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Numerical modeling of array induction log or tool (AIT)

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Extended Abstract

Summary

Resistivity logs are among the most important logs since their measurements are directly related to hydrocarbon saturation. Conventionally, Chartbooks as theoretical response of logs are used for interpretation of electrical logs. One dimensional (1D) computer codes are the cornerstones of chartbooks. These codes solve Maxwell's equations by ignoring layer inclination, non-uniform mud invasion, shoulder bed effect and well deviation. Simplifying the geometry of the model introduces significant amount of error in the interpretation of resistivity logs. Consequently, it is necessary to utilize complex numerical models for interpretation of the logs.

The main objective of this paper is to present numerical modeling of array induction log or tool (AIT). The numerical modeling enables us to understand the response of the tool in different well and reservoir situations. Proper understanding of the response of the tool improves the accuracy of interpretation of the logs and reduces the risk of logging jobs in the harsh conditions.

For verification of the model, the resistivity logs were constructed in a multi-layer model. The modeled resistivity logs were in good agreement with the true formation resistivity values in thick layers but conversely, in the thin layers, the performance of the model was not acceptable.

Sensitivity analysis was performed on the frequency, the transducer-receiver spacing of AIT and the resistivity of mud. In higher frequencies, due to skin effect, the tool is not able to measure the true resistivity of the layer. Increasing the transducer-receiver spacing does not affect the accuracy of the AIT while it decreases the vertical resolution of the tool. In wells where the conductivity of mud is below 1 S/m, the AIT tool cannot be run.

Introduction

Wireline logs indirectly measure the petrophysical properties of hydrocarbon reservoirs. The most important logs are electrical logs because they determine the amount of hydrocarbon in the pore space of the study reservoir. Since the invention of electrical logs in 1927, many researchers have investigated new methods to improve the accuracy and precision of the interpretation of electrical logs. Chartbooks, forward modeling, inversion and three dimensional (3D) numerical modeling are the main approaches for the interpretation of resistivity logs. In this paper, AIT, as a modern resistivity log, which is frequently used in oil industry, was numerically modeled to understand its behavior in hydrocarbon reservoirs. The results of the paper improve interpretation methods and give geometrical properties of reservoirs, and also, optimize the log acquisition plans.

Methodology and Approaches

Ansys-Maxwell electromagnetic simulator has been used to numerically model AIT. It numerically solves the Maxwell's equations in a specific geometry and calculates the vectors of magnetic field. All details of the tool including number of coils, distance of transmitter and receivers, materials of coils, frequencies and electrical current have been identical to the real tool.

The modeled AIT tool has also been calibrated in a multi-layers formation model. The calibrated model has been utilized to calculate the geometrical factor of shallow, medium and deep arrays. Moreover, sensitivity analysis has been performed on the frequency, transmitter-receiver distance of the tool and the resistivity of borehole mud.

Results and Conclusions

Numerical modeling of AIT enables us to analyze and predict the behavior of AIT in different logging conditions,

formation properties and geometry. In this research, it has shown that the AIT accurately measures the resistivity of thick layers but it lost its accuracy in measuring the resistivity of thin beds. The sensitivity analysis, made in this study, has demonstrated that the measured resistivity linearly depends on the frequency of transmitter. Skin effect masks the response of AIT in high frequencies and leads to improper measuring of resistivity. Precise modeling of AIT helps us to design a domestic version of the array induction tool, which is customized to the characteristics of Iranian reservoirs and borehole conditions.