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Helical Pulse-Forming Transmission Line Stack for Compact Pulsed Power Applications - Design and Simulation

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Design considerations and initial static charge and transient discharge simulations using COMSOL Multiphysics™ are presented for a stacked set of pulse-forming transmission (T-) line modules charged in parallel and discharged in series. Each module is designed to use a rigid injection-molded dielectric (cast in halves to accommodate the center conductor) with a helical discharge path of constant real impedance Z. High peak energy density U for high initial charge voltage V is possible with such materials made of ceramic or ceramic powder-polymer composite. The helical path permits a high volume utilization efficiency η (effective system mean energy density/U) for compact applications. Given the system's cylindrical return conductor housing of outer radius R and height H, $TV^2=4\pi R^2H\eta UZ$ for an impedance-matched load. Here, T is the time interval for which the load current and voltage are within the ranges for which the load is effectively driven (neglecting rise and fall times). The model is fully parameterized so, for example, each module's rectangular cross-section T-line aspect ratio AT (width/height) and helical aspect ratio AH (T-line center to helical axis distance/T-line half-width) are free to be varied. This allows for a wide range of system configurations to be studied with minimal effort. Given an optimized T-line center conductor shape, the contribution to η from the T-line itself is about 0.33 for the AT=1-4 range studied. The minimum AH considered is 2, giving a T-line volume fraction upper bound of 8/9. Their product implies an upper bound on η of about 0.3. Other system requirements, such as extra length and possibly higher AH needed to accommodate a low-inductance multi-channel spark-gap switch between modules, a tri-axial charging and multichannel trigger circuit within each module, and insulation between stages and return conductor, typically lower η to the 0.15-0.25 range for cases studied.

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