Artificial Lift R&D Council

Cloud Based Real-Time Monitoring of Tight Oil Field by Applications of Edge Gateway Device, Automatic Fluid Level technology and Analytical Dashboards

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About the field well designing

The well design for the Barmer Hill development is based on the following key project drivers:

- Rapid ramp up of field production rate.
- Maximize individual well productivity by planned use of multiple hydraulic fractures in wellbore.
- Planned use of horizontal wells to maximize the drainage to each well bore and reduce overall well count.
- Selection of optimum artificial lift mechanism to increase recovery.
- Include solutions for flow assurance against a potentially waxy, high pour point crude.
- Utilize pad drilling as the most cost effective, environmentally friendly, and operationally effective means of developing the field.

Problem Statement

- Smart field-management with cloud-based real-time monitoring and optimization of SRP wells in a tight oil reservoir for maximizing production-efficiency, improving reservoir-management, optimizing costs, ensuring safety, and minimizing environmental-impact.
- Leverage advanced data-analytics and automation to enable timely decision-making and enhance overall field-performance.
- The rectify the challenges arising from several intricate-factors such as high Gas-Oil Ratio, the persistent occurrence of sand-production, an elevated wax-appearance temperature, and inclination towards corrosion owing to a substantial concentration of carbon-dioxide (40-80% in mole-percent).
- Acquire real-time dyna-card and continuous fluid-level data to understand downhole pump-performance and well-issues.
- To resolve the lack of real-time monitoring results in well-downtime and production-loss by combination of IOT, Cloud-Computing and Machine-learning.
- To shift the approach from reactive to proactive for ALS-Optimization and production loss reduction
- To establish a smart real-time cloud-based dashboards to integrate-data and get a big picture of the actual field-conditions.
- To resolve the problems affecting echo-shot based fluid level survey because of gas flow noise in well annulus (0.2-2 MMSCFD gas rate), and variable annulus gas specific gravity (~1.1 - 1.5) which changes the sound velocity in annulus, making fluid level calculation incorrect.

Challenges associated with wells and how real-time dyna & remote monitoring plays a vital role

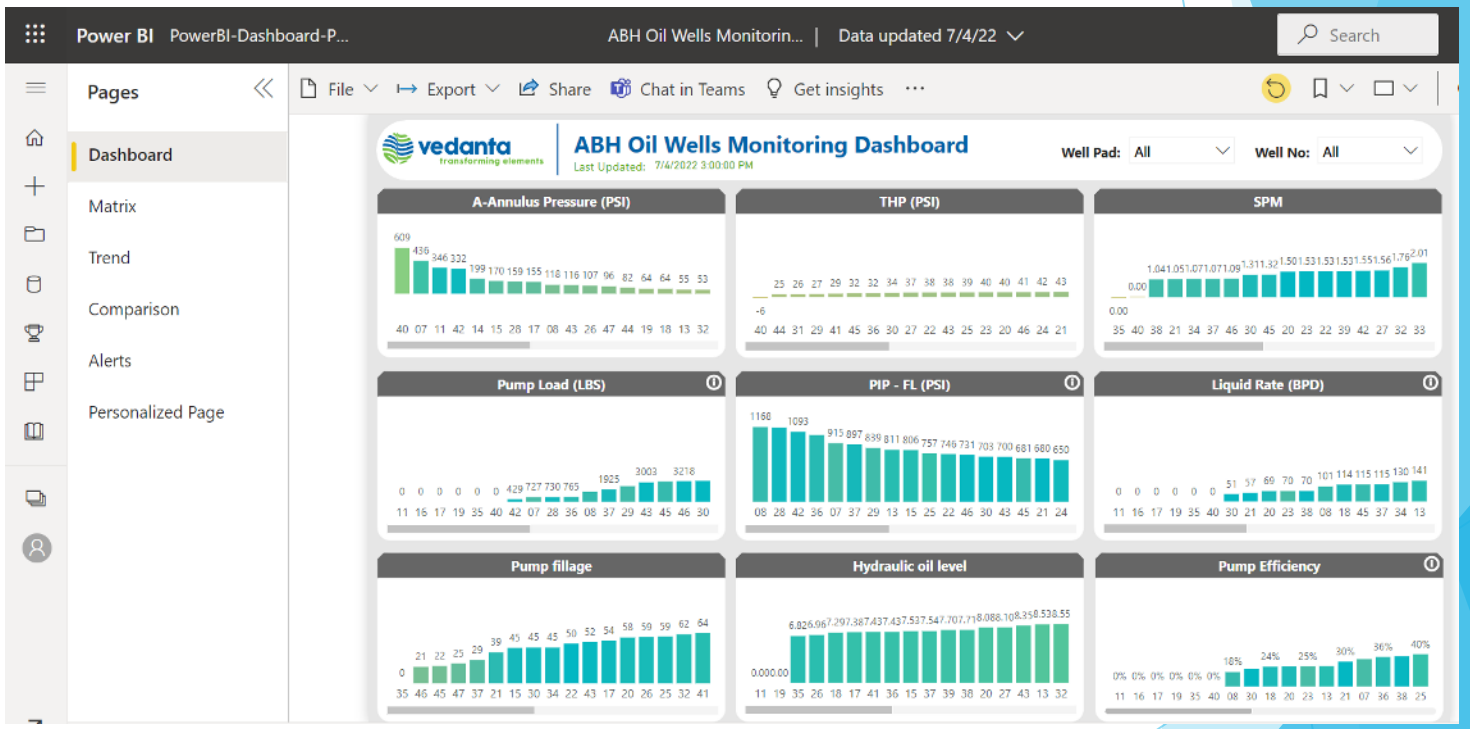
- ABH field is a tight oil field with low productivity index range (0.1-1.5 bpd/psi only) and diversified GOR range (100-4000 scf/bbl). Slug flow behavior is observed in all the horizontal wells drilled in this field due to the above 2 factors
- SAND PRODUCTION PROBLEMS: -
  - DOWNHOLE SUCKER ROD PUMP FAILURES: - Refer figures for pump section with waxy oil and dyna-card which was formed prior to failure
  - WELL PI DECLINE: - Proppant, sand and formation gravels accumulation occurs gradually in horizontal and deviation sections of well bore resulting in restriction to fluid flow path
- GAS INTERFERENCE & HIGH GOR ISSUES: - The majority (~70%) of the wells in this field are having high solution GOR that is more than 500 scf/bbl. Out of these wells more than 40% of the wells are having very high solution GOR (1000-4000 scf/bbl).
- DYNA CARD, ALS PARAMETERS MONITORING & WELL OPTIMIZATION CHALLENGES: - There were no arrangements of real time dyna card acquisition technology because of very high data frequency requirement that is 256-768 data points per minute
  - EDGE & IOT device APPLICATION
  - Analytical dashboards
- HIGH GAS FLOW RATE NOISE IN ANNULUS

Pre-edge & Pre-digitalization workflow

- Manual dynacard collection twice a week
- Manual echoshot survey for detecting fluid level once a week/month
- Dedicated teams deployed
- Manual dynacard visualization and fluid level comparison of different time stamps
- This entire process take enormous amount of time with less data availability
- The discrete data collection is insufficient for detailed analysis or building predictive models.
- Any events or issues that occurred during the non-monitoring period went unnoticed, potentially leading to sudden well failures and production losses.
- The lack of knowledge about the probable causes of these events hindered the implementation of appropriate actions to prevent their recurrence.
- This need becomes more critical during challenging times like the COVID-19 pandemic or logistical issues, where manual collection methods are even more impractical

Power BI Analytical dashboard

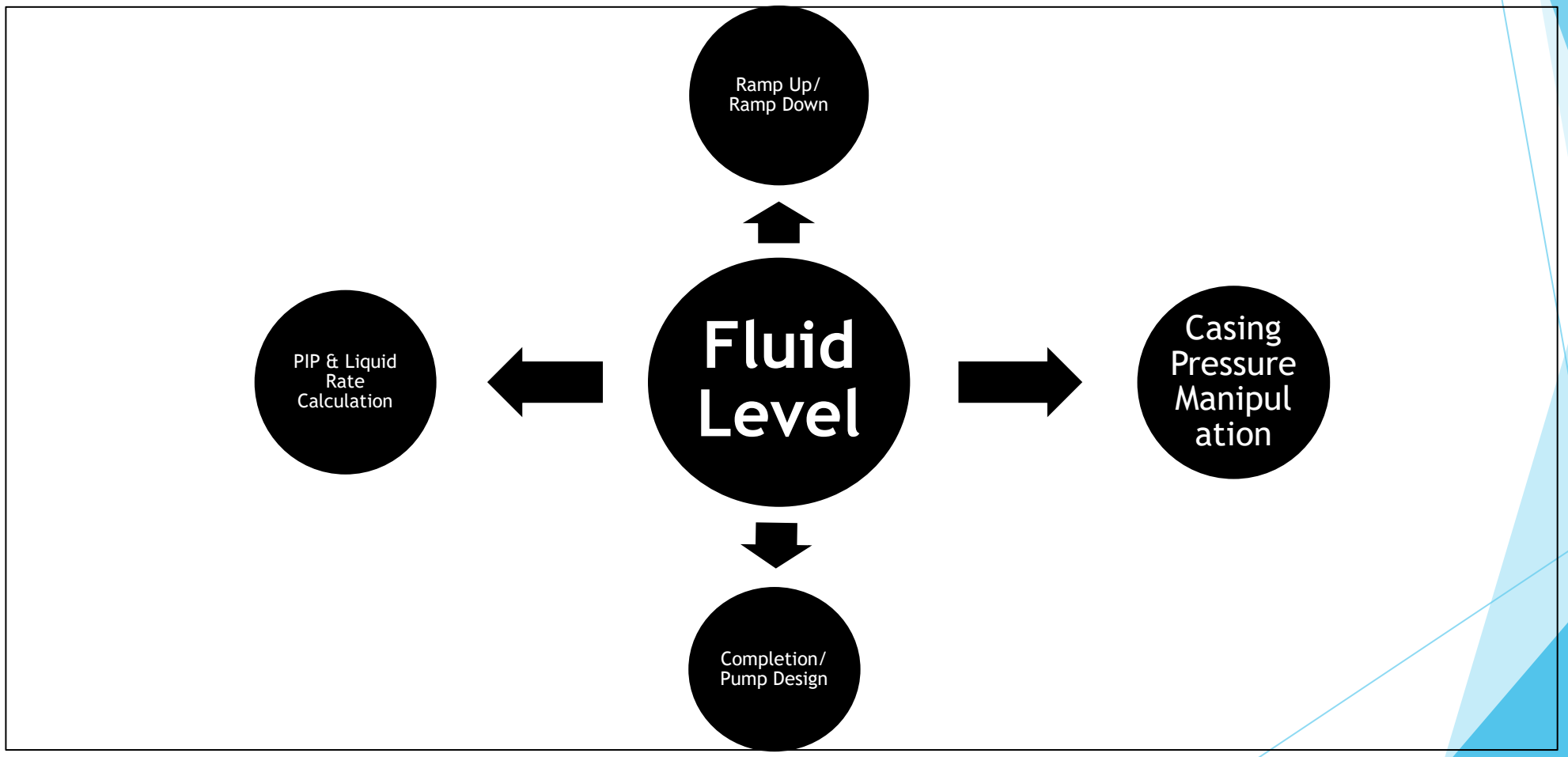
- Designed based on historian capability of 1 data point per minute frequency
- The data frequency required from acquiring dyna card is ~256-768 data per minute which is much higher than historian capability of 1 data point per minute



IOT/EDGE Technology, analytics and Machine Learning vision

- To access continuous data collection and automate the entire process of dyna-card collection and interpretation using Edge technology and Machine Learning.
- To access hydraulic pumping surface unit data, historian data, surface gauge sensor data on cloud by application of Edge or IoT gateway.
- To perform local data analysis using Machine Learning algorithms on the data collected to reduce the need for manual intervention, improvement of data quality, and enables real-time monitoring and decision-making.
- To implement long term cost-effective solution for dyna- card data collection,
- To automate the process interpretation, elimination of delays, minimization of well downtime, and reduction of well failure risks
- The adoption of Edge technology and IoT, coupled with Machine Learning, presents an innovative and efficient approach to dyna-card data collection, ALS data collection and analysis.
- This transformation from manual and reactive processes to automated and proactive decision-making has the potential to significantly enhance the efficiency, productivity, and reliability of oil well operations.

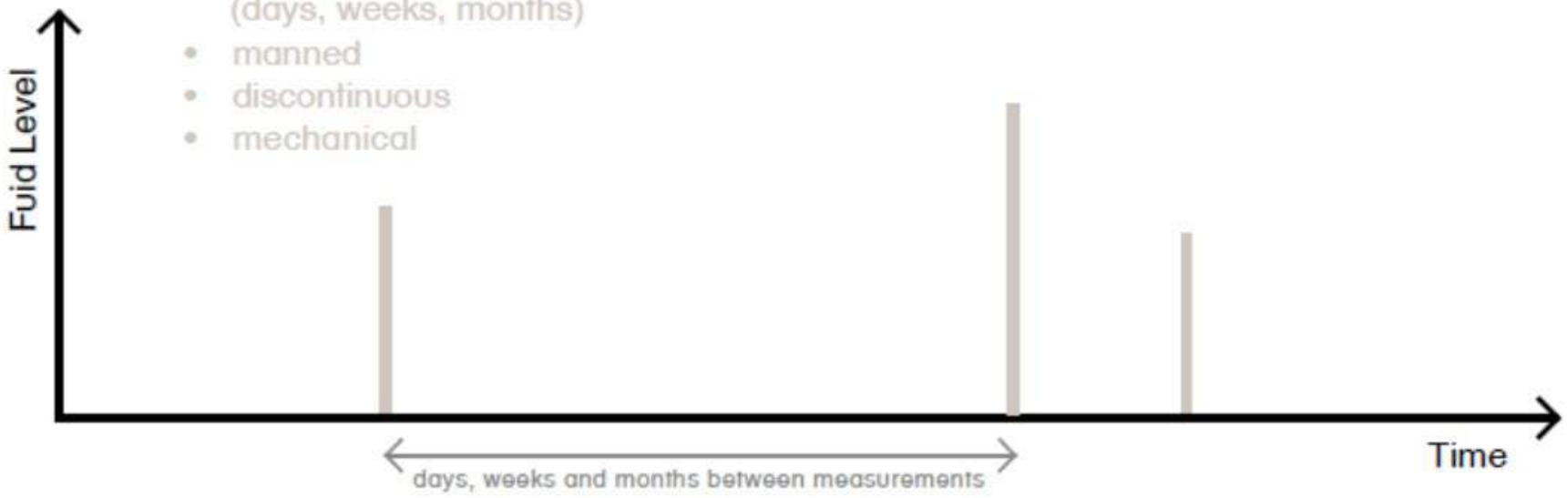
Importance of getting real-time fluid level data



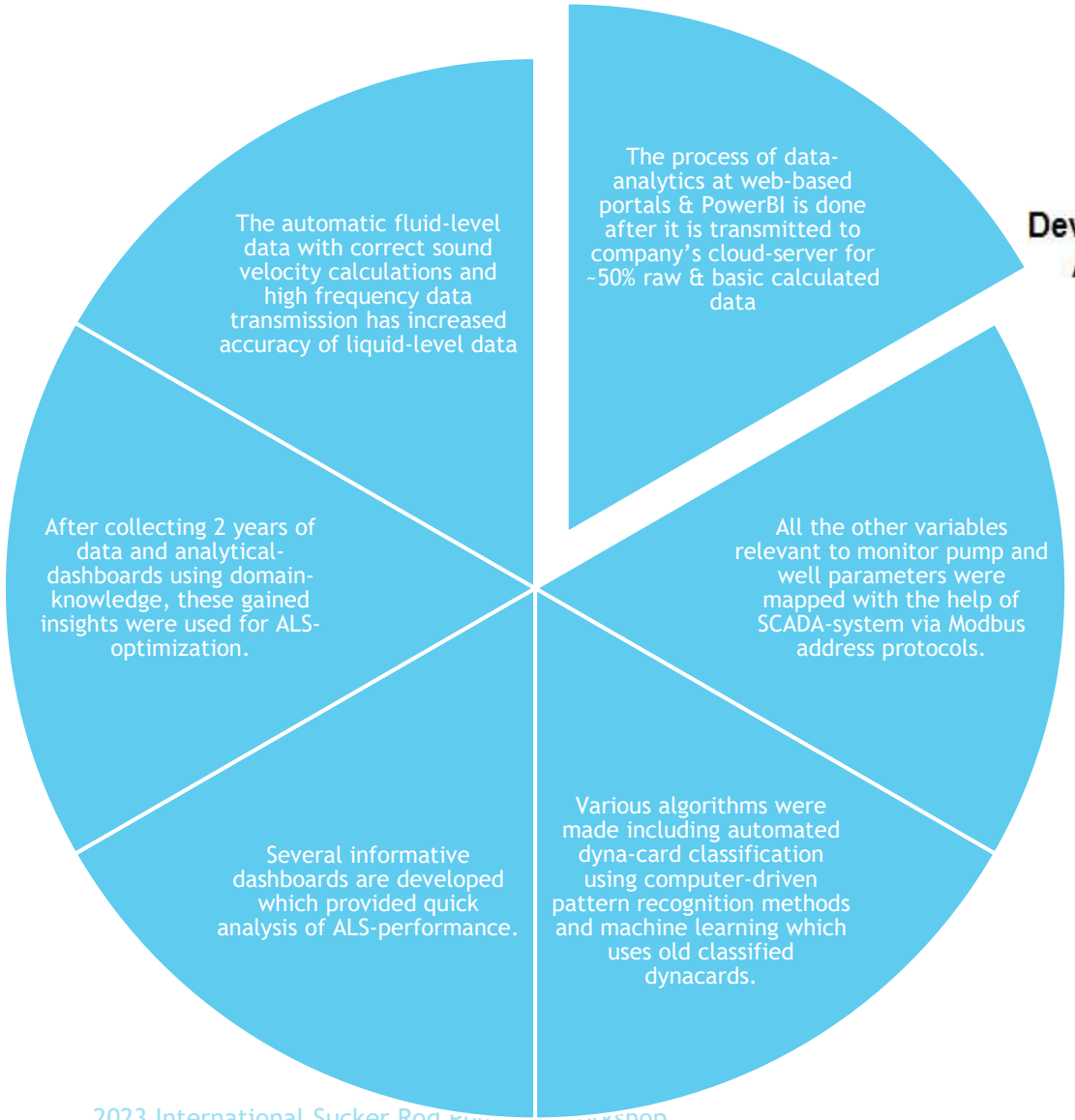
Fluid Level Measurement with Conventional Methods

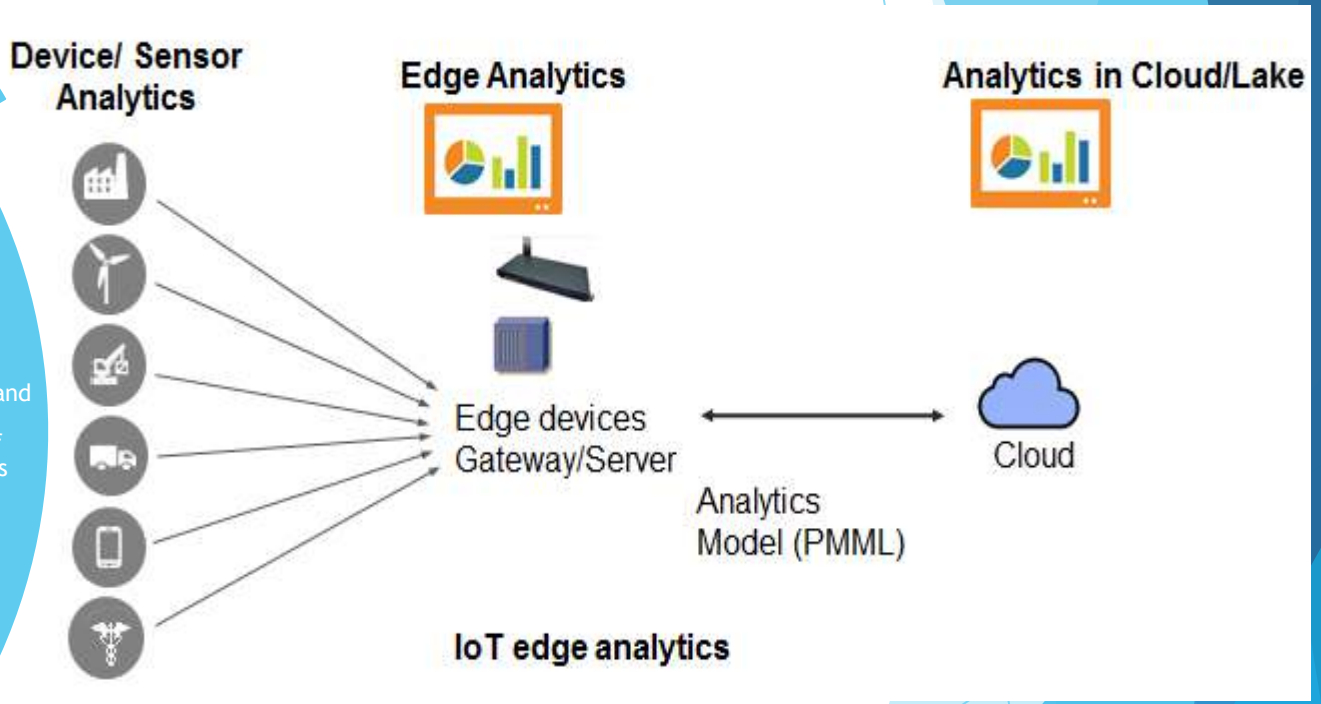
Fluid Level Measurement	MURAG	CONVENTIONAL
Value of information	high	low
Content of information	high	low
Control of production	high	low
Optimization of production	high	low
Evolution of system	4th generation	parent

- discrete information (days, weeks, months)
- manned
- discontinuous
- mechanical



Method, procedure & process



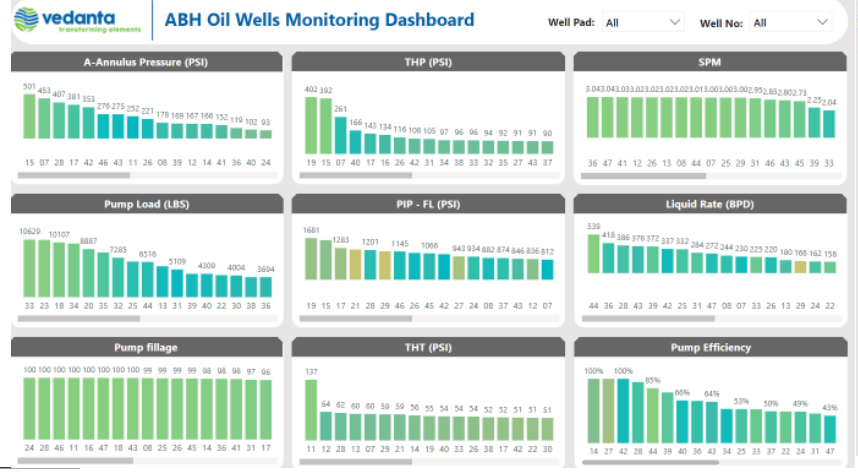


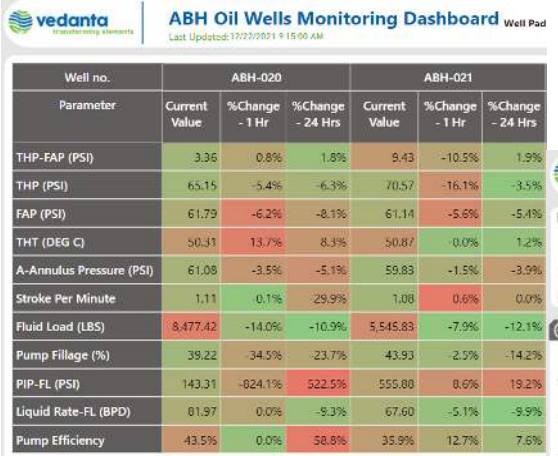
PowerBI dashboard

The monitoring process incorporates key-variables derived from well-head sensors, hydraulic-pumping unit data, etc. These variables assume critical importance in evaluating the operational performance and integrity of both the well and pump systems. The functions of important ones are-

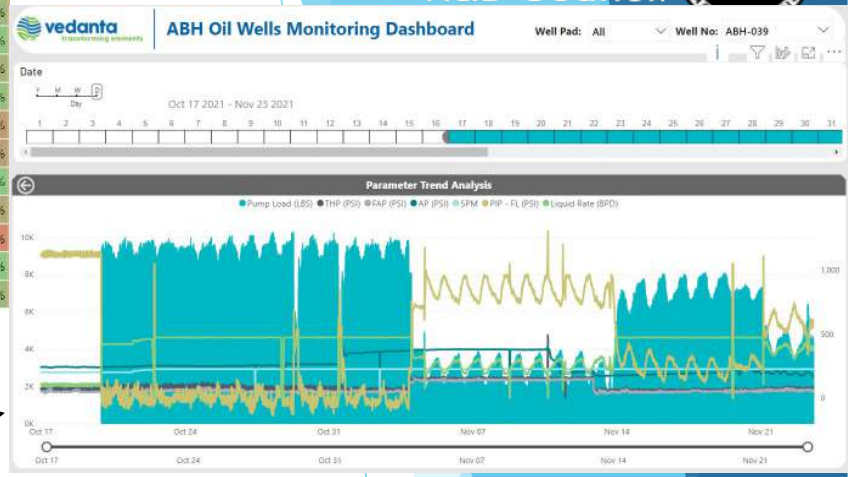
- The dashboard architecture comprises five-distinct sections, each serving a unique purpose. These sections are “summary”, “Matrix”, "Trends and Comparison", "Notifications" and "Analytics".
- The "Trends and Comparison" section offers an expansive-visualization of data, encompassing minute-by-minute frequency, enabling a holistic-understanding of well-behavior, and facilitating insightful comparisons among different-wells.
- The "Notifications" tab furnishes updates on parameter changes at 15-minute intervals, promptly notifying any instances where specified-limitations are surpassed. Additionally, the system sends email-notifications every two-hours to ensure timely-awareness and response apart from well-trips.
- The " Analytics " tab caters to individual preferences and analytical needs, offering an array of parameter analysis methods for in-depth exploration. This section allows for the analysis and preservation of various analytical approaches.

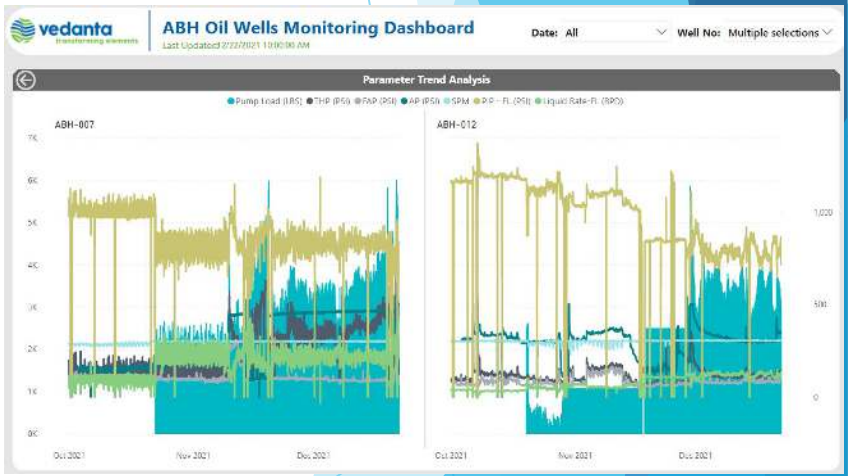
SNAPSHOTS





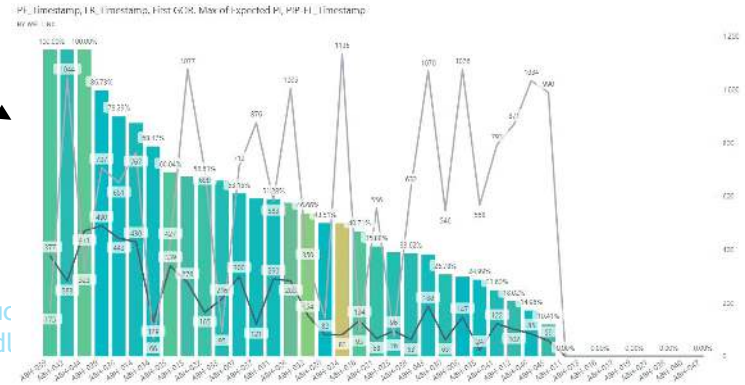
Well no.	ABH-020			ABH-021		
Parameter	Current Value	%Change - 1 Hr	%Change - 24 Hrs	Current Value	%Change - 1 Hr	%Change - 24 Hrs
THP-FAP (PSI)	3.36	0.8%	1.8%	9.43	-10.5%	1.9%
THP (PSI)	65.15	-5.4%	-6.3%	70.57	-16.1%	-3.5%
FAP (PSI)	61.79	-6.2%	-8.1%	61.14	-5.6%	-5.4%
THT (DEG C)	50.31	13.7%	8.3%	50.87	0.0%	1.2%
A-Annulus Pressure (PSI)	61.08	-3.5%	-5.1%	59.83	-1.5%	-3.9%
Stroke Per Minute	1.11	0.1%	29.9%	1.08	0.6%	0.0%
Fluid Load (LBS)	8,477.42	-14.0%	-10.9%	5,545.83	-7.9%	-12.1%
Pump Fillage (%)	39.22	-34.5%	-23.7%	43.93	-2.5%	-14.2%
PIP-FL (PSI)	143.31	-824.1%	522.5%	555.88	8.6%	19.2%
Liquid Rate-FL (BPD)	81.97	0.0%	-9.3%	67.60	-5.1%	-9.9%
Pump Efficiency	43.5%	0.0%	58.8%	35.9%	12.7%	7.6%

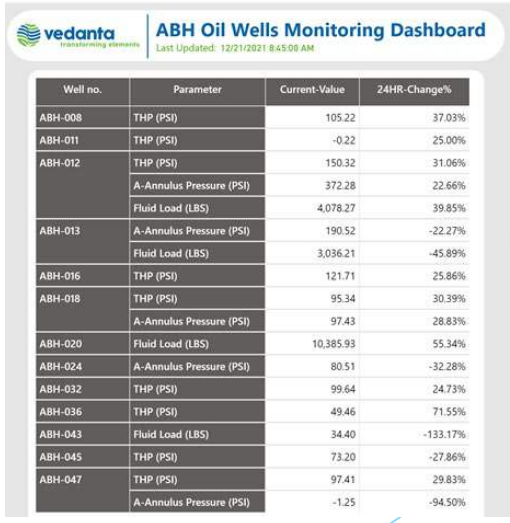




Pages

- Dashboard
- Matrix
- Trend
- Comparison
- Alerts
- Personalized Page





Well no.	Parameter	Current-Value	24HR-Change%
ABH-008	THP (PSI)	105.22	37.03%
ABH-011	THP (PSI)	-0.22	25.00%
ABH-012	THP (PSI)	150.32	31.06%
	A-Annulus Pressure (PSI)	372.28	22.66%
	Fluid Load (LBS)	4,078.27	39.85%
ABH-013	A-Annulus Pressure (PSI)	190.52	-22.27%
	Fluid Load (LBS)	3,036.21	-45.89%
ABH-016	THP (PSI)	121.71	25.86%
ABH-018	THP (PSI)	95.34	30.39%
	A-Annulus Pressure (PSI)	97.43	28.83%
ABH-020	Fluid Load (LBS)	10,385.93	55.34%
ABH-024	A-Annulus Pressure (PSI)	80.51	-32.28%
ABH-032	THP (PSI)	99.64	24.73%
ABH-036	THP (PSI)	49.46	71.55%
ABH-043	Fluid Load (LBS)	34.40	-133.17%
ABH-045	THP (PSI)	73.20	-27.86%
ABH-047	THP (PSI)	97.41	29.83%
	A-Annulus Pressure (PSI)	-1.25	-94.50%

Well no.	Stroke per minute
ABH-027	0.00
ABH-028	0.01
ABH-040	0.00
ABH-047	0.01

Preliminary structure – IOT/ EDGE Applications

The following modules are integral components of this advanced dashboard, collectively ensuring comprehensive data visualization and analysis:

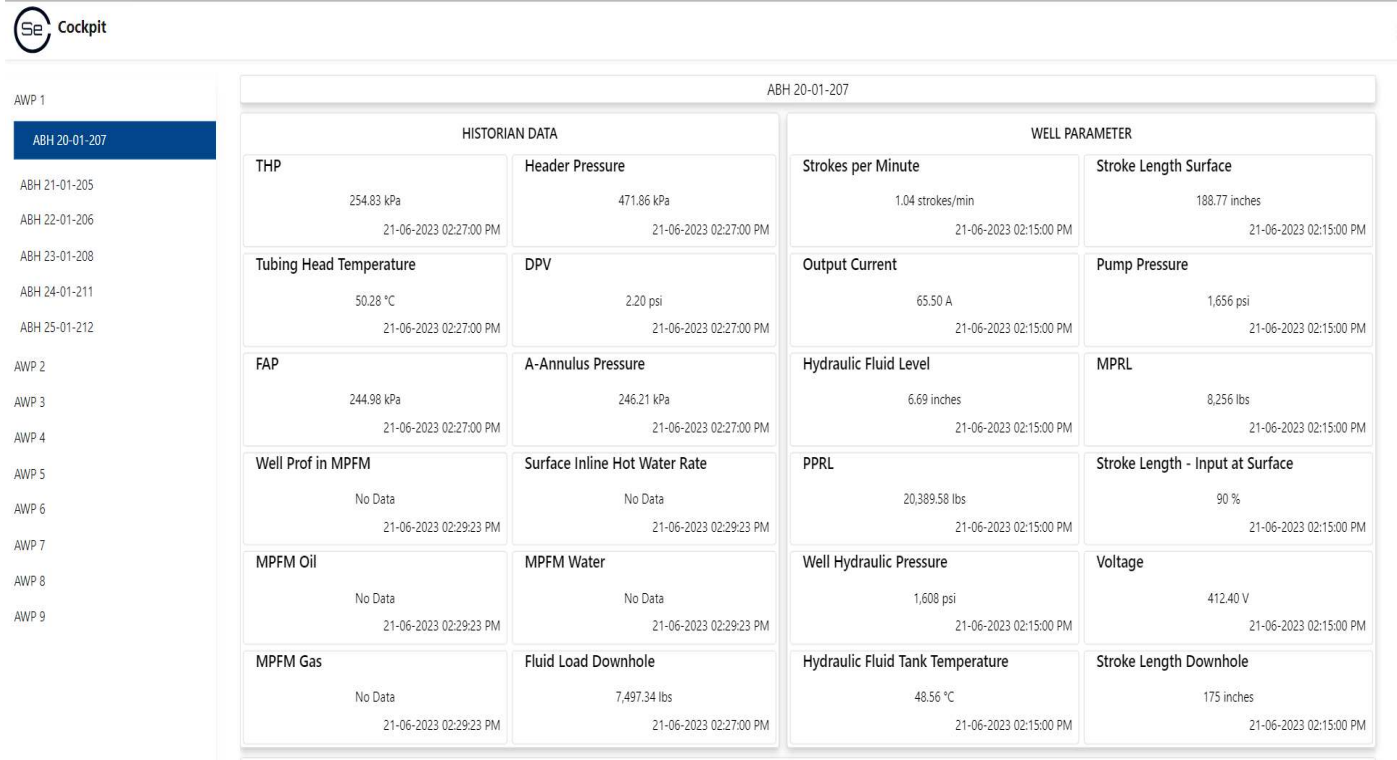
1) Parameter Trends: This enables the observation and analysis of trends in various well parameters, empowering operators to identify patterns, anomalies, and potential areas for optimization.

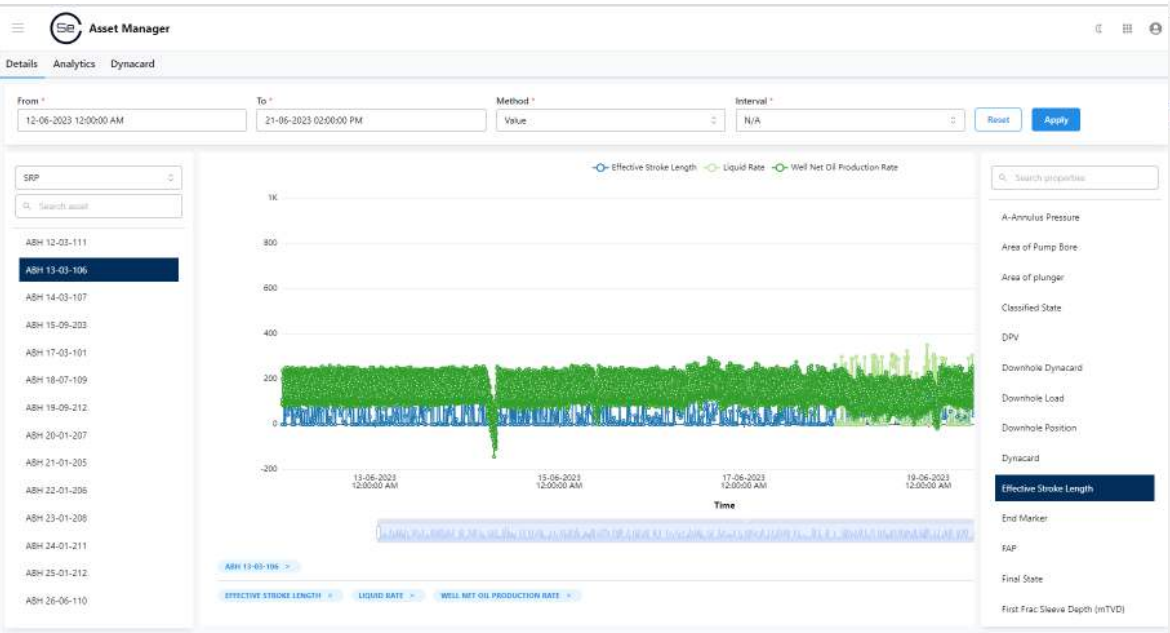
2) Production Analysis: This delves into detailed analyses of production data, including production rates, fluid composition, and overall reservoir performance. This enables proactive decision-making to optimize production efficiency and maximize output.

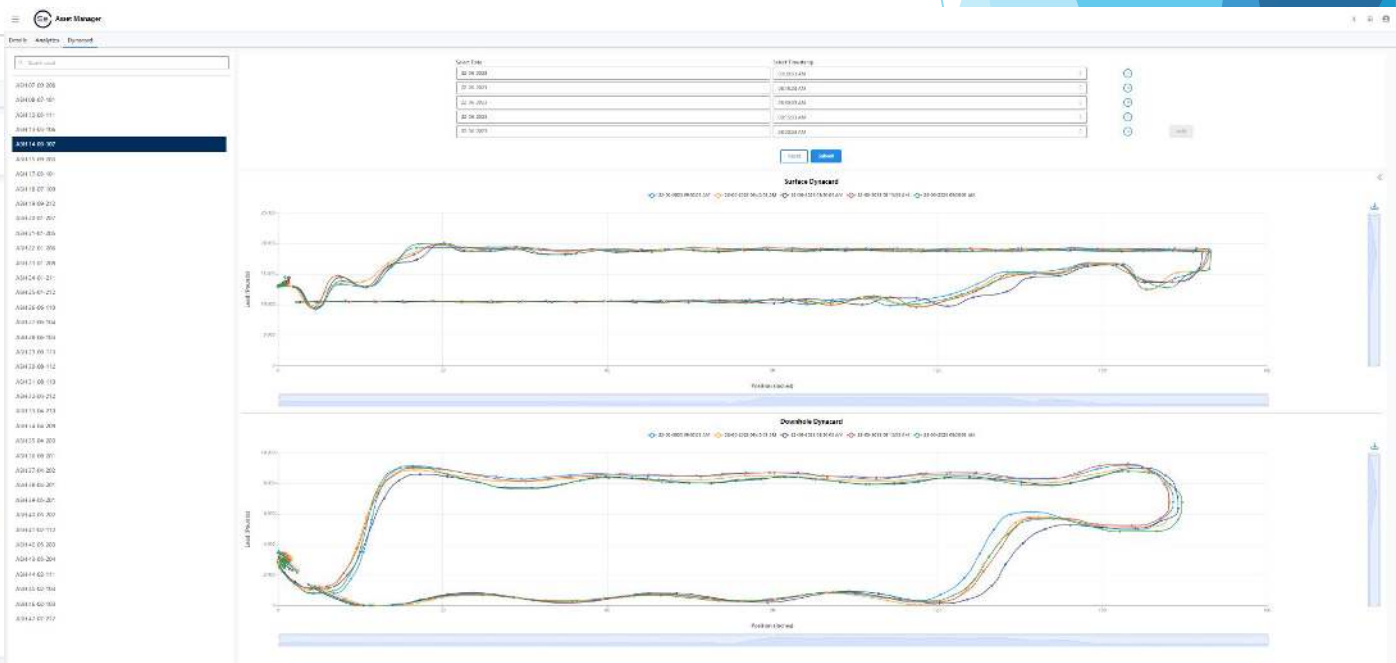
3) Operational Efficiency: This section focuses on optimizing operational efficiency by analyzing parameters such as energy consumption, equipment utilization, and maintenance schedules. It offers valuable insights for streamlining operations and reducing costs while maintaining high productivity levels.

Snapshots

- Pic-1 refers to cockpit page of well summary (Right one)
- Pic-2 refers to summary cockpit (below pic-1)
- Pic-3 refers to asset manager page where all parameters can be analyzed with other wells as well

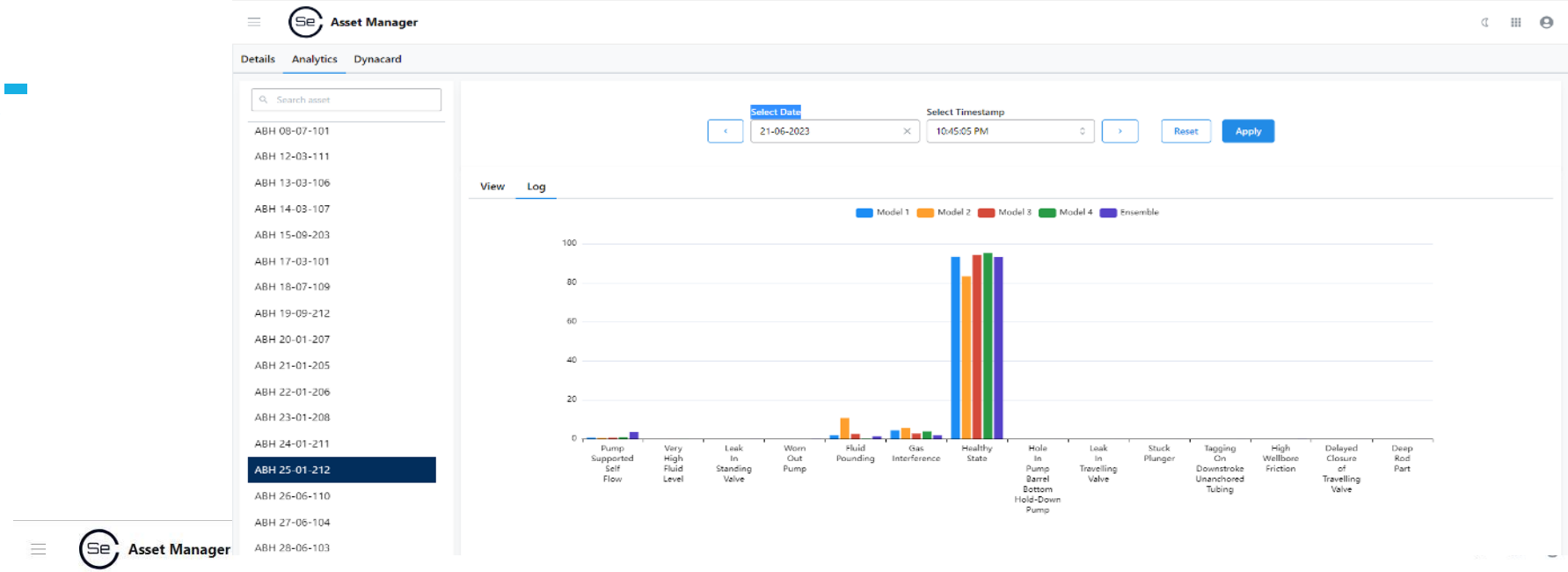


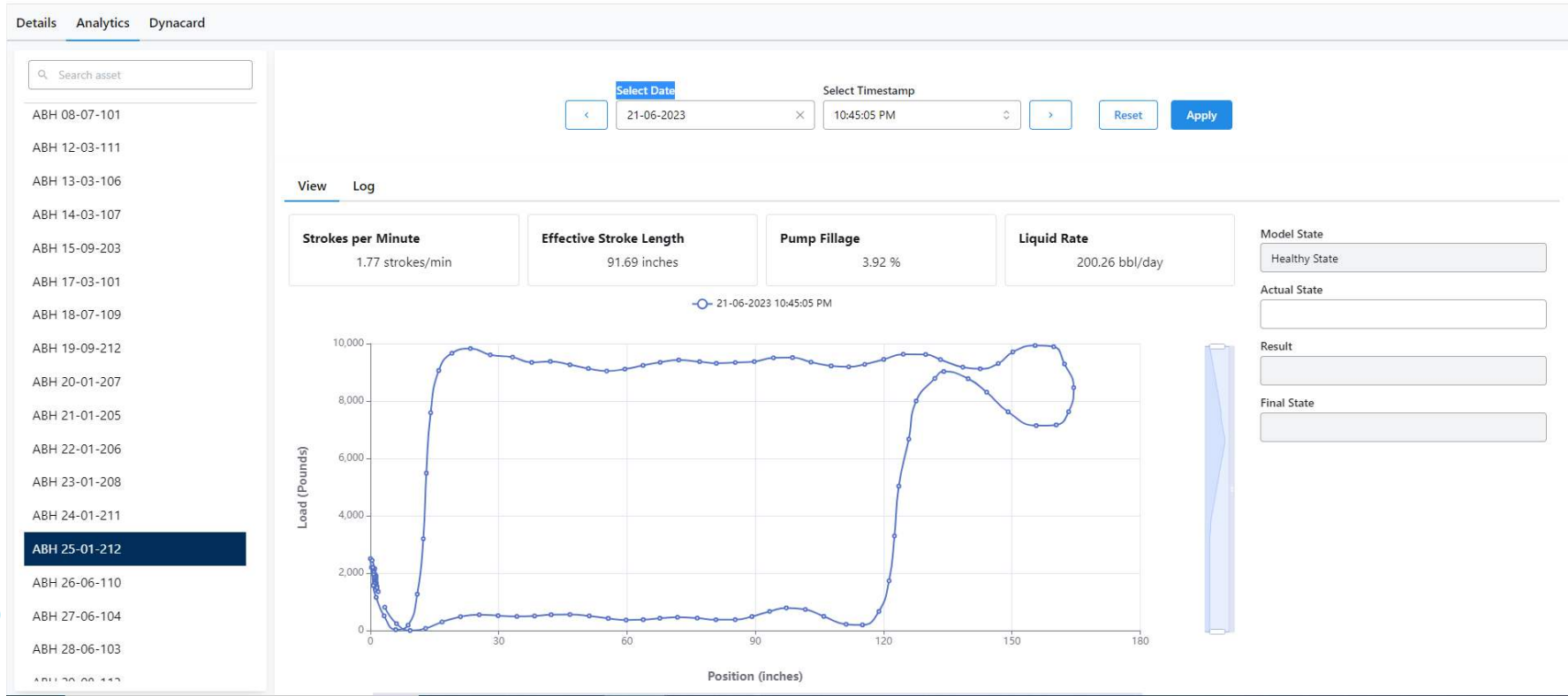




ML & DYNA-CARD

- The above snapshot refers to the ML log page - The dyna-card auto classification and bar charts showcase the comparative percentages for different dyna-card states via 5 Machine learning models which run on old classified cards data as wells as empirical shape characterizations
- The snapshot below shows the results of the ML models along option of filling the user classified actual state (ex- fluid pounding, gas interference, etc) in addition to card effective stroke length algorithm-based calculation, SPM, dynacard based liquid rate, etc





REPORT GENERATION MANAGER

The report manager module assists in the generation of reports based on the needs of the user.

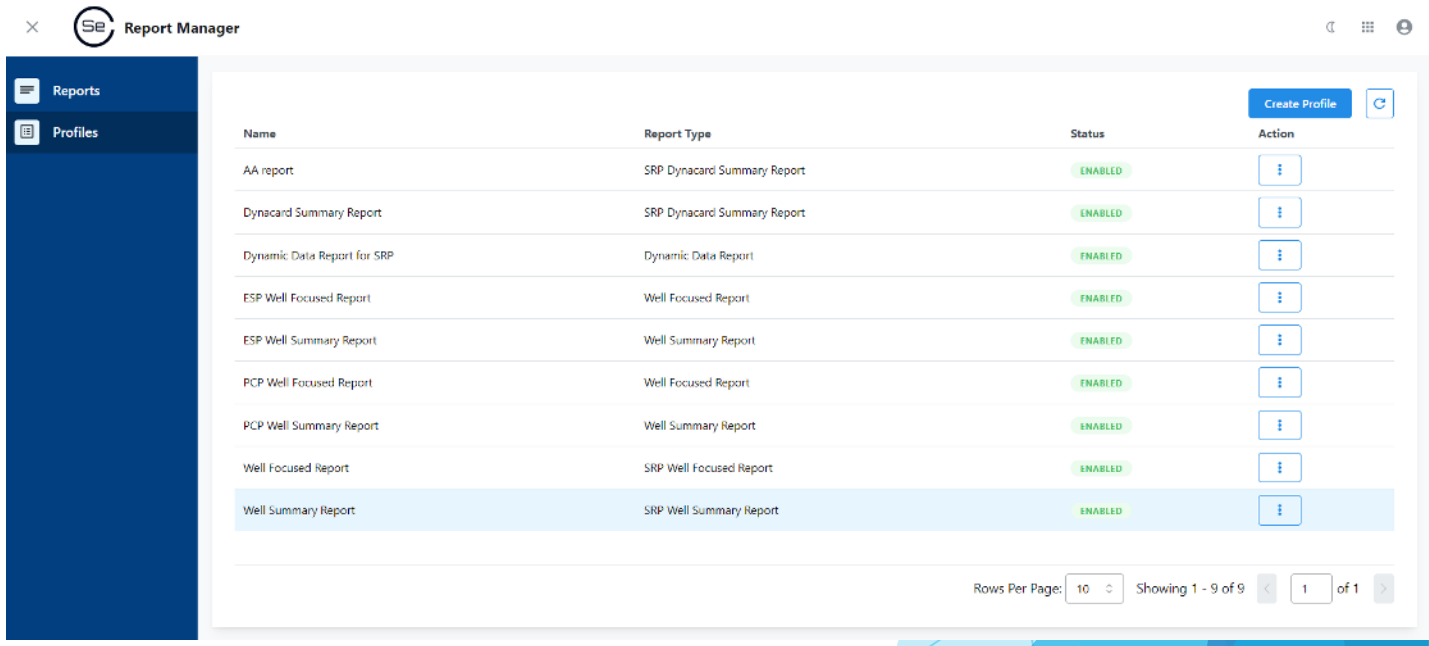
This manager generates periodic reports related to last 24 hours well performance and downhole pump behavior (with the help of last 24 hrs dynacard overlapped presentation).

Apart from periodic reports, specific wells/field behavior analysis reports are also accessed based on request on this page.

The specific reports can be generated in any time range.

Display of reports made are presented in reports page regarding its generated ID, report kind, profile, status, and time when it was generated.

The report helps in critical analysis information allows for a more informed assessment of its reliability, relevance, and implications



Alarms & Event Manager

It plays critical roles in the well management system by allowing users to set alerts for well parameters that exceed established threshold limits and produce notifications for desired alarm occurrences.

Alarm Configuration:

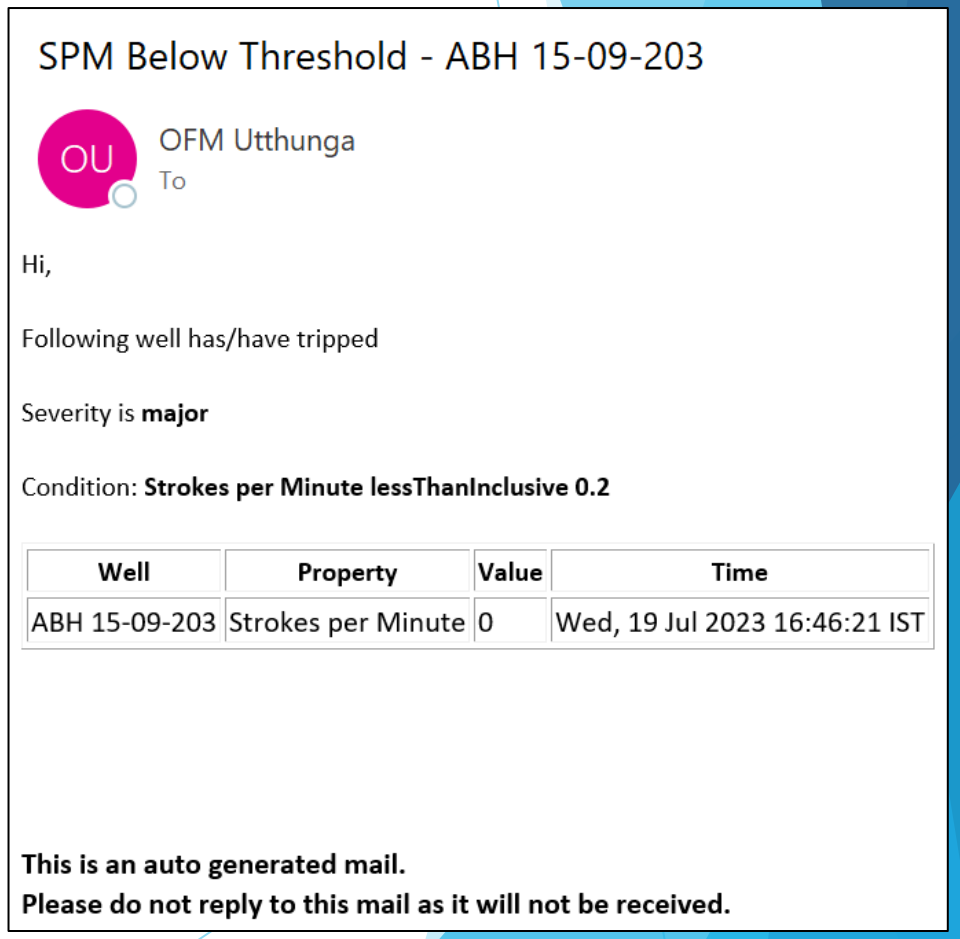
It allows user to define the threshold parameters limits associated with the wells. The parameters can include SPM, THP, Fluid load, etc. The user can set the limits for each parameter to establish desired alarm conditions.

Alarm Triggering:

As the parameter surpasses the threshold limits, the alarm module detects the deviation and raise the alert, indicating that the well has exceeded the specified limitation. The alarm triggered notify the users of any abnormalities in the well.

Notification:

As the alarm is triggered, the email notification is generated with the desired alarm set by the user. Refer beside figure which is a snapshot of the email alert



SPM Below Threshold - ABH 15-09-203

OU

OFM Utthunga
To

Hi,

Following well has/have tripped

Severity is **major**

Condition: **Strokes per Minute lessThanInclusive 0.2**

Well	Property	Value	Time
ABH 15-09-203	Strokes per Minute	0	Wed, 19 Jul 2023 16:46:21 IST

This is an auto generated mail.
Please do not reply to this mail as it will not be received.

Automatic fluid level analyzer - METHOD

This device can listen to the well noise wave frequencies and accordingly send different frequency waves as per requirement to detect correct fluid level peaks.

This device is rigged up via well annulus outlet and can continuously generate (6 data points per minute frequency) sound waves to get fluid level data for transmitting to company's cloud in real time.

This technology has eliminated the dilemma of acoustic sound velocity determination in annulus by its sound calculation box applications. This box takes the annulus gas at the same casing head pressure and calculates the sound velocity in a few meter round coil with gas composition of the same well.

This has also eliminated the requirement to install thick pup joint & count the joint collars with weak reflection signals generated by conventional sound signals that dampens severely even in explosion mode of sound generation method.

Observations & Results – PowerBI dashboard

- A smart real-time dashboard mapped with historian data mapping assisted in efficient well monitoring
- It also highlights issues in well performances in a lesser amount of time.
- It avoid/minimize well downtime in addition to remarkable data analysis & data visualization application of BI
- It generates well trip alerts & alerts of well parameters threshold breach.
- Well Liquid-Level Identification without fluid-level echoshot-survey: Real-time mapping of polished-rod-load, with the maximum and minimum possible rod-load in upstroke and downstroke
- Optimization of Pump-Stroke-Speed: Remarkable pump-fillage increase, more than 10% in SRPs
- Identification of Pump-Choking Effects: Dyna-card based analysis to detect sand-ingression or formation of scale at pump-valves.
- Gas-Separator Efficiency: Real-time quantification & optimization to ensure maximum liquid-fillage in pumps.
- Quantification and Analysis of Well Productivity-Index: Decline-trend analysis & comparison with other wells
- By leveraging real-time data and sophisticated analysis, we proactively identify and address issues, optimize production-parameters, and maximize the overall-efficiency and productivity of the wells and pumping-systems.

Observations & Results – Edge/IOT devices

The use of IoT (Internet of Things) edge gateway devices bring several benefits to sucker rod pumping operations. Here's how IoT edge gateway devices enhance sucker rod pumping:

- Real-Time Monitoring: IoT edge gateway devices collect and transmit real-time data from various sensors and devices involved in sucker rod pumping. This data provides valuable insights into the pump's performance, well conditions, and potential issues.
- Data Analytics: IoT edge gateways enable the collection and analysis of large amounts of data. Advanced analytics algorithms were applied to the collected data to detect patterns, identify anomalies, and predict failures or maintenance requirements. This helped optimize production, improve equipment reliability, and reduce downtime.
- Remote Management and Control: IoT edge gateways allow remote management and control of the sucker rod pumping system. Operators can monitor and control the system from a central location, reducing the need for physical presence at the wellsite. Remote control capabilities enable adjustments to pump parameters, optimizing production efficiency.
- Condition-Based Maintenance: With IoT edge gateways, condition monitoring data is used to implement condition-based maintenance strategies. By analyzing real-time data, early warning signs of equipment degradation or failure are detected. This enables proactive maintenance interventions, reducing unplanned downtime and maximizing equipment lifespan.

Contd…

- Enhanced Safety and Security: IoT edge gateways improved safety and security in sucker rod pumping operations. They can incorporate features such as remote emergency shutdown, leak detection, and intrusion detection systems. Real-time alerts and notifications are sent in case of any abnormal situations, allowing for timely response.
- Integration with Existing Systems: IoT edge gateways integrate with existing supervisory control and data acquisition (SCADA) systems or enterprise resource planning (ERP) systems. This integration enables seamless data flow and sharing between different operational layers, facilitating better decision-making and operational coordination.
- Optimization and Energy Efficiency: By continuously monitoring and analyzing data, IoT edge gateways optimized sucker rod pumping operations. They identify opportunities for energy efficiency improvements, such as optimizing pump speed and stroke length based on real-time production requirements. This results in energy savings and reduces operational costs.
- Scalability and Flexibility: IoT edge gateway devices are highly scalable and adaptable to different wellsite configurations. They were easily deployed in both new and existing installations, supporting a wide range of communication protocols and sensor connectivity options. This scalability and flexibility allow for future expansion and integration of additional devices and sensors.

Observations & Results – Auto fluid level analyzer

Continuous echo-shot fluid level data analysis has been very effective in improving well production, increase the pump life and increase rod run life. A few extraordinary advantages of this technology are –

1) Noise filtering and well listening capability for accurate fluid level signature

2) Correct sound velocity quantification for fluid level reflection quantification (see the table beside

3) Automatic, continuous, unmanned electrical/digital data to control pump speed

4) High frequency bottomhole flowing pressure & shut-in pressure build-up data acquisition (see the chart in next slide)

5) It can also detect changes in sound generated by well because of - well trip, pump failure, tubing leak, rod failure etc

Well Name	Speed of Sound (m/s) by box application	Old Speed of Sound (m/s)	Liquid level depth error reduction (meter)
Well-1	327	370	21.3
Well-2	267	358	45.5
Well-3	320	365	22.5
Well-4	299	362	31.2
Well-5	269	358	44.6
Well-6	286	365	39.6
Well-7	366	380	7.1
Well-8	268	358	45
Well-9	290	360	34.7
Well-10	288	366	38.8
Well-11	266	358	46
Well-12	285	365	39.8

Digitalization advantages

- There is no downtime of production or intervention loss
- No workover required compared to conventional gauges
- Immediate pressure build up data recording available real time
- Very low error rate due to choose of working principle and measurement analysis
- Working principle is continuous acoustic signals generated by diaphragm compared to discrete explosion principle vs. Implosion principle in conventional sonic tools
- Easier automated measurement & analysis (with the help of calibration box), compared to conventional computer aided manual calculation – taking constant acoustic velocity method and joint length method to get fluid level data
- Minimal manpower requirement as compared to conventional echoshot method
- Production optimization & pump damage prevention by pump control via edge gateway devices

Applications of Automatic FLA

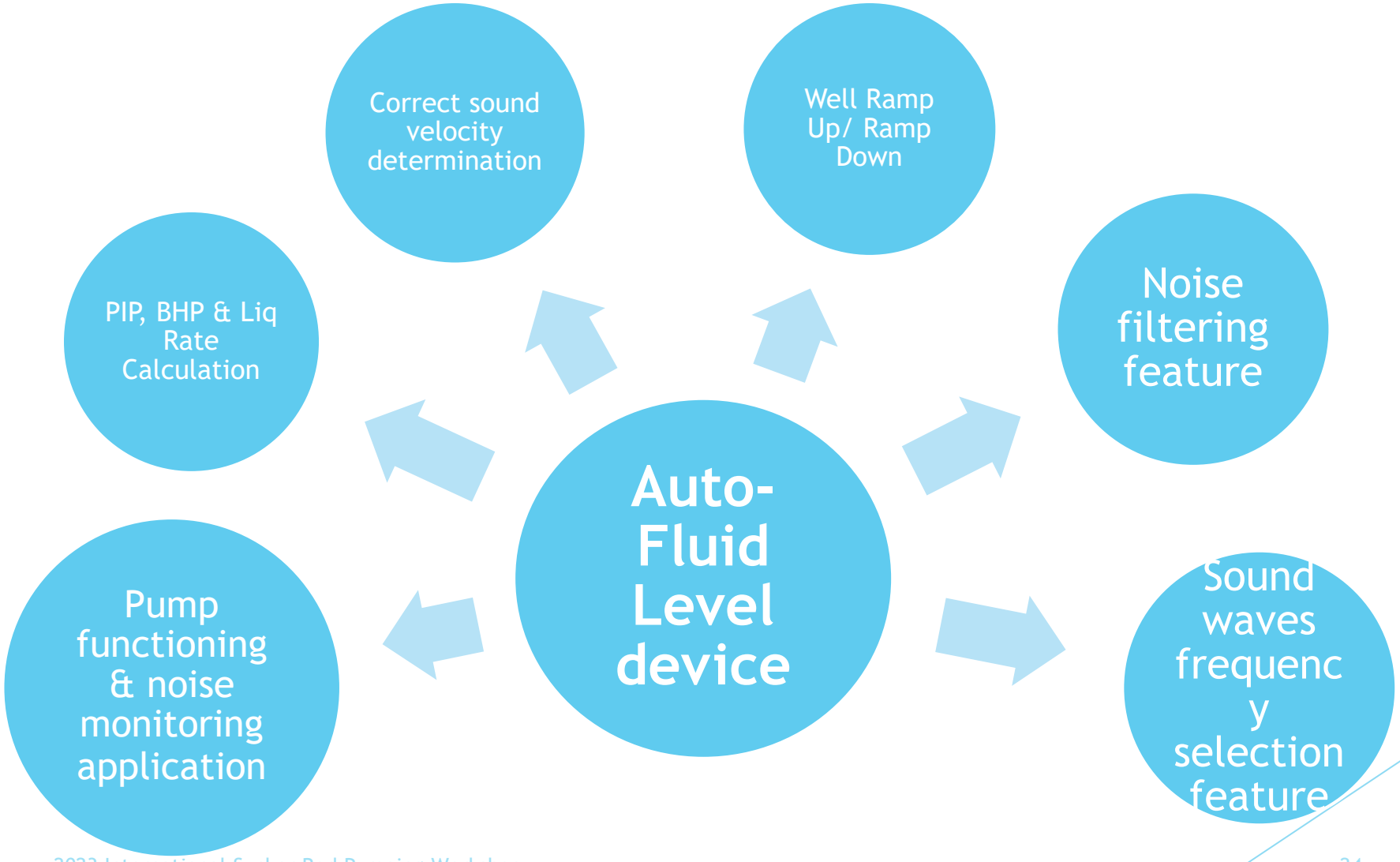
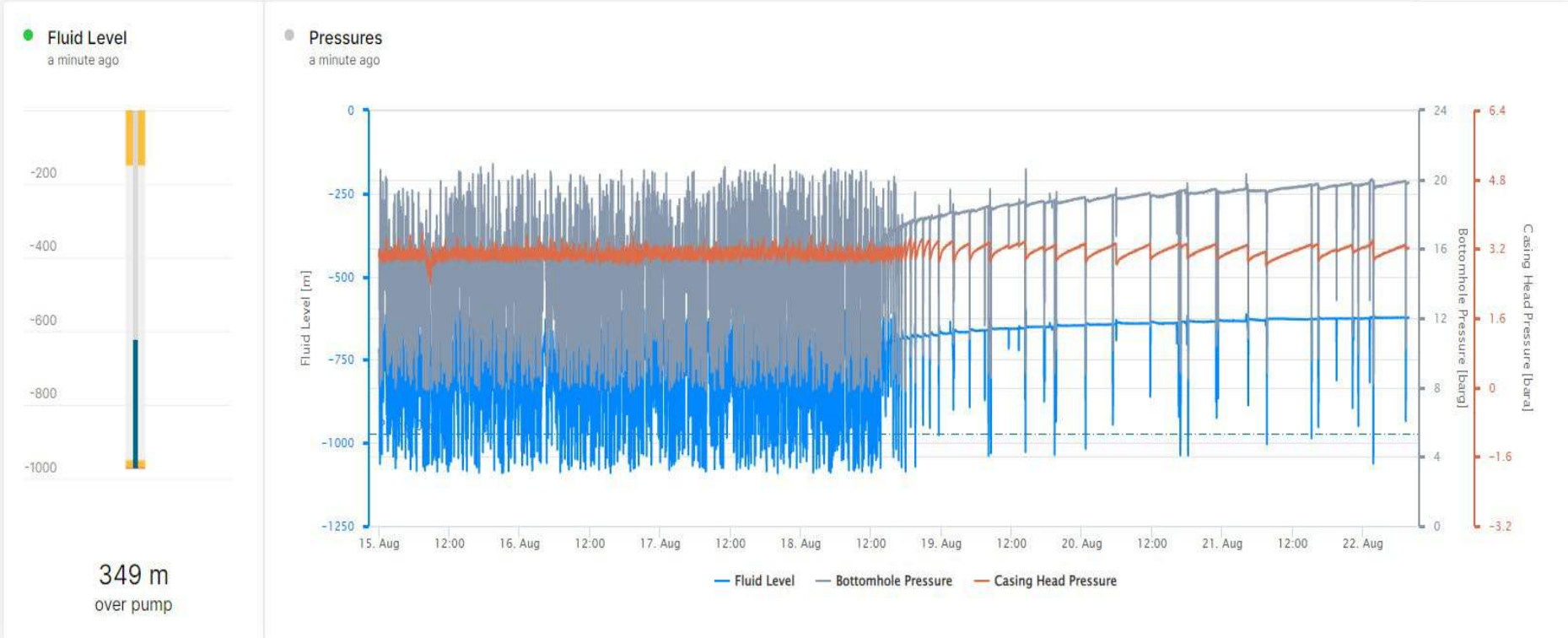


Illustration:- Pump Failure & pressure build up recording (6 data/min)



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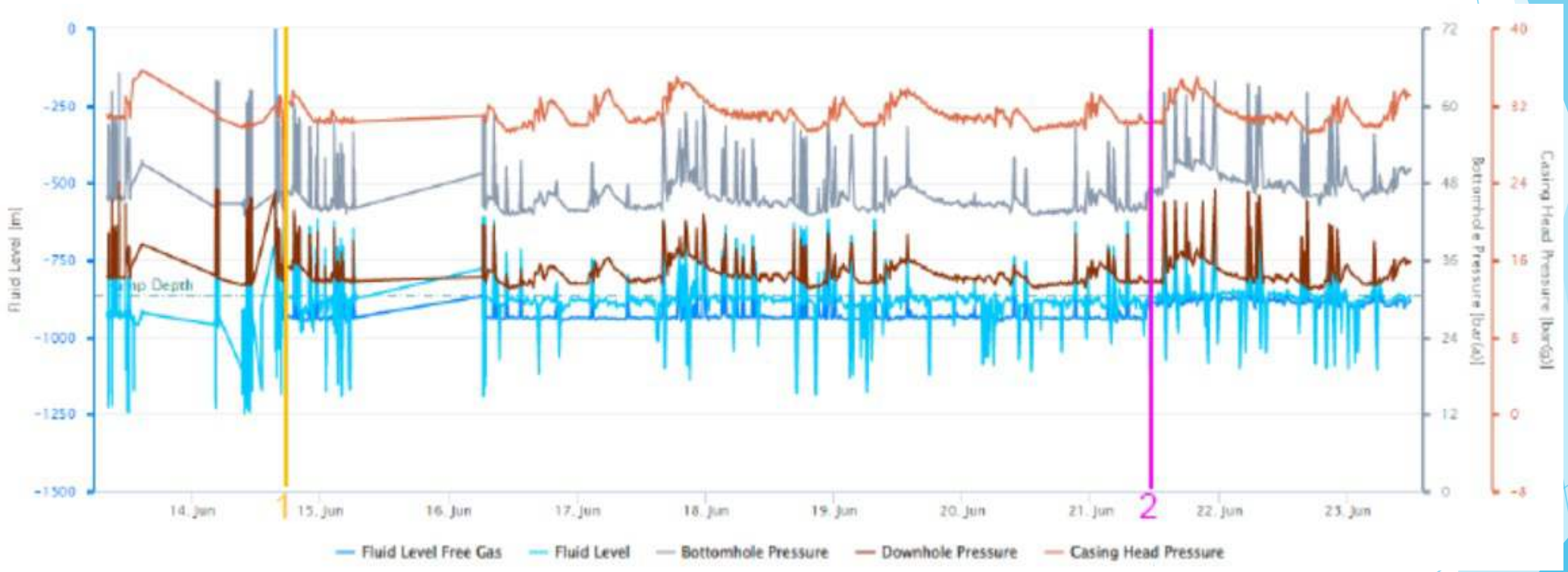
Well-1 – real-time fluid level data acquisition



CONCLUSIONS

- It has demonstrated how use of EDGE technology along with the advance analytics and machine learning techniques to manage the economically challenged remote fields.
- It assisted in effectively managing a complete asset remotely with limited resources. It provides long term production enhancement and downtime reduction which improves the ROI significantly.
- The benefits of EDGE technology are also adopted in other types of artificial lifts for substantial performance improvement coupled with high revenue and reduced cost because of the success of this project.
- The same is applied to remote site ESP and PCP wells. EDGE along with advanced analytics will gain more technological advances in near future for any industry. Its is leading to a significant business impact in terms of revenue.
- This detailed work gives a new approach to E&P companies for well intervention jobs planning, production restoration candidates identification & saving man hours.
- The output data analyzation adds value to the system from day zero hence reduce production downtime
- This project has delivered an innovative methodology for field monitoring in a very challenging tight oil fields along with many learnings & solutions adopted.

Acknowledgements & Thanks

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