Simulation of Transmission Line Effects on Nanosecond Pulsed Dielectric Barrier Discharge Plasma (NPDBD)

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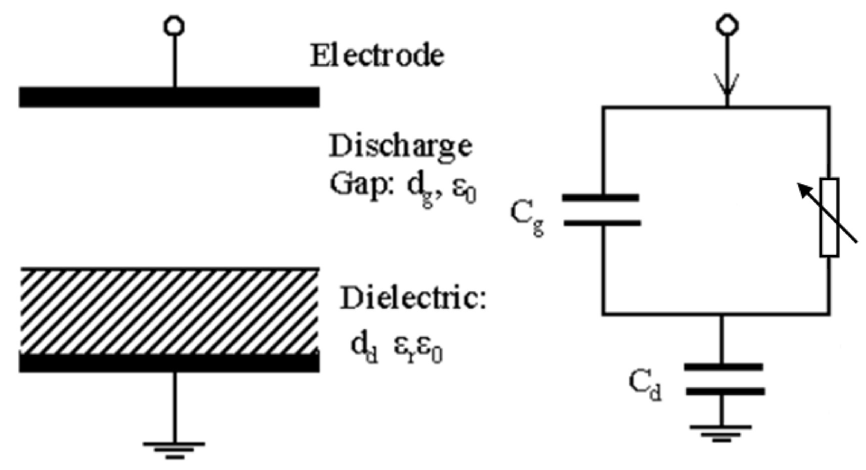
Introduction

- Simulation model of NPDBD

- Inserting a dielectric barrier in the discharge gap. The insertion of dielectric material in the discharge gap is to limit the discharge curremt thereby preventing the formation of complete breakdown. [1]
- DBD model is used as described in [2] . The equivalent circuit of this configuration is shown with Cg and Cd representing the equivalent capacitances of gap and dielectric layer respectively. But, variable resistance is used instead of current source in this study.



❖ Fig. 1. Common DBD configuration and equivalent circuit

- Transmission line effects (TL Effects)

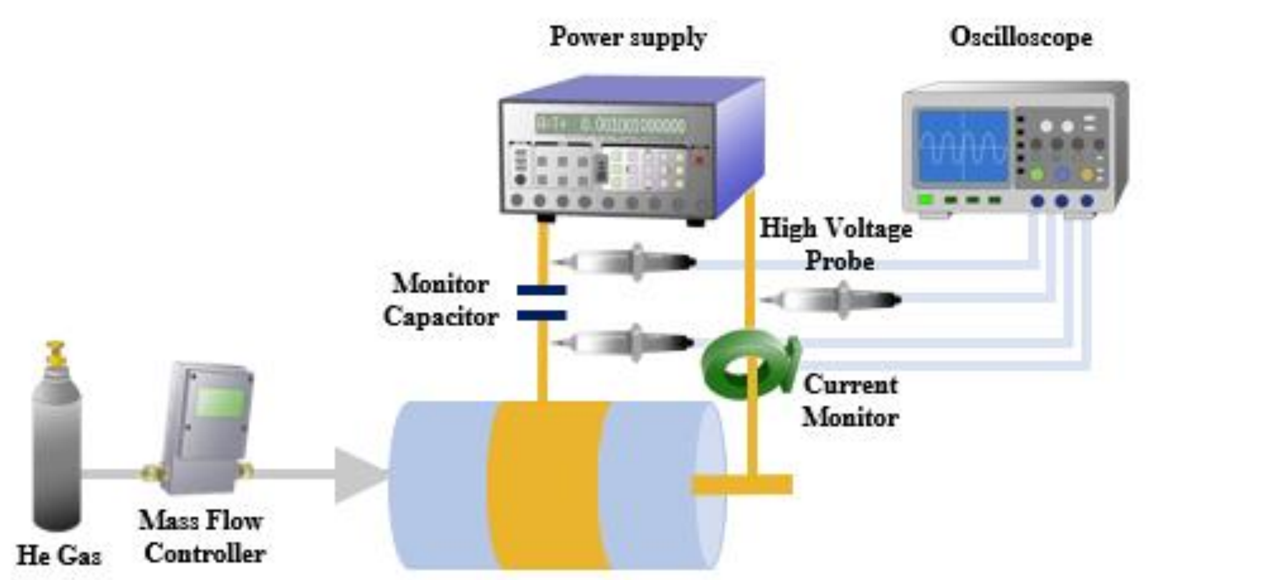
- To ensure effective transmission of high voltage, it is critical to consider the effects of transmission lines (TL). Proper understanding and simulation of TL parameters are essential for optimizing power delivery and minimizing losses.
- We simulate the TL effect by configuring an equivalent circuit based on experimental parameters. Accurately defined TL parameters are used in the simulation to replicate the experiment conditions.

Parameter	Case : Two-wire	Unit
Resistance (R')	$\frac{2R_s}{\pi d}$	Ω/m
Inductance (L')	$\frac{\mu}{\pi} ln\left[\left(\frac{D}{d}\right) + \sqrt{(\frac{D}{d})^2 - 1}\right]$	H/m
Conductance(G')	$\frac{\pi\sigma}{ln\left[\left(\frac{D}{d}\right) + \sqrt{(\frac{D}{d})^2 - 1}\right]}$	S/m
Capacitance (C')	$\frac{\pi\varepsilon}{ln\left[\left(\frac{D}{d}\right) + \sqrt{(\frac{D}{d})^2 - 1}\right]}$	F/m

❖ Table. 1. Parameters for each case of transmission line [3]

Experimental Setup & Methods

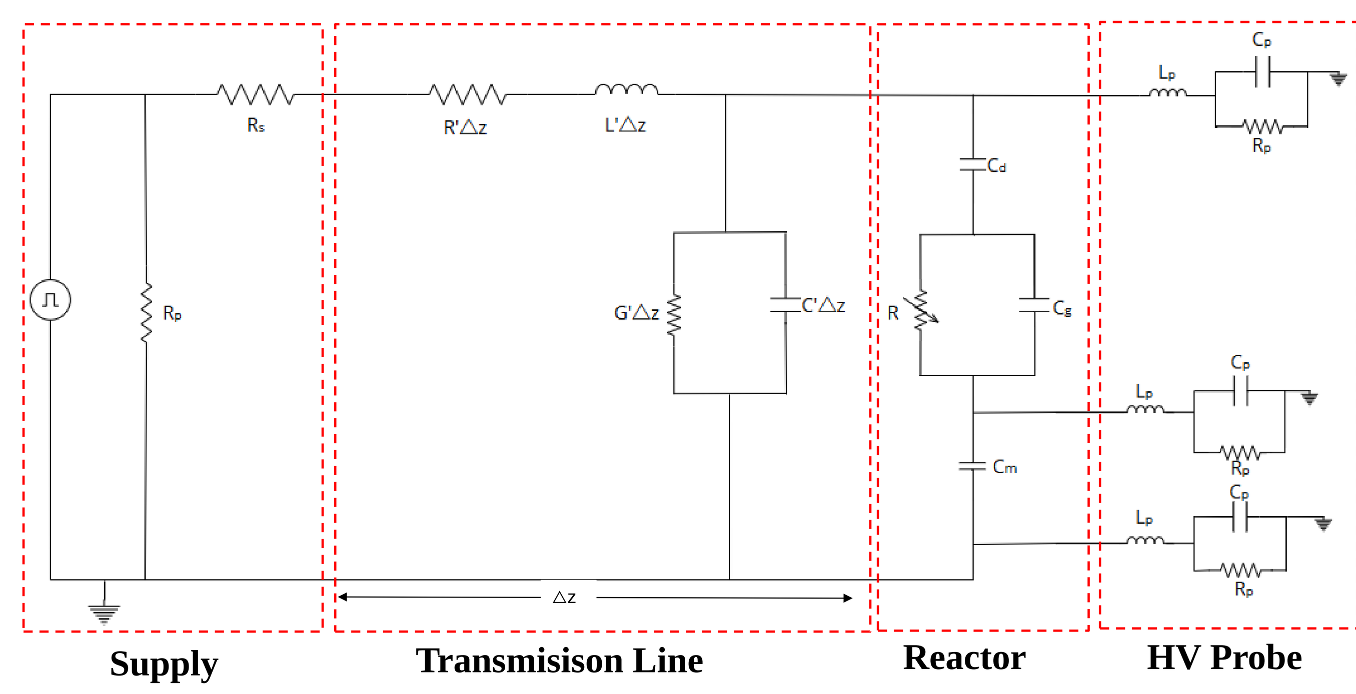
- Schematic diagram of experimental setup



❖ Fig. 2. Schematic diagram of experiment

- Power supply : NSP-60-20-P-250-TG-H, Eagle Harbor Technologies.
- Dielectric layer : Quartz
- Electrode : Copper, SS34
- Current monitor : Model 4100, Pearson
- High voltage probes : P-6015A, Tektronix.
- Oscilloscope : TDS-5054B, Tektroniz.

- Schematic diagram of equivalent circuit



❖ Fig. 3. Schematic diagram of equivalent circuit of experiment

- Equivalent circuit consists 4 sections.
- For each sections of parameters are obtained in model specifications.
- Parameters of Reactor (ex. plasma resistance, capacitance) are obtained in experiments, to compare with experimental results.

Reactor parameter	value	unit
Dielectric capacitance	30	(pF)
Gap capacitance	3.7	(pF)
Plasma resistance	Avg ~1.5	(KΩ)

❖ Table 2. Equivalent cirguit and parameter of reactor

- Plasma resistance remains during only plasma generating.

Parameter per unit length		Parameter	△z = 0.15	△z = 1.7	(m)
Resistance (R')	3.58 (μΩ/m)	R'△z	0.53	6.09	(μΩ)
Inductance (L')	0.52 (μH/m)	L'△z	0.07	0.89	(μH)
Conductance (G')	0 (S/m)	G'△z	0	0	(S)
Capacitance (C')	42.2 (pF/m)	C'△z	6.33	71.8	(pF)

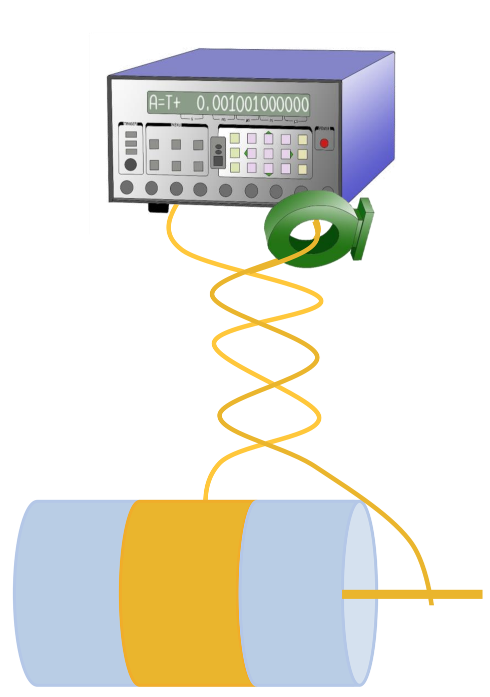
❖ Table 3. Transmission parameter of experiment

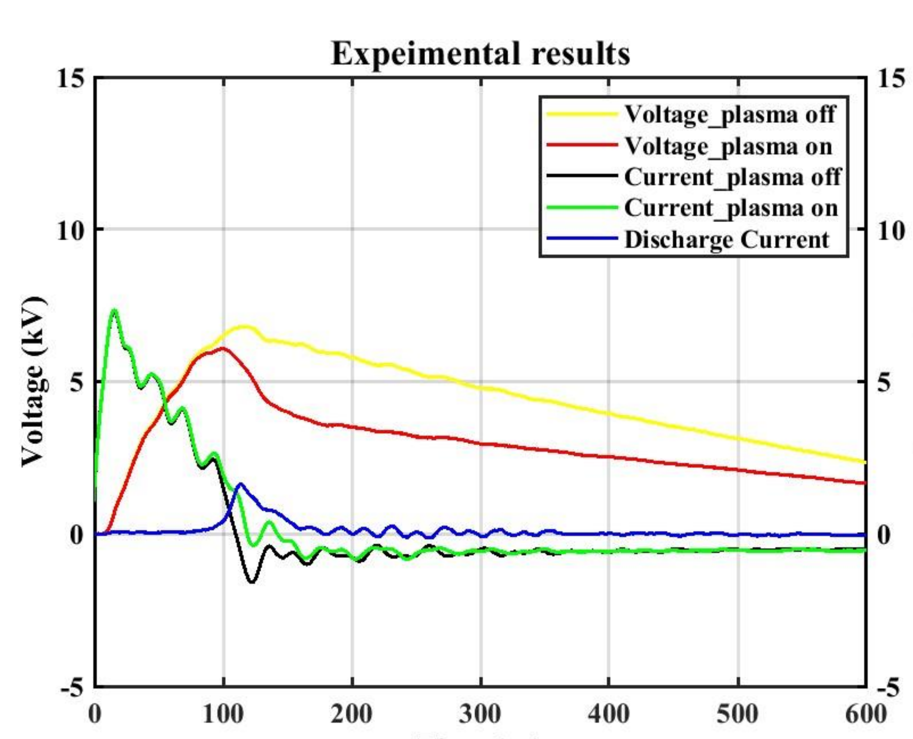
- A two-wire transmission line is used in this case.
- The dielectric material in the spacing is made of rubber.

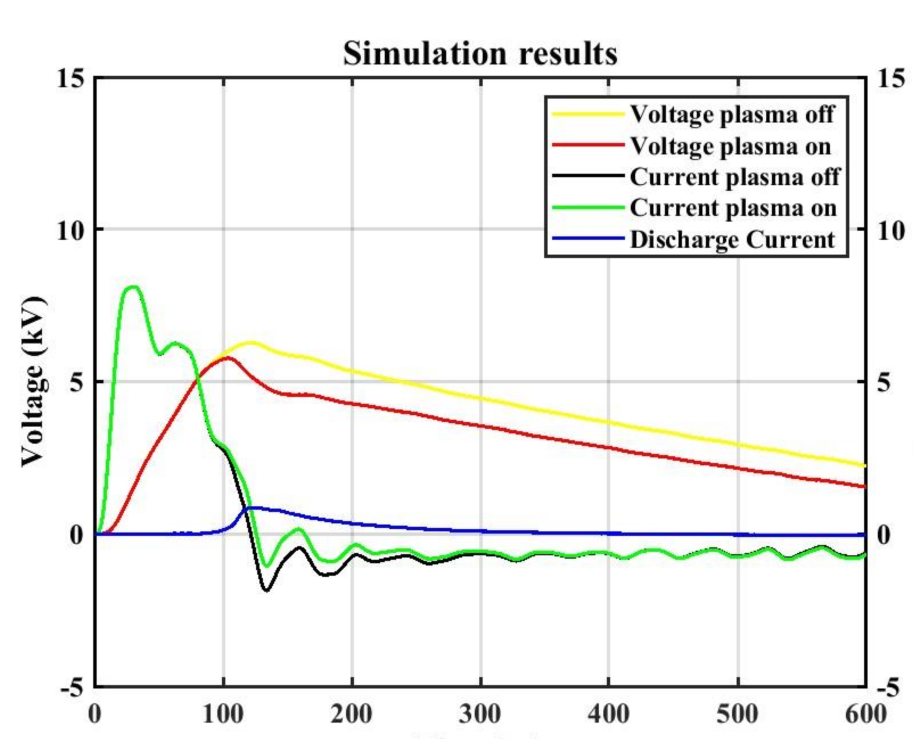
Results & Discussion

- Experimental results and Simulation results for each position of current monitor

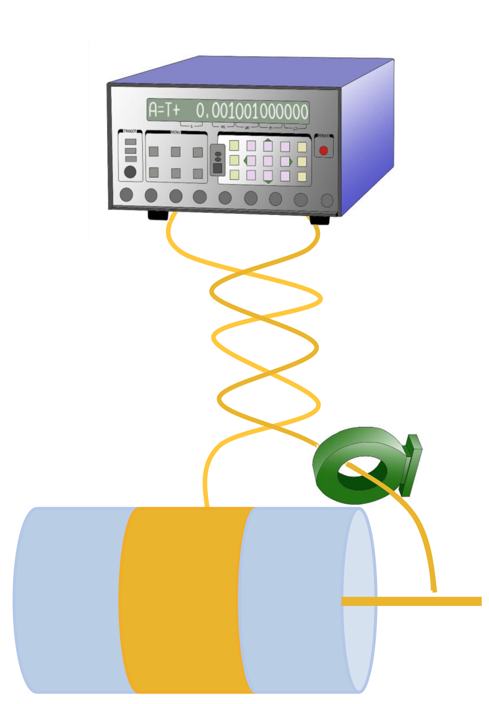
➢ **Position of current monitor close to power supply**

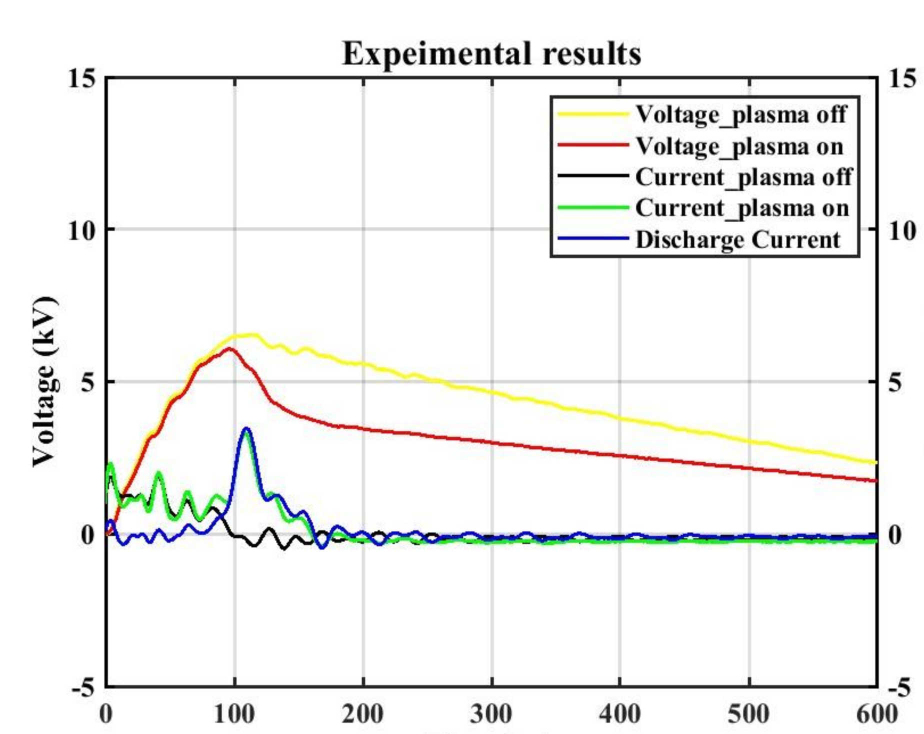


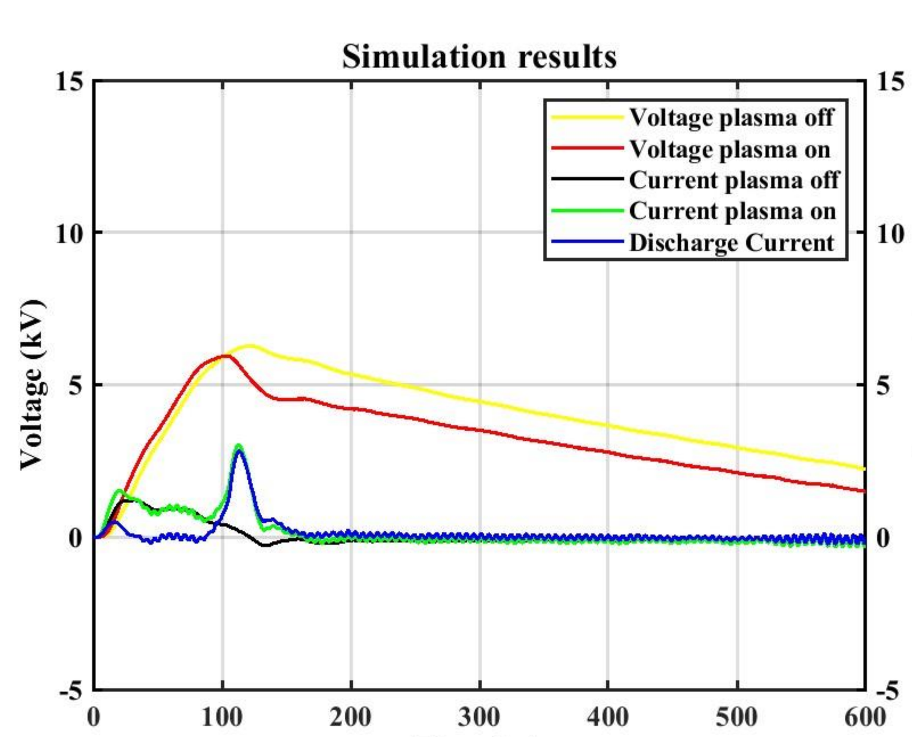




➢ **Position of current monitor close to plasma reactor**







- **Experimenetal Descriptions**
  - Experiments are conducted according to the presence or absence of He, which becomes plasma source. He is injected through the Mass Flow Controller (MFC) at 2 L/min.
  - The discharge current is calculated as the difference between the plasma-generated current and the displacement current without plasma. [4]
  - Measurements are taken near the power supply and plasma reactor to check the TL effect based on current monitor location. The power supply is located 15 cm along the cable and the plasma reactor is 185 cm away.
- **Comparisions of results about position of current monitor**
  - When measured near the power supply, both experimental and simulation data indicate a large displacement current and a small discharge current. Conversely, when measured near the plasma reactor, the opposite occurs.
  - The calculated TL parameter has a larger value than the plasma reactor capacitance. Therefore, it actually affects discharge.
  - Depending on the location, the displacement current becomes displaced, and additional discharge current from TL capacitance could be confirmed.

Conclusion & Future works

✓ Comparison of the simulation and experimental results show the transmission line effect causes differences in the output data depending on the position of the current monitor. Therefore, obtain accurate output data in NPDBD plasma without losses, it is necessary to place the current monitor closer to the reactor, minimizing the current absorbed by the transmission line and accurately measuring the discharge current.
✓ However, since the exact value of plasma resistance was not applied in the simulation, the amplitude of the discharge current and the voltage drop differ from the actual experiment. We plan to research empirical formulas for the plasma breakdown mechanism and apply them based on the given conditions.

Reference

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[2] S. Liu and M. Neiger, J. Phys. D: Appl. Phys. 34 (2001) 1632–1638
[3] Ulaby, F. Tayssir, and U. Ravaioli, Fundamentals of applied electromagnetics. Vol. 7. Upper Saddle River, NJ: Pearson, Page 159, 2015.
[4] A.V. Pipa, and R. Brandenburg, Atoms, Vol. 7, Issue 1, 14, 2019

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