Handling the ill-posedness of current retrieval in power lines from magnetic field data using Tikhonov regularization method

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An inverse source problem of reconstructing the currents in parallel conductor structures from magnetic field data is considered. In this kind of inverse source problems which arise in contact-free measurements of currents in bus bars, power lines, and cables, the magnetic field data collected by a set of sensors in the vicinity of the conductors is used to determine the currents in conductors. The method is based on inversion of the direct map from the currents to the magnetic field data using a proper model of the problem.

A significant deteriorating factor in this inverse source problem is the disturbance magnetic field from sources in the vicinity of the conductors. To handle this difficulty, a truncated spherical harmonic expansion with unknown coefficients is proposed to express the external disturbance field. Thus, the measured magnetic field in each measurement point is considered as a linear combination of currents in conductors and expansion coefficients. Therefore, a linear equation system is obtained with currents in conductors and expansion coefficients as the unknowns and currents can be reconstructed by solving this linear equation system.

Regarding truncating the expansion to a finite number of spherical harmonics, it should be noted that a too small truncation number cannot handle the disturbance field whereas a too large number increases the sensitivity to noise. Indeed, due to the ill-posedness of such inverse problems, the results become highly sensitive to noise, errors in the measured magnetic field, and deficiencies in the models by increasing the number of terms in expansion. Therefore, Tikhonov regularization method is used to solve the mentioned linear equation system. Discussion about how to choose the optimum regularization parameter is also presented.

Normally, in an out-door measurement situation with the ground under the power lines, the field from induced currents in the ground affects the measured magnetic field. Although this field can be considered as part of the external field, if the ground characteristics are known with reasonable precision, an alternative is to include a model of the conductivity in the ground in the method. Both alternatives are investigated in this study.

Several numerical examples are presented to demonstrate the performance of the algorithm with and without using regularization method as well as with and without modeling of the ground. The examples show that the proposed method can handle noisy field data and errors in the positions of the currents.