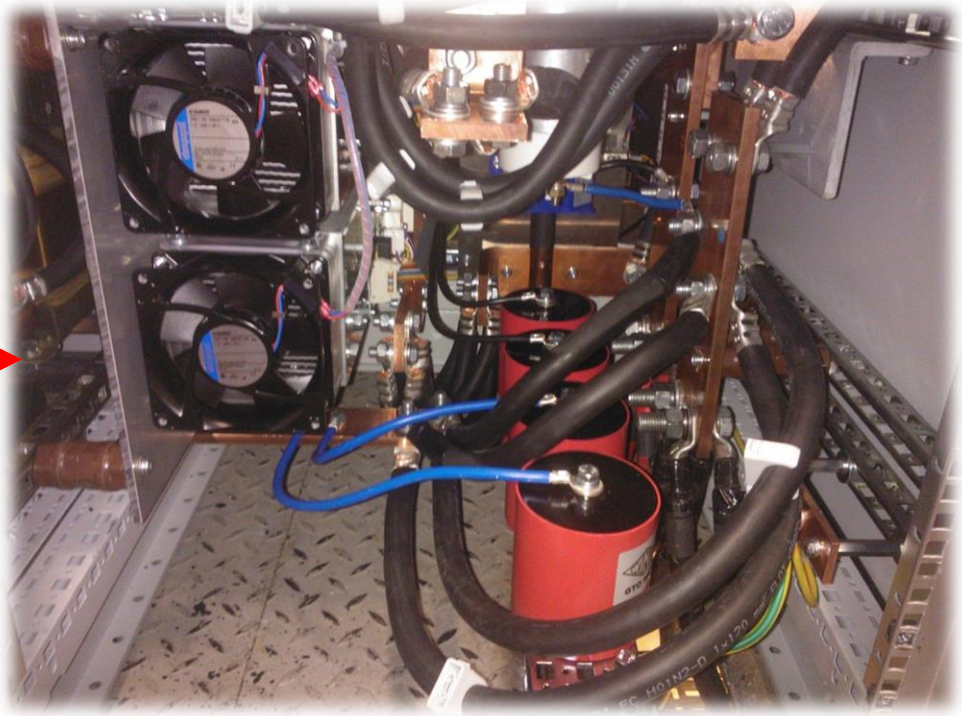
Electrical Integration

Stephen Griffiths
&
Trevor Hartnett

Decay Solenoid Power Supply



Summary of Power Supply history

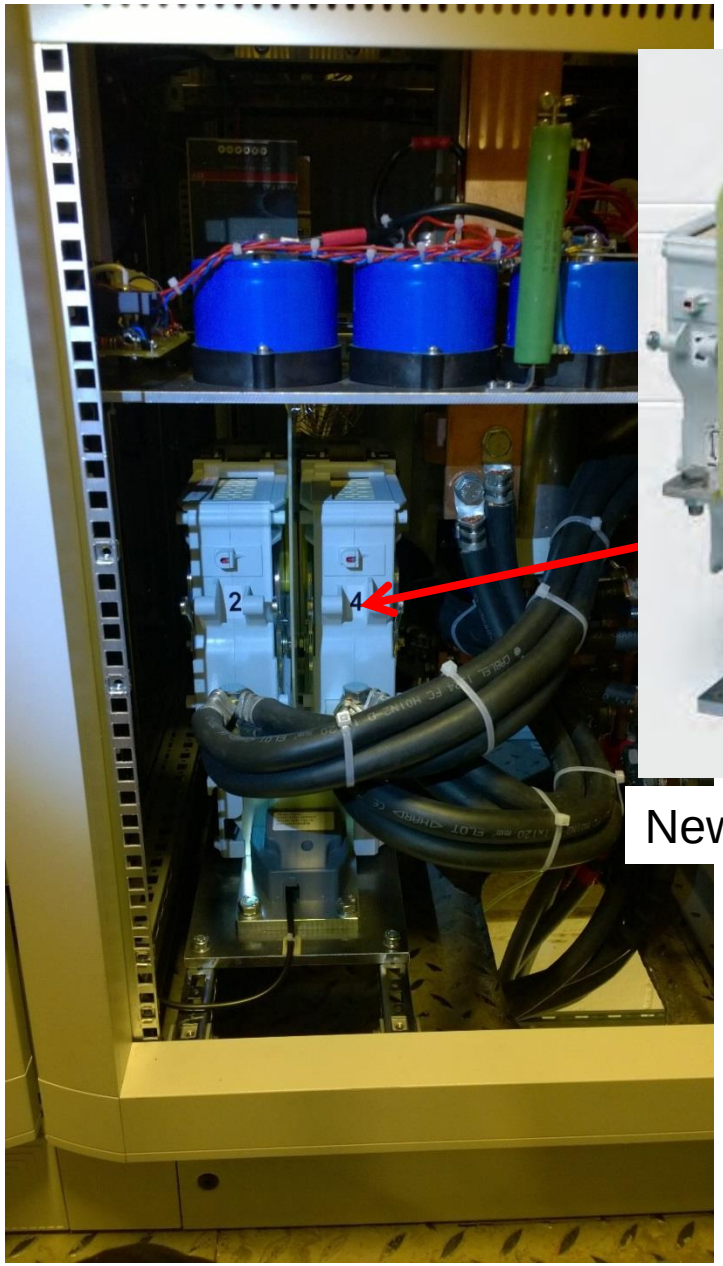
- Original PSI power supply was replaced Spring 2013
- New DC contactor failed during SAT when operated at 435A
- The DC contactor was replaced with a semi-conductor switch in Autumn 2013.
- The power supply was accepted and stability (drift) at 870A was better than 100ppm
- System was less efficient, with 2.7kW power dissipated across switch.

Decay Solenoid Power Supply

Summary of Power Supply history (cont)

- During approx. 2 years of operation there was a number of over-temperature trips.
- In Nov 2015 there was a major failure of the semi-conductor switch
- The power supply was then returned to the manufacturer for repair.
- DL electrical Group specified and procured a new DC contactor.
- The manufacturer modified the design, replaced the main control board and full tested the power supply.
- It was installed in Feb 2016, passed the SAT and operated successfully at 435A.
- The power supply has been used during the latest experimental period.

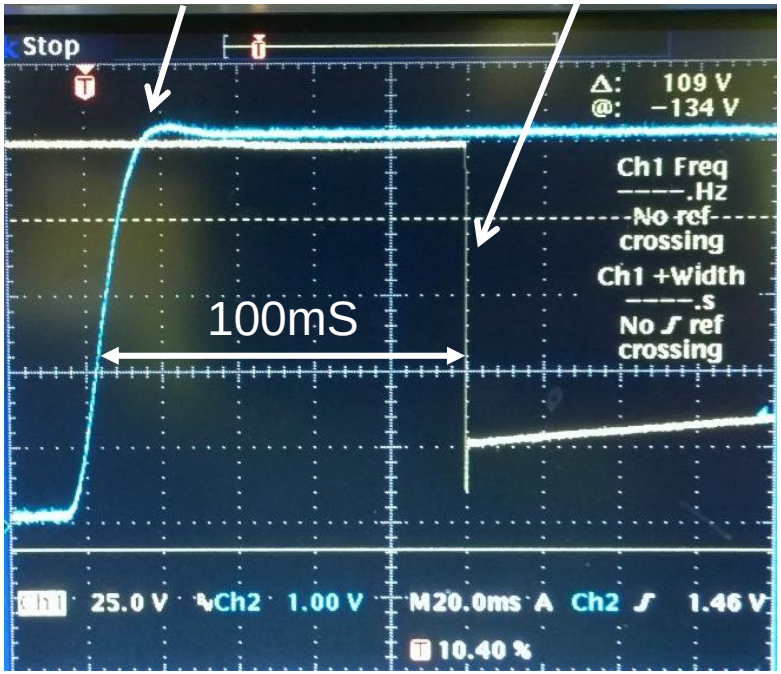
DC Contactor



New DC contactor

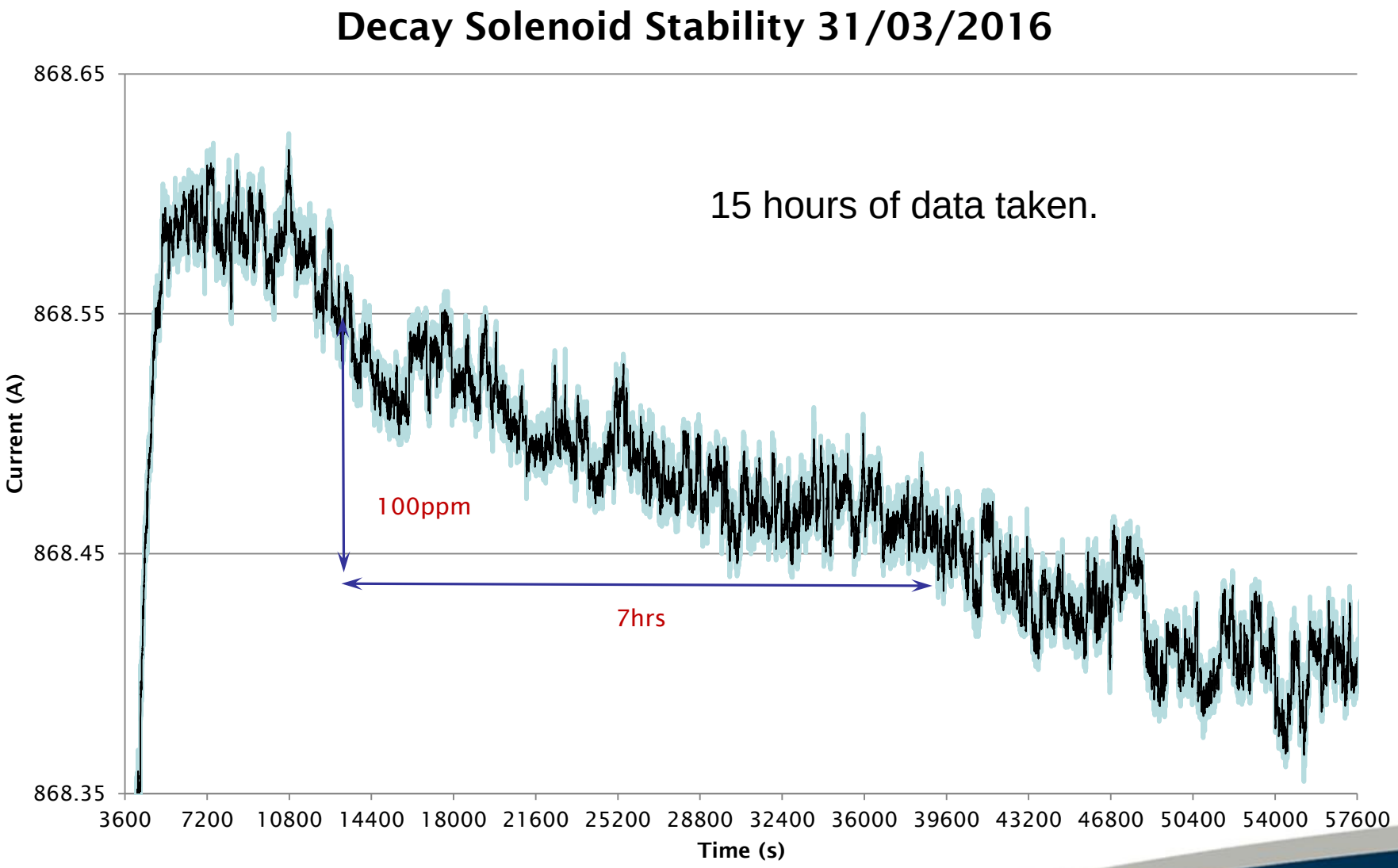
QP System trigger

DC contactor opening



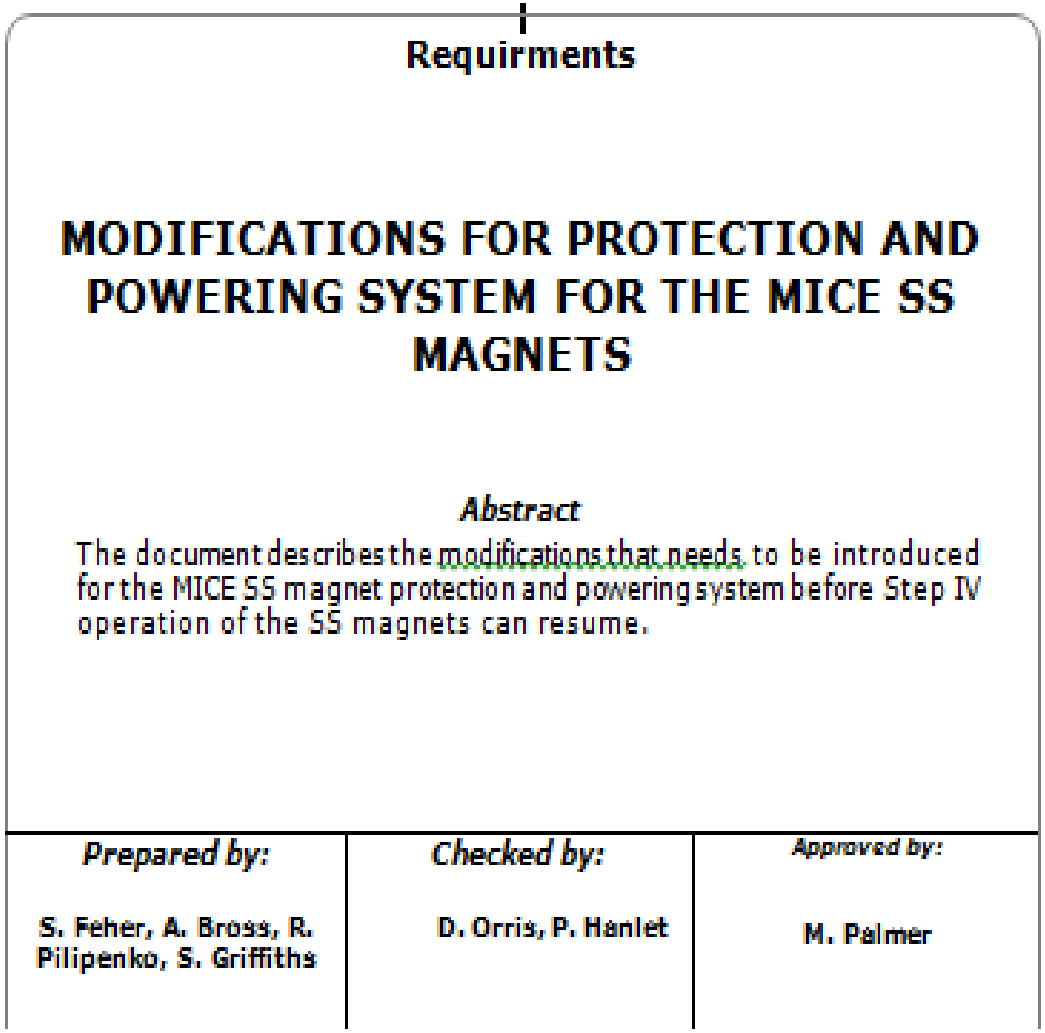
Plot of operating time

Decay Solenoid Power Supply



Science & Technology Facilities Council

SS Magnets Recommendations



Requirments

MODIFICATIONS FOR PROTECTION AND POWERING SYSTEM FOR THE MICE SS MAGNETS

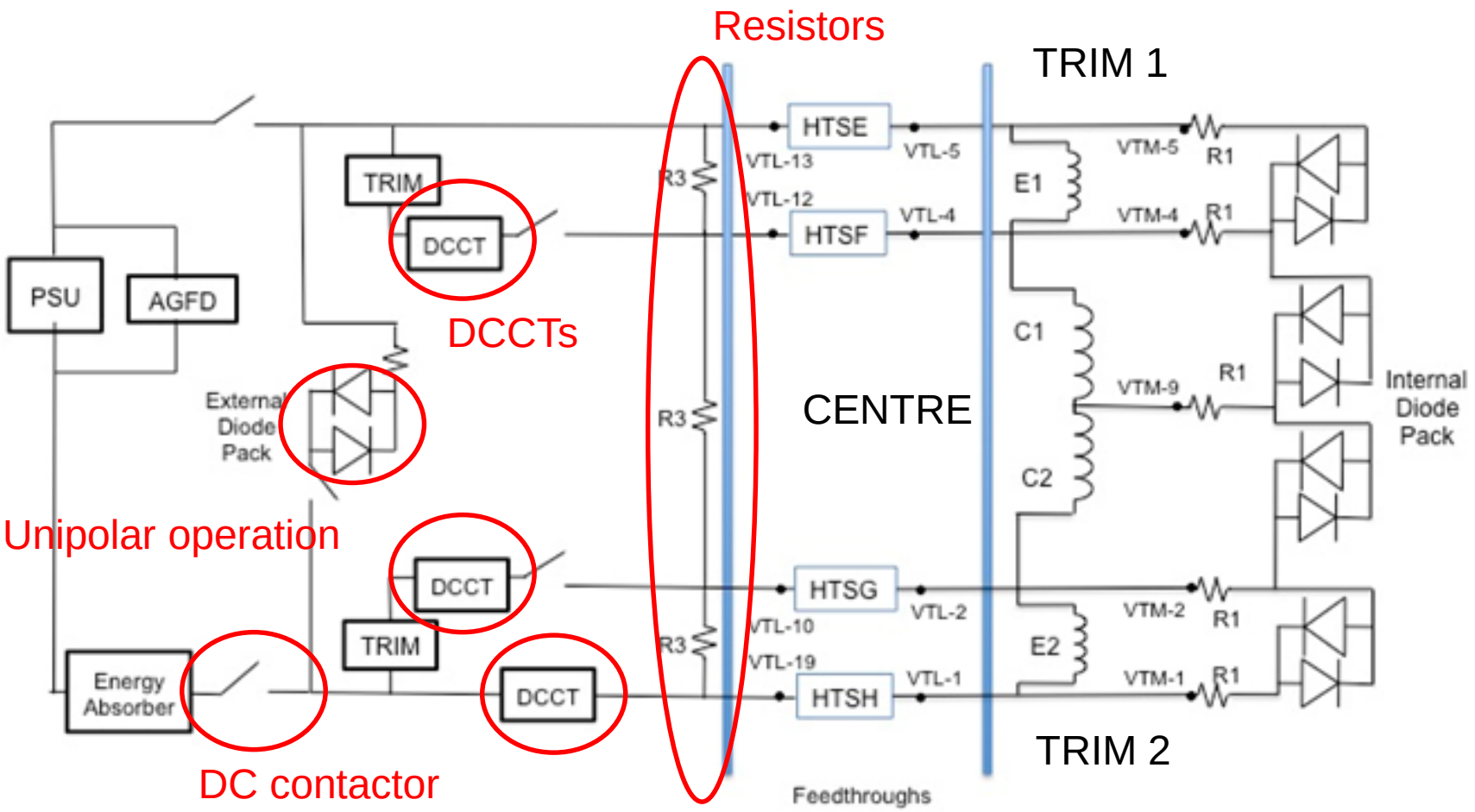
Abstract

The document describes the modifications that needs to be introduced for the MICE SS magnet protection and powering system before Step IV operation of the SS magnets can resume.

Prepared by:	*Checked by:*	*Approved by:*
S. Feher, A. Bross, R. Pilipenko, S. Griffiths	D. Orris, P. Hanlet	M. Palmer

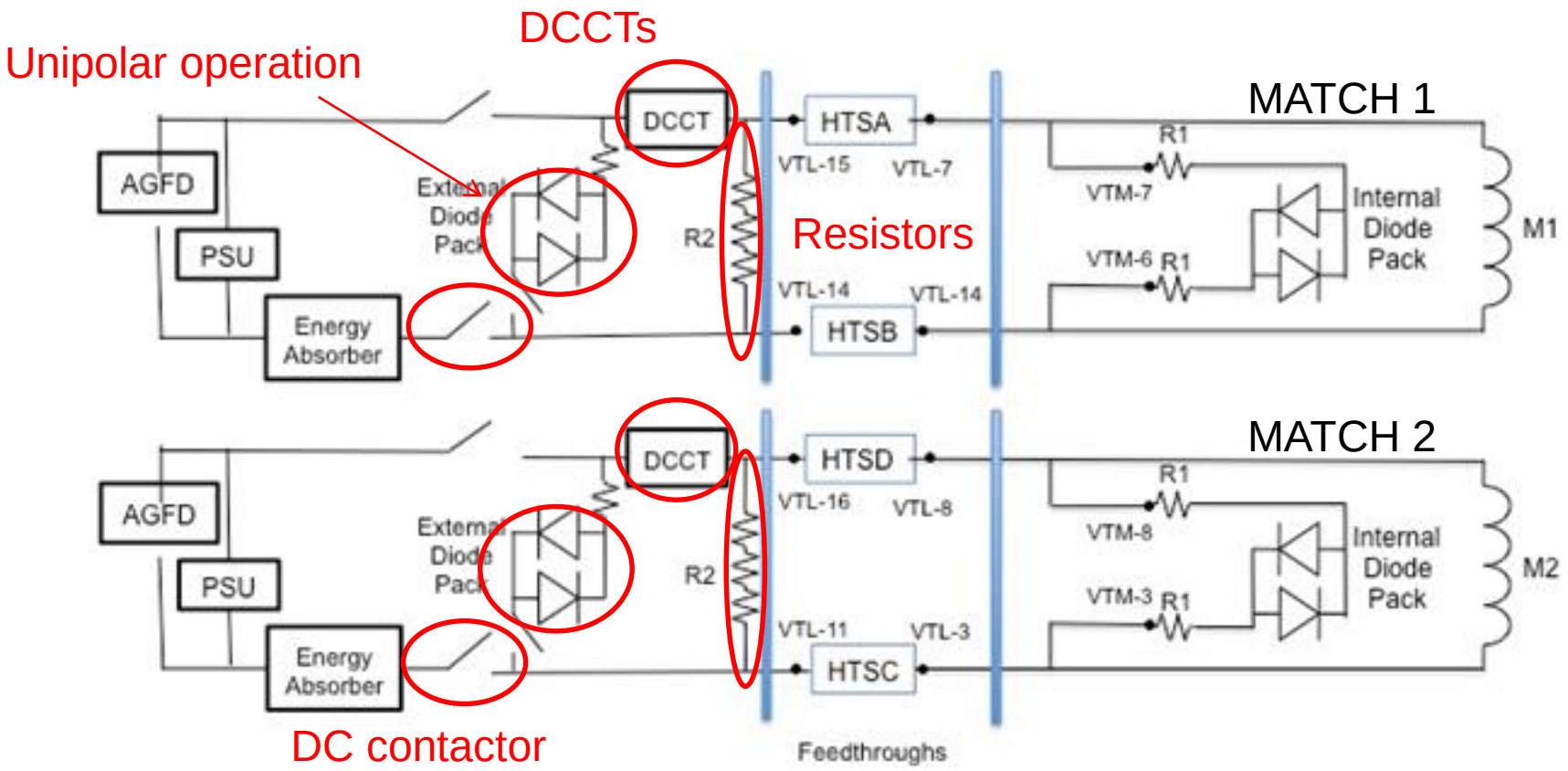
- SS Review held early Dec 2015
- Recommendations presented by FermiLab were accepted.
- Modifications to the QP/QD system were reviewed in detail and a document issued.
- The document was discussed with DL Electrical Group in Jan 2016
- The changes to the QP/QD system were agreed.
- DL generated a plan for implementing changes.

SS Magnets Recommendations (cont)

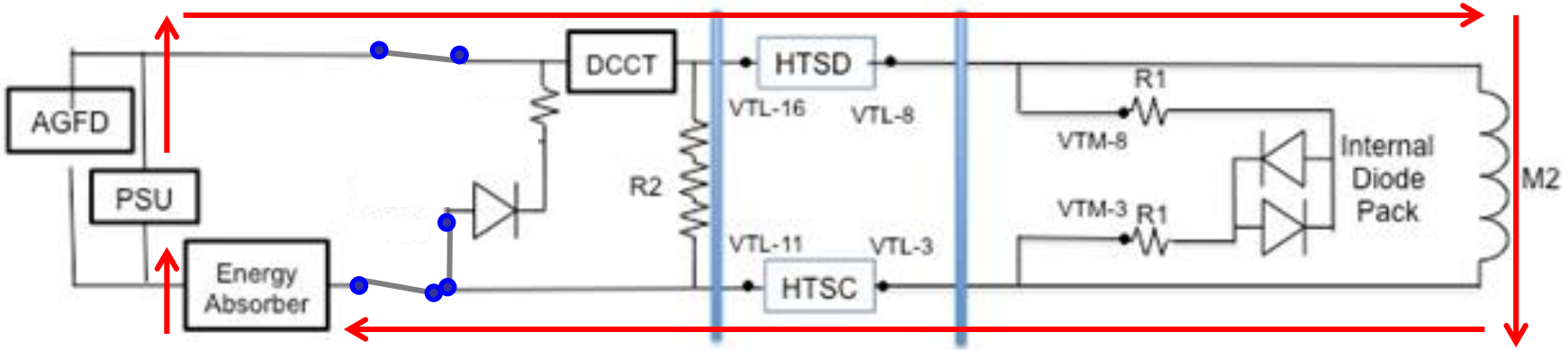


Science & Technology Facilities Council

SS Magnets Recommendations (cont)

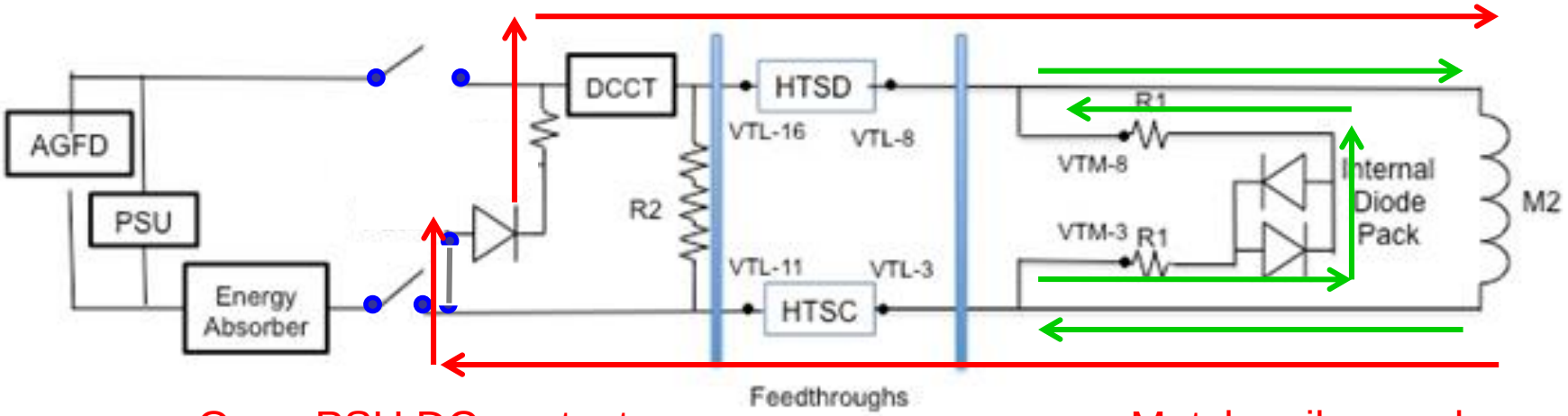


SS Magnets Recommendations (cont)



All DC contactors closed

Normal operation



Open PSU DC contactors ONLY!

Match coil quenches

RR2 Layout – rack allocation

QD System racks

Oxygen Depletion System

Auxiliary rack (Tracker & Diffuser)

FC & SS Control & Instrumentation racks

SS Ground Fault Protection rack

FC & SS Power Supply racks

SS Power Converter Racks

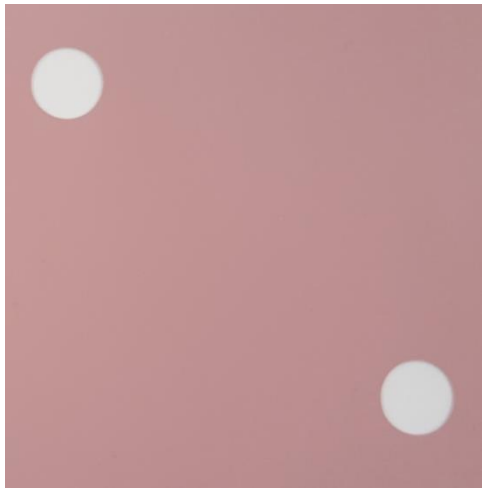
- Limited space available to install additional DCCTs and DC contactors, plus associated interface equipment.
- The ground fault protection rack is lightly populated and adjacent.
- Water cooling circuit inside Energy Absorber rack will need to be optimised to create space.

SS & FC PSU racks in RR2

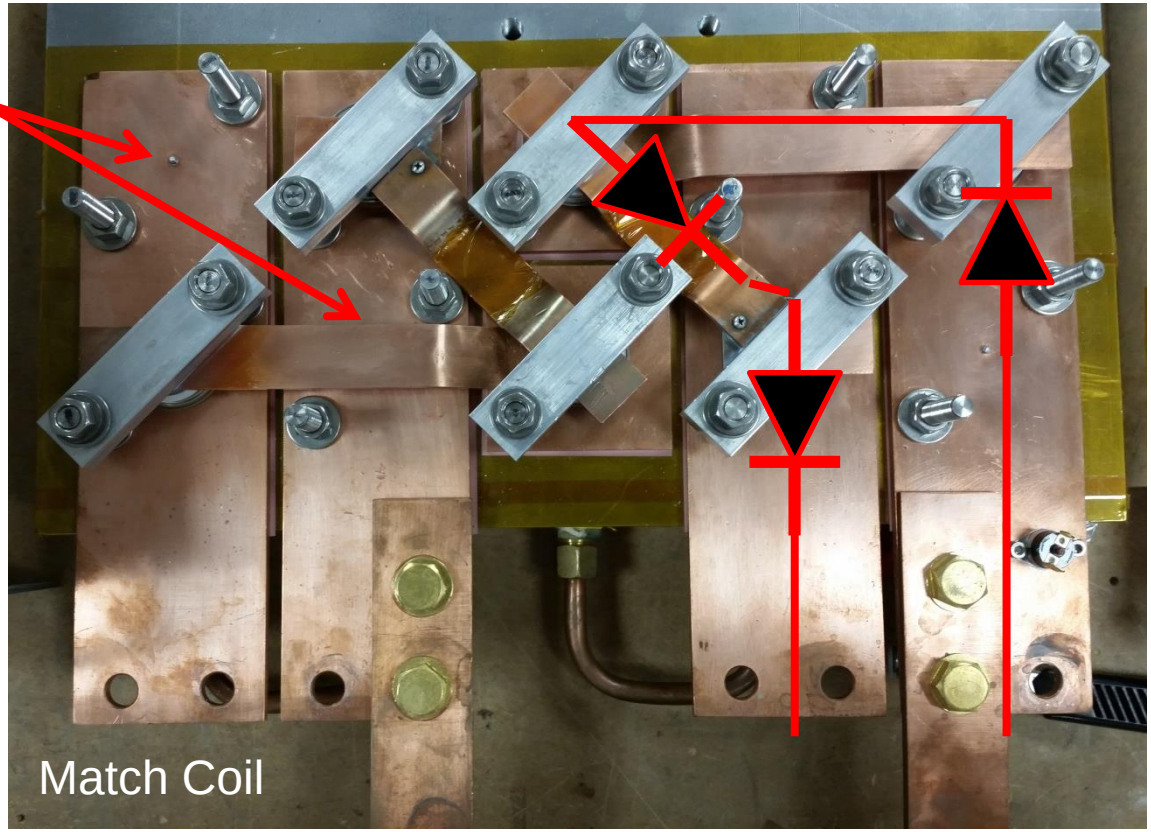
Original configuration of SS Energy absorber rack

SS Magnets Energy Discharge Diodes

Diodes removed for Unipolar operation

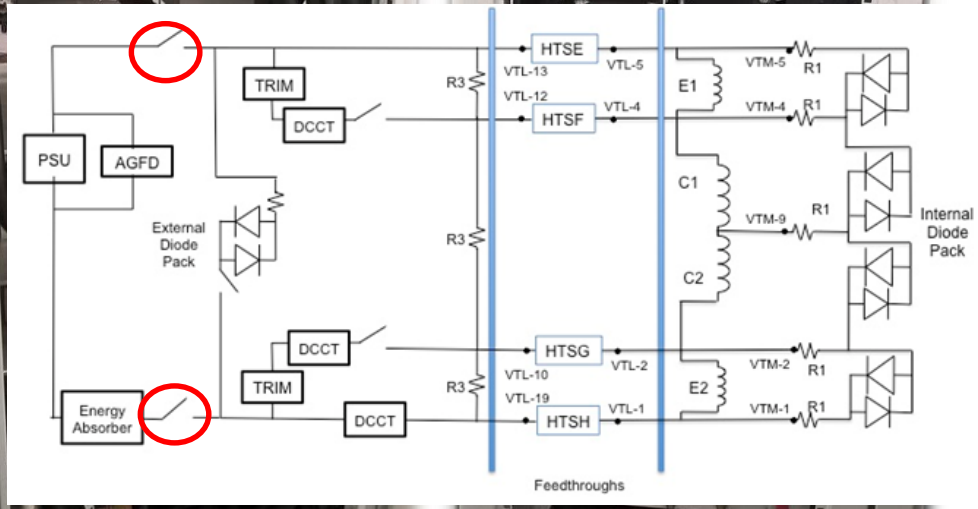


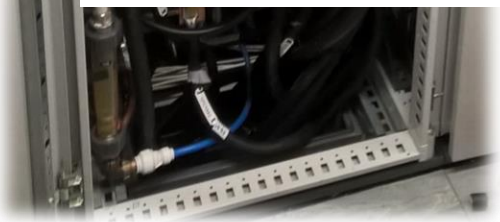
Silicon Pad



- Unipolar operation required to prevent conduction and system instabilities during normal operation.
- All units modified for unipolar operation and new silicon pads installed.
- All thermally tested at 280A and earth leakage measurements approved.
- Busbars modified to suit new configuration.

DC Contactors

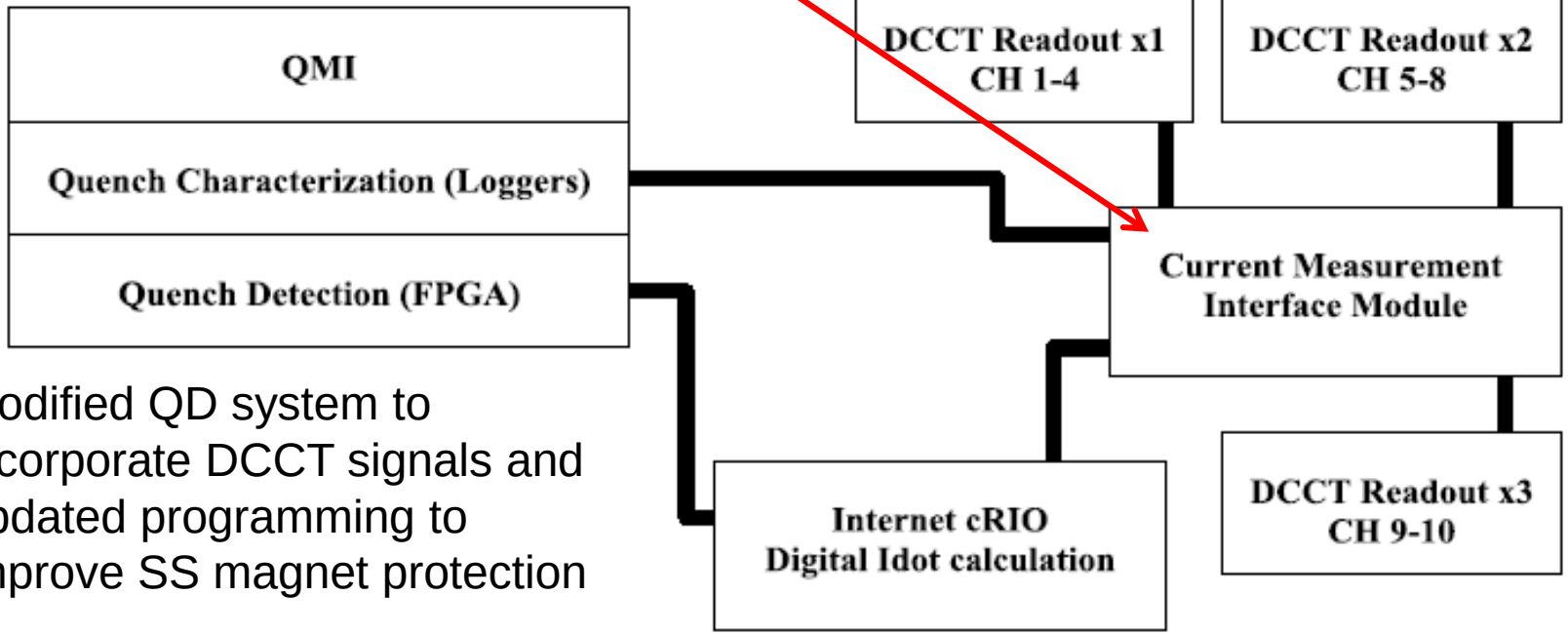




- 6 additional DC contactors are required for the Centre and Match circuits.
- These have been installed in the energy absorber diode rack.
- They will ensure the power supplies are isolated from the SS magnets during a quench.
- Previously the negative terminal of the power supply remained connected, this will improve equipment reliability.

DC contactors installed in Energy Absorber rack

DCCT Interface to QD System

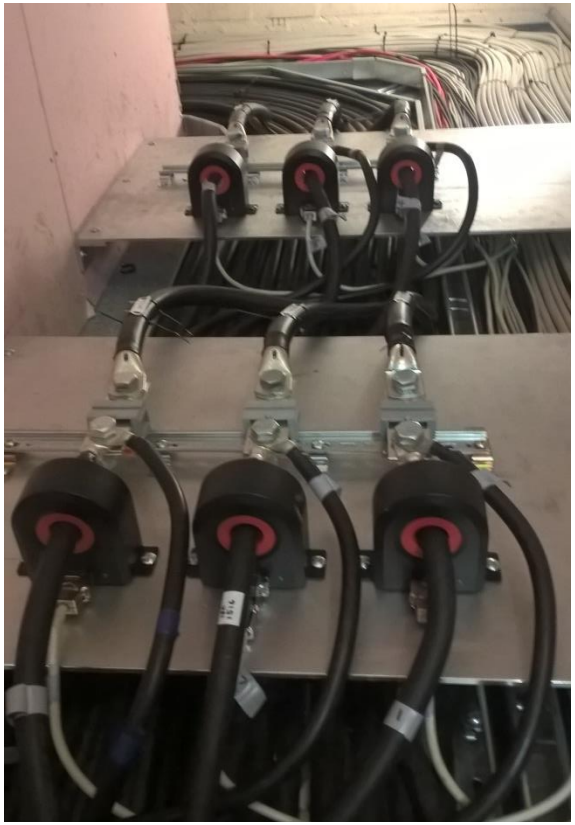


Modified QD system to incorporate DCCT signals and updated programming to improve SS magnet protection

cRIO unit to compensate for the broken SSD voltage tap

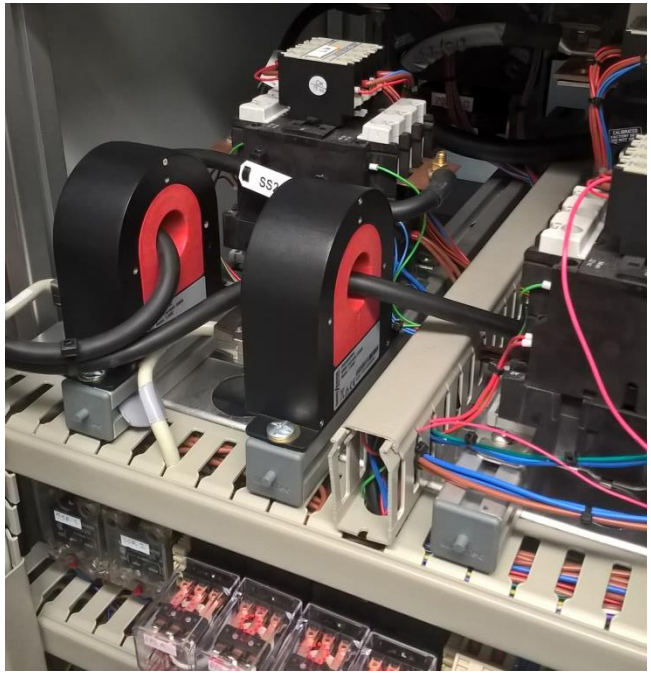
Location of DCCT Heads

- 10 DCCTs are required for independent current measurement for SSU and SSD.
- The 6 DCCTs for Centre and Match coils have been location under the stairs adjacent to rack room 2.
- The remaining 4 DCCTs for the Trim coils are mounted in the SSU and SSD power Supply racks.



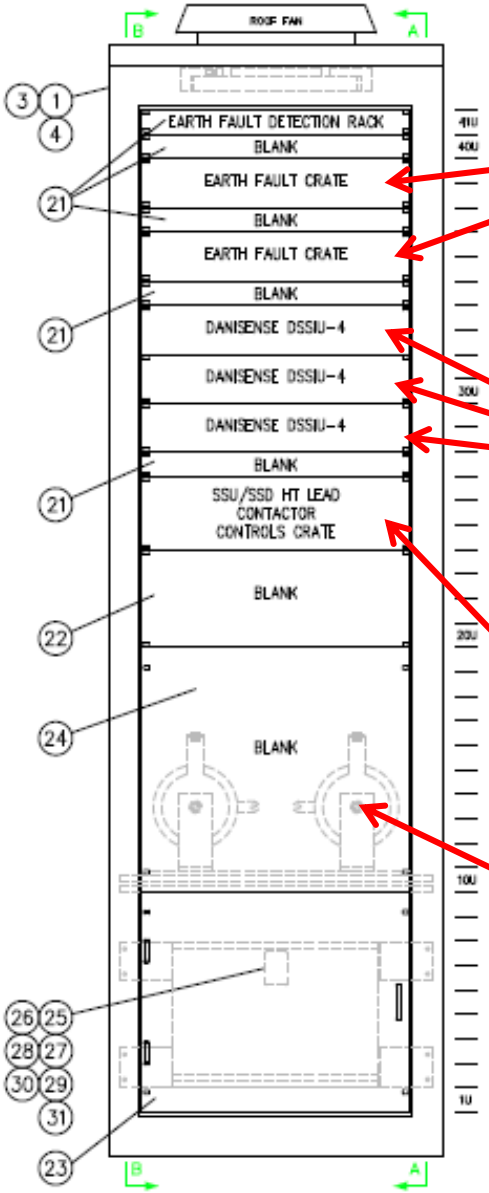
Centre & Match DCCTs mounted under stairs

- Low Power consumption 14W maximum each.
- Terminal voltages <10V to ground and shrouded by terminal covers.
- ISIS have been consulted while identifying location



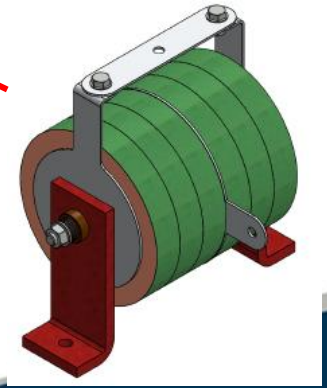
Trim DCCTs mounted in PSU rack

Ground Fault Protection Rack – Additional Equipment



Existing Ground Fault Protection crates

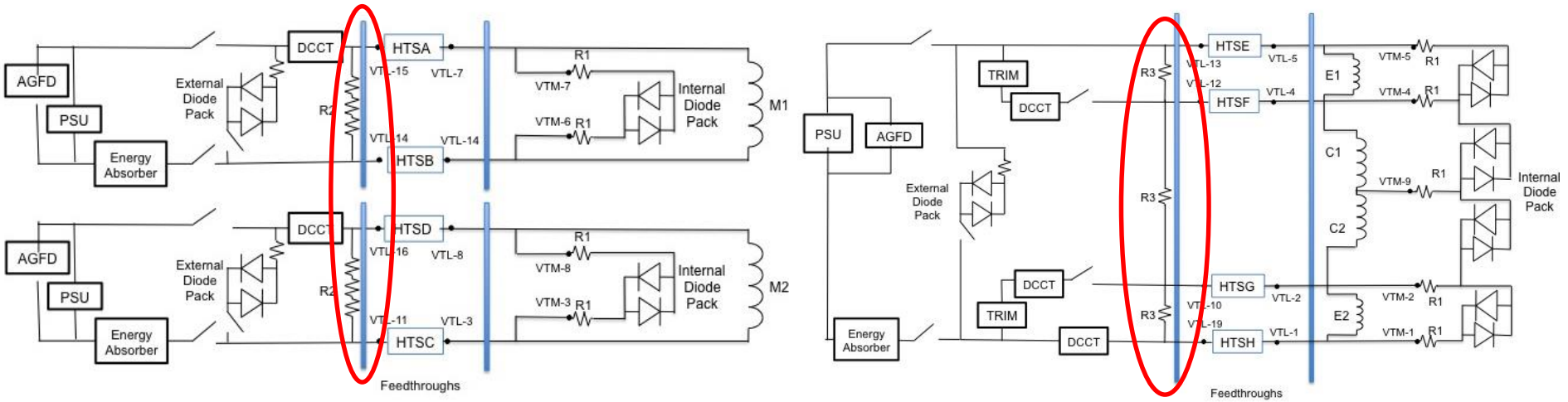
New DC contactor interface module



New Match resistors

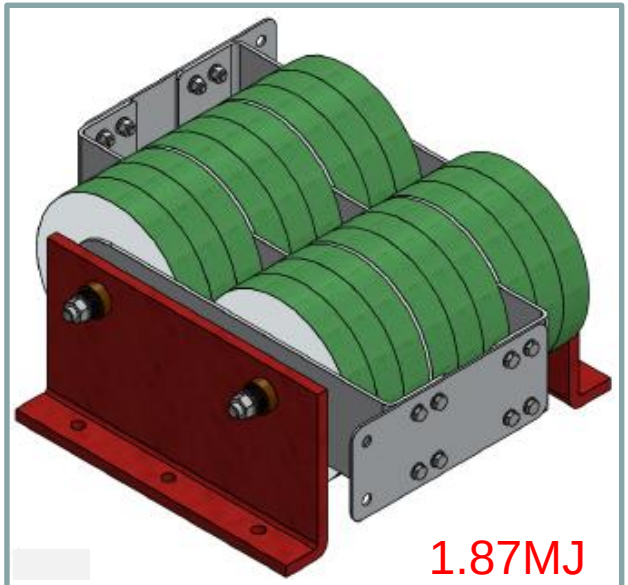
Energy Discharge Resistors

- Ceramic resistors are required as a secondary protection to discharge the energy in the SS magnets.
- These will minimise the voltage generated inside the magnet if the internal and external quench diodes can't provide a suitable conduction path.



- There are 6 resistor banks for the Centre and Trim Coils and these will be located in the Hall.
- The 4 resistor banks for the Match Coils are to be located in Rack Room 2.

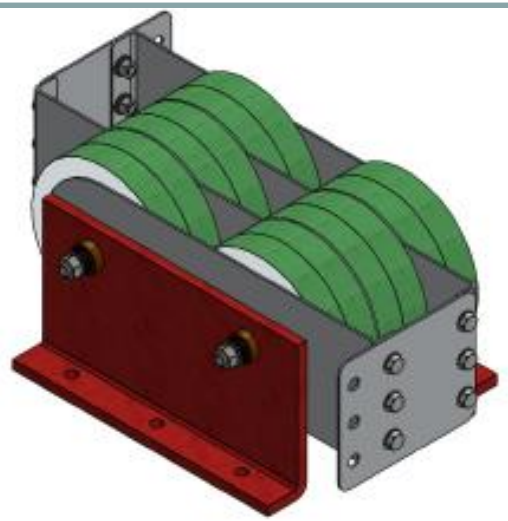
Resistor Specifications



1.87MJ

GENERAL TECHNICAL DATA	
RESISTANCE VALUE :	0R165 ± 10%
ACTIVE VOLUME :	8.028 Litres (18 x 446 cm³)
THERMAL TIME CONSTANT :	≤ 4290 s
MAXIMUM OPERATING TEMPERATURE :	150 °C (CONTINUOUS)
	200 °C (INFREQUENT)
ENERGY PER OPERATION :	≤ 1.87 MJ
ΔT PER 1.87 MJ OPERATION :	≤ 120 °C
MAXIMUM REPETITION RATE :	1 x 1.87 MJ Every 3 hours
ΔT PEAK (1.87 MJ / 3 hours) :	≤ 130 °C
COOLING :	NATURAL CONVECTION
MATERIAL RESISTIVITY :	23 Ohm.cm
VOLTAGE WITHSTAND :	≥ 50 V (CR : 230 s)
VOLTAGE SAFETY FACTOR :	≥ 50 %

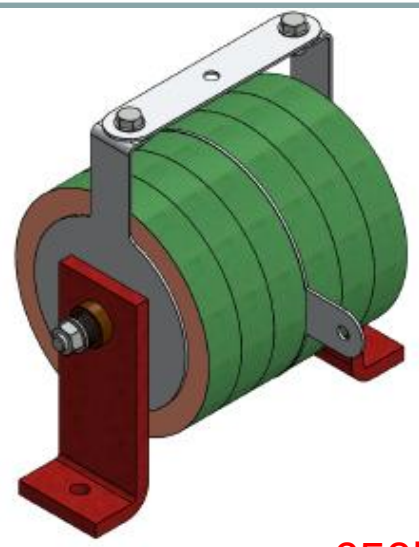
Centre Coil Resistor



1MJ

GENERAL TECHNICAL DATA	
RESISTANCE VALUE :	0R165 ± 10%
ACTIVE VOLUME :	5.352 Litres (12 x 446 cm³)
THERMAL TIME CONSTANT :	≤ 4290 s
MAXIMUM OPERATING TEMPERATURE :	150 °C (CONTINUOUS)
	200 °C (INFREQUENT)
ENERGY PER OPERATION :	≤ 1 MJ
ΔT PER 1 MJ OPERATION :	≤ 95 °C
MAXIMUM RECOMMENDED REPETITION RATE :	1 x 1 MJ Every 2 hours
ΔT PEAK (1 MJ / 2 hours) :	≤ 115 °C
COOLING :	NATURAL CONVECTION
MATERIAL RESISTIVITY :	35 Ohm.cm
VOLTAGE WITHSTAND :	≥ 50 V (CR : 132 s)
VOLTAGE SAFETY FACTOR :	≥ 50 %

Trim Coil Resistor

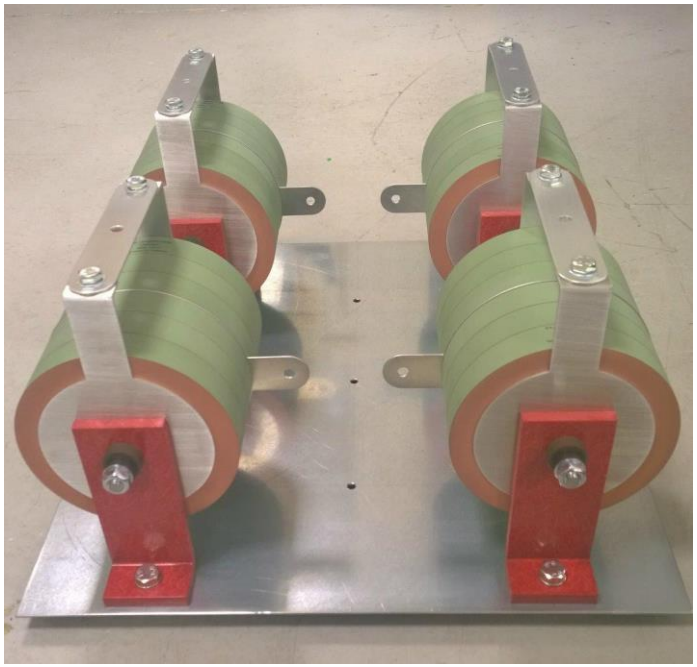


650kJ

GENERAL TECHNICAL DATA	
RESISTANCE VALUE :	0R5 ± 10%
ACTIVE VOLUME :	2.676 Litres (6 x 446 cm³)
THERMAL TIME CONSTANT :	≤ 4290 s
MAXIMUM OPERATING TEMPERATURE :	150 °C (CONTINUOUS)
	200 °C (INFREQUENT)
ENERGY PER OPERATION :	≤ 650 kJ
ΔT PER 650 kJ OPERATION :	≤ 125 °C
MAXIMUM REPETITION RATE :	1 x 650 kJ Every 4 hours
ΔT PEAK (650 kJ / 4 hours) :	≤ 125 °C
COOLING :	NATURAL CONVECTION
MATERIAL RESISTIVITY :	23 Ohm.cm
VOLTAGE WITHSTAND :	≥ 150 V (CR : 29s)
VOLTAGE SAFETY FACTOR :	≥ 50 %

Match Coil Resistor

SS Magnets Discharge Resistors



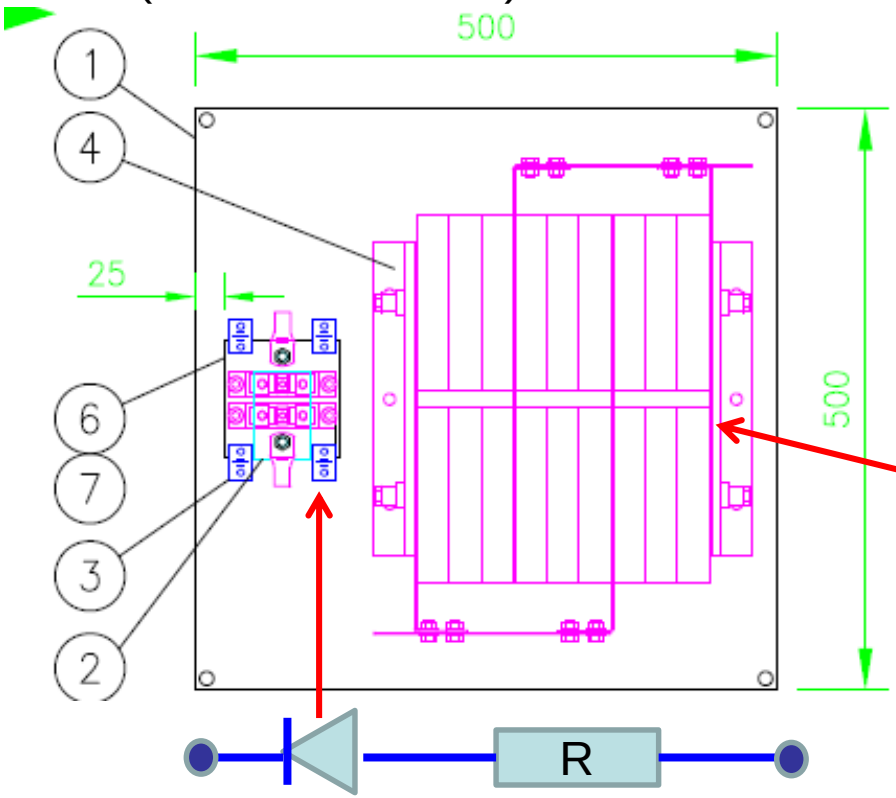
Match coil - resistor plate

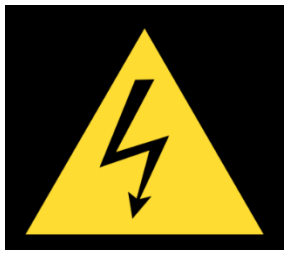
Resistors delivery to DL

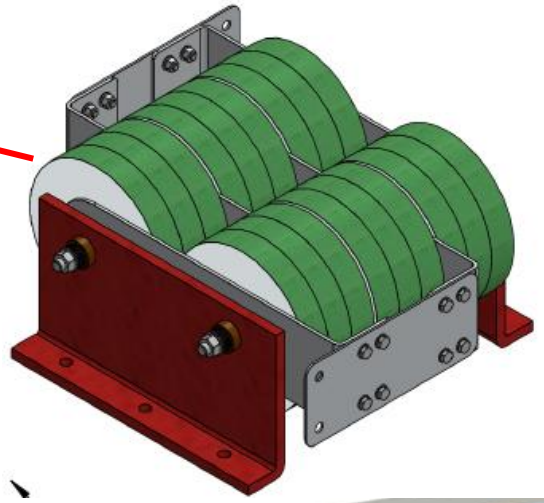
- All discharge resistors have been specified and delivered to DL.
- Resistors for the Match coils have been assembled onto a mounting plate.
- Currently the mounting plate and the DC cables are being installed and terminated.

SS Magnets Discharge Resistors – Centre & Trim

- 6 resistor plates are required for Centre and Trim coils each 500 x 500mm.
- These will need to be suitably protected due to a potential thermal and electrical hazards (120°C and 150V)

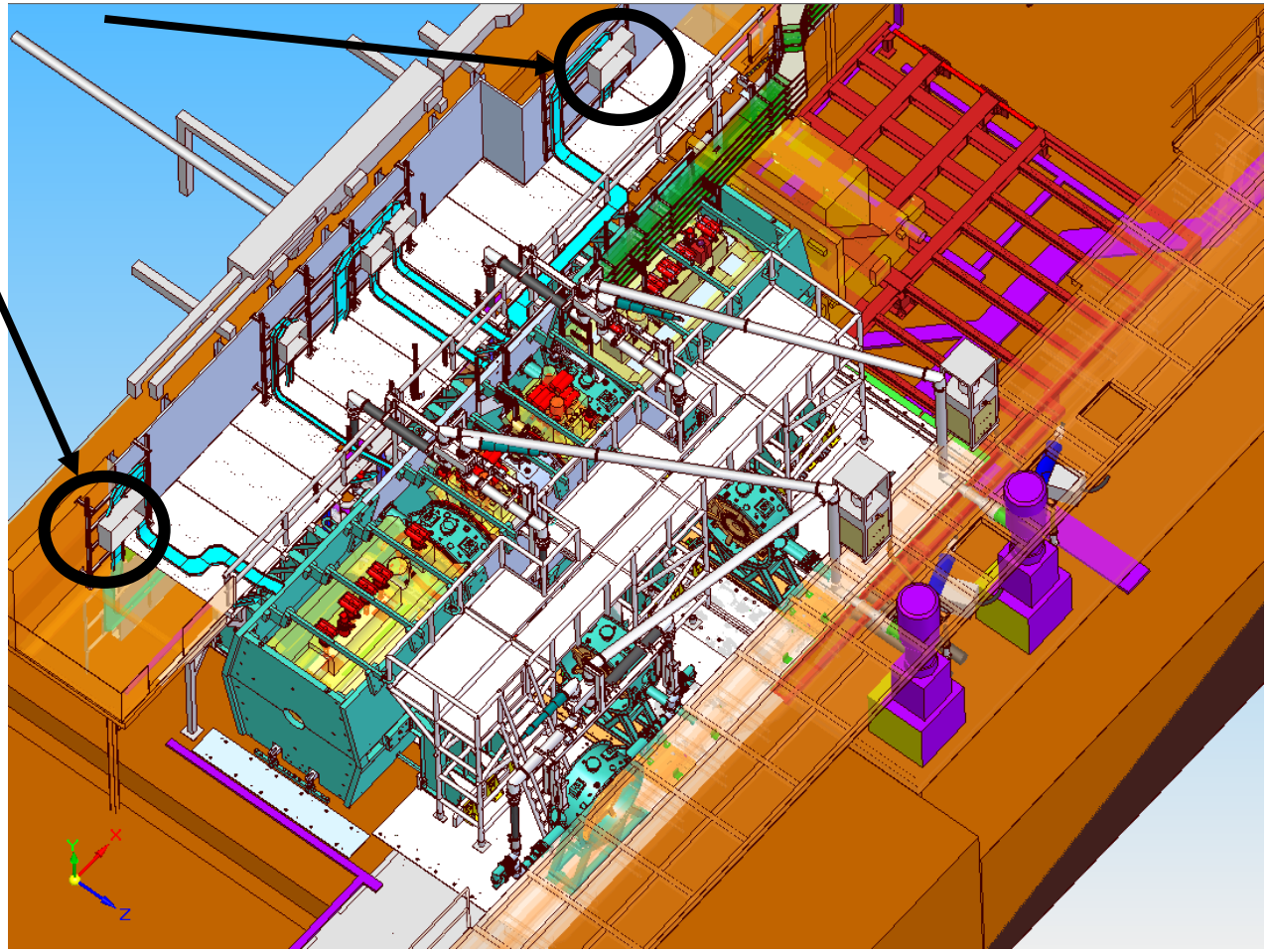






Diodes will prevent conduction during normal operation – allowing DCCTs to read accurately.

Cable management and DC Link Boxes



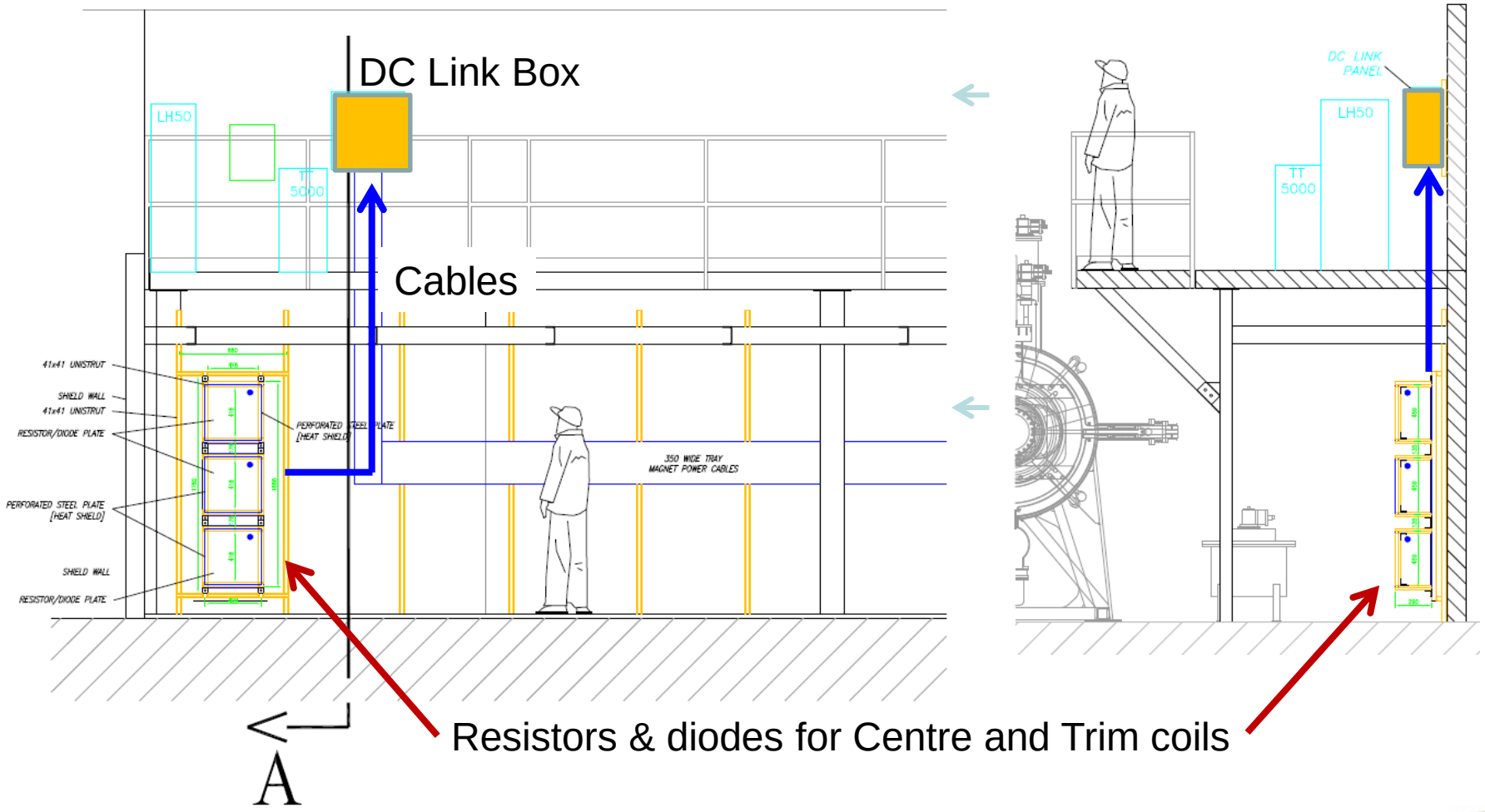
Drawing indicates the position of the DC link Boxes and DC cable management.

DC Link box

SSD – DC link box

- Connection at the DC link box is preferred as it allows access for polarity reversal.
- There are NO spare terminal blocks in the DC link box to allow installation of new cables.
- New busbar links are being manufactured to allow additional cable terminations.
- Cable length can be minimised if the resistors are be located near DC link box.
- Locating resistors inside the PRY has been avoided due to confined space issues.

Hall location for SSU Centre and Trim Resistors



Hall location for SSU Centre & Trim resistors

- Location under the mezzanine is currently occupied by equipment.
- Some equipment can be removed and the diffuser - compressed air junction box can be relocated.
- Cable tray already exists and can be used to minimise installation.
- Cable lengths will be approx. 5 metres

Hall location for SSD Centre & Trim resistors

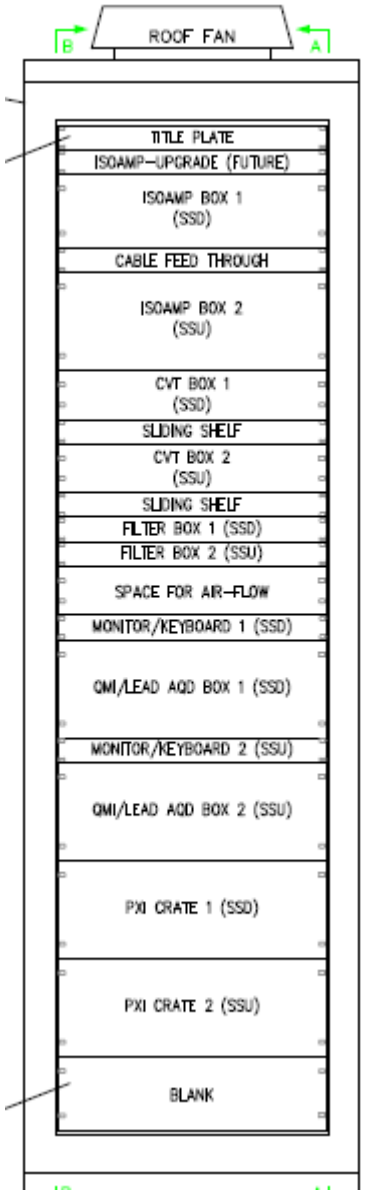
Proposed position for the SSU Centre & Trim resistors is behind steel wall.

Position of SSD DC link box

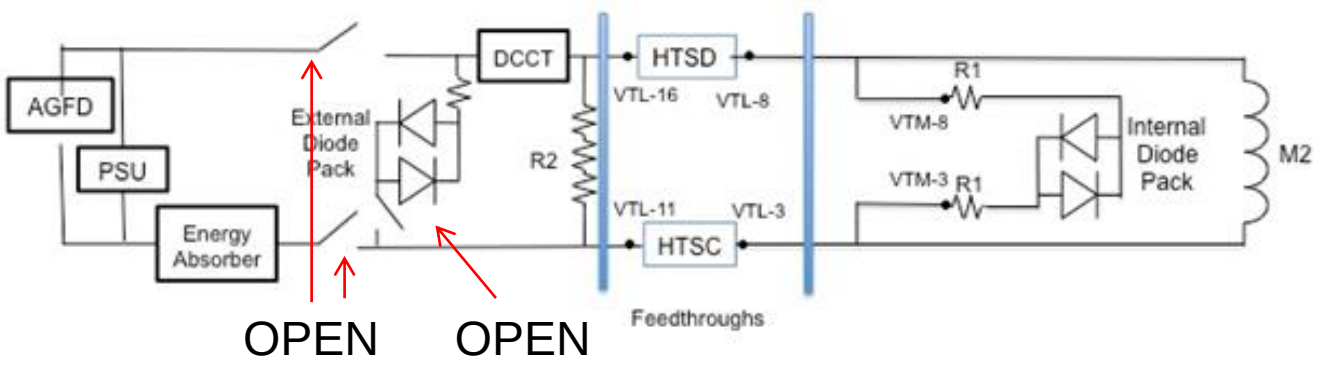
Hall location for SSD Centre & Trim resistors

- Resistors for the SSD Centre & Trims will be mounted behind the steel wall.
- This is close to the DC link box and will minimise cable installation.
- Exact positioning needs to be drawn.
- Due to controlled access during SSD operation the resistors will need to be covered.

SS Quench Detection Racks



- 2 control crates have been sent back to FermiLab for modification.
- These will provide triggers for the power supply DC contactors and the energy absorber DC contactors.
- During a quench in the any of the coils the power supply DC contactors will be opened.
- If a quench occurs in the HTS or LTS leads then all DC contactors will be opened.
- SS Quench protection rack is densely populated.
- Additional equipment needs to be housed inside the rack including cRIO unit, auxiliary power supplies and a DCCT interface.
- Location of this equipment is to be agreed.



Emergency-Off Procedure

SS PSU Racks

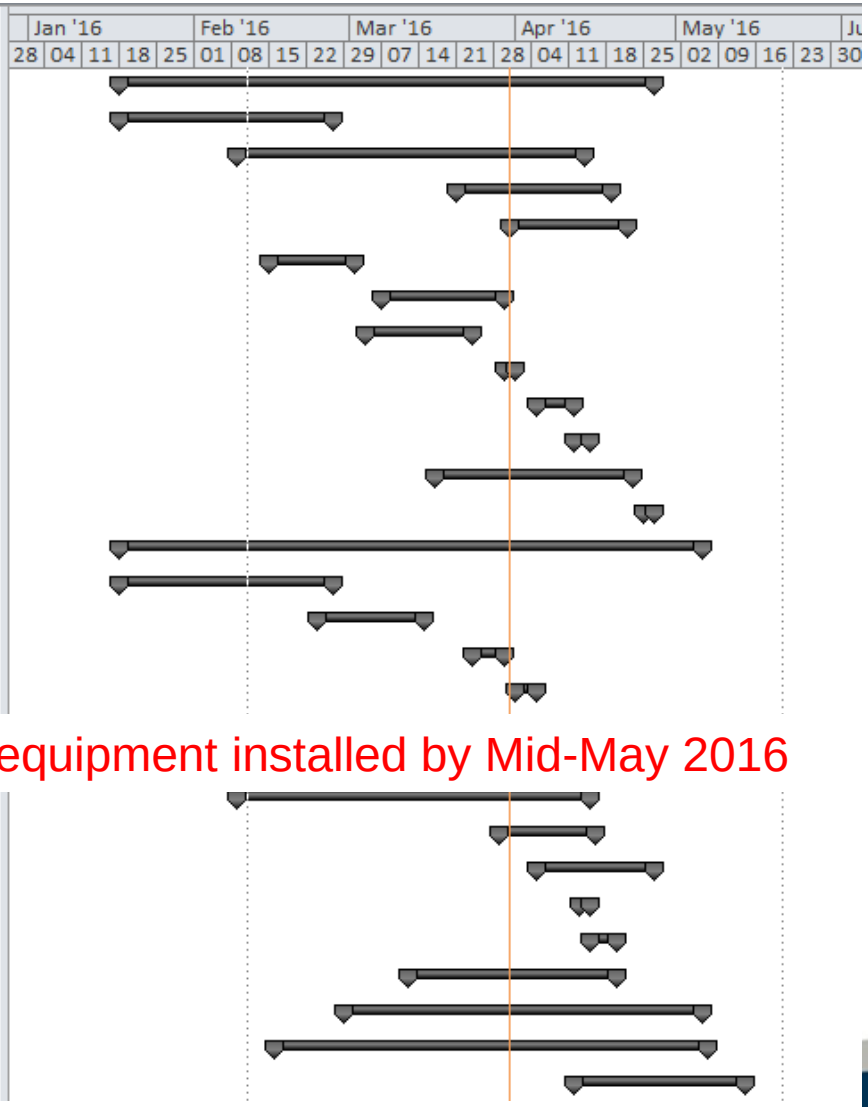
- Emergency-OFF buttons are already installed on the SS power supply racks
- There is No emergency-OFF button on the FC power supply rack.
- These Emergency-OFF buttons need to ramp the current to zero without reliance on software.
- An Emergency-OFF button is to be installed on the FC power supply rack and will interface directly with the AMI 430 controller.
- This will ramp the current to zero at the programmed ramp rate. (approx. 30ma/s)
- The SS Emergency-OFF button will directly trip the power supply DC contactors.
- This will ramp the current to zero at a rate dictated by the circuit parameters. (approx. 200ma/s)

Emergency-OFF procedure (cont.)

- Note the rack mounted Emergency-OFF buttons are for individual magnets only.
- A master Emergency-OFF button is being considered.
- This will be located near to the entrance to RR2.
- This Emergency-OFF button will ramp to zero all cooling channel magnets.
- It is envisaged that the ramp rates will be the same as the individual Emergency-OFF buttons.
- A risk assessment of the FC & SS will be required to validate the procedure.

Electrical Project Plan

Task Name	Duration	Start	Finish	Pre
SSU	70 days	Mon 18/01/16	Tue 26/04/16	
Design	30 days	Mon 18/01/16	Fri 26/02/16	
DCCT	45 days	Tue 09/02/16	Wed 13/04/16	
Match Resistors	19 days	Mon 21/03/16	Mon 18/04/16	
Centre & Trim Resistors	16 days	Thu 31/03/16	Thu 21/04/16	
SSU Absorber Trays	12 days	Mon 15/02/16	Tue 01/03/16	
RR2 Racks	15 days	Mon 07/03/16	Tue 29/03/16	
Modify SS energy absorber rack	14 days	Fri 04/03/16	Wed 23/03/16	
Modify SSU power supply rack	2 days	Wed 30/03/16	Thu 31/03/16	
Modify Controls rack	5 days	Tue 05/04/16	Mon 11/04/16	
Commission SSU changes	3 days	Tue 12/04/16	Thu 14/04/16	
Emergency OFF	25 days	Thu 17/03/16	Fri 22/04/16	
System Commissioning	2 days	Mon 25/04/16	Tue 26/04/16	
SSD	77 days	Mon 18/01/16	Thu 05/05/16	
Design	30 days	Mon 18/01/16	Fri 26/02/16	
SSD Absorber Trays	14 days	Wed 24/02/16	Mon 14/03/16	
Modify SS energy absorber rack	2 days	Thu 24/03/16	Tue 29/03/16	
Modify SSD power supply rack	2 days	Fri 01/04/16	Mon 04/04/16	
Modify Controls rack	2 days	Tue 12/04/16	We	
Commission SSD changes	2 days	Thu 14/04/16	Fri	
DCCT	46 days	Tue 09/02/16	Thu 14/04/16	
Match Resistors	14 days	Tue 29/03/16	Fri 15/04/16	
Centre & Trim Resistors	16 days	Tue 05/04/16	Tue 26/04/16	
Emergency OFF	2 days	Wed 13/04/16	Thu 14/04/16	
System Commissioning	3 days	Fri 15/04/16	Tue 19/04/16	
SS QP System	25 days	Sat 12/03/16	Tue 19/04/16	
SS Anti-Icing heater Tapes	47 days	Mon 29/02/16	Thu 05/05/16	
Oxygen Depletion System	57 days	Tue 16/02/16	Fri 06/05/16	
SSU Training	24 days	Tue 12/04/16	Fri 13/05/16	
SSD Training	8 days			



All SS equipment installed by Mid-May 2016

Electrical Systems commissioned by End of May 2016

Questions?