DIGITAL TRANSFORMATION FOR SUCKER ROD PUMP OPERATED WELLS

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ABSTRACT

The advent of low-cost IoT systems powered by Artificial Intelligence, Machine Learning Algorithms provides new production optimization tools available at the well site to achieve the digital transformation in the onshore oil and gas business. The unique capability of well diagnostic at the edge unlocks new opportunities from artificial lift condition monitoring to production optimization. The goal is to improve overall efficiency by reducing failures, anticipate deteriorating operating performance by timely introducing mitigation options. To demonstrate the value of the technology we have selected the underprivileged sucker rod pumping wells and developed remote diagnostic capabilities for these wells. Technology solution including software sensors and gateway designed and manufactured in the USA. This gives an opportunity to easily customize the system for addressing the needs of unconventional, marginal fields, stripper wells. In this talk, early technology solution development and field case studies will be presented.

INTRODUCTION

We have developed an intelligent well, asset monitoring and remote diagnosis platform designed for small to mid-size Independents, mature fields operators, unconventional oil and gas producers. The system includes battery operated wireless sensors and edge gateway capable of performing well diagnostic using proprietary Artificial Intelligence (AI) and Machine Learning (ML) algorithms.

IoT system is trained and capable of learning from multi-sensor data using AI algorithms running at edge device. System generates diagnostics reports provides actionable insights about the health of the well. These unique diagnostics are not available during pumpers' gaugers' visit to wellsite. The initial application of the system developed for monitoring and remote diagnostics of oil and gas wells operating with Sucker Rod Pumping (SRP). The motivation is to demonstrate the value, prove the affordability of the cutting-edge technology for very low-cost environment. Early field case studies demonstrated that The System could contribute reducing the operating cost, improve production, eliminate losses due to HSE incidents. Our solution opened a pathway for digital transformation of the SRP.

Monitoring production data is nothing new for operators, but it's only been something the supermajors and major companies could afford to do. They had to pick and choose "key wells" for monitoring. Only able to monitor maybe 60% to 70% of their wells. Addressing this problem has never been more important than it is today. Weak cash flows and uncertain cost inflation in new projects have led to a change in the business objective of many producers—from chasing growth in greenfield projects to optimizing production from existing fields without spending much. There is an increasing demand for affordable technologies.

Noven IoT System is a step forward for providing new production optimization tools available at well site to achieve the digital transformation in onshore oil and gas business. Unique capability of well diagnostic at the edge opens new opportunities from artificial lift to well optimization. The goal is to improve overall efficiency by reducing failures, anticipate deteriorating operating performance by timely introducing mitigation options. As a first application we have selected the underprivileged the sucker rod pumping well s and developed diagnostic capabilities for these well.

Value of Monitoring and Remote Diagnosis of oil and gas wells:

There is not a single way to describe eventual value of implementing IoT System. Figure 1 shows the 5 aspects of value of monitoring and remote diagnosis of oil and gas wells. The value for "minimize deferred production" relates to the ability to mitigate various factors acting to pull production below the planned

decline curve. Events may be abrupt (equipment failure) or gradual (flow assurance), and by watching real-time data, the problem may be detected early (time 1) rather than late (time 2), avoiding the lost production colored in lighter blue. “Accelerated Production” is possible where proactive production enhancement techniques allow operator to exceed the original decline trend. Penalty avoidance is related to avoiding an event that results in a sudden cash outlay, either regulatory, or loss of capital equipment like a sand screen.

DETAILS OF THE SYSTEM

The system composed of set of battery powered wireless sensors, wellsite edge device and a cloud platform. The raw data captured from wireless sensors, processed at local gateway, and diagnosed using proprietary AI / ML algorithms. Initial application focused for Sucker Rod Lift operated wells. Typical configuration includes, casing and tubing pressure gauge, inclinometer and clamped on polished rod load sensor data. The system is non-intrusive and takes minutes to install. System design, software development and manufacturing of sensors, gateway made in USA. This gave us an opportunity easily customize our system for addressing the needs of diverse user community. Figure 2 shows the system layout, data/information flow from wellsite sensors to engineers’ desktop. Main elements of the system described in below:

Wireless Load Cell: A patented device developed by Noven for measuring the force. Battery operated sensor attached to the polished rod with custom clamps. Sensor creates an electrical signal whose magnitude is directly proportional to the force being measured.

Wireless Inclinometer: A device developed by Noven for measuring the angle of inclination of Walking Beam from the horizontal.

Wireless Tubing Pressure Gauge: A device developed to measure pressure at the tubing of the well.

Wireless Casing Pressure Gauge: A device developed to measure pressure at the casing of the well.

Gateway: An EDGE Device developed in house capable of performing machine learning.
Communication via cellular and/or satellite link. Bluetooth 5.0 communication protocol adopted for metrology among sensors and gateways.

Supervisory/Engineer Application: An application developed to allow the field supervisor or field engineer to manage his/her day-to-day activity in each well site and the corresponding pumper in the field. It also allows the user to consolidate all reports generated by the edge gateway.

Installer Application: An application developed to allow the installation personnel to register all serialized equipment on the customer’s data base, verify the connectivity from all electronic gauges to the Gateway EDGE Device and perform the Verification and Validation (V&V) that the Total Solution is fully operational.

Administrator Application: The Administrator Application is used by authorized personnel to create the “Virtual Tenant” associated to a client. There is an Onboarding Process, when a customer signs up for our services and a preliminary Site Discovery is performed, that allow us to define all information about the customer and its fields under contract on Noven’s database. For example, company name, address, # of wells, well names, well coordinates, tank batteries, production rates, and others.

Typical SRP well installation illustrated at Figure 3.

SUCKER ROD PUMPING WELL SURVEILLANCE

There is a trend of failure frequency decrease among the companies adapted remote well monitoring systems. Pump failure frequency is the largest compared with those of sucker rod and tubing for all the sucker rod pumping wells. We have analyzed over 500 well data and short-listed diagnostic messages under five categories and automated the process (Table 1). System captures sensors data and generates AI/ML driven diagnostics on pump operating efficiency and failures.

Pressure Analytics
Artificial Intelligence Algorithm developed for casing and pressure data provides vital insight about vertical lift and well inflow performances. Time series pressure data analyzed in two stages:

1. Instantaneous, abrupt changes
2. Progressive changes over a longer time span

Pressure Algorithm is equally applicable for producers and injection wells as well as manifolds, flow lines and multiple casing annuluses. Table 2 summarizes the diagnostics derived from Time Series Pressure Data Analytics and value of information.

System Deliverables:

- 20+ Dynacard 3 to 4 times a day.
    - Dynacard is the gold standard for Sucker Rod Pump ("SRP") performance evaluation
    - All of them are automatically interpreted using "Edge Computing AI system"
    - Actionable diagnosis is delivered directly to the "Production Engineer"
- The evolution of casing and tubing pressure is continuously analyzed by Edge computing AI system for detection of well & completion issues (packer, tubing leaks, flow assurance, formation damage) on a:
    - Short time basis
    - Long time basis
- If needed, a qualitative "gas slug" monitoring, detection based on the analysis of the 20+ Dynacard taken out each acquisition
- All Wells are automatically diagnosed (a few times a day)
- System automatically highlights priority issues and proactively direct needed intervention

Approach for Cost Benefit Analysis:

- A field of 100 wells producing 50 BOPD will deliver 150,000bbls. a month, for a value of 7.5M$ (oil price of 50 $/bbl.).
- A reasonable assumption is that 10% of the wells are experiencing some of these issues (in case of gas it might be much higher).
- The early detection of the issue allows to gain on average about 2 weeks on the resolution (everything else being equal)
- The production gained would have a value of $375K per month. This is not considering any savings from the ability to have much less required human presence in the field, less driving time (on average long travel distances), less safety risk, and measurable lower carbon footprint.
- The monthly cost of the system is order of magnitude cheaper for the entire field compared to existing practice.
- Even if one takes a very conservative assumption of only 5% of the wells having issues, the system has still a high payback

CASE STUDIES

The field testing of the system is ongoing at several assets with different operating companies in Texas. These wells are unique in a sense of geometry, depth, pump size and production volumes. Data captured from sensors evaluated in two levels: transient and time-lapsed analysis. Value of two-level diagnostics illustrated for dynamometer and pressure measurements.

During extended field tests of 10 well for one-year, results were monitored closely throughout the entire period (more field tests installed without extended monitoring). This is equivalent to approximately 120 well-months well monitored and diagnosed since Q2 2020. During the test of the system in various wells geometry, the system has very efficiently detected a dozen of following issues:

- High Gas Interference, Gas slug detection
- Multiple tubing failures
- Plugged pump barrel

- Fluid pounding
- Separator dump valve failure
- Deep parted rod
- Flow assurance issues due to paraffin buildup
- Mechanical integrity caused by sanding failures
- Leaking production choke
- Blockage of surface flow line due to debris, sanding
- Intermittent production due to lack of supply gas, slug flow
- Temporary pump-off conditions
- Transient well tests; interference, build-up, and drawdown

In each of these cases, the issue resulted in a dramatic loss in pumping efficiency and production. In each case, the system allowed to act on the issue immediately and restore the production proactively ahead of what would have happened otherwise. Operators acted based on our unique diagnostics, which were not obtainable with pumper visits. Selected examples of system diagnosis and significance to operator's value-chain illustrated in below.

A Hole in the Tubing String (Figure 4):

- Dyna-card - Partial loading of the tubing capacity
- Pressure - Drop in Tubing Head pressure indicates a lower or no fluid load
- Impact - Lost 80% of oil production

Gas Interference (Figure 5):

- Dyna-card - Progressing gas interference
- Pressure - Unstable Tubing Head Pressure indicates multi-phase flow with increasing gas content
- Impact - 70% increase in gas production, oil production increased by 40% in a month after optimized pumping

Deep Parted Rod (Figure 6):

- Dyna-card - No appreciable load compared to the expected (0-3klb. vs. 15-20klb.)
- Pressure - Drop in Tubing Head Pressure indicates a lower or no fluid load
- Impact - Losing 100% oil production. Not immediately noticed, as deep well producing through commingled flow at surface manifold

Productivity Decline – Sanding (Figure 7):

- Dyna-card - No appreciable delta load compared to the expected (0-1.5klb. vs. 8-12klb.)
- Pressure - Drop in both Casing and Tubing pressure indicates a limited flow from reservoir
- Impact - Losing 90% oil production. Accelerated wear of tubulars due to sand erosion

Production Enhancement Opportunity (Figure 8):

- Dyna-card - Delta loading indicates tubing is full. However, negative slope shows upside
- Pressure - Stable high tubing pressure indicates an additional production capacity
- Impact - Raised 40% oil production (accelerated production revenue)

Production Enhancement Opportunity (Figure 8):

- Dyna-card - Delta loading indicates tubing is full. However, negative slope shows upside
- Pressure - Stable high tubing pressure indicates an additional production capacity

- Impact - Raised 40% oil production (accelerated production revenue)

Gas Slug Detection: Horizontal Oil Well (Figure 9):

- Dyna-card - Delta loading indicates unstable fluid gradient
- Pressure - Tubing pressure fluctuates
- Impact - Detecting the gas slug in horizontal well is a very instrumental to avoid premature pump, well failures. Operator can immediately act to advert costly workovers Increased production efficiency translates directly more uptime, more revenue

System Benefits

- Bluetooth Low Energy radio communication for sensors
- Non-intrusive, rapid deployment capability (<30 min)
- Pump diagnostics using surface dynamometer cards generated online at the well site
- Casing and tubing transients and trend analysis
- Focus on wells that require immediate attention
- Reduce non-productive time and production losses
- Reduce number of well site visits by providing near real time well status information
- Monitor, reduce, detect spills from tank batteries with Alerts
- Reducing wellsite visits improves safety
- Continuously monitor pressures and set up thresholds to detect anomalies
- Remote device management
- State awareness of the assets near real time
- Minimize downtime, unplanned shutdowns
- Early intervention capability for crisis management

CONCLUSION

We are coming into an age where processing power, edge technology and cloud-based solutions dominate everyday life. Bringing these different facets of advanced technology together and seeing how we can help customers solve complex problems, drive greater efficiency, and drive productivity. We developed a robust, highly scalable end to end, low cost IoT platform. This New System will be for all, from striper well operators to independents, super majors, national resource holders. Digitalization means helping the production engineers do a better more efficient job, not moving data to the cloud.

ACKNOWLEDGEMENT

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REFERENCES

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LIST of TABLES

Table 1 Surface Dynacard derived Diagnostics Messages

No	Description	Value	Action
1	The well is operating. OK	Fair	Keep monitoring
2	The well is operating with gas interference issue, slug detection	Moderate	Check gas separator efficiency, run time, production trend, choke setting
3	The well is operating with pump efficiency problems	High	Review pump performance and schedule for intervention
4	The well is working with mechanical integrity issues	Higher	Review installation, operating conditions, schedule for inspection, repair job
5	Well failure	Highest	Review well performance and schedule for well intervention

Table 2 Casing and Tubing Pressure derived Diagnostics

Diagnostic	Description	Value	Action
01	Well pressure trends stable	Fair	Keep monitoring
02	Sudden increase in Tubing Head Pressure	Moderate	Well Issue (oil/ water) Gas/Water breakthrough
03	Sudden increase in Casing Head Pressure	High	Potential Integrity Issue
04	Gradual Decline in WHP	Higher	Reservoir pressure decline, Well review for stimulation, AL
05	Sudden decline in WHP	Highest	Sanding, plugged pump intake schedule for repair / workover

LIST OF FIGURES

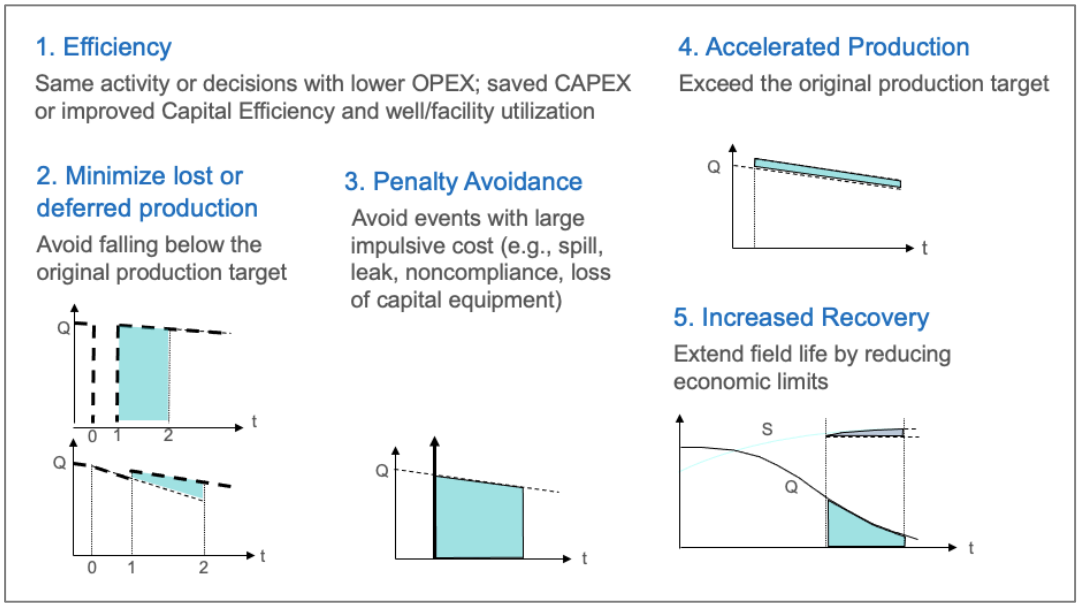

Figure 1 Value Matrix for Monitoring of oil and gas wells

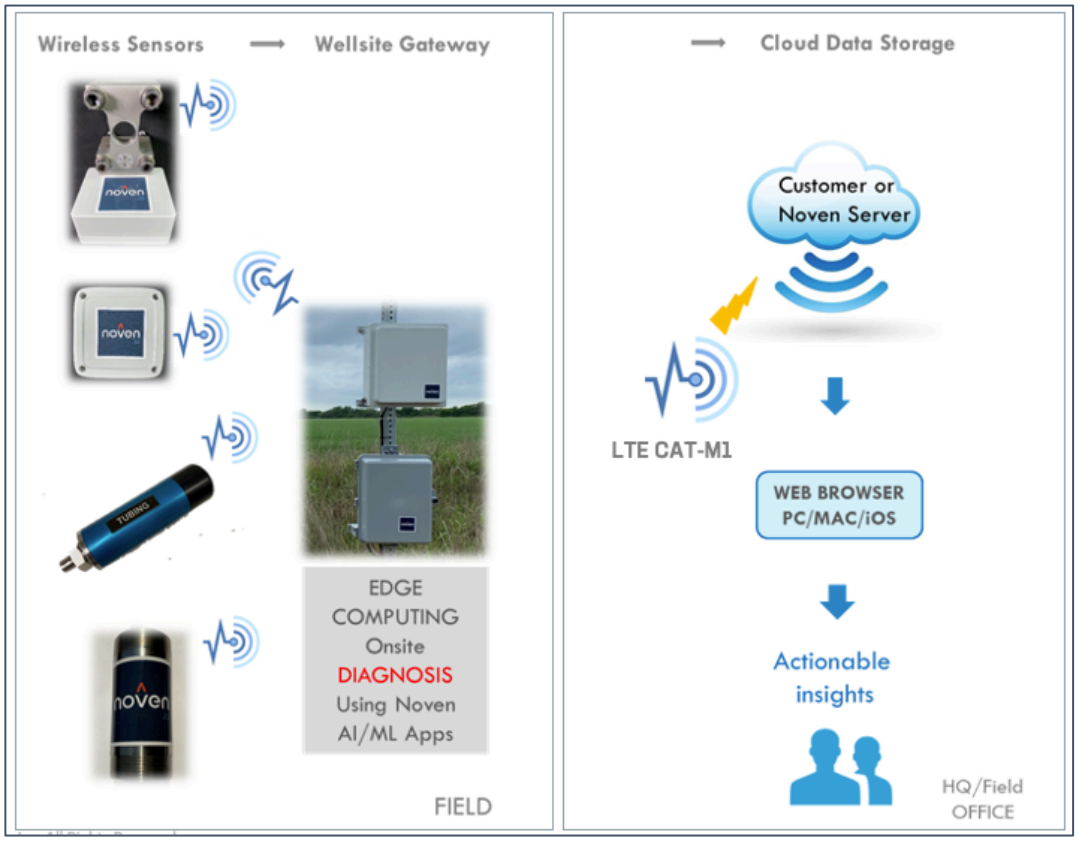

Figure 2 IoT System Diagram from sensors to engineer's desktop.

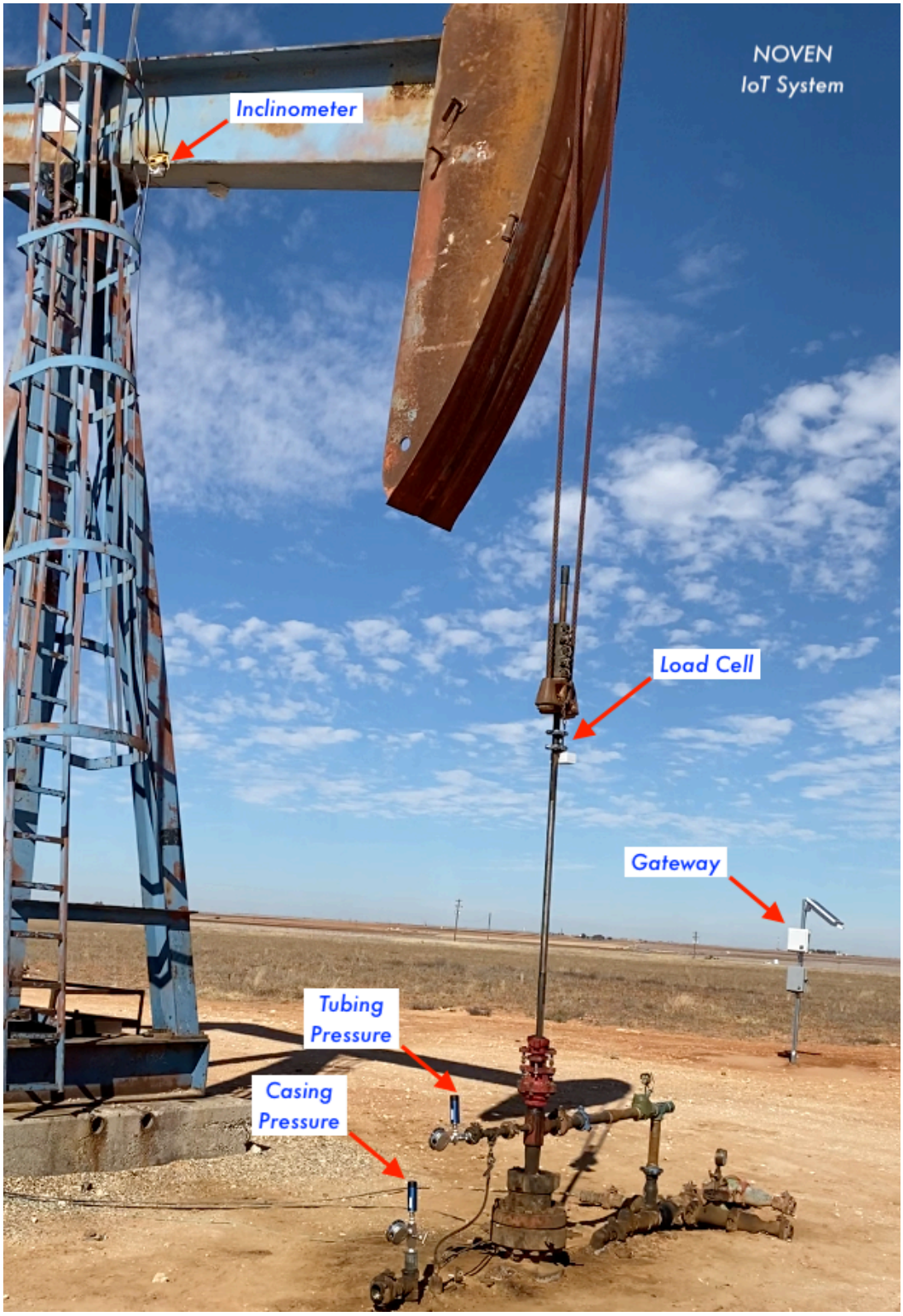

Figure 3 Typical IoT System Installation for SRP Wells

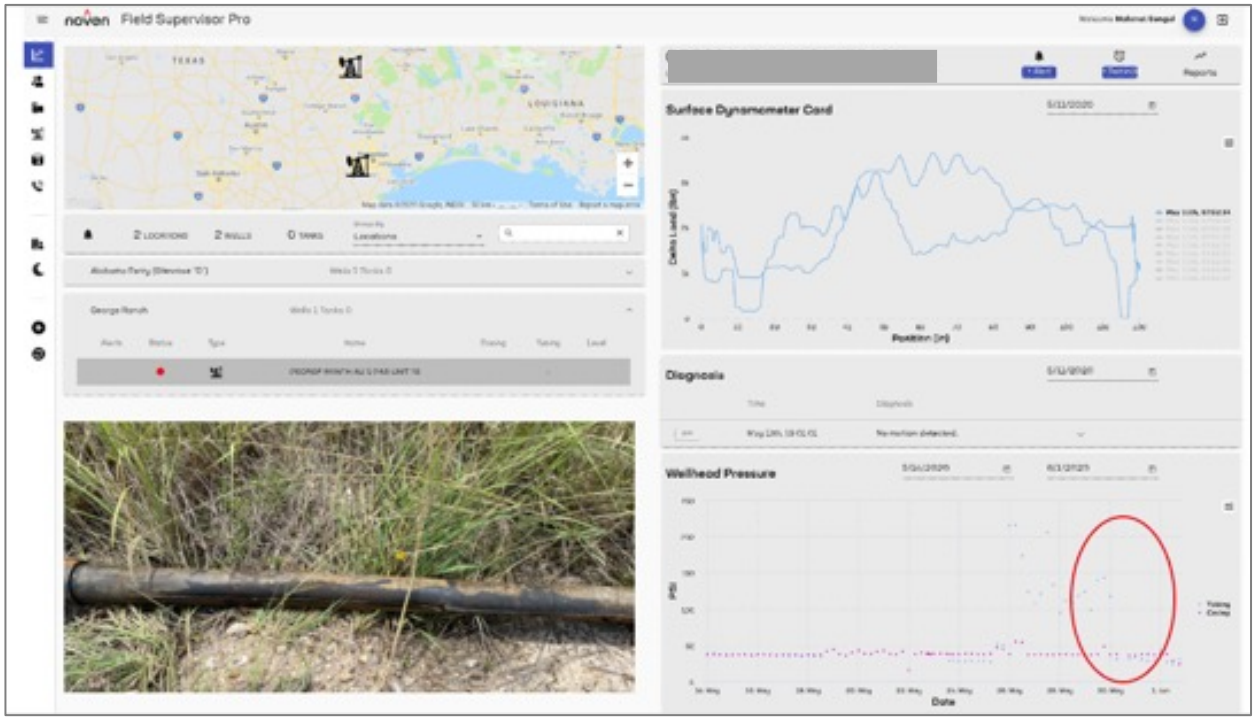

Figure 4 Communication due to hole in the tubing string

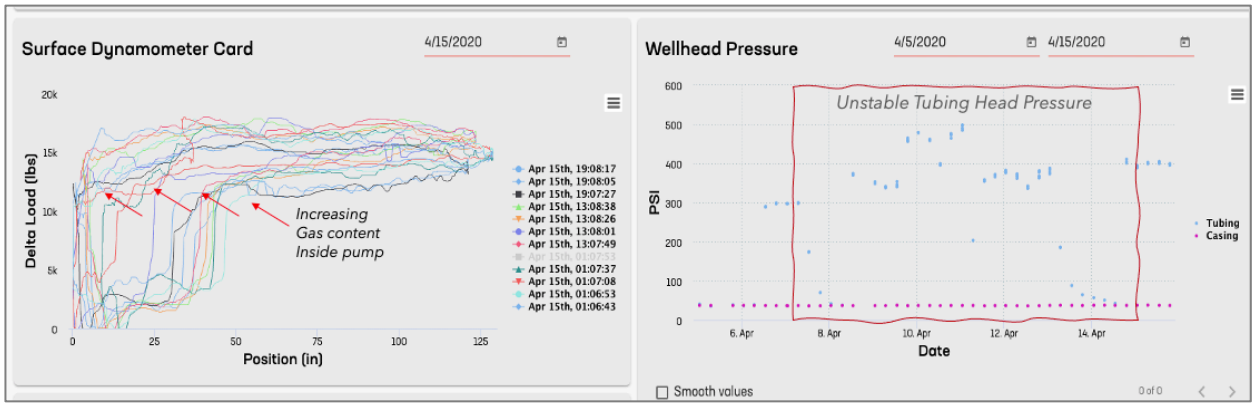

Figure 5 Progressing Gas Interference

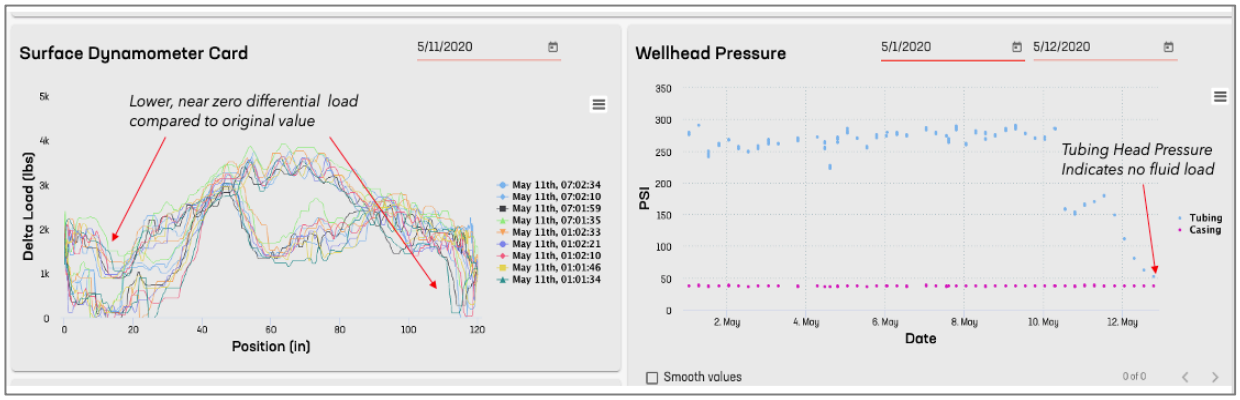

Figure 6 Deep parted Rod

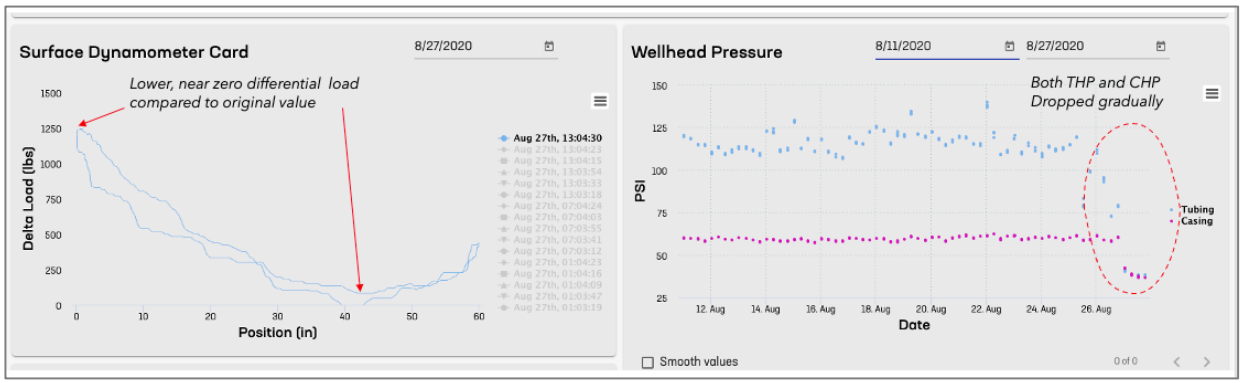

Figure 7 Productivity Decline, severe sanding issue

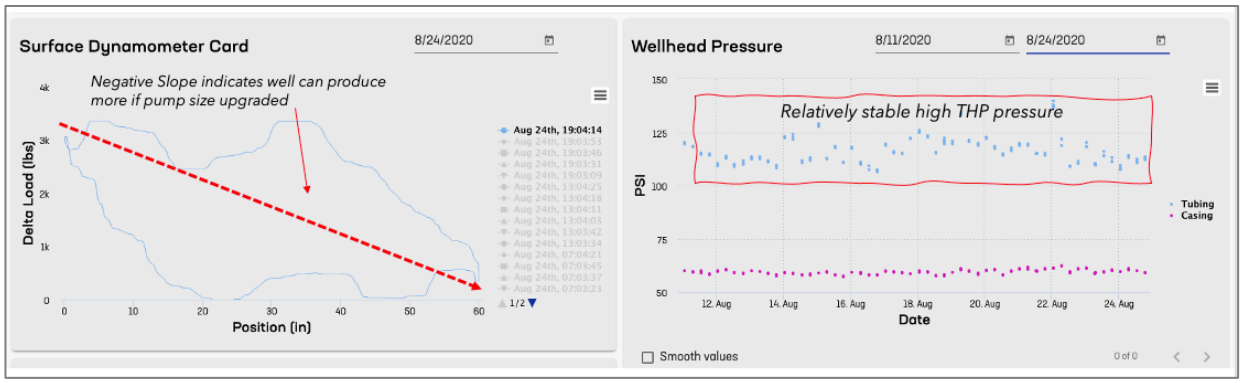

Figure 8 Undersized pump, Production Enhancement opportunity

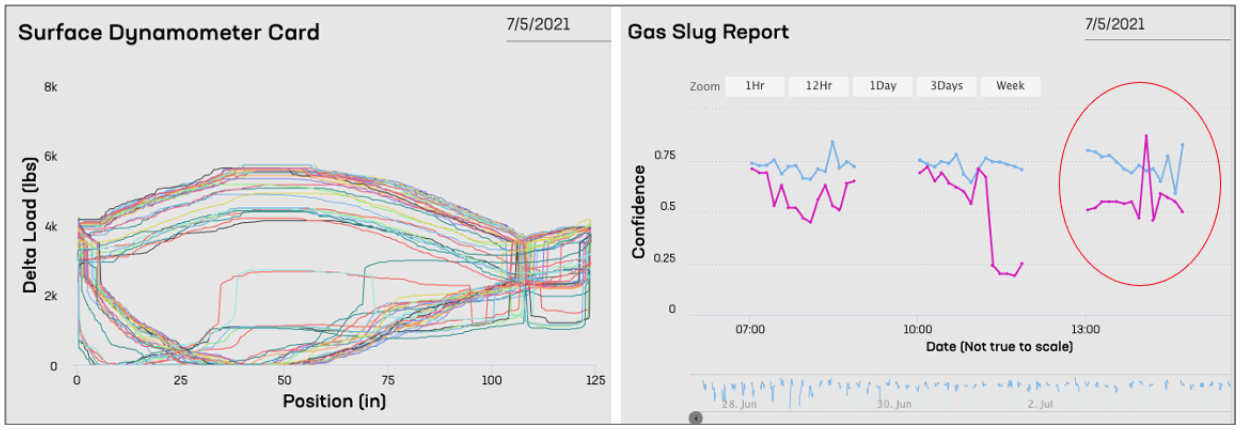

Figure 9 Gas Slug Detected in Horizontal Well