OTC 13006

Visualization of Oil, Gas, and Water in the Subsurface

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Abstract

Tracking the flow of oil, gas, and water in real-time while reservoirs are being drained is now possible through the emergence of rugged downhole sensors, the Internet, high bandwidth satellite and fiber communications and rapid middleware wrapping of software applications. The question is what information delivers economic return on the investment required. The good news is that all along the value chain, prices are coming down because of commercial pressures from outside the energy business. For example, Direct PC will likely drop the cost and increase the bandwidth of satellite communications to remote locations by an order of magnitude over the next few years.

Application

The manufacturing process by which we produce energy is being reinvented like we have never before experienced in this business. The oil and gas field of the future will be part of a much larger Information Technology (IT) network. Each field will be a wired, internet-connected, real-time monitored, remotely controlled, electronic venture. Each well, pipeline, rig, production platform, compression facility, and even the pumpers themselves, will have a IP (Internet Protocol) address. Any browser on any laptop in the company (with proper password protection) can log onto the myoilcompany.com URL at any time of the day or night -- from anywhere in the world -- and visualize production, well test, logging, and other real-time measurements coming from the 4D monitoring of field performance.

Results and Observations

However, there are fundamental reasons why such an integrated IT system for the oil and gas field is a difficult mission for the energy industry to pull off successfully. Principal among them is that the "last mile," as it is called in the communications industry, (the field connectivity to the manufacturing facility itself) is about as difficult an IT environment as could be imagined. Other IT savvy manufacturers around the globe also deal with multiple vendors, millions of customers, and millions of parts as we do, but our SITE of manufacture of energy products is NOT usually in a metropolitan area with communications infrastructure in place. Instead, it is found in whatever water depth or remote geography (usually rural) the oil and gas happens to be discovered beneath. And then, of course, the "very last mile" to the resource itself is under the ground and cannot be visited, or even imaged clearly.

Not only must energy companies deal with a constantly changing set of IT vendors and bandwidth constraints from field to field, but each must be specified from the start to operate continuously for 30+ years, as part of an internet-connected portfolio. In the future, oil and gas fields will form an information grid with other fields, pipelines, land, and sea-borne traffic, refineries and storage facilities, etc. that form the complete enterprise of the company (Figure 1).

Significance

Because of the tremendous scope of the energy industry, IT improvements that create even a small percentage increase in business productivity have a significant impact in absolute dollar terms on profitability. That statement is true for all sizes of company, from the smallest of independents to the largest of the super-majors and nationals. The successful implementation of integrated IT systems and processes has proven to result in increased profit margins in other manufacturing businesses throughout the world (Wal-Mart and Toyota are perhaps the best known examples). IT driven process improvement within these other industries has been extensively documented to reduce overall cost by a staggering 30% to 40%! The survivability of even some of the world's best known energy companies may well depend on their successful implementation of this integrated IT infrastructure that produces what we call the networked "myenergycompany.com" of the future.

But implementing a real-time communications and data-streaming infrastructure that connects the oil and gas field to the home office is only the beginning point. What must be improved is the integrated system itself: the enterprise-wide design/build/operate/support system-of-systems necessary for “game changer” improvement in the manufacturing process. The complete range of digital asset tracking, logistics, warehousing, computer-aided manufacturing, business (to say nothing of geological) simulation and optimization loops common to "easier" manufacturing industries (like automotive, aerospace, and pharmaceuticals) are not yet fully deployed into the energy industry.

It may seem funny that we are describing a "myenergycompany.com" world of integrated IT systems management at a time of great transition in the "dot.com" world, both inside and outside of the energy business. e-businesses are in a state of flux all over the oil patch, as new portals dealing with a range of "commodity" services, such as surplus equipment sales and property auctions, seem to be opening, closing, and merging every day. The paradigm shift we are talking about, however, is corporate-wide, and involves electronic linkages of virtual and real data, events, operations, supplies, and people into an advanced digital enterprise currently only active outside the energy business -- with the possible exception of the energy trading floor.

Visualizing 4D Reservoir Management

4D reservoir monitoring is the measure of the changes over time of the physical and fluid states of an oil and gas field. As such, it integrates cased-hole logging, permanent down-hole sensor emplacement, 3D seismic re-shoots, production history matching and reservoir simulation into a near-real-time understanding of what's going on inside the reservoir. The visualization of fluid behavior underground is continually updated, so the reservoir simulation gets more and more accurate as the oil field ages.

4D has been actively in development at major oil and service company research labs throughout the 1990's, so that there are now enough case histories to document benefits versus costs. Benefits come from more recovery of PUD's, proven and possible reserves. Costs come from added expenses related to 3D seismic acquisition, sensor emplacement, computing related to seismic processing and reservoir simulation, and cased-hole logging programs. The trick is to evaluate the risks of success or failure by balancing costs versus production volume and recovery efficiency increases projected forward in time to account for possible oil and gas price fluctuations.

The early evidence suggests that we are seeing significant improvements in production emerging from the added expense of 4D reservoir monitoring. All oil and gas fields have a log-normal performance profile, with production falling off exponentially over time from initial peak production. The real question is not if 4D reservoir monitoring improves production, but whether it instead just gets the oil and gas out of the ground faster. The latter is valuable in itself because of the time-value of money, but the added cost of 4D makes it necessary that more oil and gas must be ultimately recovered as well. That means that 4D must not only move production forward in time, but it also must extend the productive life of the oil and gas field (Figure 2). Data has now been reported for the early effects of 4D reservoir monitoring on the production and depletion rates for eight oil and two gas fields from the Gulf of Mexico, South Atlantic, Southeast Asia, and the North Sea (Figure 3). Not only does it appear that depletion rates are slowed, but the bigger the field, the greater the effect. Big fields are getting bigger because of 4D reservoir monitoring.

Detecting Reservoir Problems before they Happen

The modern asset team visualizing an oil field live over the web can continuously update the reservoir model with new information coming in daily from the field. Reservoir and seismic simulators can be recalculated over and over again to reach an optimal solution that best matches both the geophysical and geological data from the reservoir to anticipate problems before they damage productive wells. Resolution is now such that fluid content in 20x20x20 foot "voxels" or building blocks representing the subdivisions of the reservoir can be monitored. Think of being able to build a physical model of your reservoir on the computer using these "Lego blocks". Pull rates for the producing wells and push rates of injectors can be controlled and patterns modified to best drain the hydrocarbons in not just the fastest, but also the most efficient manner. The importance of being able to visualize the reservoir at this "micro" level cannot be overstated. This resolution comes from the fact that the reservoir model integrates the resolution of all the different data sets being input into it. As the years go by, the model gains more and more resolution and accuracy.

With this added resolution and advanced understanding of how the fluids are draining over time, production disasters can be avoided through more active management of the wells. For example, water coning from voxel to voxel can be monitored in the 4D reservoir simulator, and remedial action taken before oil migration to perforations is permanently disrupted. Water produces a recognizable seismic signal in many reservoirs that can be detected by repeated time-lapse imaging using 4D seismic re-shoots. Also, gas breakthroughs can be often imaged in the same way.

4D Reservoir Management in the Oil Field of the Future

This brings us to the future oil field. Although 4D reservoir monitoring is an emerging technology now, it is not yet being used in all new developments that are important to the industry. However, that is about to change, because the technologies that make up 4D are riding the combined wave of the Internet, the bandwidth explosion in global communications, and miniaturization of sensor technologies. Consider the monitoring of a new multilateral well recently drilled in the Gulf of Mexico by a major operator. Fiber optic monitors were active downhole from day one in the life of this well. The sensors are from CiDRA, a high technology spinout from United Technologies that is developing fiber optic technologies for the telecommunications AND oil industries, simultaneously. The data is transmitted by satellite from the wellhead to London and Houston over the Internet, and fed into the reservoir simulator daily.

Next generation fiber cables will hold three component seismic sensors every few feet all the way up and down each well. Remote 4D seismic sound sources will wander new fields acquiring focused "3D" acoustic interrogations of trouble spots in the reservoirs as needed. 4D technologies such as these are truly "disruptive" rather than incremental. It is a fundamental change to replace one-time measurements of an oil well's performance with continuous, time-lapse visualization and computational optimization over the Web. The improvement in how much oil and gas we can recover from fields can be dramatically improved if our profession is at all analogous to other industries where such disruptive events have followed cascades of complementary technical breakthroughs.

Consider the bandwidth available to your company's local area network (LAN). A 10 gigabit Ethernet has just been perfected that costs $5/switch. In five years, the network will be faster than even our most advanced workstations. Already, the Internet has overwhelmed old fashioned "bricks-and-mortar" companies with transactional speeds that outperform any human bargaining by several orders-of-magnitude. What will our offices be like when the slowest communications device we have is our PC?

This increased bandwidth will revolutionize not only the oil field of the future, but also the business processes of the future Oil Company. Business-to business, e-services, integrated technical solutions, and finally business intelligence systems will sweep across the world's oil fields. Industry best-practices will be cross matched with value drivers for their suitability in each field using a computational matrix that is multi-dimensional. Technologies that are appropriate for each field (and they are different for each) will be deployed with a vast array of computational and visualization tools supplied by software application services providers over the WorldWideWeb. Automated data schemas, and automated intelligence systems will be used to produce fluid state engines for new fields the likes of which we cannot even imagine today. The results will be more production that is delivered faster to market at lower costs-per-barrel.

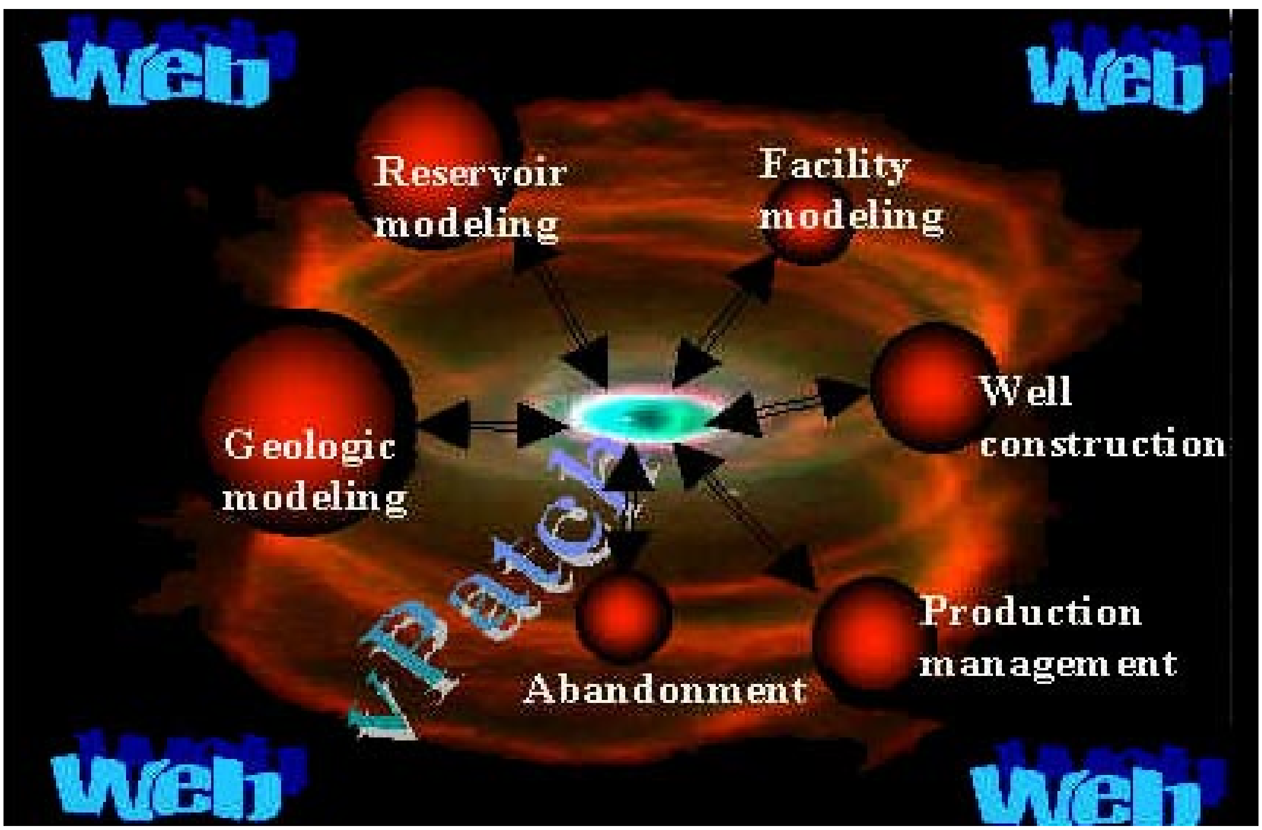
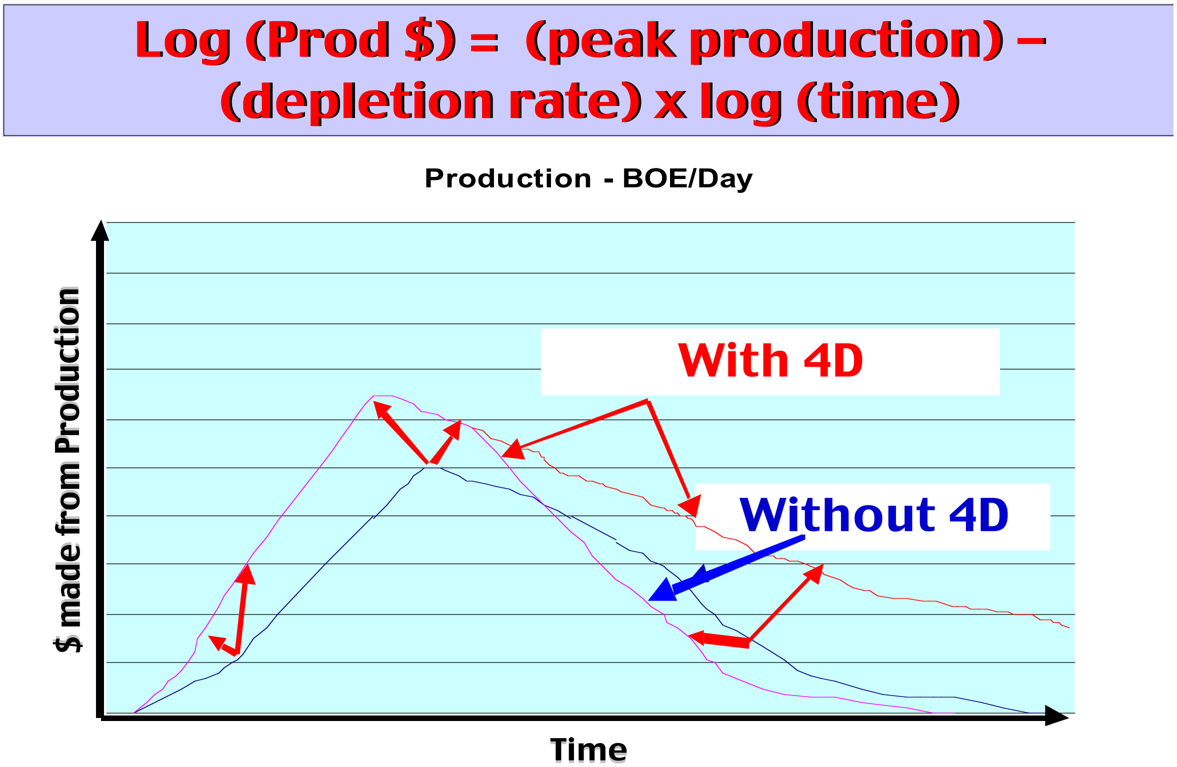


Figure 1. The wired, virtual oil patch (vPatch) will allow instant access to field monitoring of all the company's operations and visualization over any laptop with proper access codes from anywhere in the world.



Source: vPatch.com

Figure 2. 4D Reservoir Monitoring brings more oil and gas to market, sooner.

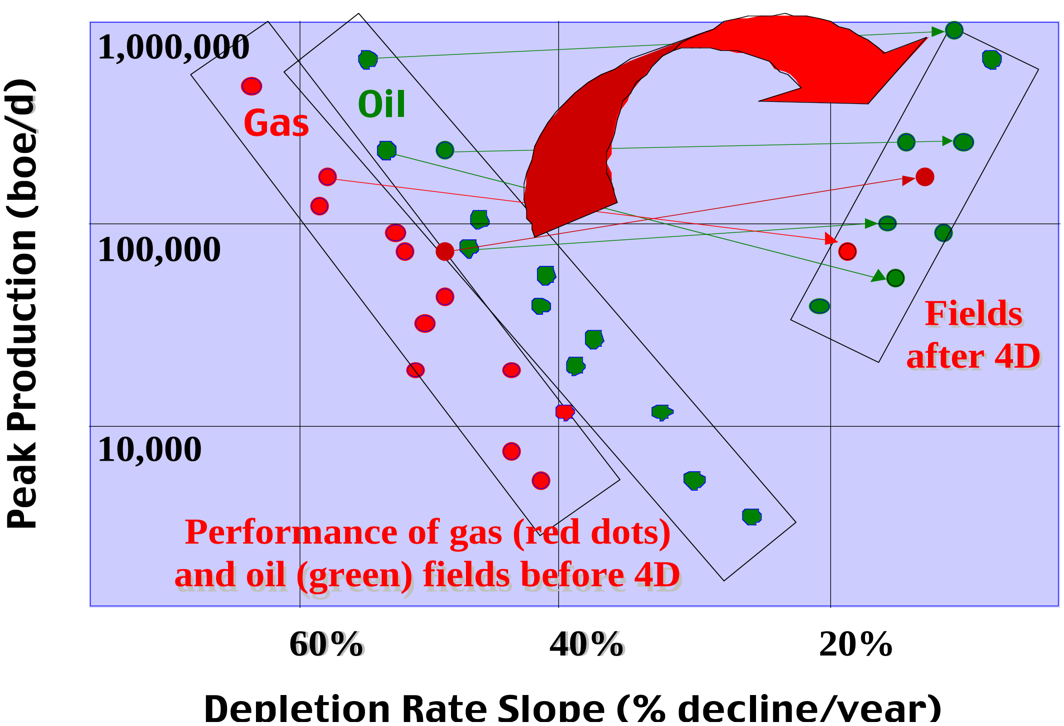


Figure 3. Monitoring results suggest that the slope of the decline curve for oil and gas fields is extended by 4D monitoring, as well.