Paris Session 2022

Pulse Shape Analysis for Complex PD Patterns Interpretation

Study Committee A1
Preferential Subject 2: Asset Management of Electrical Machines
Question 2.3

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PD Pattern Interpretation

•*How closely, or not, do the phase resolved PD patterns in one of the Informative Annexes (of IEC TS 60034-27-2), correlate with actual PD test results?*

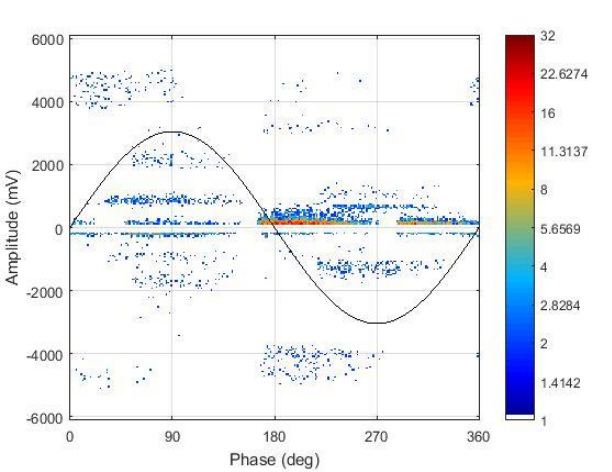
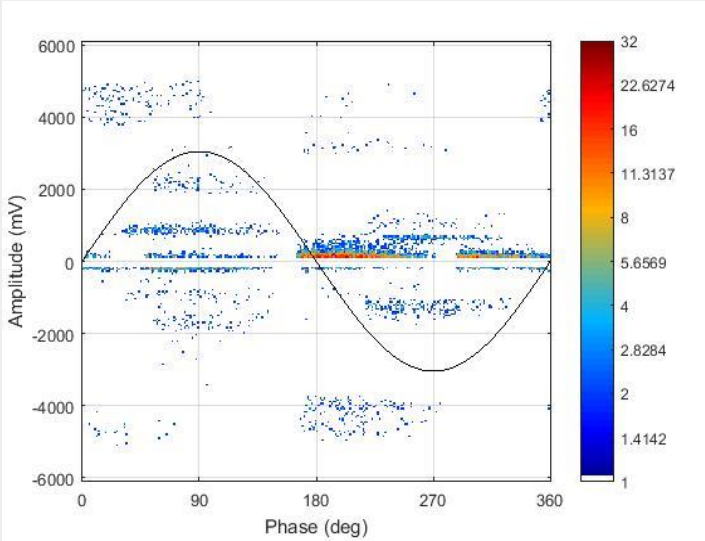


Table 2 - Typical PD Patterns in Rotating Machines.

PD Source	Pattern Description	Typical PD Pattern
Internal Voids and Internal Delamination	Positive and negative pulses equally distributed in the two half-cycles, with low to medium amplitudes.	
Delamination Between conductors and insulation	Negative pulses of greater amplitude and with greater concentration in the positive half-cycle, with higher amplitudes.	
Slot Discharges	With a characteristic triangular pattern, there is a concentration of positive pulses in the negative half-cycle, with medium to high amplitudes..	
External PD at the stress control coating	There is a concentration of positive pulses in the negative half-cycle, with medium to high amplitudes.	
Surface tracking	Usually accompanied by the pattern, there is formation of a vertical cloud of negative pulses in the positive half-cycle, with very high amplitudes.	
Gap Discharges	Horizontal clouds in both half-cycles, with medium to high amplitudes.	

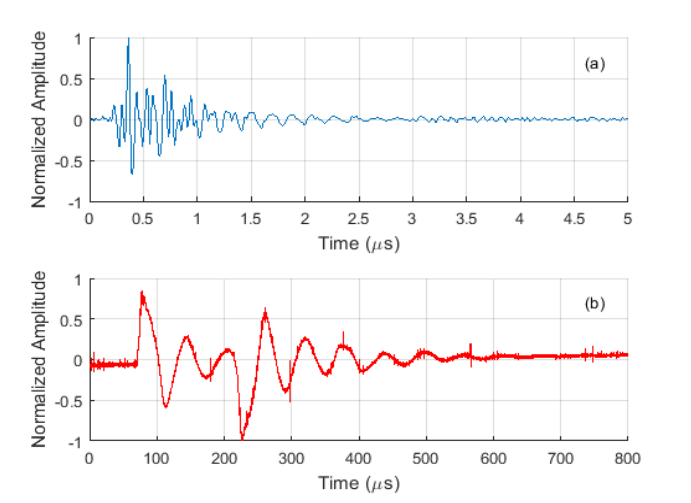
PD Pattern Interpretation is Difficult

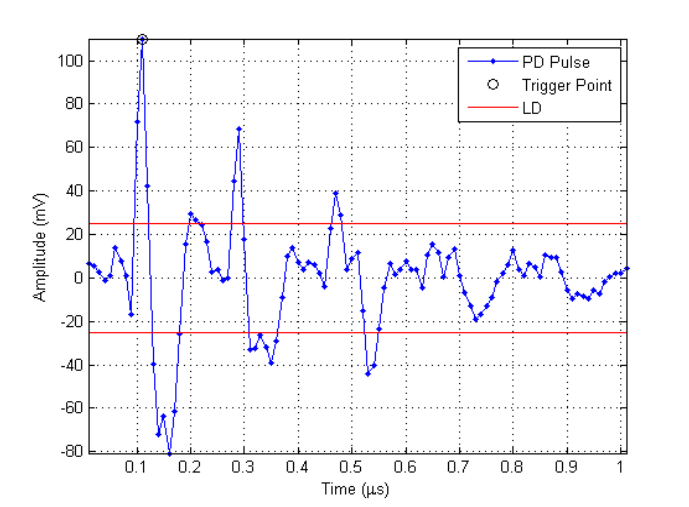
- This is a very common issue, so common that IEC TS 60034-27-2 addresses this issue at item A.4 : « Other complex examples ». Figure A.16 of the standard Pbrings some PD patterns whose « identification is very difficult » due to **« multiple PD sources », cross-coupling between phases, noise and interferences, including tyristor signals.**



Pulse Shape Analysis and Classification

- However, this difficulty can be overcome by some more sophisticated signal processing techniques like **pulse shape analysis and classification**.
- A PD pulse waveshape are determined by the PD source, and by the path traveled between the origin and the PD sensor. Therefore, different PD sources have different pulse shapes, and this fact can be used to analyze PD patterns to get a clearer interpretation.

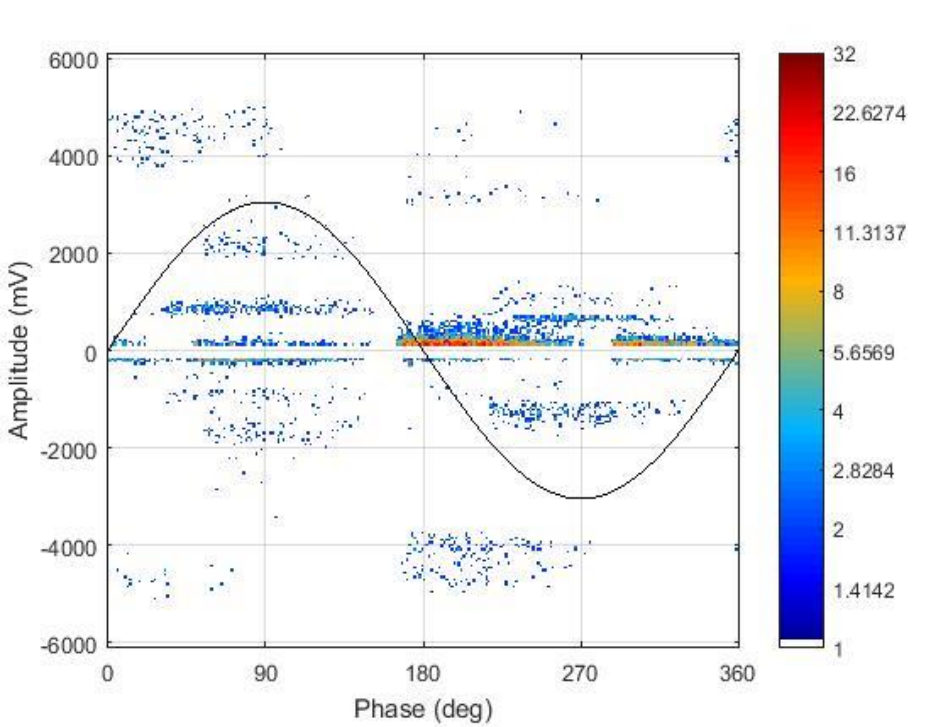


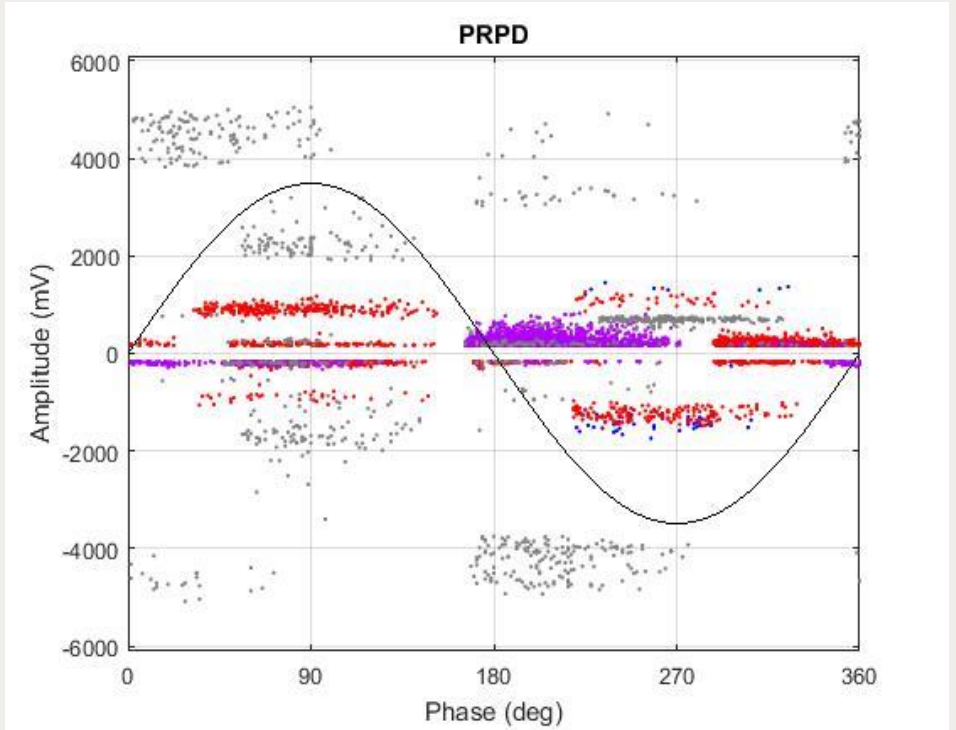


Group Discussion

Pulse Shape Analysis Example

- 13.8 kV Hydrogenerator PRPD Pattern





Pulse Shape Analysis Example

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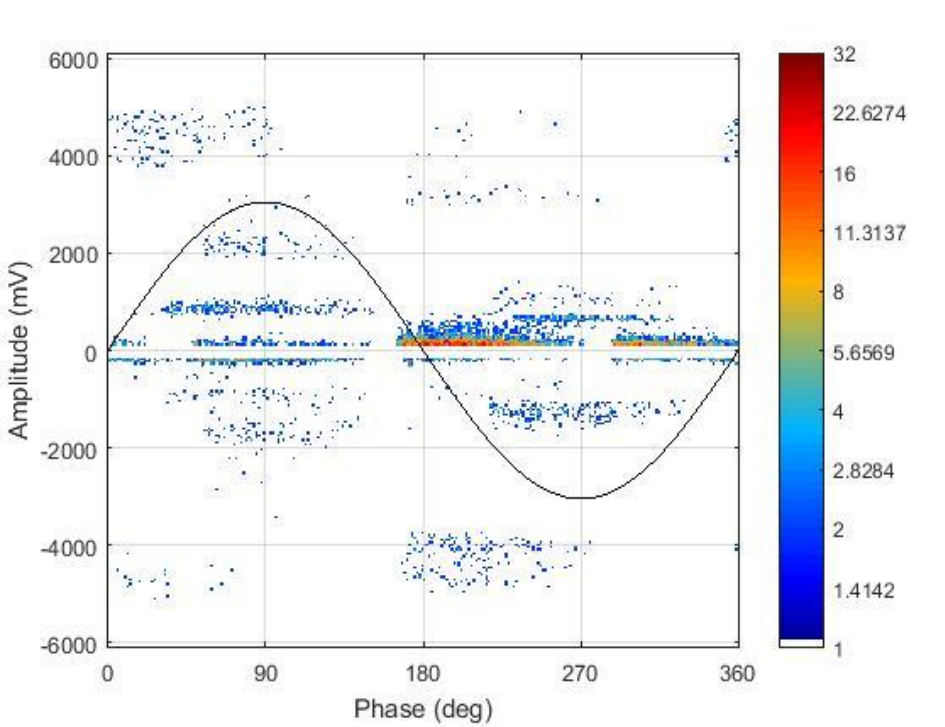
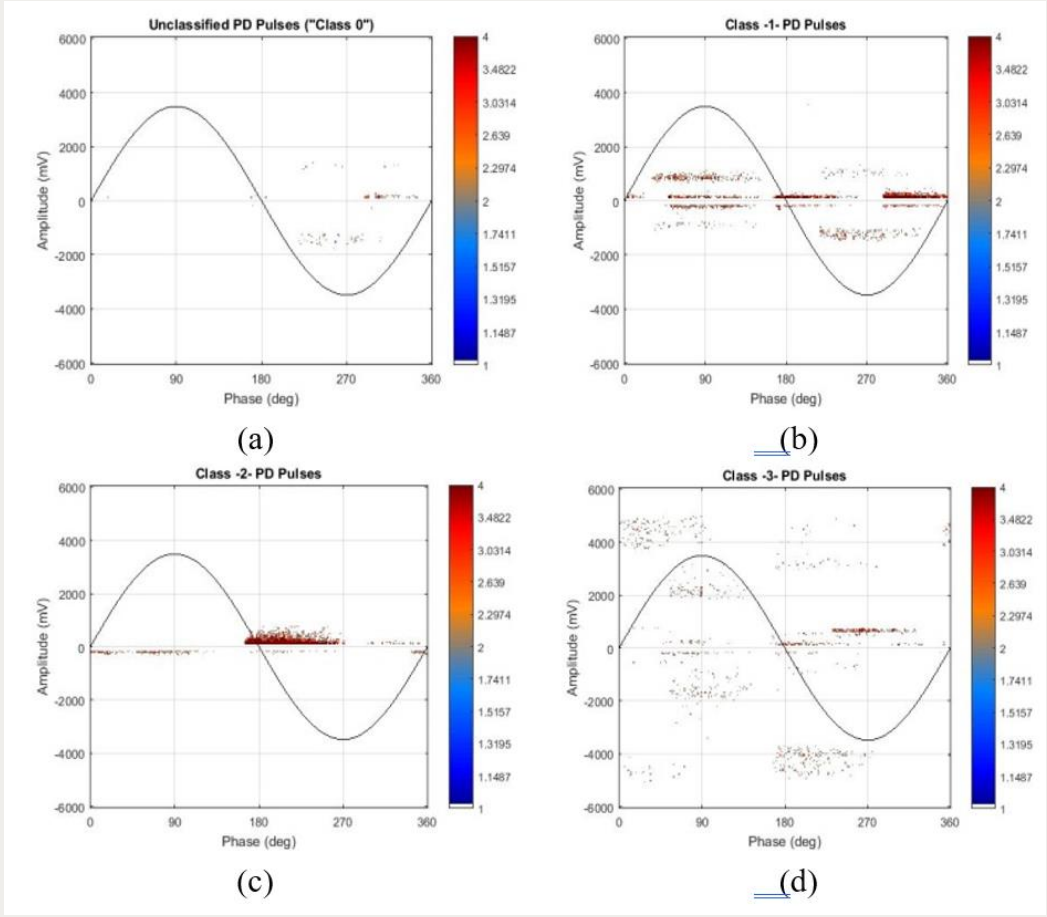
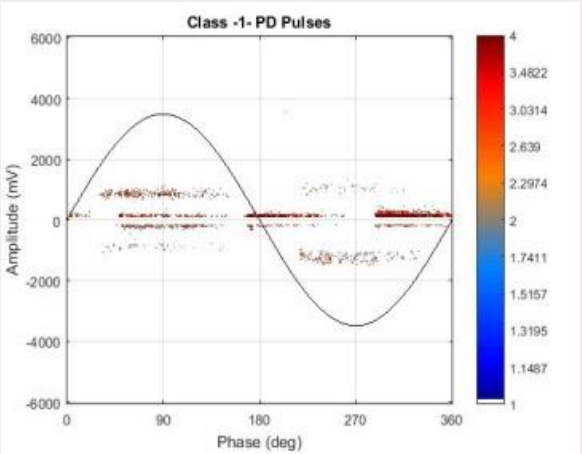


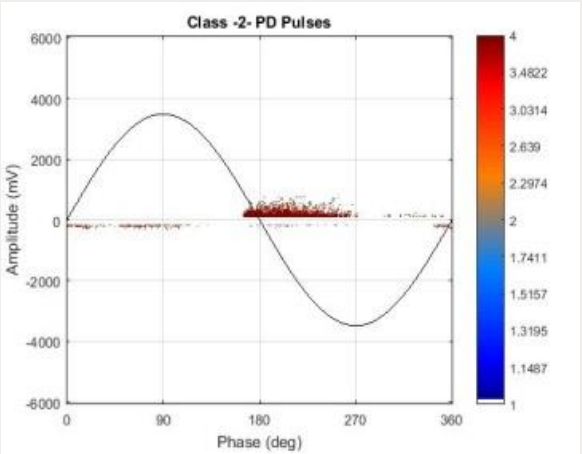


Pulse Shape Analysis Example

- In this case, we note that:
  - PRPD (c) is easily characterized as **external PD at the stress control coating**, while PRPD
  - (b) is characterized by **Gap Discharges**.

- Pulse Shape Analysis allows to interpret very difficult PD patterns, finding correspondence with the « canonical » patterns available in the standards.
- **The trending of each failure mode can be tracked independently**, allowing a better comprehension of the evolution of the insulation condition.





Measurement Bardwidth and Instrumentation

Band	f (MHz)	Characteristics
LF/MF	< 3	• Processes pulse envelopes • Necessary calibration • Unit: pC • Very sensitive to external noise in the field • Very good sensitivity to PD along the winding
HF	3 – 30	• Processes pulse waveforms • Calibration not allways possible • Unit: pC or mV • Good signal to noise ratio in the field • Good sensitivity to PD along the winding
VHF	30 – 300	• Processes pulse wavefronts • Impossible calibration • Unit: mV • Very good signal to noise ratio in the field • Little sensitivity to PD along the winding

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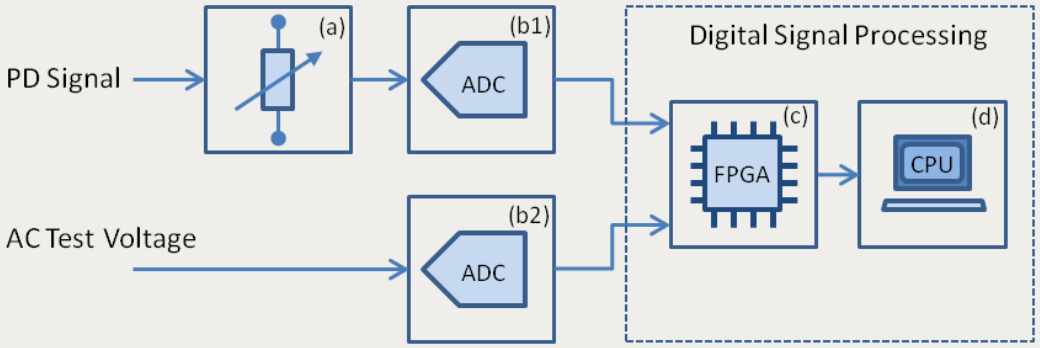
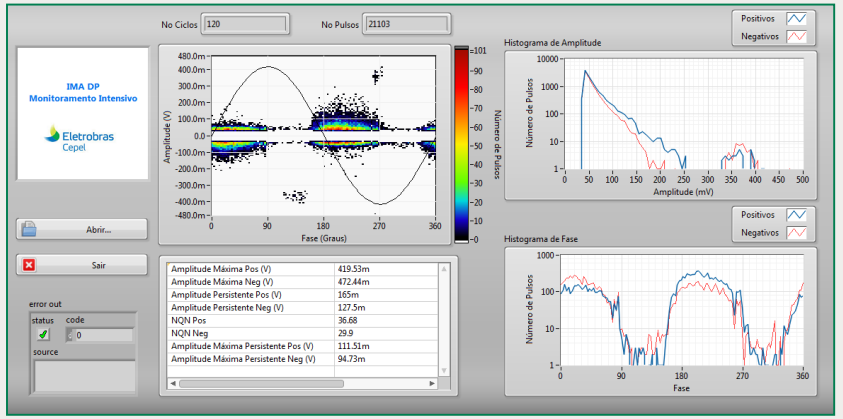
Diving Into our Pulse Shape Analysis Example

- Conclusion: Pulse Shape Analysis is always performed by measurement systems that operate in the **HF band**.
- In the previous example, since we developed our own PD measurement System (the same used in the experiences reported by the Paper 10125 – Brazil), we could explore and test many different pulse shape analysis techniques, including some more sophisticated than the usual tools provided by standard instrumentation.





An Effective Proven Methodology

- Considering the implementation facility and the better separation performance compared to other techniques, in the previous example we chased to apply the k-means clustering algorithm (KMC) with the the normalized autocorrelation function (NACF) methodology.

$$R_s(k) = \frac{\sum_{i=1}^{N} s(i)s(i+k)}{\sum_{i=1}^{N} s^2(i)}$$

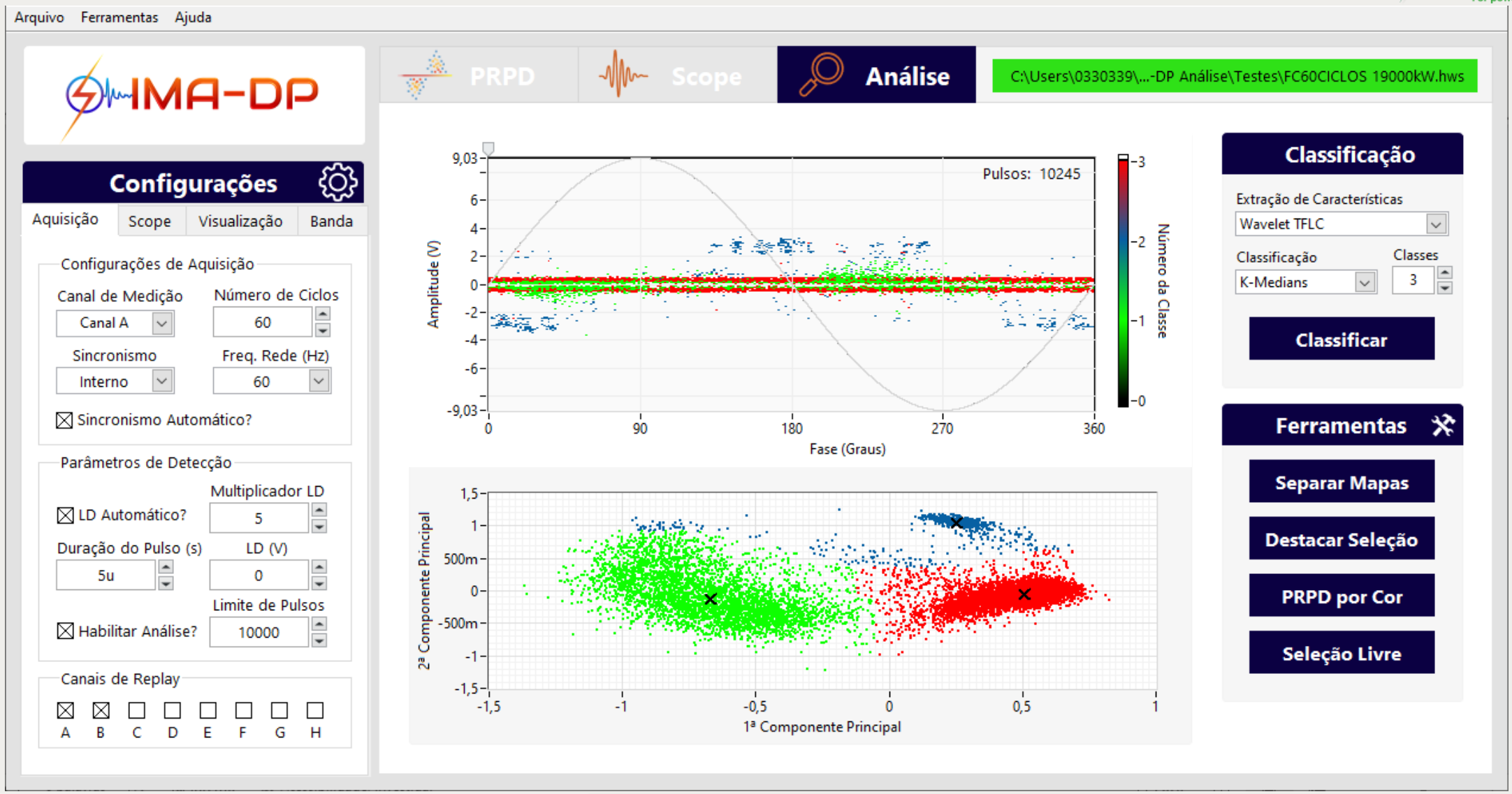
NAFC

$$d_p = \sqrt{2(1 - p_c)}$$

Distance Metric

p_c is the correlation coefficient between the NACF of the centroid and of the evaluated signal.

Different Pulse Shapes, Different Patterns



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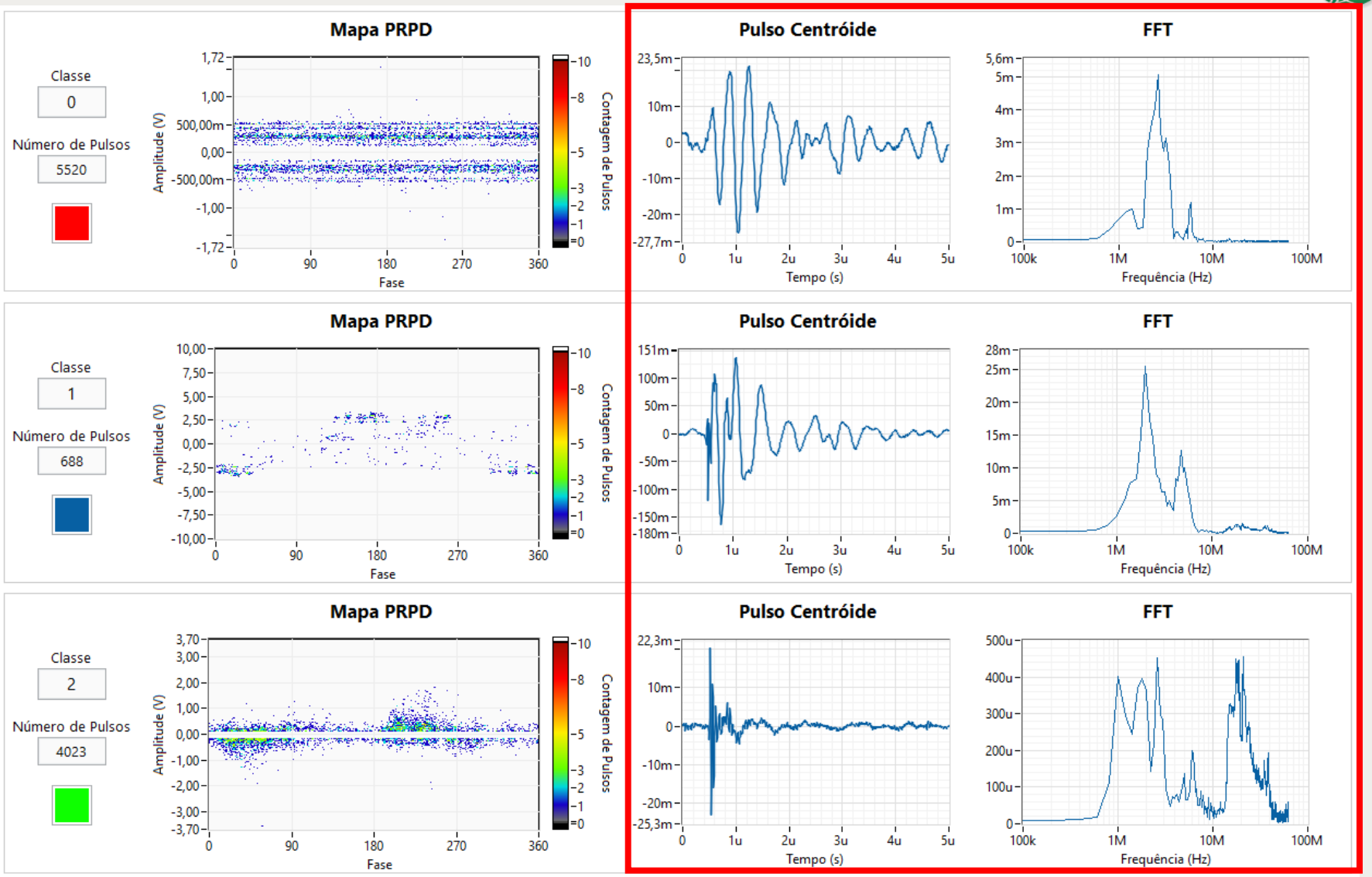

Conclusion

- It is difficult to interpret complex PD patterns.
- However, modern instrumentation with Pulse Shape Analysis capabilities can assist in this task separating many mixed PD sources in several different PRPD patterns
- This technique is very powerful, not only to characterize better the insulation condition, but also to allow trending of specific failure modes for specific PRPD patterns.