NCSX Engineering Design Document

Design Description
Electrical Power Systems (WBS 4)

NCSX PDR

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1 INTRODUCTION

This document describes the design of the Electrical Power Systems (WBS 4) of the National Compact Stellarator Experiment (NCSX). The Electrical Power Systems WBS Element covers the supply and delivery of all AC and DC electrical power to all equipment associated with the NCSX experiment.

2 DESIGN REQUIREMENTS AND CONSTRAINTS

The main loads for the Electrical Power Systems come from:

- Stellarator Magnet Systems. The stellarator core has 2 modular coil circuits, 1 toroidal field (TF) coil circuit, and 3 poloidal field (PF) coil circuits in the initial configuration. These are: M1, M2/3, TF, PF1/2/3, PF4, PF6.
- Neutral Beam Injection (NBI) System.

The Electrical Power Systems requirements for the coil systems are derived from the performance requirements for the coils. NCSX is designed to be a flexible, experimental test bed. To ensure adequate dynamic flexibility, a series of reference scenarios has been established in the General Requirements Document (NCSX-ASPEC-GRD-01_dD[1]). These scenarios include the:

- First Plasma Scenario
- Field Line Mapping Scenario
- 1.7T Ohmic Scenario
- 1.7T High Beta Scenario
- 2T High Beta Scenario
- 350kA Ohmic Scenario
- 1.2T Long Pulse Scenario

TF, PF, and modular coil systems and the vacuum vessel will be designed to meet the requirements of all the reference scenarios. The Electrical Power Systems will be designed and initially configured to meet the requirements of the First Plasma and Field Line Mapping Scenarios and designed to have an upgrade path to meet the requirements of all other reference scenarios.

Flexibility requirements have also been established. The dimensions in flexibility space include:

- Quasi-axisymmetry
- Internal and external iota
- Shear
- Beta
- Current profile

The coil systems shall be designed and the Electrical Power Systems will be upgradeable to accommodate flexibility requirements in each of these dimensions.

The NCSX Project has developed coil current waveforms for each reference scenario. These waveforms are documented in the Technical Data Sheet, which is an Appendix to the GRD and is provided as an appendix to this report (Appendix A). Plots of the waveforms and other parameters of interest are provided in Appendix B. Based

[1] This draft version of the GRD was prepared for the October 2003 Preliminary Design Review (PDR). The changes proposed in it will be formally reviewed by the Project following the PDR.

on these waveforms, maximum circuit currents and voltages were calculated. Power supply requirements were calculated based on the Transrex supplies at D-site. These are the same power supplies that were used for TFTR, some of which are currently being used by NSTX. There are a total of 74 power supply sections located at D-site. The performance characteristics of these power supplies are tabulated in Table 1. A schematic of a Transrex power supply is provided in Figure 1.

When operating at full parameters (maximum I^2t), the required repetition rate is once every 15 minutes. (The repetition rate is limited by the time required to cool down the modular coils.) The maximum CW current required in any circuit is 323 A during the first phase (First Plasma and Field Line Mapping). During subsequent phases including the final phase, the maximum CW current for the modular coils is increased to 1308 Amps. The maximum CW current for the TF and PF coils is less than 700 A.

Maximum active and apparent power requirements and stored energy requirements were calculated over the full range of reference scenarios. The maximum active power is 154 MW, with a maximum stored energy of 124 MJ, in the 2T High Beta Scenario. The maximum apparent power is 408 MVA, which occurred in the 1.7T Ohmic Scenario. These requirements are well within the capability of the D-site AC power system using the available line power and only a single MG set.

The remaining electrical loads should be comparable to electrical loads already handled by the C-site AC Power System during PBX-M operation.

3 DESIGN DESCRIPTION AND PERFORMANCE

The NCSX machine will be installed in the NCSX Test Cell formerly occupied by the PLT and PBX-M tokamaks. The existing D-site DC power conversion equipment will be utilized for NCSX in order to meet the operational requirements of NCSX in a robust and cost-effective manner. The D-site power conversion equipment will be shared with NSTX, feeding at most one machine in operation at any one time. A one-line diagram of the NCSX Electrical Power Systems is provided in Appendix C, along with circuit schematics. Existing D-site power supplies will be used to power all the NCSX coils that are powered. Each of the a) six (6) NCSX circuits for the initial phase, and b) ten circuits (10) for the final phase, has been mapped into an existing or to-be-reconfigured NSTX coil circuit, as shown in Table 2.

Real time feedback control of the magnet power systems will be accomplished via digital computer algorithms performed in a processor provided as part of the Electrical Power Systems work scope. The same Electrical Power Systems computer presently controlling the NSTX system will be used for NCSX. However NCSX will be using a dedicated program. Input/output data for this purpose will be communicated using new and old data network (PC Link and HSDL) in the FCPC building and links from C-site as required. Wiring between power systems components and the existing CAMAC crates will remain as is.

Table 1 Transrex power supply section performance characteristics

Parameter	Value	Units
No Load Avg. DC Voltage	1012.85	volt
Nominal Pulse DC Current*	24.0	kA
Nominal Pulse ESW	*5.5*	*sec*
Nominal Pulse Repetition Period	300.0	sec
Maximum DC Current	*28.2*	*kA*
Maximum Continuous DC Current	3.25	kA

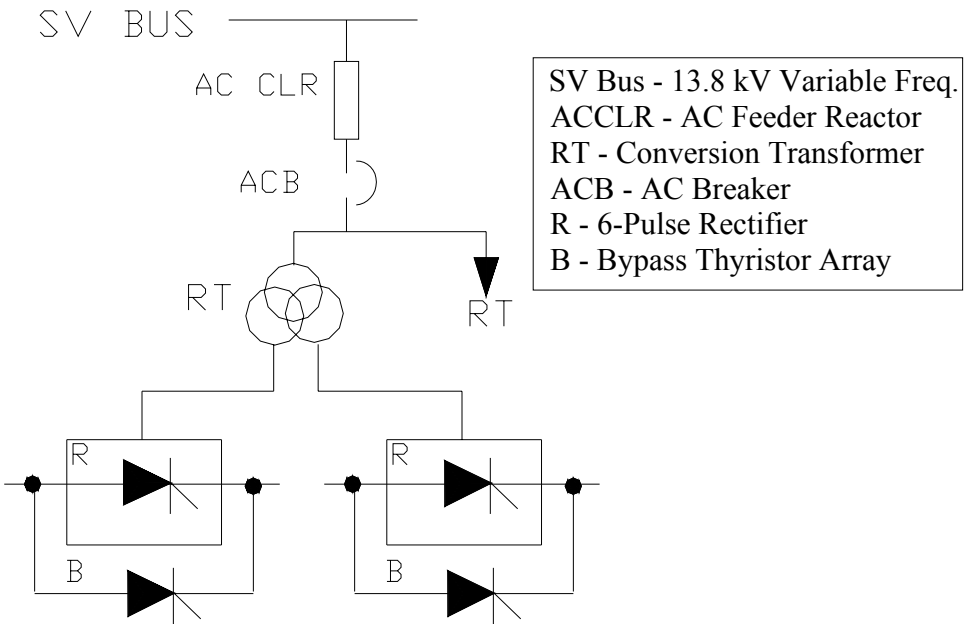


Figure 1 Transrex power supply schematic

The composite AC power demand imposed by NCSX may be supplied by a combination of power derived from the grid and one of the D-site MG sets. Available grid power for the pulsed loads through XST-1 is limited to approximately 120MVA. The total grid power availability depends on the power factor. Present contractual arrangements with PSE&G allow for instantaneous peak power demand up to 120MVA without mention of power factor.

AC power distribution to the D-site MG and power conversion rectifiers all exist and have been in service for several years at levels greater than those required for NCSX. The C-site NBI system was in operation for PBX-M. AC power distribution to NCSX auxiliary equipment will make use of existing equipment down to the 480V level under service conditions less than or equal to previous levels. Additional power panels will be purchased and installed in C-site NCSX Test Cell as required. Additional outlets and plug points will also be provided as needed. WBS 4 will provide power for all Diagnostics Systems equipment up to the power panels.

3.1 Power Loop Components

3.1.1 Power Converter

The power converter consists the rectifier transformer and associated thyristor power supply. Each rectifier transformer (manufactured by General Electric Co.) is a 3-winding 13.8kV/750V/750V unit. The 13.8kV primary of the transformer is a polygonal winding fed from the 13.8kV variable frequency (60 to 90Hz) bus supplied by the 470MVA Generator. One secondary is wye connected and the second is connected in delta.

Each conversion transformer feeds one thyristor Power Supply (manufactured by Transrex Co.). Each power supply consists of two sections rated at 1kV dc open circuit; the full load peak ESW (Equivalent Square Wave) pulsed current is 24kA for 5.5 seconds every 300 seconds. The pulsed rating was re-analyzed during the TFTR OH system upgrade and it was determined that the pulsed current can be raised to 28.4kA for 3 seconds every 300 seconds without overheating the thyristors. There are 37 power supplies installed in PPPL of this rating. Each power supply section consists of six rectifier bridges connected in parallel, and two bypass modules and associated firing generators, fault detectors and associated controls. In addition PPPL has two (2) power supplies rated at 4.5 kA

ESW of 2 seconds every 300 seconds. The reduction in rating of these two supplies is due to the reduced size of the transformer. The thyristor units are same for all the 37 supplies.

Table 2 NCSX power supply requirements

			Circuit 1	Circuit 2	Circuit 3	Circuit 4	Circuit 5	Circuit 6	Circuit 7	Circuit 8	Circuit 9	Circuit 10	Total
Initial configuration		NSTX	TF Branch 1	TF Branch 3	PF3U	PF3L	PF1a	OH (part)					
37 MW 88 MVA 25 MJ	First Plasma FL Mapping	NCSX	M1	M2,M3	PF1/2/3	PF4	PF6	TF					
	Max I2t (10^6 A2-s)		94	84	100	5	1	4					
	Max I (A)		11218	10435	12877	2774	1401	1043					
	tESW (s)		0.75	0.77	0.60	0.69	0.50	4.01					
	Idc (A)		323	306	333	77	33	70					
	Cables per pole		1	1	1	1	1	1					12 Cables
	Series PSS per branch		2	2	2	2	2	2					14 PSS
	Branches		1	1	1	1	2	1					
	Branch configuration						Anti-parallel						
Ultimate configuration		NSTX	TF Branch 1/2	TF Branch 3/4	CHI	PF3L	PF1aL	OH (part)	OH (part)	PF3U	PF2U	PF2L	
154 MW 408 MVA 124 MJ	1.7T Ohmic 1.7T Hi Beta 2T Hi Beta 1.2T Long Pulse 320kA	NCSX	M1	M2	M3	PF4	PF6	TF	PF1/2	PF3	PF5U	PF5L	
	Max I2t (10^6 A2-s)		1512	1539	1433	137	64	225	430	91	47	47	
	Max I (A)		40961	41597	40542	13891	8973	4423	25147	11832	8340	8340	
	tESW (s)		0.90	0.89	0.87	0.71	0.79	11.50	0.68	0.65	0.68	0.68	
	Idc (A)		1296	1308	1262	391	266	500	691	318	229	229	
	Cables per pole		2	2	2	1	1	1	1	1	1	1	26 Cables
	Series PSS per branch		2	2	2	2	2	4	4	2	2	2	40 PSS
	Branches		2	2	2	1	2	2	2	1	1	1	
	Branch configuration		Parallel	Parallel	Parallel		Anti-parallel	Anti-parallel	Anti-parallel				
Circuit ratings (ultimate configuration)	Max I (A)		50000	50000	50000	24000	24000	24000	24000	24000	24000	24000	
	Idc (A) forward		1800	1800	1800	900	900	900	900	900	900	900	
	Idc (A) reverse		-	-	-	900	900	750	750	750	750	750	

3.1.2 DC Current Limiting Reactors

The output of each string of the power supply is provided with a series current limiting reactor that has a value of 267 micro-henries. The reactors will limit the short circuit current to acceptable levels. Also when the branches operate in the anti-parallel configuration the reactors limit the circulating current.

3.1.3 Safety Disconnect and Ground Switches (DGS)

In the D-Site, each circuit will be provided with safety disconnect and ground switches (new purchase). The disconnect and ground switches are electrically and mechanically interlocked such that only one switch can be closed at a time. Both switches can be open at the same time.

In the C-Site also each circuit is provided with disconnect and ground switches. These are the switches originally used in each of the C-Site MG power loops.

3.1.4 Power Cabling

All the new cabling for the power loop will use 5kV shielded 1/c-1000mcm cable. The cables will be duplexed so that there is no resultant force from the pair of cables during pulsing.

3.1.5 Grounding

WBS4 scope includes all the grounding requirements for the machine. It is proposed to retain the copper ground pad/plate within the NCSX test Cell, which was originally used for earlier machines. How ever in order to reduce field errors due to eddy currents, radial cuts will be made in the copper pad/plate every 30 degrees under the foot print of the machine or beyond as determined to be necessary.

Diagnostics equipment will be provided with single point ground system to prevent ground loops. All grounding of equipment will be made per NEC taking care ground loops are avoided.

4 DESIGN BASIS

The bulk of work in this WBS element involves a) the reconfiguration of existing equipment that has been in use for several years at service levels equal to or greater than those required by NCSX and b) additional DC power cabling. All work activities will be performed in accordance with Princeton Plasma Physics Laboratory (PPPL) Engineering and Safety procedures and directives. New NCSX Electrical Power Systems components will be designed, constructed, and installed in compliance with the applicable provisions of the PPPL Health & Safety Manual (ES&H-5008) and other documents as listed in DOE Orders (e.g., ANSI/NFPA 70-(latest edition), National Electric Code, ANSI C20-(latest edition) National Electric Safety Code, etc.).

5 DESIGN IMPLEMENTATION

The Field Coil Power Conversion (FCPC) Building houses all the power conversion equipment. Reconfiguring the coil power supplies so that they may be used for both NCSX and NSTX is a major activity that will have to be planned during the maintenance and shutdown periods of NSTX. The conversion transformers are located outside the building at the back of each of the rectifier units. The Safety Disconnect Switches (SDS) and the Hardwired Control System cabinet are also located in the FCPC building first floor.

Power cables will be installed from the D-site Safety Disconnect Switches (SDS) to the NCSX Disconnect & Ground Switches (DGS) to be located in the second floor of the FCPC building. Each leg of each circuit will be provided with 1/c-1000 mcm cable (5kV rated). A new overhead DC transmission system will be installed from D- to C-site to power the NCSX coils. Transmission will be via power cables from the NCSX Disconnect & Ground Switches (DGS) to the Power Cable Termination Box (PCTB) in the EF/OH building. Provision will be made to reverse the coil polarity with links inside the PCTB. Existing power cables from EF/OH building to the C-site MG basement will be reconnected for each circuit from the PCTB to the existing C-site Bus system at the Discharge Breaker Resistor Cubicles in C-site MG Basement.

The C-site Bus System/Local Disconnect & Grounding System (LDGS) is an existing system, which was installed for earlier fusion devices located in C-site. The C-site Bus System is also already provided with a set of Local Disconnect and Grounding Switches (LDGS). These will be used for each NCSX circuit. Thus, each NCSX coil can be isolated and grounded at the coil end at C-site. The LDGS is designed such that the coils get shorted and grounded when the switch is open. After the Bus System switches, power will be delivered to the coil terminals via power cables in the Test Cell.

6 RELIABILITY, MAINTAINABILITY, AND SAFETY

There is a substantial experience in operating and maintaining the equipment in the Electrical Power Systems. On the basis of that experience, the equipment is expected to operate reliably and be readily maintainable. The equipment will be installed, tested, and maintained by experienced, trained personnel in accordance with Princeton Plasma Physics Laboratory (PPPL) Engineering and Safety procedures and directives.

7 COST, SCHEDULE, AND RISK MANAGEMENT

Table 4 is a summary of the estimate for the Electrical Power Systems (WBS 4) in the NCSX Fabrication Project. The total cost is estimated to be 5094k$ in year of expenditure dollars. The dominant expense class is labor. DC Systems (WBS 43), which covers all of the cabling to bring DC power from D-site to C-site, is the largest cost element. The overall contingency was estimated to be 20%.

The schedule for implementing the Electrical Power Systems (WBS 4) may be seen in the project Master Schedule, provided as part of the Preliminary Design Report. Title II for Electrical Power Systems will generally be completed in FY05. Installation and testing will be generally completed by the end of FY06. The peak years of expenditure are FY05 and FY06, with expenditures of approximately $1.8M in each of those years.

Technical and cost risks should be minimal as this is primarily a reconfiguration activity of existing equipment being performed by experienced personnel. PPPL has extensive experience in all aspects of the job including power cable installation. Costs for power supply reconfiguration and cabling have been assessed based on recent experience on NSTX. Vendor quotes were obtained for constructing the towers between D-site and C-site. Careful planning will be required to mitigate schedule risk due to potential conflicts with the NSTX Project since part of the work can be performed only when NSTX is not operating. This has been carefully planned and has enough float to change depending on changes in the NSTX operational schedule. The jobs in C-Site do not depend on NSTX operations. How ever the C-Site tasks are coordinated with other WBS requirements and progress. Again, enough float has been retained to ensure that the tasks do not come in the critical path. The projected planning of all WBS4 tasks is such that there will not be any risk to the critical path schedule.

Table 3 Work Breakdown Structure (WBS Level 3)

WBS			Description
4			**Electrical Power Systems**
	41		***AC Power***
		411	Auxiliary AC Power Systems
		412	Experimental AC Power Systems
	42		***AC/DC Converters***
		421	C-Site AC/DC Converters
		422	D-Site AC/DC Converters
	43		***DC Systems***
		431	C-Site DC Systems
		432	D-to-C Site DC Systems
		433	D Site DC Systems
	44		***Control and Protection Systems***
		441	Electrical Interlock Systems
		442	Kirk Key Interlocks
		443	Real Time Control Systems
		444	Instrumentation Systems
		445	Coil Protection Systems
		446	Ground Fault Monitoring Systems
	45		***Power System Design and Integration***
		451	System Design and Interfaces
		452	Electrical Systems Support
		453	System Testing (PTPs)
	46		***FCPC Building Modifications***

Table 4 Electrical Power Systems (WBS 4) cost summary by expense class (WBS Level 3)

Total Estimated Cost ($k) excluding contingency

Sum of cost		WBS3														
CAT	expcl	411	412	422	431	432	433	441	442	443	444	445	451	452	453	460	Grand Total
2) Title I & II	Labor/Other	$136	$11		$134	$53	$108	$208	$31	$38	$110	$126	$576	$39	$68	$23	$1,662
2) Title I & II Total		$136	$11		$134	$53	$108	$208	$31	$38	$110	$126	$576	$39	$68	$23	$1,662
3) Fabrication/Assembly (incl title III)	Labor/Other					$36	$6										$43
	M&S	$108	$6		$119	$149	$210	$50	$13		$116	$40		$4	$33	$16	$865
3) Fabrication/Assembly (incl title III) Total		$108	$6		$119	$185	$216	$50	$13		$116	$40		$4	$33	$16	$907
4) Installation/Test	Labor/Other	$316	$26	$19	$75		$100	$309	$51		$199	$111		$46	$86	$42	$1,379
	M&S			$3		$1,076	$65										$1,145
4) Installation/Test Total		$316	$26	$22	$75	$1,076	$165	$309	$51		$199	$111		$46	$86	$42	$2,524
Grand Total		$561	$43	$22	$329	$1,315	$489	$568	$95	$38	$425	$278	$576	$89	$187	$81	$5,094

Pivot Table Key

CAT - Cost Category
WBS3 - Work Breakdown Structure Category(Level 3)
expcl - Expense Class

Table 5 Electrical Power Systems (WBS 4) cost summary by year of expenditure (WBS Level 2)

WBS Level 2	FY03	FY04	FY05	FY06	FY07	TOTAL
41 - AC Power	$0	$63	$139	$297	$104	$604
42 - AC/DC Converters	$0	$0	$0	$22	$0	$22
43 - DC Systems	$2	$622	$1,016	$351	$141	$2,132
44 - Control and protection Systems	$0	$147	$429	$795	$33	$1,403
45 - Power System Design and Integration	$102	$182	$165	$310	$94	$852
46 - FCPC Building Modifications	$19	$35	$21	$7	$0	$81
4 - Electrical Power Systems	$123	$1,049	$1,770	$1,781	$371	$5,094

Appendix A – Excerpts from Technical Data Sheet[2]

[2] TDS-C08R00_C.xls

A.1 Coil Set Definition

Coil centroids are defined by the c08r00 coil set.

A.2 Coil Inductance Matrix (Henries)

	M1	M2	M3	PF1	PF2	PF3	PF4	PF5	PF6	TF	Plasma
M1	1.24E-02	2.83E-03	1.25E-03	-5.52E-05	9.15E-06	3.78E-05	1.22E-04	-2.29E-04	-2.82E-04	8.68E-03	-1.63E-05
M2	2.83E-03	9.23E-03	2.32E-03	2.21E-05	-1.04E-05	-5.07E-06	-1.27E-05	-4.51E-05	-6.27E-05	6.68E-03	-1.08E-05
M3	1.25E-03	2.32E-03	7.90E-03	1.02E-04	-8.50E-06	-3.48E-05	-1.66E-04	-2.03E-04	-6.19E-05	4.68E-03	-8.60E-06
PF1	-5.52E-05	2.21E-05	1.02E-04	3.03E-03	4.76E-04	7.20E-05	1.47E-04	1.68E-04	1.19E-04	0.00E+00	8.92E-06
PF2	9.15E-06	-1.04E-05	-8.50E-06	4.76E-04	2.63E-03	4.28E-04	3.22E-04	1.75E-04	1.14E-04	0.00E+00	6.78E-06
PF3	3.78E-05	-5.07E-06	-3.48E-05	7.20E-05	4.28E-04	2.61E-03	1.14E-03	1.82E-04	1.04E-04	0.00E+00	4.40E-06
PF4	1.22E-04	-1.27E-05	-1.66E-04	1.47E-04	3.22E-04	1.14E-03	1.53E-02	1.14E-03	5.90E-04	0.00E+00	1.82E-05
PF5	-2.29E-04	-4.51E-05	-2.03E-04	1.68E-04	1.75E-04	1.82E-04	1.14E-03	1.29E-02	3.49E-03	0.00E+00	4.81E-05
PF6	-2.82E-04	-6.27E-05	-6.19E-05	1.19E-04	1.14E-04	1.04E-04	5.90E-04	3.49E-03	6.26E-03	0.00E+00	3.97E-05
TF	8.68E-03	6.68E-03	4.68E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.90E-02	1.51E-06
Plasma	-1.63E-05	-1.08E-05	-8.60E-06	8.92E-06	6.78E-06	4.40E-06	1.82E-05	4.81E-05	3.97E-05	1.51E-06	2.68E-06

A.3 Reference Scenario Data

A.3.1 Current Waveforms

Conductor currents are given in amperes. ***Maxima for all reference scenarios are shown in blue, minima in red.***

0.5T First Plasma Scenario	**t(s)**	**M1**	**M2**	**M3**	**PF1**	**PF2**	**PF3**	**PF4**	**PF5**	**PF6**	**TF**	**Plasma**
	-0.600	**0**	**0**	**0**	0	0	**0**	0		0	0	**0**
	0.000	11218	10435	10435	-12877	-12877	**-12877**	-367		-1223	-1043	**0**
	0.100	11218	10435	10435	-12877	-12877	**-12877**	-367		-1223	-1043	**0**
	0.170	10227	10276	10276	-8144	-8144	-8144	-2774		1125	-325	-35310
	0.265	10227	10276	10276	-4832	-4832	-4832	-1768		1387	-325	-35310
	0.270	10227	10276	10276	-4658	-4658	-4658	-1715		1401	-325	-35310
Maximum		11218	10435	10435	0	0	0	0		1401	0	0
Minimum		0	0	0	-12877	-12877	-12877	-2774		-1223	-1043	-35310
I2t (A2-s)		9.38E+07	8.34E+07	8.43E+07	9.57E+07	9.61E+07	9.97E+07	1.39E+06		9.86E+05	4.36E+06	0
tESW (s)		0.75	0.77	0.77	0.58	0.58	0.60	0.18		0.50	4.01	0

Field Line Mapping Scenario	t(s)	M1	M2	M3	PF1	PF2	PF3	PF4	PF5	PF6	TF	Plasma
	-0.600	0	0	0				0		0	0	
	0.000	2244	2087	2087				709		-41	-209	
	0.100	2244	2087	2087				709		-41	-209	
	0.200	2244	2087	2087				709		-41	-209	
	2.600	2244	2087	2087				709		-41	-209	
	10.100	2244	2087	2087				709		-41	-209	
Maximum	0	2244	2087	2087				709		0	0	
Minimum	0	0	0	0				0		-41	-209	
I2t (A2-s)	0	5.37E+07	4.64E+07	4.61E+07				5.27E+06		1.67E+04	5.86E+05	
tESW (s)	0	10.66	10.66	10.58				10.50		10.02	13.45	

1.7T Ohmic Scenario	t(s)	M1	M2	M3	PF1	PF2	PF3	PF4	PF5	PF6	TF	Plasma
	-0.700	0	0	0	0	0	0	0	0	0	0	0
	0.000	38141	35504	35453	-25123	-25123	-9698	-7752	8284	-8997	-3548	0
	0.100	38141	35504	35453	-25123	-25123	-9698	-7752	8284	-8997	-3548	0
	0.140	34772	35327	34508	-16185	-16185	-6754	-9327	743	4396	-1106	-120052
	0.240	34772	35327	34508	-12683	-12683	-4812	-7829	766	4609	-1106	-120052
	0.440	34772	35327	34508	-5681	-5681	-928	-4832	814	5033	-1106	-120052
Maximum		38141	35504	35453	0	0	0	0	8284	5033	0	0
Minimum		0	0	0	-25123	-25123	-9698	-9327	0	-8997	-3548	-120052
I2t (A2-s)		1.39E+09	1.29E+09	1.26E+09	4.24E+08	4.30E+08	6.27E+07	4.95E+07	4.61E+07	6.36E+07	1.05E+08	
tESW (s)		0.96	1.02	1.00	0.67	0.68	0.67	0.57	0.67	0.79	8.31	

1.7T High Beta Scenario	t(s)	M1	M2	M3	PF1	PF2	PF3	PF4	PF5	PF6	TF	Plasma
	-0.700	0	0	0	0	0	0	0	0	0	0	0
	0.000	38141	35504	35453	-14619	-14619	-3872	-3256	8356	-8360	-3548	0
	0.100	38141	35504	35453	-14619	-14619	-3872	-3256	8356	-8360	-3548	0
	0.140	34772	35327	34508	-5681	-5681	-928	-4832	814	5033	-1106	-120052
	0.240	32795	32587	30018	-6129	-6129	-1953	-7029	2272	6030	3760	-178272
	0.440	32795	32587	30018	-5429	-5429	-1565	-6729	2277	6073	3760	-178272
Maximum		38141	35504	35453	0	0	0	0	8356	6073	3760	0
Minimum		0	0	0	-14619	-14619	-3872	-7029	0	-8360	-3548	-178272
I2t (A2-s)		1.34E+09	1.22E+09	1.14E+09	1.34E+08	1.36E+08	9.73E+06	3.09E+07	4.73E+07	6.10E+07	1.66E+08	
tESW (s)		0.92	0.96	0.91	0.63	0.63	0.65	0.63	0.68	0.87	11.77	

2T High Beta Scenario	t(s)	M1	M2	M3	PF1	PF2	PF3	PF4	PF5	PF6	TF	Plasma
	-0.850	0	0	0	0	0	0	0	0	0	0	0
	0.000	40908	41561	40598	-15274	-15274	-5857	-9362	1080	-24	-1301	0
	0.050	40908	41561	40598	-15274	-15274	-5857	-9362	1080	-24	-1301	0
	0.097	40908	41561	40598	-7612	-7612	-1607	-6082	952	5865	-1301	-141238
	0.192	38583	38338	35315	-8219	-8219	-2857	-8701	2666	7033	4424	-209732
	0.197	38583	38338	35315	-8201	-8201	-2848	-8693	2666	7034	4424	-209732
Maximum		40908	41561	40598	0	0	0	0	2666	7034	4424	0
Minimum		0	0	0	-15274	-15274	-5857	-9362	0	-24	-1301	-209732
I2t (A2-s)		1.51E+09	1.54E+09	1.43E+09	1.68E+08	1.68E+08	2.41E+07	7.08E+07	2.82E+06	7.40E+06	2.25E+08	
tESW (s)		0.90	0.89	0.87	0.72	0.72	0.70	0.81	0.40	0.15	11.50	

1.2T Long Pulse Scenario	t(s)	M1	M2	M3	PF1	PF2	PF3	PF4	PF5	PF6	TF	Plasma
	-0.500	0	0	0	0	0	0	0	0	0	0	0
	0.000	26923	25062	25026	-14027	-14027	-4790	-3885	5873	-6126	-2504	0
	0.100	26923	25062	25026	-14027	-14027	-4790	-3885	5873	-6126	-2504	0
	0.128	24545	24937	24359	-7725	-7725	-2716	-5001	549	3328	-780	-84743
	0.228	23150	23003	21189	-7939	-7939	-3383	-6508	1579	4038	2654	-125839
	1.728	23150	23003	21189	-2687	-2687	-470	-4260	1615	4356	2654	-125839
Maximum		26923	25062	25026	0	0	0	0	5873	4356	2654	0
Minimum		0	0	0	-14027	-14027	-4790	-6508	0	-6126	-2504	-125839
I2t (A2-s)		1.33E+09	1.28E+09	1.10E+09	1.07E+08	1.08E+08	1.21E+07	5.19E+07	1.97E+07	4.86E+07	8.59E+07	
tESW (s)		1.83	2.03	1.76	0.54	0.55	0.53	1.23	0.57	1.30	12.19	

320kA Ohmic Scenario	t(s)	M1	M2	M3	PF1	PF2	PF3	PF4	PF5	PF6	TF	Plasma
	-0.600	**0**	**0**	**0**	0	0	**0**	0	**0**	0	0	**0**
	0.000	34772	35327	34508	-22700	-22700	-10368	-12115	852	-610	-1106	**0**
	0.100	34772	35327	34508	-22700	-22700	-10368	-12115	852	-610	-1106	**0**
	0.206	34200	32057	32184	11354	11354	-11802	**-13936**	4563	5068	2191	**-320775**
	0.306	34200	32057	32184	14855	14855	-9860	-12438	4587	5280	2191	**-320775**
	0.506	34200	32057	32184	**21858**	**21858**	-5975	-9441	4634	5705	2191	**-320775**
Maximum		34772	35327	34508	21858	21858	0	0	4634	5705	2191	0
Minimum		0	0	0	-22700	-22700	-11802	-13936	0	-610	-1106	-320775
I2t (A2-s)		1.25E+09	1.18E+09	1.14E+09	4.14E+08	4.04E+08	9.10E+07	1.37E+08	1.04E+07	1.17E+07	1.32E+08	
tESW (s)		1.04	0.94	0.96	0.80	0.78	0.65	0.71	0.48	0.36	27.43	

Ref. Scenario Summary		M1	M2	M3	PF1	PF2	PF3	PF4	PF5	PF6	TF	Plasma
Maximum		40908	41561	40598	21858	21858	0	709	8356	7034	4424	0
Minimum		0	0	0	-25123	-25123	-12877	-13936	0	-8997	-3548	-320775
Max I2t (A2-s)		1.51E+09	1.54E+09	1.43E+09	4.24E+08	4.30E+08	9.97E+07	1.37E+08	4.73E+07	6.36E+07	2.25E+08	
tESW (s) at max current		0.90	0.89	0.87	0.67	0.68	0.60	0.71	0.68	0.79	11.50	

A.3.2 Temperature History

Coil temperatures are in Kelvin. *Maxima for all reference scenarios are shown in blue.*

A.3.2.1 Temperature History For Room Temperature Operation

0.5T First Plasma Scenario	**t(s)**	**M1**	**M2**	**M3**	**PF1**	**PF2**	**PF3**	**PF4**	**PF5**	**PF6**	**TF**
	-0.600	295	295	295	295	295	295	295	295	295	295
	0.000	299	299	299	298	298	298	295	295	295	295
	0.100	300	300	300	299	299	299	295	295	295	295
	0.170	301	300	300	299	299	299	295	295	295	295
	0.265	302	301	301	299	299	299	295	295	295	295
	0.270	302	301	301	299	299	299	295	295	295	295
	0.948	303	302	302	299	299	300	295	295	295	295
Dissipated Energy (J)		**5.99E+06**	**5.21E+06**	**4.37E+06**	**9.68E+05**	**9.73E+05**	**1.01E+06**	3.81E+04	**1.43E+03**	**2.40E+04**	**3.35E+05**
											1.89E+07

Field Line Mapping Scenario	**t(s)**	**M1**	**M2**	**M3**	**PF1**	**PF2**	**PF3**	**PF4**	**PF5**	**PF6**	**TF**
	-0.600	328	328	328	328	328	328	328	328	328	328
	0.000	328	328	328	328	328	328	328	328	328	328
	0.100	328	328	328	328	328	328	328	328	328	328
	0.200	328	328	328	328	328	328	328	328	328	328
	2.600	329	329	329	328	328	328	328	328	328	328
	10.100	333	332	332	328	328	328	328	328	328	328
	10.778	**333**	**332**	**332**	**328**	**328**	**328**	**328**	**328**	**328**	**328**
Dissipated Energy (J)		3.90E+06	3.30E+06	2.72E+06	3.41E+00	1.37E+00	3.39E+01	**1.62E+05**	4.22E+00	4.67E+02	5.11E+04
											1.01E+07

Summary		**M1**	**M2**	**M3**	**PF1**	**PF2**	**PF3**	**PF4**	**PF5**	**PF6**	**TF**
Max Final Temperature		333	332	332	328	328	328	328	328	328	328
Max Dissipated Energy (J)		5.99E+06	5.21E+06	4.37E+06	9.68E+05	9.73E+05	1.01E+06	1.62E+05	1.43E+03	2.40E+04	3.35E+05
											1.89E+07

A.3.2.2 Temperature History For LN2 Operation

1.7T Ohmic Scenario	t(s)	M1	M2	M3	PF1	PF2	PF3	PF4	PF5	PF6	TF
	-0.700	85	85	85	85	85	85	85	85	85	85
	0.000	97	95	96	88	89	86	85	85	86	85
	0.100	100	98	98	89	89	86	85	85	86	85
	0.140	101	99	100	89	89	86	85	86	86	85
	0.240	104	102	103	90	90	86	85	86	86	85
	0.440	111	109	109	90	90	86	85	86	86	85
	3.621	119	116	115	**90**	**90**	86	86	86	**86**	86
Dissipated Energy (J)		1.82E+07	1.61E+07	1.29E+07	**6.22E+05**	**6.31E+05**	8.62E+04	1.82E+05	2.13E+05	**2.12E+05**	1.11E+06
											5.03E+07

1.7T High Beta Scenario	t(s)	M1	M2	M3	PF1	PF2	PF3	PF4	PF5	PF6	TF
	-0.700	85	85	85	85	85	85	85	85	85	85
	0.000	97	95	96	86	86	85	85	85	85	85
	0.100	100	98	98	86	86	85	85	85	86	85
	0.140	101	99	100	86	86	85	85	86	86	85
	0.240	104	102	102	86	86	85	85	86	86	85
	0.440	110	107	107	86	86	85	85	86	86	85
	3.621	117	114	112	86	87	85	85	**86**	86	86
Dissipated Energy (J)		1.73E+07	1.48E+07	1.13E+07	1.86E+05	1.89E+05	1.33E+04	1.17E+05	**2.19E+05**	2.04E+05	1.78E+06
											4.61E+07

2T High Beta Scenario	t(s)	M1	M2	M3	PF1	PF2	PF3	PF4	PF5	PF6	TF
	-0.850	85	85	85	85	85	85	85	85	85	85
	0.000	104	106	105	87	87	85	85	85	85	85
	0.050	106	108	107	87	87	85	85	85	85	85
	0.097	108	110	109	87	87	85	85	85	85	85
	0.192	112	114	113	87	87	85	86	85	85	85
	0.197	112	114	113	87	87	85	86	85	85	85
	3.378	**122**	**123**	**120**	87	87	85	86	85	85	**87**
Dissipated Energy (J)		**2.04E+07**	**2.05E+07**	**1.53E+07**	2.35E+05	2.35E+05	3.28E+04	2.63E+05	1.37E+04	2.63E+04	**2.43E+06**
											5.95E+07

1.2T Long Pulse Scenario	t(s)	M1	M2	M3	PF1	PF2	PF3	PF4	PF5	PF6	TF
	-0.500	85	85	85	85	85	85	85	85	85	85
	0.000	88	88	88	86	86	85	85	85	85	85
	0.100	90	89	89	86	86	85	85	85	85	85
	0.128	90	90	90	86	86	85	85	85	85	85
	0.228	92	91	91	86	86	85	85	85	85	85
	1.728	113	112	108	86	86	85	86	85	86	85
	4.909	117	115	111	86	86	85	86	85	86	86
Dissipated Energy (J)		1.71E+07	1.58E+07	1.08E+07	1.49E+05	1.50E+05	1.66E+04	1.94E+05	9.14E+04	1.64E+05	9.11E+05
											1.01E+07

320kA Ohmic Scenario	t(s)	M1	M2	M3	PF1	PF2	PF3	PF4	PF5	PF6	TF
	-0.600	85	85	85	85	85	85	85	85	85	85
	0.000	93	93	93	87	87	85	85	85	85	85
	0.100	95	96	96	88	88	86	86	85	85	85
	0.206	98	99	98	88	88	86	86	85	85	85
	0.306	101	101	101	88	88	86	86	85	85	85
	0.506	107	106	106	89	89	86	86	85	85	85
	3.687	115	113	112	90	90	**86**	**87**	85	85	86
Dissipated Energy (J)		1.59E+07	1.43E+07	1.13E+07	6.22E+05	6.04E+05	**1.27E+05**	**5.18E+05**	5.04E+04	4.02E+04	1.40E+06
											4.48E+07

Summary		M1	M2	M3	PF1	PF2	PF3	PF4	PF5	PF6	TF
Max Final Temperature		122	123	120	90	90	86	87	86	86	87
Max Dissipated Energy (J)		2.04E+07	2.05E+07	1.53E+07	6.22E+05	6.31E+05	1.27E+05	5.18E+05	2.19E+05	2.12E+05	2.43E+06
											5.95E+07

A.3.3 Electrical Power Requirements

A.3.3.1 Power Supply and Cabling Requirements and Modeling Assumptions

Power supply requirements for the reference scenarios have been calculated based on the following assumptions:

[1] All coils of the same type (e.g. all M1 coils) are connected in series. All coils in the same circuit are connected in series.
Circuit configurations are defined in the table below.

[2] All coils of the same type have a single CLR connected in series with the coils. Each CLR has an inductance
of 267 micro-H and a resistance of 100 milli-ohms.

[3] DC power will be carried from D-site to the test cell via cables approximately 750 feet in length (each way).
Required DC current ratings and cables per pole in each circuit are defined in the table below.
An inductance of 132 micro-Henries per cable pair (supply and return) was assumed.

[4] TFTR power supply sections (PSS) will be used. Each PSS has an open circuit voltage of 1012.85V and a maximum current of 28kA.
When operated in parallel, the maximum rated current is reduced by 10%.

[5] Required DC ratings are based on a pulse repetation time of 15 minutes.

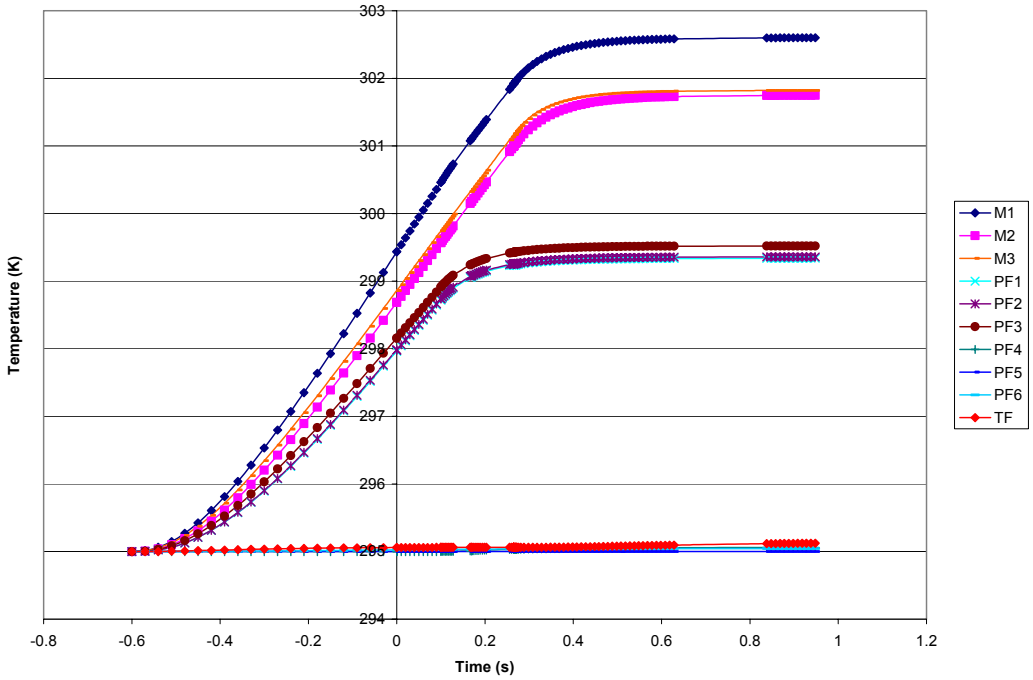
Changes in the capability required are shown in red

Description	Scenarios	Circuit 1	Circuit 2	Circuit 3	Circuit 4	Circuit 5	Circuit 6	Circuit 7	Circuit 8	Circuit 9	Circuit 10	Total
Initial capability required	First Plasma		M2,M3	PF1/2/3								
	FL Mapping	M1	M2	M3	PF4	PF6	TF					
37 MW	Max I2t (A2-s)	9.38E+07	8.43E+07	9.97E+07	5.27E+06	9.86E+05	4.36E+06					
88 MVA	tESW (s)	0.75	0.77	0.60	0.69	0.50	4.01					
25 MJ	Required DC rating (A)	323	306	333	77	33	70					
	Cables per pole	1	1	1	1	1	1					12 Cables
	Series PSS per branch	2	2	2	2	2	2					14 PSS
	Branches	1	1	1	1	2	1					
	Branch configuration					Anti-parallel						
Ultimate capability required	1.7T Ohmic 1.7T Hi Beta 2T Hi Beta 1.2T Long Pulse 320kA	M1	M2	M3	PF4	PF6	TF	PF1/2	PF3	PF5U	PF5L	
154 MW	Max I2t (A2-s)	1.51E+09	1.54E+09	1.43E+09	1.37E+08	6.36E+07	2.25E+08	4.30E+08	9.10E+07	4.73E+07	4.73E+07	
408 MVA	tESW (s)	0.90	0.89	0.87	0.71	0.79	11.50	0.68	0.65	0.68	0.68	
124 MJ	Required DC rating (A)	1296	1308	1262	391	266	500	691	318	229	229	
	Cables per pole	2	2	2	1	1	1	1	1	1	1	26 Cables
	Series PSS per branch	2	2	2	2	2	4	4	2	2	2	40 PSS
	Branches	2	2	2	1	2	2	2	1	1	1	
	Branch configuration	Parallel	Parallel	Parallel		Anti-parallel	Anti-parallel	Anti-parallel				

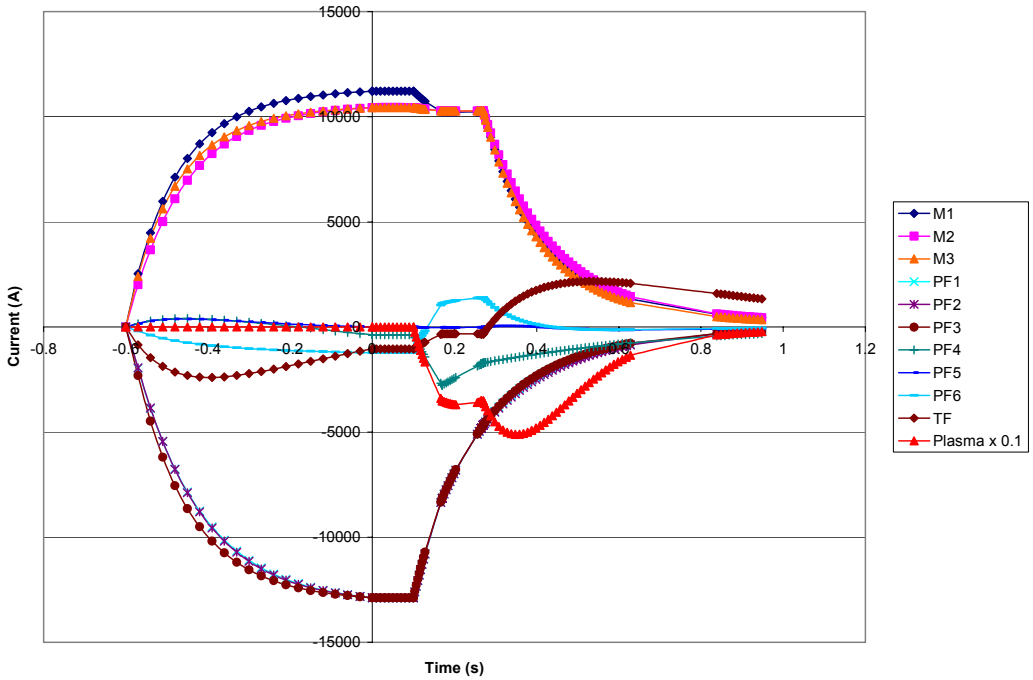
Appendix B – Plots of Electrical Power Systems Parameters

1. First Plasma Scenario

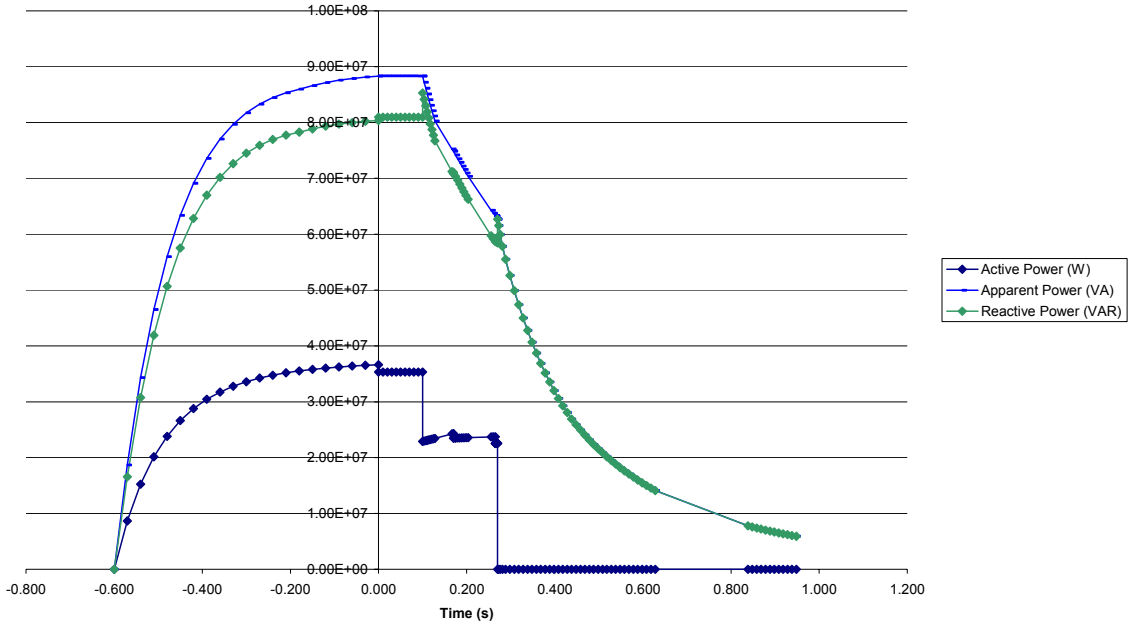
a. Temperature



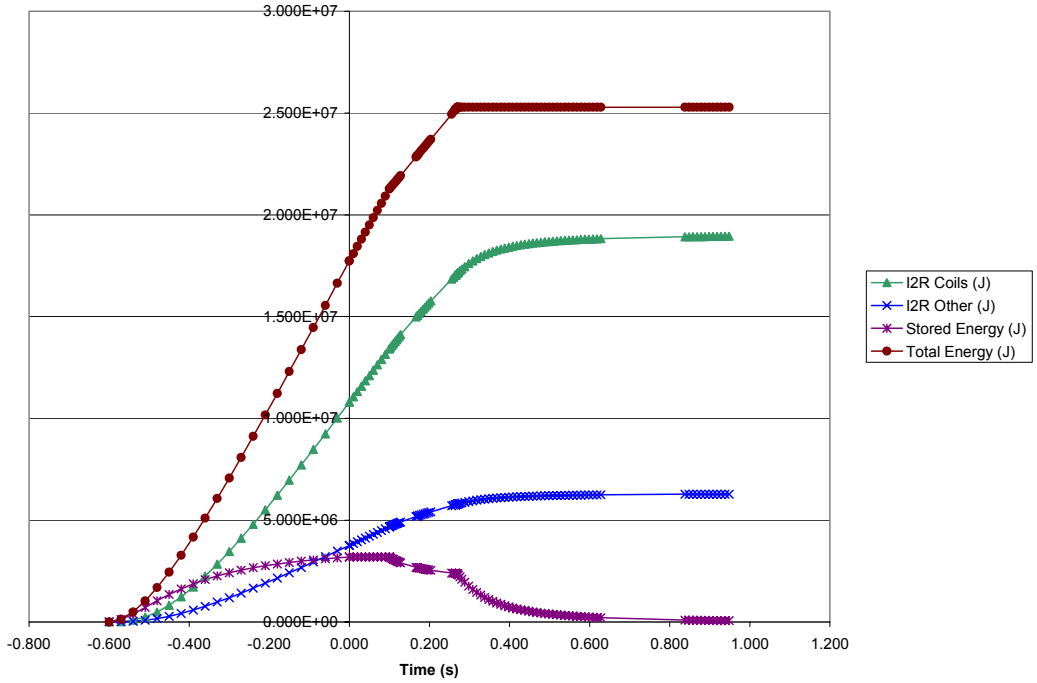
b. Current



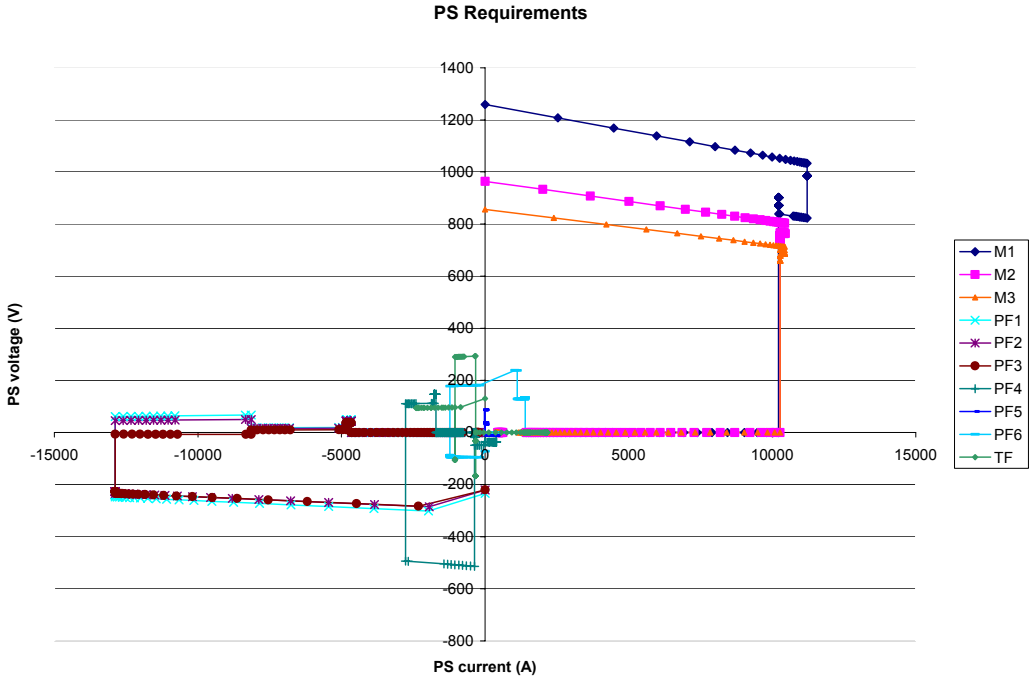
c. Power



d. Energy

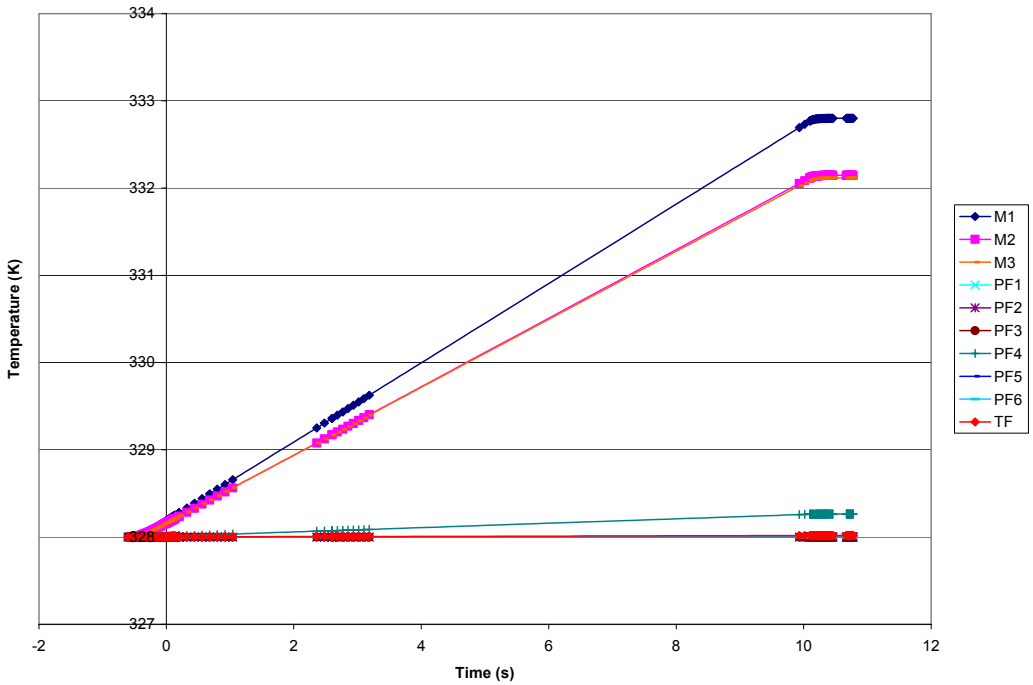


e. Power Supply Voltage

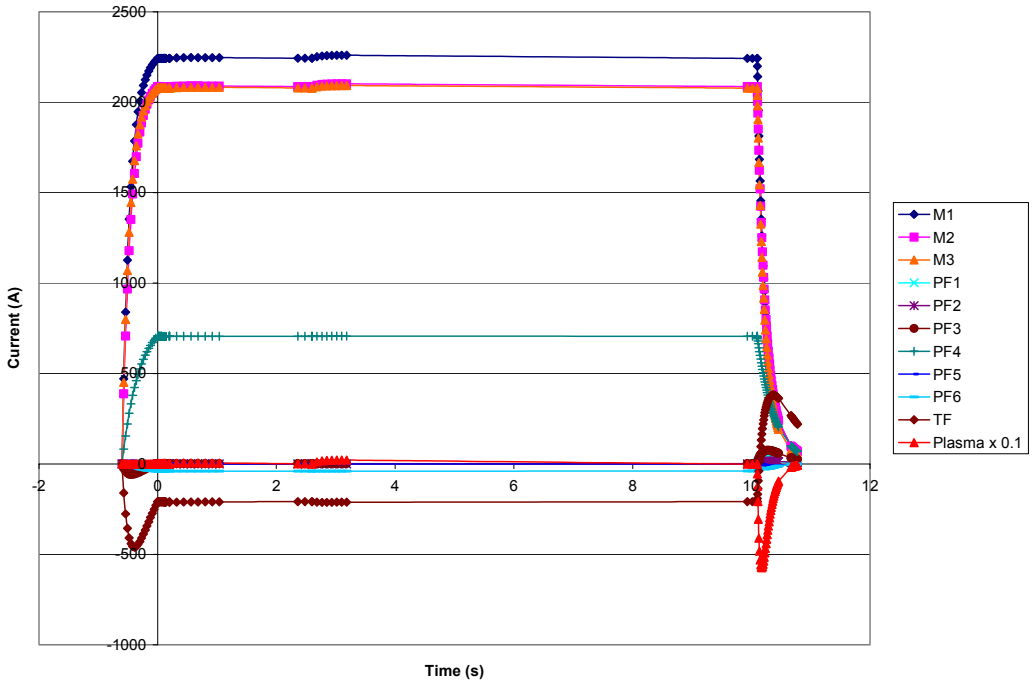


2. Field Line Mapping Scenario

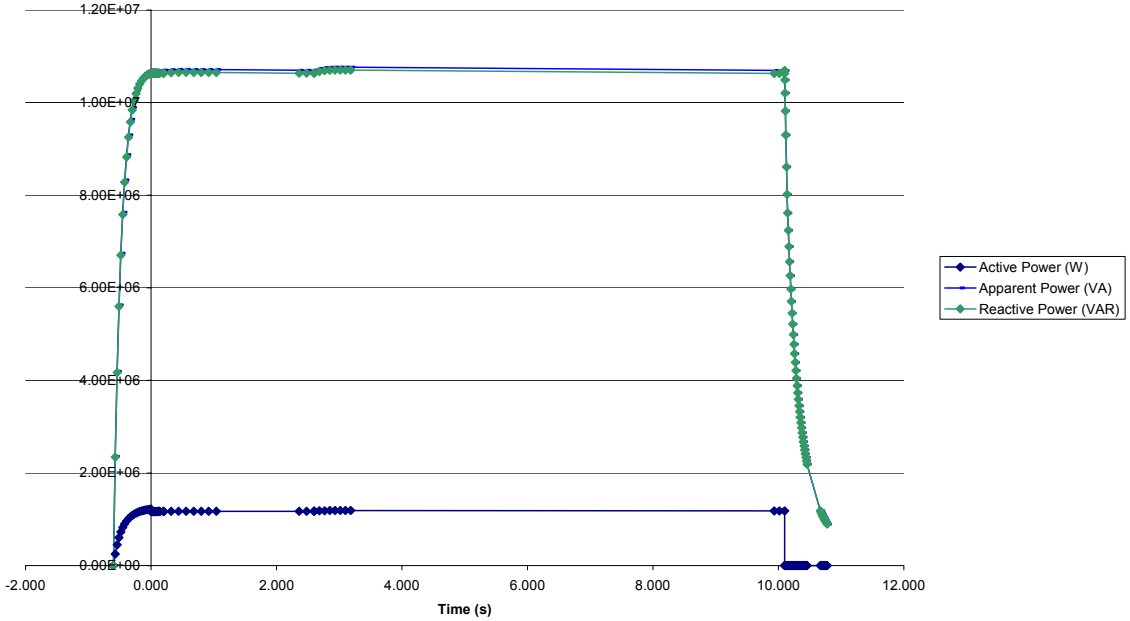
a. Temperature



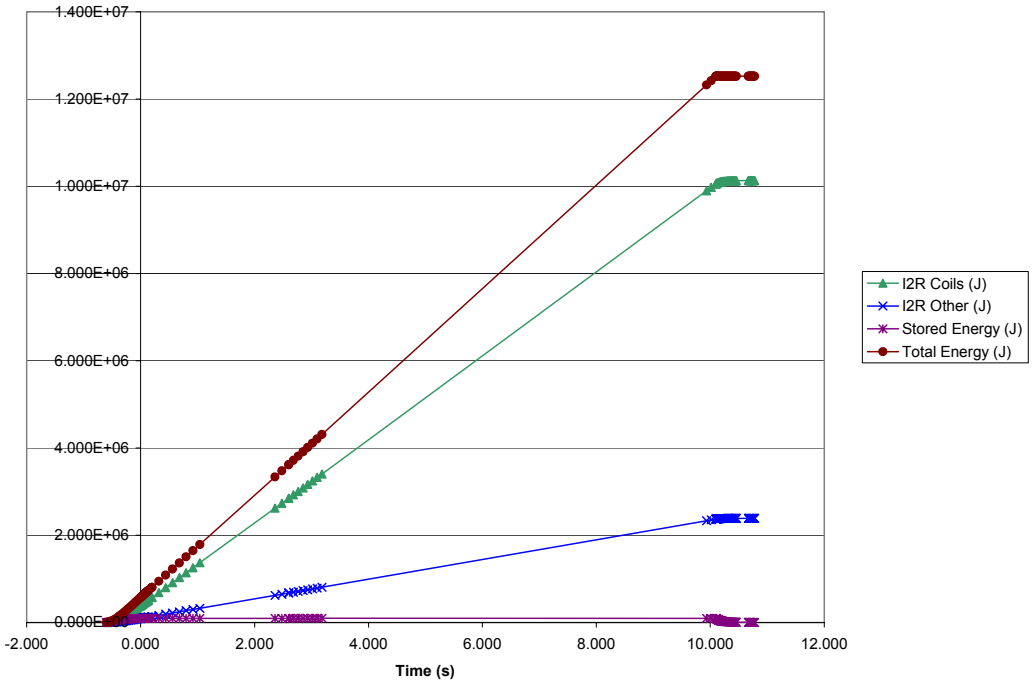
b. Current



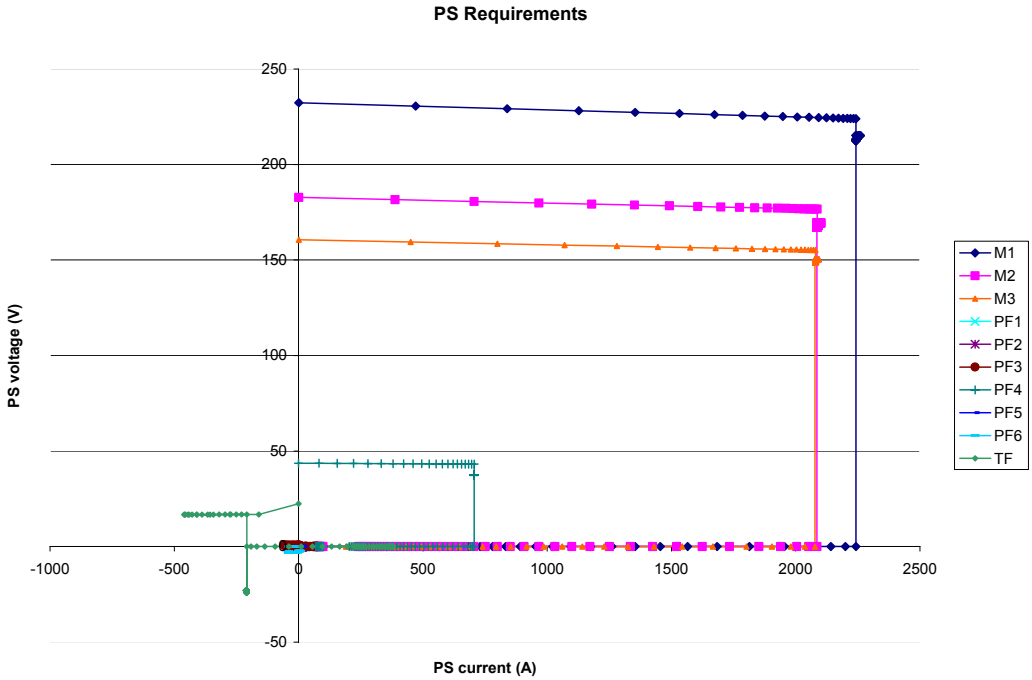
c. Power



d. Energy

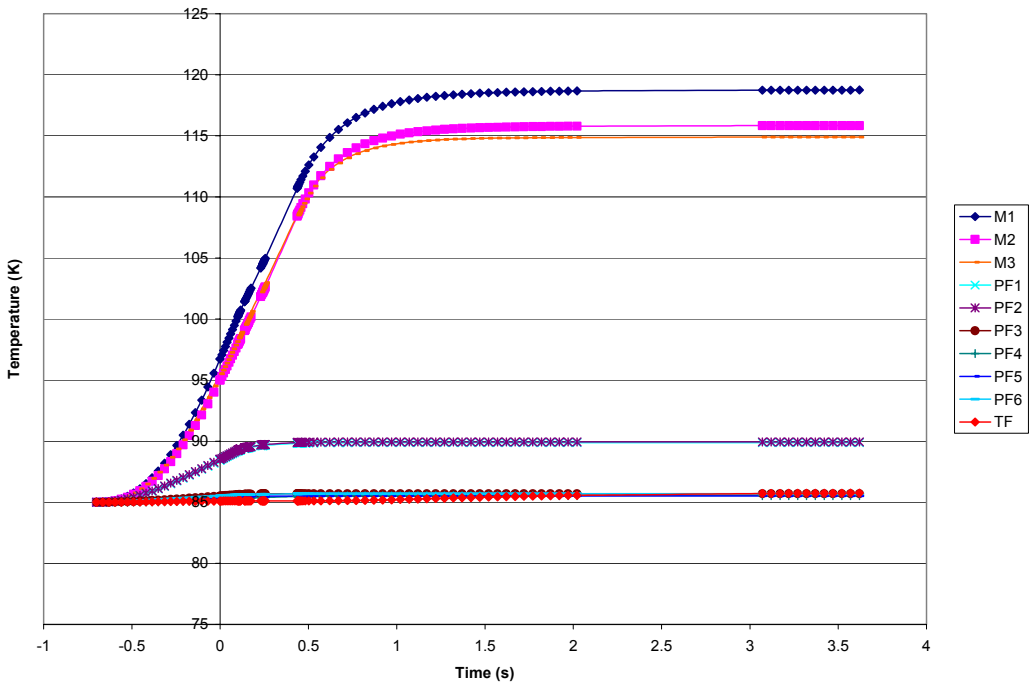


e. Power Supply Voltage

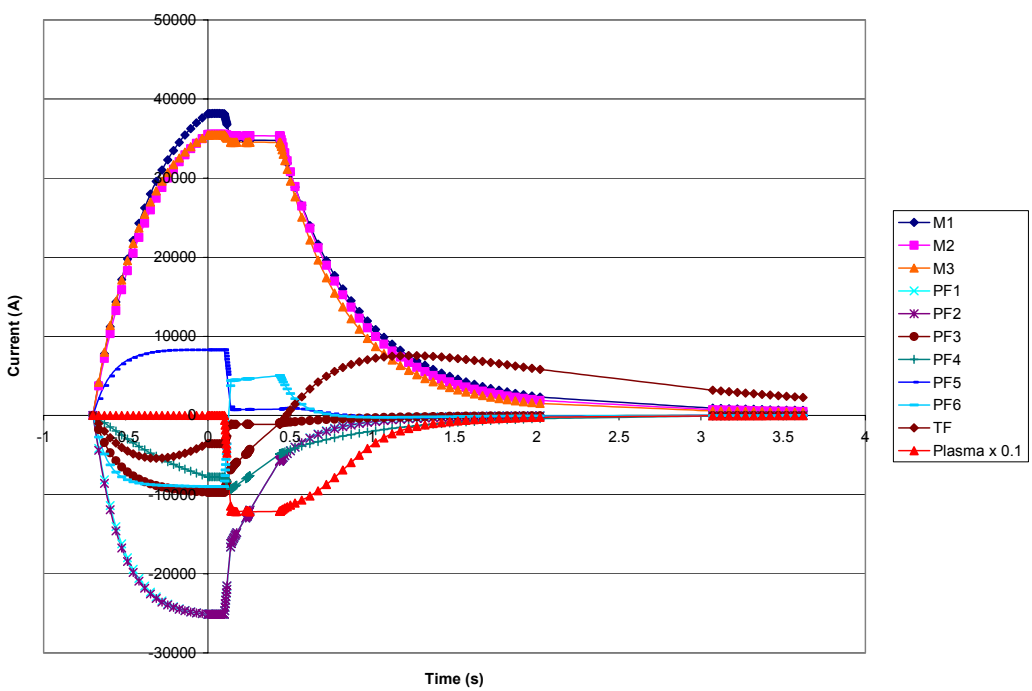


3. 1.7T Ohmic Scenario

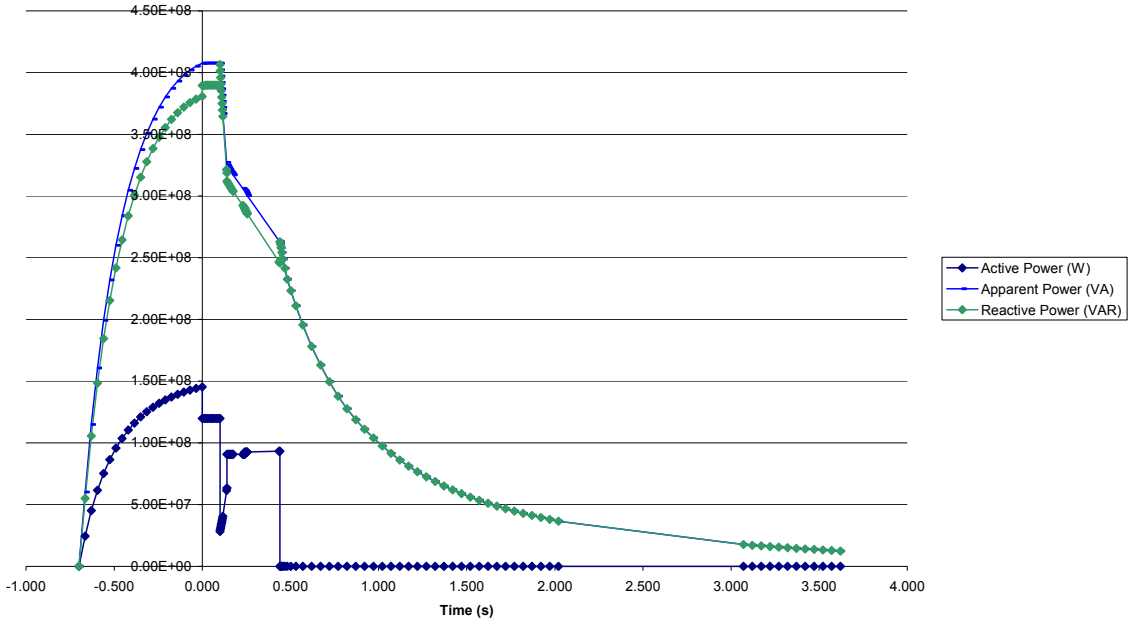
a. Temperature



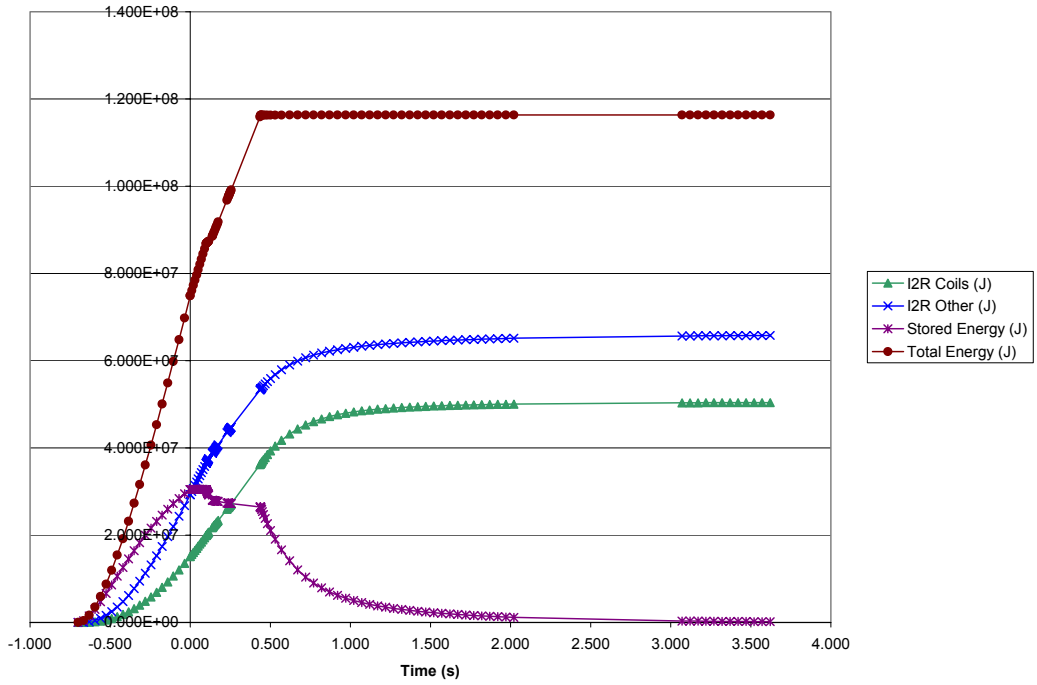
b. Current



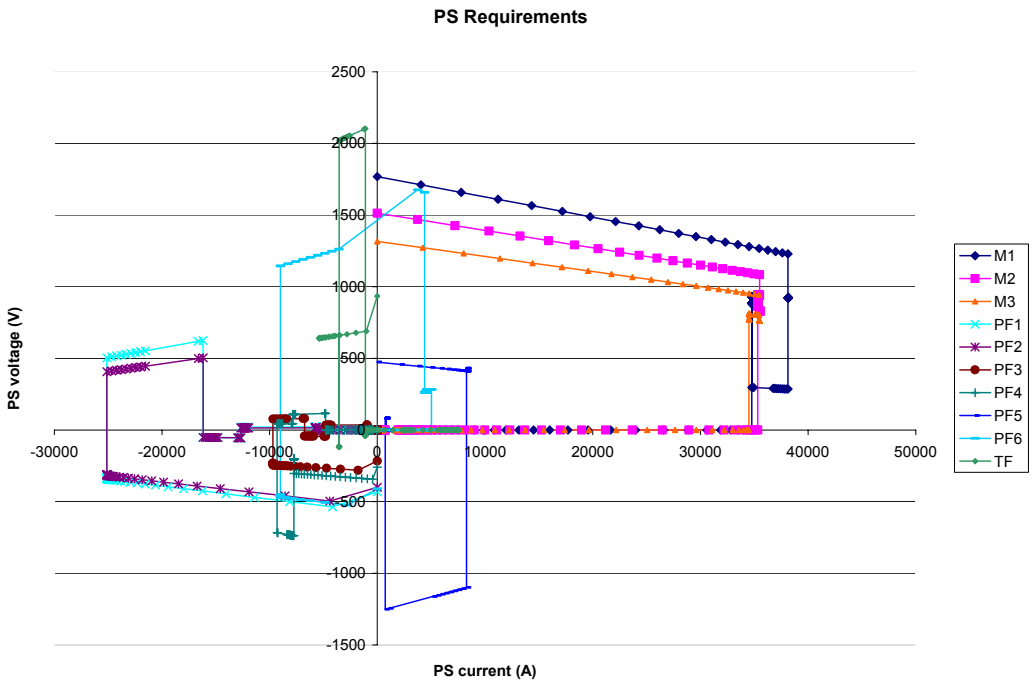
c. Power



d. Energy

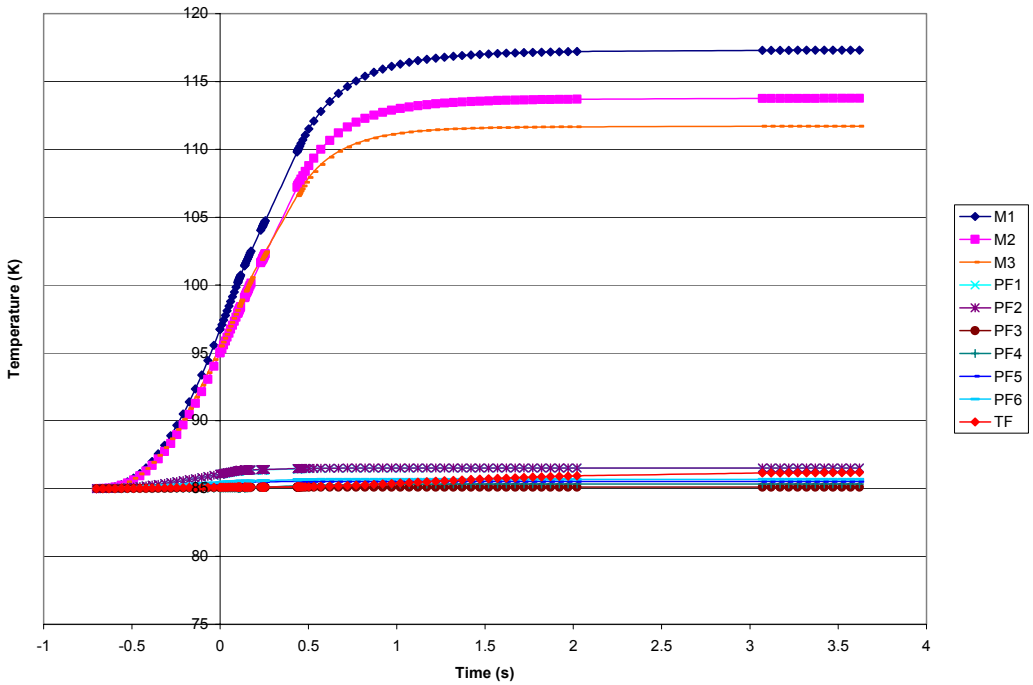


e. Power Supply Voltage

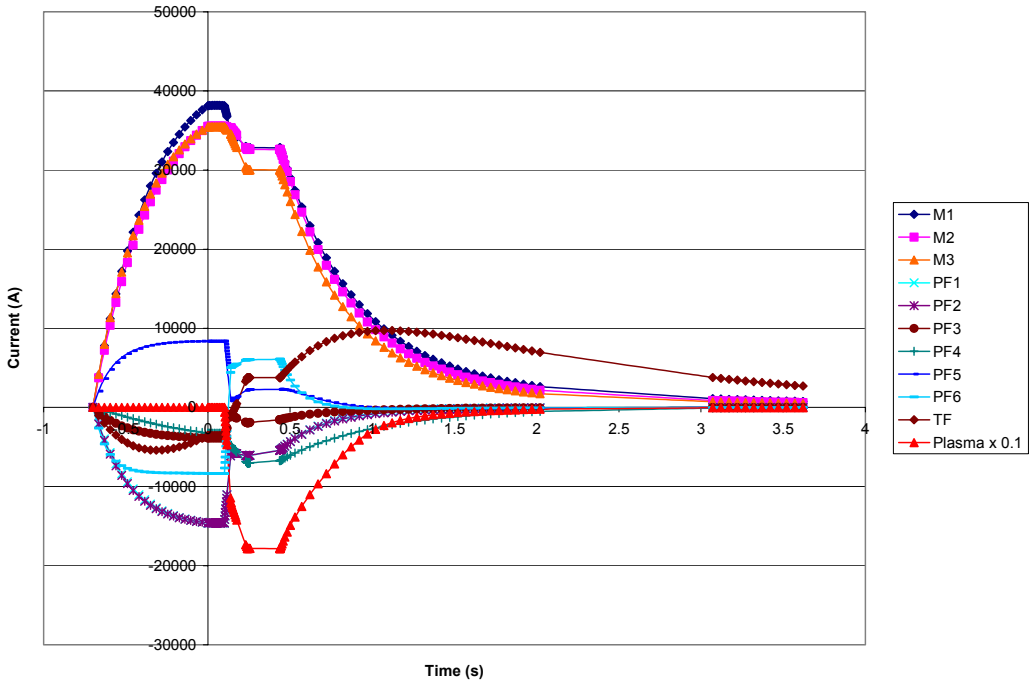


4. 1.7T High Beta Scenario

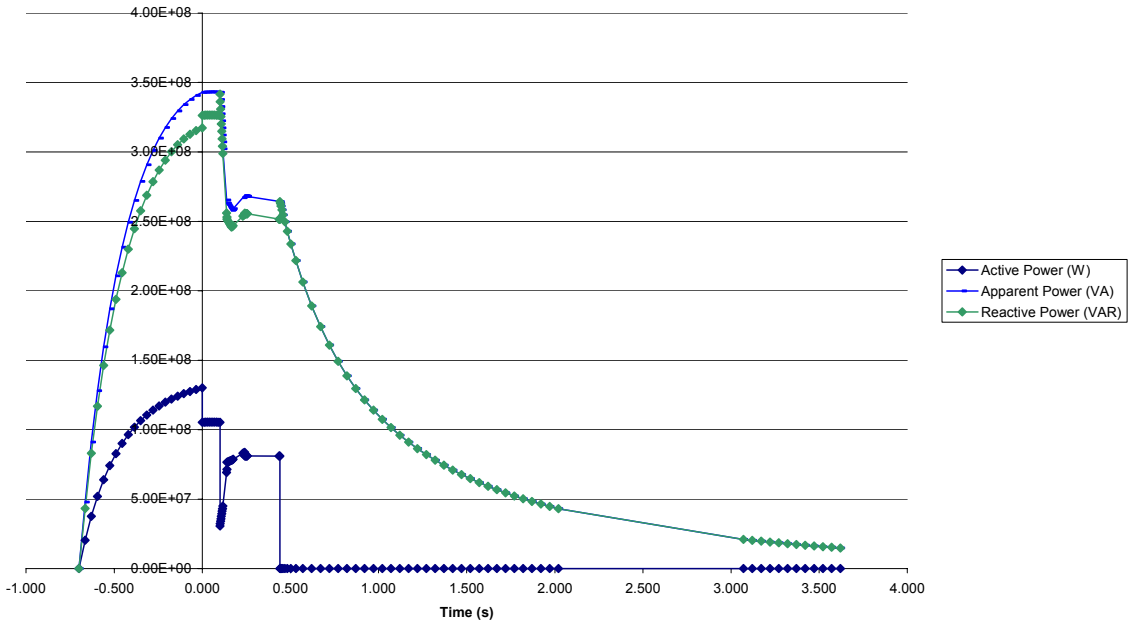
a. Temperature



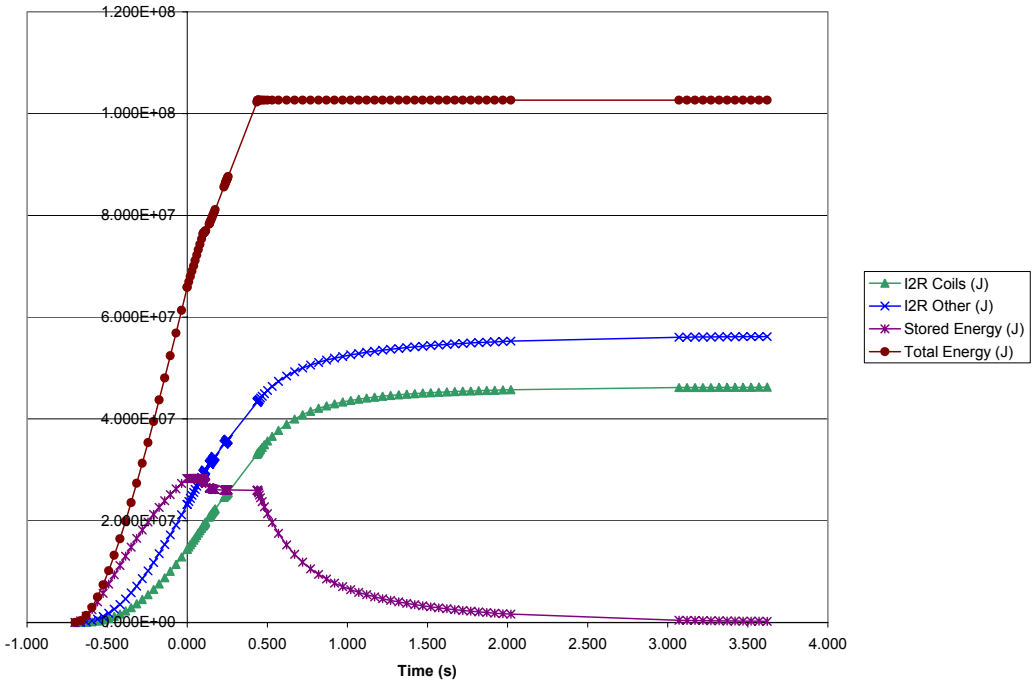
b. Current



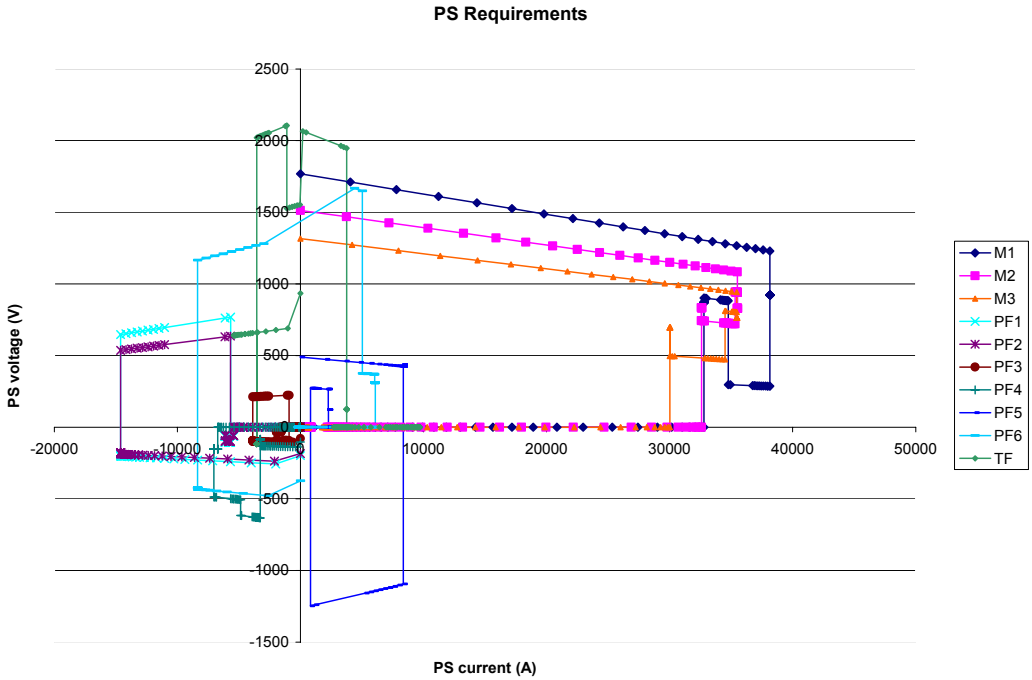
c. Power



d. Energy

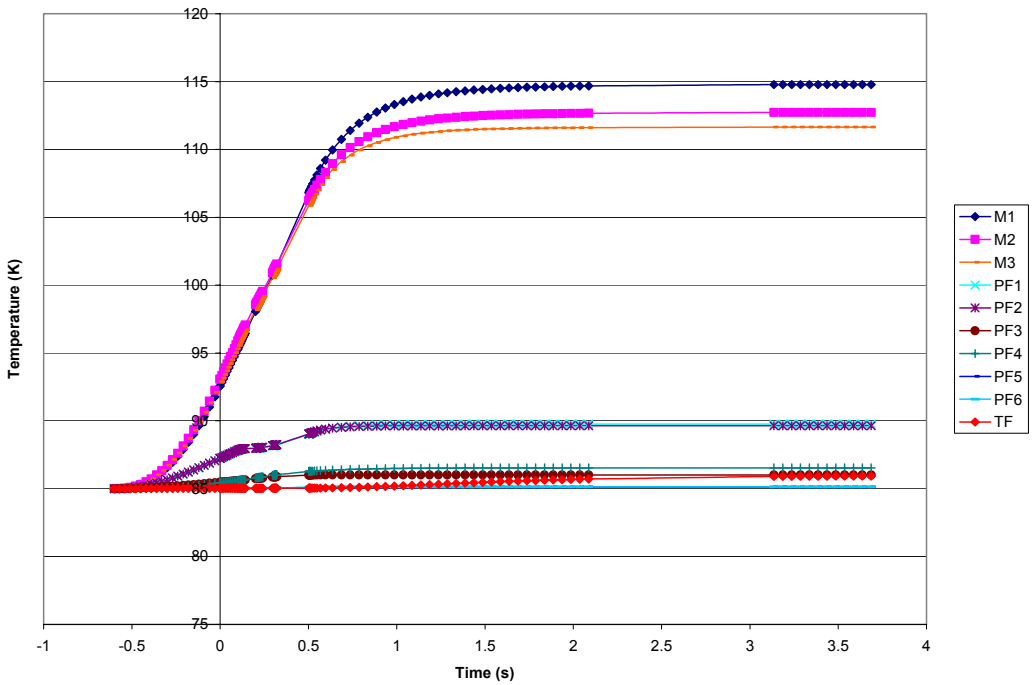


e. Power Supply Voltage

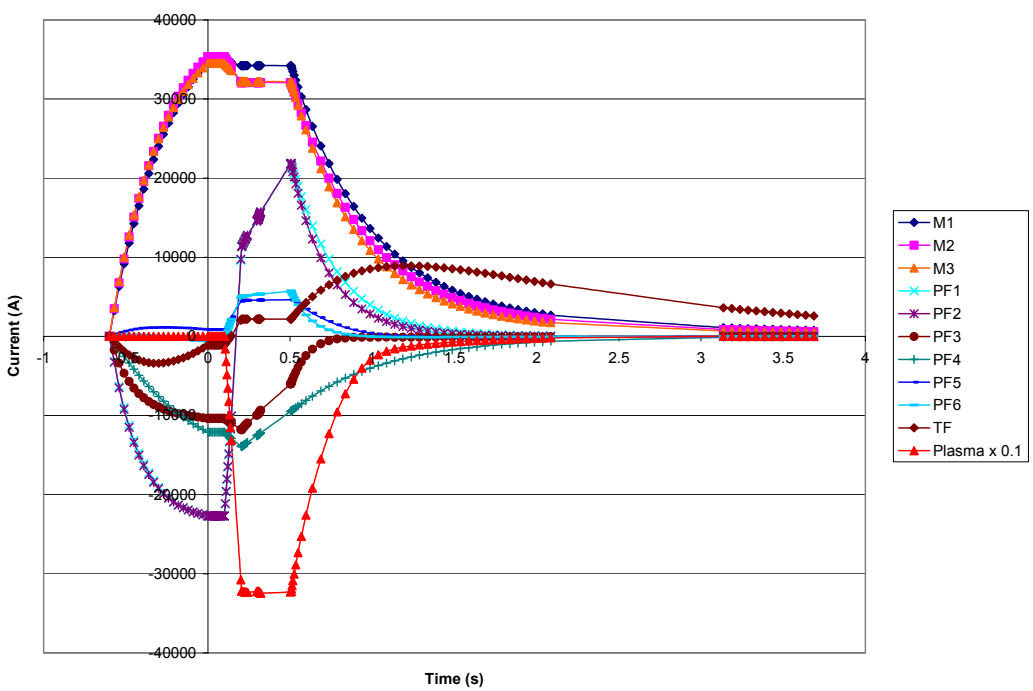


5. 320kA Ohmic Scenario

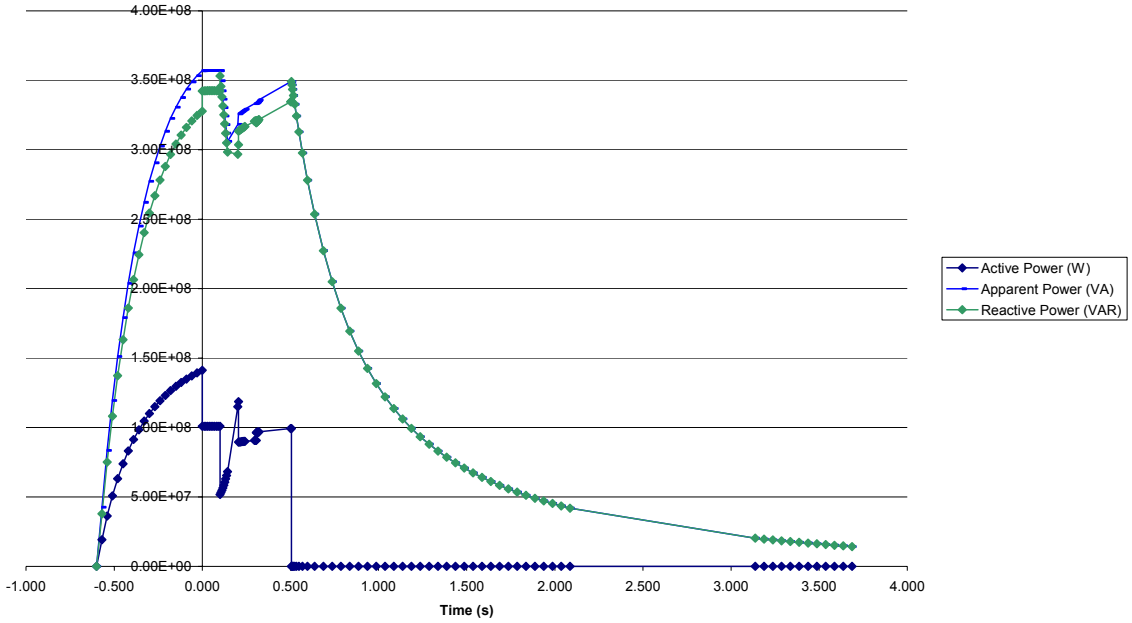
a. Temperature



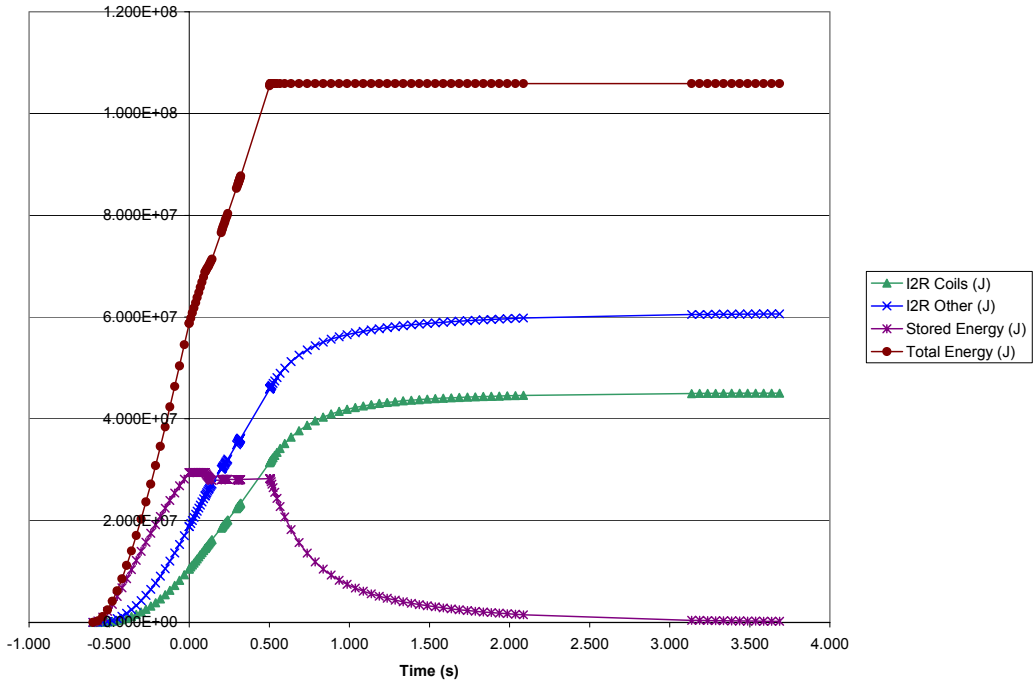
b. Current



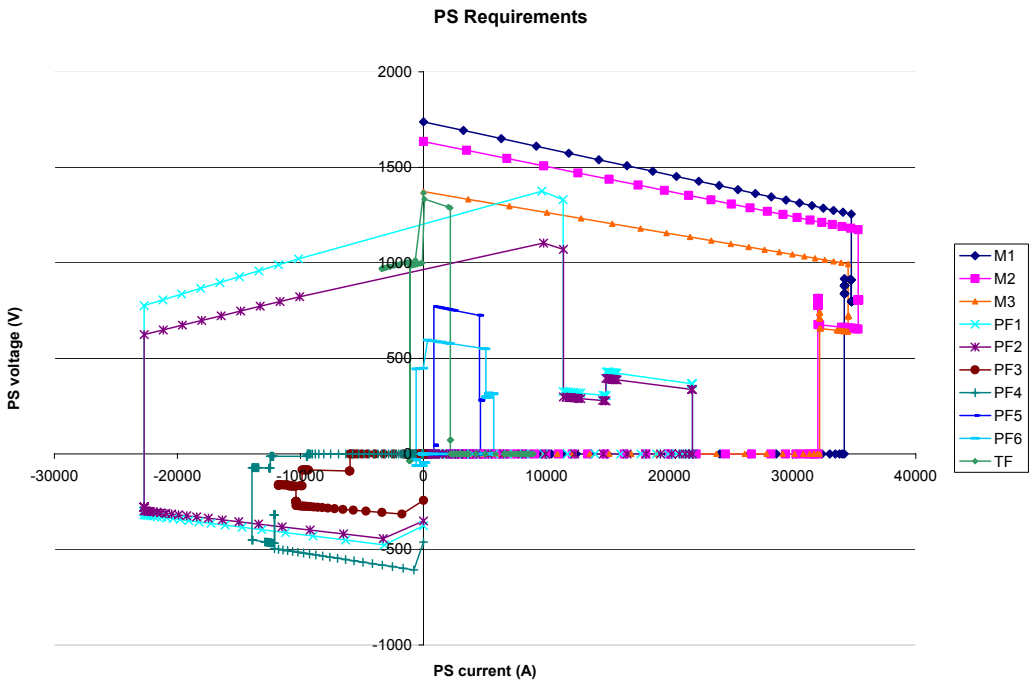
c. Power



d. Energy

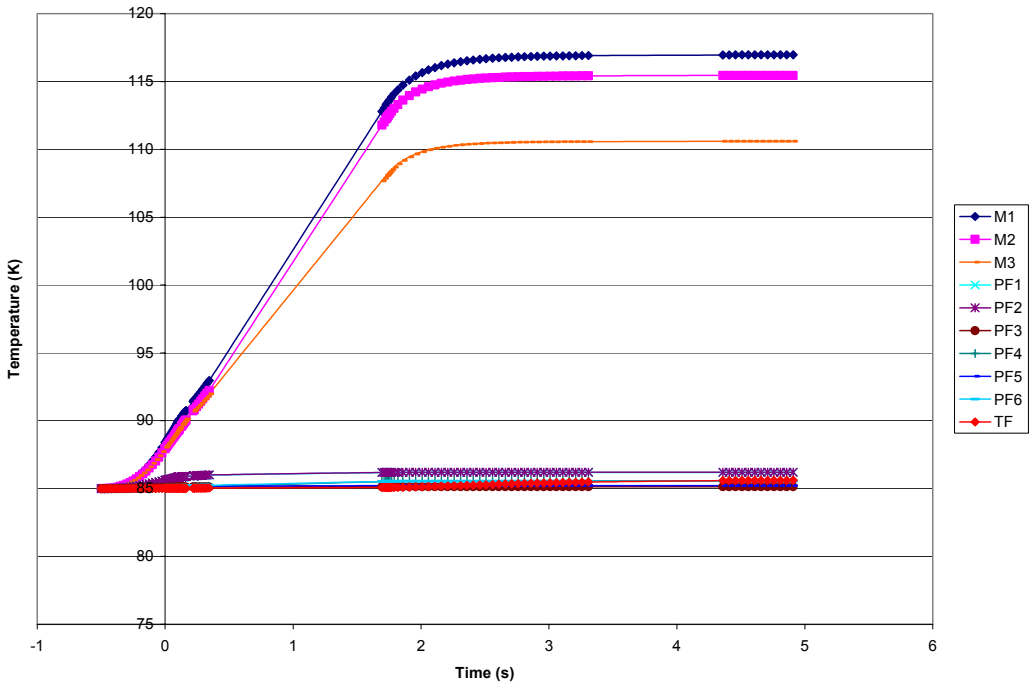


e. Power Supply Voltage

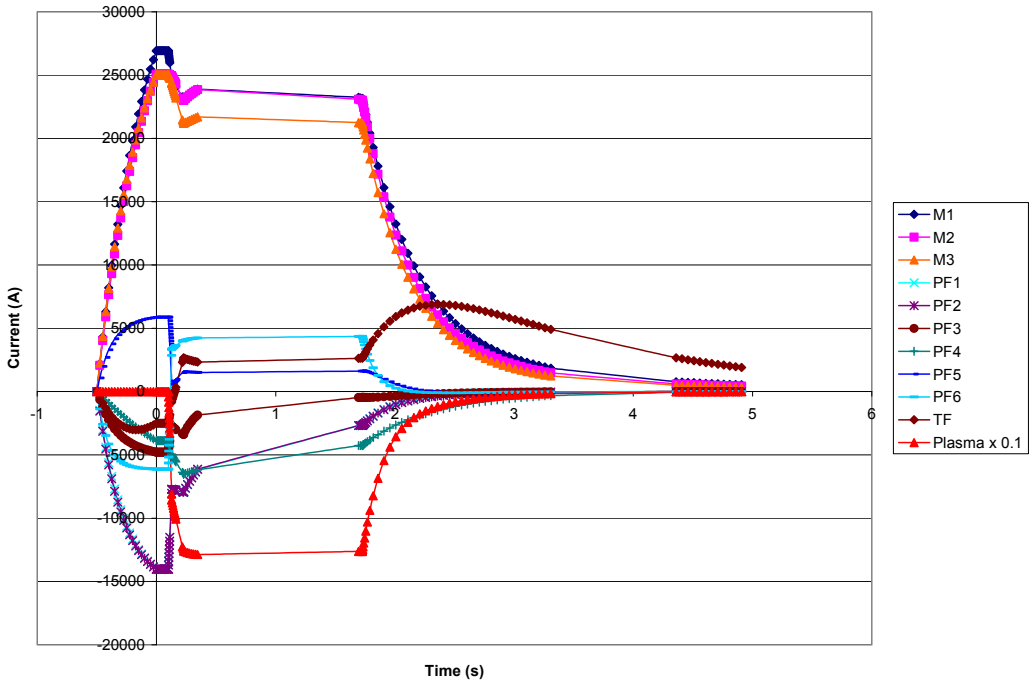


6. 1.2T Long Pulse Scenario

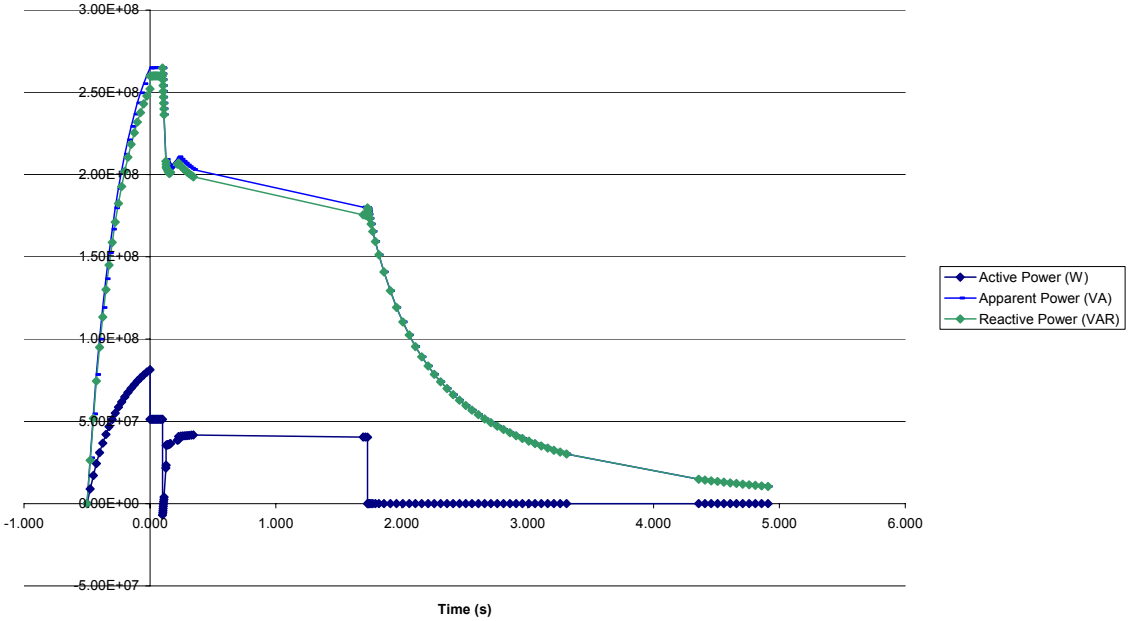
a. Temperature



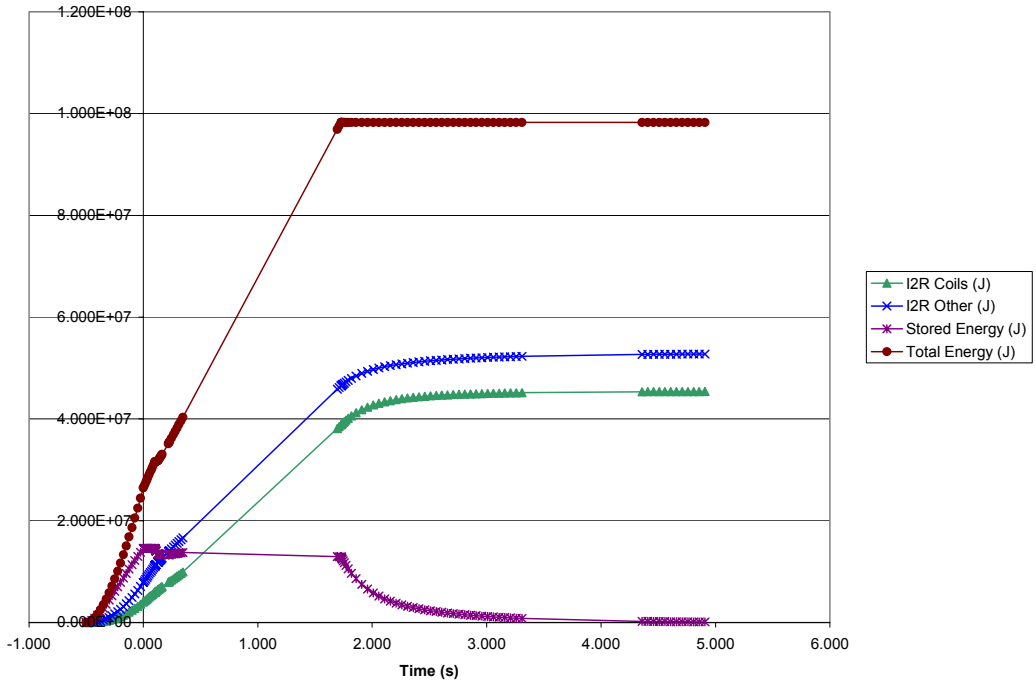
b. Current



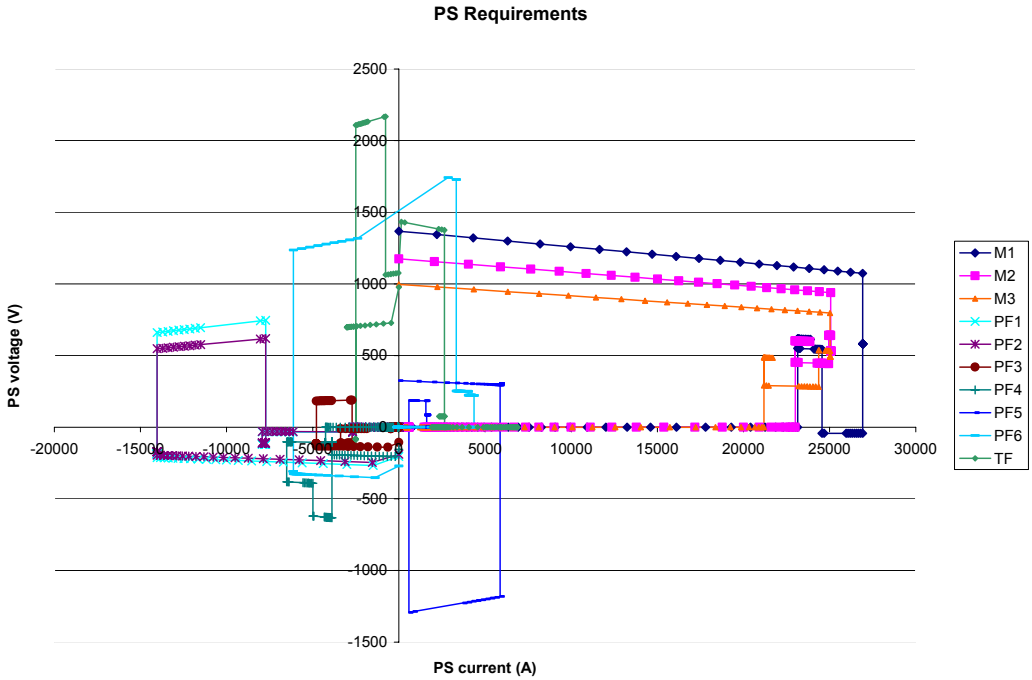
c. Power



d. Energy

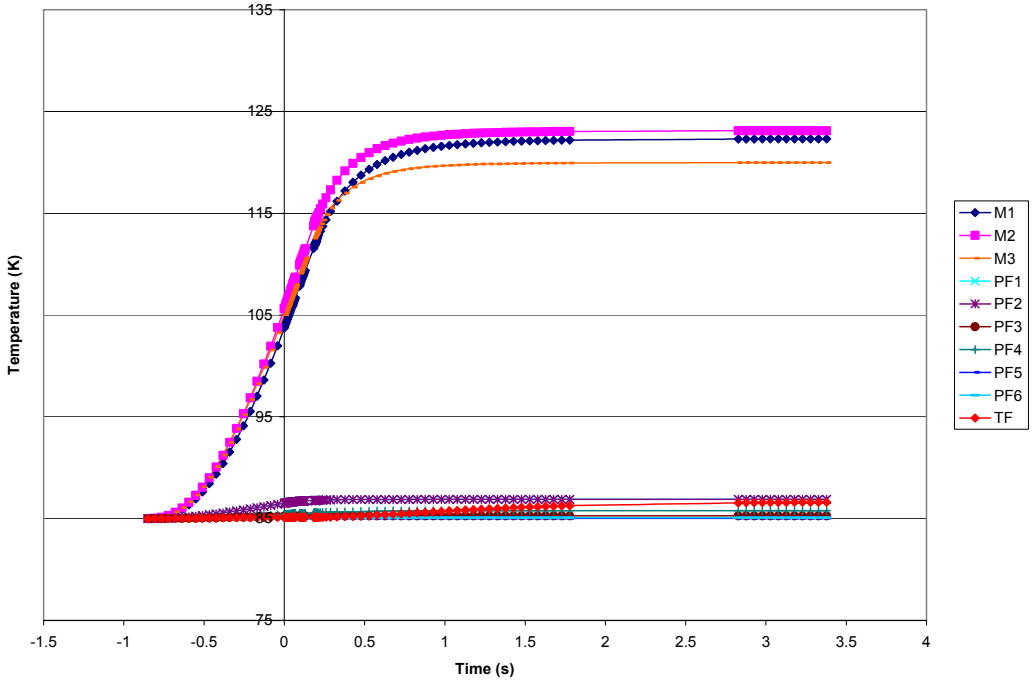


e. Power Supply Voltage

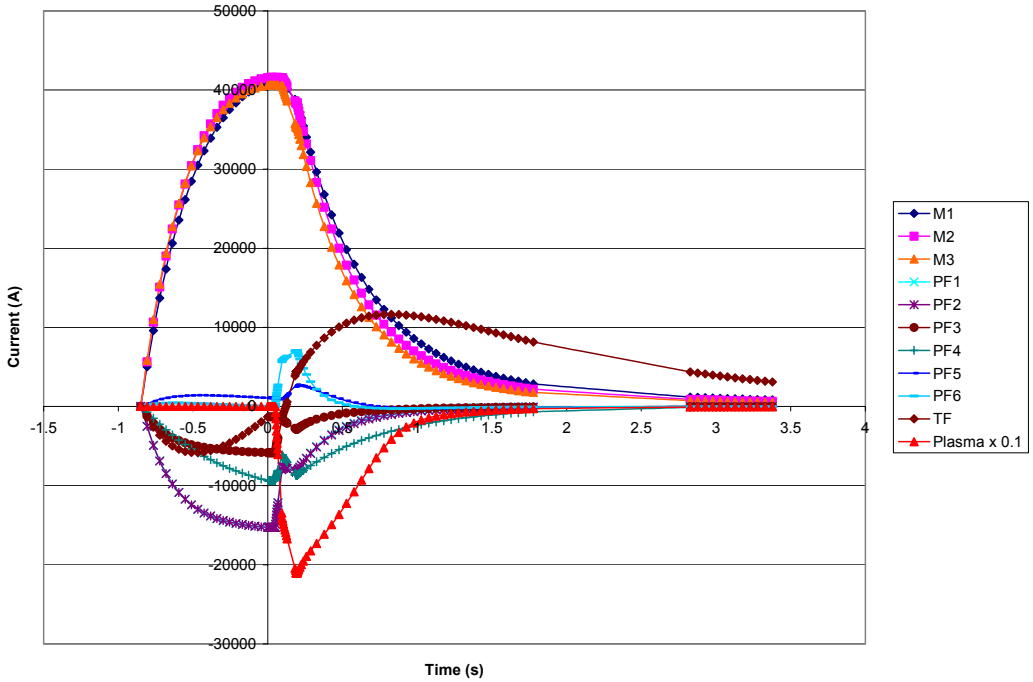


7. 2T High Beta Scenario

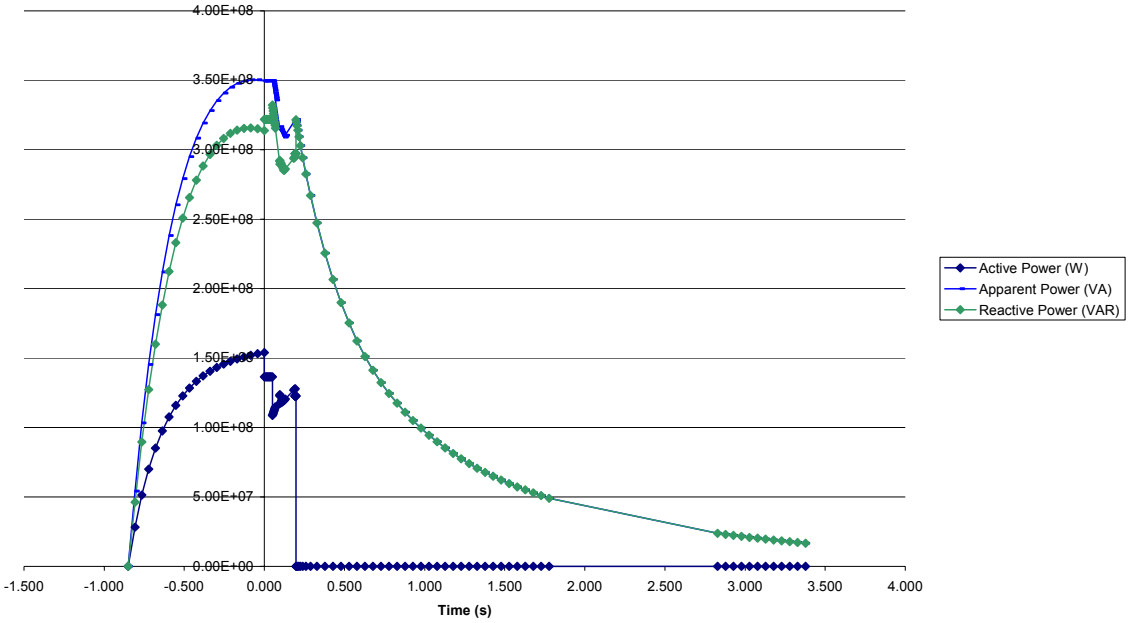
a. Temperature



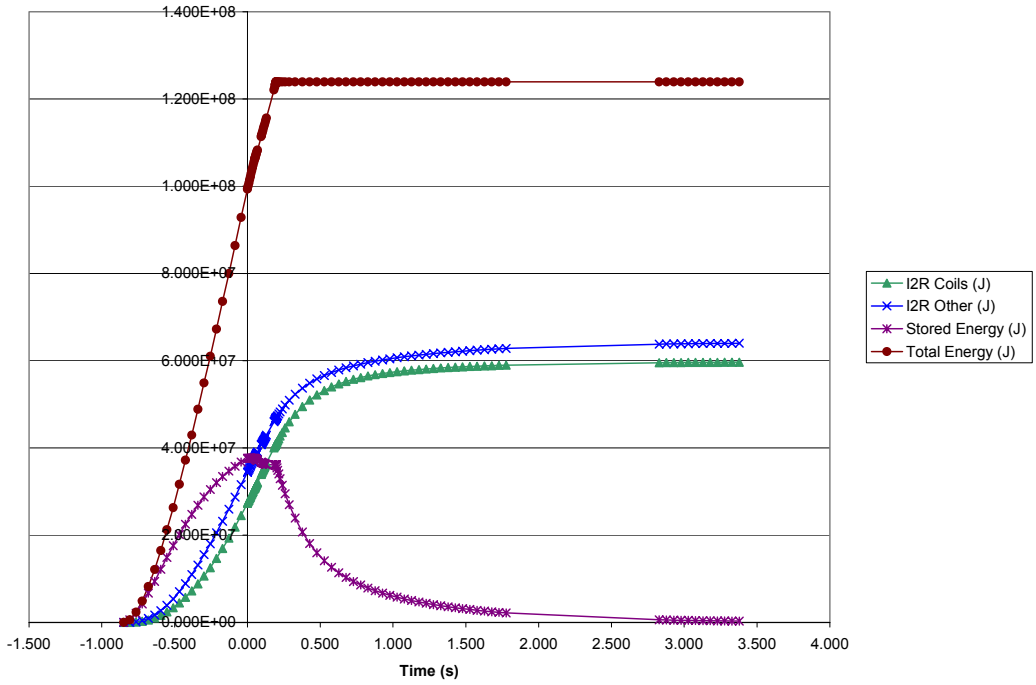
b. Current



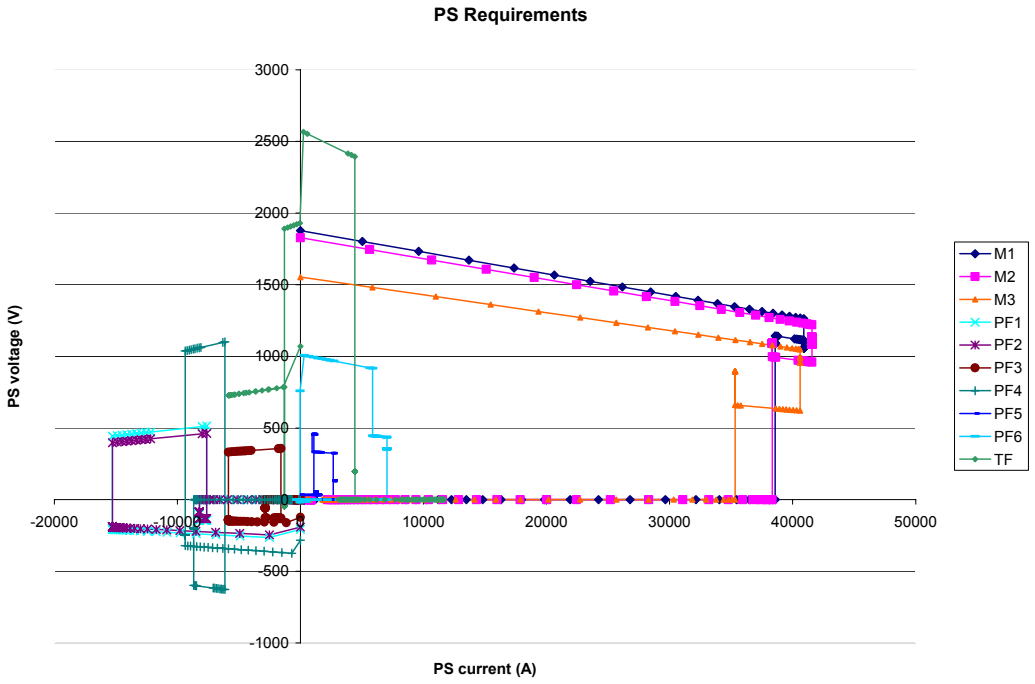
c. Power



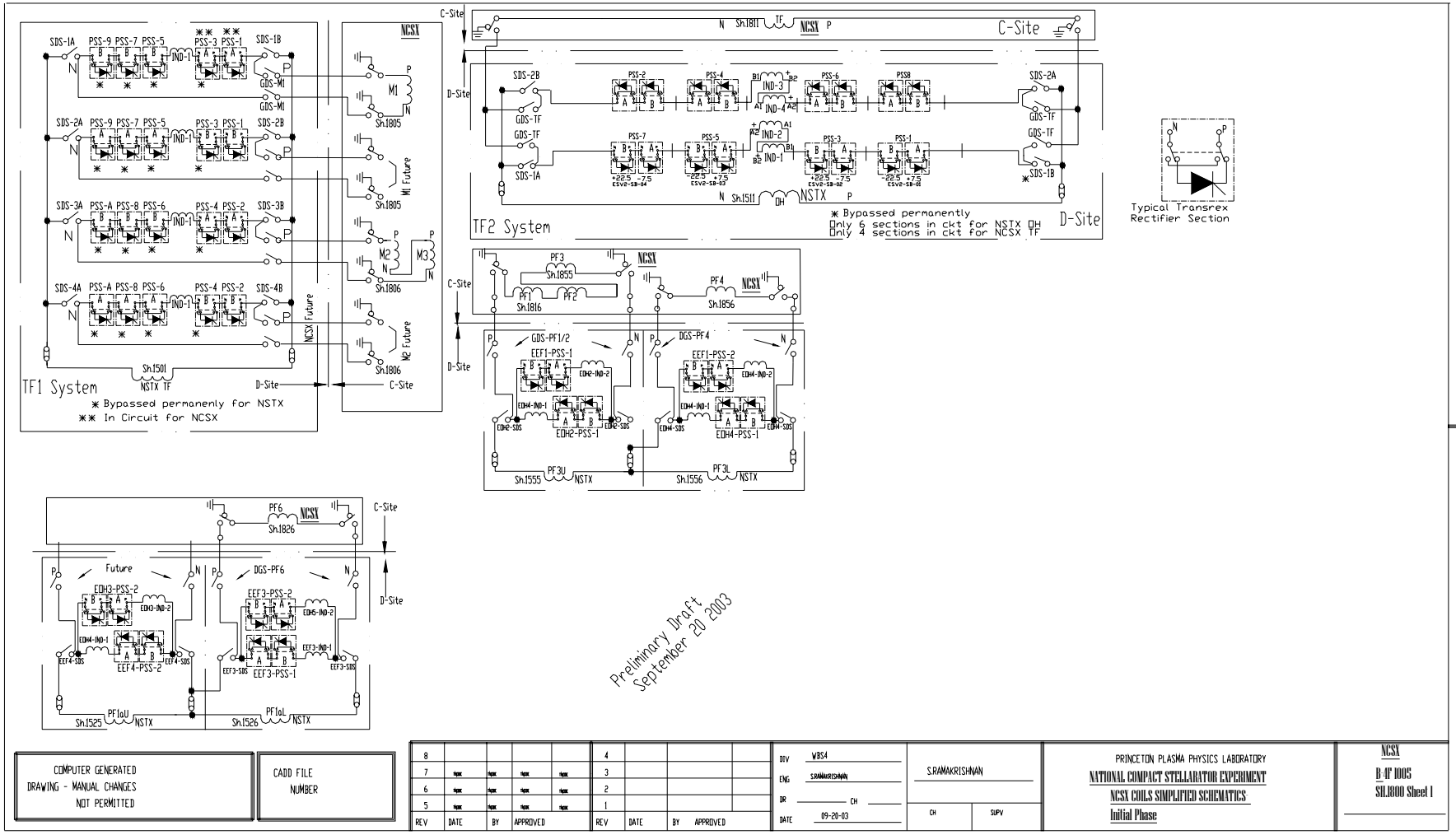
d. Energy



e. Power Supply Voltage



Appendix C – NCSX One-line Diagram and Circuit Schematics



COMPUTER GENERATED
DRAWING - MANUAL CHANGES
NOT PERMITTED

CADD FILE
NUMBER

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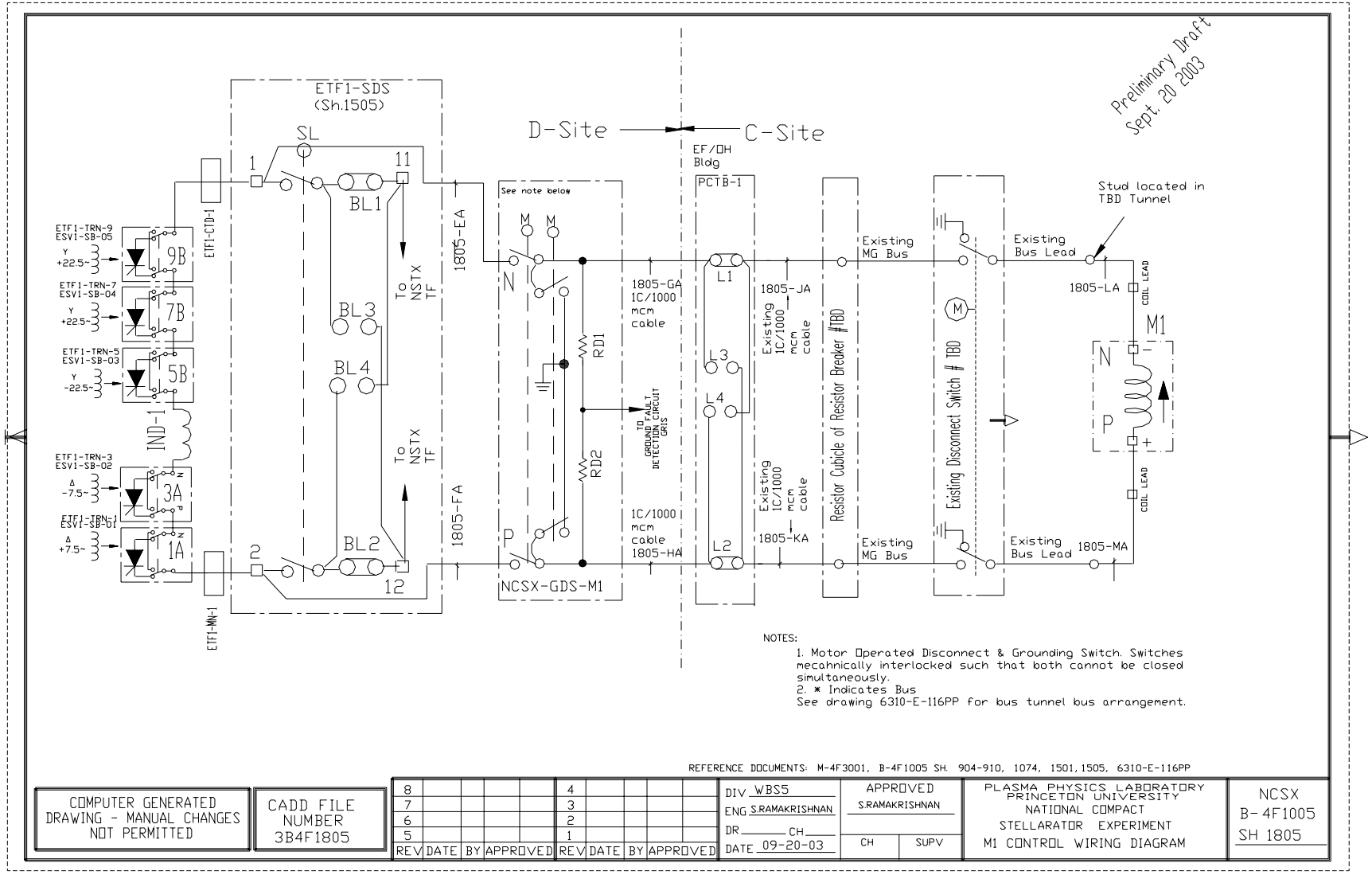
8				4			
7				3			
6				2			
5				1			

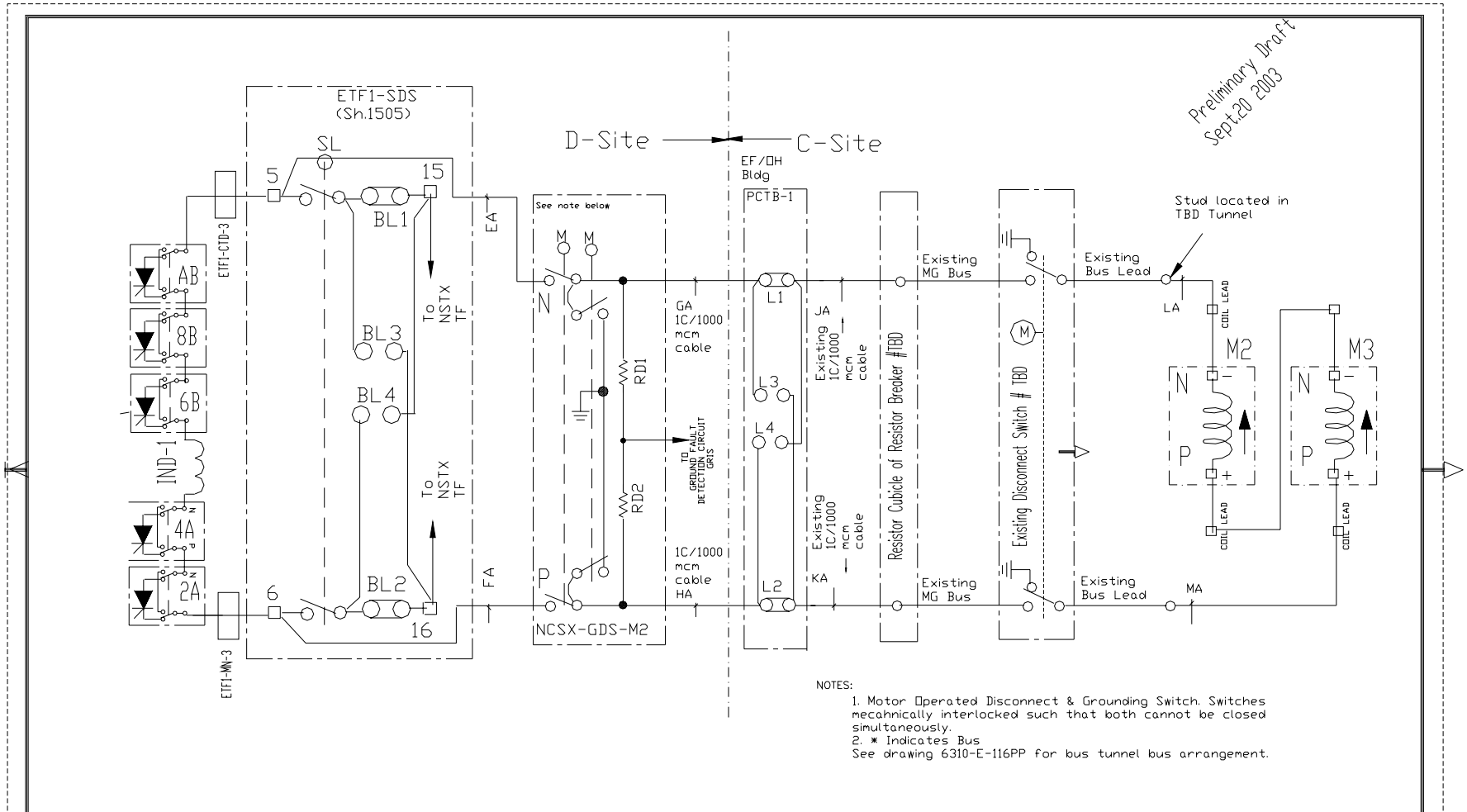
DIV WBS4
ENG S.RAMAKRISHNAN
DR CH
DATE 09-20-03

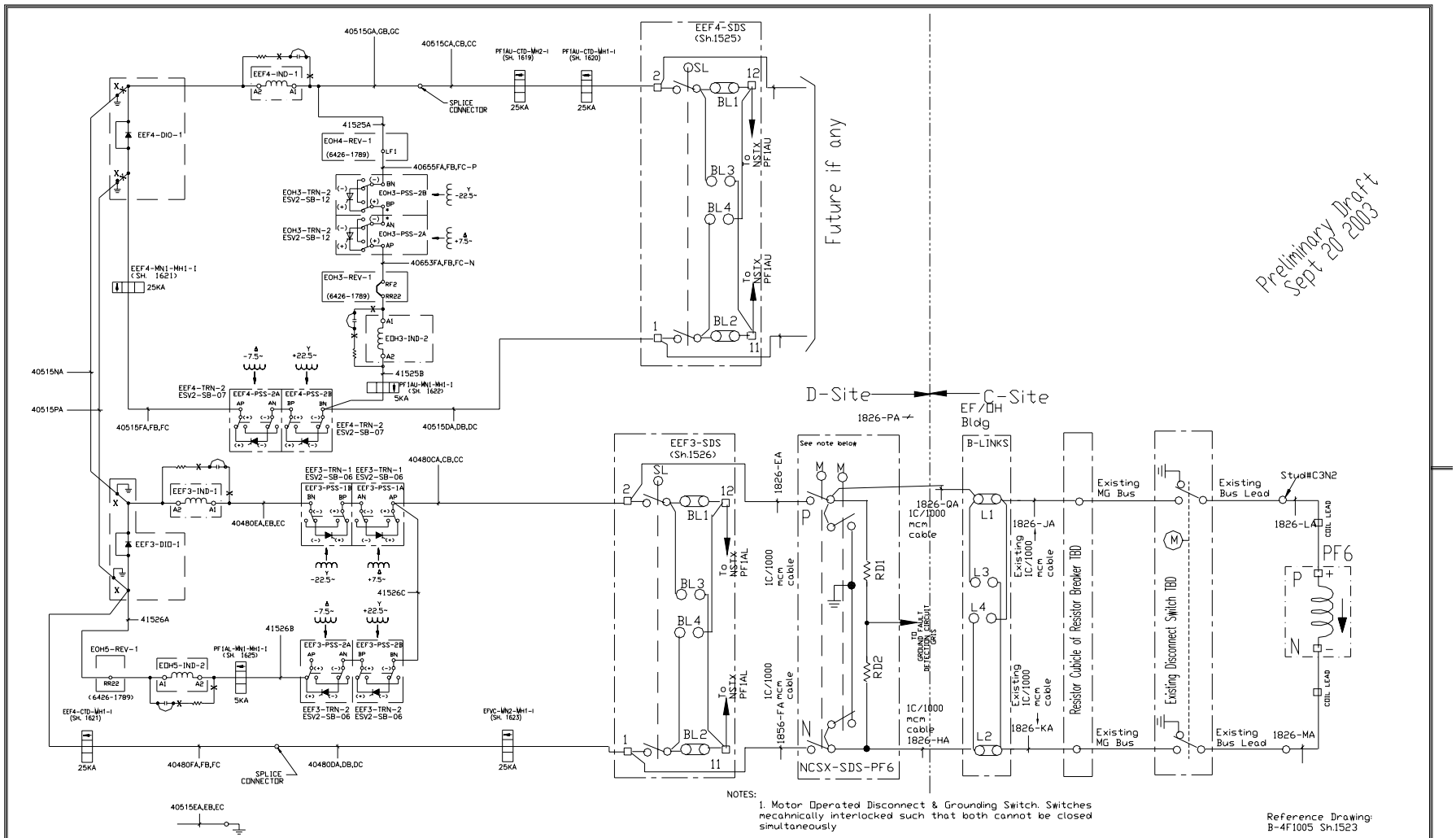
S.RAMAKRISHNAN
CH SUPV

PRINCETON PLASMA PHYSICS LABORATORY
NATIONAL COMPACT STELLARATOR EXPERIMENT
NCSX COILS SIMPLIFIED SCHEMATICS
Initial Phase

NCSX
B-4F 1005
SH.1800 Sheet 1


Preliminary Draft
Sept. 20 2003
ETF1-SDS
(Sh.1505)
SL
1
11
BL1
BL3
BL4
BL2
2
12
To NSTX TF
To NSTX TF
1805-EA
1805-FA
ETF1-CTD-1
ETF1-MN-1
ETF1-TRN-9
ESV1-SB-05
Y
+22.5~
9B
ETF1-TRN-7
ESV1-SB-04
Y
+22.5~
7B
ETF1-TRN-5
ESV1-SB-03
Y
-22.5~
5B
IND-1
ETF1-TRN-3
ESV1-SB-02
Δ
-7.5~
3A
ETF1-TRN-1
ESV1-SB-01
Δ
+7.5~
1A
D-Site
C-Site
See note below
M
M
N
P
RD1
RD2
TO GROUND FAULT DETECTION CIRCUIT GRIS
NCSX-GDS-M1
1805-GA
1C/1000
mcm
cable
1C/1000
mcm
cable
1805-HA
EF/OH
Bldg
PCTB-1
L1
L3
L4
L2
1805-JA
Existing
1C/1000
mcm
cable
Existing
1C/1000
mcm
cable
1805-KA
Resistor Cubicle of Resistor Breaker #TBD
Existing
MG Bus
Existing
MG Bus
Existing Disconnect Switch # TBD
M
Existing
Bus Lead
Existing
Bus Lead
Stud located in
TBD Tunnel
1805-LA
COIL LEAD
M1
N
P
COIL LEAD
1805-MA
NOTES:
1. Motor Operated Disconnect & Grounding Switch. Switches mecahnically interlocked such that both cannot be closed simultaneously.
2. * Indicates Bus
See drawing 6310-E-116PP for bus tunnel bus arrangement.
REFERENCE DOCUMENTS: M-4F3001, B-4F1005 SH. 904-910, 1074, 1501, 1505, 6310-E-116PP
COMPUTER GENERATED DRAWING - MANUAL CHANGES NOT PERMITTED
CADD FILE NUMBER 3B4F1805
8
7
6
5
REV DATE BY APPROVED
4
3
2
1
REV DATE BY APPROVED
DIV WBS5
ENG S.RAMAKRISHNAN
DR CH
DATE 09-20-03
APPROVED
S.RAMAKRISHNAN
CH SUPV
PLASMA PHYSICS LABORATORY
PRINCETON UNIVERSITY
NATIONAL COMPACT
STELLARATOR EXPERIMENT
M1 CONTROL WIRING DIAGRAM
NCSX
B-4F1005
SH 1805

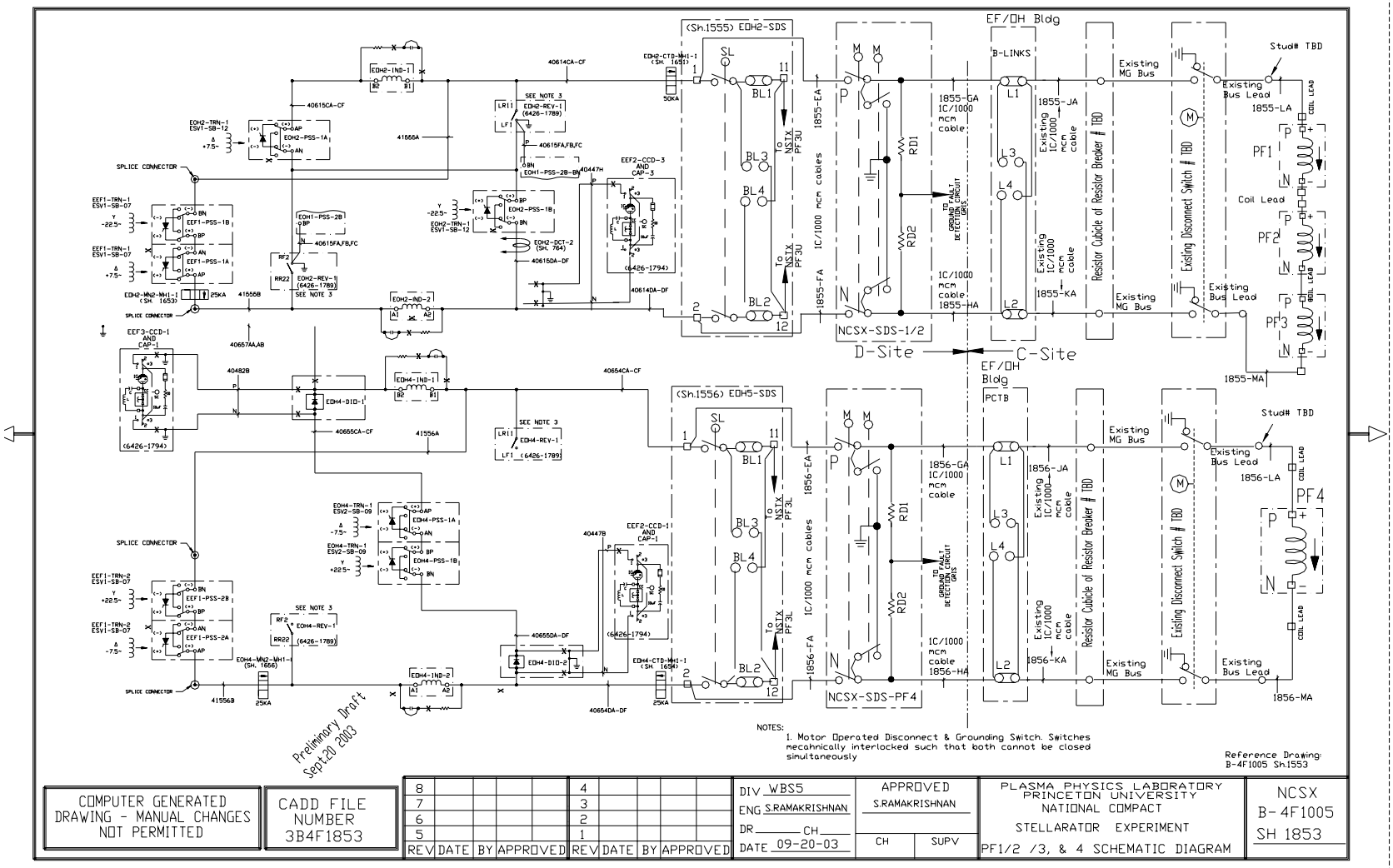

Preliminary Draft
Sept.20 2003
ETF1-SDS
(Sh.1505)
SL
5
15
BL1
BL3
BL4
BL2
6
16
To NSTX TF
To NSTX TF
EA
FA
ETF1-CTD-3
ETF1-MN-3
AB
8B
6B
IND-1
4A
2A
D-Site
C-Site
See note below
M
M
N
P
RD1
RD2
TO GROUND FAULT DETECTION CIRCUIT GRIS
NCSX-GDS-M2
GA
1C/1000
mcm
cable
1C/1000
mcm
cable
HA
EF/OH
Bldg
PCTB-1
L1
L3
L4
L2
JA
KA
Existing
1C/1000
mcm
cable
Existing
1C/1000
mcm
cable
Resistor Cubicle of Resistor Breaker #TBD
Existing
MG Bus
Existing
MG Bus
Existing Disconnect Switch # TBD
M
Existing
Bus Lead
Existing
Bus Lead
Stud located in
TBD Tunnel
LA
MA
COIL LEAD
COIL LEAD
COIL LEAD
M2
M3
N
P
N
P
NOTES:
1. Motor Operated Disconnect & Grounding Switch. Switches mecahnically interlocked such that both cannot be closed simultaneously.
2. * Indicates Bus
See drawing 6310-E-116PP for bus tunnel bus arrangement.
REFERENCE DOCUMENTS: M-4F3001, B-4F1005 SH. 904-910, 1074, 1501, 1505, 6310-E-116PP
COMPUTER GENERATED DRAWING - MANUAL CHANGES NOT PERMITTED
CADD FILE NUMBER 3B4F1805
8
7
6
5
4
3
2
1
REV DATE BY APPROVED
REV DATE BY APPROVED
DIV WBS5
ENG S.RAMAKRISHNAN
DR CH
DATE 09-20-03
APPROVED
S.RAMAKRISHNAN
CH
SUPV
PLASMA PHYSICS LABORATORY
PRINCETON UNIVERSITY
NATIONAL COMPACT
STELLARATOR EXPERIMENT
M2 & M3 CONTROL WIRING DIAGRAM
NCSX
B-4F1005
SH 1806



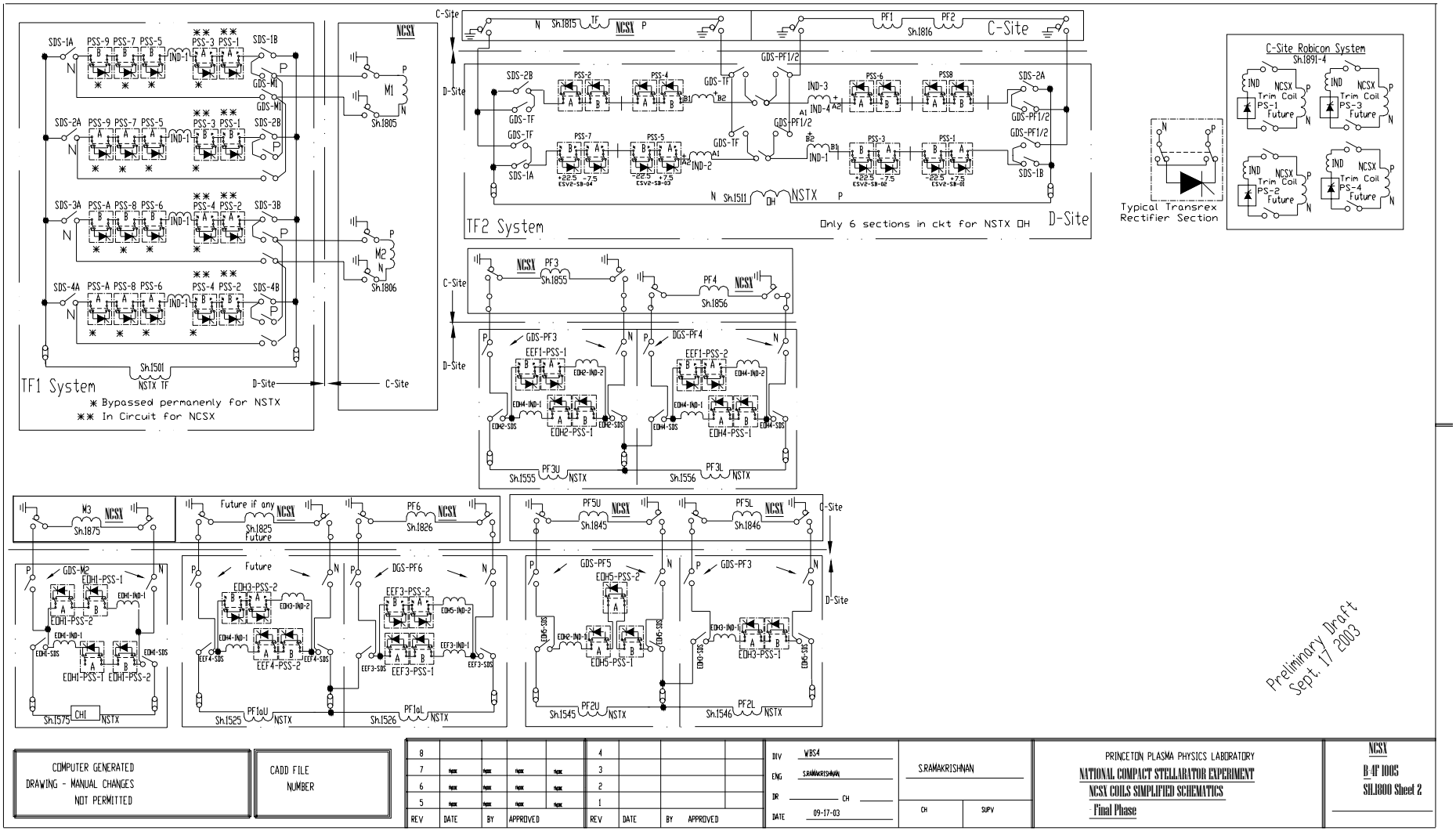
NOTES:
1. Motor Operated Disconnect & Grounding Switch. Switches mecahnically interlocked such that both cannot be closed simultaneously

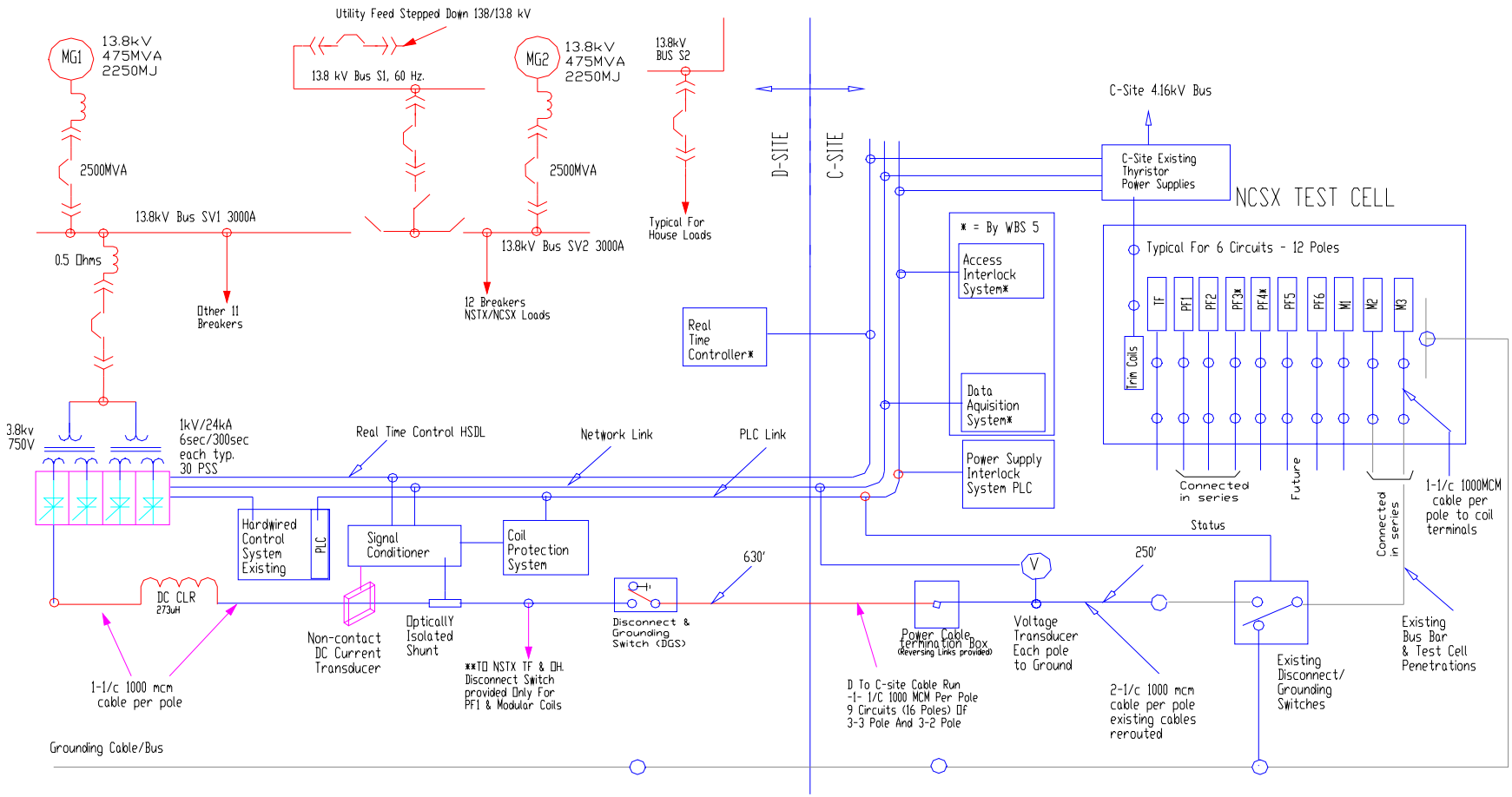
Reference Drawing: B-4F1005 Sh.1523

COMPUTER GENERATED DRAWING - MANUAL CHANGES NOT PERMITTED	CADD FILE NUMBER 3B4F1823	8				4				DIV WBS4	APPROVED S.RAMAKRISHNAN	PLASMA PHYSICS LABORATORY PRINCETON UNIVERSITY NCSX PF6 SCHEMATIC DIAGRAM	NCSX B-4F1005 SH 1823
		7				3				ENG S.RAMAKRISHNAN			
		6				2				DR ____ CH ____			
		5				1				DATE 09-20-03	CH SUPV		
		REV	DATE	BY	APPROVED	REV	DATE	BY	APPROVED				



(Sh.1555) EOH2-SDS
EF/OH Bldg
B-LINKS
Existing MG Bus
Stud# TBD
Existing Bus Lead
1855-LA
PF1
Coil Lead
PF2
PF3
1855-MA
1855-GA
1C/1000 mcm cable
1855-JA
1855-KA
1855-HA
1855-EA
1855-FA
1C/1000 mcm cables
NCSX-SDS-1/2
D-Site
C-Site
Resistor Cubicle of Resistor Breaker # TBD
Existing Disconnect Switch # TBD
(Sh.1556) EOH5-SDS
PCTB
1856-GA
1856-JA
1856-KA
1856-HA
1856-LA
1856-MA
1856-EA
1856-FA
NCSX-SDS-PF4
PF4
SPLICE CONNECTOR
SEE NOTE 3
Preliminary Draft
Sept.20 2003
NOTES:
1. Motor Operated Disconnect & Grounding Switch. Switches mecahnically interlocked such that both cannot be closed simultaneously
Reference Drawing: B-4F1005 Sh.1553
COMPUTER GENERATED DRAWING - MANUAL CHANGES NOT PERMITTED
CADD FILE NUMBER 3B4F1853
REV DATE BY APPROVED
DIV WBS5
ENG S.RAMAKRISHNAN
DR CH
DATE 09-20-03
APPROVED S.RAMAKRISHNAN
CH SUPV
PLASMA PHYSICS LABORATORY
PRINCETON UNIVERSITY
NATIONAL COMPACT
STELLARATOR EXPERIMENT
PF1/2 /3, & 4 SCHEMATIC DIAGRAM
NCSX
B-4F1005
SH 1853


TF1 System
* Bypassed permanenly for NSTX
** In Circuit for NCSX
TF2 System
Only 6 sections in ckt for NSTX OH
C-Site
D-Site
NCSX
NSTX
C-Site Robicon System
Typical Transrex Rectifier Section
Preliminary Draft
Sept. 17 2003
COMPUTER GENERATED DRAWING - MANUAL CHANGES NOT PERMITTED
CADD FILE NUMBER
PRINCETON PLASMA PHYSICS LABORATORY
NATIONAL COMPACT STELLARATOR EXPERIMENT
NCSX COILS SIMPLIFIED SCHEMATICS
Final Phase
S.RAMAKRISHNAN
09-17-03
NCSX
B-4F 1005
SIL1800 Sheet 2


Utility Feed Stepped Down 138/13.8 kV
MG1
13.8kV
475MVA
2250MJ
13.8 kV Bus S1, 60 Hz.
MG2
13.8kV
475MVA
2250MJ
13.8kV
BUS S2
2500MVA
2500MVA
13.8kV Bus SV1 3000A
13.8kV Bus SV2 3000A
Typical For
House Loads
0.5 Ohms
Other 11
Breakers
12 Breakers
NSTX/NCSX Loads
D-SITE
C-SITE
C-Site 4.16kV Bus
C-Site Existing
Thyristor
Power Supplies
NCSX TEST CELL
* = By WBS 5
Access
Interlock
System*
Data
Aquisition
System*
Power Supply
Interlock
System PLC
Real
Time
Controller*
Typical For 6 Circuits - 12 Poles
TF
PF1
PF2
PF3*
PF4*
PF5
PF6
M1
M2
M3
Trim Coils
Connected
in series
Future
Connected
in series
1-1/c 1000MCM
cable per
pole to coil
terminals
3.8kv
750V
1kV/24kA
6sec/300sec
each typ.
30 PSS
Real Time Control HSDL
Network Link
PLC Link
Hardwired
Control
System
Existing
PLC
Signal
Conditioner
Coil
Protection
System
630'
250'
Status
V
DC CLR
273uH
Non-contact
DC Current
Transducer
Optically
Isolated
Shunt
**TO NSTX TF & OH.
Disconnect Switch
provided Only For
PF1 & Modular Coils
Disconnect &
Grounding
Switch (DGS)
Power Cable
termination Box
(Reversing Links provided)
Voltage
Transducer
Each pole
to Ground
Existing
Disconnect/
Grounding
Switches
Existing
Bus Bar
& Test Cell
Penetrations
1-1/c 1000 mcm
cable per pole
D To C-site Cable Run
-1- 1/C 1000 MCM Per Pole
9 Circuits (16 Poles) Of
3-3 Pole And 3-2 Pole
2-1/c 1000 mcm
cable per pole
existing cables
rerouted
Grounding Cable/Bus