Temperature Corrections to LHC Magnet Busbar Resistances & Summer in Review

Alex Tuna
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Advised by Mike Koratzinos, TE-MPE
The Crash – 19 September 2008

Start-up tests began 10 Sept 2008

- Current in dipoles ramped up at 10 A/s
- Bad splice can’t handle current
  - At 9 kA, splice melts and arc forms
  - He\(^2\) cryostat punctured, spills into vacuum
  - Temperature and pressure spikes
  - Magnets displaced, incapacitated

[1]
TE-MPE to the Rescue

Relevant Tasks

- Finding bad splices
- Determining safe current
- Comparing 80K, 300K data
TE-MPE to the Rescue

- After reviewing our approach to high current splices following the incident, it became apparent that splices where the copper stabilizer is discontinuous and is not in good contact with the superconducting wire pose a threat.
- These bad splices can only be measured at non-superconducting temperatures.
- The measurement is easier at room temperature but is also possible at around 80K.
- It was decided not to warm all sectors to room temperature, so some sectors were measured at 80K.
Recent Developments

Current plan:

- Cool all sectors
- Accelerate beams to 3.5 TeV
- Shut down, fix, and hope for 7 TeV
Introduction to TE-MPE

Odd jobs

Comparing data

80K vs 300K
Comparing TE-MPE (speed) and in TE-MSC (accuracy) measurement methods
80K vs 300K

Projecting 80K measurements to 300K

Warm vs Cold Resistance | A45 Dipoles

\[ y = 7.696x \]
\[ R^2 = 0.987 \]

A45 Dipole Bus Resistances | 80K and 300K

Cold data
Warm data
Skills Learned

- Microsoft Excel
- Perl
- Timber
- LHC Magnets
Main Project – Temperature Correction

Temperature fluctuations result in resistance fluctuations.
First Step – Temp. Gauges

Average Temperature | 08Jul09 00:00-23:59UTC
Next Step – Fill in blanks?

Average Temperature | 08Jul09 00:00-23:59UTC

74 Empty gauges + 9 Bad gauges
Filling in blanks – Temp. fitting

Temperature patterns form in cryogenic subsectors at both 80K and 300K

Guess – temperature can be fitted piecewise
300K Data

Temperature Data | 25 June | A45 L5

Temperature Data with Pol1 Fits | 25 June | A45 L5
Temperature Data

Temperature Data | 24July | A81 L1

Temperature Data with Pol Fits | 24July | A81 L1
Plots of $\Delta R$ vs $\Delta T$

Small temperature change
- $\rightarrow$ small resistance change

$\Delta R$ vs $\Delta T$ should be linear, $\Delta$CorrectedR vs $\Delta T$ should be flat

But small $\Delta R$ can mask excess resistance, esp. at low T

Indicates success of temperature correction
Raw Temperature Data

$\Delta R$ vs $\Delta T$ | 25Jun09 and 08Jul09 | A45 Dipoles
Raw Temperature Data

ΔCorrectedR vs ΔT
Raw Temperature Data – Sys. Bias?

ΔR vs ΔT | 25Jun09 and 08Jul09 | A45 Dipoles

ΔR [μΩ]

ΔT [K]
Raw Temperature Data – Just R4

ΔR vs ΔT | 25Jun09 and 08Jul09 | A45 Dipoles
Raw Temperature Data – Just R4

ΔCorrectedR vs ΔT

Temperature Correction

ΔR [µΩ] vs ΔT [K]
Raw Temperature Data – Just L5

\[ \Delta R \text{ vs } \Delta T \mid 25\text{June}09 \text{ and } 08\text{Jul}09 \mid A45 \text{ Dipoles} \]
Fitted Temperature Data – Just L5

ΔR vs ΔT | 25June09 and 08Jul09 | A45 Dipoles
Some side projects

Calibrating new Biddle

CLI/Scripting for Timber
Cultural Experiences
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Sources

  “RB_80k_generic_official”. 31 July 2009.