Time-dependent study of Capacitively Coupled Plasma using fixed power condition

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INTRODUCTION: A power source is generally used in most plasma equipment in order to supply uniform power. The value of applied current, therefore, should be properly changed with time for fixing power when using a current source in COMSOL Multiphysics and such logic for the variable current is realized by using State Variable feature in a time-dependent Capacitively Coupled Plasma model. This study shows how to fix the power in time-dependent models and the logic to control the quantity of the current and voltage is expected to be also adopted in AC/DC module.

Simulation Methods:

1. Based on GEC CCP Reactor, Argon Chemistry tutorial model, a time-dependent Capacitively Coupled Plasma simulation is carried out by using Plasma interface . [1]
2. In order to compare the results between the time-dependent and time-periodic models, argon chemistries as well as most parameters in the tutorial model are used without any changes.
3. The current source is expressed as $I_0 \times \sin(2\pi f t)$, where I_0 is an initial current.
4. At the end of each period, the current can be changed by some adjusting factors with comparisons between the set and calculated power values.
5. The average power at the end of each period is calculated by using State Variable feature with *nojac* operator (See Appendix in associated paper).
6. The maximum step in Time-Dependent Solver is limited by the value of 1/frequency/60 for more accuracy of the calculated power.

Assumptions for Simulation:

1. Due to a self DC bias, the current source is used instead of the voltage source and the applied current is perfectly sinusoidal.
2. An initial current is given by a constant value of 0.12 A and it can be adjusted by some factors depending on calculated power values.
3. If the calculated power is lower than the set power, the current will be increased and if not, decreased.
4. 20,000 RF cycles for the periodic steady state
5. For stability on computations, the mesh is changed.
6. Instantaneous power (in Watts) : $p(t) = v(t) \times i(t)$

RESULTS:

I. Time dependences of the current and power

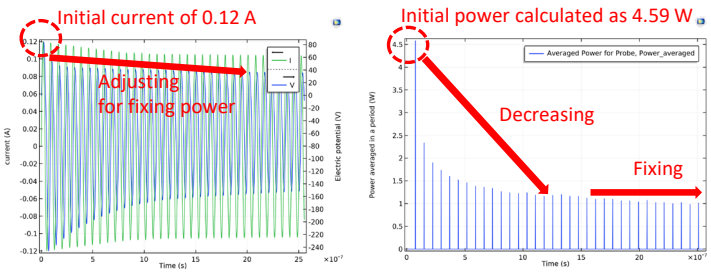

Figure 1. Time-dependent current/voltage profiles (Left) and power averaged at the end of each period (Right) for the first few periods.

II. Comparisons between the time-periodic and time-dependent models

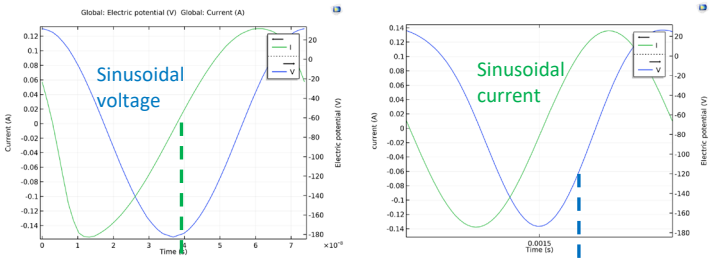

Figure 2. Current and electric potential profiles at the periodic steady state obtained using Time Periodic to Time Dependent study (Left) and Time Dependent study (Right).

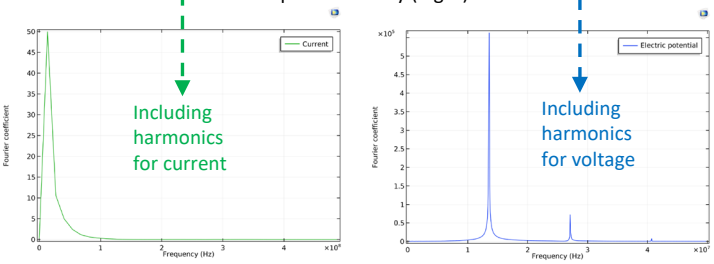

Figure 3. Fourier transform of the current in the time-periodic (Left) model and that of voltage in the time-dependent (Right) model, respectively.

III. Electron densities at the periodic steady state

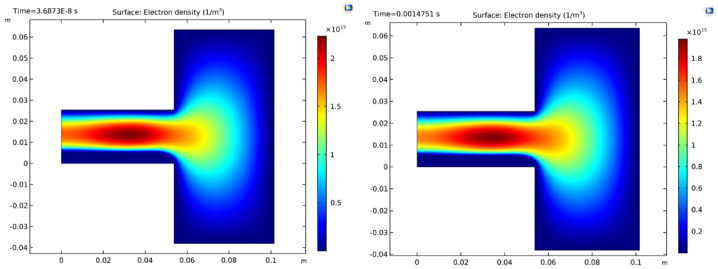

Figure 4. Electron density distributions obtained using Time Periodic to Time Dependent study (Left) and Time Dependent study (Right), respectively.

➢ The difference caused by applying the sinusoidal current

CONCLUSIONS: The time-dependent study of Capacitively Coupled Plasma using the fixed power condition is successfully performed in this research. Although there are some differences due to the assumption of the sinusoidal current, most results in the time-dependent model are consistent with those in the time-periodic model. These results indicate that the fixed power condition may be realized in the time-dependent models and such logics can also be applied in AC/DC module.

REFERENCES:

1. GEC CCP Reactor, Argon Chemistry tutorial model in COMSOL Multiphysics, https://www.comsol.com/model/gec-ccp-reactor-argon-chemistry-55011