INITIAL DESIGN OF THE 60 MEGAWATT ROTATING MAGNETIC FIELD (RMF) OSCILLATOR SYSTEM FOR THE UNIVERSITY OF WASHINGTON "TCS" FIELD REVERSED CONFIGURATION EXPERIMENT

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INITIAL DESIGN OF THE 60 MEGAWATT ROTATING MAGNETIC FIELD (RMF) OSCILLATOR SYSTEM FOR THE UNIVERSITY OF WASHINGTON "TCS" FIELD REVERSED CONFIGURATION EXPERIMENT

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I. ABSTRACT

This paper presents the initial electrical and mechanical design of two phase-locked 30 Megawatt RMS, 150 kHz oscillator systems used for current drive and plasma sustainment of the "Translation, Confinement, and Sustainment" (TCS) field reversed configuration (FRC) plasma. By the application of orthogonally-placed saddle coils on the surface of the glass vacuum vessel, the phase-controlled rotating magnetic field perturbation will induce an electric field in the plasma which should counter the intrinsic ohmic decay of the plasma, and maintain the FRC.

Each system utilizes a bank of 6 parallel magnetically beamed ML8618 triodes. These devices are rated at 250 Amperes cathode current and a 45 kV plate voltage. An advantage of the magnetically beamed triode is their efficiency, requiring only 2.5 kW of filament and a few amps and a few kV of grid drive. Each 3.5 UH saddle coil is configured with an adjustable tank circuit (for tuning). Assuming no losses and a nominal 18 kV plate voltage, the tubes can circulate about 40 kV and 9 kA (pk to pk) in the saddle coil antenna, a circulating power of over 33 megawatts RMS. On each cycle the tubes can kick in up to 1500 Amperes, providing a robust phase control. DC high-voltage from the tubes is isolated from the saddle coil antennas and tank circuits by a 1:1 coaxial air-core balun transformer. To interconnect the various system modules, multiple parallel coaxial cables are utilized, as shown in Figure 2. Six parallel RG-220 cables are used, except for the coaxial balun, which uses low inductance RG17/14 60 kV "Scyllac" cable. The system modules consist of the capacitor bank, charging power supply, tube power module, balun transformer assembly, antenna tuning (tank) network, and the saddle coil antenna. The modules may easily be shipped, with the power module being the largest, 7' x 11' x 6' tall.

III. CALCULATED PERFORMANCE

A SCEPTRE-like circuit code model was used to determine the expected oscillator performance. The equivalent model, as shown in Figure 3, includes the lump element, parasitic, and fault damping components. Damping in the capacitor bank is required to prevent ringing in the event of a crowbar or arc. The ML8618's also require plate De-Q's to prevent oscillation. The air core balun transformer provides only a 20 uH magnetizing inductance and the length of the parallel array of RG17/14 cables give a 300 nH leakage inductance. The plasma load impedance (.15 Ohm) is a guess based on field penetration and plasma density. The modeled performance shows a 9.2 kA pk to pk oscillation through the 3.5 UH saddle coil antenna, an "RMS" power of almost 37 megawatts. The machine
Figure 1. Oscillator Simplified Diagram

Figure 2. Module InterConnections
Figure 3. Equivalent Circuit Model

Figure 4. Antenna and Tube Currents
(supposedly) only requires 25 MW, this extra compliance permits either operation at a lower bank voltage or with a reduced tube count. In the event of a tube failure, operation may be continued without any detriment to operation, by simply disconnecting the terminals of the faulty tube. Additionally, when the full output swing is obtained, the tubes are only switching about 500 amps. A pair of the 250 amp ML8618 tubes could bring the system to full ratings, but with a slow build-up of circulating power. A higher switching capability would help maintain the proper phasing between the two oscillator systems.

IV. CONCLUSION

The TCS FRC oscillator power system is designed to be a utility for the physics experimental program, not a development project. The systems are conservatively designed of known technology of proven performance in similar and previous fusion applications. These previous systems operated many years with little maintenance and few “down” times. Similar performance for this system can be expected. To minimize cost, material and expertise has been leverage from the Los Alamos fusion program to assist in the continued work on alternate concepts. This work is supported through the DOE Office of Fusion Energy Sciences, and Contract No. W-7405-ENG-36.