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ADVANCED VARIABLE FREQUENCY DRIVE CONTROL: OPTIMIZATION AGAINST INCOMPLETE PUMP FILLAGE

Tim Hinojosa – Occidental Petroleum

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Purpose:

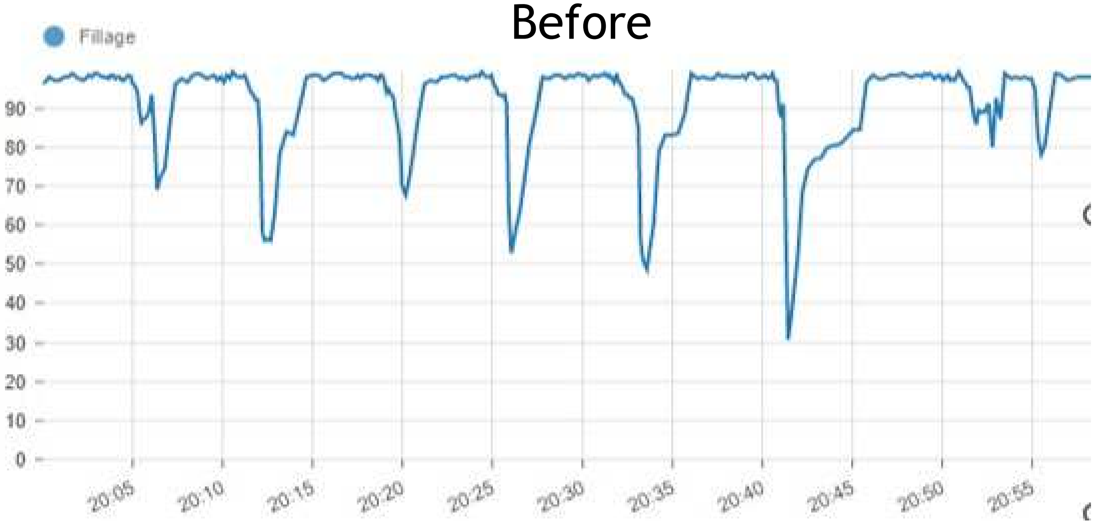
- Test the IoT-Edge system for monitoring and optimizing sucker rods pumps
- Advanced Fillage Mode (AFM)
  - Introduce AFM as another VFD control mode
  - Compare the effectiveness of AFM to traditional VFD control
  - Evaluate the results of AFM including the benefits and limitations
- FLAP Mode
  - Introduce FLAP (Fluid Level Above Pump) as another VFD control mode
  - Compare the effectiveness of FLAP mode in comparison to other control modes
  - Evaluate the results of FLAP mode including benefits and limitations
- Higher Resolution Data
  - Assess the advantages of using higher resolution data for monitoring and optimizing sucker rod pumps
- Uninterrupted Operation
  - Discuss the benefits of enabling autonomous operation without the need for human intervention

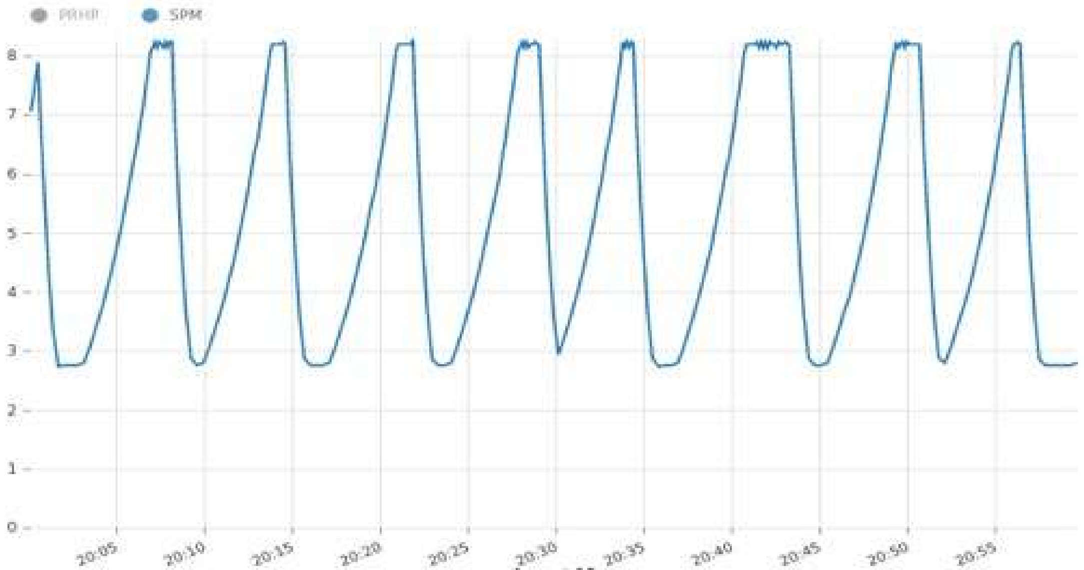
Introduction to AFM

- Aims to minimize incomplete fillage strokes by adjusting the speed of the pumping unit to synchronize the displacement of the pumping system with the inflow from the reservoir
- AFM adjusts other parameters within the controller autonomously to meet the pump fillage target set by the user
  - This includes a combination of maximum and minimum working speeds, increments in which the speed changes, and how many observation strokes are needed before initiating any changes
- Performance indicators from the high resolution data are constantly evaluated through a feedback loop to continuously make changes throughout the day without the need for the operator to make the changes

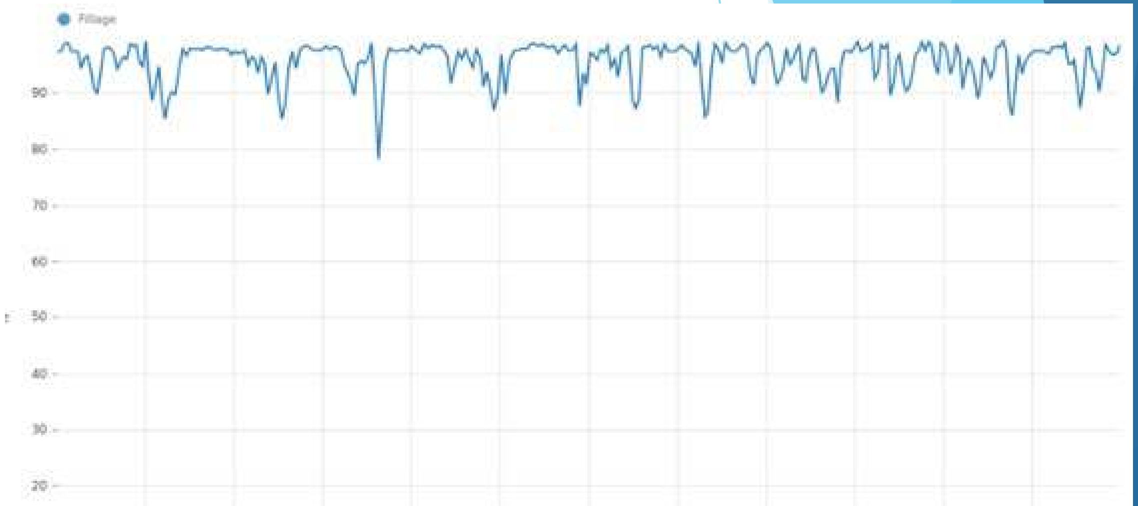
AFM Results

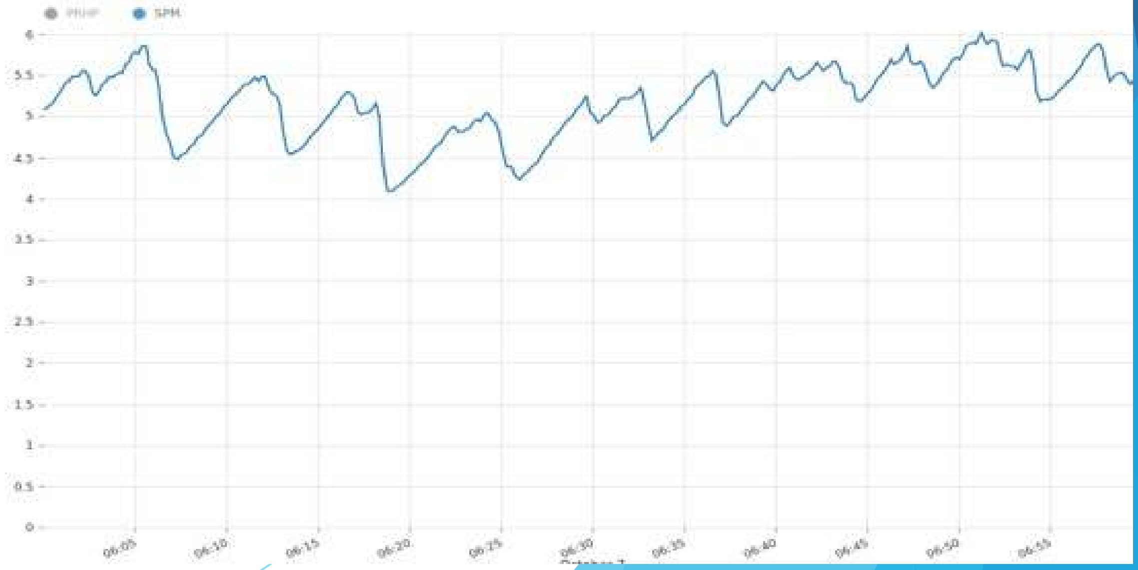
Before





After





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AFM Results

- A brief comparison shows a significant improvement in reducing incomplete fillage strokes before and after deploying AFM compared to traditional VFD control

Well #1	Before AFM	After AFM
Total Strokes	13773	12550
Fillage SetPoint	94%	94%
Fillage used for Comparison	93%	93%
Number of low Fillage Strokes.	5046 (36.36%)	2655 (21.2%)
Number of lower Fillage Strokes (<85%)	3602(26.2%)	495 (3.9%)

AFM Results

- AFM control mode was able to replicate the results in all other wells in the trial with a noticeable reduction of incomplete fillage strokes

Well #2	Before AFM	After AFM
Total Strokes	14311	14251
Fillage SetPoint	90%	90%
Fillage used for Comparison	89%	89%
Number of low Fillage Strokes.	8245 (57.6%)	748 (5.2%)
Number of lower Fillage Strokes (<80%)	688 (4.8%)	1 (0%)

Well #3	Before AFM	After AFM
Total Strokes	21727	21658
Fillage SetPoint	96%	96%
Fillage used for Comparison	95%	95%
Number of low Fillage Strokes.	1447 (6.7%)	43 (0.2%)
Number of lower Fillage Strokes (<94%)	20 (0.1%)	0(0%)

Well #4	Before AFM	After AFM
Total Strokes	9981	9487
Fillage Setpoint	94%	94%
Fillage used for Comparison	93%	93%
Number of low Fillage Strokes.	9964 (99.8%)	1842(19.4%)
Number of lower Fillage Strokes (<90%)	6691 (67%)	120 (1.3%)

AFM – Advantages vs Disadvantages

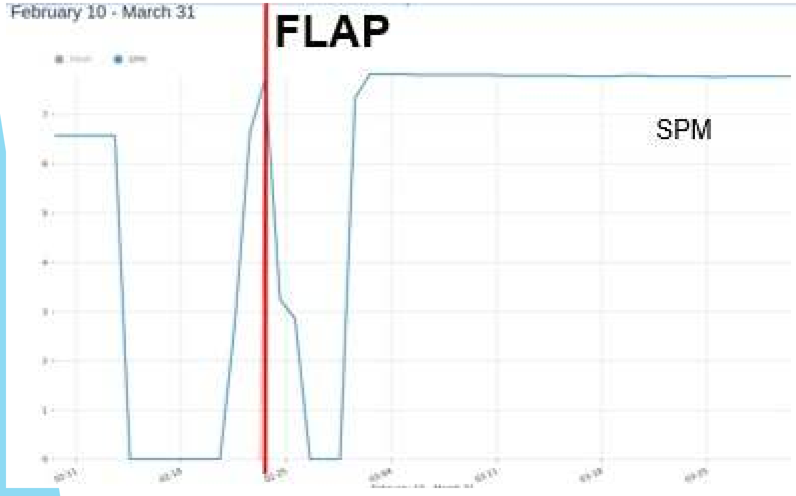
- Advantages
  - AFM allows operators to optimize a greater population of wells by taking advantage of the autonomous control features
  - The algorithm is continuously matching inflow from the reservoir to pump displacement
  - Proven to be highly effective in reducing the amount of incomplete fillage strokes
- Disadvantages
  - The lack of precision in detecting gas interference and the effect on pump fillage may slow the well down unnecessarily causing adverse effects on production
  - AFM is more effective in situations closer to pump off as opposed to applications where gas interference is more prevalent where an alternative mode would be a more suitable application

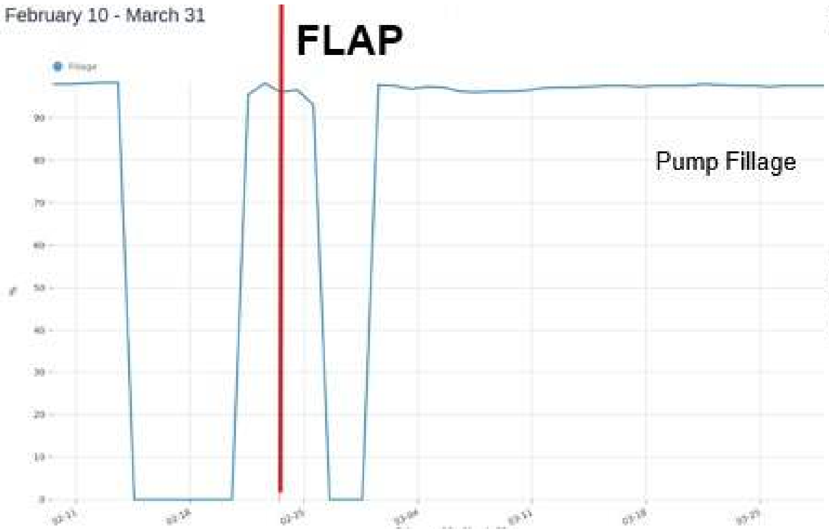
Introduction to FLAP

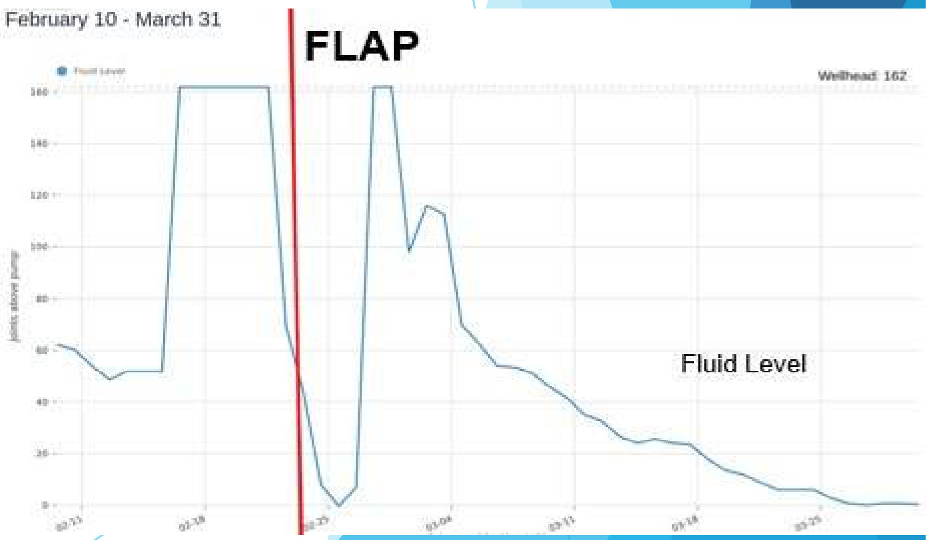
- FLAP mode operates based on a calculated fluid level target set by the operator
- When the calculated fluid level is twice the fluid level target or higher, the VFD will operate at maximum SPM allowing the fluid level to decline until it reaches the target fluid level set by the user
- Once the calculated fluid level reaches the fluid level target or below, the controller will seamlessly move into AFM mode to optimize against incomplete fillage strokes
- FLAP allows for more incomplete fillage strokes to help work through different types of incomplete fillage since there is a fluid level above the pump based on the calculated fluid level being measured in order to maximize production

FLAP Results

- Observed a higher SPM as expected to facilitate drawing the fluid level down
- Observed pump fillage drop initially, however pump fillage stabilized above the pump fillage target
- Calculated fluid level was drawn down further than historical trends in other control modes

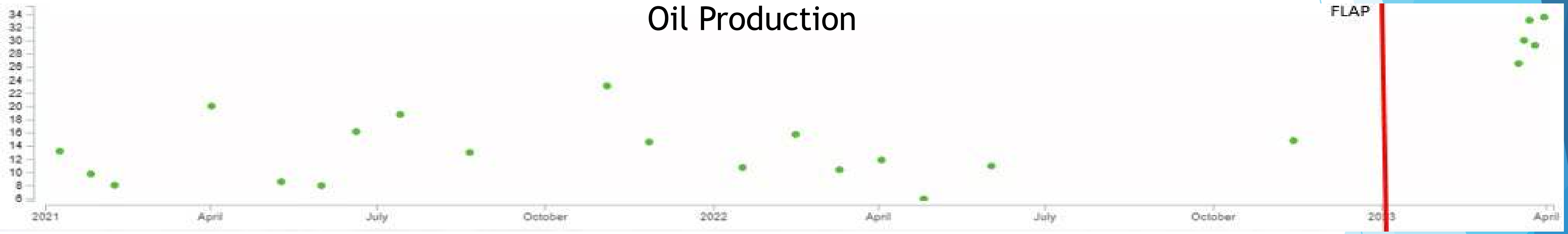






FLAP Results

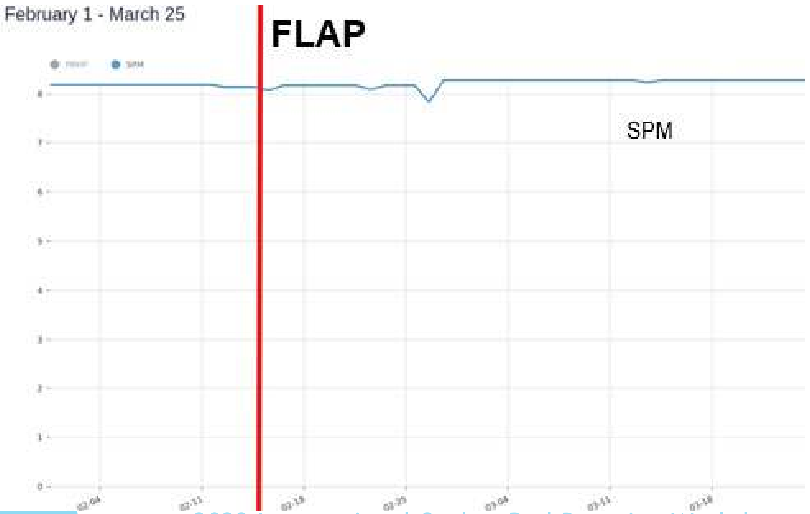
- FLAP mode successfully increased production from 14 bbls/d to 34 bbls/d
- FLAP mode achieved this by effectively drawing down the fluid level without a notable increase in low fillage strokes

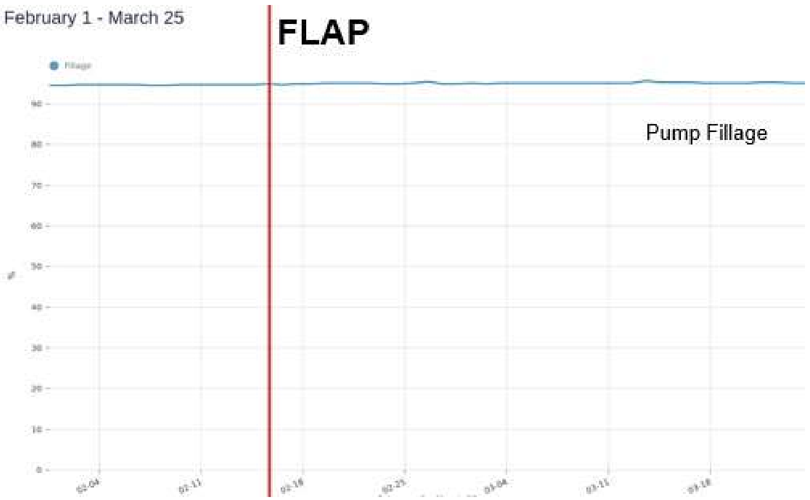


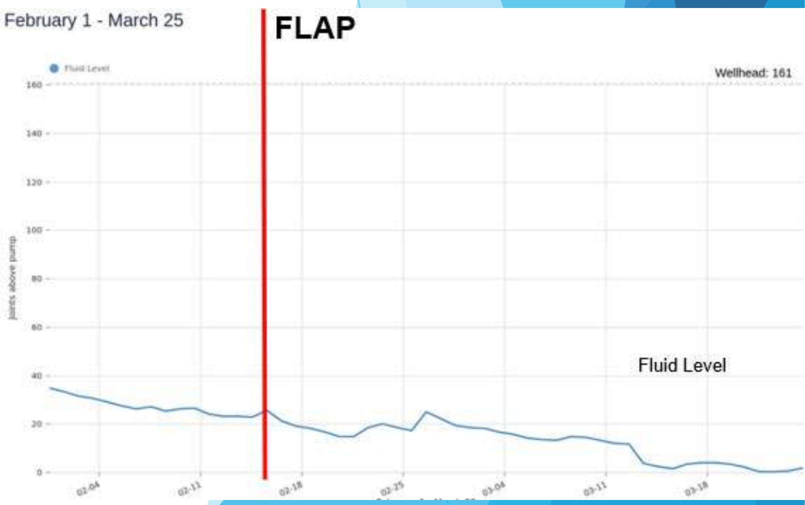
	Before AFM	After AFM	FLAP
Total Strokes	13773	12550	45150
Fillage SetPoint	94%	94%	91%
Fillage used for Comparison	93%	93%	91%
Number of low Fillage Strokes.	5046 (36.36%)	2655 (21.2%)	0(0%)
Number of lower Fillage Strokes (<85%)	3602(26.2%)	495 (3.9%)	0(0%)

FLAP Results

- After FLAP, we observed an increase in SPM as expected
- Pump fillage after FLAP was enabled stayed in line with historical trends in other modes, and improved slightly towards the end
- A noticeable decrease in calculated fluid level was also observed

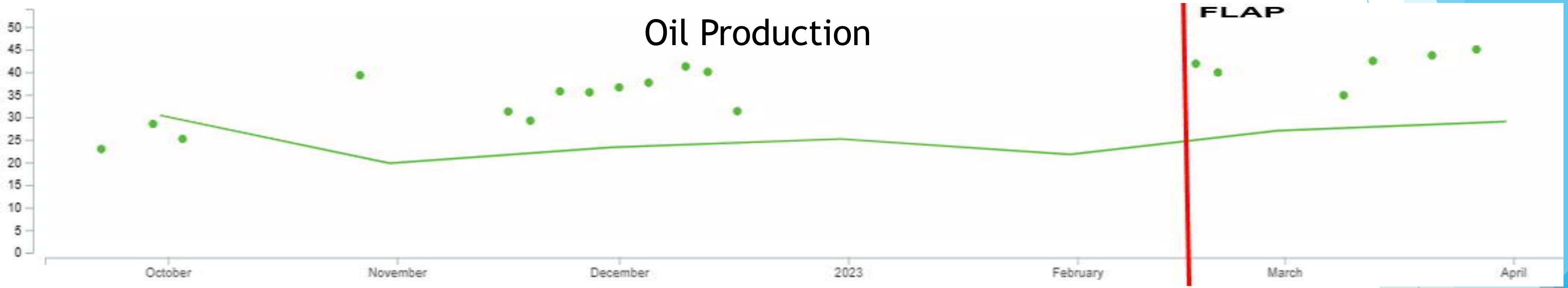






FLAP Results

- An 8 bopd incremental gain was achieved after deploying FLAP mode
- FLAP mode was again able to draw down the calculated fluid level without increasing the number of incomplete fillage strokes compared to AFM



	AFM	FLAP
Total Strokes	147568	142257
Fillage SetPoint	90%	90%
Average Fillage	92.37	95%
Number of low Fillage Strokes	5105 (3.46%)	0 (0%)

Conclusions

- Both AFM and FLAP mode were compared to traditional VFD control method, along with higher resolution data and uninterrupted operation to assess the benefits
- AFM was highly effective in minimizing incomplete fillage strokes and providing continuous optimization without human intervention
- FLAP mode achieved increased production by effectively drawing down the fluid level without a noticeable increase in low fillage strokes. This shows potential as a valuable tool for optimizing well performance
- Time utilization for the operator was also improved as these modes allowed for autonomous operation while allowing them to focus on other wells needing attention

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