THOMAS JEFFERSON NATIONAL ACCELERATOR FACILITY
12000 Jefferson Avenue
Newport News, VA 23606

HALL B PROCEDURE NO.:
B000000401-P020 Rev - K

TITLE: **Hall B Torus Power-Up and Power-Down Procedure**

BY: R. Fair

DATE: 12 / 08 / 2016

Intended Checker and Approvers:
CHK: R. Rajput-Ghoshal
1. APP: P. Ghoshal
2. APP:
3. APP: 3rd Approver (if necessary)

K		Updated MPS control screen	RF	RRG	PG		05/28/20
J		Updated interlock screen	RF	RRG	PG		10/29/19
I		Updated energization steps to include 'Turn ON MPS' and tidied up text for the other steps.	RF	RRG	PG		02/07/19
H		Added step in energization process to check that all SOE timestamps have been 'zeroed' and updated Appendix A accordingly. Added section on torus key parameters.	RF	RRG	PG		01/24/19
G		Corrected current ramp-down rates	RF	RRG	PG		08/08/18
F		Included chart showing times to ramp to target currents and information on E-Stops and QD resets	RF	RRG	PG		08/06/18
E		Ensure magnet is ramped to zero Amps before reversing polarity. Updated SME contact names.	RF	RRG	PG		12/12/17
D		Updated to use latest MPS EPICS control screen	RF	RRG	PG		10/06/17

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C		Changed authorship from C. Luongo to R. Fair. Added Renuka Rajput-Ghoshal as checker and moved Probir Ghoshal to Approver. Updated Tables III and B.1 and the Interlock Status screenshot	RF	RRG	PG		01/18/17
B		Added section with simplified instructions for shift workers and made it central to document. Moved commissioning procedure to Appendix	RF				12/08/16
A		Fixed typo in page 9 (step 19)	CL	PG	RF		10/19/16
REV.	ECO#	DESCRIPTION	BY	CHK.	APP.	APP.	DATE
SUMMARY OF CHANGES FROM PREVIOUS REVISION:							

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Contents

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1. Hall B Torus Key Parameters

CLAS12 HALL B TORUS MAGNET PARAMETERS

PARAMETER	DESIGN VALUE
	TORUS
Number of Coils	**6**
Coil structure	Double Pancake potted in Aluminum Case
Total Number of turns	1404 (117 x 2 x 6)
NbTi Rutherford cable	SSC 36 strands
Nominal current (A)	3770
Central field (T)	N/A
Conductor Peak Field (T)	3.6
Field homogeneity in ϕ25mm x L40 mm cylinder	N/A
Inductance (H)	2
Stored Energy (MJ)	14
Warm bore (mm)	124
Total weight (KG)	25,500
Cooling mode	Conduction cooled
Supply temperature (K)	4.5
Temperature margin	1.5
Stabilized conductor	W20 mm x T2.5 mm copper channel
Turn to Turn Insulation	0.003” Glass Tape ½ Lap
Heat Shield Cooling	LN2 Thermo-Siphon

2. Scope and Requirements

This document describes the power up and power down procedure for the Hall B CLAS12 Torus superconducting magnet.

This document is organized as follows:

- Operations Manual for the magnet/power supply, based on the commissioning experience
- An appendix containing the Power-up sequence followed during 12 GeV commissioning, at the conclusion of which the project transferred operational responsibility to Hall B
- Power-up sequence for post-commissioning phase (but prior to regular operations) as envisioned during commissioning (but open to modifications based on Hall B priorities)

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3. Magnet/Power Supply Operation (Regular Physics Operations)

Introduction

This section summarizes the power up (energization) and power down (de-energization) procedure for the Hall B CLAS12 Torus superconducting magnet. It is primarily a guide for shift workers.

Emergency Contact Names

Should the need arise, first call the 'ENGINEER ON CALL' – his/her name and contact telephone number should be on the white board in the Hall B Counting Room.

The ENGINEER ON CALL will then (if necessary) call in the relevant Subject Matter Experts (SME).

Table I – Contact Names

Sub-System	SME
Magnet Power Supply	Denny Insley, Krister Bruhwel, Sarin Philip
Magnet Fast Dump / Quench	Ruben Fair, Probir Ghoshal, Renuka Rajput-Ghoshal
Cryogenics System	Denny Insley, Dave Kashy
Vacuum System	Dave Anderson
Instrumentation and Control	Nick Sandoval, Brian Eng, Pablo Campero-Rojas

Pre-Energization Checklists

The following checks should already have been completed.

IF IN DOUBT PLEASE CONTACT THE 'ENGINEER ON CALL'

1. *B000000401-P021 Hall B Torus Operations Power Up Checklists*
2. *B000000402-P002 Hall B Superconducting Magnets Power Supply Maintenance Turn-On Checklist*
3. *B000000402-P001 Hall B Superconducting Magnets Pre-Power-Up Power Supply Internal Interlock Checklist*
4. *B000000401-P022 Hall B Torus Pre-Power-Up Water-Cooled Leads Checkout Procedure*
5. *B000000401-P023 Hall B Torus Pre-Power-Up Vapor-Cooled Leads Checkout Procedure*
6. *B000000401-P025 Hall B Pre-Power-Up Instrument Checkout Procedure*
7. *B000000401-P026 Hall B Pre-Power-Up Quench Detector Tuning Procedure*
8. *B000000401-P027 Hall B Pre-Power-Up Interlock Checkout Procedure*

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Magnet Operation

The Operator controls the Magnet Power Supply (MPS) for the magnet and monitors the magnet and its sub-systems via a PLC using a series of EPICS screens. Bringing the Torus to operating field is done in a series of current steps at differing current ramp rates. Each time the operator establishes the desired current on the EPICS screen and clicks anywhere outside the 'Set point' box, the power supply automatically begins the ramp to the set point current at a pre-programmed slew rate (Ramp rate). This slew rate is set within the PLC code and is not accessible to the operator.

Shift workers will typically operate the magnet using the Magnet Power Supply (MPS) Control Screen shown in Figure 1 below.

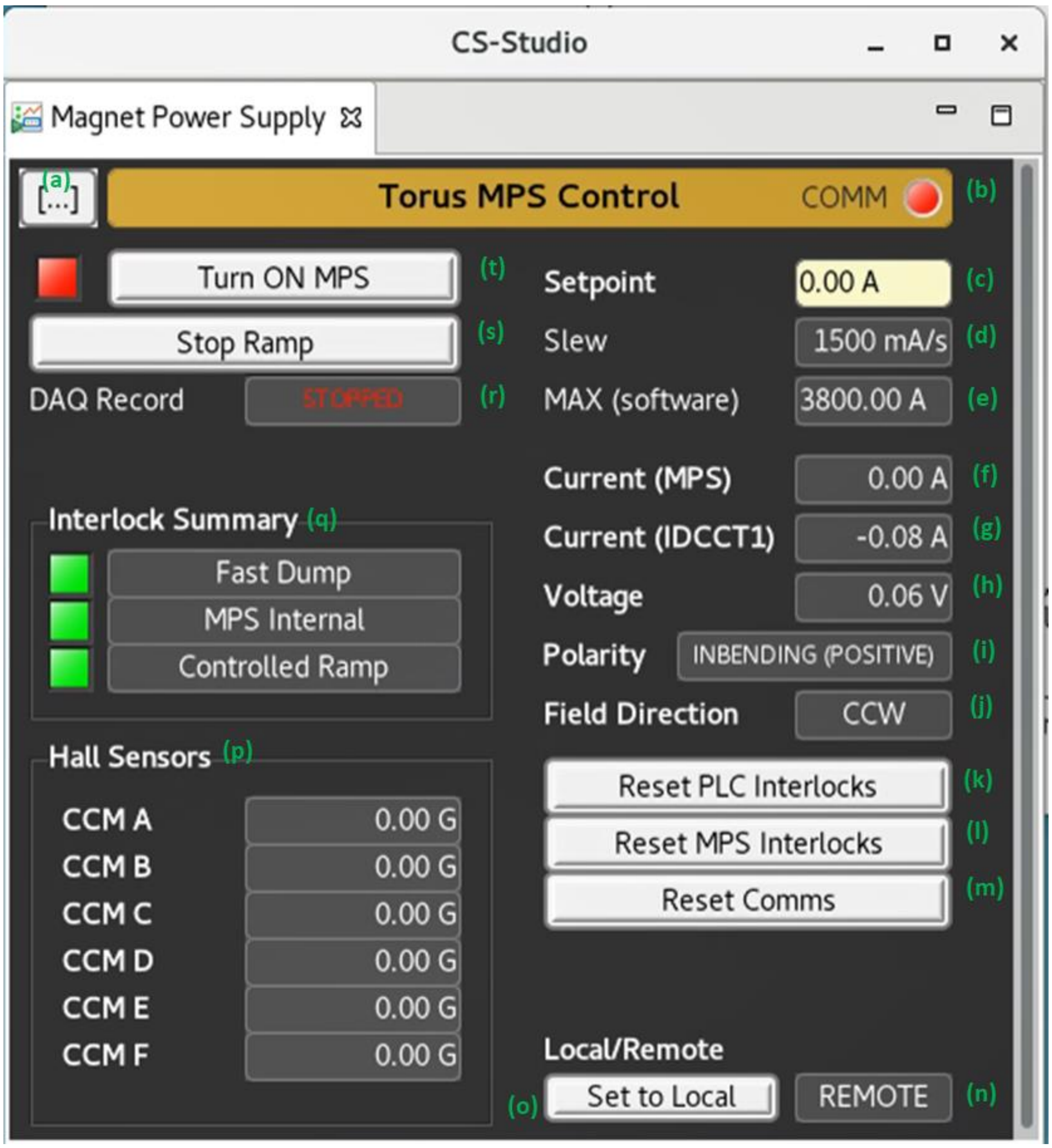

Figure 1 - JLab MPS Control – EPICS

Table II – Definition of items on MPS EPICS Control Screen

	Description	Expected value
(a)	Launches 6 additional windows: (i) Interlock Status (ii) Fast DAQ recording control (iii) Fast DAQ live data (iv) Current Mismatch Alarm Settings (v) SOE Timestamps (vi) Trigger Fast Dump (**Note: Initiates a fast dump of the magnet current through the dump resistor**. On clicking this button, the user will be prompted to confirm the action.)	N/A
(b)	Ethernet to RS232 communication between Torus PLC, 435NBX, and Magnet Power Supply	GREEN
(c)	Desired target current. User types value into the field shown and presses enter. Use a negative value if ramping to a negative polarity is required. User only needs to enter a number (no units are required). If the user enters a number greater than the software limit (see (e) below), the target current (c) will automatically be set to (e). **NOTE: WHEN CHANGING POLARITY, ALWAYS RAMP TO ZERO FIRST, WAIT 5 MINUTES AND THEN TYPE IN THE NEW CURRENT SET POINT.**	User Defined
(d)	Present slew rate. The various different slew rates are pre-programmed within the PLC code and cannot be changed by the user.	N/A
(e)	Software (SW) magnet current limit set within the PLC code	N/A
(f)	Magnet current read back from magnet power supply, A/D 16 bit	N/A
(g)	Magnet current read back from buffered analog output of control crate (through cRIO)	N/A
(h)	Magnet Power Supply output voltage	N/A
(i)	Magnetic field direction (and therefore magnet current polarity)	INBENDING (Positive), OUTBENDING (Negative)
(j)	Magnetic field direction. Positive field direction is CCW when looking downstream	CCW or CW
(k)	Resets only PLC interlocks	N/A
(l)	Resets only the MPS internal interlocks	N/A
(m)	Resets only communications between the magnet power supply and PLC	N/A
(n)	Used to switch between local and remote mode on the MPS display unit	N/A
(o)	Read back of MPS control state: will display 'LOCAL' in local mode, and 'REMOTE' in remote mode. Must be set to 'REMOTE' to allow changes on the MPS EPICS screen to affect the power supply.	N/A
(p)	Read backs from the 6 hall sensors mounted on the outside of the vacuum jackets of the individual coils. Positive readings signify POSITIVE polarity (i.e. CCW field direction)	+20000 Gauss @ +3770 A
(q)	Sum status of the three sets of interlocks	GREEN
(r)	Indicates whether the Fast DAQ system is writing data to disk. Always ensure this is 'WRITING' before energizing the magnet	WRITING
(s)	Stops the ramping of the magnet by EPICs changing the set point to a value close to the current read back	N/A
(t)	Button to turn on MPS after communications has been established (Enables output). On clicking this button, the user will be prompted to confirm the action.	ON

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Power Up

Reference should be made to Figure 1 and Table II.

	Instruction	Action
CHECKS AND INITIAL SETTINGS ON THE MPS CONTROL SCREEN BEFORE ENERGIZING MAGNET		
1	Set the *(c) Setpoint* to 0 (zero) A. [This is to avoid any unintentional current ramps before all checks have been completed].	• Type '0' (i.e. zero) in the field *(c)* and hit the *Enter* key on the keyboard. • If the control screen does not allow you to do this, call the ENGINEER ON CALL
2	Check that *(b) COMM* is GREEN	• If it is RED, click *(m) Reset Comms* • If it does not turn GREEN, call the ENGINEER ON CALL
3	Check that *(e) MAX (software)* limit is set to a value higher than the final target current.	• If it isn't, call the ENGINEER ON CALL
4	Check that *(n)* is displaying REMOTE.	• If it isn't, click *(o) Set to Remote* to set it to REMOTE • If it does not switch to REMOTE, call the ENGINEER ON CALL
5	Check that all the *(q) Interlock Summary* indicators are GREEN.	• If any of the indicators are RED, call the ENGINEER ON CALL • From the pull-down menu: Select *Interlock Status* • This will bring up another window (*Torus MPS Interlock Status - PLC*). • Report to the ENGINEER ON CALL which indicators are RED. • Go back to the MPS Control screen
6	Check that the 'SOE Timestamps' are all zero	• Click on *(a)* (upper left of screen). • From the pull-down menu: Select *'SOE Timestamps'.* • This will bring up another window (*Solenoid and Torus SOE Timestamps*). • Ensure that all the timestamps are zero. • If any cells are non-zero, go back to the MPS Control Screen and click on *(k) Reset PLC Interlocks*. • Re-check the SOE Timestamps window again *[Note: you may have to wait a few seconds for the changes to register. Click (k) once more if necessary]* • Go back to the MPS Control screen
7	Turn ON the Magnet Power Supply	• Click on *(t)* to 'Turn ON MPS' (upper left of screen)
8	Check that *(r) DAQ Rec* is displaying WRITING	• If it says STOPPED, click *(a)* (upper left of screen). • From the pull-down menu: Select *Fast DAQ Recording Ctrl.* • This will bring up another window (*Torus Fast DAQ ROOT File*). • Click the 'Start Recording' button. • Check that a filename is displayed below and that the file size is increasing before continuing with magnet energization. • Go back to the MPS Control screen

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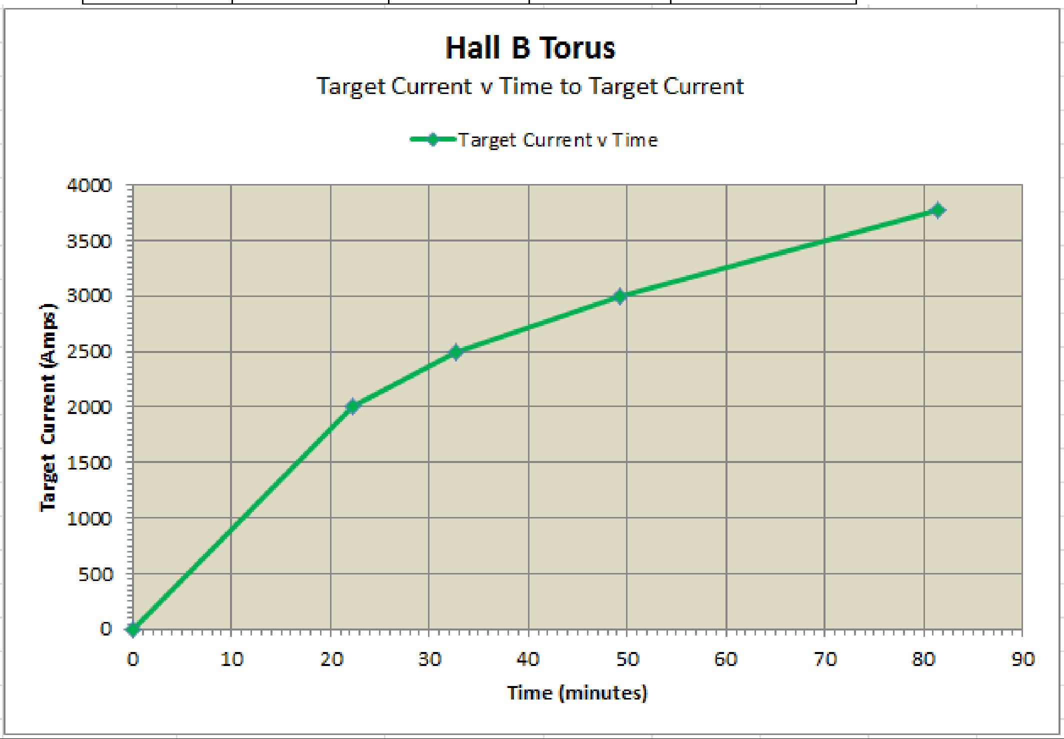
ENERGIZING (POWERING UP) THE MAGNET	
9	The following ramp rates and target currents to power up the magnet to full field (3770 A) are pre-programmed in the PLC. Simply type in the 'Target Current' in the *(c) Setpoint* field and either hit *<enter>* or click anywhere outside the field to start the ramp up.

From Current (A)	To Target Current (A)	Slew rate (mA/s)	Time Steps (mins)	Time – accumulated (mins)
0	2000	1500	22.22	22.22
2000	2500	800	10.42	32.64
2500	3000	500	16.67	49.31
3000	3770	400	32.08	81.39



10	If there are any trips (magnet, cryogenics, control, communications etc), one of more of the *(r) Interlock Summary* indicators will turn RED and the magnet with either Fast Dump or initiate a Controlled Ramp Down. If this happens call the ENGINEER ON CALL.

Power Down

Table III provides the nomenclature for various magnet discharge modes.

Table III – Definition of Magnet Discharge Modes

Type of discharge	Definition	Discharge time
Normal ramp down	Discharge following the prescribed maximum ramp rate at a given current, through the Power Supply	~ 4920 sec (82 min) from full current (3770 A)
Controlled ramp down	Discharge at 1 A/sec irrespective of magnet current, through the Power Supply	3770 sec (63 min) from full current (3770 A)
Fast Dump	Discharge (emergency) through the Dump Resistor (dump switch) – this is also the discharge mode during a magnet quench	80 sec from full current (3770 A) to zero (16 sec time constant)

Note: Torus Magnet inductance = 2 Henries, Dump resistor = 0.124 Ohms

Reference should be made to Figure 1 and Table II.

	Instruction	Action
DE-ENERGIZING (POWERING DOWN) THE MAGNET		
1	The following ramp rate, which is used to power down the magnet from full field (3770 A), is pre-programmed in the PLC. Simply type in the 'Target Current' in the *(c) Setpoint* field and either hit *<enter>* or click anywhere outside the field to start the ramp down. **From Current (A)** / **To Target Current (A)** / **Slew rate (mA/s)**: 3770 / 0 / 1500	
2	If there are any trips (magnet, cryogenics, control, communications etc), one of more of the *(q) Interlock Summary* indicators will turn RED and the magnet will either Fast Dump or initiate a Controlled Ramp Down. If this happens call the ENGINEER ON CALL.	

Reversing Polarity

Reference should be made to Figure 1 and Table II.

<table>
<tr><th></th><th>Instruction</th><th>Action</th></tr>
<tr><td colspan="3">REVERSING POLARITY</td></tr>
<tr><td>1</td><td colspan="2">

Note that POLARITY is defined as follows:

CCW Field Direction (looking downstream) = POSITIVE POLARITY (INBENDING)
CW Field Direction (looking downstream) = NEGATIVE POLARITY (OUTBENDING)
Typing a POSITIVE number in (c) Setpoint will cause the magnet to ramp in POSITIVE POLARITY MODE
Typing a NEGATIVE number in (c) Setpoint will cause the magnet to ramp in NEGATIVE POLARITY MODE
<u>Note</u>: If the magnet is in POSITIVE POLARITY MODE and you wish to run it in NEGATIVE POLARITY MODE, do the following:

Type zero (0) Amps into the set point field (c)
Wait till the magnet power supply (MPS) current read back (f) reads zero or is as close to zero as it is going to get.
Wait at least 5 minutes for it to settle.
Now type in the negative current set point into the set point field (c)

Do the reverse if ramping from NEGATIVE POLARITY to POSITIVE POLARITY – i.e. always ramp to zero Amps first.
<u>Additional Note</u>: If any of the Quench Detection (QD) units trip while carrying out the polarity reversal procedure described above, do the following:

Turn OFF the MPS (t)

Reverse polarity by typing in either a negative current or positive current in the set point field (c) should clear the QD fault. If this does not work, call the ENGINEER ON CALL who may have to go down into the hall to clear the QD fault locally on the power supply remote control crate.

</td></tr>
<tr><td>2</td><td colspan="2">If there are any trips (magnet, cryogenics, control, communications etc), one or more of the (q) Interlock Summary indicators will turn RED and the magnet with either Fast Dump or initiate a Controlled Ramp Down. If this happens call the ENGINEER ON CALL.</td></tr>
</table>

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Emergency Stops

There are 3 Emergency Stop buttons (E-Stops) for the Torus Magnet.

How Many E-Stops?	Where is the E-Stop located?	What does it do?
1	Counting Room, on the rack inside the electronics room	Fast Dumps the magnet : (+/-) 3770 Amps to 0 Amps in 1.5 minutes*
1	Outside of power supply cabinet, Level 3 in the hall	Fast Dumps the magnet : (+/-) 3770 Amps to 0 Amps in 1.5 minutes*
1	Outside of remote Control Crate, Level 2 in the hall	Runs the magnet down via the transistor bank and the TH1 thyristor : (+/-) 3770 Amps to 0 Amps in 2 hours*
ALWAYS OBTAIN CONFIRMATION FROM THE ON-CALL ENGINEER BEFORE RESETTING THE EMERGENCY STOPS		

** - theoretical times*

What to do after a Fast Dump or Quench

- ❑ Always contact an engineer from the Magnet Group (i.e. whomever is 'On Call'):
  - Ruben Fair
  - Probir Ghoshal
  - Renuka Rajput-Ghoshal
  - Dave Kashy
- ❑ On the 'phone to the magnet engineer, please have the following information ready:
  - Status of Magnet Power Supply EPICS screen
  - Status of interlock screen – click on Item (a) (see Figure 1) and select 'Interlock Status'
  - Cryogenic status and any other information you feel is relevant
- ❑ Re-setting the Quench Detector (QD) units remotely
  - Note that this reset of the quench detectors (i.e. to clear their fault status) should only be done AFTER consultation with either the ON-Call Engineer or the Magnet Group. This is so that the engineer can confirm that the acquired voltage data has been reviewed and all is still well with the magnet.
  - The 'QD Hard Reset' button can found on the same EPICS screen as the Interlocks. Click on button (a) (See Figure 1) and select 'Interlock Status'. The reset button is at the bottom right of the screen.

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Appendix A – Magnet Power Supply Control Screens (EPICS)

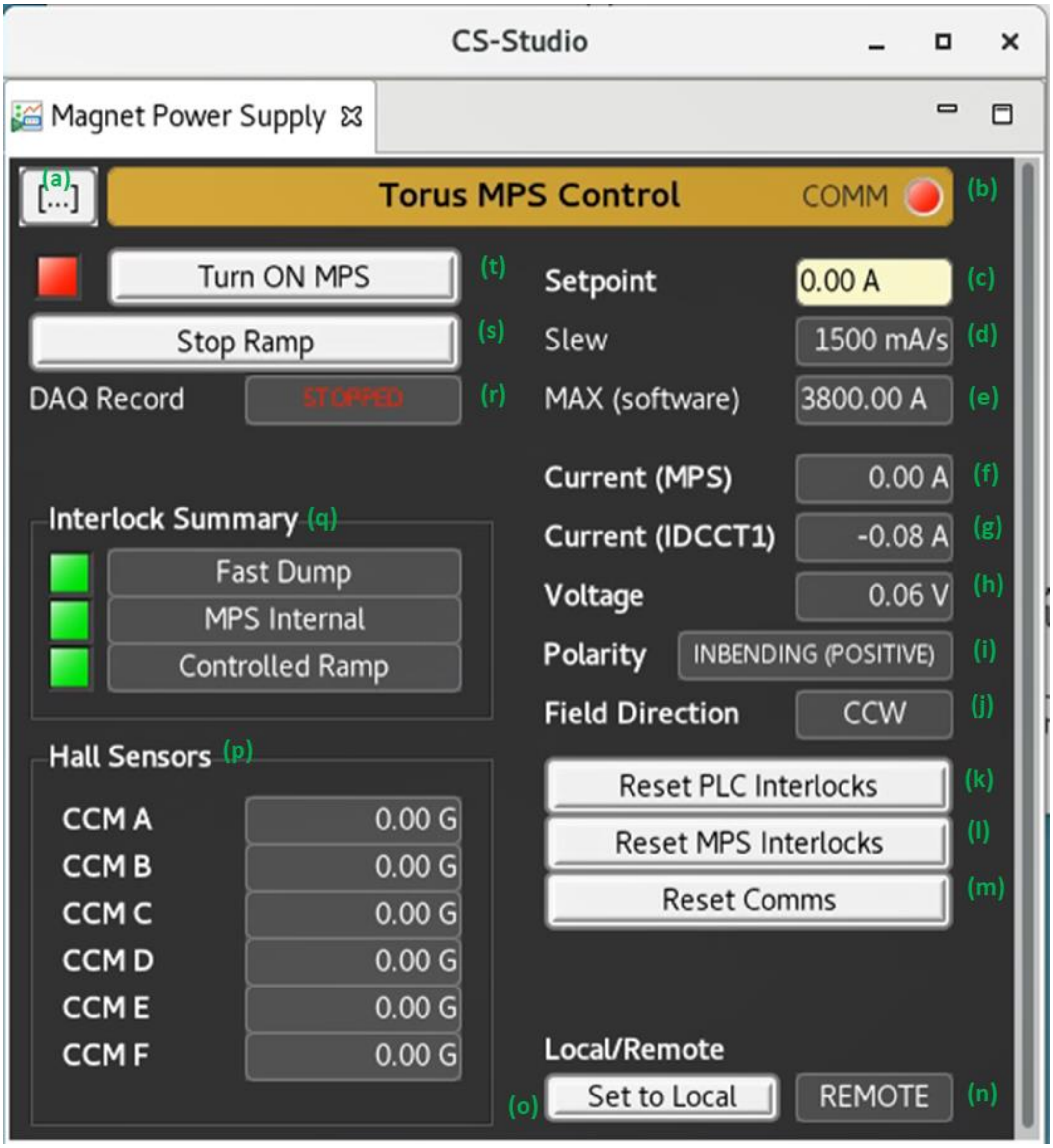

Figure A.1 - JLab MPS Control – EPICS

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Clicking on Item (a) (Figure A.1), will provide the user with access to six further EPICS screens as follows, (of which only 3 may be relevant for a shift worker):

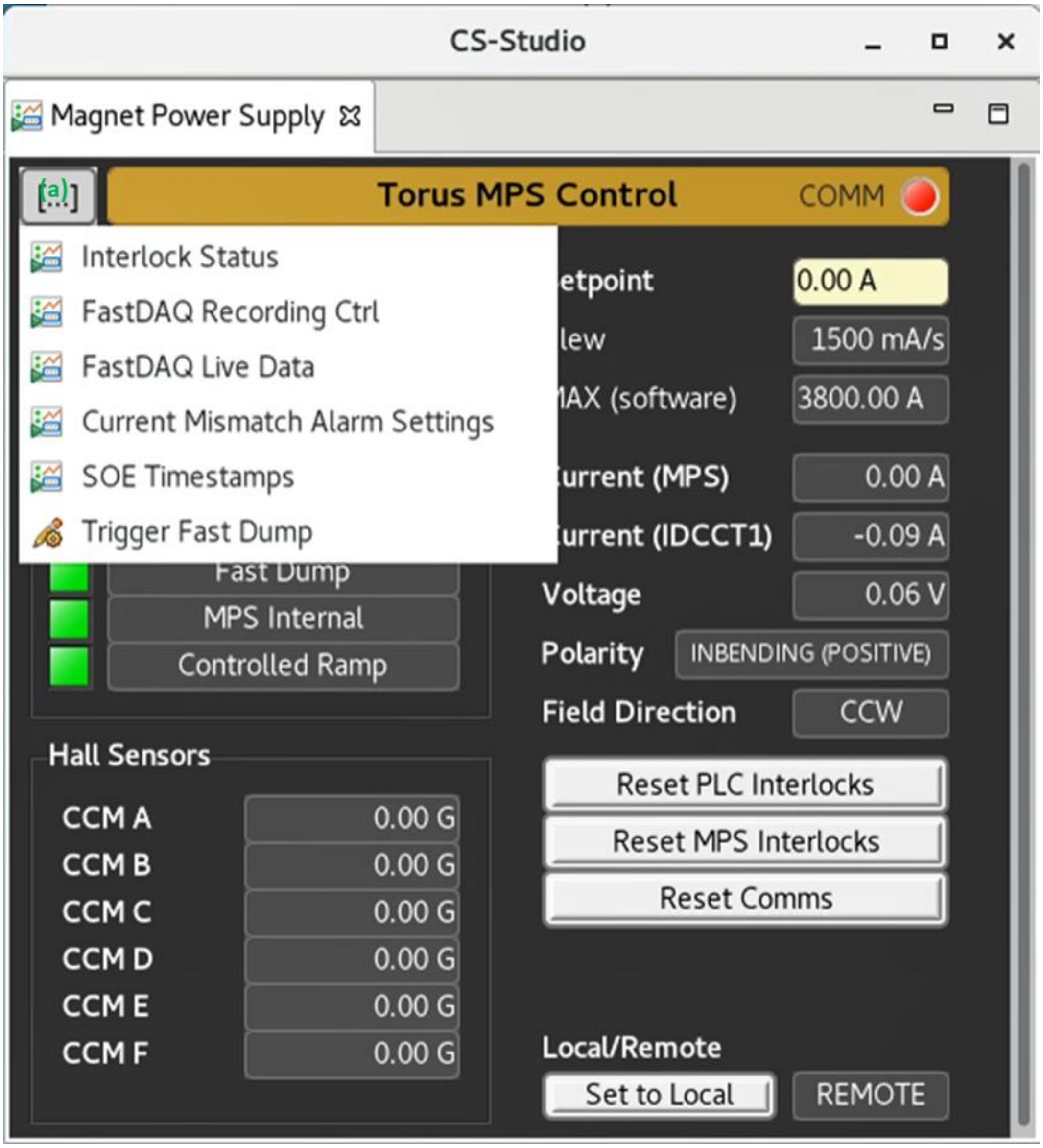

Figure A.2 - Clicking on button (a) produces a drop-down menu with 6 additional window selections

Interlock Status

All interlock indicators should be GREEN before start of magnet energization

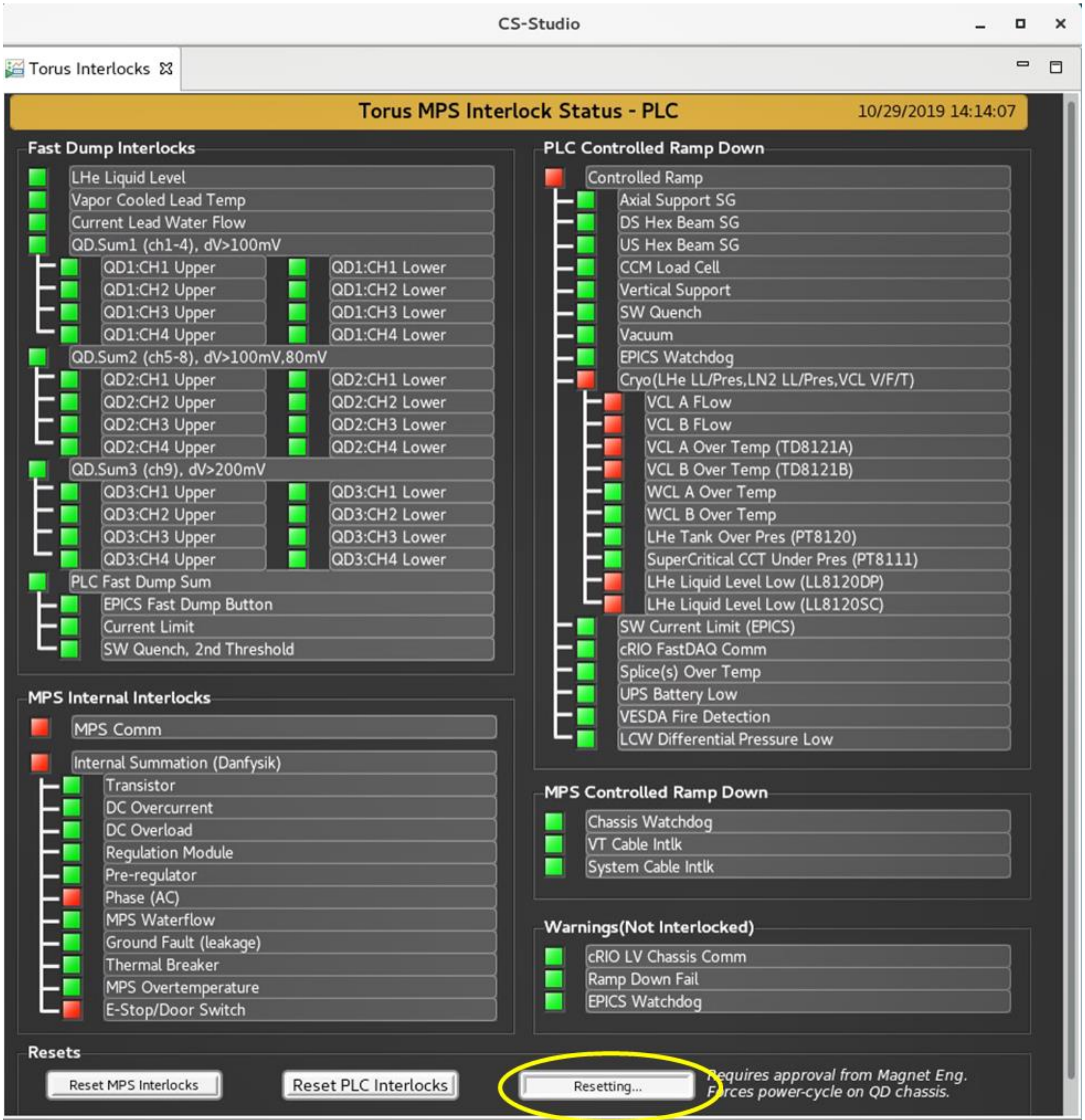

Figure A.3 - Interlock Status Screen

<u>Note</u>: The 'QD Hard Reset' (bottom right of the Interlocks Status screen should only be pushed once confirmation has been received from either the ON-Call Engineer or the Magnet Group

Fast DAQ Recording Status

The Recording Status should be RECORDING before start of magnet energization. Click the ‘Start Recording’ button if necessary. Check that a filename is displayed below and that the file size is increasing before continuing with magnet energization.

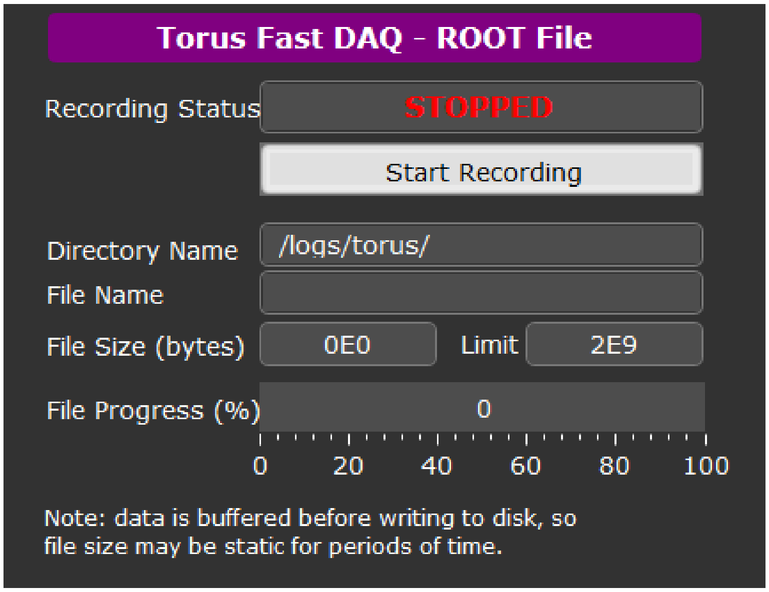

Figure A.4 - Fast DAQ Recording Screen

Fast DAQ Live Voltage Data

This displays live voltage tap data for all the voltage channels as well as the magnet current IDCCT1 – i.e. as read by the Fast DAQ National Instruments cRIO modules.

The screens below (without the magnet in operation) are an indication of the noise levels to be expected for each of the voltage channels. Noise levels typically vary from ±10 mV to ±60 mV for individual channels and can be as high as ±170 mV across the whole magnet.

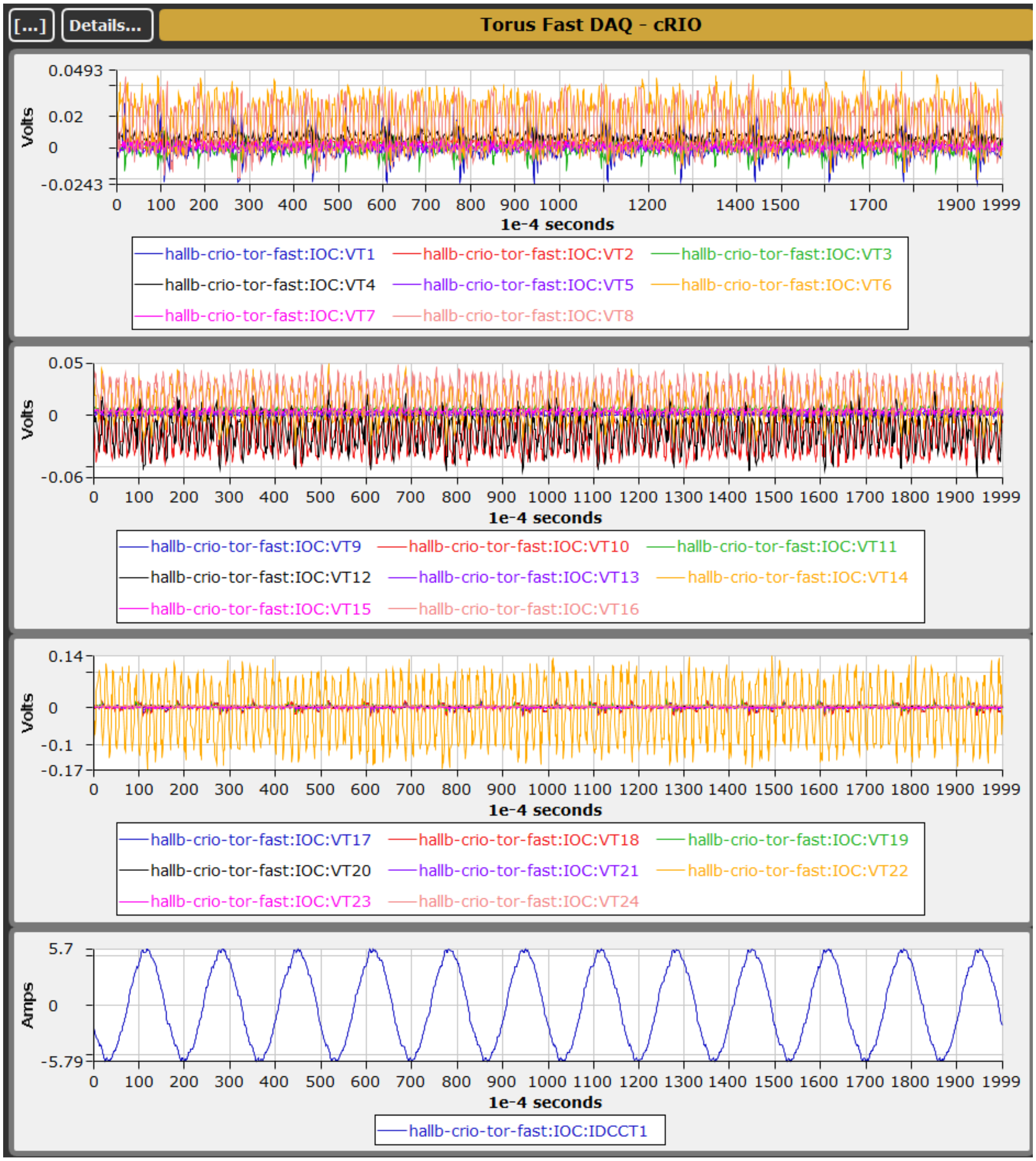

Figure A.5 - Fast DAQ Live Voltage Data

SOE Timestamps

This displays the timestamps for all the SOE (Sequence of Events) relays. If an ‘event’ occurs (for example a fast dump of the magnet), the user can refer to this screen to review the timestamps to determine which relay triggered first. This helps with diagnosis as to what may have initiated the event.

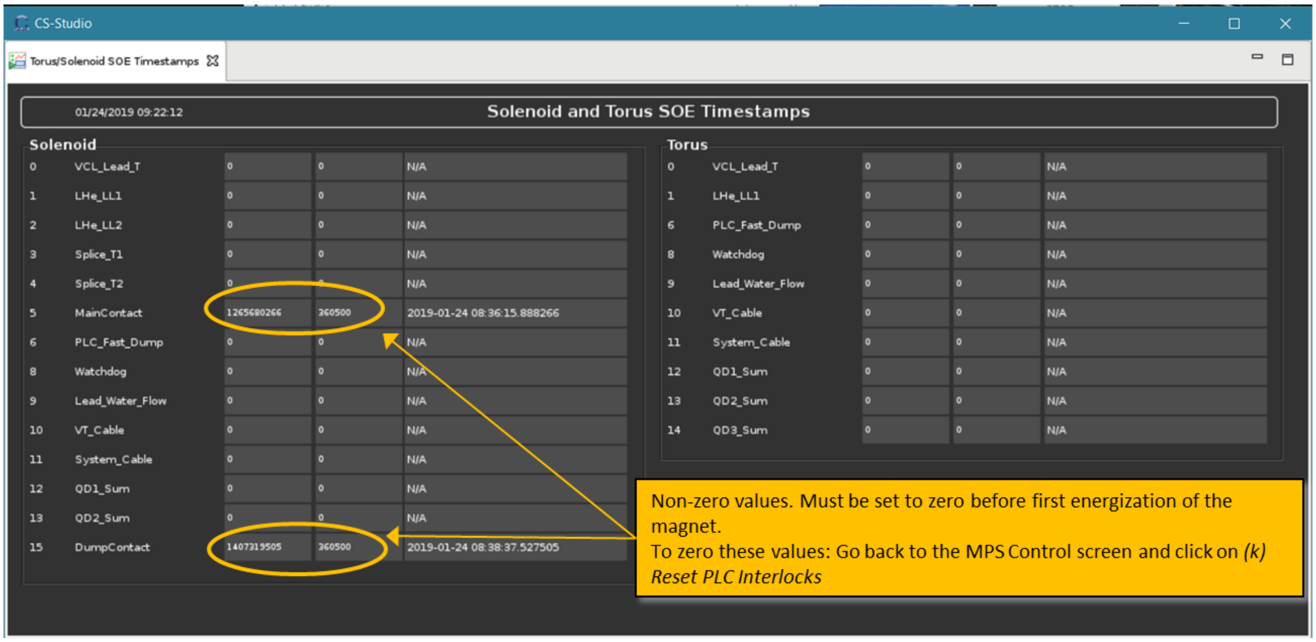

Figure A.6 - SOE Timestamps Screen

Appendix B - 12 GeV Commissioning Power Up & Power Down

This is the procedure followed for magnet commissioning.

This procedure:

- Picks up where the power supply checklists end (B000000401-P027)
- Ends when magnet is brought to operating current and is ready for field mapping
- Distinguishes between "first ramp up" (commissioning), pre-operational ramps done after 12 GeV project commissioning but prior to regular operation, and subsequent ramp ups during regular operations
- During first ramp up (12 GeV commissioning):
  - Going up in current in steps
  - Reversing after each ramp to observe behavior of instruments (strain gages in particular); watching OOPS loads and adjusting if necessary
  - Exercising the fast dump capability of the power supply at least once (at partial current)
  - Reverse the magnet polarity (at partial current) to ensure instruments and controls, power supply, and other systems, can operate in reverse polarity
- A sub-procedure (checklist) to be followed in the event of quench

Pre-Energization Checklists

In the Intervening time between start of cool-down and complete helium fill, many of the system operation controls as well as interlocks can be tested and verified using the following set of checklists:

10. *B000000401-P021 Hall B Torus Operations Power Up Checklists*
11. *B000000402-P002 Hall B Superconducting Magnets Power Supply Maintenance Turn-On Checklist*
12. *B000000402-P001 Hall B Superconducting Magnets Pre-Power-Up Power Supply Internal Interlock Checklist*
13. *B000000401-P022 Hall B Torus Pre-Power-Up Water-Cooled Leads Checkout Procedure*
14. *B000000401-P023 Hall B Torus Pre-Power-Up Vapor-Cooled Leads Checkout Procedure*
15. *B000000401-P025 Hall B Pre-Power-Up Instrument Checkout Procedure*
16. *B000000401-P026 Hall B Pre-Power-Up Quench Detector Tuning Procedure*
17. *B000000401-P027 Hall B Pre-Power-Up Interlock Checkout Procedure*

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12 GeV Commissioning Power Up & Power Down

The Operator controls the Magnet Power Supply (MPS) for the magnet and monitors the magnet and its sub-systems via a PLC using a series of EPICS screens. Bringing the Torus to operating field is done in a series of current steps at differing current ramp rates.

Each time the operator establishes the desired current on the EPICS screen and clicks anywhere outside the 'Set point' box, the power supply begins the ramp to the setpoint current at the specified slew rate (Ramp rate).

The power supply can either be controlled via its own remote control interface (mounted in a rack within the hall itself), see Fig. B.1 below; or via a JLab-developed EPICS screen, see Fig. B.2.

Figure B.1 - Danfysik Remote Control Crate

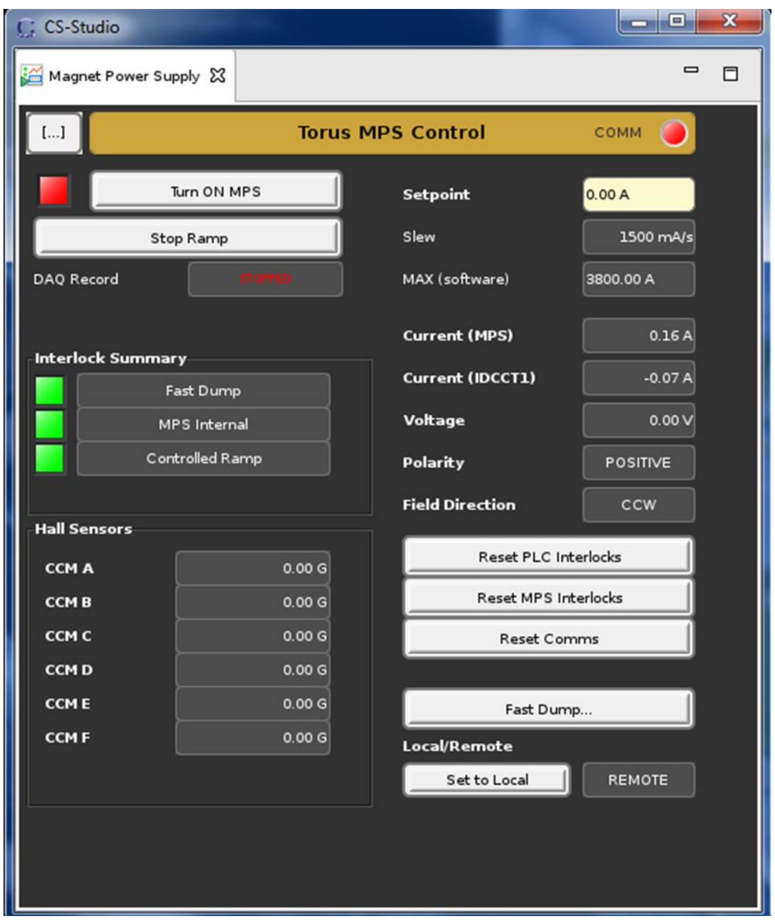

Figure B.2 - JLab MPS Control – EPICS

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For the power-up procedure, the following nomenclature will be used for a magnet discharge:

Table B.I – Definition of discharge mode

Type of discharge	Definition	Discharge time
Normal ramp down	Discharge following the prescribed maximum ramp rate at a given current (see Table II), through the Power Supply	~ 4000 sec (65 min) from full current (3770 A)
Controlled ramp down	Discharge at 1 A/sec irrespective of magnet current, through the Power Supply	3770 sec (63 min) from full current (3770 A)
Fast Dump	Discharge (emergency) through the Dump Resistor (dump switch) – discharge mode during quench	80 sec from full current (3770 A) to zero (16 sec time constant)

Note: Torus Magnet inductance = 2 Henries, Dump resistor = 0.124 Ohms

Power-Up Sequence (12 GeV Commissioning)

During commissioning ramp-up certain parameters will be monitored and recorded (aside from the EPICS logs). Values are to be monitored and compared during the stops between ramps to ensure behavior is as expected before moving on to the next step. A spreadsheet with what is being recorded at each step is a companion to this procedure, and will be filled out both on paper and electronically as the power-up proceeds. Final spreadsheet will be placed on the Hall B log.

Before defining the steps of commissioning ramp-up, it is useful to define magnet polarity. We define polarity as the direction of the toroidal field when looking downstream at the magnet from the current leads; clockwise or anti-clockwise. Determination of polarity is done as part of the pre-power up checklist.

The commissioning power-up will start with the magnet connected in the ***clockwise*** polarity.

The steps to follow during commissioning power-up are:

STEP 1a

Purpose:

- To check on inductance of coils and magnet
- To allow 'tuning' of quench detector circuits
- To check for signs of eddy-current heating in CCMs and thermal shields
- To check for signs of stress in coil cases
- To check for load unbalances on OOPs and supports
- To verify correct Gauss/Amp for each coil

- To verify integrity of coil splices
- To check for hysteresis in instrumentation

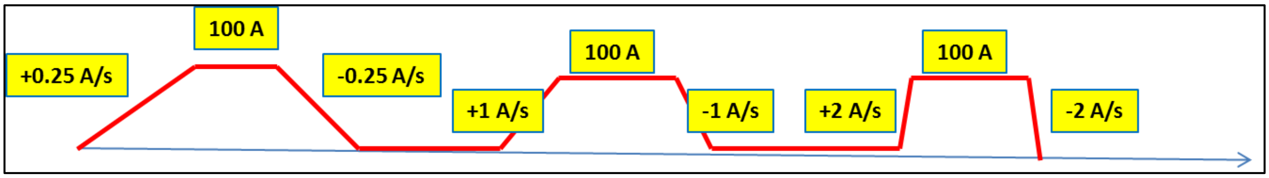

Figure B.3 - Ramp-up schedule for Step 1a

(1) Pre-Power-Up Checklist complete

(2) Verify magnet polarity is clockwise

(3) Ramp up current from 0 to 100A, stay at 100A at least 10 minutes, and then decrease back to zero at the same ramp rate. Repeat three times at increasing ramp rates (0.25, 1, and 2 A/s) and staying at 0 A at least 10 minutes each time

(4) During ramp up or ramp down monitor:

   a. Voltages across coils (and entire magnet)

   b. Voltages in current leads (and stop ramping if abnormal)

(5) During stay at 100A check, record and evaluate:

   a. Strain gages

   b. Load cells (OOPS + supports)

   c. Hall probes

   d. CCM and shield temperature

   e. Splice voltages (especially when we are at high current)

   f. VCL voltage

(6) Upon cycles completion, check for consistent behavior, signs of hysteresis in the instrumentation

STEP 1b

Purpose:

- To verify all instruments and controls, power supply, and magnet, can operate in reverse polarity
- To verify that all the checks done on Step 1a are still valid in reverse polarity mode

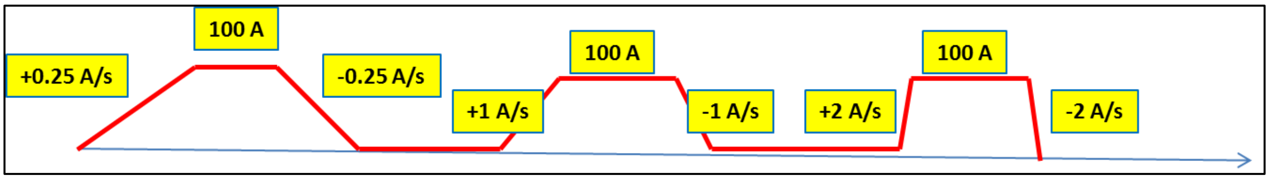

Figure B.4 - Ramp-up schedule for Step 1b

(7) Reverse polarity to ***counter-clockwise***

(8) Verify all instruments and controls are operational

(9) Proceed with a similar ramp and same steps as in Step 1a (but now in reverse polarity)

(10) Ramp up current from 0 to 100A, stay at 100A and then decrease back to zero at the same ramp rate. Repeat three times at increasing ramp rates (0.25, 1, and 2 A/s)

(11) During ramp up or ramp down monitor:

a. CCM and shield temperatures
b. Voltages across coils (and entire magnet)

(12) During stay at 100A check, record and evaluate:

a. Strain gages
b. Load cells (OOPS + supports)
c. Hall probes
d. CCM and shield temperature
e. Splice voltages (especially when we are at high current)
f. VCL voltage

(13) Upon cycles completion, check for consistent behavior, signs of hysteresis in the instrumentation

(14) Compare findings of Step 1b with those of Step 1a and check for consistency

For all the next steps, the polarity of the magnet is NOT changed, it remains ***counter-clockwise***.

STEP 2

Purpose:

- As for Step 1b but at higher currents
- To test the Fast Dump process

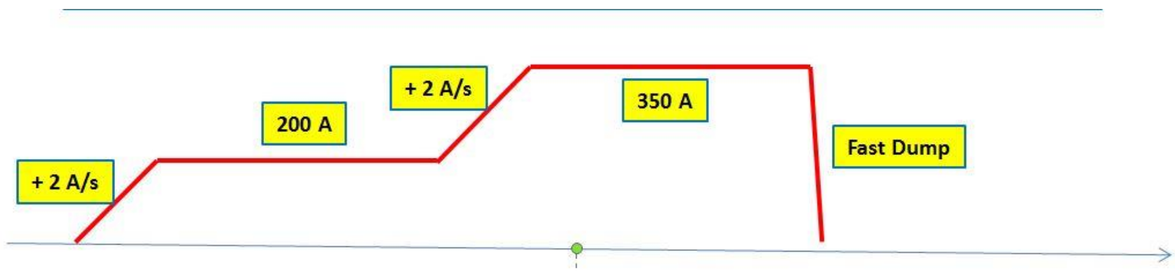

Figure B.5 - Ramp-up schedule for Step 2

(15) Ramp up current from 0 to 200A at +2 A/sec, wait at 200 A (time needed to do the checks below)

(16) Proceed to 350 A at the same ramp rate, wait and record

(17) During ramp-ups monitor:

  a. CCM and shield Temperatures

  b. Voltages across coils (and entire magnet)

(18) During stays check:

  a. Strain gages

  b. Load cells (OOPS + supports)

  c. Hall probes

  d. CCM and shield temperature

  e. Splice voltages (especially when we are at high current)

  f. VCL voltage

(19) From 350 A level, trip Fast Discharge (by soft or hard button). After Fast Discharge, stay discharged:

  a. Collect data and look at voltages,

  b. If anything trips, why

  c. Look at all mechanical sensors (are they back to values at 0 A?)

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STEP 3

Purpose:

- To stress and de-stress the coils and structural members during ramp-up
- To test the Controlled Ramp Down process from full operating current

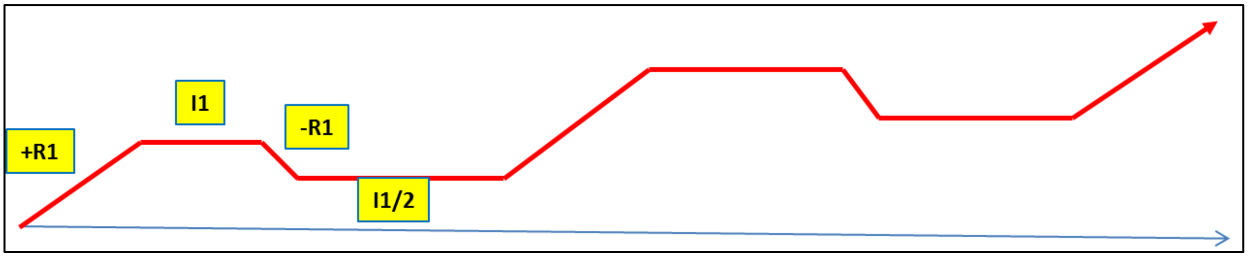

Figure B.6 - Ramp-up schedule for Step 3 (illustration)

(20) After Fast Dump checklist is complete, commence ramp-up to slightly above nominal current (3800 A) following a pattern:

1. Ramp current up to I1 at a rate +R1
2. Stay at I1 to conduct checks (30-60 minutes)
3. Decrease current to I1/2 at a rate –R1
4. Stay at I1/2 for checks (30-60 minutes)

(21) Continue this process of ramp up/wait/ramp down/wait to increasing levels of current at the appropriate ramp rates. The levels and rates are the same used during a regular ramp up, as follows:

Table B.II - Maximum ramp rate as a function of current, schedule of current ramps for Step 3[1]

Current (A)	Ramp rate (A/sec)
0 - 500	2
500 - 1000	2
1000 - 2000	2
2000 - 2500	1.5
2500 - 3000	1
3000 - 3500	0.5
3500 - 3770	0.25

(A)	(A/sec)
500	2
250	-2
1000	2
500	-2
2000	2
1000	-2
2500	1.5
1250	-1.5
3000	1
1500	-1
3500	0.5
1750	-0.5
3770	0.25

Wait

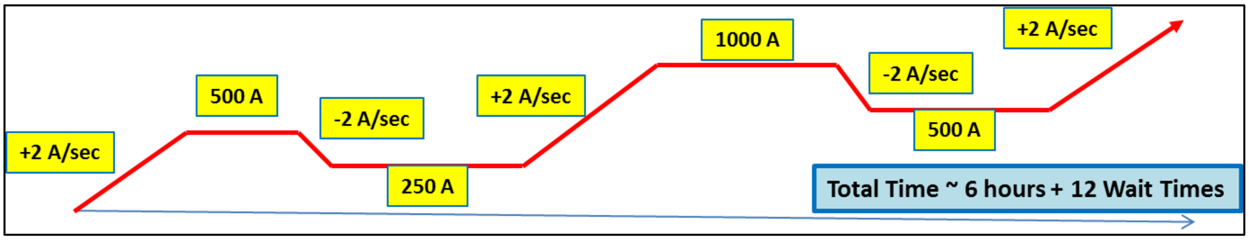

Figure B.7 - Ramp-up schedule for Step 3 (showing ramp rates)

(22) During ramp-ups monitor:

c. CCM and shield Temperatures

d. Voltages across coils (and entire magnet)

(23) During stays check:

g. Strain gages

h. Load cells (OOPS + supports)

i. Hall probes

j. CCM and shield temperature

k. Splice voltages (especially when we are at high current)

l. VCL voltage

[1] Note that these values for ramp rates were determined BEFORE the start of commissioning. Observation of thermal transients (AC losses) during magnet ramping led us to decrease the maximum ramp rate as a function of current. Lower values were used during the remaining steps of commissioning, the values given in the Operations Manual section were determined during commissioning

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(24) It is important to record and evaluate the VCL voltage during ramping-up, as values may be incorporated to the control system in the form of an alarm on deviations from expected trend

(25) At 3000A, and AFTER lowering the current to 1500A, stop the process, evaluate all the data collected up to this point, and only proceed with this step if no anomalies in magnet behavior are noted.

(26) After evaluation, resume the step, and charge magnet to 3800 A (0.8% above nominal).

(27) From the final current of 3800 A, come down to nominal current of 3770 A, and then perform a Controlled Ramp Down using a ramp rate of -2 A/s all the way down to 0 A while monitoring all instrumentation – in particular temperature sensors to identify any eddy current issues (both in shields and coils).

Actions in the event of training quench

1. In the event of a training quench during power up, the step will be stopped to investigate and try to localize where the quench originated, and if data permits, identify a root cause for the quench. The steps are:
    a. Analyze all temperature, pressure, mechanical, and voltage fast DAQ data to determine location, and if possible, source of the quench
    b. Check the interlock SOE (sequence of events)
    c. Attempt to isolate location and root cause of quench
    d. From the voltage tap data estimate quench propagation velocity, and use the information to validate assumptions of quench propagation modeling (in particular, if quench originates in splice region, confirm that quench propagates into the coils)
    e. Do a visual inspection of all magnet, power supply, and cryo systems
    f. Unless investigation uncovers a problem, then:
2. Re-start by following the cooldown check list (as per appropriate section in the Cooldown Procedure B00000901-P007)
3. Proceed to cooldown (as per appropriate section in the Cooldown Procedure B00000901-P007)
4. Go through procedure B000000402-P001 Hall B Superconducting Magnets Pre-Power-Up Power Supply Internal Interlock Checklist
5. Re-start the power up step at which the quench occurred (1a or 1b, 2, or 3), going back to the beginning of the step

Power-Up Sequence (Post-Commissioning)

After taking the magnet to 3800 A, and a Controlled Ramp Down from 3770 A, the 12 GeV commissioning phase is considered complete. Post-commissioning operation begins, and is intended to further exercise certain features prior to unrestricted operation. There are two steps in this post-commissioning phase:

(1) Exercise a reverse polarity ramp-up to high current
   a. Reverse the polarity from counter-clockwise to clockwise
   b. Proceed to execute Step 3 from the Commissioning Power-Up (Section 4), but only up to a current of 2665 A

(2) Exercise a fast Dump from high current
   a. After stopping at 2665 A and recording data, exercise a Fast Dump (via soft or hard button) from this level back to 0 A
   b. Analyze the data from the ramp-up and Fast Dump, in particular, any indication that the coils may have quenched during the Fast Dump

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