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Pulsed Power Technology for Transient Plasma Applications at Eindhoven University of Technology

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In this contribution we give an overview of pulsed power technology development for transient plasma applications at Eindhoven University of Technology at the Electrical Energy Systems group. These applications include pulsed corona plasma for air purification and plasma-activated water generation. The success and efficiency of these applications depends largely on the power modulator that is used to generate the transient plasma and on the interaction between the modulator and the plasma. We will show such modulators, transient plasma results obtained with these modulators and how we analyze and optimize modulator-plasma interaction. Additionally, we will present new research lines we are developing.

Our recent pulse modulators are based on the solid-state Impedance-Matched Marx generator concept we introduced in 2019 [1], see Fig. 1 . The advantage of using the IMG topology is that by using transmission lines to transmit the pulses from the Marx stages the rise time of the pulses can be maintained at the output waveform (when carefully impedance-matched). By designing the Marx stages very compactly and using fast semiconductor components, adjustable pulses with rise times of just several nanoseconds are feasible with this topology. Since we require such fast rising pulses for transient plasma generation, the solid-state IMG is ideally suited for our purpose. We will present the development of new versions of the solid-state IMGs. The first version is being developed to have the fastest possible rise time, utilizing 12 stages of gate-boosted [2] and series-connected 1200V SiC MOSFETs and achieving several ns rise time at 30-kV output voltage. The second solid-state IMG version is being developed to have maximum flexibility in its output voltage waveform. This version also uses 1200V SiC MOSFETs (not series-connected) in 20 stages and achieves a 6-ns rise time at 20-kV output voltage. Furthermore, we will show the FPGA control of the IMGs and how we automatically calibrate the stages with this control system to obtain the fastest possible rise time. Additionally, we present our plans for >100kV solid-state IMGs.

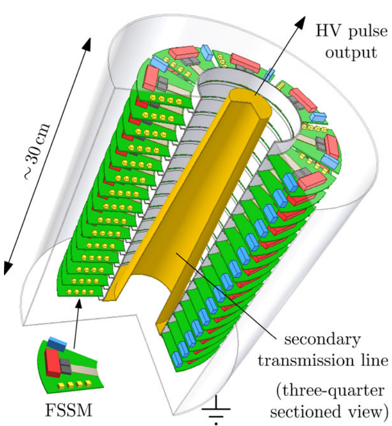

Figure 1. The solid-state IMG concept. Multiple circular stages are connected in series and each stage is a parallel connection of fast semiconductor switch modules (FSSMs). Each FSSM produces a pulse which travels into the central coaxial structure. When perfectly impedance-matched, all pulses add up at the load, producing a high-voltage pulse [1]

Second, we will present recent results on pulsed streamer discharge generation with a 10-kV version of a solid-state IMG. The IMG is capable of 6-7-ns rise time pulses on the load formed by the corona-plasma reactor in this study (we used a cylinder-wire reactors with an outer diameter of 16 mm and 20 mm). Because the stages of the IMG can be controlled at will, arbitrary waveform pulses can be generated. The purpose of the study was to perform some first experiments on waveform variation (e.g. rise time variation, stepped waveforms, etc.) and see the effects on the generated streamer plasma and if we can "control" the streamers with the IMG. For this purpose, we used an ICCD camera to observe the streamers. The results show that we can indeed control the streamer propagation with arbitrary waveforms

References
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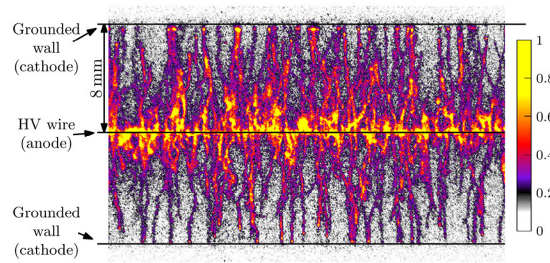

Figure 2. An example long-exposure ICCD image, with the grounded reactor wall and HV wire indicated. A 6.8-ns rise-time pulse from a 10-kV IMG was used to produce this image [3].