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Next-Generation Crosswell EM Imaging Tool

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Abstract

A new crosswell electromagnetic (EM) tool, now in field test, provides unique means to remotely sense the resistivity between two wells without having to drill an intermediate well. The wells can be open hole or cased with fiberglass, nonmagnetic chromium steel, or ordinary magnetic carbon steel.

This tool allows one to determine the resistivity distribution between wells spaced up to 1000 m apart. It is an induction measurement with a large magnetic field transmitter in one well and sensitive low-noise receivers in a second well. The transmitter generates a time varying field in the frequency range of 5 Hz to 1000 Hz. Since the transmitter and the receivers are not at a fixed position, the primary field cannot be cancelled as in conventional induction tools. Instead, the receiver senses the primary field of the transmitter combined with the secondary field produced by the formation between the wells. This secondary field increases with frequency of operation, formation conductivity and spacing between wells. In general, a high-frequency measurement with large formation effect is combined with a low-frequency effect to provide a geometry correction for the wells.

Data from multiple transmitter and receiver positions are processed through a two-dimensional non-linear inversion algorithm to produce a resistivity image of the formation between the wells. A priori information about the formation as well as conventional well logs are used to constrain or improve the image. Although the performance of this technique is strongly dependent upon the specific problem, the resulting image can be used for detecting bypassed oil, or in a time-lapse application, it can be used to monitor the movement of a reservoir or of injected fluid.

This paper presents the unique tool features, the survey planning process, and factors important for success as well as modeling and measurement examples. In addition, sensitivity to frequency and the starting model used as the initial step in processing the data to an image are examined.

Introduction

Traditional resistivity logging tools measure the formation resistivity at a distance of a few inches to perhaps ten feet from the wellbore. This is generally sufficient to determine the properties of the formation beyond the invaded zone and to characterize the formation near the wellbores. There are no commercial tools that directly measure the resistivity at large distances from the wells. The crosswell EM tool is designed to meet that need, providing resistivity measurements at reservoir level. This capability is important as in mature fields fluid movement typically occurs over periods of years or decades. Whether the field is undergoing primary production or enhanced production, it is important to be able to identify the movement of fluids at distances of hundreds or thousands of meters from the wells.

Although crosswell EM logging has existed since the mid 1990s (e.g., Alumbaugh and Morrison, 1995a; Wilt et al., 1995) recent industrial interest coupled with advances in technology have enabled the development of a next-generation system that we have named Cross-well EM Resistivity. This system provides significant advances in terms of measurement accuracy, resolution, logging speed, field operations, modeling, and processing tools.