Statement of Work (SOW)
for
Design of Capacitor Charge/Discharge Power Supply (CCDPS) for FLARE

FLARE-CCDPS-150828

Reference Work Planning #: NA

REVISION 0

Wednesday, September 09, 2015

PREPARED BY: Zhi Gao
Digitally signed by Zhi Gao
DN: cn=Zhi Gao, o=Engineering, ou=AC Power, email=agao@pppl.gov, c=US
Date: 2015.09.10 09:26:26 -04'00'

Cognizant Individual / ATI

REVIEWED BY: Barry L. Jedic
Digitally signed by Barry L. Jedic
DN: cn=Barry L. Jedic, o, ou, email=bjedic@pppl.gov, c=US
Date: 2015.09.09 15:46:10 -04'00'

Quality Assurance (Barry Jedic)

REVIEWED BY: Michael Kalish
Digitally signed by Michael Kalish
DN: cn=Michael Kalish, o=PPPL, ou=Engineering, email=mkalish@pppl.gov, c=US
Date: 2015.09.09 15:53:06 -04'00'

Project Manager (Michael Kalish)

APPROVED BY: John C. Lacenere
Digitally signed by John C. Lacenere
DN: cn=John C. Lacenere, o=PPPL, ou=AC Power, email=lacenere@pppl.gov, c=US
Date: 2015.09.09 15:19:28 -04'00'

Supervisor / RLM (John Lacenere)

PRINCETON UNIVERSITY
PLASMA PHYSICS LABORATORY
P.O. BOX 451
PRINCETON, N.J. 08543

Table of Contents

TABLE OF FIGURES

Table of Tables

1. Introduction and Scope

1.1 Background

The Princeton Plasma Physics Laboratory (PPPL) is in the process of designing and constructing the FLARE (Facility for Laboratory Reconnection Experiment) experimental machine. The purpose of FLARE experiment is to study the magnetic reconnection in regimes previously inaccessible. The project is a multi-year project funded by the National Science Foundation and the Department of Energy.

The FLARE experiment will be performed in two phases – initial proof-of-concept phase and full experimental phase. The FLARE machine is the same during these two phases, but the voltage and current required from the power supplies are different. In the initial phase, the current and voltage required is the minimum needed to achieve plasma in the FLARE machine.

The power supply for FLARE consists of a number of capacitor banks, to be switched at high speed, and discharged rapidly into the various coil sets indicated below in this SOW. The typical discharge time is in the range of 0.01-100 msec. The FLARE machine will consist of nine (9) coil systems and each coil system will be powered and controlled by its own separate capacitor bank and charging/discharging power supply set.

This Scope of Work (SOW) covers the minimum requirements for a Subcontractor to prepare a Final Design for the Capacitor Charge/Discharge Power Supplies (CCDPSs) for the nine (9) coil systems necessary for the PPPL FLARE experiment (flare.pppl.gov).

1.2 Scope

1.2.1 Scope of Equipment

Final Design package should include technical documentations suitable for inclusion in purchasing specifications to be prepared by PPPL for competitive procurement of the CCDPS hardware. The technical aspects below should be fully analyzed and specified:

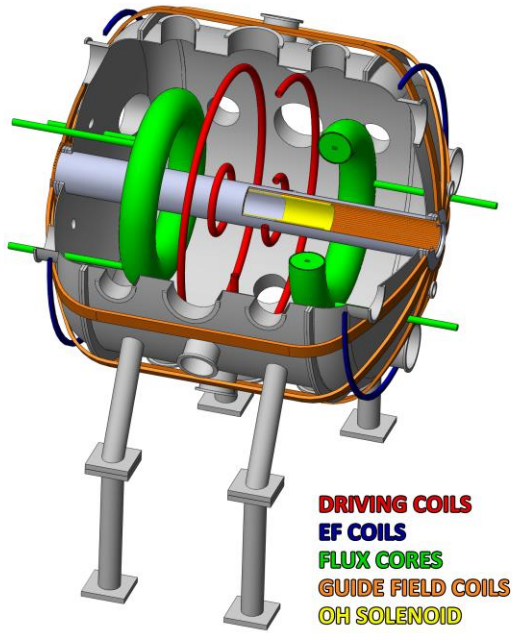
1. Specify the design components' DC voltage/current ratings, control modes, set-points and limits.
2. Specify the capacitor bank charging power supplies.
3. Furnish design for capacitor banks including size and ratings for capacitors, bleeder resistors, fuses, discharge resistors, disconnect switches, and grounding switches.
4. Present basis for estimating capacitor life.
5. Specify recommended "Crowbar" or energy discharge switches for normal pulsing operations and system protection. Diode commutation of less critical coils may be utilized, if appropriate (see 5.2.2 below).
6. Specify all interconnecting power cables from the CCDPSs to the FLARE machine. This includes, but not limited to, cable types and impedances, types of terminations for the connections.
7. Specify all control cables for the required proper CCDPS and coil pulsing operations.
8. Specify local CCDPS controller and I/O interface and human-machine interface (HMI)
9. Specify recommended voltage and current measuring devices that interface with PPPL LabVIEW data acquisition system.
10. Specify mechanical guarding system requirements for each CCDPS. Guarding design should include minimum clearances and grounding requirements for personnel protection.

1.2.2 Task and Deliverables

The Subcontractor shall perform/submit the following tasks/deliverables in accordance with the deliverables attached hereto.

1. Submit the quote/proposal to PPPL before the deadline with all the accompanying documents (see section 4.2.2)
2. Evaluation of scope and data provided by PPPL and schedule for a Q&A session if unclear about the project scope and requirement. Provide a list of additional data needed to PPPL
3. Perform circuit simulations to provide a conceptual electrical design, which takes into consideration the intended waveforms, skin effect, stray inductance and capacitance, cable impedances, eddy currents in passive structures, etc. This should determine the total capacitances, cables and ratings of other components needed to achieve the intended waveform. (See section 5.2)
4. Hold first milestone review meeting to determine method of modularization for the CCDPS based on conceptual design. Sensitivity analysis will be required to evaluate different scenarios. An initial evaluation of the space adequacy at PPPL site should also be finished by this point
5. Update the conceptual design based on chosen modularization method
6. Develop LabView control and protection modules (See section 5.2.3 and 5.2.4)
7. Develop conceptual schematic diagram(s) that show all major components and their configuration
8. Perform appropriate design calculations as required to specify components (e.g. short circuit calculations, temperature rise calculations, etc.)
9. Develop bill of materials of all components including description, ratings and quantity of each component with appropriate level of detail for estimation of cost and physical size
10. Develop design for power cabling, terminations and splitter boxes
11. Develop physical layout and confirm that space and access for installation is adequate (refer to architectural drawings)
12. Determine facility requirements (AC input power, cooling water, HVAC, etc.) to be provided by PPPL
13. Hold second milestone review meeting to present to PPPL technical review committee the detailed design of the CCDPS and recommendations for facility changes at PPPL
14. Modify the conceptual design into final design based on PPPL comments
15. Provide recommendation for bundling the items from the bill of materials list into one or more separate procurement packages (e.g. cap banks, charging power supplies, power cabling, etc.)
16. Develop a recommended component list with individual component budget pricing
17. Provide a technical description document for each recommended procurement package suitable for direct inclusion by PPPL in a purchasing specification
18. Provide cost and schedule estimates for each recommended procurement package including back-up documentation in package
19. Hold the third/final review meeting to present finalized deliverables to the entire FLARE team
20. Provide final deliverables to PPPL. (See section 13)

1.3 FLARE Machine



The FLARE machine consists of 9 coil systems, hereafter referred to as:

1) OH (Ohmic Heating)
2) EF (External Field)
3) GF (Guide Field)
4) PF-A (Poloidal Field A)
5) PF-B (Poloidal Field B)
6) TF-A (Toroidal Field A)
7) TF-B (Toroidal Field B)
8) DC-I (Inside Driver Coil)
9) DC-O (Outside Driver Coil)

Each of these 9 coil systems is made up of different number of sub-coils connected in parallel. The number of sub-coils for each coil system is shown in Table 1. All sub-coils of each coil system are to be connected in parallel.

Table 1 Number of Sub-Coils for each FLARE Coil System

	OH	EF	GF	PF-A	PF-B	TF-A	TF-B	DC-I	DC-O
Number of Sub-Coils	2	2	1	4	4	4	4	2	2

Each coil requires different current and voltage. At full experimental phase, the theoretically required voltage and current for each coil system is shown in Table 2.

Table 2 Voltage and Current Required for Each Coil for the Full Experimental Phase

	OH	EF	GF	PF-A	PF-B	TF-A	TF-B	DC-I	DC-O
Voltage Rating	20 kV	1.4 kV	14 kV	20 kV	20kV	20 kV	20 kV	60 kV	60 kV
Full System Current Rating	225 kA	26 kA	40 kA	540 kA	540 kA	250 kA	250 kA	50 kA	50 kA

Due to cost constraints it may be required that the initial phase of the project operate with a reduced capacitor bank capability. The minimum required voltage and current during the initial phase is shown in Table 3. As shown here, OH, DC-I and DC-O coils are not needed during the initial phase. Current requirements for the other coils are also reduced in the initial phase. Voltage requirement is lower for DC-I and DC-O coils. The final system design will be for the full capability specified in Table 2, but provide a modular design that allows for an incremental choice of lesser capabilities with the lower bound being the capability defined in Table 3. Also a future upgrade may require a 60kV DCI and DCO system. Designing for the 60kV contingency is not a requirement of this SOW but physical space must be provided in the mechanical layout in the DCI & DCO equipment area.

Table 3 Voltage and Current Required for Each Coil for the initial Phase

	OH	EF	GF	PF-A	PF-B	TF-A	TF-B	DC-I	DC-O
Voltage Rating	Same	Same	Same	Same	Same	Same	Same	20 kV	20 kV
% of Full System Current Rating	Not Needed	33.3%	20%	33.3%	33.3%	33.3%	33.3%	Not Needed	Not Needed

FLARE operation requires the generation of pulses of currents in the various circuits based on capacitor discharge. Each circuit is to be equipped with a fixed value of capacitance that can be charged to a voltage prior to the pulse.

Each coil system shall be driven by a single, independently controllable power supply. The output voltage from each power supply shall be continuously variable all the way to the maximum voltage rating.

The FLARE coil systems fall into two groups - coils that generate poloidal fields (ie fields the r-z plane where z is the axis of the machine, and r is radial) and coils that generate toroidal fields (ie fields that circle around the machine axis in the theta direction). The OH, EF PF and DC coils generate poloidal fields and the GF and TF coils generate toroidal fields. The two groups do not couple inductively with each other since the flux from one does not intercept the other. This gives rise to two separate inductance matrices. The inductance matrix for the poloidal field coils contains the self-inductance of each coil as the diagonal term and the mutual inductance between pairs of coils as the off diagonal terms. In addition the poloidal field coils couple with the Vacuum Vessel inducing toroidal eddy currents. To capture the effect of eddy current redistribution, the VV is modeled as 14 parallel passive loops in the poloidal inductance matrix. The VV does not couple with the toroidal field coils since it is not electrically continuous in the poloidal direction, so does not contribute to the toroidal inductance matrix.

The load inductance matrices of the coil systems (not considering external connections) are provided in Appendix C. The excel version of the inductance matrix can be provided upon request. The inductive coupling effect should be included in the analysis.

The FLARE device includes various water-cooled copper coils that comprise the electrical load of the CCDPS. A list of the coils and their DC resistances at 20°C is shown in Appendix C. Furthermore, eddy currents induced by the load should be carefully evaluated and considered.

The power supplies are to be located in the basement directly underneath the FLARE machine. Coaxial cables are preferred by PPPL to connect the CCDPSs (power supplies) to the FLARE experimental machine. Cable split boxes may be specified to be installed at either end of the cable run to split the cable according to the number of sub-coils connected. If utilized, cable split box(es) should be located and installed near the FLARE machine terminals to minimize the total number of parallel cables. However, if it becomes necessary to minimize cable impedances to meet the FLARE experimental requirements, then the cable split box(es) may specified to be installed nearer to the CCDPSs.

2. Applicable Standards and Documents

2.1 PPPL ESHD Requirements

The final design shall comply with the PPPL ESHD manual. The PPPL ESHD manual can be found at the PPPL website (http://bp.pppl.gov/ESHD_Manual/sm.html). An outline of the different sections of the ESHD manual can be found in Appendix A.

2.2 Standards

The engineering design of the equipment/system shall comply with all relevant industrial regulations, practices, standards, safety codes as well as specific performance requirements specified by PPPL, unless otherwise agreed upon in writing by both parties. The services are subjected but not limited to the following standards:

- ANSI IEEE 18 Shunt Power Capacitors
- ANSI/IEEE 4 Techniques for Dielectric Tests
- ANSI/NEMA ICS 1 Industrial Control and Systems General Requirements
- ANSI C2 National Electrical Safety Code
- ANSI/NFPA National Electrical Code No. 70

3. Applicable Drawings

N/A

4. Responsibilities

4.1 Princeton Plasma Physics Laboratory (PPPL)

1. PPPL will provide the footprint of the area, electrical performance specification of the system derived from physics experiment requirement to the Subcontractor.
2. PPPL will provide independent review of design.
3. PPPL will inform the Subcontractor which version of software the CCDPS operating system should be compatible to.

4.2 Subcontractor

4.2.1 General Responsibility

1. All prospective Subcontractors, before submitting a bid, must thoroughly familiarize themselves with the existing conditions at the project site, the performance requirements and service restrictions. Should any discrepancies arise between the existing conditions and the plans and specifications, they shall be reported to the Bid Contact prior to submitting the quote/proposal.
2. The Subcontractor shall perform all services and design activities within the schedule that is agreed upon.
3. The Subcontractor is responsible for the design as well as the proof and validation of the design.
4. All prospective Subcontractors, before submitting a bid, must thoroughly familiarize themselves with the existing conditions at the project site, the performance requirement and service restrictions. Should any discrepancies arise between the existing conditions, the plans and specifications, they shall be reported to the Bid Contact prior to submitting the quote/proposal.

4.2.2 Quote/Proposal

All quotes/proposals will be evaluated based on their schedule, technical qualification and price. The accepted Subcontractor will be notified electronically.

The following information should be included in the quote:

1. Overall, breakdown of price and detailed schedule
2. A detailed description of the technical plans
3. Prior experience of company
4. Names and resumes of key personnel that will contribute to the project, including any Subcontractors.
5. A detailed list of deliverables and a PERT and/or GANTT chart to show how work will be executed in terms of sequence, linkage, resources, and schedule for the project before the contract is awarded.

5. Requirements

This section documents the service and engineering requirement for the Subcontractor set forth for this project.

5.1 Service Requirements

The Subcontractor is contracted to provide the full electrical-mechanical design of the FLARE power supply system as outlined in this SOW. The design activity shall consider the usage, configuration, characteristics, and ratings of various components typically included in capacitor charge/discharge systems with due consideration of the FLARE performance requirements, convenience of operation, and personnel safety. The Subcontractor is required to perform the design activity to the best of care and comply with PPPL ESHD manual and relevant industrial standards.

5.1.2 MileStone Review

Throughout the design process, the progress should be formally validated and documented at each major milestone. Subcontractor should notify PPPL at each major design hold-point to schedule for a design review. No work shall be continued until PPPL approves the already-performed design. The documentation and validation of design milestones shall be submitted to PPPL upon request.

5.1.3 Progress Reporting

The Subcontractor is required to provide weekly progress reports to PPPL outlining all progress, design changes, intended delays as well as outlook for follow-up activities. All documents produced, models created and results obtained shall be provided to PPPL for review upon request.

5.1.4 Design Sensitivities

Sensitivity analyses are requested to be performed throughout the design process. These analyses are aimed at helping PPPL to better understand cost effectiveness, impact on performance as well as optimizing the physics results. These sensitivity analyses are part of the project scope and no additional cost should be incurred to PPPL.

5.2 Power Supply System Performance Requirement

The system performance specification is derived from the physics experimental needs.

5.2.1 Power Supply Modularization

Since the experiment will be performed in two phases – the initial proof-of-concept phase, where the experiment is performed in a reduced scale and the full experimental phase, where the experimental is expected to be at full rating, the design of the CCDPS is required to be modular.

The Subcontractor is required to provide detailed designs for both the initial and full experimental phase to eliminate repetition of work in future. The design of the power supplies for GF, TF-A, TF-B, PF-A, PF-B, and OH should be modular in terms of current and design of power supplies for DC-I and DC-O should be modular in terms of voltage. This means the modular systems can be placed in parallel or series to achieve overall higher current or voltage capability in the future without redesigning of each module and control circuitry.

The choice of modularization is not unique. The process to determine the best modularization method is iterative. The Subcontractor should discuss with PPPL technical representatives how to modularize the CCDPS and provide more than one option as sensitivities. The choice of design shall be subjected to the following constraints:

1. Minimize the cost, space and complexity of equipment, while achieving performance and quality requirements
2. Cost analysis of different ways of modularization should be provided to PPPL for review at design review meeting. This shall include a detailed breakdown of cost, pros and cons of each design choice.

5.2.2 Experimental Waveforms

The experimental waveform is defined by the peak current, rise time, crowbar time, and minimum first swing load current. A sample waveform, which explains various terms used in Table 4, is shown in Figure 1.

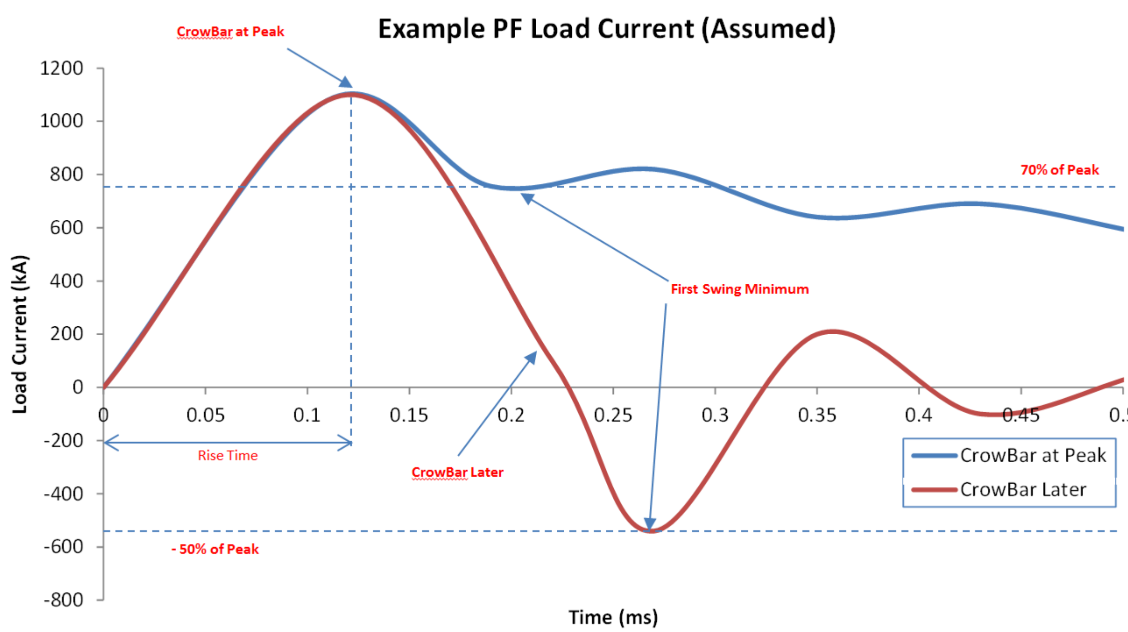


Figure 1 Sample Load Current Waveform of a FLARE shot

The CCDPS capacitor banks are pre-charged to a voltage. After capacitor banks are charged to the required voltage, the “forward” switch fires and the banks discharge into the load. After the current reaches peak, a “crowbar” switch fires and creates another resistive path for the coil current. This additional path shapes the current tail end to have the desired characteristics. The discharge current is required to reach peak with time constraints. For EF, the current is required to reach peak no sooner than 30 msec, current is required to reach peak no later than a defined time for other banks.

The required operation after peak current depends on the circuit. For PF and TF, a zero crossing (and hence bi-polar crowbar switch) is required. For OH, EF, GF and DC the first swing current will always be greater than zero so a uni-polar crow bar switch (i.e., diode commutation) may be used.

For PF A/B, the earliest time for the crowbar to fire is at the peak of the load current, the resulting first swing minimum current is required to be 70% of the peak current. The minimum first swing current is defined as the minimum current of the first cycle of oscillation after the crowbar fires. The latest time for the crowbar to fire is the time, when the resulting first swing minimum current equal to negative 50% of the peak current. Crowbar can fire in between these two times and the first swing minimum current is expected to be in between the two values. The same rule applies to TF, except that the crowbar firing time is between peak to 50% of peak current, and the correlated first swing minimum current is expected to be between 70% of the peak current to 0 kA. For all other coils, the crowbar fires at peak current and the first swing minimum current is required to be non-negative.

The tail end of the discharge current waveform is required to meet the constraints as give in Table 4.

Table 4 Waveform Requirement for FLARE Project

	OH	EF	GF	PF*	TF*	DC-I	DC-O
Peak I (kA)	180	26	40	1080	500	50	50
Rise Time (ms)	< 0.45	> 30	NA	< 0.11	< 0.08	< 0.01	< 0.03
CrowBar Time (Point on Falling Edge)	Peak	Peak	Peak	Peak – as needed	Peak – 50%	Peak	Peak
First Swing Minimum Current (% of peak)	Positive	Positive	Positive	70% - (-50%)	70% - 0	Positive	Positive

*Currents shown here are the total current of all sub-coils for each coil system

The required duty cycle is **one full power shot** of all (9) coils **every 3 minutes** (fully cooled and discharged and ready for next full power shot) and with **a maximum of 1000 shots per week**.

5.2.3 Control System Requirement

The protection, monitoring and control system must be designed and implemented in Labview software and easily implemented at PPPL.

Charging voltage of the capacitor banks must be controllable between zero (0) and the full design rating.

Firing for each power supply must be controlled independently from other power supplies. Firing for each half of the banks for PF and TF are required to be controlled independently from the other half.

All controls shall be derived from a separate 120V AC, 20 Amps, 60Hz single phase power circuit feed from PPPL. Each sub-unit shall have a circuit breaker of suitable ratings which can also be used as a switch to remove control power from the sub-unit.

Design and implementation of the control system in Labview shall be flexible so that other functions can be added easily in the future if necessary.

5.2.4 Protection Function Requirement

Protection function is part of the control system, and is used to automatically disable and protect the experimental equipment from further operation following a fault. The FLARE shall be equipped with suitable sensing of faults such as over-current, over-temperature, etc., as required to ensure safe and reliable operation of the equipment. In addition, interlocks shall prevent mis-operation of the equipment when a fault condition exists and/or when the configuration of the equipment is not in the proper state for operation. The overcurrent protection shall be manually adjustable and shall be designed such that no single point failure will defeat the protection. Latched indicators shall be provided that indicate the cause of any fault. The Subcontractor shall address the internal fault sensing and interlocks in the design.

Electronic and physical E-stop button must be implemented to provide safe emergency stop of the experiment. Upon activated, all system shall be shut down in a safe manner and energy stored must be dissipated through energy dumps. The system must be capable of being locked and tagged out until completion of further investigation.

5.2.5 Experimental Conditions

Under normal condition, it is required that a **full power shot** can be taken **every 3 minutes**. The Subcontractor should provide an estimate of the minimum time spacing between shots for various other shot conditions and levels other than full power shot.

5.2.6 Heat Dissipation

Under certain scenarios, the crowbar resistor is required to dissipate all the stored energy (early crowbar action). In such a situation, the system is required to be able to ride through safely and without equipment and insulation life being reduced significantly. Cooling water is available upon request.

5.2.7 Operating Environment

The FLARE power supply will be placed indoors in PPPL. Temperature conditions should be considered.

5.2.8 Space Occupancy

The power supplies are expected to fit in the confined space that is available on site. Appendix B shows a simplified view of the basement, where the CCDPS should be installed. CAD file of floor plan and physical dimension of the site is available and can be provided to the Subcontractor upon request. The Subcontractor should design the CCDPS container, so that it can be successfully delivered and installed at the site.

5.2.9 Designed Life

The power supply system shall be designed for a **minimum of 10 years design life** and a **minimum of 100,000 full power shots** with regular maintenance.

5.2.10 Reliability

N/A

5.2.11 Maintainability

N/A

5.2.12 Human Factors

N/A

5.2.13 Sustainability

N/A

5.2.14 Warranty

N/A

5.3 Equipment Specification

5.3.1 Performance Characteristics

FLARE is a pulsed machine. All equipment used should be rated correctly for pulse application. Equipment design margin should be cleared stated on the report.

Capacitors

1. The capacitors are expected to see reversal voltages during the experimental shots. The Subcontractor should determine the voltage reversal magnitude through analysis.
2. Each capacitor unit should be individually fused and self-protected.
3. Energy dumping resistor(s) shall be specified for safe dissipation of stored energy, if required. The dissipation time should be limited to the shorter of the relevant industrial standards or the experimental needs.
4. The capacitor is expected to survive **at least 500,000 full power shots** without failure.

Ignitrons

1. Wherever practical and appropriate, PPPL prefers the following ignitron to be used for OH, PF and TF banks. Ignitron model NL8900, by Richardson Electronics.
   The spec sheet can be found online at: http://www.rell.com/filebase/en/src/Datasheets/NL8900.pdf
2. The ignitrons are expected to see reverse voltage and pulse currents. Life time of the ignitron contact shall not be significantly shortened or the minimum design life of the equipment should be maintained.
3. The ignitrons are expected to survive a **minimum of 10,000 full power shots without failure.**

Insulation

The power supply should be properly insulated based on design. The rule of thumb to be followed is **2E+1**, where **E** is the maximum system voltage.

Separation and Barrier

FLARE power supply should be installed with proper separation. Protective screens/barriers should be designed so that no cascading failures shall occur and endanger personnel.

Nameplate

Nameplates shall be in accordance with ANSI C34.2, modified to take into account the pulsed operating ratings (as well as thermal ratings).

Other

1. All bus work should be taken into consideration so that the inductance does not limit the system performance.
2. All equipment should be protected under normal and abnormal conditions. No single point failure should damage the entire system.
3. All fault interlocks and indicators shall be latching, fail-safe.

5.3.2 Cooling

Cooling water should be taken into consideration while designing for thermal capability. Relevant drawings can be obtained from PPPL upon request.

5.3.3 MATERIALS

Non-magnetic materials should be used throughout the construction. All equipment shall be designed that eddy current losses are minimized.

6. Test and Inspection Requirements

Inspection and testing are required for the implementation portion of the project. In this engineering design phase, the Subcontractor is required to properly design, validate and document all design activities.

6.1 Performance Tests

Design Review – Subcontractor must provide to PPPL calculations, computerized analysis, and appropriate system simulation(s) to demonstrate the viability of the Subcontractor's design.

6.2 Acceptance Tests

N/A

6.3 Supplier Hold Points

See Section 13 for PPPL specified hold points.

6.4 Quality Control Receipt Inspections

N/A

7. Qualifications

The Subcontractor warrants that all personnel and personnel involved are properly trained and suitable for this project. The Subcontractor should provide the basic information, experience and qualification of all personnel involved in the project to PPPL prior to receiving a PO.

8. Environment, Safety, and Health

N/A

9. Quality Assurance Requirements

1. Inspection/Surveillance/Audit by Princeton Representatives of PPPL shall have the right to visit the Subcontractor's premises during the performance of this procurement as stated in the General Provisions. The Subcontractor shall make available records and documentation necessary for this function. PPPL recognizes the Subcontractor's right to withhold information concerning proprietary

processes.

2. Changes to Princeton Approved Documents Revisions or changes by the Subcontractor to documents approved by PPPL shall be reviewed and approved by PPPL prior to use.
3. Subcontractor’s Responsibility for Conformance: PPPL's review and/or approval of the Subcontractor's design documents, or PPPL's inspection of Subcontractor's services shall relieve the Subcontractor of responsibility for full compliance with requirements of the written purchase order/contract. The Subcontractor is responsible for assuring that all PPPL requirements and restrictions are transmitted to, and imposed on any of the Subcontractor’s lower-tier Subcontractors.
4. Non-conformance & Corrective Actions and Notification to Princeton Nonconforming services shall be positively identified. The Subcontractor shall document each nonconformance. The written approval of Princeton is required prior to the use of the nonconforming service. The Subcontractor shall provide not only for timely resolution of non-conformances but also for analysis of non-conformances to determine root causes and to implement appropriate and effective corrective actions.

10. Shipping Storage and Handling

N/A

11. Warranty

N/A

12. Attachments

The CAD drawing of the site shall be provided to the Subcontractor upon request. The excel version of the load inductance and resistance matrix shall also be provided to the Subcontractor upon request.

13. Documentation and Deliverables

The Subcontractor should provide a detailed list of all deliverables and an estimated schedule including milestones for furnishing final design (FDR) documents before receiving the PO. All design activity should be documented thoroughly and submit to PPPL for review upon request.

Final deliverable documents must include a technical report documenting all analysis and result, schematics/drawings of all design, recommendation for PPPL to implement facility changes, recommended components list with unit pricing and lead times, design document in PPPL procurement format, estimates for fabrication cost per each power supply assembly, the anticipated shipping charges, and the estimated fabrication/delivery schedule starting from PPPL approval until delivery at PPPL

Deliverables List

PO / Subcontract / BOA / BPA #:____

PPPL Required Physical Deliverable Checklist

#	Physical Deliverables Required	When Deliverable Is Required	Deliverable Received (✓)
1	N/A		
Exceptions			

PPPL Required None-Physical Deliverables Checklist

#	Document Deliverables Required	When Deliverable Is Required	Deliverable Format	Storage Location of Deliverable	Deliverable Received (✓)
1	Power Supply Design Schedule, team profile info and quote/proposal Submittal (Action item 1 in section 1.2.2)	With Proposal	Electronic and Paper	PPPL Procurement	
Contract Awarded					
2	Request for additional information by Subcontractor if needed, Q&A section can be arranged (Action item 2 in section 1.2.2)	Before PO is awarded	Electronic	FLARE Princeton Technical Rep. (PTR)	
Official Start of Project (Initial Online or In-person Meeting should be arranged)					
3	Conceptual design of the electrical circuitry (Action item 3 in section 1.2.2)	Within 2 weeks after Subcontractor receives PO	Electronic	FLARE PTR.	
Milestone Hold Point 1 (Review conceptual design, determine modularization method, initial budgetary cost) (Action item 4 in section 1.2.2)					
4	Detailed design of the CCDPS, develop schematics and ratings of equipment, provide drawings and recommendations for PPPL facility change (Action item 5-12 in section 1.2.2)	Within 2 weeks after design hold point 1	Electronic	FLARE PTR.	
Milestone Hold Point 2 (Review of detailed design) (Action item 13 in section 1.2.2)					
5	Finalize all design activities based on PPPL comments (Action item 14 in section 1.2.2)	Within 1 weeks after hold point 2	Electronic	FLARE PTR	
6	Develop equipment list, cost and documents for inclusion in	Within 1 weeks after hold point	Electronic	FLARE PTR	

	PPPL procurement package. Provide recommendation for procurement phase. (Action item 15-18 in section 1.2.2)	2			
Milestone Hold Point 3 (Review of detailed final design and procurement package) (Action item 19 in section 1.2.2)					
7	Furnish Bid Quality Final Design documents to PPPL. (Action item 20 in section 1.2.2)	Within 1 week after design hold point 3	Electronic and Paper	FLARE PTR	
Exceptions					

Princeton Technical Representative/COG:____

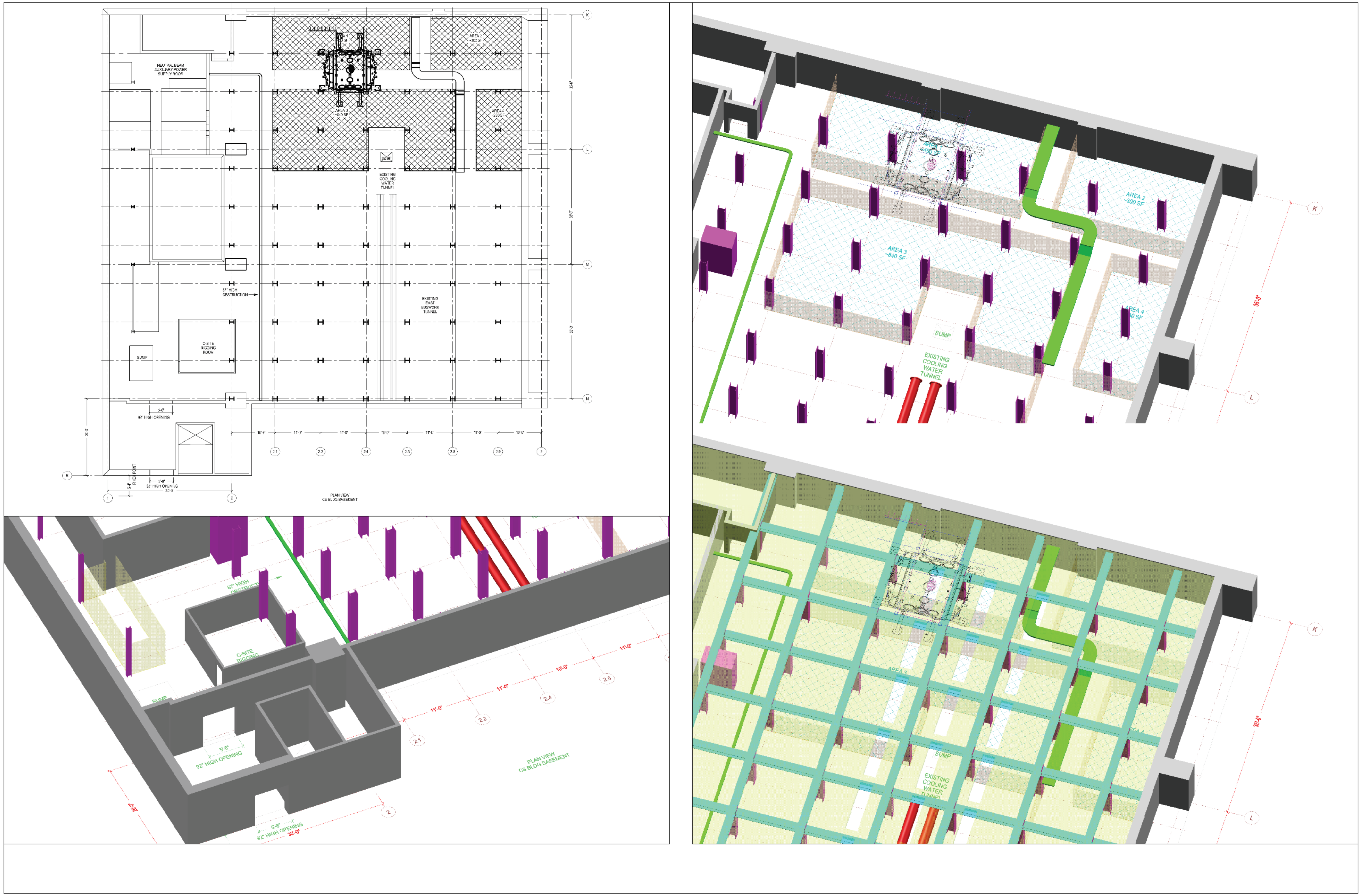
(Sign-off and provide to the Operations Center when job is completed and deliverables are dispositioned and placed/filed in Operations Center (or other Project, Department or Division designated file center).

Appendix A Outline of the PPPL ESHD Requirement Document

The PPPL ESHD requirement can be found at (http://bp.pppl.gov/ESHD_Manual/sm.html). The outline of the ESHD document is shown below.

Section 0 - **Preparation, Review and Approval of ES&H Directives**
Section 1 - **Construction Safety**
Section 2 - **Electrical Safety**
Section 3 - *Laser Safety – (N/A)*
Section 4 - **RF, Microwave & Magnetic Safety**
Section 5 - **Fire Protection**
Section 6 - *Nuclear Safety – (N/A)*
Section 7 - **Waste Management**
Section 8 - **Industrial Hygiene**
Section 9 - **Occupational Safety**
Section 10 - *Radiation Safety – (N/A)*
Section 11 - **Operations Hazard Criteria and Safety Certification**
Section 12 - **Environmental Protection**

Appendix B Space demonstration at PPPL



Appendix C FLARE Machine Inductance Matrix

PF Inductance Matrix with Segmented VV (for eddy currents)

Inductance, henries					PF - A				PF - B																									
	OH1	OH2	EF1	EF2	FCPF1	FCPF2	FCPF3	FCPF4	FCPF5	FCPF6	FCPF7	FCPF8	DriverIn1	DriverIn2	DriverIn3	DriverIn4	DriverOut1	DriverOut2	DriverOut3	DriverOut4	VV1	VV2	VV3	VV4	VV5	VV6	VV7	VV8	VV9	VV10	VV11	VV12	VV13	VV14
OH1	6.26E-05	4.18E-06	7.20E-06	2.76E-06	1.16E-06	1.21E-06	1.28E-06	1.19E-06	2.29E-07	1.91E-07	1.96E-07	2.5E-07	1.79E-06	1.90E-06	5.05E-07	4.65E-07	1.09E-06	1.10E-06	7.59E-07	7.45E-07	6.87E-07	4.29E-07	2.09E-07	4.54E-08	1.15E-08	3.78E-08	3.16E-07	2.98E-06	1.51E-06	1.53E-07	2.58E-07	6.58E-07	8.69E-07	8.99E-07
OH2	4.18E-06	6.26E-05	2.76E-06	7.20E-06	2.29E-07	1.91E-07	1.96E-07	2.5E-07	1.16E-06	1.21E-06	1.28E-06	1.19E-06	5.05E-07	4.65E-07	1.79E-06	1.9E-06	7.59E-07	7.45E-07	1.09E-06	1.1E-06	8.99E-07	8.69E-07	6.58E-07	2.58E-07	1.53E-07	1.51E-06	2.98E-06	3.16E-07	3.78E-08	1.15E-08	4.54E-08	2.09E-07	4.29E-07	6.87E-07
EF1	7.20E-06	2.76E-06	1.89E-03	3.86E-05	9.32E-06	7.01E-06	6.39E-06	9.42E-06	1.43E-06	1.09E-06	1.06E-06	1.55E-06	6.63E-07	6.75E-07	4.05E-07	3.98E-07	8.69E-06	8.85E-06	5.38E-06	5.29E-06	7.39E-06	4.71E-06	2.19E-06	4.23E-07	7.94E-08	1.26E-07	2.12E-07	3.70E-07	6.37E-07	9.37E-07	7.01E-06	2.81E-05	2.20E-05	1.23E-05
EF2	2.76E-06	7.20E-06	3.86E-05	1.89E-03	1.43E-06	1.09E-06	1.06E-06	1.55E-06	9.32E-06	7.01E-06	6.39E-06	9.42E-06	4.05E-07	3.98E-07	6.63E-07	6.75E-07	5.38E-06	5.29E-06	8.69E-06	8.85E-06	1.23E-05	2.20E-05	2.81E-05	7.01E-06	9.37E-07	6.37E-07	3.70E-07	2.12E-07	1.26E-07	7.94E-08	4.23E-07	2.19E-06	4.71E-06	7.39E-06
FCPF1	1.16E-06	2.29E-07	9.32E-06	1.43E-06	4.88E-06	1.89E-06	1.67E-06	3.14E-06	7.55E-08	5.88E-08	5.84E-08	8.22E-08	8.84E-08	9.14E-08	3.56E-08	3.45E-08	6.23E-07	6.39E-07	3.2E-07	3.12E-07	3.66E-07	2.09E-07	9.44E-08	1.91E-08	3.89E-09	7.94E-09	1.91E-08	5.32E-08	1.10E-07	7.89E-08	2.94E-07	9.04E-07	9.22E-07	6.40E-07
FCPF2	1.21E-06	1.91E-07	7.01E-06	1.09E-06	1.89E-06	4.08E-06	2.49E-06	1.74E-06	5.88E-08	4.59E-08	4.57E-08	6.4E-08	8.13E-08	8.46E-08	2.97E-08	2.87E-08	4.78E-07	4.89E-07	2.48E-07	2.42E-07	2.78E-07	1.59E-07	7.21E-08	1.46E-08	3.02E-09	6.32E-09	1.61E-08	5.10E-08	1.25E-07	8.24E-08	2.54E-07	6.77E-07	6.67E-07	4.78E-07
FCPF3	1.28E-06	1.96E-07	6.39E-06	1.06E-06	1.67E-06	2.49E-06	3.94E-06	1.6E-06	5.84E-08	4.57E-08	4.55E-08	6.36E-08	8.64E-08	9E-08	3.05E-08	2.95E-08	4.74E-07	4.85E-07	2.46E-07	2.41E-07	2.73E-07	1.56E-07	7.08E-08	1.44E-08	2.99E-09	6.36E-09	1.66E-08	5.45E-08	1.3E-07	7.72E-08	2.27E-07	6.14E-07	6.31E-07	4.65E-07
FCPF4	1.19E-06	2.5E-07	9.42E-06	1.55E-06	3.14E-06	1.74E-06	1.6E-06	5.03E-06	8.22E-08	6.4E-08	6.36E-08	8.94E-08	9.54E-08	9.87E-08	3.88E-08	3.77E-08	6.84E-07	7.01E-07	3.49E-07	3.41E-07	3.97E-07	2.26E-07	1.02E-07	2.06E-08	4.23E-09	8.66E-09	2.08E-08	5.68E-08	1.09E-07	7.42E-08	2.8E-07	9.08E-07	9.82E-07	6.95E-07
FCPF5	2.29E-07	1.16E-06	1.43E-06	9.32E-06	7.55E-08	5.88E-08	5.84E-08	8.22E-08	4.88E-06	1.89E-06	1.67E-06	3.14E-06	3.56E-08	3.45E-08	8.84E-08	9.14E-08	3.2E-07	3.12E-07	6.23E-07	6.39E-07	6.4E-07	9.22E-07	9.04E-07	2.94E-07	7.89E-08	1.1E-07	5.32E-08	1.91E-08	7.94E-09	3.89E-09	1.91E-08	9.44E-08	2.09E-07	3.66E-07
FCPF6	1.91E-07	1.21E-06	1.09E-06	7.01E-06	5.88E-08	4.59E-08	4.57E-08	6.4E-08	1.89E-06	4.08E-06	2.49E-06	1.74E-06	2.97E-08	2.87E-08	8.13E-08	8.46E-08	2.48E-07	2.42E-07	4.78E-07	4.89E-07	4.78E-07	6.67E-07	6.77E-07	2.54E-07	8.24E-08	1.25E-07	5.1E-08	1.61E-08	6.32E-09	3.02E-09	1.46E-08	7.21E-08	1.59E-07	2.78E-07
FCPF7	1.96E-07	1.28E-06	1.06E-06	6.39E-06	5.84E-08	4.57E-08	4.55E-08	6.36E-08	1.67E-06	2.49E-06	3.94E-06	1.6E-06	3.05E-08	2.95E-08	8.64E-08	9E-08	2.46E-07	2.41E-07	4.74E-07	4.85E-07	4.65E-07	6.31E-07	6.14E-07	2.27E-07	7.72E-08	1.3E-07	5.45E-08	1.66E-08	6.36E-09	2.99E-09	1.44E-08	7.08E-08	1.56E-07	2.73E-07
FCPF8	2.5E-07	1.19E-06	1.55E-06	9.42E-06	8.22E-08	6.4E-08	6.36E-08	8.94E-08	3.14E-06	1.74E-06	1.6E-06	5.03E-06	3.88E-08	3.77E-08	9.54E-08	9.87E-08	3.49E-07	3.41E-07	6.84E-07	7.01E-07	6.95E-07	9.82E-07	9.08E-07	2.8E-07	7.42E-08	1.09E-07	5.68E-08	2.08E-08	8.66E-09	4.23E-09	2.06E-08	1.02E-07	2.26E-07	3.97E-07
DriverIn1	1.79E-06	5.05E-07	6.63E-07	4.05E-07	8.84E-08	8.13E-08	8.64E-08	9.54E-08	3.56E-08	2.97E-08	3.05E-08	3.88E-08	1.45E-06	1.09E-06	6.2E-08	5.78E-08	1.52E-07	1.52E-07	1.17E-07	1.15E-07	9.95E-08	6.37E-08	3.12E-08	7.05E-09	1.80E-09	6.07E-09	4.23E-08	2.01E-07	3.16E-08	5.12E-09	1.53E-08	5.67E-08	9.64E-08	1.18E-07
DriverIn2	1.90E-06	4.65E-07	6.75E-07	3.98E-07	9.14E-08	8.46E-08	9E-08	9.87E-08	3.45E-08	2.87E-08	2.95E-08	3.77E-08	1.09E-06	1.45E-06	5.78E-08	5.39E-08	1.52E-07	1.52E-07	1.15E-07	1.13E-07	9.84E-08	6.26E-08	3.05E-08	6.87E-09	1.75E-09	5.79E-09	3.90E-08	1.98E-07	3.41E-08	5.35E-09	1.58E-08	5.79E-08	9.75E-08	1.18E-07
DriverIn3	5.05E-07	1.79E-06	4.05E-07	6.63E-07	3.56E-08	2.97E-08	3.05E-08	3.88E-08	8.84E-08	8.13E-08	8.64E-08	9.54E-08	6.2E-08	5.78E-08	1.45E-06	1.09E-06	1.17E-07	1.15E-07	1.52E-07	1.52E-07	1.18E-07	9.64E-08	5.67E-08	1.53E-08	5.12E-09	3.16E-08	2.01E-07	4.23E-08	6.07E-09	1.8E-09	7.05E-09	3.12E-08	6.37E-08	9.95E-08
DriverIn4	4.65E-07	1.9E-06	3.98E-07	6.75E-07	3.45E-08	2.87E-08	2.95E-08	3.77E-08	9.14E-08	8.46E-08	9E-08	9.87E-08	5.78E-08	5.39E-08	1.09E-06	1.45E-06	1.15E-07	1.13E-07	1.52E-07	1.52E-07	1.18E-07	9.75E-08	5.79E-08	1.58E-08	5.35E-09	3.41E-08	1.98E-07	3.9E-08	5.79E-09	1.75E-09	6.87E-09	3.05E-08	6.26E-08	9.84E-08
DriverOut1	1.09E-06	7.59E-07	8.69E-06	5.38E-06	6.23E-07	4.78E-07	4.74E-07	6.84E-07	3.2E-07	2.48E-07	2.46E-07	3.49E-07	1.52E-07	1.52E-07	1.17E-07	1.15E-07	7.88E-06	6.45E-06	1.57E-06	1.52E-06	1.67E-06	8.69E-07	3.79E-07	7.62E-08	1.59E-08	3.19E-08	6.01E-08	7.75E-08	5.65E-08	2.94E-08	1.37E-07	6.75E-07	1.57E-06	2.51E-06
DriverOut2	1.10E-06	7.45E-07	8.85E-06	5.29E-06	6.39E-07	4.89E-07	4.85E-07	7.01E-07	3.12E-07	2.42E-07	2.41E-07	3.41E-07	1.52E-07	1.52E-07	1.15E-07	1.13E-07	6.45E-06	7.88E-06	1.52E-06	1.48E-06	1.64E-06	8.52E-07	3.72E-07	7.47E-08	1.56E-08	3.12E-08	5.91E-08	7.76E-08	5.75E-08	3.01E-08	1.40E-07	6.90E-07	1.61E-06	2.51E-06
DriverOut3	7.59E-07	1.09E-06	5.38E-06	8.69E-06	3.2E-07	2.48E-07	2.46E-07	3.49E-07	6.23E-07	4.78E-07	4.74E-07	6.84E-07	1.17E-07	1.15E-07	1.52E-07	1.52E-07	1.57E-06	1.52E-06	7.88E-06	6.45E-06	2.51E-06	1.57E-06	6.75E-07	1.37E-07	2.94E-08	5.65E-08	7.75E-08	6.01E-08	3.19E-08	1.59E-08	7.62E-08	3.79E-07	8.69E-07	1.67E-06
DriverOut4	7.45E-07	1.1E-06	5.29E-06	8.85E-06	3.12E-07	2.42E-07	2.41E-07	3.41E-07	6.39E-07	4.89E-07	4.85E-07	7.01E-07	1.15E-07	1.13E-07	1.52E-07	1.52E-07	1.52E-06	1.48E-06	6.45E-06	7.88E-06	2.51E-06	1.61E-06	6.9E-07	1.4E-07	3.01E-08	5.75E-08	7.76E-08	5.91E-08	3.12E-08	1.56E-08	7.47E-08	3.72E-07	8.52E-07	1.64E-06
VV1	6.87E-07	8.99E-07	7.39E-06	1.23E-05	3.66E-07	2.78E-07	2.73E-07	3.97E-07	6.4E-07	4.78E-07	4.65E-07	6.95E-07	9.95E-08	9.84E-08	1.18E-07	1.18E-07	1.67E-06	1.64E-06	2.51E-06	2.51E-06	4.89E-06	2.37E-06	8.91E-07	1.67E-07	3.22E-08	5.09E-08	6.15E-08	5.15E-08	3.27E-08	1.88E-08	9.64E-08	4.95E-07	1.16E-06	2.37E-06
VV2	4.29E-07	8.69E-07	4.71E-06	2.20E-05	2.09E-07	1.59E-07	1.56E-07	2.26E-07	9.22E-07	6.67E-07	6.31E-07	9.82E-07	6.37E-08	6.26E-08	9.64E-08	9.75E-08	8.69E-07	8.52E-07	1.57E-06	1.61E-06	2.37E-06	4.89E-06	1.80E-06	2.90E-07	5.04E-08	6.15E-08	5.20E-08	3.33E-08	1.91E-08	1.11E-08	5.80E-08	2.95E-07	6.60E-07	1.16E-06
VV3	2.09E-07	6.58E-07	2.19E-06	2.81E-05	9.44E-08	7.21E-08	7.08E-08	1.02E-07	9.04E-07	6.77E-07	6.14E-07	9.08E-07	3.12E-08	3.05E-08	5.67E-08	5.79E-08	3.79E-07	3.72E-07	6.75E-07	6.9E-07	8.91E-07	1.80E-06	2.96E-06	5.91E-07	7.92E-08	5.96E-08	3.22E-08	1.64E-08	8.80E-09	5.06E-09	2.67E-08	1.35E-07	2.95E-07	4.95E-07
VV4	4.54E-08	2.58E-07	4.23E-07	7.01E-06	1.91E-08	1.46E-08	1.44E-08	2.06E-08	2.94E-07	2.54E-07	2.27E-07	2.8E-07	7.05E-09	6.87E-09	1.53E-08	1.58E-08	7.62E-08	7.47E-08	1.37E-07	1.4E-07	1.67E-07	2.90E-07	5.91E-07	1.01E-06	1.37E-07	3.05E-08	9.32E-09	3.76E-09	1.83E-09	1.02E-09	5.33E-09	2.67E-08	5.80E-08	9.64E-08
VV5	1.15E-08	1.53E-07	7.94E-08	9.37E-07	3.89E-09	3.02E-09	2.99E-09	4.23E-09	7.89E-08	8.24E-08	7.72E-08	7.42E-08	1.80E-09	1.75E-09	5.12E-09	5.35E-09	1.59E-08	1.56E-08	2.94E-08	3.01E-08	3.22E-08	5.04E-08	7.92E-08	1.37E-07	2.48E-07	3.36E-08	3.52E-09	9.80E-10	4.03E-10	2.04E-10	1.02E-09	5.06E-09	1.11E-08	1.88E-08
VV6	3.78E-08	1.51E-06	1.26E-07	6.37E-07	7.94E-09	6.32E-09	6.36E-09	8.66E-09	1.1E-07	1.25E-07	1.3E-07	1.09E-07	6.07E-09	5.79E-09	3.16E-08	3.41E-08	3.19E-08	3.12E-08	5.65E-08	5.75E-08	5.09E-08	6.15E-08	5.96E-08	3.05E-08	3.36E-08	2.48E-07	3.36E-08	3.53E-09	9.80E-10	4.03E-10	1.83E-09	8.80E-09	1.91E-08	3.27E-08
VV7	3.16E-07	2.98E-06	2.12E-07	3.70E-07	1.91E-08	1.61E-08	1.66E-08	2.08E-08	5.32E-08	5.1E-08	5.45E-08	5.68E-08	4.23E-08	3.90E-08	2.01E-07	1.98E-07	6.01E-08	5.91E-08	7.75E-08	7.76E-08	6.15E-08	5.20E-08	3.22E-08	9.32E-09	3.52E-09	3.36E-08	2.48E-07	3.38E-08	3.53E-09	9.80E-10	3.76E-09	1.64E-08	3.33E-08	5.15E-08
VV8	2.98E-06	3.16E-07	3.70E-07	2.12E-07	5.32E-08	5.10E-08	5.45E-08	5.68E-08	1.91E-08	1.61E-08	1.66E-08	2.08E-08	2.01E-07	1.98E-07	4.23E-08	3.9E-08	7.75E-08	7.76E-08	6.01E-08	5.91E-08	5.15E-08	3.33E-08	1.64E-08	3.76E-09	9.80E-10	3.53E-09	3.38E-08	2.48E-07	3.36E-08	3.52E-09	9.32E-09	3.22E-08	5.20E-08	6.15E-08
VV9	1.51E-06	3.78E-08	6.37E-07	1.26E-07	1.10E-07	1.25E-07	1.3E-07	1.09E-07	7.94E-09	6.32E-09	6.36E-09	8.66E-09	3.16E-08	3.41E-08	6.07E-09	5.79E-09	5.65E-08	5.75E-08	3.19E-08	3.12E-08	3.27E-08	1.91E-08	8.80E-09	1.83E-09	4.03E-10	9.80E-10	3.53E-09	3.36E-08	2.48E-07	3.36E-08	3.05E-08	5.96E-08	6.15E-08	5.09E-08
VV10	1.53E-07	1.15E-08	9.37E-07	7.94E-08	7.89E-08	8.24E-08	7.72E-08	7.42E-08	3.89E-09	3.02E-09	2.99E-09	4.23E-09	5.12E-09	5.35E-09	1.8E-09	1.75E-09	2.94E-08	3.01E-08	1.59E-08	1.56E-08	1.88E-08	1.11E-08	5.06E-09	1.02E-09	2.04E-10	4.03E-10	9.80E-10	3.52E-09	3.36E-08	2.48E-07	1.37E-07	7.92E-08	5.04E-08	3.22E-08
VV11	2.58E-07	4.54E-08	7.01E-06	4.23E-07	2.94E-07	2.54E-07	2.27E-07	2.8E-07	1.91E-08	1.46E-08	1.44E-08	2.06E-08	1.53E-08	1.58E-08	7.05E-09	6.87E-09	1.37E-07	1.40E-07	7.62E-08	7.47E-08	9.64E-08	5.80E-08	2.67E-08	5.33E-09	1.02E-09	1.83E-09	3.76E-09	9.32E-09	3.05E-08	1.37E-07	1.01E-06	5.91E-07	2.90E-07	1.67E-07
VV12	6.58E-07	2.09E-07	2.81E-05	2.19E-06	9.04E-07	6.77E-07	6.14E-07	9.08E-07	9.44E-08	7.21E-08	7.08E-08	1.02E-07	5.67E-08	5.79E-08	3.12E-08	3.05E-08	6.75E-07	6.90E-07	3.79E-07	3.72E-07	4.95E-07	2.95E-07	1.35E-07	2.67E-08	5.06E-09	8.80E-09	1.64E-08	3.22E-08	5.96E-08	7.92E-08	5.91E-07	2.96E-06	1.80E-06	8.91E-07
VV13	8.69E-07	4.29E-07	2.20E-05	4.71E-06	9.22E-07	6.67E-07	6.31E-07	9.82E-07	2.09E-07	1.59E-07	1.56E-07	2.26E-07	9.64E-08	9.75E-08	6.37E-08	6.26E-08	1.57E-06	1.61E-06	8.69E-07	8.52E-07	1.16E-06	6.60E-07	2.95E-07	5.80E-08	1.11E-08	1.91E-08	3.33E-08	5.20E-08	6.15E-08	5.04E-08	2.90E-07	1.80E-06	4.89E-06	2.37E-06
VV14	8.99E-07	6.87E-07	1.23E-05	7.39E-06	6.40E-07	4.78E-07	4.65E-07	6.95E-07	3.66E-07	2.78E-07	2.73E-07	3.97E-07	1.18E-07	1.18E-07	9.95E-08	9.84E-08	2.51E-06	2.51E-06	1.67E-06	1.64E-06	2.37E-06	1.16E-06	4.95E-07	9.64E-08	1.88E-08	3.27E-08	5.15E-08	6.15E-08	5.09E-08	3.22E-08	1.67E-07	8.91E-07	2.37E-06	4.89E-06

	OH1	OH2	EF1	EF2	FCPF1	FCPF2	FCPF3	FCPF4	FCPF5	FCPF6	FCPF7	FCPF8	DriverIn1	DriverIn2	DriverIn3	DriverIn4	DriverOut1	DriverOut2	DriverOut3	DriverOut4	VV1	VV2	VV3	VV4	VV5	VV6	VV7	VV8	VV9	VV10	VV11	VV12	VV13	VV14
Resistance, ohm	0.000671	0.000671	0.012637	0.012637	0.000872	0.000753	0.000731	0.000894	0.000872	0.000753	0.000731	0.000894	0.000325	0.000325	0.000325	0.000325	0.0013	0.0013	0.0013	0.0013	0.001385	0.001385	0.000739	0.000422	0.00631	0.00631	0.00631	0.00631	0.00631	0.00631	0.000422	0.000739	0.001385	0.001385

Flare Inductance Matrix for the TF like coils (non-coax)

Inductance, henries		TF - A				TF - B			
	GF	FCTF_L1	FCTF_L2	FCTF_L3	FCTF_L4	FCTF_R1	FCTF_R2	FCTF_R3	FCTF_R4
GF	3.37E-03	1.10E-05	1.10E-05	1.10E-05	1.10E-05	1.10E-05	1.10E-05	1.10E-05	1.10E-05
FCTF_L1	1.10E-05	1.40E-05	4.13E-07	2.91E-08	4.13E-07	-6.97E-09	9.93E-10	4.85E-09	1.13E-09
FCTF_L2	1.10E-05	4.13E-07	1.40E-05	4.13E-07	2.91E-08	1.13E-09	-6.97E-09	9.93E-10	4.85E-09
FCTF_L3	1.10E-05	2.91E-08	4.13E-07	1.40E-05	4.13E-07	4.85E-09	1.13E-09	-6.97E-09	9.93E-10
FCTF_L4	1.10E-05	4.13E-07	2.91E-08	4.13E-07	1.40E-05	9.93E-10	4.85E-09	1.13E-09	-6.97E-09
FCTF_R1	1.10E-05	-6.97E-09	1.13E-09	4.85E-09	9.93E-10	1.40E-05	4.13E-07	2.91E-08	4.13E-07
FCTF_R2	1.10E-05	9.93E-10	-6.97E-09	1.13E-09	4.85E-09	4.13E-07	1.40E-05	4.13E-07	2.91E-08
FCTF_R3	1.10E-05	4.85E-09	9.93E-10	-6.97E-09	1.13E-09	2.91E-08	4.13E-07	1.40E-05	4.13E-07
FCTF_R4	1.10E-05	1.13E-09	4.85E-09	9.93E-10	-6.97E-09	4.13E-07	2.91E-08	4.13E-07	1.40E-05

Resistance, Ohms									
	GF	FCTF_L1	FCTF_L2	FCTF_L3	FCTF_L4	FCTF_R1	FCTF_R2	FCTF_R3	FCTF_R4
	8.84E-02	3.27E-03	3.27E-03	3.27E-03	3.27E-03	3.27E-03	3.27E-03	3.27E-03	3.27E-03