Design of a variable high voltage power supply for the operation of cold plasma reactors

Student

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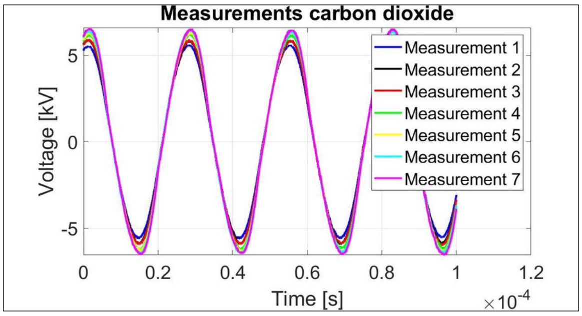
Introduction: Carbon dioxide, which is produced during the generation of thermal energy, pollutes the environment and can generate high costs. Changing over to more environmentally friendly electrical energy involves a high financial investment. One option is integration through electrical generation of alternative fuels in the form of e-fuels (power-to-fuel). The feedstock for e-fuels in this case is carbon monoxide, which can be extracted from carbon dioxide with thermal or electrical power using a plasma. In this work, a high voltage power supply for the generation of a plasma will be designed and built. An efficient as well as robust variant is offered by dielectric barrier discharge (DBD), which is investigated in this project. This is a flexible method for generating a high voltage that will finally lead to the ignition of the plasma. The power supply should be able to generate different voltages up to 10 kV as well as powers of at least 300 W and voltage pulses with a repetition frequency of several kHz.

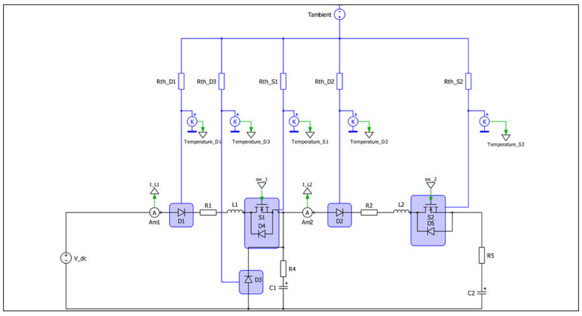
Approach: The need of the Power Supply in this project is to optimize already existing high voltage generators for the generation of the plasma at specific DBD reactors. To this end, the first step is to take measurements on a functioning system for generating a plasma. This will allow estimations to be made of the power and voltage required to ignite a plasma in the presence of carbon dioxide. Subsequently, the functioning of existing high-voltage power supplies will be investigated. Circuit simulations will be used to design and build the hardware in the form of a printed circuit board (PCB), as well as the transformer required for the high voltage. The transformer constructed in this work is a modification of a so-called Tesla transformer. It uses toroidal iron powder cores with low magnetic permeability and high magnetic saturation. This allows a more compact design compared to the classical Tesla transformers.

Conclusion: Based on the power electronics simulations in Plexim's PLECS software, the design and construction as well as the final control of the semiconductor switches offers a lot of room for optimization. Tradeoffs arise between the maximum possible performance that the power supply can deliver and the required space as well as the costs that have to be spent on the hardware. The key issues are the magnitude and duration of the voltage pulse, which is determined by the resonant frequencies of the primary and secondary capacitances and inductances of the Tesla transformer, and the repetition rate until a voltage pulse is possible again. At the beginning, this project was about designing a working high-voltage power supply. For this purpose, already known values of components were used and adapted to the task. To save resources, the Tesla transformer was built from existing iron powder cores and optimized. Based on the calculations and simulations, it should be possible to ignite the plasma with the newly built High Voltage Power Supply. This will allow experience to be gained, so that in a next step the hardware can be improved to the highest possible efficiency by adjusting its components and the switching cycle of the semiconductor switches.

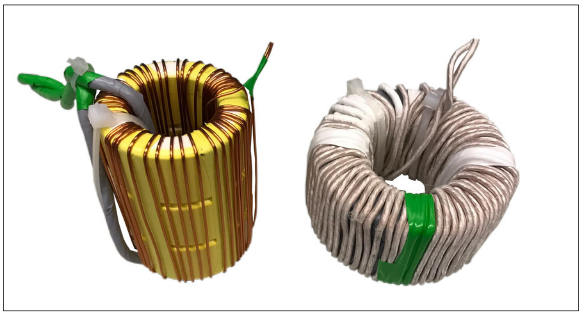
Measured voltages which cause ignition of the plasma at the DBD reactor.
Own presentment



Overview diagram of the simulation of the high voltage power supply in PLECS.
Own presentment



Realized Tesla transformer (left) with corresponding leakage inductance (right) to adjust the desired coupling factor
Own presentment



Examiner
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Subject Area
Energy and Environment

Project Partner
IET, UMTEC, Rapperswil, St.Gallen