Radar geosteering in Geothermal Reservoirs

Or

Development of Radar-Controlled Directional Drilling Bottom Assembly for Geothermal Reservoirs

by
Larry G. Stolarczyk, Sc.D.
Stolar Research Corporation
848 Clayton Highway
Raton, New Mexico 87740

INTRODUCTION

Medium-radius horizontal directional drilling in geothermal reservoirs offers the potential for increasing the recovery of minerals from brine and the heat transfer rate in hydrothermal electricity generation. The technical challenges to be overcome in developing horizontal directional drilling technology are many. Exceedingly high reservoir temperatures require technology breakthroughs in designing electronics that can withstand the high-temperature environment. Geosteering of the bottom-hole assembly (BHA) requires low-frequency radar with antenna arrays with side- and forward-looking antenna patterns. The radar requires an electric-power generation supply and automated control signals for the gimbals. Solving these technical problems requires breakthroughs in the current state of the art.

Assuming that these technical challenges can be overcome, horizontal boreholes lined with high-temperature pipe can use super-heated steam to generate electricity using closed-circuit turbines. Because the construction area extends over the horizontal cross-sectional area of the geothermal reservoir, the heat transfer can be maximized using multiple horizontal boreholes. The possibility of using distilled water circulating in a closed system eliminates the extreme scaling problem experienced in highly mineralized geothermal reservoirs, reducing the operating cost of producing electricity.
Radar-controlled directional drilling can intercept geothermal reservoirs where brine flow pathway density maximizes. This paper describes the development of the radar-controlled drilling hardware.

Approach to Solving the Exceedingly High-Heat Problem

The radar already has been designed to meet military temperature specifications.
The basic radar design temperature specification is substantially below the geothermal reservoir temperature; the reservoir temperature exceeds 600 °Celsius.

Additional mechanical design steps are required. The electronics have been designed to be mounted on 1-in.-wide, multilayer printed wiring boards. These boards fit inside of thin-wall titanium vacuum-tube enclosures. The vacuum tube enclosures employee shock absorber centralizes for NQ drilling pipe. The drilling system may use air or mud drilling fluids to power the downhole cutting motors.

Beam-Forming Antennas

A composite NQ drill rod has been developed to withstand high temperatures. Using the composite drill rod enables low-frequency radar electromagnetic waves to propagate through the sidewall of the composite pipe and detect anomalous geologic structures located at least a skin depth from the well head. A radar antenna array has been developed with a focused beam that is steerable by phase control. Beam steering enables side- and forward-looking capability. The detection and sensing distance is limited by the electrical isolation between the transmitting antenna and receiving antenna.
A significant increase in isolation, hence detection range, in slight to moderate electrical conductivity geothermal reservoirs has been realized with patent-applied-for transmission processes. The transmit-antenna-to-receive-antenna suppression is a breakthrough setting a quantum leap forward in the state of the art.

Radar Electronics

The radar electronics design features a software-definable transceiver. The software controls both the magnitude and phase of each frequency component that is simultaneously transmitted in the radar signal. The predistortion in the radar signal overcomes the frequency and phase shift transfer function of the radar signal transmission path. Nonstationary problems are resolved so that the frequency-to-time domain transforms can be stationary, simplifying range-to-target determination. The software processing enables downhole control of the geosteering mechanism in the BHA gimbal.

Electric-Power Generation

A high-temperature titanium-enclosed three-phase hydrodynamic turbine has been developed for geosteering with sufficient power to operate the radar and gimbal.

Conclusion

The radar enclosures have been designed for an NQ bottom-hole assembly and down-the-hole drill motor. The radar can be used with medium-radius coiled tubing drilling machines.

Acknowledgement

The radar was developed with partial funding provided by the U.S. Department of Energy (DOE) Mine of the Future program. The coil tubing drilling system bottom-hole assembly development was administered by the National Engineering Technology Laboratory in Morgantown, West Virginia. Additional funding was provided by the DOE Initiative for Prevention of Proliferation Program administered by the DOE Kansas

City Plant with technical oversight provided by the Albuquerque Operations Center, Kirkland Air Force Base.