HUB TECH IA

Deliverable report 27

AI and IAGEN Application Use Case

Detection of anomalies and inefficiencies

Process Optimization in Vaca Muerta through Artificial Intelligence Generative

I. Introduction

Vaca Muerta, the second largest unconventional gas reserve in the world and the fourth in unconventional crude oil, has become a key driver for the Argentina's energy development.

With the goal of achieving a production of 1 million barrels of shale oil per day at the end of this decade, the industry faces the challenge of optimizing its processes and maximize profitability.

In this scenario, Generative Artificial Intelligence (GAI) is presented as a disruptive tool with the potential to revolutionize operations in Vaca Dead. This report analyzes in detail how IAG can be applied to optimize the processes in the oil industry in Vaca Muerta, considering the challenges and region-specific opportunities.

Generative Artificial Intelligence (GENAI) 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 content and original that is often indistinguishable from that created by humans.

II. Current Processes in the Petroleum Industry in Vaca Muerta

To understand the potential of IAGen in Vaca Muerta, it is crucial to analyze the current processes in the petroleum industry in the region. These processes include from extraction to distribution, and include:

a. Extraction

Oil extraction in Vaca Muerta is based on the drilling of wells. horizontal wells and the application of the hydraulic fracturing or *fracking technique.* The wells horizontal, which can extend up to 3 kilometers, allow access to an area greater reservoir capacity and increase productivity. Hydraulic fracturing involves the injection of a high-pressure fluid, composed mainly of water, sand and chemical additives, to fracture the rock and release the hydrocarbons.

Different types of wells are used in Vaca Muerta, including vertical wells. exploratory, horizontal wells with associated pilots for data acquisition, and multiwells at different navigation levels. The choice of well type depends of the geological characteristics of the area and the production objectives.

To optimize extraction, companies have incorporated innovative technologies such as "Skidding rigs", drilling equipment that slides on rails, which reduces travel time between wells by up to 80% and allows for production earlier.

Another important advance is the incorporation of precision drilling technologies, such as the iCruise X system and the HyperSteer drills developed by Halliburton. These Tools allow you to drill curves and side sections in a single operation,

avoiding disruptions and reducing operating costs. In recent operations, Curve penetration speeds of 22.2 meters per hour were recorded and lateral sections of 75.3 meters per hour.

b. Transportation

The transportation of oil and gas from Vaca Muerta is carried out mainly through oil and gas pipelines. The Oldelval system, for example, transports 70% of the oil produced in the Neuquén Basin towards Bahía Blanca. However, the Transport infrastructure is one of the main bottlenecks for the development of Vaca Muerta. The lack of transportation capacity limits the growth of the production and export of hydrocarbons.

c. Refining

The oil extracted from Vaca Muerta is transported to various refineries in Argentina, including Plaza Huincul (Neuquén), Trafigura in Bahía Blanca (Buenos Aires), and Luján de Cuyo (Mendoza). The Luján de Cuyo refinery, for example, covers one-third of its capacity with crude oil from Vaca Muerta. The La Plata Industrial Complex in
YPF, one of the most important refineries in South America, has adapted its facilities to process unconventional crude oil from Vaca Muerta.

d. Storage

Oil and gas storage in Vaca Muerta is carried out in different facilities, including storage tanks and pipelines that are used in exceptional way to store crude oil. The storage capacity is a critical factor to ensure the continuity of operations and efficiency in the distribution.

For the transport and storage of sand and water, essential for fracturing

hydraulics, "arenoductos" and "aqueductos" are used.

e. Distribution

The distribution of oil and gas from Vaca Muerta is carried out through different channels, including oil pipelines, gas pipelines, trucks and ships. The markets for Vaca Muerta includes both the domestic market and the export market. Vaca Muerta's export potential is enormous, but it faces logistical challenges and infrastructure.

The main destinations for Vaca Muerta crude oil are the west coast of the United States. United States, Brazil, Chile, Netherlands, Denmark, Hawaii and the Caribbean.

III. Environmental Impact

Oil extraction in Vaca Muerta, using the hydraulic fracturing technique, generates various environmental impacts that must be managed in a responsible.

One of the main impacts is the generation of "flowback", a liquid waste composed of water and toxic substances that returns to the mouth of the well after the fracture. In addition, drilling produces mud and cuttings that also must be managed properly.

IV. Challenges and Bottlenecks in Processes

The oil industry in Vaca Muerta faces various challenges that limit its growth and efficiency. Some of the most important challenges are:

- Extraction: The geological complexity of the formation, the high pressure and temperature of the wells, and the presence of water and sand in the production are some of the Challenges in extraction. Exploiting the Vaca Muerta River through fracking differs considerably from traditional oil extraction, requiring

thousands of perforations and horizontal wells to achieve the same amount of hydrocarbons.

- Transportation: Lack of transportation capacity, the state of the roads and the The need to transport inputs over long distances are important challenges in Transport. The heavy movement of trucks and machinery has deteriorated the routes, generating risks to the safety of workers.
- Refining: The need to adapt refineries to process crude oil does not conventional Vaca Muerta and the management of waste generated in the process are challenges in refining.
- Storage: Lack of storage capacity near the sites of extraction and efficient inventory management are challenges in the storage.
- Distribution: The logistical complexity of distributing production nationwide and international, competition in the global market and the need to ensure Long-term contracts are challenges in distribution.

V. Generative Artificial Intelligence in the Petroleum Industry

IAGen is transforming the global petroleum industry, offering innovative solutions for a wide range of challenges. Some of the applications IAGen's most important initiatives in the oil industry are:

1. Extraction

- Drilling Optimization: The IAGen can analyze geological data in real-time to guide the drilling of horizontal wells, avoiding zones problems, maximizing productivity and optimizing placement and well trajectory.
- Failure prediction: IAGen can predict failures in drilling equipment, enabling preventative maintenance and reducing downtime.
- Hydraulic Fracturing Optimization: IAGen can analyze data from

production to optimize hydraulic fracturing parameters, maximizing the release of hydrocarbons and minimizing environmental impact.

- Geological hazard prediction: IAGen can analyze geological data and seismic to predict geological risks and optimize drilling strategies.

2. Transportation

- Route optimization: IAGen can analyze traffic, weather and road status data. routes to optimize transport routes, reducing travel times and costs.
- Fleet management: IAGen can optimize truck fleet management, improving efficiency in the transportation of inputs and products.
- Demand Prediction: IAGen can predict transportation demand, allowing for better logistics planning and avoiding bottlenecks.

3. Refining

- Process optimization: IAGen can analyze production data to optimize refining processes, improving the efficiency and quality of the products.
- Quality control: IAGen can be used to control the quality of the products. refined products, ensuring that they meet the required standards.
- Predictive maintenance: IAGen can predict equipment failures. refining, allowing preventive maintenance and avoiding unplanned shutdowns planned.

4. Storage

- Inventory management: IAGen can optimize inventory management oil and gas, ensuring a continuous supply and minimizing costs storage.
- Demand Prediction: IAGen can predict the demand for oil and gas, allowing better storage planning and avoiding saturation of the facilities.
- Tank monitoring: The IAGen can monitor the status of the tanks.

storage, detecting anomalies and preventing leaks.

5. Distribution

- Logistics optimization: IAGen can optimize distribution logistics, coordinating the transportation, storage and delivery of oil and gas to the customers.
- Demand Prediction: IAGen can predict demand for oil and gas in the different markets, allowing for better distribution planning and avoiding shortages.
- Risk management: IAGen can help manage the risks associated with distribution, such as accidents, spills, and price fluctuations.

VI. Specific application areas of IAGen for anomaly detection

1. Drilling

- Pressure and torque anomalies in the drilling equipment.
- Unexpected geological deviations detected through log interpretation in real time.
- Fluctuations in the rate of penetration (ROP) that could indicate training problems.

2. Hydraulic fracturing

- Detection of low response areas through real-time pressure analysis and caudal.
- Identification of unwanted microfractures by seismo-geomechanical analysis.

- Analysis of proppant behavior in fractures.

3. Transportation

- Anomalies in fleet fuel consumption .
- Extreme temperatures or abnormal pressure in pipelines.
- Detection of unauthorized routes or logistical deviations.

4. Storage

- Leaks or pressure losses in tanks.
- Detection of hazardous vapors using AI-powered sensors.
- Unexpected variations in levels or temperature.

5. Refining and distribution

- Failures in valves or sensors of the SCADA system.
- Quality deviations in refined product.
- Early warnings of overload in distribution.

VII. Application of IAGEN-powered agents for the activity

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 context changes in real time. These qualities distinguish them from traditional chatbots, and open 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. IAGen Agentic Flow design proposal for anomaly detection

This is a flow based on intelligent agents that collaborate with each other, orchestrated by a supervising agent who manages the operation:

a. Integration and Decision Supervisory Agent

- Orchestrate the entire flow.
- Prioritize alerts, determine criticality, and escalate to humans if necessary.

b. Intake and Preprocessing Agent

- Connects to SCADA sensors, IoT, and geological data sources.
- Cleans and normalizes data.
- Generates real-time vectors for further analysis.

c. Anomaly Detection Agent

- Uses hybrid LLM + ML models trained with historical operating data.
- Identifies out-of-range patterns or inconsistencies in:
    - pressure
    - flow rate
    - vibrations
    - emissions
    - valve behavior

d. Contextualization Agent

- Compare the anomaly with historical data, previous maintenance and events similar.
- Determine whether the anomaly is critical, repetitive or expected.

e. Response Generating Agent

- Generates explanatory reports in natural language.
- Suggests corrective actions with pros/cons and potential operational impacts.

f. Visualizer Agent / Dashboard •

Feeds dynamic dashboards for engineers.

• Highlights anomalies by criticality, area and trend.

g. Continuous Learning Agent •
Retrain based on human labels (whether the operator confirms or discards a anomaly).
• Progressively improve the system.

VIII. Potential Benefits of IAGen in Vaca Muerta

The implementation of IAGen in Vaca Muerta can generate significant benefits. for the petroleum industry, including:

- Increased efficiency and productivity: IAGen can optimize processes at all stages of the value chain, from extraction to distribution, improving efficiency and productivity. By predicting equipment failures, IAGen enables proactive maintenance, reducing downtime and improves security.
- Cost reduction: IAGen can reduce costs in various areas, such as drilling, transportation, maintenance and risk management.
- Improved safety: IAGen can improve safety in operations, predicting equipment failures, optimizing transportation routes and monitoring storage facilities.
- Minimizing environmental impact: IAGen can help minimize the environmental impact of operations, optimizing hydraulic fracturing, reducing emissions and improving waste management. In addition, IAGen can optimize refining processes to reduce emissions and improve the energy efficiency, contributing to environmental sustainability.

IX. Barriers to the Implementation of IAGen

Despite the potential benefits, the implementation of IAGen in Vaca Muerta faces certain barriers, including:

- Implementation costs: Implementing IAGen may require a significant investment in software, hardware and training.
- Lack of trained personnel: The oil industry needs personnel trained in IAGen to develop, implement and maintain solutions.
- Resistance to change: The implementation of IAGen can generate resistance to change. change by staff, who may fear job losses or need to adapt to new ways of working.
- Regulations: The lack of a clear regulatory framework for IAGen in the industry oil can generate uncertainty and make implementation difficult.
- Solutions to Overcome Barriers

To overcome the barriers to the implementation of IAGen in Vaca Muerta, the following can be done: consider the following solutions:

- Short-term investment in AI agent implementation teams Technology and training: Investment in proof of concept and testing is required pilot. The focus here has to be on training the talent to implement, since There is a trend towards cost reduction in systems that allow "no code" and "low code" automation. For the first stage, we also recommends using teams with experience in design and implementation AI agents. Finally, it is key to form an in-house team for the accompaniment and appropriation of an agentic culture that redefines the human-computer interaction.
- Government incentives: The government may offer incentives for adoption from IAGen, such as subsidies, tax exemptions and training programs.
- Business-to-Business Collaboration: Businesses can collaborate to share costs and knowledge in the implementation of IAGen.
- Staff training: Companies must invest in staff training.

staff at IAGen, both at the technical and managerial levels. They can be implemented training programs for educators and administrators, as well as investing in continuous training.

- Development of a regulatory framework: It is necessary to develop a regulatory framework clear for IAGen in the oil industry, which provides legal security and foster innovation. Flexible and adaptable frameworks can be considered define the results to be achieved, rather than prescribing the details of how achieve them.
- Communication and change management: It is essential to communicate clearly the benefits of IAGen and managing resistance to change, involving the employees in the transformation process. Changes can be implemented gradual, celebrate progress and rely on digital tools to facilitate the adaptation.

X. Conclusions

Generative Artificial Intelligence has the potential to revolutionize the industry oil in Vaca Muerta, optimizing processes, increasing efficiency, reducing costs and minimizing environmental impact. While the implementation of the IAGen faces certain barriers, there are solutions to overcome them. Collaboration between government, businesses and academic institutions will be key to promote the adoption of IAGen and ensure the sustainable development of Vaca Dead.

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