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Mon-Af-Po1.15-06 [38]: Expansion of the magnetic field in toroidal harmonics and correlations with the current distribution

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Toroidal magnets are widely exploited in industry and scientific research, involving a vast spectrum of applications, such as thermonuclear fusion, particle detectors, SMES systems and medical devices. Toroidal configurations may involve different number of coils of different planar and three-dimensional geometries; to properly analyse these systems, it is crucial to determine the magnetic field generated by various configurations.

The multipole expansion theory in the complex plane is widely adopted to describe the magnetic field of particle accelerator magnets with straight axis. The main advantage of this analytical description is the possibility of identifying multipolar field components of the magnetic system and use them to predict the interaction of a charged particle beam with the field itself. In this case, the correlation between current distribution and field harmonics is well known.

The multipole expansion theory can also be applied to the analysis of toroidal configurations, by solving the Laplace equation for the magnetic scalar potential in toroidal coordinates. In this case however, the correlation between the current distribution and the field harmonics cannot easily be identified.

This paper proposes a methodology for the determination of the field harmonics in toroidal coordinates. The starting point of the model is the calculation of the magnetic scalar potential, based on a hybrid analytical-numerical approach, which was validated versus well-established software for electromagnetic calculations.

The developed algorithm was applied to explore the correlation between the shape and number of coils disposed along the torus and the multipolar components generated by the magnetic system. A specific focus on non-planar configurations and corrector coils is presented, reporting the effect on the field harmonics of various geometric solutions.

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