highlighted the importance of PD detection for identifying insulation defects, underscoring the relevance of extending similar monitoring approaches to low-voltage residential wiring.

A wide range of PD detection methods has been developed for high- and medium-voltage applications, as tabulated in Table 1, including high-frequency current transformers (HFCT), capacitive couplers, and ultra-wideband (UWB) antennas (Shahid *et al.*, 2020; UE Systems, n.d.); IRISS Group, 2022; Ghaedi *et al.*, 2025; Zhang *et al.*, 2021). While effective in industrial settings (Hussain *et al.*, 2023), these systems often require bulky hardware, expensive instruments, and trained personnel, making them unsuitable for routine residential inspections. Acoustic and ultrasonic sensing methods have also been widely used, as PD generates measurable high-frequency emissions (Z. Weixia *et al.*, 2012). However, traditional systems remain non-portable, costly, and impractical for household use.

Commercial portable devices, such as the Sonus PD Pro and UE Systems Ultraprobe 9000, demonstrated high sensitivity and portability but are prohibitively expensive (often exceeding RM 9,000) and require calibration or trained operation. Research prototypes offered promising low-cost alternatives, such as the ultrasonic-based systems by Radzi *et al.* (2020) and the acoustic emission devices by Ranachowski

et al. (2022). Nevertheless, these designs are limited by single-sensor configurations, a lack of proximity verification, and minimal consideration for portability or user-friendliness in domestic environments.

While PD detection is well established for industrial and high-voltage systems, there remains a clear gap in developing compact, affordable, and user-friendly solutions for residential wiring. This study addressed that gap by presenting a proof-of-concept portable diagnostic device that integrates an acoustic emission sensor (MAX4466), an ultrasonic distance sensor (HC-SR04), and an ESP32 microcontroller (2023). The system enabled real-time monitoring, dual-sensor validation, and proximity-based verification, thereby reducing false positives and improving reliability. By facilitating early detection of insulation faults, the proposed device aimed to enhance electrical safety, prevent failures, and provide a practical diagnostic tool for domestic applications.

The novelty of this work lies in the integration of acoustic emission sensing and distance verification into a compact, portable system for non-intrusive PD detection in domestic wiring environments. Unlike conventional PD measurement techniques that require direct electrical access or high-voltage setups, the proposed method provides a safer and more accessible alternative suitable for low-voltage applications.

Table 1. Summary of selected PD detection devices

Device/ Research	Sensing Method	Portability	Estimated Cost (RM)	Target System	Remarks
UE Systems Ultraprobe 9000 (Shahid <i>et al.</i> , 2020; UE Systems, n.d.)	Ultrasonic	Handheld	High (> RM 9,200)	MV/HV cables	High sensitivity, costly
Sonus PD Pro (IRISS Group, 2022)	Acoustic + Ultrasonic	Handheld	High (> RM 11,500)	MV cables	Requires expert operation
Radzi <i>et al.</i> (2020)	Ultrasonic	Portable prototype	Low (< RM 940)	MV XLPE cables	No proximity validation
Ranachowski <i>et al.</i> (2022)	Acoustic emission sensor	Portable (AE- based)	Medium (~RM 500–1000)	Cable insulation and cable head	Effective for MV cables
This work	Acoustic + Ultrasonic with ESP32	Fully portable	Low (< RM 700)	LV domestic wiring	Real-time monitoring, multi- sensor fusion

II. METHODOLOGY

In this section, the methodology is divided into three main stages: device setup, signal acquisition, and data analysis. First, the device is configured with suitable sensing elements that can capture high-frequency transient signals generated by PD activity. The system is designed to operate passively, meaning that no external power is injected into the wiring during the measurement process. Next, measurements are carried out on selected domestic wiring configurations. The sensor is placed close to the conductor to capture electromagnetic signals induced by possible PD activity. These signals are then processed and converted into digital form using an analogue-to-digital converter (ADC). Finally, the collected data is analysed based on signal amplitude and pattern characteristics. The ADC readings are used as an indicator of PD activity, where higher values generally correspond to stronger discharge events. A threshold-based approach is applied to differentiate between normal conditions, background noise, and potential defects.

A. Experimental Setup

The experimental setup consists of a domestic wiring model, the proposed portable PD diagnostic device, and a data acquisition system. The test wire represents typical household electrical wiring conditions. The developed device is positioned externally without direct electrical connection to the conductor, enabling non-invasive measurement. The sensor captures transient signals generated by PD activity through electromagnetic coupling. All measurements are recorded in ADC values, which represent the magnitude of detected signals. Multiple measurements are conducted to ensure repeatability and consistency of results.

A flowchart of the overall work process is shown in Figure 1, illustrating the systematic procedure for detecting and analysing PD activity in domestic wiring systems. The process begins with device initialisation and parameter setting, followed by positioning the device near the test wire for non-intrusive measurement. The system then continuously monitors PD activity. If no PD activity is detected, monitoring continues. Once PD is identified, the acquired data is analysed and an alert is generated. The results are then evaluated, and the experiment is repeated using different

cables conditions to verify the reliability and performance of the proposed diagnostic device.

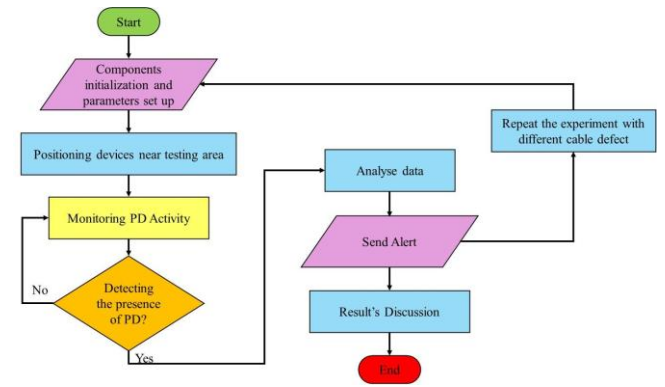


Figure 1. Project Flowchart.

B. Device Operation and Measurement Procedure

This work utilises two primary sensors, particularly acoustic emission (AE) sensors (MAX4466) and the ultrasonic distance sensor (HC-SR04), as shown in Figure 2. These sensors, together with the ESP32 microcontroller, form the core components of the proposed portable PD diagnostic device. The detailed operational workflow of the system is summarised in Table 2.



Figure 2. (a) Acoustic emission sensors (MAX4466); (b) ultrasonic distance sensor (HC-SR04)

The MAX4466 acoustic sensor is employed to detect acoustic emissions generated by PD activity for low-noise environments. During a PD activity, rapid localised energy release within insulation defects produces high frequency pressure waves. These acoustic signals are captured by the sensor and converted into analogue voltage signals. The built-in operational amplifier, with adjustable gain ranging from 25 to 125, enhances the sensitivity of the sensor, allowing detection of weak PD-related signals in domestic wiring conditions. Previous studies have shown that acoustic emission techniques are effective in detecting PD activity, particularly in identifying insulation defects and localised discharge sources (Ranachowski *et al.*, 2022; Cselkó *et al.*, 2011). In addition, advancements in MEMS technology have enabled the development of compact and sensitive AE sensors suitable for such applications (Aggelis *et al.*, 2021).

Table 3. Operation of Portable PD Diagnostic Device

No	Component	Process	Description	Output
1	MAX4466 Acoustic Sensor	Signal Detection	Detects acoustic emissions generated by partial discharge activity	Analogue signal
2	HC-SR04 Ultrasonic Sensor	Distance Monitoring	Measures distance to ensure consistent sensor positioning and reduce measurement variation	Distance data
3	Signal Conditioning Circuit	Signal Processing	Filters noise and amplify weak PD signals for better detection	Conditioned signal
4	ESP32 Microcontroller	ADC Conversion	Converts analogue signals into digital ADC values	ADC reading
5	ESP32 (Processing Unit)	Data Analysis	Analyses ADC values based on predefined thresholds	PD indication level
6	Output System	Alert & Display	Displays results and triggers alert when PD is detected	Warning / status output

The analogue signals obtained from the MAX4466 are then processed by the ESP32 microcontroller, where they undergo signal conditioning and analogue-to-digital conversion (ADC). The resulting ADC values represent the magnitude of the detected transient signals and are used as an indicator of PD activity. The detection principle of the proposed system is based on passive sensing. During a PD activity, rapid ionisation within insulation defects produces high-frequency transient signals and associated emissions. These signals propagate along the conductor and surrounding medium, generating detectable acoustic disturbances. The sensor captures these signals through indirect coupling mechanisms without requiring direct electrical contact or external power injection into the test wire. This passive sensing approach enables safe and non-intrusive monitoring of domestic wiring systems, making the proposed device suitable for portable PD detection applications.

To ensure consistency and reliability in the measurement process, the HC-SR04 ultrasonic sensor is used to monitor the distance between the device and the test wire. The distance is calculated equation (1):

$$d = \left(\frac{v \times t}{2} \right) \quad (1)$$

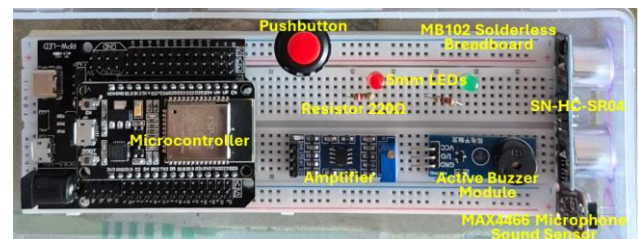
Critical distance detection from the cable was determined, where v is the speed of sound (343 m/s), and t is the measured time delay. In this study, a critical distance of approximately 5 cm is maintained to ensure accurate signal acquisition and to minimise the influence of environmental noise.

The use of the ultrasonic sensor serves as a positioning verification mechanism rather than a PD detection tool. By ensuring that the device is correctly aligned with the test cable, the likelihood of false detection due to improper

placement or external interference is reduced. Similar approaches have been reported in previous studies, where maintaining close proximity to the PD source improves detection accuracy and reliability (Shahid *et al.*, 2020). In this work, the integration of acoustic sensing with distance verification enables a practical and non-intrusive approach for PD detection in domestic wiring systems. A pictorial representation of the developed portable PD diagnostic device and its components is shown in Figure 3.



(a)



(b)

Figure 3. (a) Portable diagnostic devices; (b) Portable Device Components

C. Signal Processing Flow and Algorithm

The structured signal processing flow shown in Figure 4 ensured high reliability by combining amplification, frequency filtering, and dual-condition validation. The result was a portable, low-cost PD detection solution that provided accurate and timely alerts while being easy to operate in residential environments. The operation of the portable PD

detection device began with an initialisation stage, where the ESP32 microcontroller powered up and performed a self-check to ensure all components were functioning correctly. This included verifying the AE sensor (MAX4466), the ultrasonic distance sensor (HC-SR04), the operational amplifier, and the bandpass filter. During this stage, the system also set threshold values for detection, specifically an ADC limit of 2500 counts and a distance limit of 5 cm.

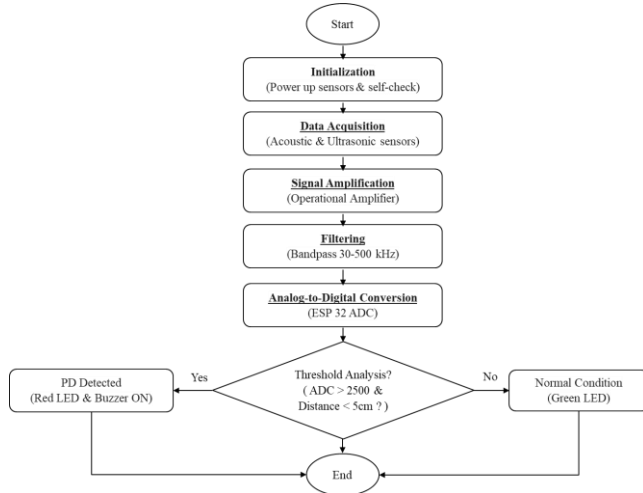


Figure 4. Signal Processing Flow

Once initialisation was complete, the device proceeded to the data acquisition stage. In this step, the acoustic sensor captured high-frequency sound waves generated by PD activity inside the cable insulation, particularly around exposed cable areas in this work. Meanwhile, the ultrasonic sensor measured the distance between the device and the cable surface to ensure that measurements were taken within the optimal range of 5 cm. The acoustic sensor produced an analogue voltage proportional to the detected sound pressure, while the ultrasonic sensor output digital pulses corresponding to the measured distance.

The analogue output from the acoustic sensor was typically weak, often in the millivolt range, and was therefore passed through an operational amplifier integrated into the MAX4466 module. This amplifier had an adjustable gain ranging from 25 to 125 times, allowing small PD signals to be amplified to measurable levels. Amplification was necessary to ensure that low-intensity PD activity was distinguishable from background noise.

After amplification, the signal was passed through a bandpass filter with a 30–500 kHz frequency range. This filter removed low-frequency environmental noise, such as

human speech and mechanical vibrations, and high-frequency interference not associated with PD activity. The filter improved the signal-to-noise ratio by isolating the relevant frequency range, which was crucial for accurate detection.

The ESP32's 12-bit ADC converted the filtered analogue signal into a digital signal, which provided a resolution from 0 to 4095 counts. This conversion enabled precise measurement of voltage changes caused by PD activity, allowing the system to process and analyse the data in real time.

Once digitised, the signal was evaluated using a dual-condition threshold analysis. The first condition was to check whether the ADC reading exceeded 2500 counts, indicating significant acoustic activity consistent with PD. The second condition verified whether the measured distance from the ultrasonic sensor was 5 cm or less, confirming that the device was positioned correctly relative to the cable. PD was only classified as detected when both conditions were met, thereby reducing false positives caused by distant noises or unrelated environmental sounds.

If a PD activity was detected, the system activated a red LED and a buzzer to alert the user, while turning off the green LED. In the absence of PD, the green LED remained on to indicate normal cable conditions, with the red LED and buzzer inactive, as shown in Table 3. An example of PD occurrence testing is presented in Figure 5. Additionally, the system could be configured to log detection data or transmit it wirelessly for remote monitoring and historical analysis.

Table 3. The proposed system description

Description	Green LED	Red LED	Buzzer
Less than 5cm	OFF	ON	ON
More than 2500 bits			
More than 5cm	ON	OFF	OFF
Less than 2500 bits			

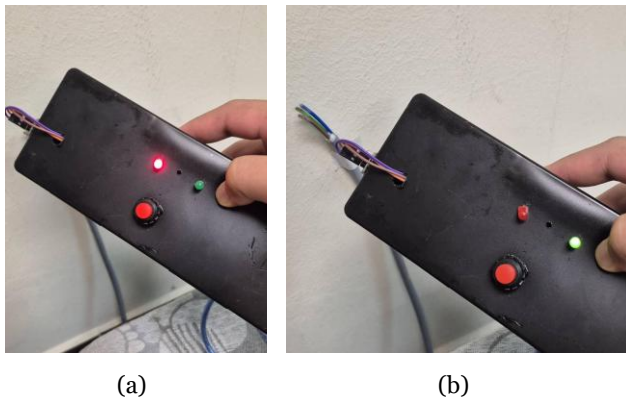


Figure 5. The LED indicates (a) high (red LED ON) and (b) low (green LED ON) chance for a PD activity to occur

D. Cable Testing

The cable was tested on standard and exposed (defective) cable conditions, as shown in Figure 6, to evaluate the device's functioning in detecting early signs of PD under various cable conditions as follows:

- i. Normal cable;
- ii. Abnormal Cable with one defect;
- iii. Abnormal Cable with two defects and
- iv. Abnormal Cable with three defects.

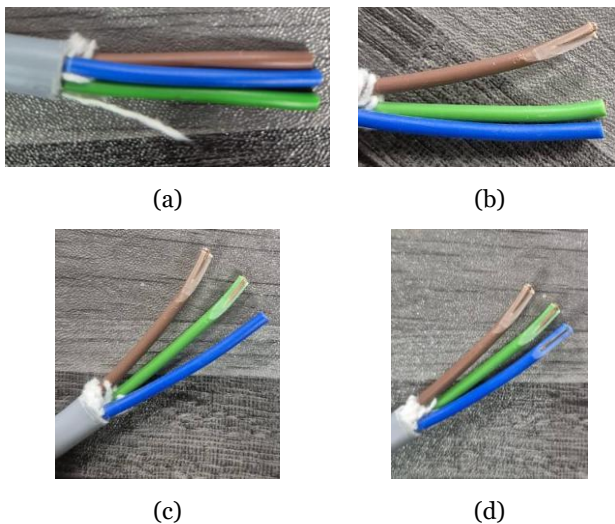


Figure 6. The pictorial view of (a) normal cable condition; (b) abnormal cable with one defect; (c) abnormal cable with two defects; and (d) abnormal cable with three defects.

A typical domestic three-core wiring cable was used during cable testing under standard installation conditions to represent a 400V setup. The cable condition shown in Figure

6a appears undamaged, with no cracks or tears in the insulation. All three conductors were well insulated, and no damage was visible in the sheath. This intact wiring served as a reference for detecting PD in subsequent tests.

Cable testing under abnormal conditions, shown in Figures 6b, 6c, and 6d, was crucial for detecting and diagnosing specific defects that may compromise domestic wiring systems. Targeted tests can identify the presence and characteristics of individual defects by simulating fault scenarios such as PD, enabling timely corrective actions to prevent potential system failures. During abnormal condition testing, visual inspection revealed intentionally induced damage exposing the copper core. This insulation defect simulated natural deterioration, scratches, or errors that can trigger PD activity at lower voltages. Such testing was allowed to assess the system's response in a PD-prone environment.

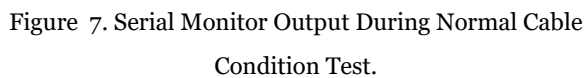
III. RESULT AND DISCUSSION

This section discusses the experimental findings of the developed PD detection system under different cable conditions. The results obtained from the experimental measurements are analysed based on the proposed ADC classification framework.

A. Normal Cable Condition

The experimental results are presented in terms of ADC values corresponding to detected signal amplitudes. The analysis focuses on identifying patterns that distinguish between normal operation, noise, and potential PD activity. The interpretation of ADC values in this study is based on the relative magnitude and consistency of the detected signals. It was observed that ADC values below approximately 1500 are associated with background noise and normal operating conditions, characterised by irregular and low-amplitude signals. ADC values in the intermediate range (1500–3000) indicate transient disturbances, which may be attributed to minor environmental interference or weak insulation irregularities. These signals are typically inconsistent and do not exhibit repetitive patterns. ADC values exceeding 3000 are associated with high-intensity transient events. These signals demonstrate higher amplitude and more consistent repetition, which are characteristic features of partial

Figure 7 presents the serial monitor output during testing of a normal cable condition. Under normal conditions, the ultrasonic sensor readings remained within the predefined limits, and most PD ADC values stayed below the 2500 threshold. These observations were consistent with the findings of (I. Radzi *et al.*, 2019), who demonstrated that a well-designed ultrasonic sensor system can effectively detect PD activity. Furthermore, in the absence of voids or defects, sensor reading remained within normal limits, confirming the system's capability for early fault detection in power cables. The results validated that the insulation functioned properly and the system reliably differentiated between normal and abnormal conditions.



PD Detection - Distance vs ADC Values (Normal)

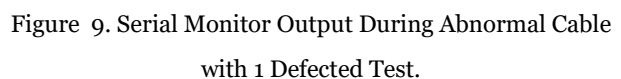
Distance (cm)	Above 2500 (Red)	Below 2500 (Green)
3.00	1875	1257
3.05	2960	1630
3.10	1011	2448
3.15	2272	1530
3.20	1206	1840
3.25	2850	1088
3.30	2315	2346
3.35	1605	1261
3.40	2826	2125
3.45	1378	1728
3.50	2645	912
3.54	2602	1068
3.59	1125	1857

B. Cable Testing under Abnormal Conditions for 1 Defect

Serial Monitor X

Message (Enter to send message to 'ESP32 Dev Mon

Distance: 5.83 cm | PD ADC Value: 2282
 Distance: 5.83 cm | PD ADC Value: 1911
 Distance: 3.59 cm | PD ADC Value: 1878
 Distance: 4.22 cm | PD ADC Value: 1450
 Distance: 4.22 cm | PD ADC Value: 2679
 Distance: 3.89 cm | PD ADC Value: 3081
 Distance: 2.60 cm | PD ADC Value: 2252
 Distance: 2.62 cm | PD ADC Value: 3419
 Distance: 2.62 cm | PD ADC Value: 1225
 Distance: 2.62 cm | PD ADC Value: 1225
 Distance: 2.62 cm | PD ADC Value: 2862
 Distance: 2.62 cm | PD ADC Value: 1523
 Distance: 2.62 cm | PD ADC Value: 1990
 Distance: 2.62 cm | PD ADC Value: 2064
 Distance: 2.62 cm | PD ADC Value: 1439
 Distance: 2.62 cm | PD ADC Value: 1632
 Distance: 2.62 cm | PD ADC Value: 2862
 Distance: 2.62 cm | PD ADC Value: 1344
 Distance: 2.62 cm | PD ADC Value: 1137
 Distance: 2.62 cm | PD ADC Value: 3120
 Distance: 4.22 cm | PD ADC Value: 3759
 Distance: 4.22 cm | PD ADC Value: 1616
 Distance: 4.22 cm | PD ADC Value: 1249
 Distance: 4.22 cm | PD ADC Value: 1072
 Distance: 4.22 cm | PD ADC Value: 3153
 Distance: 4.22 cm | PD ADC Value: 2706



For the cable with a single defect, more frequent fluctuations compared to the normal condition can be seen in Figure 10. Several ADC readings surpassed the 2500 threshold, with peaks reaching above 3000. These values suggested localised PD activity caused by the exposed section of the cable insulation. Although not all readings were high, the increased variability highlighted early-stage deterioration and confirmed that the device was sensitive enough to detect minor insulation faults. In this case, the red LED and buzzer would be intermittently activated, alerting the user to a potential early fault.

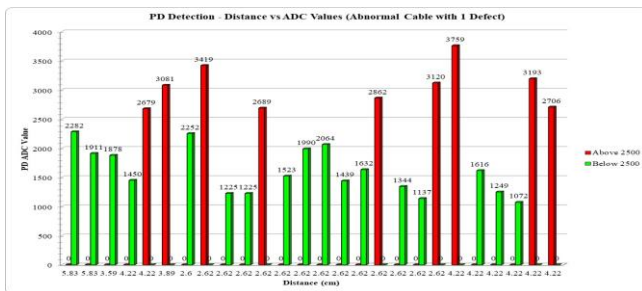


Figure 10. Data Analysis During Abnormal Cable with 1 Defected Test.

B. Cable Testing under Abnormal Conditions for 2 Defect

Figure 11 presents the data observed on the serial monitor during PD detection testing when two cables were exposed (defective). The results demonstrated signal fluctuations and elevated ADC values, with readings exceeding 3000, significantly above the predefined PD threshold of 2500. This observation corroborated prior research (Bissett *et al.*, 2024), which established that progressive insulation degradation correlates with substantially increased PD intensity. Consistent with the detection logic, sustained ADC values surpassing the 2500 threshold and ultrasonic proximity measurements of 5 centimetres or less from the cable surface can trigger PD activity classification. The persistence of supra-threshold ADC measurements, characterised by rapid and sustained spikes, provided robust evidence of abnormal conditions. This dual-sensor validation mechanism effectively minimises false positives from ambient noise while confirming genuine insulation degradation events.

Serial Monitor	
Message (Enter to send message to 'ESP32 Dev Modu	
Distance: 2.30 cm PD ADC Value: 635	
Distance: 2.28 cm PD ADC Value: 774	
Distance: 2.30 cm PD ADC Value: 944	
Distance: 2.30 cm PD ADC Value: 1125	
Distance: 2.30 cm PD ADC Value: 1264	
Distance: 2.30 cm PD ADC Value: 1460	
Distance: 2.30 cm PD ADC Value: 1840	
Distance: 2.30 cm PD ADC Value: 2064	
Distance: 2.28 cm PD ADC Value: 2193	
Distance: 2.30 cm PD ADC Value: 2330	
Distance: 2.30 cm PD ADC Value: 2443	
Distance: 2.30 cm PD ADC Value: 2539	
Distance: 2.30 cm PD ADC Value: 2672	
Distance: 2.30 cm PD ADC Value: 2828	
Distance: 2.28 cm PD ADC Value: 2985	
Distance: 2.30 cm PD ADC Value: 3168	
Distance: 2.30 cm PD ADC Value: 3379	
Distance: 2.30 cm PD ADC Value: 3501	
Distance: 2.30 cm PD ADC Value: 3633	
Distance: 2.30 cm PD ADC Value: 3748	
Distance: 2.30 cm PD ADC Value: 3647	
Distance: 2.30 cm PD ADC Value: 3309	
Distance: 2.30 cm PD ADC Value: 2863	
Distance: 2.30 cm PD ADC Value: 2451	
Distance: 2.30 cm PD ADC Value: 1638	
Distance: 3.26 cm PD ADC Value: 3120	

Figure 11. Serial Monitor Output During Abnormal Cable with 2 Defected Test.

In case of two defects, the graph showed an apparent PD activity as a large portion of the ADC values consistently exceeded 2500, with peaks between 3000 and 3700 can be seen, as shown in Figure 12. Unlike the one-defect scenario, here the supra-threshold readings were more sustained and occurred in sequence, reflecting more severe insulation degradation. The results demonstrated that as the number of defects increases, the magnitude and frequency of PD activity also intensify. The dual-sensor approach ensured that these high values were not caused by noise, confirming the abnormal cable condition with substantial evidence.

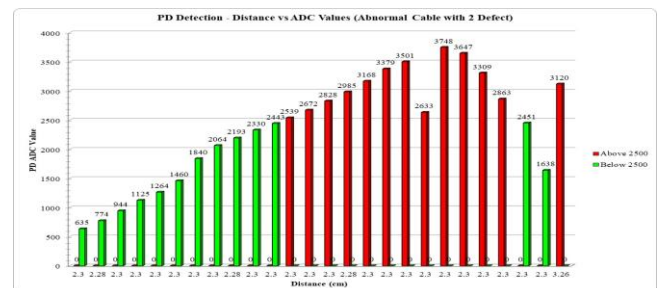


Figure 12. Data Analysis During Abnormal Cable with 2 Defected Test.

D. Cable Testing under Abnormal Conditions for 3 Defect

The output of the serial monitors in Figure 13 reflected the system's response via the ESP32 platform during PD detection testing when three cables were exposed (defective). Most signal values are observed above 2500, with some reaching as high as 4095, indicating strong spikes associated with discharge activity. The ultrasonic sensor continued to measure safe distances; therefore, the PD sensor triggered the alert in this case. This behaviour aligned with the findings

of (M. Shafiq *et al.*, 2019), which indicated that multiple defects along medium-voltage cables can produce overlapping discharge sources and cumulative effects. In this situation, the variations in PD ADC readings were attributed not to cable distance changes but to the defects' electrical condition.

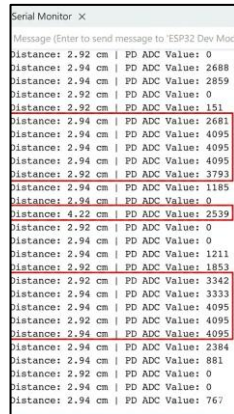


Figure 13. Serial Monitor Output During Abnormal Cable with 3 Defected Test.

As observed in Figure 14, the case with three defects represented the most severe condition, with nearly all ADC values exceeding the 2500 threshold. Multiple readings reached the maximum ADC value of 4095, indicating vigorous discharge activity. Only a few isolated green values (below 2500) were present, while most of the data showed heavy and continuous PD occurrence. This behaviour reflected overlapping discharge sources from multiple insulation failures, resulting in cumulative effects. In this situation, the system generated a constant abnormal signal, with the red LED and buzzer persistently active, indicating a high-risk condition that required immediate intervention.

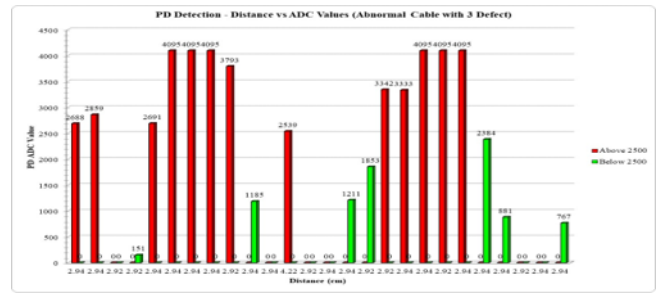


Figure 14. Data Analysis During Abnormal Cable with 3 Defected Test.

IV. CONCLUSION

This study presents the development and validation of a portable, non-intrusive partial discharge (PD) diagnostic device for domestic wiring systems. The system integrates an acoustic emission sensor (MAX4466), an ultrasonic distance sensor (HC-SR04), and an ESP32 microcontroller to enable real-time PD detection without direct electrical contact.

The results show that PD activity can be identified through analysis of ADC signal patterns. A simple classification framework was established, where low ADC values indicate normal conditions, intermediate values represent transient disturbances, and high values (above 3000) suggest significant PD activity. This provides a practical method for assessing insulation conditions in domestic wiring.

The use of passive acoustic sensing improves safety and ease of implementation, while the distance verification feature enhances measurement reliability. Overall, the proposed system demonstrates strong potential as a cost-effective and user-friendly tool for early detection of insulation defects. Future work may focus on calibration with standard PD measurement techniques to enable more accurate and quantitative analysis.

V. ACKNOWLEDGEMENT

The authors sincerely thank Universiti Tun Hussein Onn Malaysia (UTHM) for providing financial support and access to its facilities. This research was funded through the Tier 1 Grant (Vote No. Q362). The facilities and financial support provided by UTHM have significantly contributed to the successful execution and progress of this research project.

I. REFERENCES

- Aggelis, DG, Sause, MGR, Packo, P, Pullin, R, Grigg, S, Kek, T & Lai, Y-K 2021, 'Structural health monitoring damage detection systems for aerospace', Springer Aerospace Technology, pp. 175-217.
- Ahrens, M 2013, 'Lightning fires and lightning strikes. National Fire Protection Association', Quincy, MA.
- Babrauskas, V 2008, 'Research on electrical fires: The state of the art', Fire Saf. Sci, vol. 9, pp. 3-18.
- Bissett, JV, van Vuuren, PA and Walker, JJ 2024, 'Evaluation of unconventional partial discharge and Tan Delta assessment techniques on medium voltage cable terminations with artificial defects', SAIEE Africa Research Journal, vol. 115, no. 1, pp. 24-26. <https://doi.org/10.23919/saiee.2024.10463754>
- Campbell, RB 2019, Home electrical fires: National Fire Protection Association Quincy, MA, USA.
- Cselkó, R, Tamus, ZÁ and Berta, I 2011, 'Practical issues of partial discharge testing of low-voltage cables', in 2011 Electrical Insulation Conference (EIC), pp. 83-87.
- Ghaedi, A, Mahmoudian, M, Eduardo, MG, Rodrigues and Melicio, R 2025, 'Localization of partial discharge in the high voltage apparatus', Results in Control and Optimization, vol. 19, p. 100562. <https://doi.org/10.1016/j.rico.2025.100562>
- Hussain, GA, Hassan, W, Mahmood, F, Shafiq, M, Rehman, H and Kay, JA 2023, 'Review on Partial Discharge Diagnostic Techniques for High Voltage Equipment in Power Systems', IEEE Access, vol. 11, pp. 51382-51394. <http://dx.doi.org/10.1109/ACCESS.2023.3279355>
- IRISS Group 2022, 'Sonus PD Pro operating manual', retrieved August 12, 2025, <<https://cdn-assets.iriss.com/Main/Products/Product%2BManuals/2022%2BSonus%2BPD%2BPro%2BOperating%2BManual.pdf>>.
- Pattanadech, N, Haller, R, Kornhuber, S & Muhr, M 2023, 'Partial Discharges (PD): Detection, Identification and Localization', Wiley-IEEE Press.
- Radzi, I, NA, NH, N, Rameli, M, Abd Rahman, M, Ahmad, and A, Salleh 2019, 'Partial discharge detection device using ultrasonic sensor on medium voltage XLPE cable', All Open Access, Gold, Green.
- Radzi, IF, Nik Ali, NH, Rameli, N, Mohd Ariffin, A, Abd Rahman, MS, Ahmad, MR and Salleh, AS 2020, 'Partial discharge detection device using ultrasonic sensor on medium voltage XLPE cable', Indonesian Journal of Electrical Engineering and Computer Science, vol. 17, no. 2, pp. 886-894. <https://doi.org/10.11591/ijeecs.v17.i2.pp886-894>
- Ranachowski, Z, Wieczorek, K, Ranachowski, P & Dębowski, T 2022, 'Monitoring of partial discharges in cable insulation and cable head using acoustic method', Archives of Acoustics, vol. 47, no. 2, pp. 259-265.
- Shafiq, M, Robles, G, Hussain, A, Kauhaniemi, K and Lehtonen, M 2019, 'Identification and Location of Partial Discharge Defects in Medium Voltage AC Cables', Nordic Insulation Symposium.
- Shahid, MA, Khan, TM, Zafar, T, Hashmi, MF and Amir, F 2020, 'Novel health diagnostics schemes analyzing corona discharge of operational aerial bundled cables in coastal regions', IEEE Transactions on Power Delivery, vol. 36, no. 1, pp. 84-91.
- Standard, I 2000, 'High-voltage test techniques: partial discharge measurements', IEC-60270, pp. 13-31.
- UE Systems, Inc. (n.d.). The Ultraprobe 9000 manual. UE Systems, Inc., <<https://www.uesystems.com>>.
- Weixia, Z, Xianping, Z, Z. Shutao, Z, Hong, Y, and Dada, W 2012, 'Study on Partial Discharge Detection of 10kV XLPE Power Cable', TELKOMNIKA Indones. J. Electr. Eng, vol. 10, pp. 1795-1799.
- Yaacob, M, Alsaedi, MA, Rashed, J, Dakhil, A and Atyah, S 2014, 'Review on partial discharge detection techniques related to high voltage power equipment using different sensors', Photonic sensors, vol. 4, pp. 325-337.
- Zhang, X, Pang, B, Liu, Y, Liu, S, Xu, P, Li, Y, Liu, Y, Qi, L and Xie, Q 2021, 'Review on detection and analysis of partial discharge along power cables', Energies, vol. 14, no. 22, p. 7692. <https://doi.org/10.3390/en14227692>