Evaluation of PDIV, PDEV, BDV in Low-GWP Gases

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Context and our scope

In order to use high voltage technologies is often required to adopt gas insulated solution.

SF_6 (Sulfur hexafluoride) has excellent electrical performance, but it have a deep -negative- impact on the environment.

Searching for an alternative gas mixture based on low-GWP gases is essential to preserve bioresources.

Theoretical Background

Practical Part

Result Discussion & Conclusion

Fundamental Gas Kinetics and Ionization Processes

1 Classical Gas Laws

Boyle's and Gay-Lussac's Law which describe the relationship between pressure, volume, and temperature in gases

2 Kinetic Theory of Gases

Molecular collisions,Velocity distribution , Mean Free Path

3 Ionization and Decay Process

at higher electric fields, charged particles gain energy and cause ionization.

4 Classification

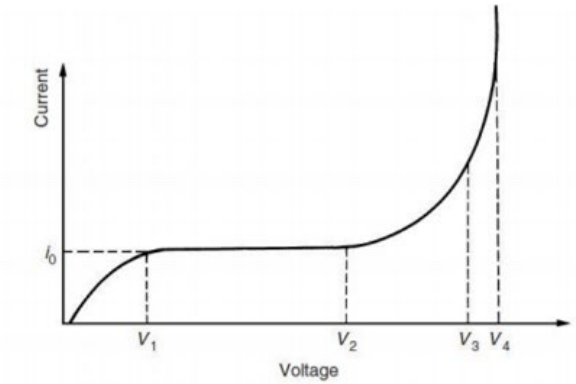
Processes like photoionization, ionization by metastables , thermal ionization , and electron Impact Ionization which is the most critical process for breakdown.

5 Townsend First Ionization

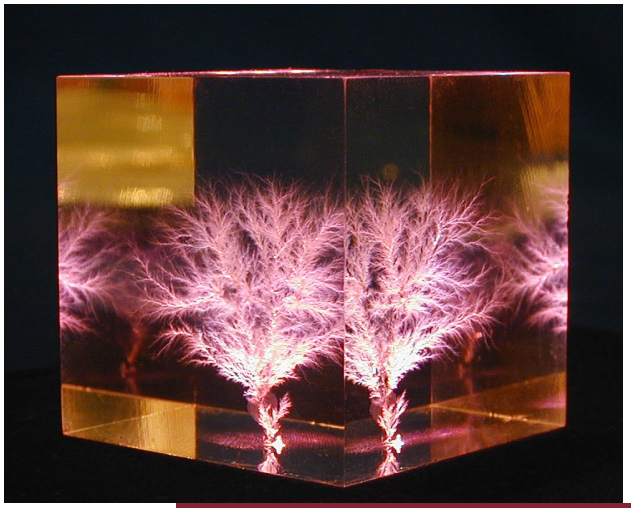
the number of electron-ion pairs produced by an electron per unit drift in the field direction

Mechanisms of Electrical Breakdown

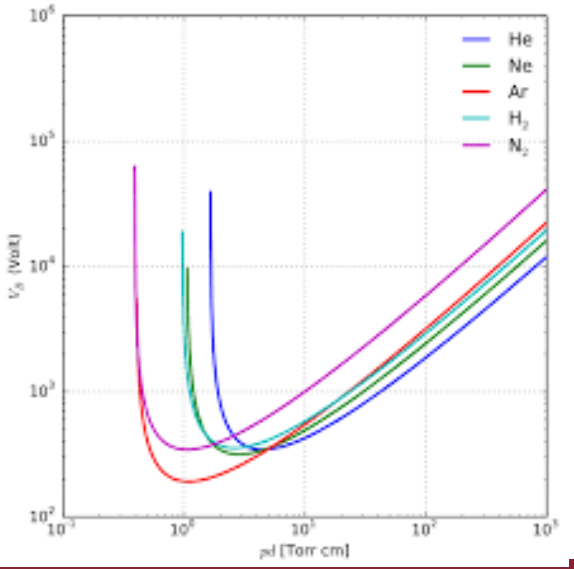
1 Townsend Mechanism



2 Streamer Kanal Mechanism



4 Paschen's Law



Partial Discharge Phenomenon

1 Definition

localized electrical discharge in the insulating gas, caused by excessive electric field stress, which does not bridge the electrodes but precedes complete breakdown.

2 Partial Discharge Inception Voltage

The minimum voltage at which sustained PD initially occurs.

3 Partial Discharge Extinction Voltage

The voltage at which PD ceases when the voltage is decreased.

4 Breakdown Voltage

The minimum voltage that causes a complete dielectric failure, forming a conducting path (spark).

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5 SF6 properties

Advantages:Excellent electrical insulation ,Thermal stability ,Cost-effectiveness.Disadvantages:High Global Warming Potential (GWP),Potential health risks,Leakage and containment

Experimental Apparatus

In order to study the electrical behavior of different gases, one can primarily employ the following equipment:

- Step-up transformer;
- Coupling Capacitor;
- PD detector;
- Calibrator;
- Vacuum chamber;
- Air compressor;
- Gas cylinders;
- Electrodes;

PD detection apparatus setup: some images

V_{BD} evaluation apparatus setup: some images

PDIV-PDEV determination flowchart

1 SAFETY

Operating with HV impose to adopt every safety procedures.

2 Electrodes configuration setting

In order to measure the inception of Partial Discharge process ones chose to set a needle electrode to increase the Electric field magnitude.

3 Chamber depletion and gas refill

To avoid contaminations of the examining gas, it is necessary to remove from the chamber as much previous gas as possible.

4 PD detector calibration

This step is fundamental to better distinguish noise from the PD pulse and to obtain relevant results.

5 Measurements

Once that everything is ready one can proceed with the measurement process.

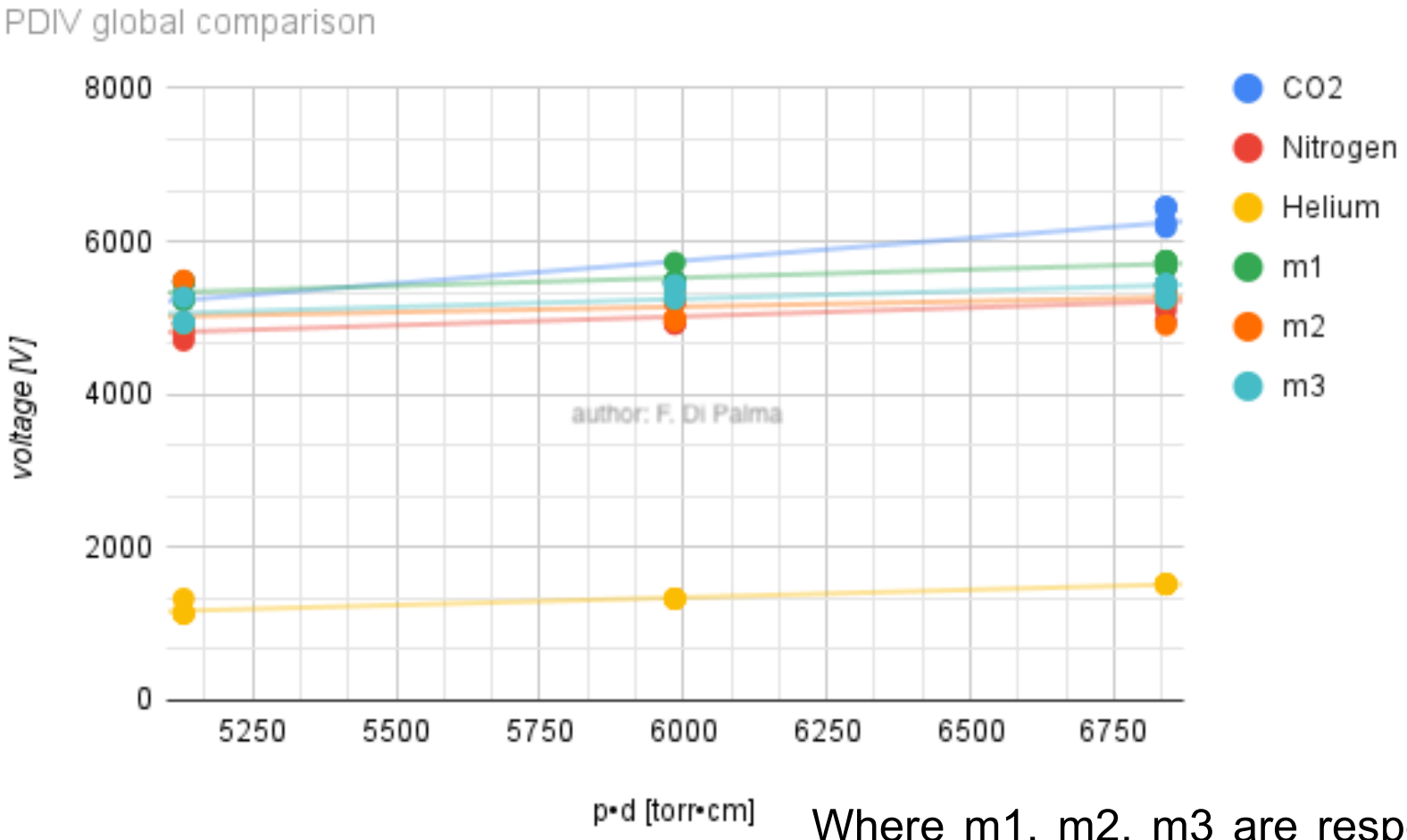
PDIV-PDEV: determination criterion

PDIV: One defines the PDIV as the value of Voltage such that the stable charge pulse amplitude is larger than the mean value of the noise.

PDEV: One defines the PDEV as the value of voltage such that the charge pulse begins to be discontinuous and the mean charge amplitude value is equal to the mean value of the noise.

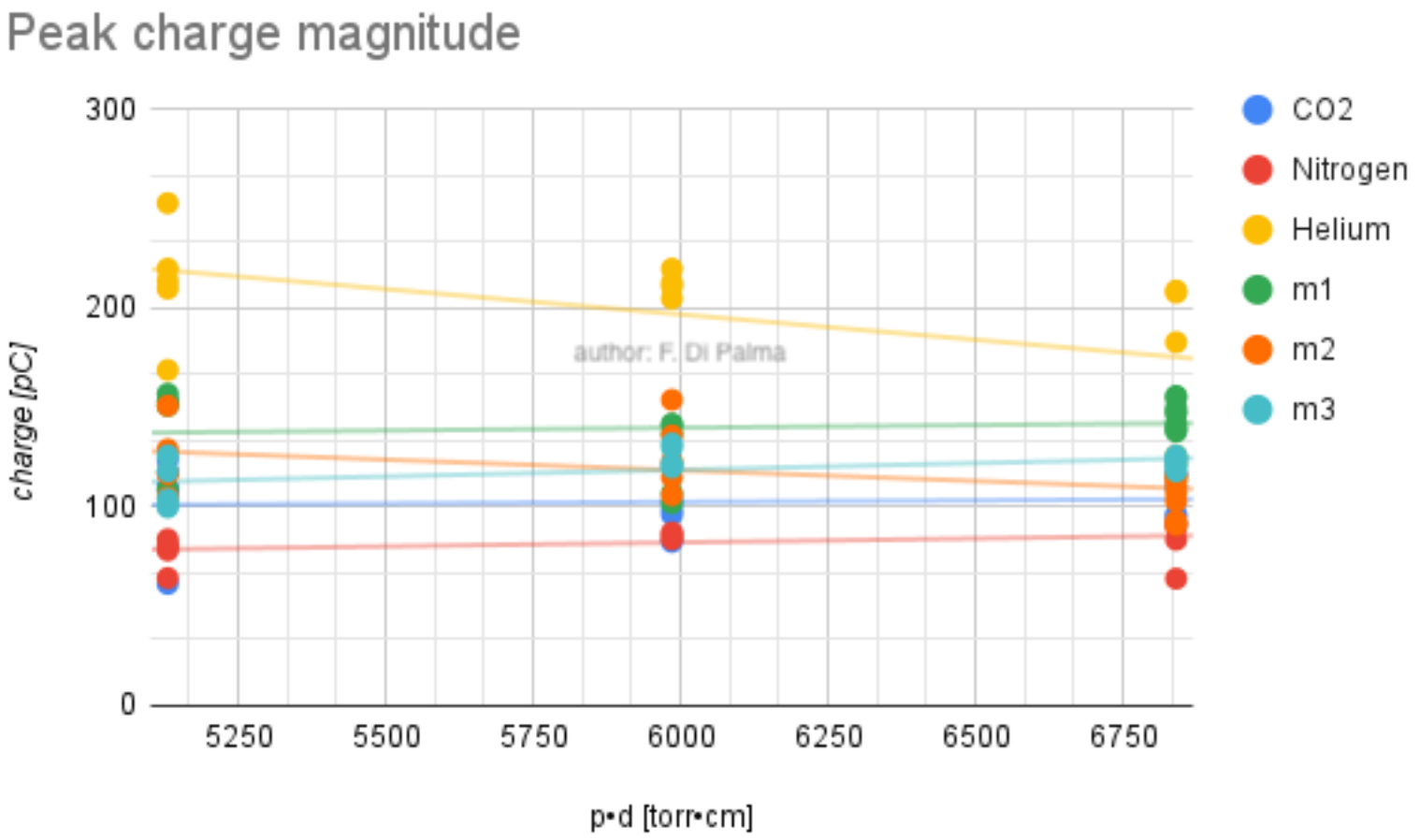
For each definitions, this studio has collected 5 values, in order to decrease the variance. In addition, voltage rise speed was linear.

PDIV global comparison



Where m1, m2, m3 are respectively gas mixtures, all nitrogen based.

Peak charge magnitude



V_{BD} determination flowchart

1 **SAFETY**

Operating with HV impose to adopt every safety procedures.

2 **Electrodes configuration setting**

In order to measure the Breakdown Voltage ones chose to set two plate electrodes to increase the Electric field uniformity.

3 **Chamber depletion and gas refill**

To avoid contaminations of the examining gas, it is necessary to remove from the chamber as much previous gas as possible.

4 **Measurements**

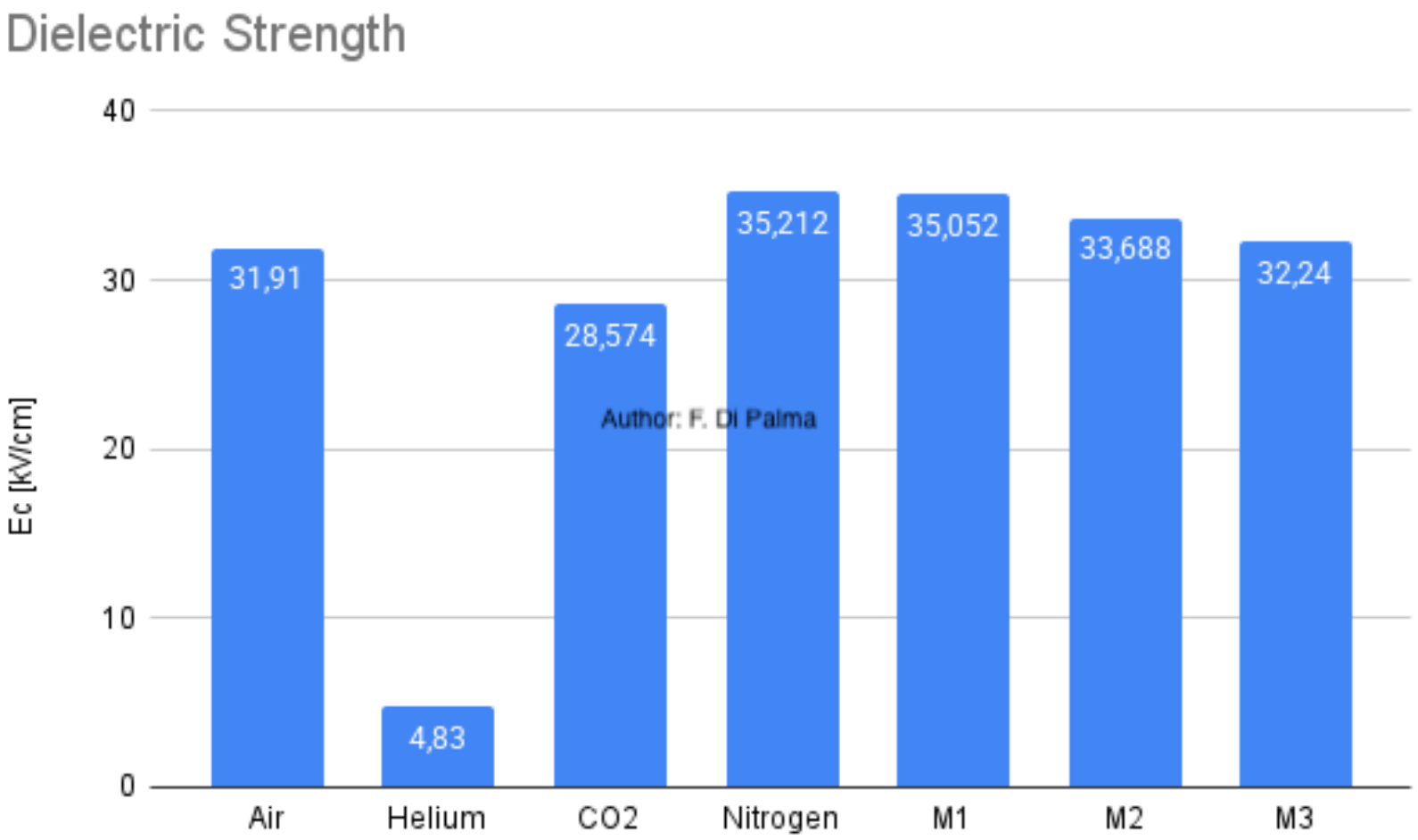
Once that everything is ready one can proceed with the measurement process.

V_{BD} determination criterion

Using a step-up transformer which increases the voltage at 1kV/sec one defines V_{BD} as the voltage value such that it is defined an electric current whose superior of 0.1kA.

The gap between the hemispheric electrodes is 1 cm, and the absolute pressure is 1037 hPa at 25 °C. Temperature and pressure variations can be considered negligible.

Dielectric strength: results



Conclusions

Nitrogen based gas mixtures may offer a valid alternative to SF6, especially if the value of pressure is increase significantly.

As evident from PD analysis, Nitrogen has low electronic attachment potential. For this reason it is important to add electronegative gases or composites to face this necessity.

All the procedures proposed can be applied successfully to other gas mixtures.

Question time

Thanks you for your attention!