Autonomous Monitoring of Production

P-222 FEW0082

Program
This project was selected in response to DOE's Natural Gas and Oil Technology Partnership Upstream FY 2001 call for proposals on oil and gas technology to increase U.S. production.

Project Goal
The project goal was to demonstrate a semi-autonomous system that delivers data of sufficient quality to monitor small changes resulting from production over time without additional drilling or intensive investment of manpower. Key project elements were to produce time-dependent maps of changes in formation resistivity caused by production or stimulation, utilizing existing infrastructure without interruption of field production/stimulation activities.

Performer
Lawrence Livermore National Laboratory (LLNL)
Livermore, CA

Project Results
Results from this project were the construction, testing, and demonstration of a data-acquisition system for electrical resistance tomography (ERT) that would allow remote operation. The system works through a combined land-and-satellite communications link that allowed remotely set system parameters, data collection, monitoring of system health, switching the system to waiting mode, and retrieving data for processing.

Benefits
One goal of this work was to reduce the cost of long-term (3-10 years) geophysical monitoring of oilfield operations by using a single measurement system that could be operated remotely to produce data for a large (hundreds of acres) area. The project accomplished this by control of the data-acquisition system, through a land-and-satellite communications link, that allowed researchers to remotely set system parameters, initiate data collection, monitor system health, switch the system to waiting mode, and retrieve the data for processing. The system could be left in place for several years, saving considerable travel and manpower costs, and yet allows frequent sampling of the reservoir. A demonstration of the system was accomplished as part of the work at Buckeye, NM, a relatively remote site where frequent data acquisition, requiring frequent site visits, was rather expensive.

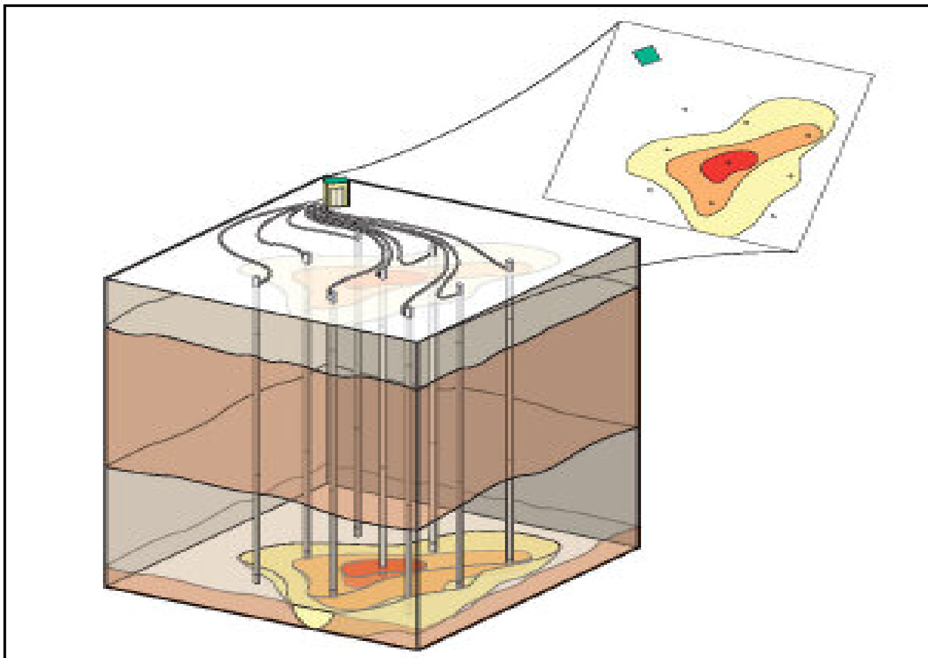
Illustration of long electrode electrical resistance tomography.

Technical improvements include:

• Decoupling the downhole casing from surface piping (using insulating subs at the surface) and improving signal-to-noise ratio.

• Establishment of a data-acquisition system (permanently installed in the field and designed to operate autonomously). When information is desired, the operator calls the system up, initiating an acquisition sequence.

• The system acquires data in an unattended mode, stores and transmits the data stream, and shuts itself down. Alternatively, the system can be programmed to obtain data periodically on its own.

• The most important benefit of this technology is a new and better method for monitoring stimulation during oil production.

Background
Oil production is commonly assessed by measuring bulk oil produced at the wellhead. Operators want to know what portions of the reservoir are being drained or swept and where significant oil-in-place remains. Some survey techniques can be field-deployed but provide low-quality information and are expensive relative to the knowledge gained. These techniques often require interrupting production to acquire data. Electrical methods such as ERT are well-suited for monitoring processes involving fluids in exploration and production activities, as electrical properties are sensitive to the presence and nature of the formation fluids.

Recent communication and computational improvements have made it possible to obtain high-quality 3-D electrical tomographs providing the equivalent of electrical logs deployed every few feet between existing wells. Thus formation characterization and monitoring of subsurface fluid movement are possible, even over time where fluid saturations can be used to map swept and unswept zones and can help guide infill development to recover hydrocarbon from these areas. This project demonstrated a semi-autonomous system that delivers data of sufficient quality to monitor small changes resulting from production over time without interrupting production or drilling or requiring intensive investment of manpower.

Project Summary
A semi-autonomous monitoring system was designed and installed in an oilfield undergoing CO_2 injection and waterflood. Issues addressed included system design, worker safety, signal-to-noise ratio, and

remote access. Numerical simulations were performed to aid in system design and to assess signal strength under realistic injection scenarios. Multiple hardware types in the field enabled the assessment of system impacts under different operating conditions.

The remotely operated system successfully monitored operations over a year. Time-lapse data correlated with the production history. Changes in electrical properties correlated with displacement of oil by water and movement of water and gas in the production intervals.

The methodology is quite straightforward. Using well casings as electrodes for electrical imaging permits long-term and relatively inexpensive surveys of stimulation or production. While this field-monitoring capability is new, it constitutes an extension of already proven technology and has a high expectation for success. Although ERT imaging is usually performed in a crosswell configuration using arrays of electrodes placed along insulated casings, project researchers developed a means for acquiring and interpreting data using existing metallic casings as long electrodes, requiring no downhole modification. Data are interpreted using existing tested computer codes that treat the fully 3-D case. The products are time-dependent maps of the horizontal changes in formation resistivity caused by stimulation or production (if horizontal casings are available, some vertical resolution may be provided as well). These data can be interpreted to infer fluid behavior during production.

The general-purpose communication system that was developed has the flexibility to support different kinds of remote experimentation or data-gathering activity; this system is called GET-NET. The remote local area network (LAN) has a data-acquisition and control laptop computer that front-ends the long-electrode electrical resistance tomography (LEERT) instrumentation. Through the firewall/virtual private network device, the remote LAN is connected to the satellite network using an internet protocol-enabled satellite modem.

The most important benefit of this technology is a new and better method for monitoring stimulation during oil production—a direct result of the fact that the electrodes used for ERT are already scattered throughout the reservoir (the cased wells). No new "monitoring" wells are needed. Any well casing can be used as an electrode if it reaches to the depth of the formation of interest. This means that the capital cost for doing LEERT is very small. Considering that the cost of a monitoring well can be as high as $1 million, this advantage can make the difference between a method being practical or impractical and thereby the difference between used or not used.

Well casing can be used irrespective of what else the well is used for or what it contains. It may be a production well, an injection well, or even a monitoring well and still be used as an LEERT electrode. The only real restrictions are that the casing must be steel (no insulators such as fiberglass) and in good electrical contact with the formation. If it is a production well, then production tubing need not be removed for the casing for it to be used as an electrode. Production can continue uninterrupted, another significant cost benefit. Similarly, if it is an injection or monitoring well, its original function is unaffected.

LEERT requires minimal field personnel to operate, thereby minimizing survey costs. Moving sondes in boreholes for logging or crosshole tomography, or moving sources and receivers on the surface for reflection seismology, is time-consuming and expensive. The cost of a 3-D surface seismic survey can run $1 million or more. Conventional borehole geophysics is less expensive but has an upfront cost as well as a downtime cost. In contrast, steel well casings used by LEERT are all connected to a central multiplexer and are chosen automatically as a current source or for voltage measurement by an appropriate switching algorithm. It's all done automatically and with no moving parts.

For any monitoring method, the time interval between surveys is generally limited by the survey costs and the reluctance to remove wells from production. In contrast, LEERT can be used as a truly long-term monitoring tool, capable of nearly continuous imaging but not limited by mobilization, survey, downtime, or demobilization costs. LEERT can provide on-demand, real-time continuous imaging.

Current Status (August 2005)

Project funding was terminated during the field demonstration. As a result, final field testing and sensitivity analyses were not completed, which prevented transfer of the technology and training of a commercial partner(s). However, a company that provides ERT services could quickly make this technology commercially available. Equipment and software used in the project are at LLNL.

Publications

Daily, W., A. Ramirez, R. Newmark and K. Masica, Low-Cost Reservoir Tomographs of Electrical Resistivity, The Leading Edge (May, 2004) v. 23, I 5, 472-480.

Ramirez, A.L., R.L. Newmark, W. D. Daily, Monitoring Carbon Dioxide Floods Using Electrical Resistance Tomography (ERT): Sensitivity Studies, Journal of Environmental and Engineering Geophysics, (September 2003), v. 8, no.3, 187-208.

Newmark, R.L., A. L. Ramirez, W. D. Daily, Monitoring Carbon Dioxide Sequestration Using Electrical Resistance Tomography (ERT): A Minimally Invasive Method, 6th International Conference on Greenhouse Gas Control Technologies (GHGT-6), (September 30-October 4, 2002), Kyoto, Japan, UCRL-JC-148146.

Website:
http://www.llnl.gov/IPandC/technology/profile/environment/ElectricalResistanceTomography/index.php

Project Start: June 12, 2001
Project End: June 11, 2004

Anticipated DOE Contribution: $560,000
Performer Contribution: $0

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