

# ROXIE - THE ROUTINE FOR THE OPTIMIZATION OF MAGNET X-SECTIONS, INVERSE FIELD COMPUTATION AND COIL END DESIGN

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## **Abstract**

The ROXIE software program package has been developed for the design of the superconducting magnets for the LHC at CERN. The software is used as an approach towards the integrated design of superconducting magnets including feature-based coil geometry creation, conceptual design using genetic algorithms, optimization of the coil and iron cross-sections using a reduced vector-potential formulation, 3-D coil end geometry and field optimization using deterministic vector-optimization techniques, tolerance analysis, production of drawings by means of a DXF interface, end-spacer design with interfaces to CAD-CAM for the CNC machining of these pieces, and the tracing of manufacturing errors using field quality measurements. This paper gives an overview of the methods applied in the ROXIE program.

## **1 Introduction**

The LHC magnet system consists of 1232 superconducting dipoles and 386 main quadrupoles together with about 20 different types of magnets for insertions and correction. The design and optimization of these magnets is dominated by the requirement of a extremely uniform field which is mainly defined by the layout of the superconducting coils. Even very small geometrical effects such as the insufficient keystoneing of the cable (cable inner and outer diameter not following curvatures of circles), the insulation, grading of the current density in the cable due to different cable compaction and coil deformations due to collaring, cool down and electromagnet forces have to be considered for the field calculation. In particular for the 3-D case, commercial software has proved to be hardly appropriate for this task. Therefore the ROXIE (Routine for the Optimization of magnet X-sections, Inverse field calculation and coil End design) program package was developed at CERN for the design and optimization of the LHC superconducting magnets. It is now also more and more applied in institutes outside CERN. The development of the program was driven by three main objectives:

- To write an easy-to-use program for the design of superconducting coils in two and three dimensions considering field quality, quench margin and persistent current multipoles.
- To include the program into a mathematical optimization environment for field optimization and inverse problem solving.
- To include appropriate methods for the calculation of the iron magnetization without meshing of the coil and
- to develop an integrated design tool with sophisticated graphic routines and interfaces to CAD-CAM systems for the making of drawings and manufacture of coil end-spacers.

## **2 Coil modeller**

As will be explained below, the use of a reduced vector potential formulation in FEM or the application of the BEM-FEM coupling method does not require the meshing of the coil for the numerical field calculation of iron saturation effects. Therefore the coil modelling and yoke modelling parts are completely separated.

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