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Evaluation of Trends in Optimal Design of Pulse Transformers for Long Pulse High Power Applications

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Solid state klystron modulators are typically based on oil-immersed pulse transformers due to their high performance, robustness, simplicity and straightforward design. However, the size of such transformers are highly impacted by pulse power, output voltage, pulse length, and required rise time; key parameters which are difficult to combine in long pulse high power linac applications.

In this paper, pulse transformer design models for two winding configurations (single layer winding and pancake winding), including calculation of parasitic elements, are developed and validated in a 3D finite element analysis environment. These models are then employed in a global optimal design procedure used to study the evolution of pulse transformer footprint, magnetic core volume, oil tank volume, and efficiency as pulse length is increased from 100 µs to 4 ms while constraining maximum pulse rise time and overshoot. The impact of required pulse power and output voltage is also studied.

The single layer winding based on standard enameled round wire is first investigated without externally imposed restrictions on size to study the limitations of this first winding technique. This is followed by a study of the same configuration but with constraints on transformer size imposed mainly by manufacturability and maintainability, in which it is seen that sub-optimal rise time and therefore transformer size is attained for long pulse high power applications. Consequently, the pancake winding configuration is evaluated under the same conditions, demonstrating that, although more complex and costly, its flexibility allows a more compact design.

Finally, a pulse transformer rated for pulse amplitude 115 kV, output current 25 A, pulse length 2.8 ms, and 0-99% rise time <300 µs is designed, demonstrating the design procedure and showcasing limitations experienced in design. Its performance is assessed in circuit simulation whereas the validity of the derived parameters is demonstrated through finite element analysis.

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