Advanced electrical quality assurance methods for the series production of the superconducting coils of the HL-LHC high order corrector magnets

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The industrial production of 54 High Order (HO) corrector magnets and their 510 NbTi superconducting coils posed Quality Assurance (QA) challenges. Standard and custom QA methods were adopted for the analysis of the electrical parameters of the coils. This poster discusses their sensitivity and the final observed effectiveness on the series production. In some cases, the methods led to Early Defect Detection (EDD) thus avoiding possible severe damages already observed in a prototype magnet. Link video by SRV and Saes Getters

I. HO CORRECTOR MAGNETS

INFN – LASA follows the design, prototyping, construction and test of 54 HO corrector magnets for the HL-LHC interaction regions, from skew quadrupole to dodecapole

Superferric design
- ~50% of the field by racetrack NbTi coils + ~50% by laminated iron
- Compact and modular, few components easier to industrialize w.r.t. other magnets

Construction was awarded to industry ➔ How to maintain the high-quality production standards over a relatively large series production of special components?

II. PROJECT STATUS

Series production completed, ~50% of the magnets tested and found compliant, ~40% of the magnets delivered to CERN

Test at LASA are proceeding, present schedule: all magnets delivered to CERN by Sep. 2022

CERN acceptance ongoing. MCSXF01 first HL-LHC series magnet accepted in memory of Giovanni Volpini

III. SERIES PRODUCTION CHALLENGES

Challenges
- Learning curve
- Manufacturing defects & human factor
- New specifications
- Design changes
- Production constraints
- Large number of tests

Key tools
- Stringent QA methods (in coop. with CERN)
- Good communication with the firm
- Flexibility (new spec. or schedule)
- Fast prototyping and testing
- Dedicated test station with automation

IV. ELECTROMAGNETIC COMPARISON (ECCO)

The number of turns is checked through a custom measurement setup optimized through FE simulations and automated with LabVIEW for its industrial use

1. Repeatable results over the large coil production
2. Five coils with measurement above threshold
- 6p: coil #4, #5, 8p: coil #1, #2, (12pm: coil #27 discussed in par. V)
- Measurements compatible with predictions for one turn less
- Root cause: new operator and insufficient details in the winding procedures

V. SURGE TEST

Surge test at V0 = 2 kV to detect internal insulation defects
1. Very good sensitivity: down to 1 turn over 754, up to 10 G turn short over 100 mΩ turn resistance
2. Repeatable results over the large coil production
3. One coil with measurement above threshold: interlayer short in the fault of MQSXF01

VI. IMPEDANCE COMPARISON

The impedance Z(0) is the “electrical ID card” of the magnet

Measured at warm for the sake of production control, the information is then extracted by means of a 5-parameters fit

Repeatable results for all magnet families
Example: measurements for the 10p corrector

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