5X-960923-CLN-01

TO: M ONO
FROM: C NEUMEYER
SUBJECT: IMPLEMENTATION OF NSTX WBS5 AT D-SITE

This memo presents a pre-conceptual scheme and cost estimate for the implementation of NSTX at D-site, assuming the same machine configuration (electrical load) as per the present design.

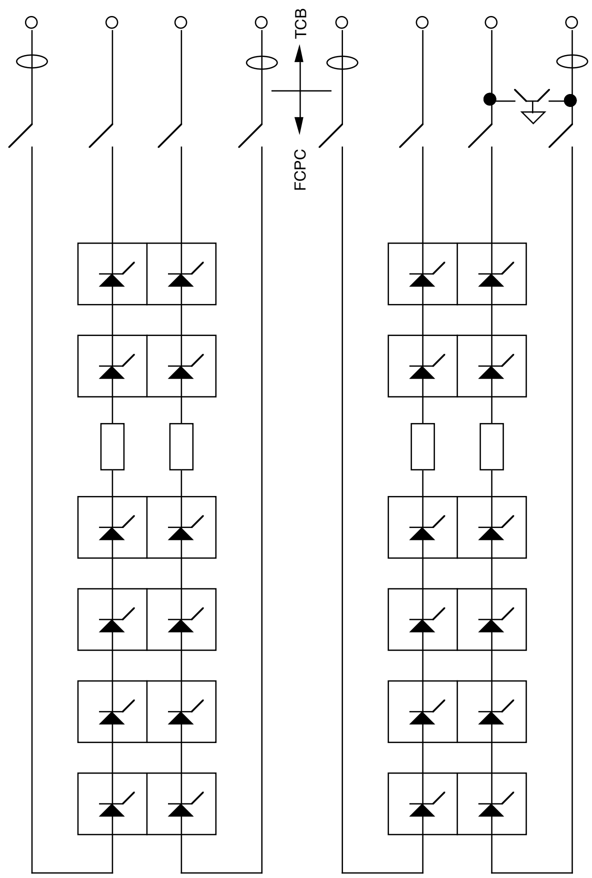
The basic scheme adopted includes the following features:

• power provided by one D-site MG set
• output of FCPC rectifiers routed to NSTX at SE corner of D-site Test Cell from SW corner of basement ("waterfall area") using cable in tray
• minimal reconfiguration of power cables in FCPC buildings
• all coil circuits isolated via existing Safety Disconnect Switches (SDS), using existing Safety Lockout Device (SLD) to control access to the Test Cell
• input/output data links for high speed (1kHz) (i.e. the "HSDL" and "PC Link") used as is, but interfaced to a new computer system to replace the PC SEL
• existing Hardwired Control System (HCS) in the FCPC building replaced by new PLC system

The TFTR TF power supply system consists of two converters, each having 4 parallel branches with six "layers" of series power supply sections. The original design used five layers; a sixth was formed by reconfiguration of 8 power supply sections from the EF system The topology is such that the power supply sections in parallel branches are part of the same power supply unit, subject to a common control system (firing generator and fault detector). Each branch has a 256μH CLR, at least one 25kA DC Current Transducer (The TF1 converter has redundant DCCTs per branch), and a line switch . The (+) and (-) poles of each branch are cabled together to the waterfall area via interleaved cables in a tray. There is only one ground switch per converter. The ground switch is available as a crow bar as well as a safety grounding device.

For NSTX the following assignments will be made using the TF converter:

• Two parallels of the TF1 converter will be used for the TF system. Two series layers will be used; the other layers will be in mechanical ("Pringle switch") bypass. Thus the system will be capable of 2kV/48kA. There will be one CLR and two DCCTs in each branch.



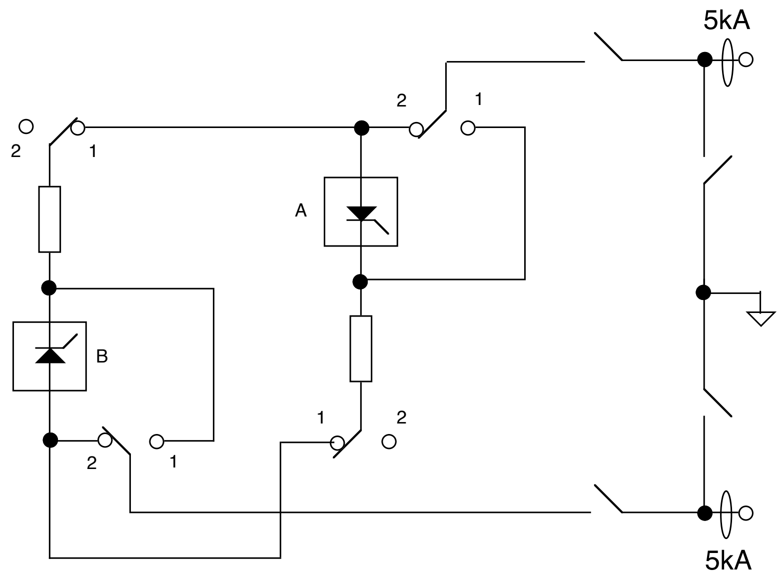
TFTR TF Converter

• Two parallels of the TF2 converter will be used for the NSTX OH system. The anti-parallel configuration will be established using the SDS bus links. Since the control of the (+) branch must be separate from that of the (-) branch, the selected parallels must be 1 and 3 or 2 and 4. The 1 and 2, or 3 and 4 combination will not work because the control is common to those pairs. Four layers should suffice (the adequacy of the voltage with four layers, given the V vs. I characteristic with the MG supply, needs to be confirmed). Thus the system will be capable of 5kV/(+/-) 24kA. There will be one CLR and one DCCT in each branch. The unused layers will be in mechanical ("Pringle switch") bypass.

• Two parallels of TF1, and two parallels of TF2 are used for the NSTX outer PF coil systems. Thus each system will be capable of 1kV/(+/-) 24kA. There will be one CLR and at least one DCCT in each branch (two in case of the TF1 converter). The unused layers will be in mechanical ("Pringle switch") bypass.

So, the TF power supply system can be used to supply the NSTX TF, OH, and four of the outer PF coil circuits. No FCPC power cable modifications are required.

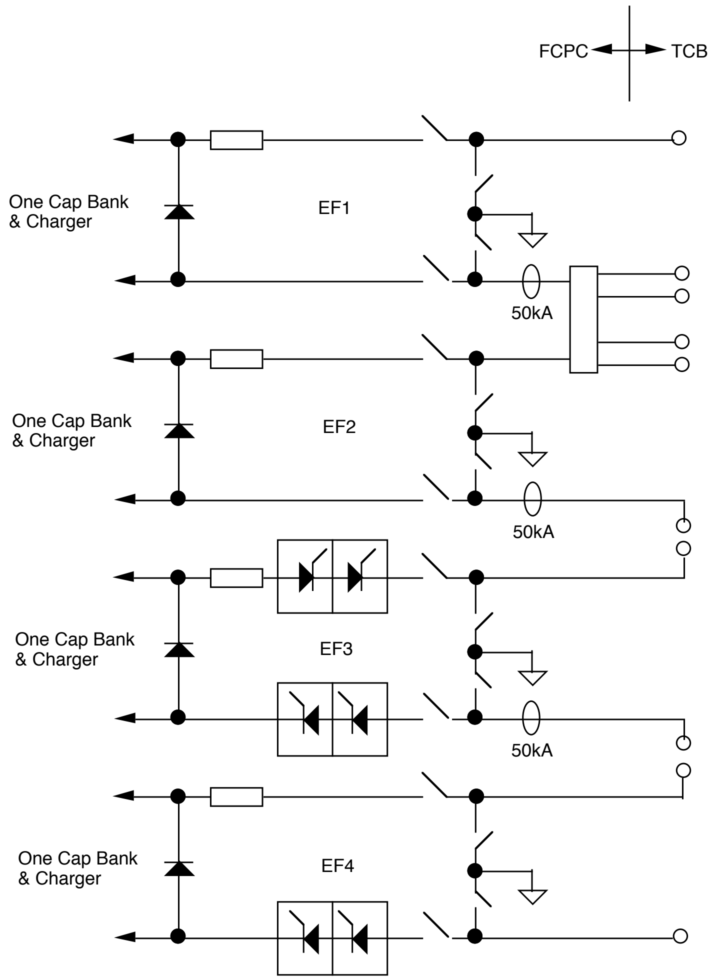
The TFTR HF power supply system consists of one converter, with two power supply sections which can be connected in series with either polarity or in antiparallel. The power supply sections are rated 1kV/5kA. The firing generator associated with this power supply is designed for the anti-parallel mode. So, the power supply has two 5kA DC Current Transducers (one redundant), and a line switch . The (+) and (-) poles of each branch are cabled together to the waterfall area via interleaved cables in a tray. There is a ground switch available as a crow bar as well as a safety grounding device.



TFTR HF Converter

The HF converter will be assigned to power one of the NSTX outer PF circuits. Thus it will be capable of 1kV/(+/-) 5kA. There will be two DCCTs, line switches, and a ground switch. No FCPC power cable modifications are required.

The TFTR EF power supply system consists of four Converters in series, each of which was originally equipped with two power supplies (four sections total), in series with a Power Diode Assembly (PDA). Three 15kV/1MJ capacitor banks and associated Capacitor Charge Discharge (CCD) units were provided for discharge across each of the PDAs. Subsequent modifications moved several of the power supplies into other circuits, so only EF3 still has the full set of power supplies. In addition, capacitor banks have been relocated so that each interleaf is now equipped with one capacitor bank. The output cabling makes a transition in the Cable Spread Room, from a converter association to a coil circuit association. In other words, beyond the Cable Spread Room, the (+) and (-) cables which are interleaved together in tray are grouped according to the coil interleaves to which they will connect. There are three EF current transducers (50kA).



For NSTX, the original power supply assignments will be restored (the EF power supplies returned back to the EF system from the TF system). This is a fairly simple matter.

One EF interleaf will be assigned CHI duty. Since two cap banks are needed, one of the four remaining banks needs to switch interleaves. This is probably accomplished most easily in the first floor of the FCPC building, PF reactor area.

The other three EF interleaves will be assigned to power the NSTX outer PF coil systems. Thus each system will be capable of 1kV/(+/-) 24kA. There will be one CLR in each circuit, and a line switch/ground switch. The unused layers will be in mechanical ("Pringle switch") bypass. Some relocation of DCCTs will be required. In addition some relocation of cables in the Cable Spread Room will be required so that the (+) and (-) cables associated with each circuit are interleaved in the same tray. Capacitor discharge capability will be available in these circuits, which may prove useful.

So, via the above scheme, the NSTX TF, OH, CHI, and eight outer PF circuits are accommodated. Assignments are summarized in the following table.

NSTX PS	C-site V	C-site I	D-site V	D-site I	D-Site PSS Config	#PSS	Comments
TF	+/- 1700	35400	+/- 2000	48000	2s x 2p	4	Two TF1 branches, unused pss (4s x 2p) in bypass
OH	+/- 4000	+/- 24000	+/- 4000	+/- 24000	4s x 2 antiparallel	8	Two TF2 branches, unused pss (2s x 2p) in bypass, other converter branches for NSTX PF
PF 5kA	+/- 300	5000	+/- 1000	+/- 5000	1s x 2 antiparallel	2	HF
	+/- 300	5000	+/- 1000	24000	1s x 1p	1	One TF1 branch, unused pss (5s x 1p) in bypass, other converter branches part of NSTX OH
	+/- 300	5000	+/- 1000	24000	1s x 1p	1	One TF1 branch, unused pss (5s x 1p) in bypass, other converter branches part of NSTX OH
	+/- 300	5000	+/- 1000	24000	1s x 1p	1	One TF2 branch, unused pss (5s x 1p) in bypass
PF10kA	+/- 200	10000	+/- 1000	24000	1s x 1p	1	One TF2 branch, unused pss (5s x 1p) in bypass
PF20kA	+/- 500	20000	+/- 1000	24000	1s x 1p	1	One EF interleaf, unused pss (3s x 1p) in bypass
CHI			+/- 1000	24000	1s x 1p	1	One EF interleaf, unused pss (3s x 1p) in bypass
Other PF			+/- 1000	24000	1s x 1p	1	One EF interleaf, unused pss (3s x 1p) in bypass
Other PF			+/- 1000	24000	1s x 1p	1	One EF interleaf, unused pss (3s x 1p) in bypass

The possible use of the TFTR OH system for NSTX OH duty was examined. It was concluded that the system is designed for much higher interruption voltages than NSTX would need (or be able to withstand). If the inserted resistor value was decreased to reduce the voltage, then the parasitic shunt current from the power supplies would be too high. If the system was used in a bipolar fashion without interrupters (a.k.a. "low voltage start-up mode) then the current reversal sequence would be too slow for NSTX due the mechanical reversing switches. Instead, it was decided to adopt the anti-parallel power supply scheme described earlier. If, at a later date, NSTX needs an interrupter capability, one could use the TFTR OH but some modifications would be required.

For control of the power supplies, since they do not have their own feedback control, the loop must be closed by another device. For TFTR a SEL computer is used. This computer has a command output interface with the power supplies (the "PC Link") and a data input (the "High Speed Data Link", or "HSDL"). For NSTX it is planned to utilize a new control computer (the existing system now being adapted for TFTR Plasma Control) which would serve both the power supply control and plasma control functions. New interfaces will need to be constructed for data exchange with the PC Link and HSDL.

The TFTR Hardwired Control System is not readily adapted to NSTX since it is hardwired for a much different power supply utilization scheme. It is envisioned that PLCs would be installed in each of the four existing HCS control boards and would utilize the input/output signals already wired thereto. One additional PLC would serve a supervisory function and would interface with the control room.

Main issues associated with the use of the TFTR power supply system for NSTX are listed in the following table.

Issue	Tentative Resolution	Comment
Lack of resistive dump feature in case of TF power supply fault	TBD	Must allow for L/R decay @ EOFT. Maybe better PS rise time performance will make I2T margin available. May have to reduce Tflat.
D-site OH scheme resistor insertion until current reversal; no exclusion feature	Use alternate OH scheme (antiparallel)	Could modify to reclose interrupter.
D-site OH scheme mechanical reversing switches too slow	Use alternate OH scheme (antiparallel)	Could modify by replacing mechanical switches with thyristor switches.
D-site OH scheme interruption voltage too high	Use alternate OH scheme (antiparallel)	Could use lower resistor, but would conduct too much parasitic current, unless resistor exclusion scheme added.
OH PS regulation	TBD	V vs. I characteristics of PS are different in 60-90Hz MG service; maybe 4kV no-load is not adequate. Can introduce additional 1kV, but coil insulation requirement would increase.
D-site TF branch terminals do not have individual ground switches & accessories	Need new ground switches, and other parts from other unused SDS cabinets.	Need safety ground switch, grounding resistors, voltage dividers, non-linear resistors.

D-site Ground Switches are also crow bars.	Use all new safety only (no load) ground switches which can fit in the line switch cubicles.	Probably don't need crow bars, and probably can't fit in line switch cubicles.
D-site SDS non-linear resistor voltages too high	Replace with suitable units.	
D-site grounding resistors wrong ohmic value for low voltages of NSTX	Replace with suitable units.	
D-site PS Voltage and SC current >> C-site PS. Can Outer PF (S-1) Coils take it?	TBD	
D-site EF& OH load side cables grouped based on interleaved coils, not on power supplies or direct connected coils.	Move cables in Cable Spread Room as required, provide one SDS cubicle per coil.	All outer PF coils must be wired to an SDS for protection, even if a dedicated PS is not made available.
Dedicated PS per coil circuit?	Must wire to SDS cabinets anyway, and PS are available. Small cost adder, great operating advantage.	
Patch panel for series coil operations?	Provide series connection capability in FCPC area above SDS cabinets.	May be able to use some of the existing EF paralleling features.
Only one cap bank remaining per EF interleaf	Relocate Cap output cables in CCD input area.	Caps removed and shipped to Wisconsin.
D-site DCCTs not in proper locations to monitor individual EF circuits	Relocate as req'd.	
D-site EF & OH DCCTs 50kA full scale	Swap others so all (except CHI) are 25kAFS	
D-site EF & OH DCVTs 30kV full scale	Use as is	
PC SEL Control Computer Obsolete, assembly language code not compatible w/NSTX	Use new processor, new code	New processor and new code costs less than time for programmer to recode on SEL in assembly language.
PC Link/PC SEL Interface Unique	Need new PC Link Interface	
HSDL/PC SEL Interface Unique	Need new HSDL Interface	
D-site HCS not compatible	Replace w/PLC based system.	
D-site GFD not compatible	Rewire for NSTX.	Per existing design use three circuits: TF, OH, ∑PF

Costs for the D-site implementation were derived using the same spreadsheet formats as was used for the C-site implementation. These are attached. The estimated cost is about $2M, including contingency, which compares with the $2.4 we had for the C-site implementation.

Annual costs for the MG and rectifier operations are compared in the following table.

	D-site	C-site	
MG System			
#months/yr	9.00	9.00	mo
#days/month	20.00	20.00	day
#hrs/day	8.00	8.00	hrs
repetition period	5.00	5.00	min
#pulses/day	96.00	96.00	pulses
Idling Power	4.00	1.00	MW
Pulse Energy	100.00	100.00	MJ
Average Power	4.33	1.33	MW
Energy/Day	34.67	10.67	MW-hr
Energy Cost	0.08	0.08	$/kW-hr
Peak 15 min Avg Power	4.33	1.33	MW
Demand Cost	10.00	10.00	$/kW
Energy Cost/month	55466.67	26453.33	$
Demand Cost/month	43333.33	20666.67	$
Annual Electricity Costs	889200.00	424080.00	$
Annual Maintenance Cost	125000.00	80000.00	$
Annual Electricity & Maintenance	1014200.00	504080.00	$
G&A	55.00	55.00	%
Subtotal	1572010.00	781324.00	$
#Engineers	1.00	0.50	Engr
#Technicians	1.00	2.00	Tech
Engineer Cost/Day	868.00	868.00	$
Technician Cost/Day	414.00	414.00	$
Annual Operator Cost	283322.00	278902.00	$
Total	1855.33	1060.23	$K
Rectifier System			
#Engineers	2.00	1.00	Engr
#Technicians	2.00	1.00	Tech
Engineer Cost/Day	868.00	868.00	$
Technician Cost/Day	414.00	414.00	$
Annual Operator Cost	566644.00	283322.00	$
Total	566.64	283.32	$K
Grand Total	2421.98	1343.55	$K

In conclusion the D-site implementation appears to be quite straightforward. It is somewhat less costly to install but more costly to operate. It can provide enhanced capabilities on day one.

Please note that these results are not based on a detailed conceptual design. I have increased the contingencies accordingly.

cc:

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NSTX File