NOVEL TECHNOLOGIES FOR EFFECTIVE DATA ACQUISITION AND AUTOMATION ON OILFIELDS

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ABSTRACT

Production engineers rely upon a variety of data streams from the field to optimize production and maintain safe, environmentally responsible operations; without the reliable collection of this information, we cannot do our jobs. Given the challenges of operating assets spread over vast areas and the inadequacies of workflows relying upon manual measurements and communication, automated data gathering & telemetry systems have long been key focuses in the industry. Today, SCADA systems are the established standard to address these issues. They also interface with industrial controllers that allow operators to both acquire data and take remote action.

However, these incumbent systems suffer from severe drawbacks: mediocre data resolution and integrity, high implementation costs and complexity, as well as siloed data streams leading most information to be lost or stranded on the field. This leads to major frictions in the widespread roll-out of automation systems, which are typically only installed on high production assets, and often underutilized due to their excessive complexity. Low data resolution and overall quality also turn out to be major impediments to the feasibility of higher value-added data science use cases such as predictive maintenance. The primary cause of this situation is that these systems remain largely insulated from the trail blazing developments in more open-source technologies that have been fostered by the development of widespread internet services and advancements seen in consumer electronics.

In this paper, we introduce state-of-the-art developments in terms of hardware and computing technologies that leverage those advances to allow low friction, turnkey, high-resolution data collection and field automation. These are combined with novel automated processing frameworks that provide high value insights without drowning users in impractical amounts of data. Ultimately, we show how these developments effectively leverage data points across the field to (1) reduce the cost of monitoring assets by an order of magnitude, (2) minimize the need for routine in-person inspections of leases, and (3) increase production and equipment lifetime while reducing power consumption through optimization.

A NEW FRONTIER IN OILFIELD AUTOMATION SYSTEMS

Traditionally, oilfield automation has been the territory of complex, often limited, but very expensive automation and telemetry systems. Indeed, controllers on the market typically must embed significant processing power in the form of expensive ruggedized industrial computers, thus inflating hardware costs. Installation is also a significant burden, involving major electrical work and often requiring that heavy equipment be brought on site to dig trenches and bury wiring. These systems are usually the product of a long history (as many modern rod pump controllers are direct heirs to the pioneering work of Sam Gibbs), involving sophisticated instrumentation and data processing (for instance in the form of the modified wave equation for rod pumping), but very little in terms of actual control algorithms and self-supervisory capabilities. As a result, while they are great tools for data acquisition and performing basic control logic, they often require constant, tedious supervision – considerable fine tuning and oversight by engineers – to perform optimally.

Simultaneously, communications have historically been a challenge in remote locations where most oil and gas producers operate. This has led to the adoption of solutions such as SCADA setups relying on custom radio networks to retrieve instrumentation data and, in some cases, control the assets remotely. Unfortunately, these systems require significant infrastructure investments and maintenance. They have also become infamous for their very low polling rates and overall complexity. In the context of rod pumping, it is common for operators to be forced to optimize their wells based on a just a few dynacards transmitted each day, while in-depth troubleshooting might require sending a technician on location to physically retrieve the limited history stored in the local memory of the controller.

Ultimately, these factors combine to make oilfield monitoring & control extremely expensive, often not only requiring a significant outlay for the equipment and installation, but custom network and backend staffing to maintain the system, creating additional continuous expenses. Even inheriting existing systems comes with significant hurdles as integration is almost never straightforward.

Combined, these challenges have dramatically held back the potential benefits from automation in the oilfield. Indeed, in our experience it is rare to see any kind of automation on wells producing less than 10 or 15 barrels of oil a day. Even on larger assets whose production justifies the significant cost and operational complexity of adopting some of these legacy solutions, there is a pressing need for more automated optimization and supervision of existing controllers.

In this context, several revolutions have taken place that transform the perspectives of oilfield automation:

- The advent of reliable, long range cellular networks is on the brink of offering a solution to the connectivity issues experienced in the industry, thus removing the need for any custom telecom infrastructure. Leveraging those newer long range, low bandwidth networks (5G networks today, satellite constellations tomorrow) requires a great deal of sophistication in data processing and compression, but continuous, high-resolution instrumentation data streaming is now within grasp (for instance, providing all rod pump dynacards at stroke-by-stroke resolution)
- By unlocking consistent two-way communication channels, these new networks allow for a much greater leveraging of cloud systems. Consequently, many painstaking computations can be offloaded to the cloud while tailored, light-

weight AI models generated at great computational cost, but cheaply run, can be pushed back to edge devices. This allows lightweight, microcontroller-based hardware to replace even the most powerful and sophisticated systems, thus collapsing hardware costs.

- By making high resolution instrumentation data available in real-time in a clean format, data-intensive AI algorithms can be deployed to supervise and optimize operations. In this paradigm, computational resources cease being a barrier to implementation. Another benefit often overlooked is that data from a given set of equipment can readily be augmented with information coming from other parts of the field. A straightforward example of this is the systematic pairing of wellhead and tank data to optimize production in real-time.

Acoustic Wells strives to make the best use of all those windfalls to provide breakthrough fieldwide automation solution. Our solution is designed to be asset-light and easy to install while also providing capabilities far beyond traditional SCADA systems and controllers. In fact, all parts of our well system are shipped within a 12”x12”x6” box and can be installed by a single technician in less than 30 minutes per site.

COMPLETE AND CONTINUOUS MONITORING FROM ANYWHERE

Early in the development of our solution we endeavored to interview nearly a hundred of owners and operators of assets. The feedback we received was consistent in that operators are looking to evolve into true remote field operations, in other words being able to “pump their assets from the office.” Managing this functionality need with the minimum hardware footprint needed to achieve it in an extremely dependable way, we settled on two key points of data collection: the wellhead and the tanks (see **Figure 1**), the latter of which we will focus on here.

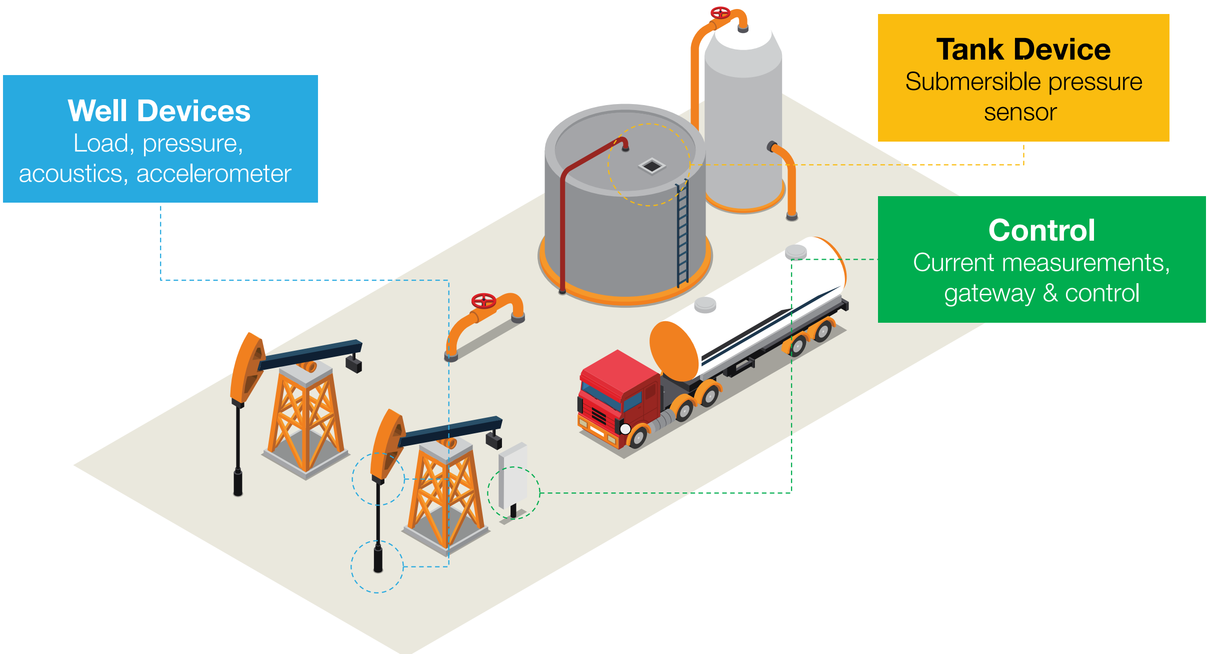

Figure 1 – Full system overview

Acoustic Wells' system was built from the ground up as a fieldwide solution, providing high resolution monitoring of wells and tanks, both oil and water (along with other pieces of equipment such as compressors or saltwater injectors, etc.). **Figure 2** presents an example of the kind of high-resolution data recorded on a simple tank battery consisting of a stock tank and a saltwater tank. While the oil tank data is straightforward, the saltwater tank level is difficult to process for a human due to the high fill rate and the transfer pump frequently kicking in to empty the unit. However, a machine learning algorithm can still process this data to extract useful production information. **Figure 3** gives a sense of the granularity of the water flow rate data that can be obtained from such readings. Interestingly, this well exhibits a significant amount of structured variation in volumes of water produced, which is of interest to a reservoir engineering team.

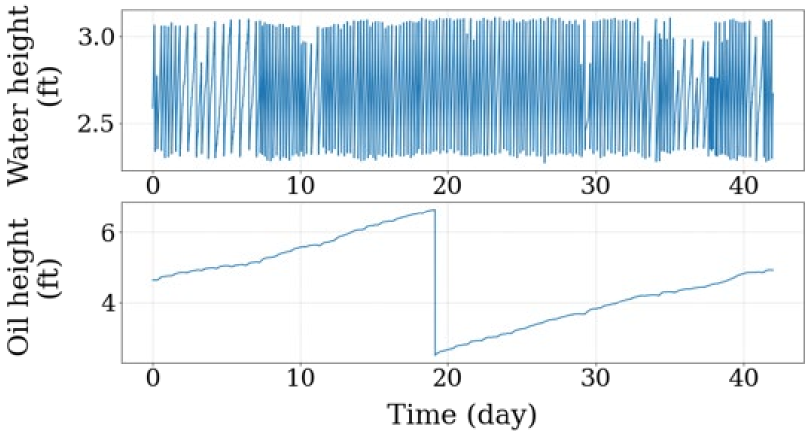

Figure 2 – Salt water and oil tank levels

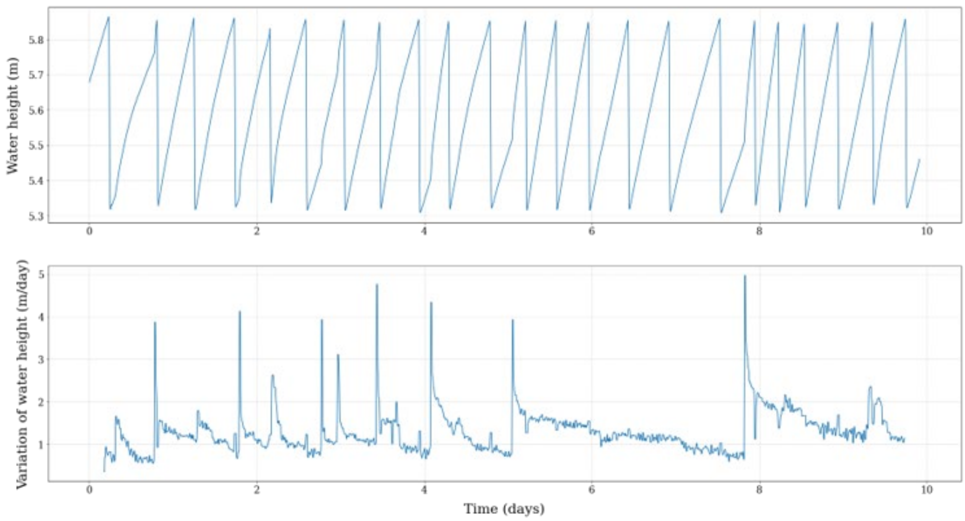

Figure 3 – High resolution water tank fillage data

A key input in the production engineer's workflow is tank inventory data. Unfortunately, on oil tanks it often comes in the way of sporadic sensor readings, or worse, as manual gaging sheets. Additionally, water inventory is often not tracked, even on water floods. This is especially detrimental to the understanding of the field in formations where water makes up the bulk of the produced fluid. Furthermore, somewhat surprisingly, very few well controllers take advantage of this production data to increase their efficacy (*e.g.* by computing accurate pump slippage figures) or provide additional services such as out-of-the-box tank overflow alerts or mitigation (which is typically ensured by additional automation systems).

This native integration of tank monitoring with well control presents many straightforward automation benefits. For instead, it becomes extremely simple to configure alarms shutting down production in case of tank overflow, thus avoiding large remediation costs and environmental violations. This can happen either in the case where a transfer pump fails and is unable to empty a tank, or if a water leg is obstructed and leads to large amounts of produced water flowing to an oil tank.

Fusing this high-resolution tank and wellhead data allows for far more potent applications still. **Figure 4** presents an example where such a monitoring system detected a collapse in oil production while water production increases, leading the operator to diagnose a casing leak. More generally, by fusing tubing pressure data, inferred well production estimated from dynacards and tank level data, one can readily detect surface leaks in real-time (for instance due to damaged flowline).

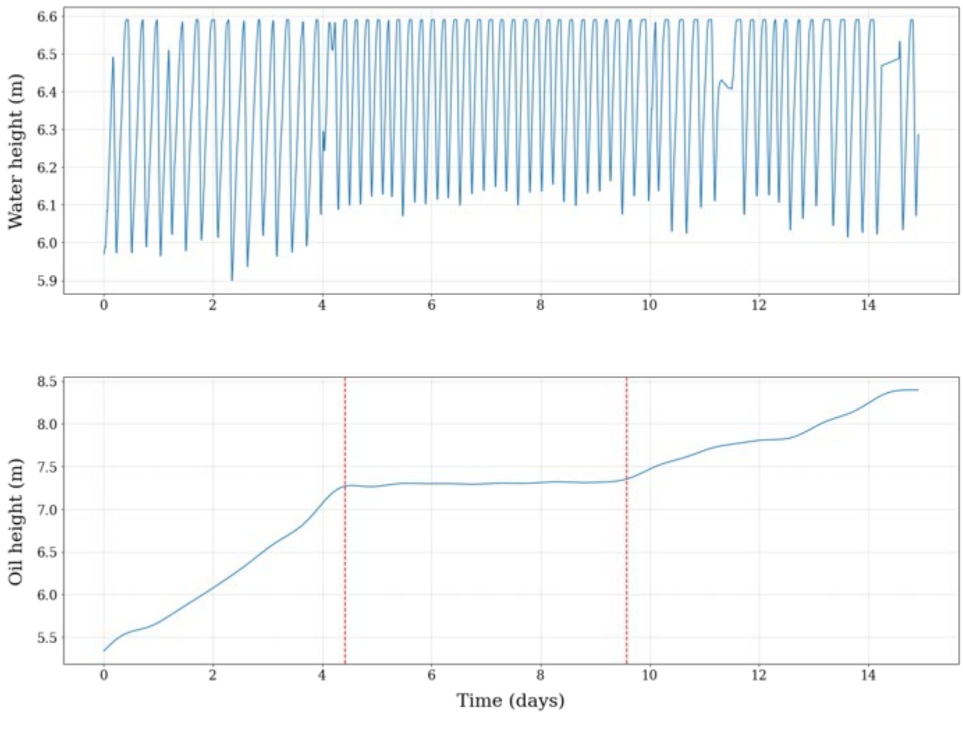

Figure 4 – Tank level data signaling a casing leak

Ultimately, one of the key goals here is to integrate all these data streams to create a virtual flowmeter, allocating the production of a lease to various wells in real time, even when several producers are connected to one tank battery. Here we present the result of this analysis on a lease of three stripper wells. **Figure 6** shows how the production history of the lease can be very accurately reconstructed using runtime (see **Figure 5**) and pump fillage data, allowing us to build a machine learning model providing real-time oil production estimates for each well. The results of this analysis are presented on **Figure 7**. Importantly, on this example we discovered that, unbeknownst to the operator, one of the wells was virtually producing no oil due to a very high water cut. This information was then used to prompt further investigation and prioritize capital allocation to optimize the economics of the field in given the context of high rig demand environment.

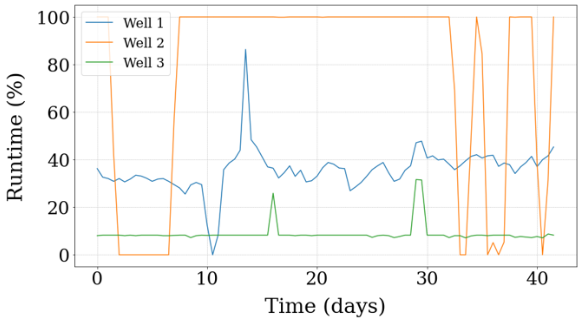

Figure 5 – Wells runtime data

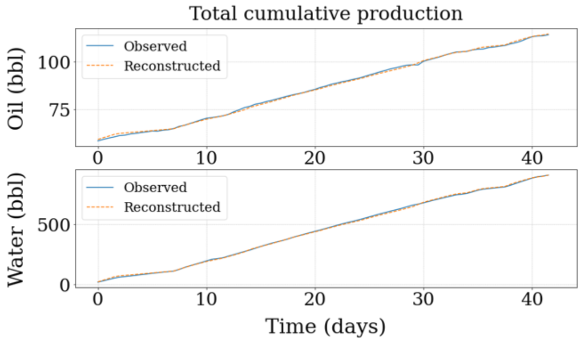

Figure 6 – Lease production reconstruction

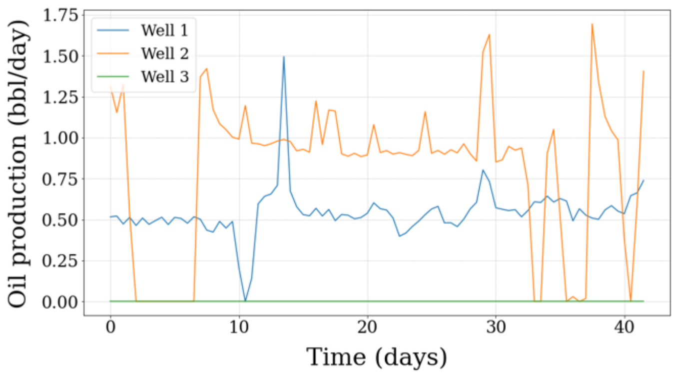

Figure 7 – Wells estimated flowrates

STROKE-BY-STROKE FILLAGE ANALYSIS FOR ROD PUMP OPTIMIZATION

Using 5G networks and advanced on-device compression algorithms, our system is able to stream continuous, very high resolution (*eg*; 100 Hz) data back to our centralized cloud system, including well-head position and rod pump loading. Using these signals, our system automatically generates dynacards for every single stroke of the pumping unit. A machine learning algorithm then automatically processes these cards to generate pump fillage results and diagnose mechanical issues. This stroke-by-stroke data is used to control the well and optimize its production while minimizing runtime and mechanical failures.

In situations where we both control and monitor all the assets on a lease, we can consistently confirm improved performance not just from mechanical inference, but downhole fluid levels as well.

On average, our system improves overall production by 5-10% while reducing total runtime by 30% or more. By greatly cutting down on the amount of runtime, we are able to decrease electricity usage by the same proportion (not to mention optimize around peak demand and on/off-peak usage). Moreover, we increase equipment life by (1) simply subjecting the equipment to fewer cycles for a given production and (2) minimizing poor pumping regimes (i.e., eliminating fluid pound and low fillage stokes).

We present data from two leases grouping a dozen low flow wells. In both cases, runtime is cut significantly after installing the system, and measurents show that production is not adversely impacted (see **Figure 11**).

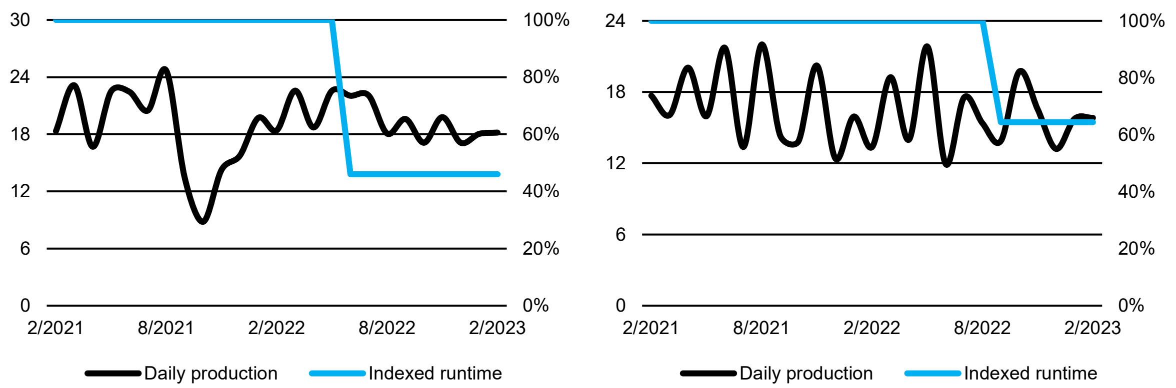

Figure 11 – Lease-level production vs. indexed runtime for two different leases

Not only that, but from a reservoir & inflow optimization perspective, we can confirm that fluid levels (shot monthly) are either flat or lower once our system controls the wells **(Figure 12)**. Over longer periods, it also appears that fluid level variability also decreases as our system actively responds and calibrates itself to the given inflow from the reservoir.

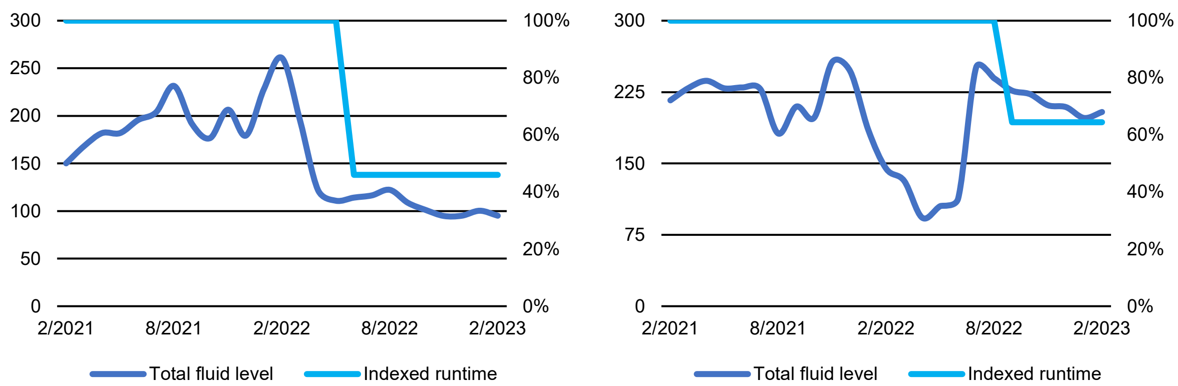

Figure 12 – Cumulative well fluid level (rolling 12-month average) vs. indexed runtime for the same two leases above

CONCLUSION

In this paper, we presented state-of-the-art developments in terms of hardware and computing technologies that leverage those advances to allow low friction, turnkey, high-resolution data collection and field automation. Combined with novel automated processing frameworks to provide high value insights without drowning users in impractical amounts of data, we have developed a solution that can effectively leverage data points across the field to (1) reduce the cost of monitoring assets by an order of magnitude, (2) minimize the need for routine in-person inspections of leases, and (3) increase production and equipment lifetime while reducing power consumption through optimization.