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Machine Learning Helps Production Engineers Optimize Artificial Lift

By Jesse Filipi and Brian Arnst

HOUSTON–Artificial lift optimization is one of the core activities that production engineers and technicians are asked to perform on a daily basis. The emphasis on optimizing the performance of artificial lift systems is particularly important in today's operating environment with operators restarting shut-in wells and focusing like never before on improving the overall economics of every producing asset.

By far the most widely used type of artificial lift, rod lift is deployed on horizontal and vertical wells alike in all types of conventional and unconventional fields. Because of the prolific application of rod lift systems, a strong body of best practices exists for designing, operating, and maintaining beam pumps and rod strings. When operators closely adhere to these operational best practices, meaningful increases in field profitability of even the lowest-producing wells often follow.

Despite their differences in the horizontal development and vertical legacy well context, industry best practices to optimize rod lift around efficiency have a consistent logic and methodology. First, wells are diagnosed as underpumping, dialed in or overpumping. Second, based on well classifications, remediating actions increase production or lower the number of wasteful, damaging strokes into the system.

The primary daily operational set point levers to optimize rod lift wells are on/off time, pump speed (strokes per minute) and pump fillage. Following the Pareto principle, these levers represent the lion's share of the value-added changes that an engineer or field technician can make to optimize wells. The third and final step is to apply a change to the control system–whether a pump-off controller, variable frequency drive, or timer–and observe the results to judge success.

Ideally, the optimization workflow is performed for every well on a regular basis. However, this involves significant time and resources to accomplish, and even when done daily, a tiny fraction of available stroke data receives attention and contributes to decision making. The reality is that field personnel have too many wells, too little time and not enough of the right analysis or technology to enable a step-change in profitability.

Sisyphean Tasks

The question that operators have to ask is whether it is beneficial to have their skilled engineers and production managers devoting so much time to performing such Sisyphean tasks. With so many advanced technologies at the ready, does it make sense for production personnel to carry out repetitive, defined logic workflows when they could devote their attention to more complex and nuanced field problems? Would production operations take that next step by following the manufacturing model and allowing machines to automate tasks such as set-point changes?

The answers to these questions are obvious considering that doing so would enable artificial lift experts to do what they do best: solve problems, design solutions, and think strategically to keep wells dialed in at all times and add bottom-line value. Physics-based data science and artificial intelligence, combined with rod lift domain expertise, deliver operators a step-change in operating leverage and optimization capabilities for both horizontal and vertical wells (Figure 1).

Well optimization technology has been driven by high-rate offshore and horizontal onshore shale wells, but there are of course vast numbers of vertical, rod-pumped wells that remain unconnected and uninstrumented. Each of these wells may only make a couple barrels of oil or few thousand cubic feet of gas per day, which tampers the economic case for retrofitting with conventional automation technologies beyond a simple timer.

As a result, wells are visited with an "every well, every day" mentality, where routine generally substitutes for criteria-based route prioritization. Sometimes, these fields are closely bunched together, while other times they span hundreds of miles. This means if wells go down after the daily check, they are down until at least the next scheduled visit.

In reality, operations teams are generally in reactive mode and focused on addressing critical, nonwell-related activities at the central tank batteries or across gathering systems. With hundreds of wells under their management responsibility, pumpers may not look at wells for long periods. Moreover, engineers and field operators charged with managing legacy fields may have 1,000 or more wells under their direction, which means they cannot possibly direct their attention to more than a small percentage of wells at any given time.

Adding to the difficulties in managing these wells is the lack of downhole visibility or remote control capabilities. Resulting optimization efforts occur slowly and inconsistently, generally following heuristics to fill the gap. There is no well data to view, no feedback loop to quantify the impact, and no confirmation back to the office that a change was ever made. This severely restricts any value creation beyond basic maintenance.

Adaptive Control

When there is more work than manual processes can handle and vast amounts of data available to inform decision making, the stage is set for technology to drive step-change improvement in well profitability and even economic life. However, not any technology will tackle the challenges of optimizing fields of wells at scale. AI provides the right

FIGURE 1A

Artificial Lift Operational Hierarchy of Needs

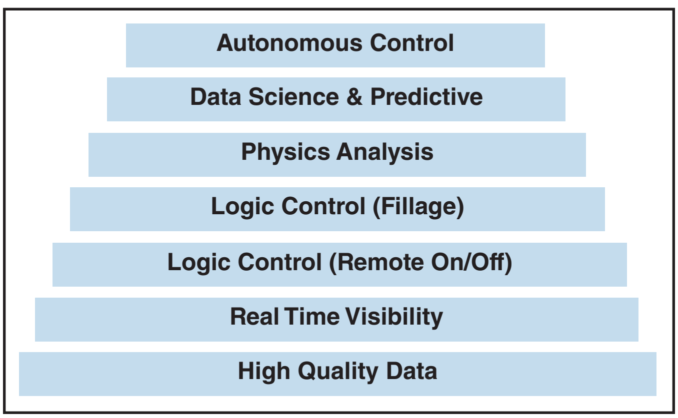


FIGURE 1B

Data Science Hierarchy of Needs

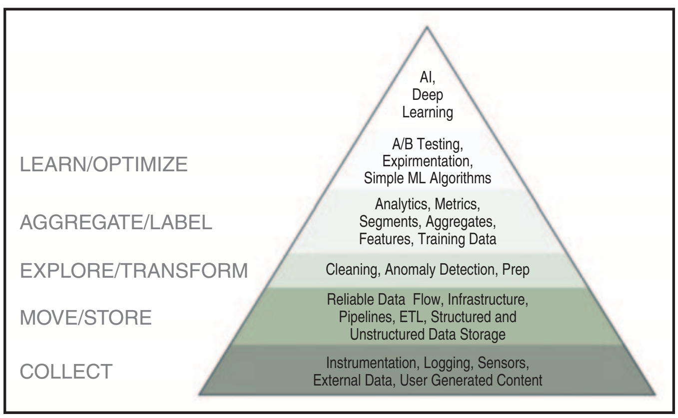
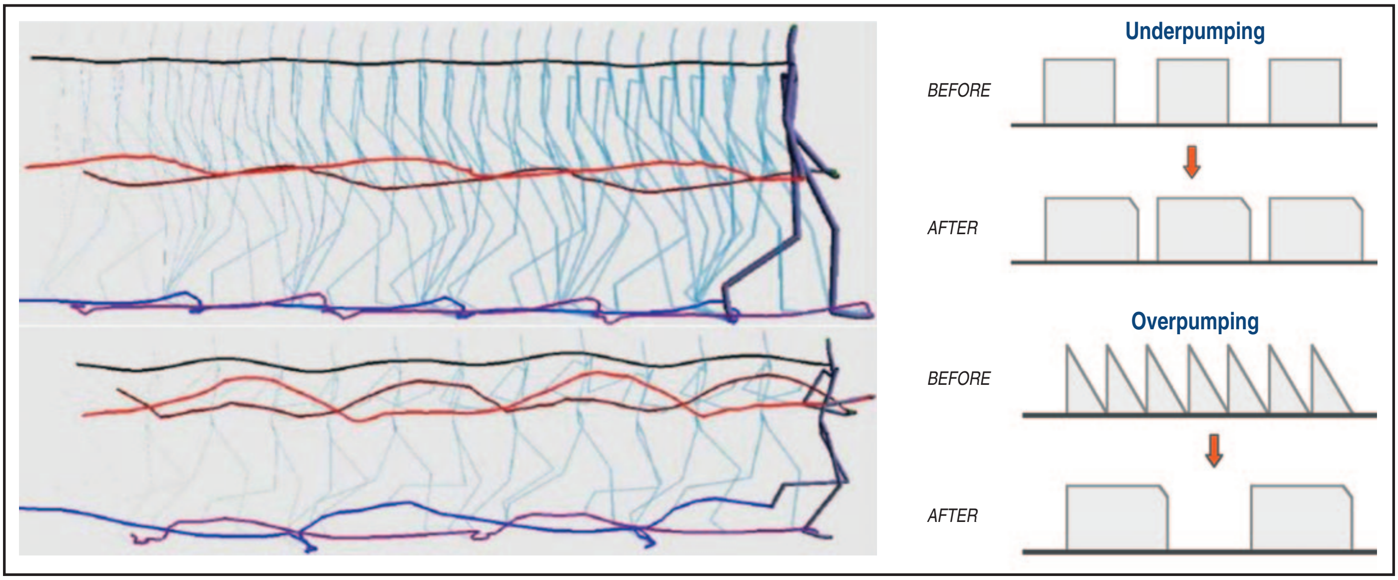


FIGURE 2

Machine Algorithm Analyses of Human Movement (Left) and Well Optimization (Right)



mix of complex problem solving and adaptive control to deliver both pump by exception and optimization at scale. AI connotes many things to many people, but it is technology that is widely deployed in different industries and is well suited for the repetitive, high-value optimization tasks that overwhelm today's operational teams.

The foundation of any AI application is the acquisition of sufficiently complete and detailed data. When connected to a supervisory control and data acquisition network, AI ingests that data easily. When wells lack communications, employing an edge device with embedded communications such as satellite, LTE or WiFi enables sufficiently high-resolution data that can feed an AI engine for consistent analysis and closed-loop control.

Machine learning algorithms analyze an unlimited number of strokes and identify patterns in well behavior. Much like humans, however, machines also require training by domain experts to become truly effective at their jobs. Studies across multiple industries show that even the most accurate machine learning systems involve "humans in the loop," which can account for up to 20% of the solution. This primarily is accomplished either through helping label training datasets or correcting inaccurate predictions to refine the algorithm. In the case of artificial lift optimization, this methodology requires having production engineers collaborate with developers and data scientists alike.

The left-hand image in Figure 2 demonstrates how a machine algorithm effectively detects whether a human is walking or running. Through the use of trained data and neural networks, AI can recognize nuanced differences to classify motion accurately. The human brain, of course, understands the difference immediately. Machines have the same ability, but they rely on different mechanisms to do so.

For an electric motor operating on a marginal well, a similar algorithm can determine on/off cycle well optimization, in which a computer identifies underpumping (walking) or overpumping (running) conditions by interpreting current and torque trends, and turning them into an inferred downhole fillage. This enables insights into both surface and downhole conditions. Optimization occurs without the need for expensive additional sensors. Going a step further, those inputs help classify the well into overpumping, dialed in or underpumping (at right in Figure 2). From there, closed-loop control optimizes the on/off time of the well automatically.

AI reduces wasteful, damaging strokes on overpumping wells, saving costs on electricity and failure remediation. Many of these wells become unprofitable with another failure, and yet their production helps retain leases for future horizontal drilling. Consequently, it is critical to extend the well's run life in the most cost-effective way, and know for certain it produces in paying quantities to avoid losing leases. On the few underpumping wells that do exist on the stripper well side, AI finds the extra barrels and frees critical cash flow.

Similar to a timer, edge-based controller devices tie into the cross/soft starter panel of the electric motor. Above and beyond a timer, the latest generation devices also are connected via embedded communications to provide real-time status and remote set point change capabilities. What's more, these devices can automatically classify wells into one of three categories: overpumping, underpumping or dialed-in.

This is similar to the methodology used for wells with pump-off controllers and variable frequency drives. In lieu of load and position data, which is readily available with POCs, the machine learning algorithm uses the physics-based parameters from the well and the stroke level information from the electric motor to generate the classifications.

AI can execute well optimization set point adjustments more quickly, objectively, consistently and routinely than overtaxed operations teams. This is a win-win for field personnel as they are unburdened by routine optimization changes, allowing them to focus on delivering higher-value tasks. Additionally, management is happy because wells are dialed in, which means they produce more oil and fail less frequently. This approach provides a simple, turnkey end-to-end solution that provides scale without overinvesting to "achieve it all" while increasing cash flow on legacy assets. ❒

JESSE FILIPI

Jesse Filipi is technical director for Ambyint, which provides artificial lift optimization solutions for oil and gas industry applications. He previously served as a petroleum engineer with Marathon Oil, where he was the first field-based production engineer in the Eagle Ford and later managed nearly 1,000 wells in the company's core play. Filipi holds a B.S. from McGill University and an M.S. and M.B.A. from Rice University in material science.

BRIAN ARNST

Brian Arnst is a product manager at Ambyint. Since joining the company in 2018, he has created and implemented cutting-edge data science and artificial intelligence models aimed at establishing autonomous well operations while steering Ambyint's software platform roadmap. Arnst previously served as a production engineer and workover and production supervisor at Marathon. He holds a B.S. in petroleum engineering from Texas A&M University.