Design of a Three-phase Rotating Magnetic Field Power Processing Unit for Inductive Plasmoid Propulsion

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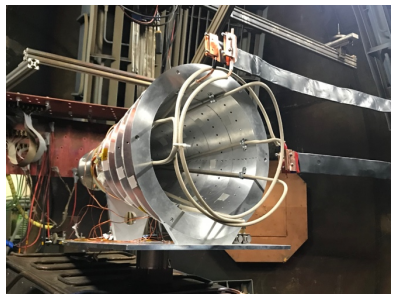
Motivation

The 3-Phase RMF PPU is designed for use in inductive plasmoid propulsion. The rotating field generates azimuthal currents in the propellant plasma and produces thrust via a Lorentz force interaction. Inductive propulsion is advantageous due to its lack of propellant dependence, and ability to trade I_{sp} and thrust in multi-mode operation [1]. Previous RMF propulsion schemes have used 2-phase RMF antenna arrangements. The advantage of a 3-phase RMF system is to eliminate the spatial harmonics in the RMF and improve thruster performance [2].



UM RMF Thruster

Expected Performance

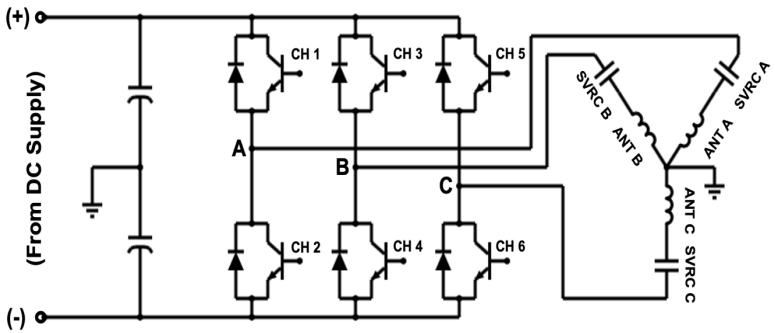
- 16 kW per phase
- Max duty cycle: 10%
- Pulse width: 100 µs
- Freq: 0-300 kHz
- Peak current: 4 kA

The 3-phase RMF PPU is the second iteration of a UM RMF supply. The new configuration adds a 3rd phase and allows for higher power, longer pulse times, and higher frequencies.

Three-phase PPU Design

The 3-Phase PPU configuration is a series-loaded resonant sine inverter, which generates kA level currents while only exposing the driving switches to several hundred volts. The primary circuit schematic consists of three half-bridge IGBT switching units fed by a backing DC capacitor bank and 3 switched variable resonant capacitor banks (SVRCs) connected in series to the RMF antennas. The resonant capacitor banks are varied to form an LC oscillator at various RMF frequencies, which then resonates with the square wave from each half-bridge unit.

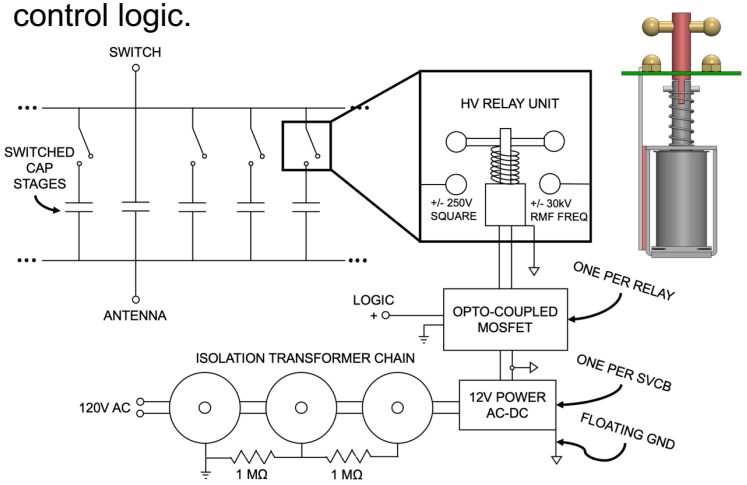
3-Phase RMF PPU



3-Phase PPU Schematic

Switched Variable Resonant Capacitors

The SVRCs permit rapid changes of RMF frequency between test points in 20 kHz increments. They employ pulse film capacitors and custom high voltage solenoid relays. The relays are designed to withstand 20 kV rms under high vacuum and use an isolated power supply with optically isolated control logic.



SVRC Functional Diagram

References

[1] J.L. Rovey, et. al, J. P. Aero Sci. **118** (2020): 100627.
[2] W.N. Hugrass, Aust. J. Phys. **39(4),** 513-528 (1986).

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