Design of a 5.5 MJ Charge Dump Power Supply for the PPPL FLARE Experiment

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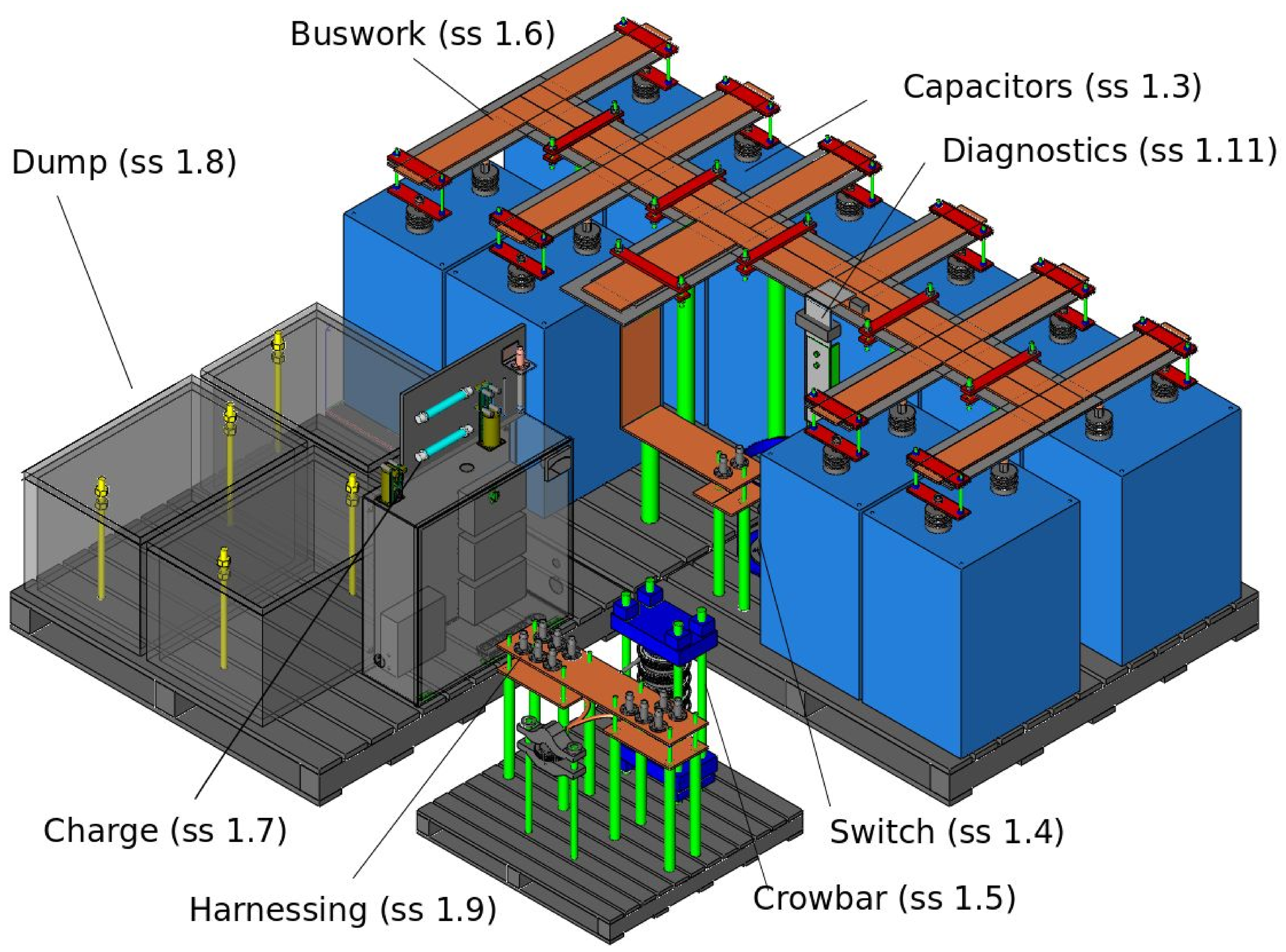
Introduction

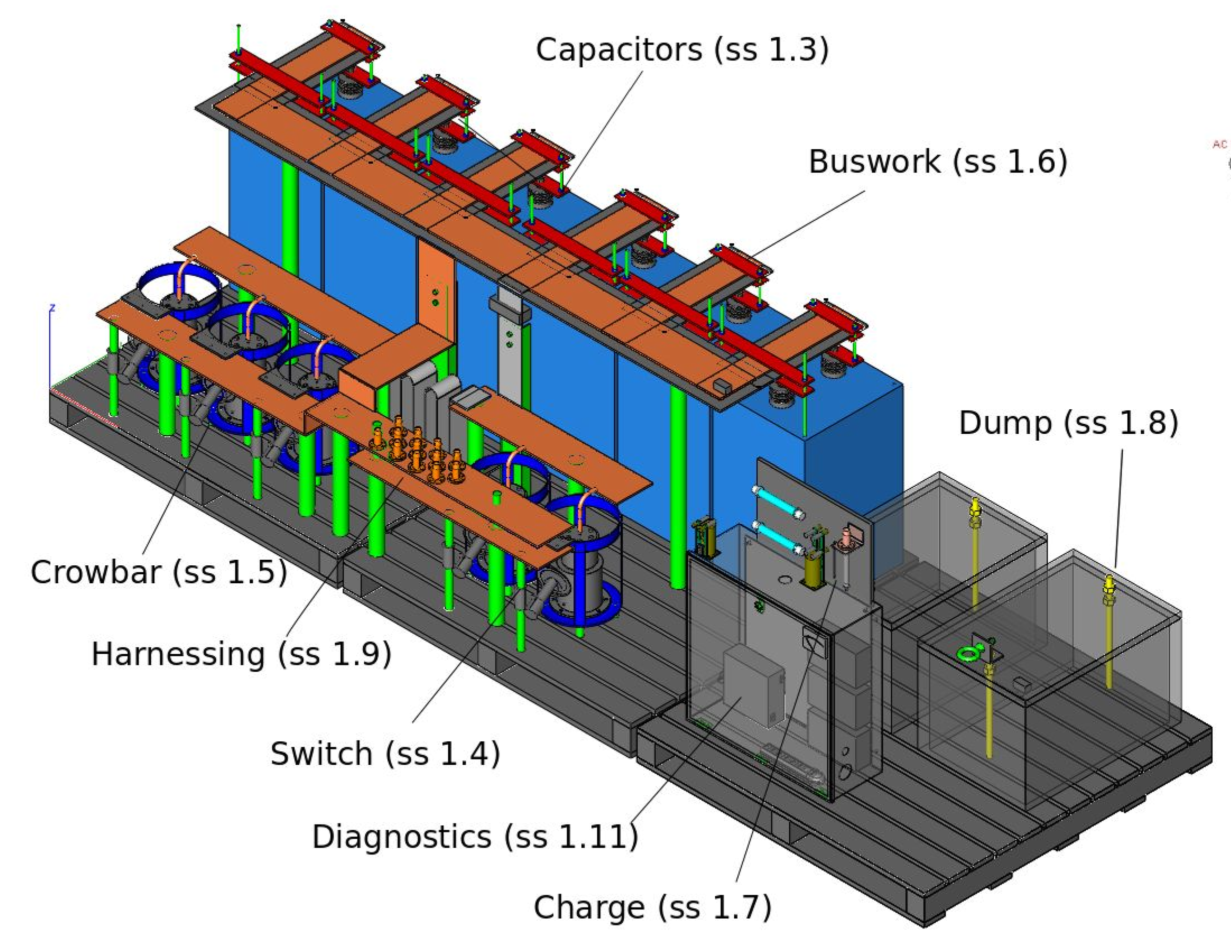
The Facility for Laboratory Reconnection Experiments (FLARE) is an intermediate laboratory experiment currently under construction at Princeton University by a consortium of five universities and two Department of Energy (DoE) national laboratories, located at the PPPL. The goal of FLARE is to provide experimental accesses to new regimes of the magnetic reconnection process and related phenomena directly relevant to heliophysics, astrophysics, and fusion plasmas.

The device comprises a vacuum chamber and 9 coils sets that are independently programmable to provide the poloidal and toroidal magnetic fields required to form plasma and study the effects of magnetic reconnection. Each of these 9 coil sets requires a separate pulsed power system, it is the design of the power systems that is reported here. The 9 separate pulsed power systems combine to produce over 5.5 MJ of energy to the experiment and each presented their own unique challenges. The most energetic power system is a 3.4 MJ, 19.2 mF capacitor bank charged to 20 kV that provides the guide field, with a rise time of approximately 12 ms it delivers an average peak current of 40 kA over 5.3 ms to 12 coils wired in series. The poloidal field coils consist of two separate coilsets each requiring 540 kA peak current which is produced by two 20 kV, 2.64 mF capacitor banks. The design of the two driver coilsets each charged to 60 kV will also be presented.

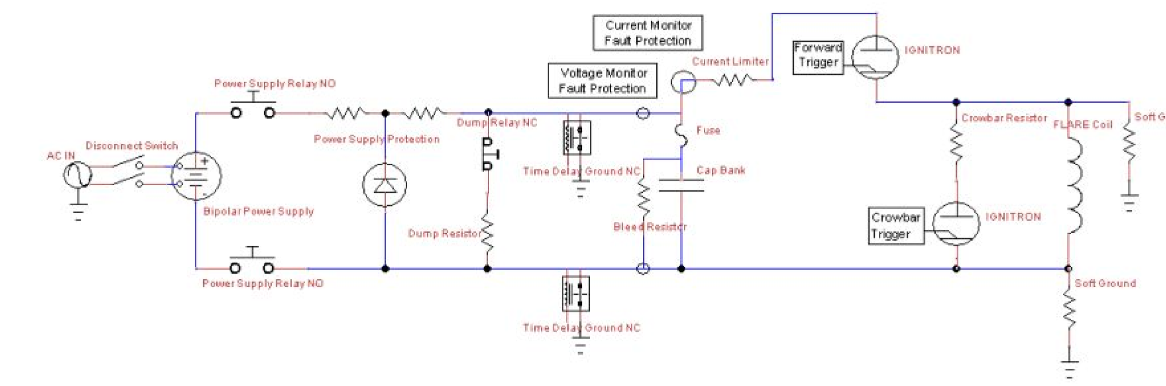
Render of One Guide Field Module

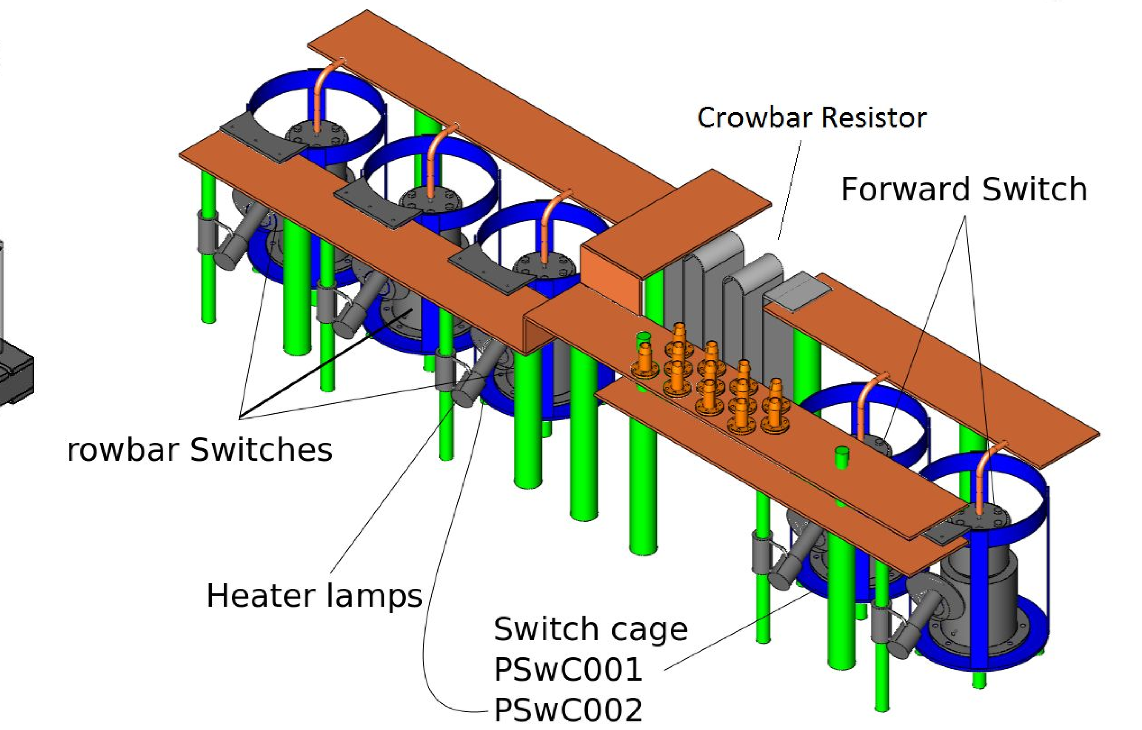


Render of One Poloidal Field Bank



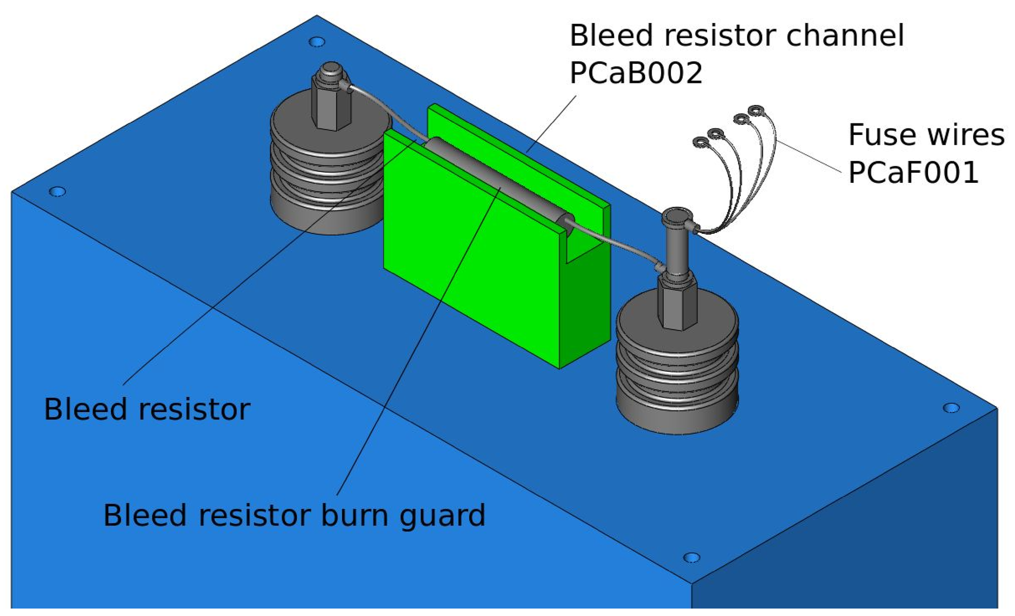
Ohmic Heating Coil Schematic





FLARE Experiment Power Requirements

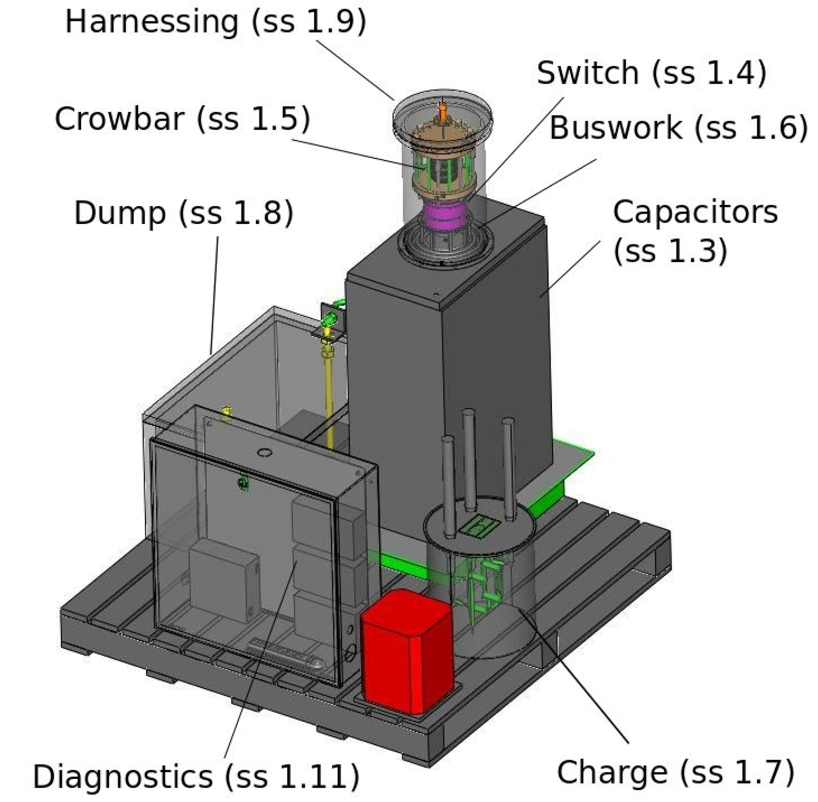
	OH	EF	GF	PF-A	PF-B	TF-A	TF-B	DC-I	DC-O
# Sub-Coils	2	2	12	4	4	4	4	2	2
V (Volts)	20000	1400	20000	20000	20000	20000	20000	60000	60000
Imax (A)	180000	26000	40000	540000	540000	250000	250000	50000	50000
Vmax	Same	Same	Same	Same	Same	Same	Same	20 kV	20 kV
Day 1	0	33.3	20	33.3	33.3	33.3	33.3	0	0
Peak I (kA)	180	26	40	540	540	250	250	50	50
trise (ms)	< 0.45	> 30	NA	< 0.11	< 0.11	< 0.08	< 0.08	< 0.01	< 0.03
tcrowbar	Peak	Peak	Peak	Peak	Peak	Peak 50%	Peak 50%	Peak	Peak
Swing Imin	+ve	+ve	+ve	70% -50%	70% -50%	70% 0	70% 0	+ve	+ve

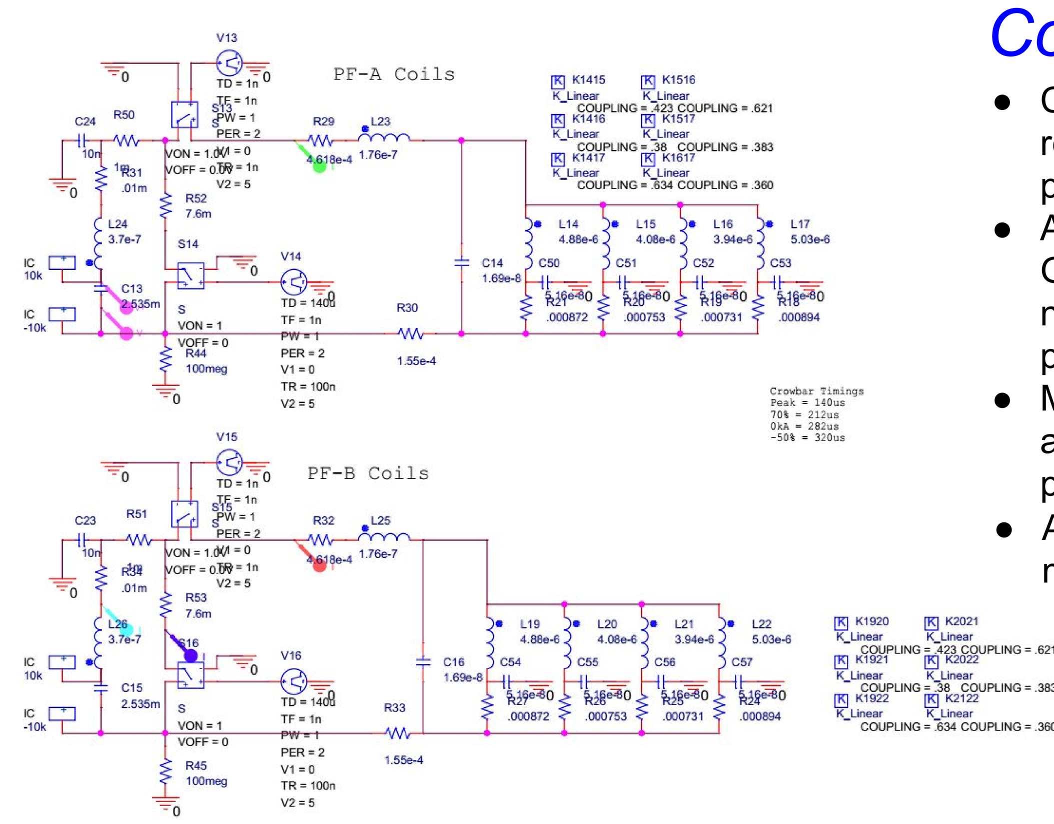


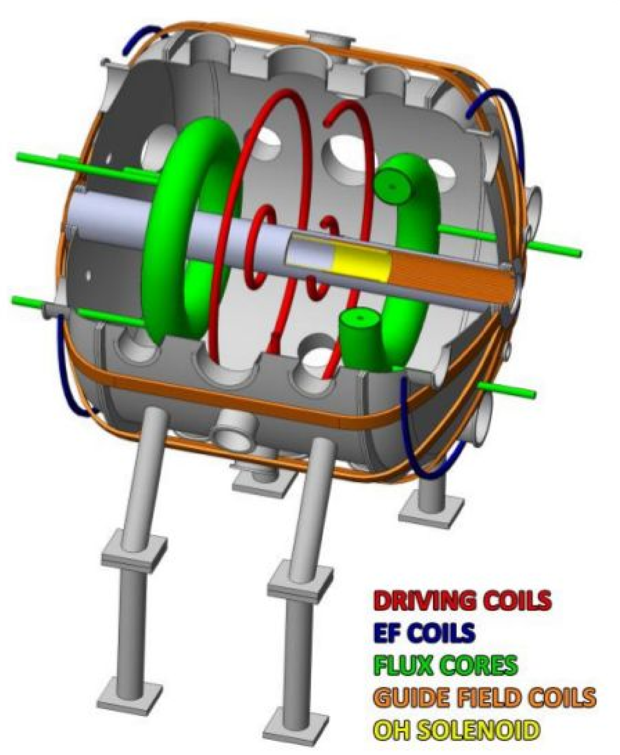
Complete Engineering Design

- A full engineering design was completed for all capacitor banks
- The banks are designed to minimize the inductance and resistance of all buswork and harnessing
- The copper buswork connecting the capacitors are water-cut from one large sheet to virtually eliminate contact resistance
- The buswork is designed such that the positive and negative busses can be cut from one standard sheet
- All banks are designed with redundant fail-safes including specified fuses, bleed resistors, large copper sulfate pentahydrate dump resistors, and hard grounding straps on time delayed relays

60 kV Driver Coil Bank







FLARE Vacuum Chamber and Magnet Coils

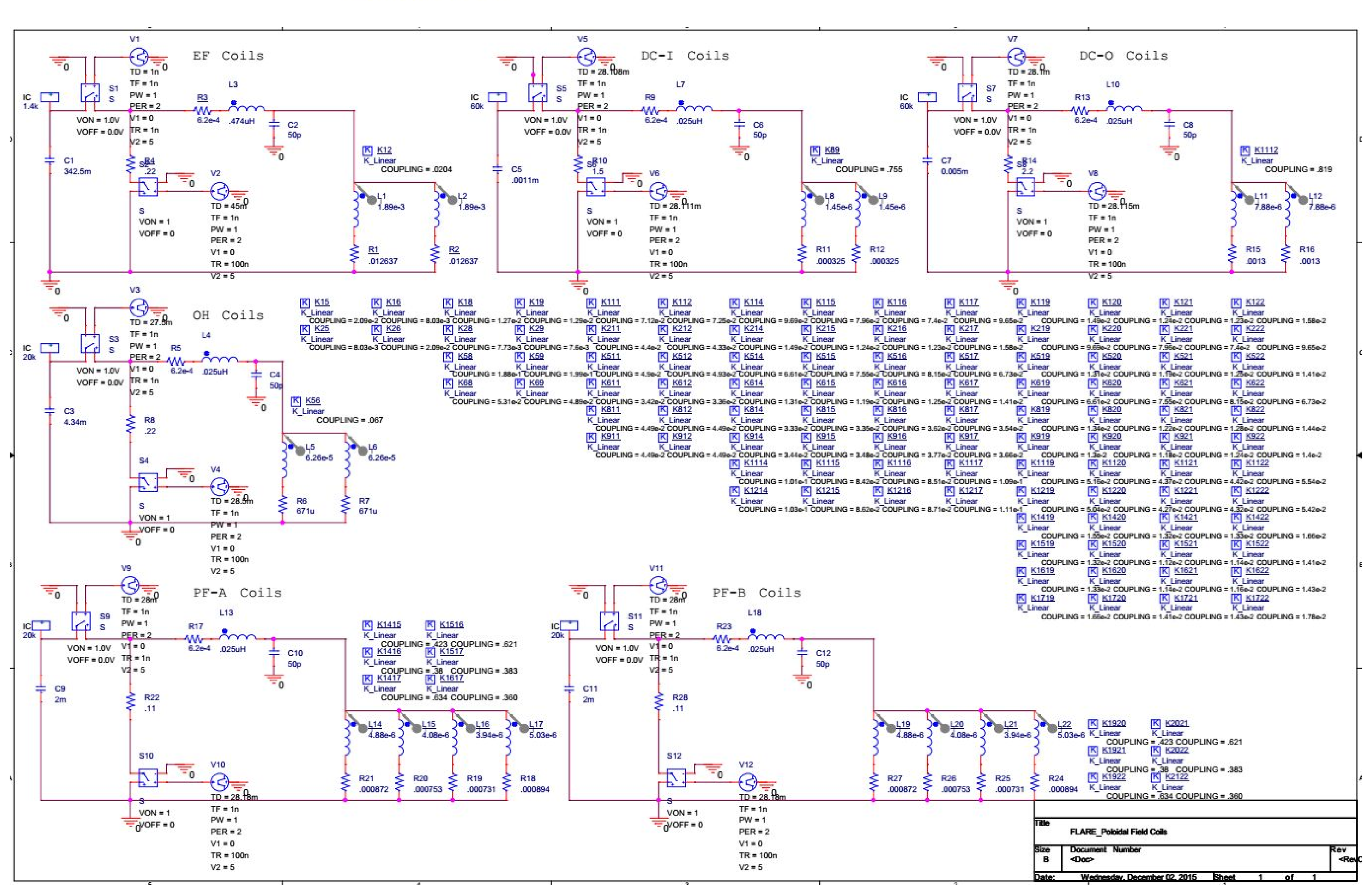
- The FLARE experiment will provide experimental access to new regimes of the magnetic reconnection process
- The design is based on the Magnetic Reconnection Experiment (MRX) and will further our understanding of heliophysics, astrophysics, and fusion plasmas.
- The vacuum chamber measures 3 m in diameter and 3.5 m in length and consists of 9 separate capacitor banks and 36 magnet coils

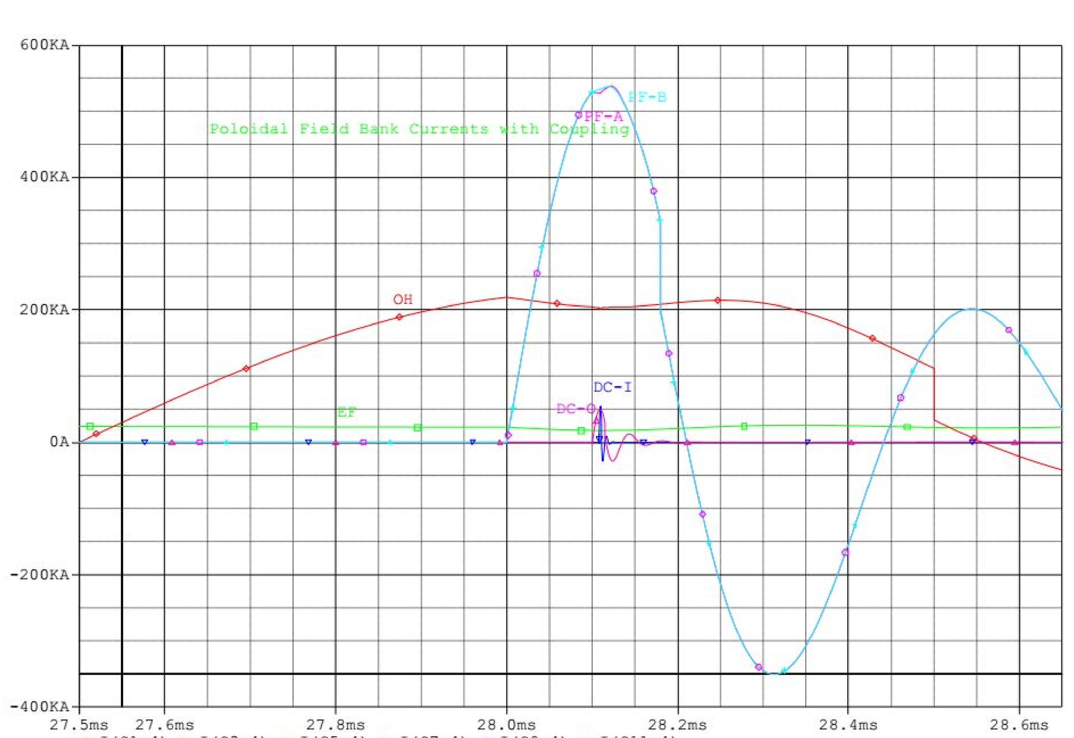
Cost Optimization

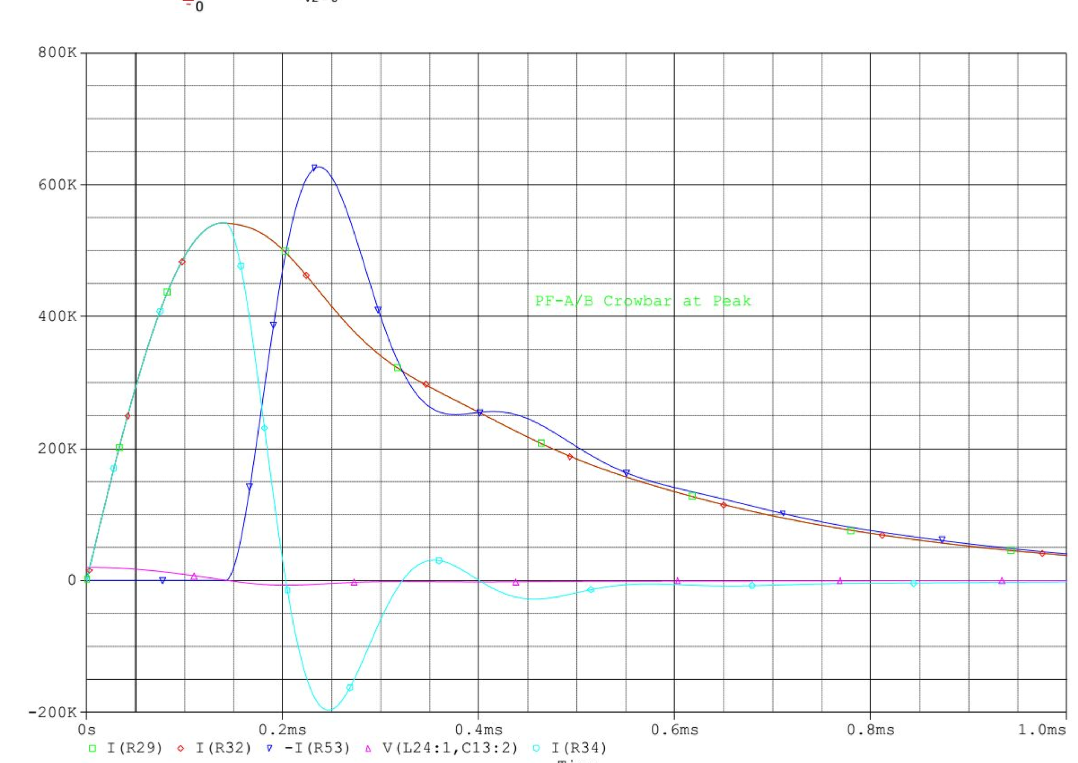
- Considerable cost savings were realized during all phases of this project
- A major redesign of the energetic Guide Field Bank resulted in a nearly 10% reduction of the entire project cost
- Multiple PSpice simulations were analyzed to maximize the power per dollar
- All banks were engineered not only to maximize performance but to minimize material costs, labor, and complexity

PSpice Simulations

- An extensive PSpice analysis was completed for every capacitor bank
- The inductance, capacitance, and resistance of components was calculated and included in the simulations with a safety factor
- The mutual inductance between all coupled magnet coils was included and complete models of all toroidal and poloidal field capacitor banks were developed
- A full poloidal field model and an individual bank model are shown along with the corresponding transient analysis







Data Acquisition and Control Wiring Diagram