Design challenges and manufacturing status of field regulated systems

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INTRODUCTION

More and more users prefer to have magnets with field regulated power supplies instead of usual current regulation. Although these systems present the advantage of being user-friendly, they must be carefully designed and calibrated to guarantee an easy end-user experience. Main challenges in the design and calibration of such system are presented below through two examples.

CHALLENGES

Magnetic design

Location of the probe is a key issue as space can be reduced sometimes.

Glued on the pole?
Glued on the vacuum chamber?
Assembled inside the pole/yoke?

If groove in the yoke, be careful of field homogeneity and saturation.

Hall Probe glued on pole for a quadrupole

Power supply / regulation / calibration

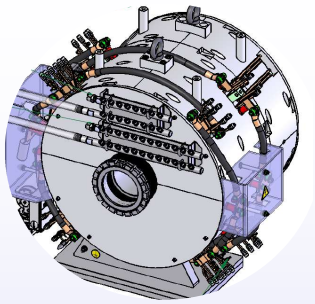
Great care must be taken when choosing the Hall Probe:
- Bandwidth
- Quality factor
- Stability and fidelity

Supplementary field regulation loop must be programmed in the command and control system, considering Hall Probe parameters.

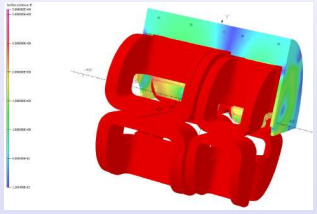
Possible choices for power supply topology:
- Thyristor controlled rectifier
- Switch mode : switch frequency shall be cross-checked with Hall Probe design

System calibration during field mapping:
- Regulation Hall Probe measured field VS measurements in good field region.
- Integration of calibration data in the command and control power supply software.

EXAMPLE 1 : QUADRUPOLE DOUBLET FOR ANL



Quadrupole doublet assembly

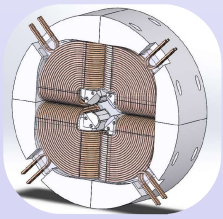


OPERA calculation of the doublet

Quadrupole Q1
- Bore diameter 70mm
- Max pole field tip : 0.9 T
- Max Gradient : 26.8 T/m
- Magnetic length : 140 mm
- 7 kW

Quadrupole Q2
- Bore diameter 150mm
- Max pole field tip : 0.74 T
- Max Gradient : 10.3 T/m
- Magnetic length : 300 mm
- 15.5 kW

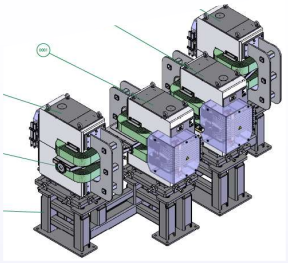
Power supplies
- DC monopolar
- Regulation accuracy : ± 0.1%



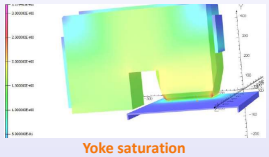
Quadrupole singulet Q1

Status
- contract signed in June 2016
- manufacturing completed
- measurements in progress
- delivery in June 2017

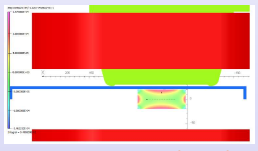
EXAMPLE 2 : DIPOLES FOR ELI



4 dipoles assembled with vacuum chamber



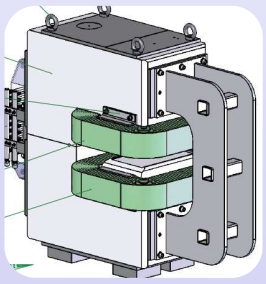
Yoke saturation



Field homogeneity (<4.10⁻⁴)

Field regulated C-shape dipoles
- Gap > 50mm
- Bnom : 1.2 T
- Magnetic length : 450 mm
- Required homogeneity < 5.10^{-3} in GFR ± 20mm, ± 50mm (H x V)
- common vacuum chamber
- 40 kW max (total for the 4 dipoles)
- Hall probe glued on the lower pole

Power supplies
- DC monopolar
- Field regulated stability : 1 Gauss
- Time response < 1s with 10 Gauss accuracy



Dipole overview

Status
- contract signed in September 2016
- manufacturing in progress
- measurements planned in August
- delivery in September 2017

Conclusions

Great care must be taken when designing a field regulated system. The probe location must be wisely chosen as it can affect the field homogeneity. Hall probe model and quality are also important and must be suitable for the chosen power supply topology. Calibration during magnetic measurements is the last important step, as regulation system is based on this data. By mastering all products and technologies necessaries for a field regulated system (magnets, power supplies, measurements systems), Sigmaphi is your preferred partner for your next project.