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Question 2.01: *Since several years, alternatives to SF_6 are under investigation and some gases are already applied in gas-insulated systems worldwide. What are open technical questions concerning the application of SF_6 gas alternatives? How can CIGRE support?*

The need to lower the emission of greenhouse gases leads to the application of SF_6 alternatives with a low global warming potential in gas-insulated systems (GIS). Investigations with respect to the dielectric strength, the material compatibility and the long-term stability of the gases have been carried out during the last decade, leading to an increasing number of installed GIS with eco-friendly insulating gases in the grids. Partial discharge (PD) measurements are one sensitive method to assess the condition of high-voltage assets and they have to be used especially if new or modified assets are integrated in the grid. The measurements are carried out during manufacturing (factory acceptance test - FAT) and after the installation (site acceptance test - SAT) using conventional methods according to IEC 60270 or field-bound measurements in the UHF-range. One area of research concerning the application of SF_6 gas alternatives is the partial discharge (PD) behaviour of typical defects in GIS. The recently published CIGRE TB 849 “Application of non-SF_6 gases or gas mixtures in medium and high voltage gas-insulated switchgear” even recommends experiments subjected to the investigation of the PD behaviour of alternative gases [1], since the published experimental results dealing with this topic are less frequent than for SF_6 (Table 1).

Table 1: Selection of literature dealing with the PD behaviour of alternative insulating gases under AC voltage stress

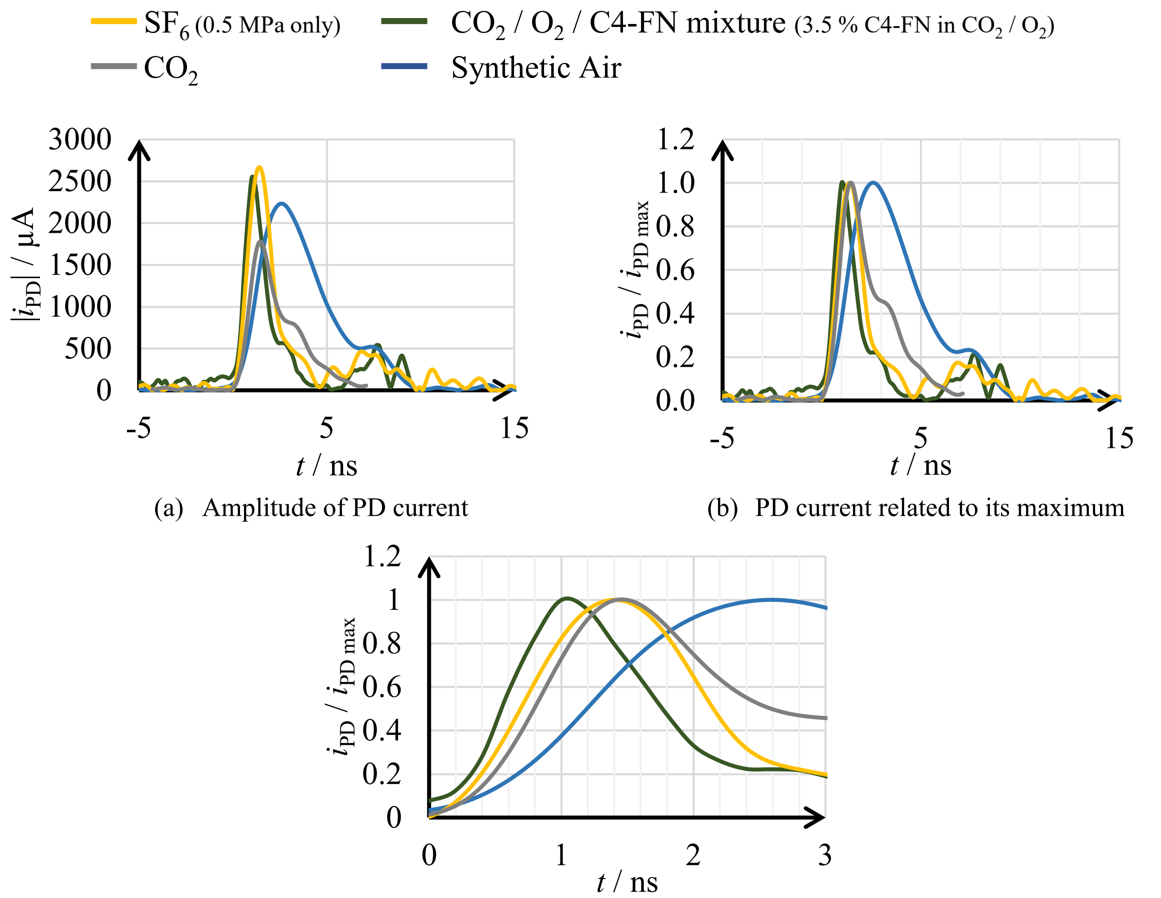
Gas mixture with SF_6	Gas mixture with N_2 and O_2 (synthetic air)	Pure natural gases (CO_2, N_2, …)	Gas mixture with C4-FN	Gas mixture with C5-FN	Gas mixture with CF_3I
[2,3]	[4]	[5–7]	[3,7–10]	[3]	[11]

It can be expected that the PD behaviour depends on the insulating gas used, since the mobility parameters of the charge carriers generated during a PD event, the number of charge carriers generated and other physical parameters vary with the gas used. Further, the typical gas pressure differs for alternative gases resulting in an influence on the PD behaviour. As one example, the different rise times and generated charges of one single PD event can be analysed (Figure 1). It becomes evident, that the PD impulse current rise time of the gas mixture containing C4-FN is the lowest and the one of synthetic air is the highest. Even though the rise times of SF_6, CO_2 and the C4-FN gas mixture seem to be almost equal, it could be that they are close to the bandwidth limit of the used measurement circuit [12,13]. These differences may lead to different spectra in the UHF-measurement, leading to different measurement frequencies.

In addition, the generated charges vary depending on the gas investigated. They are highest for synthetic air in this chosen example (Figure 1 (b)). The reason for the different behaviour of a single impulse as well as its influence on the PD behaviour itself is not clearly evaluated in literature so far. Reasons might be a different build-up of space charges, phenomena specific to the respective gas or gas mixture or even the different, pressure depending, effective ionization coefficients of the gases compared.

Measurements of the PD current i_{PD} with a C4-FN gas mixture under AC voltage stress have been carried out in the same sphere-plate electrode arrangement as designated in Figure 1. The protruding needle is placed at ground potential to measure the discharge current i_{PD}. Hence, the needle becomes a negative protrusion during the positive half-wave and vice versa.

The maximum PD current does not occur at the maximum voltage amplitude, but in the rising edge of the negative half-wave (Figure 2). In addition, a pulseless discharge can be observed which might suppresses discharge impulses during the voltage peak of the positive half-wave. This phenomenon is not specific to the C4-FN mixture, since it is already known from SF_6 and synthetic air under DC voltage stress [12]. Nevertheless, more detailed investigation is necessary, because it could affect the conventional PD measurement.



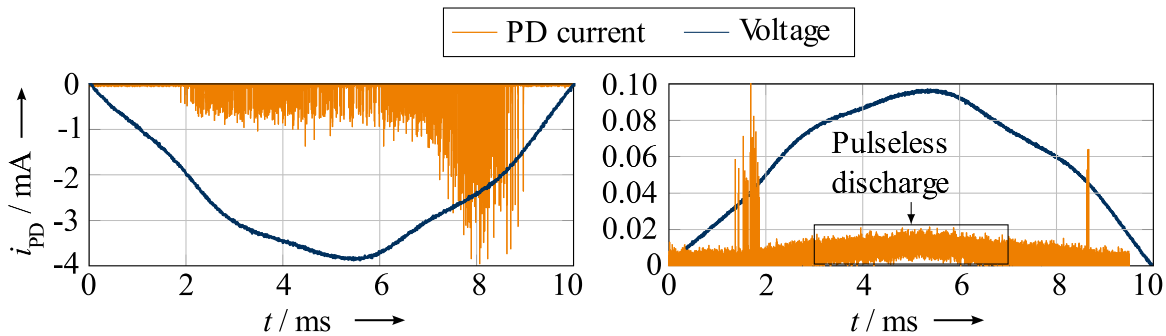
(a) Amplitude of PD current

(b) PD current related to its maximum

(c) PD current related to its maximum, zoom to the front of the current impulse (keep bandwidth of measurement circuit in mind)

Figure 1: Current of single PD impulses at a positive protrusion at a gas pressure of 0.7 MPa_{abs} measured in a sphere-plate electrode arrangement with a 5-mm-protruding needle (SF_6 and synthetic air measured under DC voltage stress, other under AC voltage stress) as presented in [12]

These examples show that the PD behaviour could be different in SF_6 alternatives. The physical reasons are diverse and have to be investigated in detail in order to further improve PD diagnosis. CIGRE can support the transmission and distribution system operators as well as the manufacturers of GIS on their path to a SF_6-free power grid by facilitating an increase of experience with PD measurement and the respective analysis of the results in GIS with SF_6 alternatives. This could be the start of a new working group with an included round-robin test as already performed in the very successful CIGRE WG D1.67.



(a) Positive Protrusion

(b) Negative Protrusion

Figure 2 : PD current i_{PD} at U=3.5 U_i in a gas mixture with 3.5 % C4-FN in CO_2 / O_2 at a gas pressure of 0.7 MPa_{abs}

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