NONLINEAR INVERSION OF CROSS-WELL ELECTROMAGNETIC DATA IN METALLIC CASED WELLS

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Electromagnetic (EM) methods are essential tools for the appraisal of a reservoir because of their sensitivity to the formation resistivity which is a function of the fluid saturation. One of the traditional EM techniques for well logging is the induction single-well measurement. This technique is employed to estimate near well-bore resistivity. It has a sensitivity of up to a few meters from the well and is a function of the separation between the transmitters and receivers as well as the frequency of operation. To reach deeper into the reservoir, a cross-well EM induction technology was developed. The system operates very similar to the single-well logging tool however with transmitters and receivers deployed in separate wells. During a cross-well survey the receivers are lowered into one well, initially to the bottom of the survey-depth interval. Then the transmitter is lowered into the second well and is moved to log the entire survey-depth interval. During logging the transmitter broadcasts EM signals at a number of pre-prescribed frequencies while at the receiver well these signals are recorded. After the transmitter run is completed the receiver array is moved to the next depth station in the survey interval and the process is then repeated until the entire depth interval has been covered. After the data set has been collected, an inversion process is applied to obtain the resistivity distribution between the wells.

However, because most of the existing wells are cased with steel pipes, the measured data can deviate from those without casing. Hence, in order to process the data correctly the so-called casing effects need to be removed before the inversion process can be started. We present two approaches to remove the casing effects in the measured cross-well EM data.

The first approach is the so-called data ratio inversion method where we invert for the interwell conductivity distribution from the ratio of two data points. For two data points collected at the same transmitter location, the method will correct for the casing effect at the transmitter well, and for two data points that are collected using the same receiver, the method will correct for the casing effect at the receiver well. In this way there is no need to estimate the casing coefficients prior to carrying out the inversion of the conductivity distribution between wells. The drawback of this data ratio inversion method is that by taking the ratio of data we also unintentionally reduce the signal to noise ratio.

In order to deal with this drawback, we introduce a modified cost function in the inversion algorithm where we avoid taking the ratios explicitly. In this approach, the so-called casing coefficient inversion method, the casing coefficients are reconstructed as part of the optimization process to reconstruct the conductivity distribution. By designing the appropriate cost function, we are able to robustly estimate the casing coefficients and at the same time reconstruct the conductivity distribution. The attractive feature of this approach is that it does not affect the signal to noise ratio. Inversion results of synthetic and field data will be presented in order to demonstrate the pros and cons of both approaches.