Using IoT-Enabled Machine Learning to Autonomously Optimize Rod Pump Setpoints

Jesse Filipi, Technical Director
Legacy technology limits the “As-Is” state of production operations to heavily manual and reactive workflows.

Legacy Equipment + Human Limitations → Commonly Accepted Operating Philosophy

“Focus on your high value wells”

“Prioritize on production”

“We don’t look at those wells, they don’t make much production”

“The production isn’t going anywhere, no sense pushing it”

“Optimization is a settled science”
As-Is advisory-based operations and workflows are reactive, time consuming, and labor intensive.
Autonomous well operations enable proactive operating mindset and workflows

What is autonomy?

Similar to "lights out" concept in manufacturing where machines can operate the factory without supervision so staff can go home at night and turn the lights out.

Advisory
Staff responsible for data analysis and implementing actions to optimize wells
Staff also responsible for solving complex design and equipment problems

Autonomy
Autonomy in artificial lift is having the lift system optimize itself
Staff focus on higher value activities such as solving complex design and equipment problems

Reactive
Increasing Autonomy
Proactive
The Language of Digital Technology

POP vs. BOL vs. RTP

- **Artificial Intelligence (AI):** the capability of a machine to imitate intelligent human behavior
- **Cloud:** A communications network. The word "cloud" often refers to the Internet, and more precisely to some datacenter full of servers that is connected to the Internet
- **Data Science** involves using automated methods to analyze massive amounts of data and to extract knowledge from them
- "**Big data**" typically refers to data on the scale of terabytes (10 to the 12th power) and petabytes (10 to the 15th power)
- **Internet of Things (IOT)** is the network of physical objects that contain embedded technology to communicate and sense or interact with their internal states or the external environment
- **Edge Computing:** part of the work happens right at the edge of the network where IoT connects the physical world to the Cloud
- **Machine learning (ML):** science of getting computers to act without being explicitly programmed
Unique team expertise to properly frame problem and apply proper ML and DL techniques leveraging HRAC data.

Machine learning uses algorithms to parse data, learn from that data, and make informed decisions based on what it has learned.

Deep learning structures algorithms in layers to create an “artificial neural network” that can learn and make intelligent decisions on its own.
Regardless of the technology controlling the well: POC+VFD, POC or timer: less than 15% of wells dialed in.

POC+VFD, POC, and Electric motor/timer

<table>
<thead>
<tr>
<th>Well Classification</th>
<th>Percentages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Underpumping</td>
<td>12.9%</td>
</tr>
<tr>
<td>Dialed In</td>
<td>11.4%</td>
</tr>
<tr>
<td>Overpumping</td>
<td>75.7%</td>
</tr>
</tbody>
</table>

POC+VFD Only

<table>
<thead>
<tr>
<th>Well Classification</th>
<th>Percentages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dialed In</td>
<td>14.7%</td>
</tr>
<tr>
<td>Underpumping</td>
<td>22.7%</td>
</tr>
<tr>
<td>Overpumping</td>
<td>62.7%</td>
</tr>
</tbody>
</table>

Data set spans multiple operators, basins and well types over 300 wells; Optimized well % roughly matches the 80/20 rule.
Optimization is perfectly suited for a machine to autonomously manage and adds significant value to operations today.

**Optimization:**
- Follows consistent best practices
- Requires knowledge and time
- Is a highly repetitive process
- Involves large volumes of data

When performed by humans, this leads to process dispersion.

When performed by machines, this leads to consistent, repeatable outcomes.
Optimization is susceptible to wide dispersion in outcomes when left to manual processes and existing technology.

Significant value derived from standardization and alignment of inputs and outputs across actionable KPIs.
Technology and process gaps exist preventing 4+ σ operations

- Unoptimized well equals a defect
- Only 15% of wells optimized means 85 defects out of 100
- Moving to 95-99% optimized requires step change in technology
Legacy stack creates significant information losses which limit operational value creation & inhibit high end data science.

Information Loss Sources & Value Creation Opportunities:
1. Pump to surface
2. Surface to PLC
3. PLC to PI via SCADA
4. Historian data quality issues
5. PLC to optimization software
6. Software to end user
7. Well time/data overload human variation
8. Well to field time/data overload human variation
9. Human back to PLC
10. POC to Pumpjack
IOT-enabled edge controller deployed onsite and connected to PLC helps overcome legacy data & infrastructure limitations.
ML uses physics-based inputs, classifies the well, and delivers optimization action to drive value.

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Physic based inputs analyzed over various time series

**ML** uses physics-based inputs, classifies the well, and delivers optimization action to drive value.

**Feature Extraction**

**Classification**

**Output**

*Dialed In*

*Overpumping*

*Underpumping*

*Do Nothing*

*Decrease SPM / Increase Idle time*

*Increase SPM / Decrease Idle time*
ML models consistently evaluate results and use them to learn and improve over time.

Classification: underpumping well → increase speed OR decrease downtime

Sustained production increase; same efficiency

Classification: overpumping well → decrease speed OR increase downtime

Speed range optimization machine learning applied: pattern recognition + anomaly detection
Taming the POC reduces process variance lowering the wasted strokes in the system and introducing consistency to apply ML

Before

After

Cycles per day vs. Fillage

Standardizing setpoints and optimization inputs leads to significant reduction in cycles per day and consistent fillage
Increased SPM with liquid production aligns the most critical input (SPM) with desired output (BBL) optimizing profit.

**Before**

*Liquid production (BFPD) vs. Effective SPM*

- **Avg. Total Liquid Production, bbl/d vs. Average SPM**
  
  **R2 = 0.001**
  
  No correlation and no influence of SPM inputs and liquid production.

**After**

- **Avg. Total Liquid Production, bbl/d vs. Average SPM**
  
  **R2 = 0.40**
  
  Positive slope to increased production with increased SPM inputs.
All revenue and cost OPEX metrics improved post ASPM

- 93% wells dialed in when removing design limitations and flumping
- Using workflow tools and safe operating limits to flag for pump upsizes, stroke length changes, sheave resizing

### Well Classifications After ASPM

<table>
<thead>
<tr>
<th>Metric</th>
<th>Average Before</th>
<th>Average After</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max SPM</td>
<td>5.7</td>
<td>5.2</td>
</tr>
<tr>
<td>Effective SPM</td>
<td>5.2</td>
<td>4.8</td>
</tr>
<tr>
<td>Fillage (%)</td>
<td>83%</td>
<td>90%</td>
</tr>
<tr>
<td>Liquid Production (BFPD)</td>
<td>182</td>
<td>189</td>
</tr>
<tr>
<td>Calc Pump Displacement (BFPD)</td>
<td>334</td>
<td>275</td>
</tr>
<tr>
<td>Pump Efficiency (%)</td>
<td>58%</td>
<td>67%</td>
</tr>
</tbody>
</table>
Autonomous workflows and modern technology are enabling 4+ σ production operations

- Technology gap to unlocking 4+ sigma production operations addressed through:
  - HRAC solves legacy data quality problem
  - Machine learning solves manual optimization process
- Significant operational value realized in ASPM
References

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