FLIR Si2-PD

PARTIAL DISCHARGE ANALYSIS

FLIR

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INTRODUCTION

The FLIR Si2-PD and Si2-Pro are equipped with intelligent partial discharge analysis features. 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.

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 a 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 in this guide.

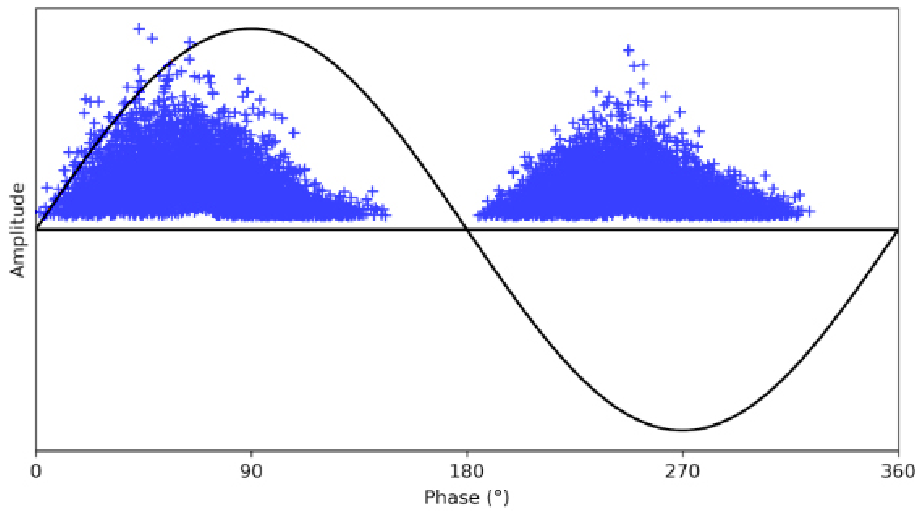
USING THE FLIR SI2 TO FIND PARTIAL DISCHARGES

For general usage instructions of the Si2, please refer to the user manual. The Si2 shows different types of sound sources on the display, not only partial discharges (see the chapter Other sound sources for some examples). The Si2 will, however, detect when the sound source in focus is a possible partial discharge and show a so-called phase-resolved partial discharge (PRPD) pattern calculated from that sound signal. You can press the PRPD to toggle between a small view and a large view of the pattern. For on-device AI-assisted analysis and severity assessment of the detected PD, take a snapshot of it, set the distance, voltage, and component where the PD was detected, and click "PD analysis". A classification of the PD type will be shown, together with the estimated severity of the PD, as well as a description and a recommendation of the detected issue for immediate, in-the-field decision support.

The Si2 features AI-assisted on-device analysis and severity assessment for in-the-field decision support.

PHASE-RESOLVED PARTIAL DISCHARGE PATTERNS

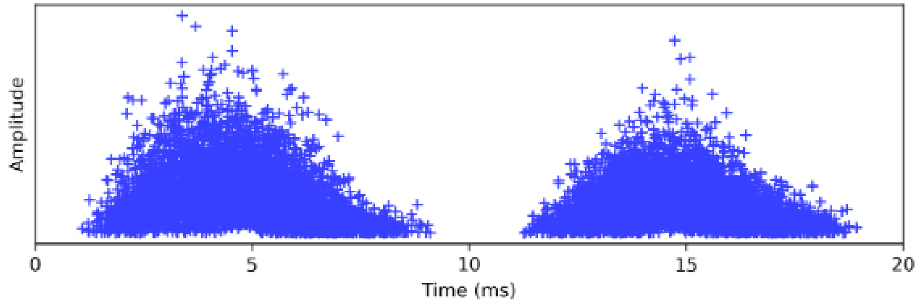
Different types of PD appear as pulses or clusters thereof during different parts of the 50 or 60 Hz period. Electrical measurements of PD can measure the charge transferred during these pulses and show it relative to the phase of the voltage. This is called a phase-resolved partial discharge (PRPD) pattern and it 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.



Phase-resolved partial discharge (PRPD) pattern.

There are several different features of a PRPD 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 PRPD patterns are discussed in more detail below in the sections covering different types of partial discharges.

The Si2 will automatically detect a signal with a strong 50 or 60 Hz periodicity and construct a similar PRPD pattern. However, while electrical PD measurements are often aware of the phase of the voltage, the Si2 does not have this information available. For this reason, the PRPD patterns constructed from the sound signal will have relative phase information but not absolute phase information.



PRPD pattern without reference to the absolute phase of the voltage.

If detected, the PRPD pattern will be shown in the user interface of the Si2. Note, that even though a PRPD pattern is shown, the sound source is not in every case necessarily a partial discharge. For example, some types of low-voltage electronic devices may 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 four categories on the Si2: negative corona, positive and negative corona, floating discharge, and surface or internal discharge. These categories are described in more detail below, together with examples of typical PRPD patterns.

TERMINOLOGY

The terminology used in this field is not always consistent and may therefore 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 superficial 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.

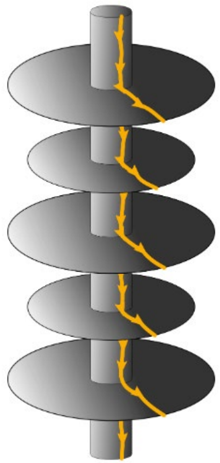
SURFACE OR INTERNAL DISCHARGE

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 PRPD patterns and are therefore classified in the same category on the Si2. Since internal discharges might take place deep inside the components, these may not generate any sound that the Si2 can pick up. However, if the internal discharges are relatively close to the surface, e.g., in a cable termination, they often emit a sound that the Si2 can localize.

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

SURFACE DISCHARGE

Partial discharges across an insulator surface may begin to occur 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 will rapidly cause especially organic insulator materials to deteriorate, 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 for inspections. The term tracking may also be used when talking about surface discharges.



TYPICAL LOCATIONS

- All different types of insulators and bushings
- Cable terminations and joints

PROBLEMS AND RISKS

- May lead to insulator breakdown and outages

INSPECTION SCHEDULE

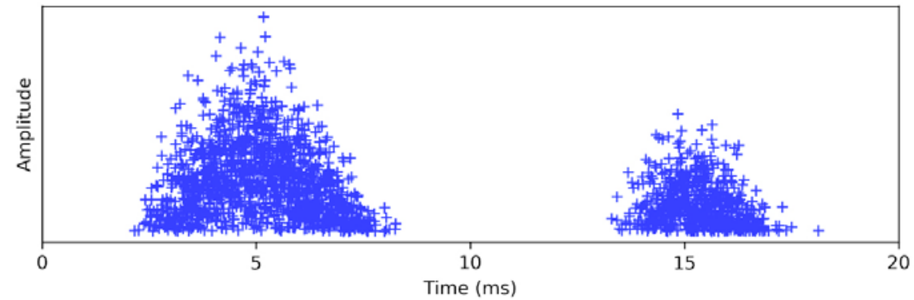
- Regular inspections, for example once every year
- Shorter intervals once potentially severe partial discharges have been found

SUGGESTED ACTIONS

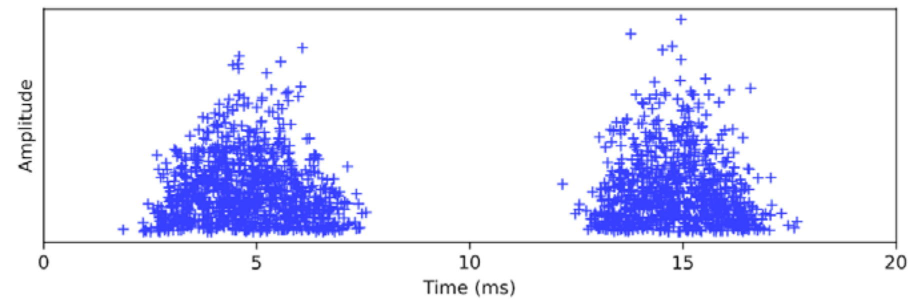
- Risk assessment of any detected partial discharges
- Has the partial discharge progressed over time?
- What are the risks associated with an insulator breakdown?
- Cleaning or replacement of critical components
- Quick replacement of faulty cable terminations and joints

PRPD PATTERN

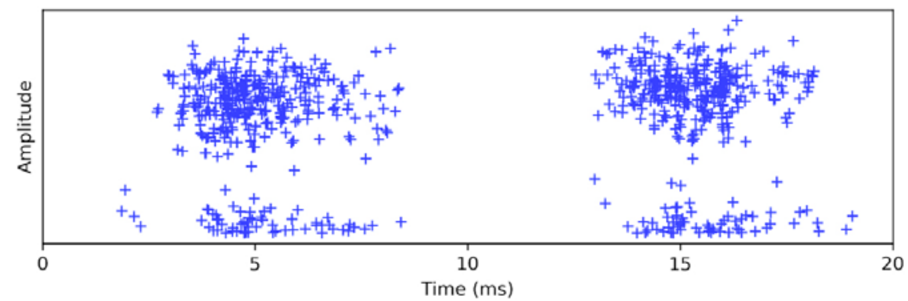
Discharges on the surface or inside components have PRPD patterns characterized by two clusters of somewhat symmetric shape and size. Surface discharges may, however, have a moderate amplitude difference between the two clusters. The clusters often have a triangular or "hill-like" shape.



Example of the PRPD pattern of a surface discharge.



Example of the PRPD pattern of a surface discharge.

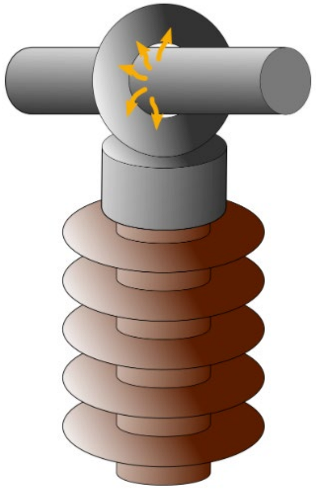


Example of the PRPD pattern of an internal discharge.

FLOATING DISCHARGE

Floating discharges take place between two components or parts of a medium or high-voltage system. Floating discharges have a highly symmetrical PRPD pattern, with an equal number of discrete discharges during each half cycle of the voltage.

A floating discharge takes place between a conductor and a metal object at a 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

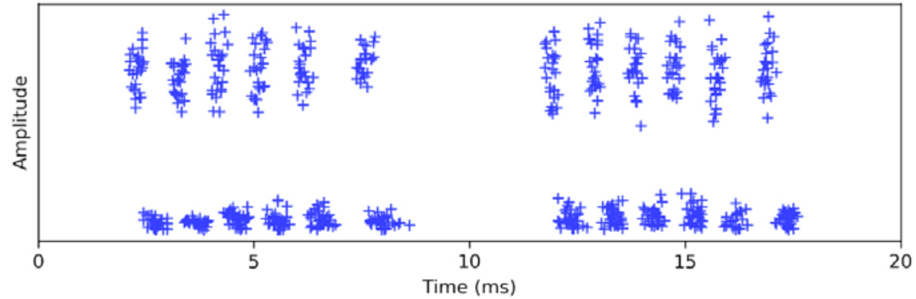
- Inspection when commissioning new substations, power lines, and equipment
- Regular inspections, for example once every two years

SUGGESTED ACTIONS

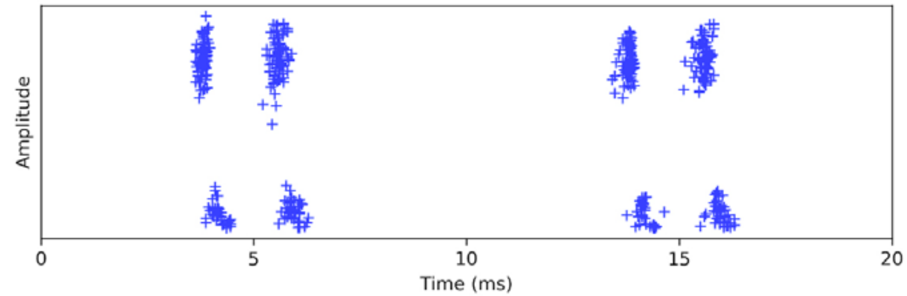
- Risk assessment of any detected partial discharges
- Is the partial discharge due to bad contact between components? Is this a problem in this specific case?
- Does the partial discharge indicate design or installation faults or damaged components?
- Repair or replacement of faulty designs and installations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

PRPD PATTERN

Floating discharges have a distinct PRPD pattern that 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 symmetrical in size and shape. During each pulse, an 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.

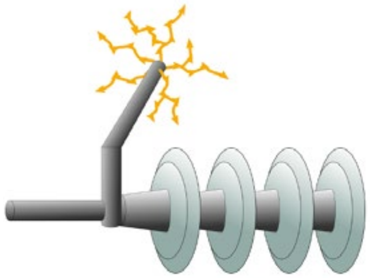


Example of the PRPD pattern of a floating discharge.



Example of the PRPD pattern of a floating discharge.

CORONA DISCHARGE



Corona discharges typically produce highly asymmetrical PRPD patterns. A weak corona has discharges only during the negative half cycle of the voltage. A stronger corona may cause discharges also during the positive half cycle. These discharges have a larger amplitude than during the negative half cycle, but the cluster is often not as wide.

Corona is a partial discharge into the 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, the corona is observed during the negative half cycle of the voltage (so-called negative corona). If the electric field strength is high enough, the corona can be observed also during the positive half cycle (so-called positive corona). A positive corona contains fewer discharges per half-cycle than a 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. Often the most severe problem associated with corona is that it produces ozone and corrosive chemical compounds that damage nearby organic materials, such as polymeric insulators [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 polymeric insulating materials

INSPECTION SCHEDULE

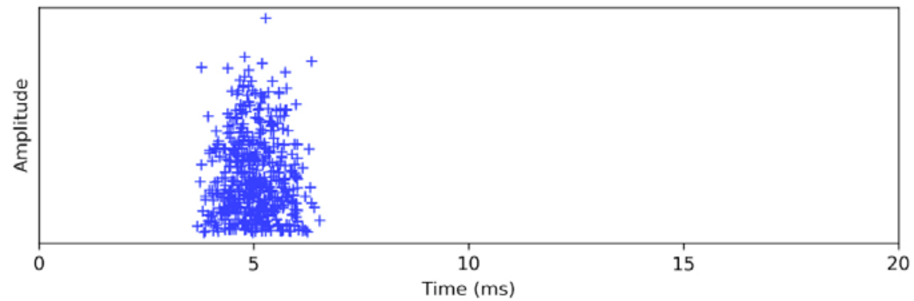
- Inspection when commissioning new substations, power lines, and equipment
- Regular inspections, for example once every two years

SUGGESTED ACTIONS

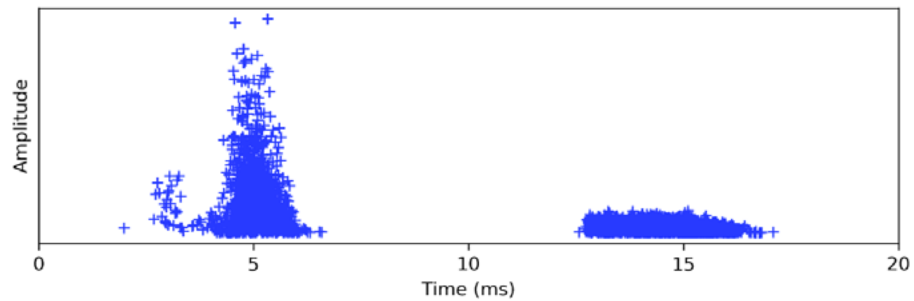
- Risk assessment of any detected partial discharges
  - Is electromagnetic interference or audible noise a problem?
  - Should broken strands be repaired?
  - Are there insulators nearby that might be damaged by the corona?
- Add missing corona rings near polymeric insulators
- Repair power lines with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

PRPD PATTERN

The PRPD pattern of partial discharge into air (corona) is highly asymmetrical. In the case of a 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. A 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 PRPD pattern of negative corona discharge.



Example of the PRPD 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 Si2 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 most often do not produce a PRPD pattern. Some typical examples of other sound sources that can be found using the Si2 are listed below.

VIBRATION

The hum from transformers and reactors, among other things, may cause different components to vibrate. This type of vibration will mostly not produce a PRPD 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 Si2, but will not produce a PRPD pattern.

ELECTRONICS

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

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1. Kimmo Nepola: Feasibility of radio frequency interference measurements in condition monitoring of high voltage substations. Master's thesis, Aalto University, 2013.
2. Kristoffer Bäckström: Statistical analysis of partial discharges. Master's thesis, Uppsala University, 2010.
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