Deliverable report 31

AI and IAGEN Application Use Case

Oil and Gas Well Monitoring - Pressure Analysis, temperature and flow to minimize failures

I. Introduction

The oil and gas sector plays a key role in the supply global energy, and faces constant pressure to improve efficiency operational, ensure the safety of its workers and minimize its impact environmental.

Well monitoring is an essential component of oil production and gas, as it allows you to monitor performance, identify potential problems and optimize extraction strategies.

Traditionally, this monitoring has been based on manual methods and analysis. newspapers, which are often laborious, time-consuming and can be prone to human error.

Artificial intelligence (AI) has emerged as a disruptive technology with the ability to overcome these limitations, offering advanced tools for revolutionize well monitoring practices. This report aims to aim to provide a comprehensive analysis of the applications, benefits, Challenges and future trends of AI in improving well monitoring within the oil and gas industry.

II. AI in the Oil and Gas Industry

The implementation of AI has spread throughout the entire value chain of the oil and gas industry, ranging from exploration to distribution.

- Upstream: In the initial exploration phase, AI is used to analyze large amounts of seismic data and geological information, allowing to identify more precisely the promising locations for drilling and characterize reservoirs. During drilling, AI algorithms optimize operating parameters, reducing risks and improving performance efficiency . At the production stage, AI helps optimize production rates. extraction and to manage deposits more effectively.
- Midstream: AI plays a crucial role in pipeline monitoring and gas pipelines to detect leaks and anomalies , as well as in the optimization of the logistics and storage management.
- Downstream: In refineries, AI optimizes processes, improves efficiency energy and manages the supply chain. Predictive maintenance, powered by AI, is applied at all stages to prevent failures in the equipment and reduce operating costs.

III. AI-Powered Well Monitoring

1. Real-Time Data Acquisition and Analysis

Well monitoring has been transformed by the convergence of the Industrial Internet of Things (IoT) and artificial intelligence.

A network of advanced sensors, deployed at various points in the wells, collects continuously collect large volumes of data in real time, including parameters critical factors such as pressure, temperature, flow rate and vibration.

AI algorithms analyze this data to identify complex patterns, detect subtle anomalies and anticipate potential operational problems in real time.

This real-time monitoring capability offers numerous benefits, including proactive detection of problems before they become serious, response times faster response to any incident and a significant improvement in decision-making operational decisions. The synergy between IIoT and AI enables monitoring continuous and intelligent that overcomes the limitations of traditional methods based on manual and punctual inspections.

2. Predictive Maintenance for Well Equipment

AI has revolutionized the maintenance of equipment used in oil wells. Oil and gas. AI algorithms can accurately predict equipment failures. critical devices such as electric submersible pumps (ESPs), surface pumps and valves, both in subsurface and surface infrastructure.

The process begins with the collection of data from sensors installed in the teams, followed by training machine learning models to identify patterns and anomalies that precede a failure.

These models can predict the remaining useful life (RUL) of equipment, allowing to companies to plan maintenance interventions proactively.

The economic benefits of this strategy are significant, including the reduction of unplanned downtime, decreased maintenance costs and extending the useful life of critical equipment.

Predictive maintenance represents a paradigm shift from the reactive repairs towards proactive interventions, which translates into savings substantial and gains in operational efficiency.

3. Improving Well Integrity through Anomaly Detection

AI plays a pivotal role in early detection of problems that could compromise the integrity of the wells. By continuously analyzing the operating parameters, such as pressure, temperature and flow rate, AI systems can identify anomalies that suggest possible ring leaks, corrosion, or failures mechanics .

AI models, fed by time-series sensor data, learn normal operating patterns and can point out any deviations significant that requires attention. The feasibility of monitoring has been demonstrated of AI-based well integrity for different well types, including gas lift, natural flow and water injection.

Early detection of integrity problems not only improves the security of operations, but also provides environmental benefits by preventing possible hydrocarbon spills or leaks. AI-powered anomaly detection acts as an early warning system, preventing catastrophic failures and minimizing the potential environmental damage.

4. Optimizing Hydrocarbon Production with AI

AI has proven to be an effective tool for optimizing production hydrocarbons. AI models analyze historical and real-time data on the well production to identify opportunities for performance improvement. These models can dynamically adjust operating parameters such as rates flow, pressure levels and configuration of artificial lift systems to maximize extraction efficiency. This translates into a potential increase of production and a reduction in resource waste.

AI enables dynamic optimization of production parameters, which leads to higher yields and better utilization of resources in compared to static human-controlled settings.

IV. Applications of AI in Non-Resource Well Monitoring Conventional (e.g. Vaca Muerta)

Well monitoring in unconventional resource fields, such as Shale gas and tight oil present particular challenges due to the geological complexity and low permeability of these formations. The AI offers advanced solutions to address these challenges.

- In the geological exploration of unconventional deposits, AI is used to predict the probability of finding gas, classify lithology, estimate the brittleness index, predict total organic carbon (TOC) content and parameters geomechanical.
- In reservoir engineering, AI is applied to characterize reservoirs, permeability prediction, reservoir simulation and historical adaptation of models.
- For the prediction of production in unconventional wells, they are used AI techniques, including time series analysis.
- AI also plays an important role in fracturing optimization hydraulics in these deposits.

In remote locations like Vaca Muerta, where connectivity infrastructure may be limited, solutions such as satellite internet and area networks are used Low Power Wide Area Network (LPWAN) to enable IoT applications in the well monitoring.

AI is essential to harness the potential of unconventional resources, providing sophisticated tools to understand and optimize your unique characteristics and extraction processes.

V. Key AI Technologies and Models for Well Data Analysis

Well data analysis benefits from a variety of machine learning (ML) algorithms.

These include supervised learning (such as regression and classification), unsupervised learning (for clustering and anomaly detection) and reinforcement learning.

Deep learning (DL) architectures are also well suited for well data analysis, especially for time series data.

Recurrent neural networks (RNNs), including LSTMs and GRUs, are particularly effective for capturing temporal dependencies in data sequential. Convolutional neural networks (CNNs) are used to extract spatial features from data , while transformers have proven to be useful in overcoming the need for large amounts of data in the production prediction.

Generative AI models are being applied to tasks such as modeling and reservoir simulation. Specific models such as SACNN and MPSO-ANN for gas probability prediction, 1D-CNN and STNet for lithology classification, ANN for rate of penetration prediction (ROP), RNN and LSTM for well integrity monitoring and ANN, SVM and RF for the prediction of oil flow.

Please note that Generative Artificial Intelligence (GENA) is a branch of artificial intelligence that focuses on creating new content, such as models, images, code or text, from existing data. This technology uses advanced algorithms to analyze large amounts of information, identify patterns and generate new and original content that is often indistinguishable from created by humans.

The choice of AI model depends largely on the specific task of well monitoring and the nature of the data being analyzed.

VI. Application of IAGEN-powered Agent in Intelligent Real-Time Monitoring Royal for Wells

1. Concept of IAGEN agents

In recent years, generative artificial intelligence (GAI) has revolutionized the way we interact with technology, enabling the development of systems capable of generating content, answering complex questions and assisting with tasks high-demand cognitive skills. From this capacity, a new architecture emerges Technological: IAGen-powered agents. These agents are not simple conversational interfaces, but autonomous systems that can interpret instructions, make decisions, execute tasks and learn from their interactions with the around.

An IAGen agent combines large language models with components additional features such as external tools, memory, planning and autonomous execution. This allows them to operate in complex environments, with the ability to break down objectives in steps, coordinate multiple actions, interact with digital systems (such as databases, APIs or documents) and adapt to changes in context in real time. These qualities distinguish them from traditional chatbots, and open up a spectrum of more sophisticated and customizable applications.

At the organizational level, these agents are being used to automate processes, generate data analysis, assist in decision making and improve the user experience, both internally and externally. For example, they can assume human resources, legal, financial or logistical tasks, and even those linked to the technical areas of production processes, acting as intelligent assistants that collaborate with human teams. This ability to integrate knowledge and execute tasks autonomously transforms the way organizations can scale your operations without losing quality or control.

In addition, agentic workflows—structures where multiple agents collaborate with each other to solve complex problems—allow responsibilities to be distributed between different agent profiles, each with specific functions. This generates Hybrid work environments where humans and agents coexist, optimizing times, costs, and results. The ability to connect agents with tools such as Google Drive, CRMs or document management platforms further expands its capabilities.

The development of IAGen-powered agents represents a crucial step towards a new era of intelligent automation.

Among the benefits of authentic workflows driven by business models generative artificial intelligence, the possibility of automating processes is found complete, end-to-end production systems, and even add value from the leveraging the skills of language models based on these technologies.

However, its implementation also poses technical, ethical and legal challenges, from responsible design to human oversight. Therefore, understanding your architecture, its operational logic and its potential impacts is fundamental to its effective and safe adoption in various professional contexts.

2. Agent design proposal applicable to the activity

Aim

Monitor, diagnose and anticipate critical operating conditions in oil and gas wells by continuously analyzing real-time data from
IoT sensors, applying advanced AI models to optimize production,
prevent failures and protect system integrity.

3. Functional Components of the Agent

a. Data Acquisition Module (SensorNet)

- **Input:** Real-time data from sensors distributed in the wells.
  - Pressure
  - Temperature
  - Flow rate
  - Vibrations
  - Oil/gas/water level
- **Function:** Normalizes, validates, and routes data to analytical modules.
- **Capacity:** Edge processing for low latency.

b. Anomaly Detection Module

- **Models:** Autoencoders + Transformers + trained time series (LSTM) with historical data of normal behavior.
- **Function:**
  - Detects subtle and multivariate deviations.
  - Classify anomalies: mechanical, geological, electrical or environmental.
- **Output:** Early warnings with criticality level and exact location.

c. Predictive Maintenance Module

- **Models:** RUL (Remaining Useful Life) + Random Forests + Neural Networks.
- **Application:** ESP pumps, valves, surface motors.
- **Function:**
  - Estimate the remaining useful life of equipment.
  - Suggests optimal windows for preventive maintenance.
  - Generates automatic scheduled intervention spreadsheets.

d. Well Integrity Module

- **Inputs:** Differential pressure series, inconsistent flow rate, vibrations anomalous.
- **AI trained in:** leak detection, corrosion, mechanical wear.
- **Function:**
  - Issues alerts for structural risk or loss of confinement.
  - Prioritizes wells by level of operational and environmental risk.
  - Recommends temporary preventive closure or specific tests.

e. Production Optimization Module

- **Models:** RL (Reinforcement Learning) + nonlinear regression + optimization stochastic.
- **Function:**
  - Adjust parameters in real time: bottom hole pressure, injection rate, valve opening.
  - Suggests configurations to maximize production with less wear.
  - Simulates extraction scenarios under changing conditions.

f. Natural Communication Module (GPT)

- **Function:**
  - Generates automatic reports for operators and engineers.

- Explains causes of detected anomalies in technical or executive language.
- Integrates with dashboards, WhatsApp/Teams/email alerts.

3. Operational Capabilities

- **Scalability:** monitoring from a single well to an entire network.
- **Multiplatform:** compatible with SCADA, PI System, cloud platforms.
- **Self-learning:** the agent improves with each case confirmed/rejected by human operators.

4. Metrics reported by the Agent

Metrics	Description
Time half until detection (MTTD)	How long does it take for the system to detect an anomaly? since its appearance.
Prediction accuracy of failures	% of correct predictions of failures before occur.
Reduction of the time idle	Recovered operating time thanks to to the predictive maintenance.
% structural integrity	Percentage of wells without structural risk

Metrics	Description
Time half until detection (MTTD)	How long does it take for the system to detect an anomaly? since its appearance.
safe	significant.
Extraction efficiency	Relationship between extracted vs. expected volume according to yield curve.

VII. Key Benefits

- **Avoid catastrophic failures** through early warnings.
- **Reduces OPEX** by reducing reactive maintenance.
- **Improves operational and environmental safety.**
- **Increases daily well productivity.**

VIII. Challenges and Considerations for a Successful AI Implementation

Despite the numerous benefits, successful implementation of AI in the Well monitoring presents several important challenges and considerations.

One of the main obstacles is data quality and integration with legacy systems, which are often fragmented and lack standardization [3].

Increasing connectivity and data sharing also increase the risks of cybersecurity, which requires the implementation of robust protection measures.

In addition, there is a pressing need for a skilled workforce.

in AI and data science within the oil and gas industry. The regulatory considerations and the need to ensure regulatory compliance are also crucial aspects that need to be addressed.

Cultural resistance to the adoption of new technologies within the industry It may also be a factor to take into account , as well as the high initial costs of investment associated with the implementation of AI solutions .

It is recommended to move forward with short-term investment in implementation teams. of AI agents in technology and training. In essence, investment is required in proof of concept and pilot tests. The focus here has to be on the training of the talent to implement, since a trend of cost reduction is verified in systems that enable “no-code” and “low-code” automation. For the first stage, It is also recommended to use teams with experience in design and implementation. of AI agents. Finally, it is key to form an in-house team for the accompaniment and the appropriation of an agentic culture that redefines interaction human-machine.

IX. Conclusion

Artificial intelligence has established itself as a powerful tool for transform the oil and gas industry, and its application in monitoring wells offers significant benefits in terms of operational efficiency, safety Improved production optimization, cost reduction and sustainability environmental. As technology continues to advance, AI will play a role increasingly important in the management and optimization of oil and gas operations gas, allowing companies to face the challenges of the future and take advantage of the opportunities presented by a constantly evolving energy landscape. Strategic adoption of AI in well monitoring is not just an improvement technological, but a strategic imperative for the future of the industry.

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