5 Electrical onset for uniform field and coaxial cylindrical field and DC corona

SAFETY MEASURES: Interlocks are provided to prevent high voltage to be switched on while the gates/ doors are open. Despite these measures it is necessary to connect the safety earth stick to the HV parts before touching. (There could be some charge left on the capacitors). Special safety rules for the High Voltage laboratory must be read, understood, signed and always followed to every detail!

5.1 Objectives

The student must gain the following knowledge and comprehension in the following topics:

- Understand the concept of field utilization factor
- Be able to measure the breakdown voltage for uniform field in air.
- Be able to measure the onset/breakdown voltage for coaxial cylindrical field in air.
- Calculate onset E-fields for the above electrical onsets
- Visualize DC corona and polarity influence.

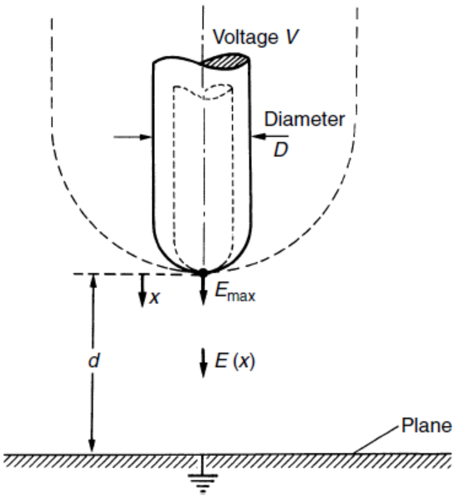
5.2 General description

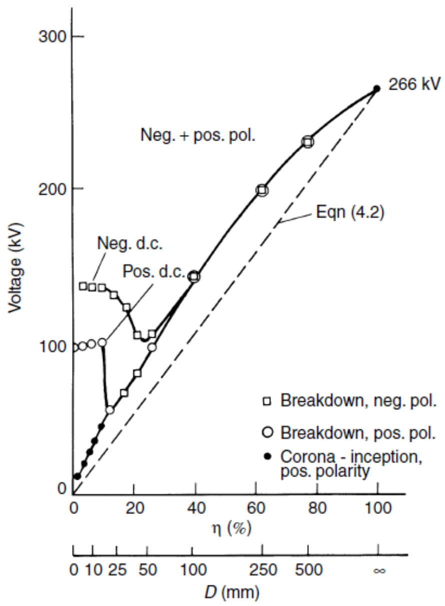
Electric fields govern every discharge process. Their strength delivers the force with which charged particles can act in a dielectric material.

The basic concept of calculating the "engineering relevant" quantity breakdown voltage (i.e. what a certain device can withstand) relies on the onset E-field being a constant.

$$\eta = \frac{E_{\text{mean}}}{E_{\text{max}}} = \frac{V}{dE_{\text{max}}}$$

Schwaigers equation gives the relation between E-field degree of uniformity, gap distance d, maximum E-field Emax and breakdown voltage V assuming Emax to be a constant value regardless of the degree of E-field uniformity. As we know from experimental work, see figure below:

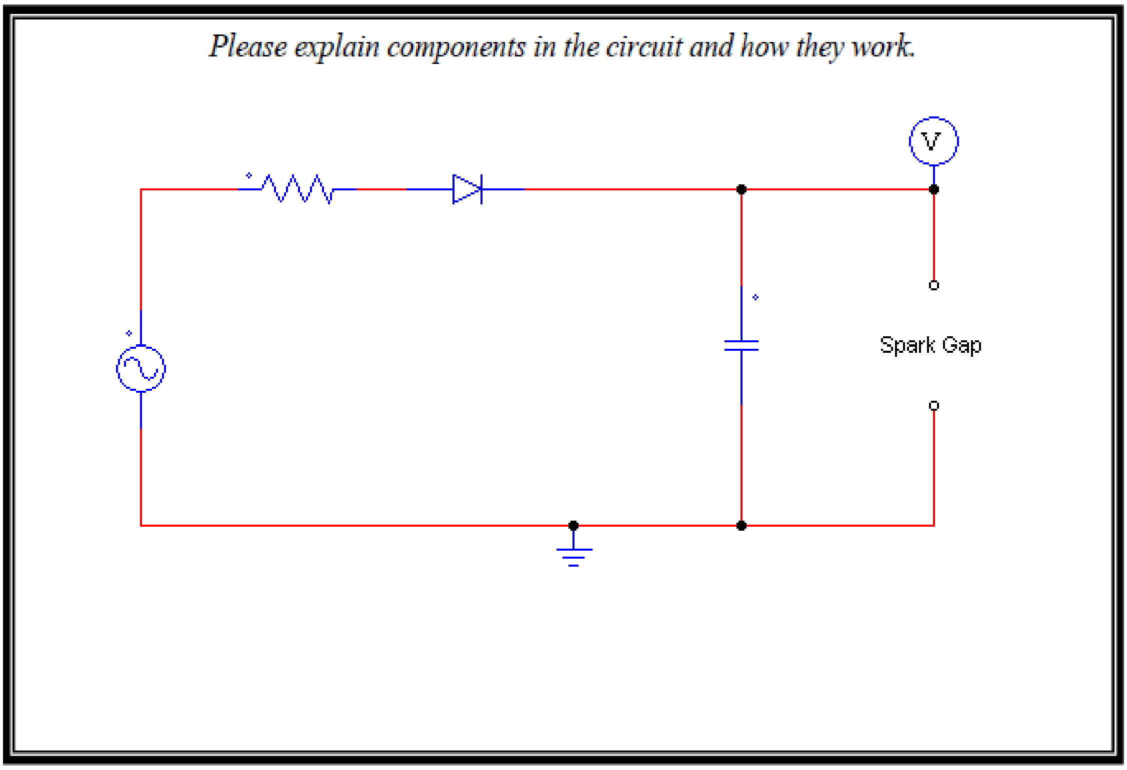




5.3 Laboratory work

The purpose of the laboratory work is to illustrate the different characteristics of uniform vs. non-uniform field discharges. This is accomplished by measuring the onset/breakdown voltage for a uniform gap and a non-uniform gap. Furthermore DC corona and its appearance will be illustrated and documented by photos/videos.

5.3.1 Setup



5.3.2 Measurements

- Measure the breakdown voltage for different E-field types
  a. Measure the positive and negative breakdown voltage for uniform field (the Bruce electrode profiles) for a gap distance $\boldsymbol{d} = 8\text{mm}$. Convert to standard atmospheric conditions.
  b. Measure both the positive and negative onset/breakdown voltage for the coaxial cylindrical field using inner cylinder to be **2 mm**. Onset means the first time you can see the smallest signs of discharges on the inner cylinder – lab must be dark for this. Breakdown is when you see loudly flashes from inner cylinder to outer cylinder. Convert to standard atmospheric conditions.

  Notice: When measuring breakdown voltage, the current measuring setup (see below) must be disconnected to the circuit!!!

E-field types	Onset/Breakdown voltage [kV]	
	Positive	Negative
Uniform	13.5	13.5
Non-uniform	Corona: 16.5 Breakdown: 26.5	Corona: 17.5 Breakdown: 28

- Measure the **negative** discharge current for the coaxial cylindrical field using inner cylinder to be 2 mm at three voltage levels being safely below the breakdown voltage. And calculate the corona losses at different voltage levels. Discuss what is causing this.
  Notice: For the following three voltage levels, the scale of the micro-ammeter should be adjusted to $100\mu A, 1000\mu A$ and $1000\mu A$ respectively!!! Always start the scale at 2000 μA and lower from that to the scales mentioned above.

Voltage [kV]	Current [μA]	Corona loss [W]
-25	160	4
-28	280	7.8
-30	360	10.8

- Take photos/videos of DC corona in positive and negative voltage in dark laboratory.

5.3.3 Analysis of results

- Calculate, on the basis of the measurement, the breakdown field strength $E_{max,uniform}$ for uniform field and compare to textbook value chapter 4.1. Comment.

  The field was calculated following the formula:
  E = V / d, being E = 13.5 kV / 8 mm = 16.87 kV/cm.

  The value is significantly different to the textbook value, which is 26,6 kV/cm, the explanation might be due to COMPLETE, we considered that the difference might be due to imperfections in the structure but double check because according tok HV book page 217 figure 4.2, the efficiency is really small.

- Calculate, on the basis of the measurement, the onset/breakdown field strength $E_{max,coax}$ for coaxial cylindrical field with inner conductor negative and comment. The outer cylinder's diameter is 10cm.

  Using the formula E_max_cyl = V / (r1 * ln(r2/r1)), the result obatained is
  E_max_cyl_corona = 17.5 / (0.2 * ln(10/0.2)) = 22.37 kV/cm
  E_max_cyl_breakdown = 28 / (0.2 * ln(10/0.2)) = 35.79 kV/cm

- Calculate the onset/breakdown voltage using Schwaigers equation (4.2) for uniform field using the standard value for Emax from textbook page 203. Compare with the value you got in the measurement. Comment.

  Using the forementioned formula: V = E_max * d * n, assuming uniform field, n = 1.
  V = 26.6 * 0.8 = 21.28 kV.

  The value experimentally obtained is smaller than the theoretical one.

- Calculate the onset/breakdown voltage using Schwaigers equation (4.2) for coaxial cylindrical field using the standard value for Emax from textbook page 203. Compare with the value you got in the measurement. Comment.

  The efficiency is calculated with equation (4.1) eta = E_max_cyl_corona/E_max:
  eta = 22.37 / 26 = 0.86

  Now its possible to calculate the voltage with equation (4.2):
  Vb = Emax*d*eta = 26*0.8*0.86 = 17.90 kV

  The calculated voltage is lower than the measured, because of the lower efficieny

- Discuss the different appearances of DC corona for various voltage levels and polarities using the photos/videos you took with the lights out. **After the 7th lecture, explain why there are differences.**

  The corona effect with positive polarity started being a small and punctual glow. When the voltage was increased, the punctual glow vanished and the inner conductor started glowing homogeneously. When the voltage increased further, eventual breakdowns happened, leading to a bright and short current discharge. The main difference with the negative polarity experiment was that the corona effect appeared as many punctual glowings. The voltage which lead to corona effect and later to breakdown, was higher than in the positive polarity experiment.