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# MONITORING OF PARTIAL DISCHARGES AS A TOOL FOR ASSESSING THE INSULATION CONDITION OF A 110 KV CABEL LINE

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**Abstract:** *Partial discharges most commonly occur in high voltage electrical equipment systems, such as transformers, cables, and insulators. This paper presents the results of long term online monitoring of partial discharges on a 110 kV cable line connecting the Obrenovac Substation and the TENT A SP Substation. The analysis of the acquired data enabled an assessment of the criticality of the cable line condition, indicating that the recorded activities do not pose a risk to the internal insulation and that the monitored section was classified within the ,,Green'' category. These findings confirm the importance of online partial discharge monitoring as a reliable tool for preventive maintenance and for reducing the risk of operational interruptions.*

**Keywords:** Monitoring, partial discharges, cable line, diagnostics, condition assessment.

## 1. INTRODUCTION

Partial discharges (also referred to as partial or incomplete discharges) are phenomena that occur in electrical systems, particularly within insulating materials, where local defects may develop due to the presence of inhomogeneities or irregularities in the insulation structure [1]. One of the main challenges limiting the widespread application of partial discharge testing in distribution and transmission networks is the high cost associated with the acquisition of measurement and diagnostic equipment for insulation fault detection, which often restricts its practical implementation [2].

The importance of partial discharge monitoring cannot be sufficiently emphasized, as such measurements not only enable the early identification of potential insulation defects but also contribute to the optimization of maintenance processes, as well as to increased reliability and operational safety of high voltage systems [3].

Depending on the location of occurrence and the physical mechanism, partial discharges are most commonly classified into the following types [4]:

- internal partial discharges, which occur within the insulation, most often in gas-filled voids,
- surface partial discharges, which develop along the surface of insulating materials, typically in the presence of moisture or contamination,
- floating potential discharges, which occur on metallic parts that are not properly grounded or are electrically floating.

The paper presents a system for online monitoring of partial discharges (PD) that uses sensors to collect signals [5]. These sensors feature high technical performance, including high sensitivity, uniform frequency response, high noise immunity, self-calibrating coil, and exceptional dielectric strength. Thanks to these characteristics, the system enables mass installation at strategic points of the cable line. This approach aligns with modern monitoring architectures developed for pilot distribution grids which utilize powerful data processing tools for PD pulse discrimination, source localization,


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clustering, and defect identification [6].

The intelligent software integrated into the system is capable of automatically separating different sources of partial discharges and recognizing the condition of the insulation of the cable line. This approach enables technical personnel to perform periodic checks of the equipment insulation condition without the need for specialized training in the field of partial discharges. In order to determine the rough state of the insulation, a basic knowledge of PD is required, while only a small percentage of suspicious cases must be referred to experts specialized in detailed PD measurements.

The aim of this paper is to demonstrate, based on real operational data the application of modern diagnostic methods in the assessment [1] of the insulation condition of cable lines as well as to highlight the importance of proper interpretation of measurement results.

## 2. CONTINUOUS MONITORING SYSTEM OF THE CABLE LINE OBRENOVAC SUBSTATION – TENT A SP SUBSTATION

### *2.1 CABLE LINE OBRENOVAC SUBSTATION – TENT A SP SUBSTATION*

The underground 110 kV cable line connects the substations TS Obrenovac and TS TENT A SP, as well as optical cables which are a functional unit of the power cable.

As part of the analyses carried out due to change in the state of the power system caused by the „shutdown'' of fossil fuel generation capacities, in this particular case the Kolubara Thermal Power Plant, it was concluded that the most optimal solution is the introduction of a 220/110 kV transformation at the Obrenovac substation and its connection with the TENT A SP substation via the newly constructed cable line. In this way, the energy from TS TENT A could be transmitted through the available transmission lines and neighboring facilities into the system, which would ensure a safe and reliable power supply to consumers in the Kolubara area.

In accordance with the internal standard of EMS (Elektromreža Srbije), for the 110 kV network, cables with a conductor section of 1000 mm² Al with electrical protection of a section of 95 mm² Cu are used. However, taking into account the required minimum nominal current of 900 A, and the real situation in the field where the cable is laid at a depth of 4.5 meters, it was found that the necessary condition for achieving the nominal current is an increase in the cross section of the conductor. Due to all of the above the installation of the A2XS(FL)2Y 1400/120 64/110 kV cable with cross linked polyethylene XLPE insulation was carried out. Optical cables that belong to the telecommunications system and are used for signal transmission and detection of mechanical damage are also laid along the entire route of the cable line in the same channel. In addition to the telecommunications equipment, active equipment for thermal monitoring, equipment for detecting mechanical damage, as well as equipment for online monitoring of partial discharges in real time has been installed [5].

For diagnostic purposes an online partial discharge monitoring system was installed, enabling continuous monitoring of activities during the period from 3. June 2025 to 30. September 2025. Sensors were placed in both substations mentioned, which enabled monitoring of partial discharges by phase and their precise spatial localization.

The measurement methodology included the following activities:

- continuous recording of partial discharge signals,
- analysis of discharge amplitude and frequency,
- formation of phase-resolved patterns,
- monitoring of daily and hourly activity evolution.

Based on predefined criteria each detected activity is classified into the appropriate criticality category. Special attention is paid to distinguishing discharges that may threaten internal isolation from

those that are external or critical in nature.

## 3. CONTINUOUS PARTIAL DISCHARGE MONITORING SYSTEM

This system consists of an acquisition unit, whose main role is to collect and process signals that are detected locally using sensors mounted on cable ends, then a fiber optic communication network and a local data storage server. There are two measuring points on the project, one at the beginning and the other at the end of the 110 kV underground cable line that connects the substation TS 400/220/110 kV Obrenovac with the substation TS 110/6.3 kV TENT A SP.

At each measuring point, a cabinet is mounted in which the acquisition unit is placed. The cabinet is positioned as close as possible to the cable end of the 110 kV cable for better signal detection. The total length of the cable is 985 meters, which is shown in Figure 1. The acquisition unit detects and collects signals through the HFCT sensor, while the fiber optic communication network connects each acquisition unit (placed inside the cabinet) with a local server mounted in a 19'' rack located in the Obrenovac substation.



*Fig 1. The route of the underground 110 kV cable line*

The architecture of the entire system which serves as a pilot project mounted on an underground 110 kV cable line connecting TS Obrenovac with TS TENT A SP is shown in Figure 2.

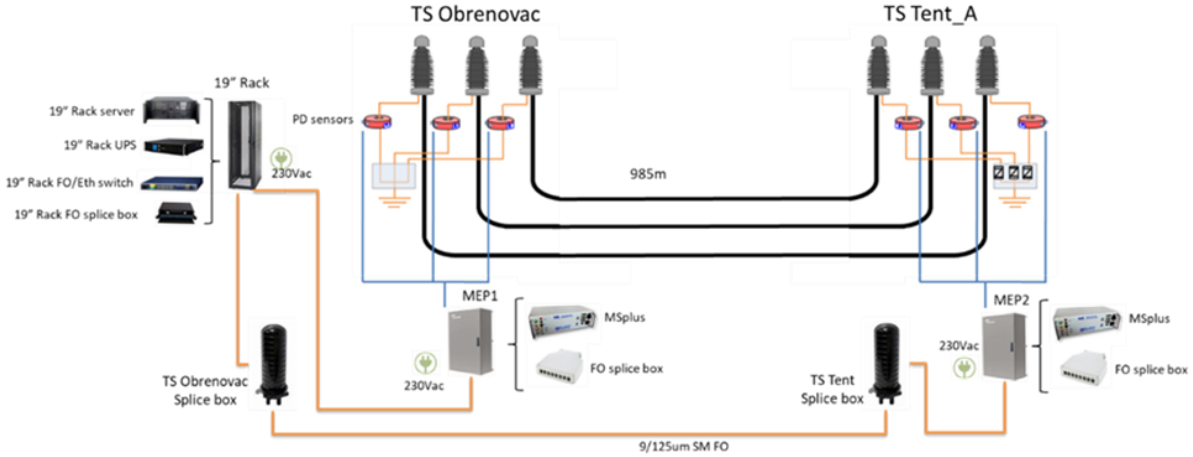



***Fig 2.*** *Functional Block Diagram of the Continuous Monitoring System*

High frequency current transformers (HFCT)[7] are the sensors that are most often used to measure partial discharge. In the absence of application standards the characteristics of these sensors are not clearly specified. However, the most important features that these sensors must satisfy are the following:

- Transfer impedance better than 8 mV/mA in the measurement range from 1 MHz to 30 MHz,
- Self-test capability using an auxiliary signal injection coil,
- Interference immunity better than -40 dB, for frequencies up to 30 MHz to limit interference,
- Dielectric strength greater than 10 kV at 50 Hz,
- Good corrosion performance.

Two cabinets with acquisition equipment were installed:

- Cabinet 1 in TS Obrenovac, with three sensors mounted around the shield of the 110 kV cable. Each phase has its own sensor,
- Cabinet 2 in TS TENT A SP, with three sensors mounted around the shield of the 110 kV cable. Each phase has its own sensor.

The cabinet installation locations are shown on a and b on Figure 3.



a) b)

*Fig3. a) TS Obrenovac, b) TS TENT A SP*

Each cabinet contains the following components:

- Mounting plate 600x600x300 mm x mm x mm (HxWxD) – stainless steel,
- Terminals X1-X8,
- Surge protection 275VAC, 40kA – 2U1,
- Circuit breaker 25 A, 30 mA – 2Q1,
- 2 x circuit breaker 6 A, 10 kA, curve C – 2F1,
- DIN rail,
- Isolation transformer 230 VAC - 230 VAC – 10 kV – 30 VA - 2T1,
- 2 x Socket – 2E1, 3E1,
- Heater – R91,
- Fan – 3EC1,
- Thermostat – 3BT2,
- MS Plus acquisition,
- Optical cable splicing box,
- Lamp – 3H1,
- Cable glands,
- Filter.

## 4. PERIODIC REPORT ON PARTIAL DISCHARGE MONITORING OF THE CABLE LINE TS OBRENOVAC – TS TENT A SP

As already mentioned the installed system monitored partial discharges in the period from 3. June 2025 to 30. September 2025, and all registered discharges are shown in Table 1.

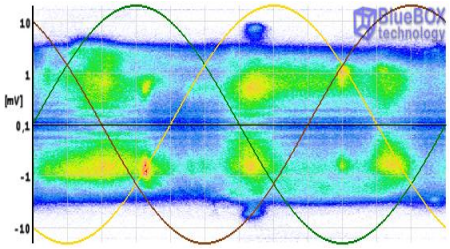
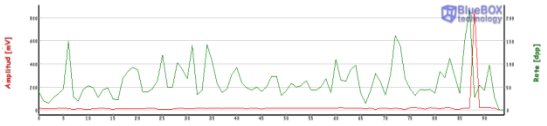
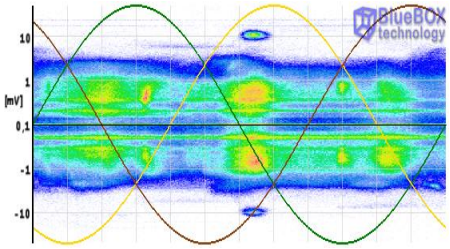
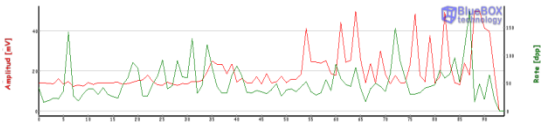
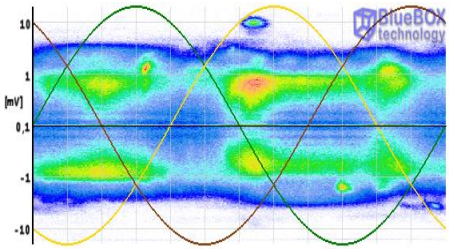
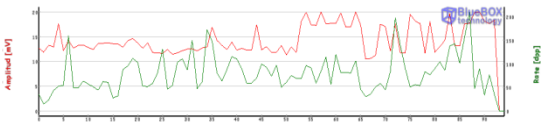
No characteristic pattern of partial discharge phenomena was observed which would represent a risk for the tested section. Based on this it can be concluded that the condition of the cable line between the two power facilities is classified as ,,Green'' criticality.

*Table 1. Registered discharges*

| TS. Obrenovac – TS Tent A | | Phase R | | Phase S | | Phase T | |
|---|---|---|---|---|---|---|---|
| | | Start | Recommendation | Start | Recommendation | Start | Recommendation |
| 0 m | TS Obrenovac | Surface discharge in air 03/06/2025 | Green<br>Registered | Surface discharge in air 03/06/2025 | Green<br>Registered | Surface discharge in air 03/06/2025 | Green<br>Registered |
| | | Floating potential 31/08/2025 | Green<br>Registered | | | | |
| 985 m | TS Tent A | | | Floating potential 31/08/2025 | Green<br>Registered | Floating potential31 /08/2025 | Green<br>Registered |

A cumulative display of the results of partial discharge measurements by phase, registered by sensors which are installed at the Obrenovac substation, is illustrated in Table 2.

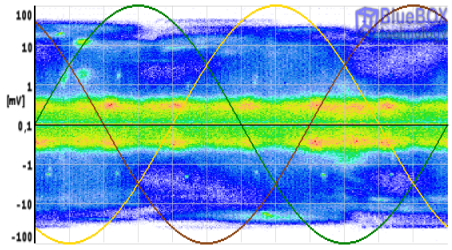
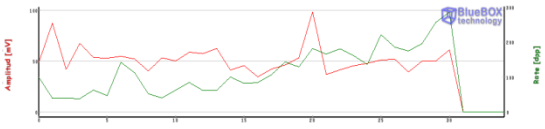
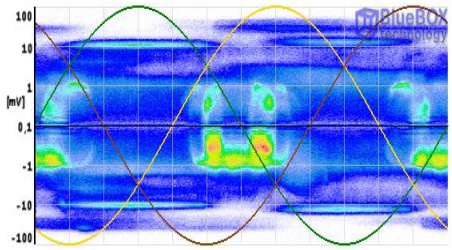
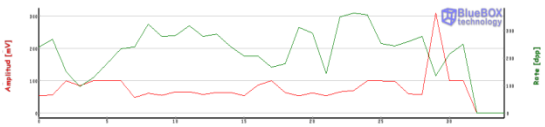
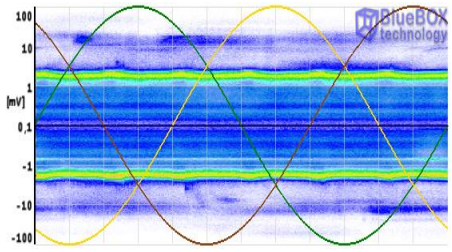
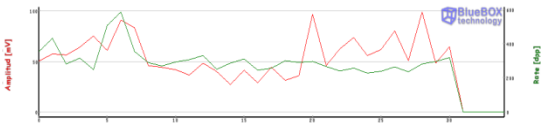
*Table2. Registered discharges at TS Obrenovac*

| **TS. Obrenovac** | | |
|---|---|---|
| **Sensor** | **Phase resolved pattern** | **Daily evolution of amplitude vs. rate [03/06/2025 - 30/09/2025]** |
| **R** | <br>Ampl. Max.: 867 mV Rate Max.: 217 dpp<br>Ampl. Avg.: 23,2 mV Rate Avg.: 62,5 dpp |  |
| **S** | <br>Ampl. Max.: 50,0 mV Rate Max.: 179 dpp<br>Ampl. Avg.: 19,9 mV Rate Avg.: 51,2 dpp |  |
| **T** | <br>Ampl. Max.: 20,0 mV Rate Max.: 211 dpp<br>Ampl. Avg.: 14,5 mV Rate Avg.: 80,4 dpp |  |

A cumulative display of the results of partial discharge measurements by phase, registered by sensors installed in TS TENT A SP, is illustrated in Table 3.

During the observed period, partial discharge monitoring was performed on all three phases of the cable line.

*Table3. Registered discharges in TS TENT A SP*

| TS Tent A SP | | |
|---|---|---|
| **Sensor** | **Phase resolved pattern** | **Daily evolution of amplitude vs. rate [03/06/2025 - 30/09/2025]** |
| **R** |  Ampl. Max.: 98,2 mV Rate Max.: 286 dpp Ampl. Avg.: 52,1 mV Rate Avg.: 120 dpp |  |
| **S** |  Ampl. Max.: 309 mV Rate Max.: 365 dpp Ampl. Avg.: 81,2 mV Rate Avg.: 243 dpp |  |
| **T** |  Ampl. Max.: 98,9 mV Rate Max.: 585 dpp Ampl. Avg.: 56,2 mV Rate Avg.: 304 dpp |  |

## 5. RESULTS AND DISCUSSION

The analysis of the obtained data clearly shows that in the observed time interval no pattern was identified that would indicate the occurrence of dangerous internal partial discharges, which is confirming the safe functioning of the system.

In the TS Obrenovac substation, mainly surface types of discharges in the air as well as occurrences of floating potential were registered. These discharges occurred at all R, S and T phases with intermittent activity that was limited to certain time intervals during the day. The analysis of the amplitudes showed that the mean values remained at a low level while the maximum values were recorded only in short periods of time without any growth tendency.

Floating potential discharges were also registered but with a very small percentage of active time and without significant impact on internal insulation. This phenomenon is characteristic for metal parts that are not completely equalized in potential, and therefore does not represent an immediate danger to the stability and reliability of the cable system.

In the TS TENT A SP substation slightly higher values of discharge amplitudes and frequencies were recorded, however a detailed analysis of phase resolved patterns clearly shows that these discharges also do not indicate degradation of the internal insulation. It is particularly important to point out that the increased current values were not accompanied by a stable increase in frequency which unequivocally indicates the external or transitory nature of the detected phenomena.

The overall analysis of the obtained results confirms that all registered activities are classified in the „Green'' category. This clearly indicates a stable state of the system without the need for emergency or emergency interventions. This classification is a reliable indicator that the detected phenomena do not have a negative impact on internal insulation or work safety and the overall situation can be assessed as satisfactory and under control. This additionally confirms that the system functions within the expected parameters without indications that would require corrective measures.

### *5.1 CRITICALITY ASSESSMENT AND OPERATIONAL SIGNIFICANCE*

The assessment of the criticality of the condition of the cable line was carried out on the basis of a comprehensive analysis of several parameters including the type of partial discharges, their amplitudes, frequency of occurrence and temporal evolution during the observed period. The key factor in making the final assessment was the absence of internal partial discharges as well as the absence of a stable activity growth trend which clearly indicates that the system operates within safe limits and that there are no indications of internal insulation degradation.

Categorizing the condition as „Green'' means that the cable line can continue to work in a completely normal mode with the recommendation that continuous monitoring should be carried out in order to detect any changes in time. Such assessment allows the system operator to avoid unnecessary shutdowns and interventions, which ensures the stability of operation and reliability of supply. It is especially important to emphasize that this approach is of key importance for facilities with high power supply criticality where any interruption can affect the entire functionality and security of the system.

The results of this research confirm that online monitoring of partial discharges is a reliable and effective tool to support decision making in the maintenance process. Its application makes it possible to detect potential problems at the right time which significantly reduces the risk of unplanned downtime and breakdowns. At the same time it ensures rational planning of activities and optimal use of resources which contributes to increasing system reliability and long-term preservation of its functionality.

## 6. CONCLUSION

Monitoring and detection of faults on highnvoltage cable lines are key elements in the maintenance, reliability and efficiency of modern power systems. High voltage cables are a basic component of networks, enabling safe and constant transmission of electricity in industrial, urban and critical infrastructure areas. Bearing in mind the complexity of their structure as well as the high costs of interventions in case of failure continuous monitoring of the condition of cables becomes an inseparable part of the process of exploitation and maintenance planning.

The paper presents the application of online monitoring of partial discharges on a real high voltage cable line between TS Obrenovac and TS TENT A SP substations. The analysis of the obtained measurement

results showed that the registered discharges were mainly of a surface character as well as the occurrence of floating potential which do not represent a risk for the internal insulation of the cable system.

The monitoring system discussed in the work enables the detection of faults in different stages of their development which ensures comprehensive control over the state of the cable system. Monitoring of key parameters such as temperature, load currents, humidity and partial discharges provides the possibility of timely identification of potential problems and taking appropriate measures to eliminate them. Based on a detailed analysis of the collected data an assessment of the criticality of the situation was carried out which determined that the observed section is in the „Green'' category which means stable and safe functioning. The obtained results confirm the justification of the application of online monitoring as an integral part of the modern system of preventive maintenance. Modern approaches based on the use of artificial intelligence enable the automated analysis of large amounts of data collected using various sensors, the integration of which is planned in the presented project in the near future. The application of such systems opens up the possibility of moving from traditional reactive and periodic maintenance to advanced methods of predictive maintenance. This significantly reduces operating costs increases the reliability of the power grid and ensures long term stability of operation.

In conclusion, it can be pointed out that the long term monitoring of partial discharges allows not only early detection of potential problems but also a better understanding of the behavior of the cable system in real operating conditions. This approach represents a significant contribution to improving the reliability and safety of the power system.

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