Full Field EM Monitoring

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Abstract

Increasing production efficiency and monitoring water/CO2 floods are key issues to be addressed with borehole and surface technologies. At the same time linking the information to 3D surface seismic data and borehole data is required to extrapolate in the inter-well space and find the sweat spots between wells and in the 3D reservoir space. Electromagnetic has the strongest coupling to the fluid content of the reservoir while seismic can delineate impedance contrasts or lithological boundaries.

Present logging technologies only reach about 3 meters away from the well bore. Deep reading techniques are still in commercial field trial stage. Surface electromagnetic techniques are presently proposed and only used for monitoring in engineering geophysics. The reason lies in the higher order sensitivity decay with distance from the target. A logical conclusion is to combine methods not only to sense different physical reservoir properties but to also overcome the weakness of each method and to approach the problem in a synergetic fashion.

We evaluated several monitoring methods and technologies leading us to a practical concept of Full Field Fluid Monitoring (F3M). Our implementation includes marine and land sources and receivers, surface-to-borehole arrays and single well system that can look tens or even 100 m around and ahead of the bit. Except for the single well component all systems are well past the research phase and we have carried out various parts of field trials.

The enabling technology is a multi-component cable we are building for marine application which can measure magnetotellurics as well as controlled source EM signals. It allows much denser, cost efficient, semi-permanent or permanent operation and can be combined with nodes to cover a larger footprint with wider spacing. Similar technology with a variety of fit-for-purpose telemetry can be used onshore. For borehole use we are combining our EM sensor packages with borehole seismic acquisition system or build special purpose LWD sub-assemblies. In all case the data can be acquired and streamed over the internet to allow efficient operation.

One of the major learning during the various projects was that surface electromagnetic methods alone are ambiguous if they are not used in combination with surface-to-borehole measurements. The reason lies in the up-scaling issues associated with the inherent averaging EM methods do.