NL Camera

Partial discharge analysis

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Introduction

The NL Camera is equipped with intelligent partial discharge analysis features as an option. These features will help the user to detect, recognize, and analyze partial discharges, which often indicate problems and impending failures in electricity generation, transmission, and distribution equipment. Some of the partial discharge analysis features are available in the NL Camera itself, while some of the features are available only in the NL Cloud.

What is a partial discharge?

A partial discharge (PD) is, as the name implies, a partial failure of an insulator. This means that electrical charges will move across the insulator either sporadically or, more often, regularly. If the failure progresses, it may lead to complete insulator breakdown. The presence of partial discharges can therefore be used to predict catastrophic system failures and preemptively fix these problems through planned maintenance actions.

Partial discharges may occur across any type of insulator: solid, air, gas, vacuum, or liquid. There are several different types of partial discharges, depending on the type of insulator as well as other factors. These different partial discharge types are described in more detail below.

Using the NL Camera to find partial discharges

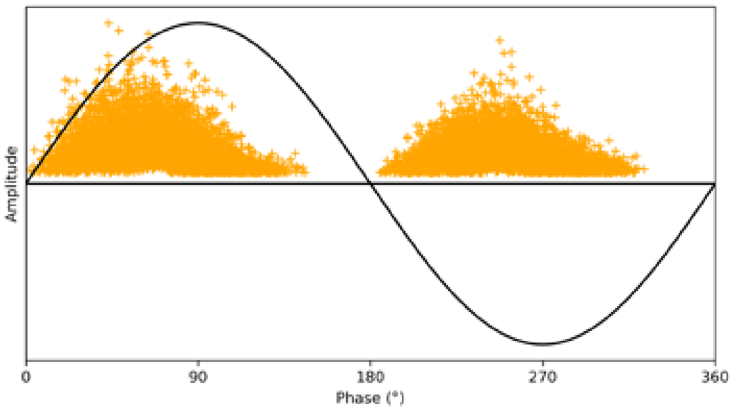
For general usage instructions of the NL Camera and the NL Cloud, please refer to the NL Camera Quickstart Guide. Refer to the Usage techniques chapter regarding hints about how to differentiate between actual sound sources and reflections and how to find weaker sound sources in the presence of stronger sound sources. The Usage techniques chapter also talks about the frequency range and usage distance of the NL Camera.

The NL Camera shows different types of sound sources on the display, not only partial discharges (see the chapter Other sound sources below for some examples). The NL Camera will, however, detect when the sound source in focus (shown with a crosshair on top) is a possible partial discharge and show a so called partial discharge pattern (PD pattern) calculated from that sound signal. You can press the partial discharge pattern view to toggle between a small view and a large view of the pattern.

Partial discharge patterns

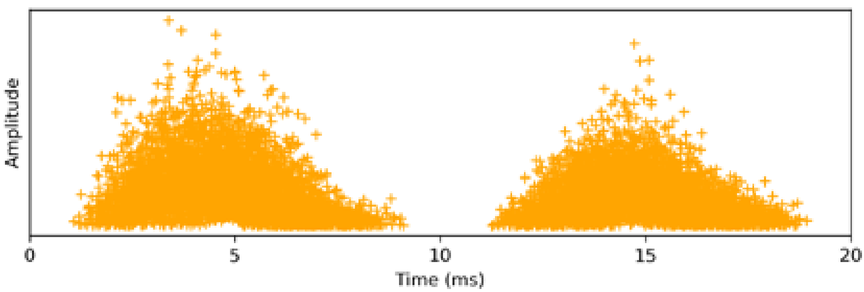
Different types of PD appear as pulses or clusters thereof during different parts of the 50 or 60 Hz period. Electrical measurements of PD can measure the charge transferred during these pulses and show it relative to the phase of the voltage. This is called a phase-resolved PD pattern and usually shows the amplitude of these pulses as well as their location relative to the phase of the voltage, using data gathered over a longer period of time.

There are several different features of a PD pattern that can be used to infer the type of partial discharge in question. For example, the pattern will often have two distinct clusters, e.g., one near the positive voltage peak and one near the negative voltage peak. These clusters may vary in size and shape. The two clusters may either be symmetrical in size and shape, or there can be a large asymmetry between them. In some cases there may be only one cluster instead of two. These different features of PD patterns are discussed in more detail below in the sections covering different types of partial discharges.



Phase-resolved partial discharge pattern.

Both the NL Camera and the NL Cloud will automatically detect a signal with a strong 50 or 60 Hz periodicity and construct a similar PD pattern. However, while electrical PD measurements are often aware of the phase of the voltage, the NL Camera does not have this information available when taking a snapshot. For this reason, the PD patterns constructed from the sound signal will not be phase-resolved.



Partial discharge pattern without reference to the phase of the voltage.

If detected, the PD pattern will be shown in the user interface of the NL Camera and the NL Cloud. Note, that even though a PD pattern is shown, the sound source is not necessarily a partial discharge. For example, some types of low-voltage electronic devices may normally also produce similar periodic patterns.

Partial discharge types

There are several different types of partial discharges with different characteristics. For practical usage, these are classified into three categories in the NL Cloud: discharge on surface or inside component, discharge between components, and discharge into air. Below, these three categories are described in more detail, together with examples of typical PD patterns.

Terminology

The terminology used in this field is not consistent and may cause confusion and misunderstandings. It is not uncommon to use the word corona when talking about any type of (external) partial discharge. When some people talk about partial discharges they mean only internal partial discharges, as opposed to corona and other external partial discharges.

In this document, the word partial discharge is used for any type of partial discharge, external or internal: corona, floating discharge, surface discharge, or internal discharge. The word corona is reserved for actual corona discharges, i.e., partial discharges into air.

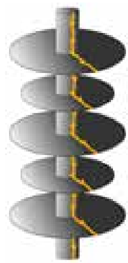
Discharge on surface or inside component

The most critical types of partial discharges are those taking place on the surface of or inside insulating materials. If left untreated, these will often progress and eventually lead to insulator breakdown. Surface discharges and internal discharges both have very similar PD patterns and are therefore classified in the same category in the NL Cloud. Since internal discharges might take place deep inside the components, these may not generate any sound that the NL Camera can pick up. However, if the internal discharges are relatively close to the surface, e.g., in a cable termination, they often emit sound that the NL Camera can localize.

The pattern of these partial discharges is often quite symmetrical between the two half cycles of the voltage, compared with discharges into air. In some cases, the amplitude may differ considerably between the two half cycles.

Surface discharge

Partial discharges across an insulator surface may begin to take place due to contamination or damage to or defects in the insulator surface. So called dry-band arcing may also take place when different regions of the insulator are wet while others are dry. Surface discharges rapidly deteriorate especially organic insulator materials and may easily lead to flashover across the whole insulator [1]. Any sign of surface discharges should therefore be thoroughly inspected and the need for action assessed. The presence of surface discharges depends highly on environmental conditions such as humidity and temperature [2], and this should be taken into account when planning inspections. The term tracking may also be used when talking about surface discharges.



Typical locations:
- All different types of insulators and bushings
- Cable terminations

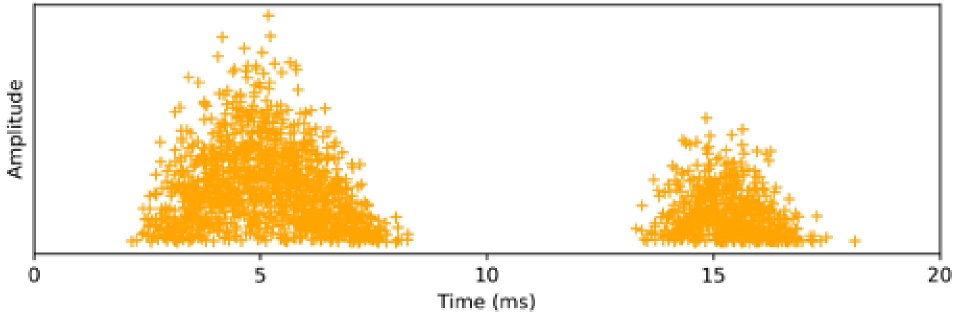
Problems and risks:
- May lead to insulator breakdown and outages

Inspection schedule:
- Regular inspections, for example once every year
- Shorter intervals once partial discharges have been found

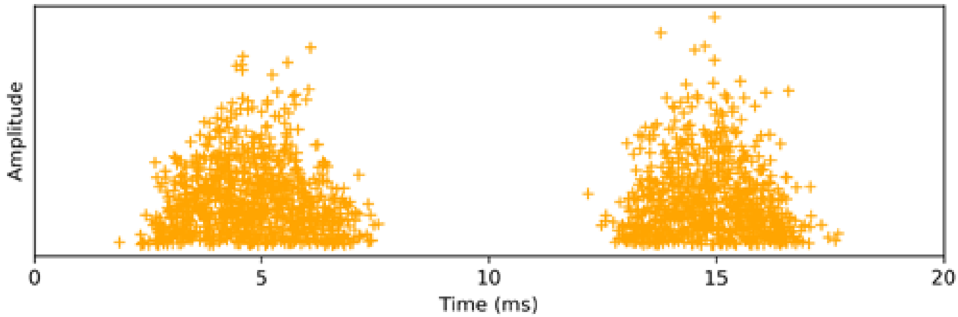
Suggested actions:
- Risk assessment of any detected partial discharges
  - Has the partial discharge progressed over time?
  - What are the risks associated with an insulator breakdown?
- Cleaning or replacement of critical components

Partial discharge pattern

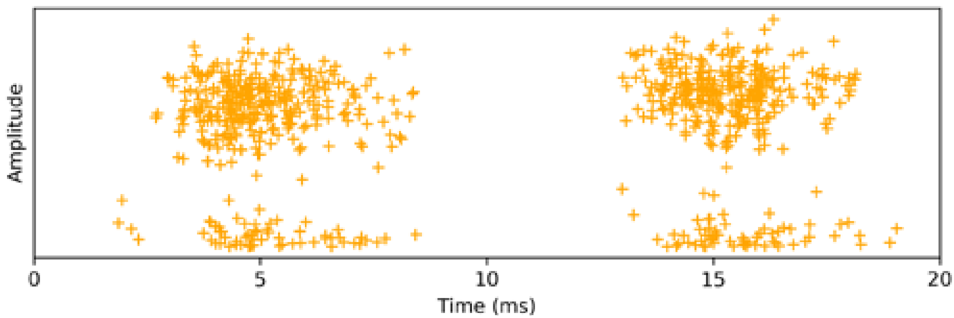
Discharges on the surface or inside components have PD patterns characterized by two clusters of somewhat symmetric shape and size. Surface discharges may, however, have a moderate size difference between the two clusters. The clusters often have a triangular or "hill-like" shape.



Example of the PD pattern of a surface discharge.



Example of the PD pattern of a surface discharge.



Example of the PD pattern of an internal discharge.

Discharge between components

Partial discharges classified under this category are so called floating discharges. Floating discharges have a highly symmetrical PD pattern, with an equal number of discrete discharges during each half cycle of the voltage.

Floating discharge

A floating discharge takes place between a conductor and a metal object at floating potential. Discharges take place when the potential difference between the two objects grows large enough to induce sparking. Floating discharges may be a result of bad contact between different components, for example due to oxidized or contaminated contact surfaces [1]. In some cases, floating discharges are harmless, but they may also be a sign of faults in design or installation, as well as damaged components. Depending on the location of floating discharges, they may lead to more severe problems over time. When found, this type of discharge should always be inspected more closely.

Typical locations:

- Clamps of busbar support insulators
- Ungrounded or poorly grounded components

Problems and risks:

- May indicate damaged components or faulty design or installation

Inspection schedule:

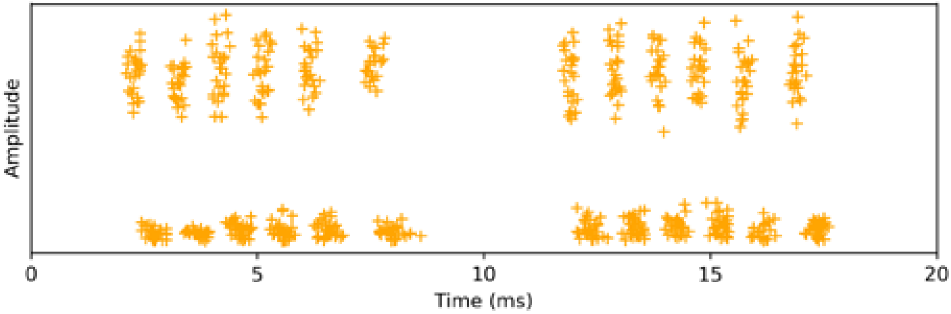
- Inspection when commissioning new substations, power lines, and equipment
- Regular inspections, for example once every two years

Suggested actions:

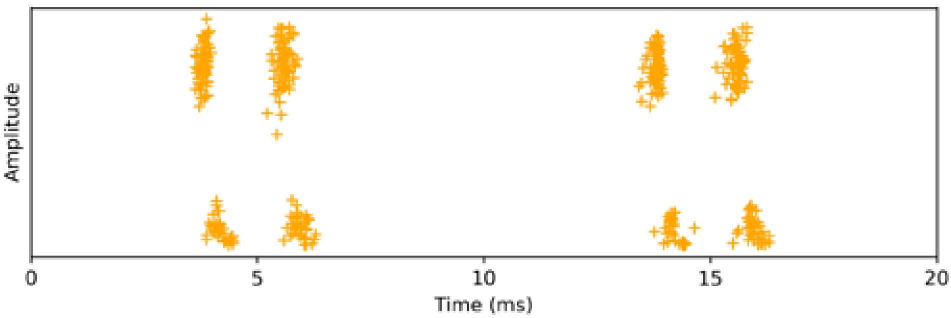
- Risk assessment of any detected partial discharges
  - Is the partial discharge due to bad contact between components?
  - Is this a problem in this specific case?
  - Does the partial discharge indicate design or installation faults or damaged components?
- Repair or replacement of faulty designs and installations as well as damaged components

Partial discharge pattern

Discharges between components, i.e., floating discharges, have a distinct PD pattern. The pattern consists of two clusters of separate pulses. The number of pulses per cluster may vary from one pulse upwards, and it is not uncommon that the number of pulses varies while observing the floating discharge. The two clusters have the same number of pulses and are also otherwise symmetric in size and shape. During each pulse, electrical charge will transfer either from a conductor to an object at floating potential, or from the object at floating potential back to the conductor.



Example of the PD pattern of a floating discharge.



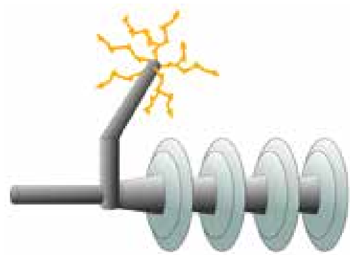
Example of the PD pattern of a floating discharge.

Discharge into air

Partial discharges classified under this category are so called corona discharges. Corona typically produces highly asymmetrical PD patterns. Weak corona has discharges only during the negative half cycle of the voltage. Stronger corona may cause discharges also during the positive half cycle. These discharges have larger amplitude than during the negative half cycle, but the cluster is often not as wide.

Corona discharge

Corona is a partial discharge into air from a sharp point at high potential. Corona discharges take place when the strength of the electric field is large enough to ionize the air. Typically, corona is observed during the negative half cycle of the voltage (so called negative corona). If the electric field strength is high enough, corona can be observed also during the positive half cycle (so called positive corona). Positive corona contains less discharges per half-cycle than negative corona but the amplitude is larger [3]. In some cases, corona may also be observed at overstressed points at ground potential [4]. In most cases, corona is harmless. Corona does, however, cause power loss, electromagnetic interference, and audible noise, which might be a problem in some cases. The most severe problem associated with corona is often that it produces corrosive chemical compounds that damage nearby materials such as insulator surfaces [1].



Typical locations:

- Sharp points, edges, and corners of conductors
- Arcing horns
- Broken strands on power lines

Problems and risks:

- Power loss
- Electromagnetic interference
- Audible noise
- Deteriorates nearby insulating materials

Inspection schedule:

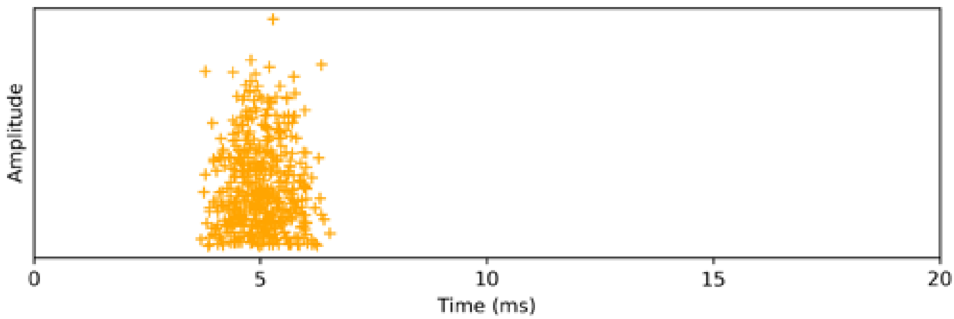
- Inspection when commissioning new substations, power lines, and equipment
- Regular inspections, for example once every two years

Suggested actions:

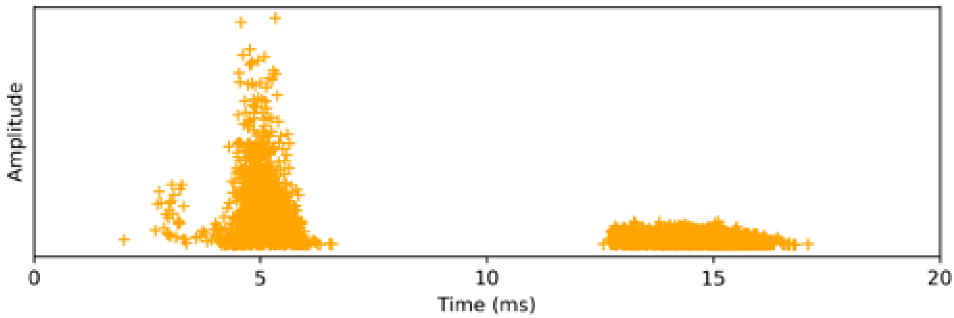
- Risk assessment of any detected partial discharges
  - Is electromagnetic interference or audible noise a problem?
  - Should broken strands be repaired?
  - Are there insulators nearby that might be damaged by the corona?
- Add missing corona rings near insulators
- Repair broken strands

Partial discharge pattern

The PD pattern of partial discharge into air (corona) is highly asymmetrical. In the case of negative corona, there is a single cluster of pulses centered around the negative voltage peak. If the partial discharge is stronger, positive corona can also be observed, in addition to the negative corona. Positive corona can be seen as a cluster of pulses centered around the positive voltage peak. This cluster is significantly larger in amplitude compared to negative corona, and the cluster is typically not as wide.



Example of the PD pattern of negative corona discharge.



Example of the PD pattern of negative and positive corona discharge. Positive corona is seen on the left and negative corona on the right side.

Other sound sources

Since the NL Camera localizes partial discharges based on the sound they emit, it will also show sound sources other than partial discharges. These are often easy to distinguish from partial discharges since they do not produce a PD pattern. Some typical examples of other sound sources that can be found using the NL Camera are listed below.

Vibration

The hum from transformers and reactors, among other things, can cause different components to vibrate. This type of vibration will not produce a PD pattern and can thus easily be distinguished from partial discharges.

Gas leaks

Gas leaks and compressed air leaks produce a hissing sound with a lot of energy at high frequencies. These types of leaks are localized by the NL Camera, but will not produce a PD pattern. Note, that the NL Camera is not a tool intended for finding tiny gas leaks, such as SF6 leaks.

Electronics

Some low-voltage electronic components will produce sound that has a 50 or 60 Hz periodicity. This type of sound will produce a pattern similar to a PD pattern, but are easily distinguished from high-voltage or medium-voltage partial discharges based on their location.

References

1. Kimmo Nepola: Feasibility of radio frequency interference measurements in condition monitoring of high voltage substations. Master's thesis, Aalto University, 2013.

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3. Li-Jung Chen, Ta-Peng Tsao, and Yu-Hsun Lin: New diagnosis approach to epoxy resin transformer partial discharge using acoustic technology. IEEE Transactions on Power Delivery, vol. 20, no. 4, 2005.

4. David A. Nattrass: Partial discharge measurement and interpretation. IEEE Electrical Insulation Magazine, vol. 4, no. 3, 1988.