Spiro

Digital Twin for Energy Value Chain Optimization

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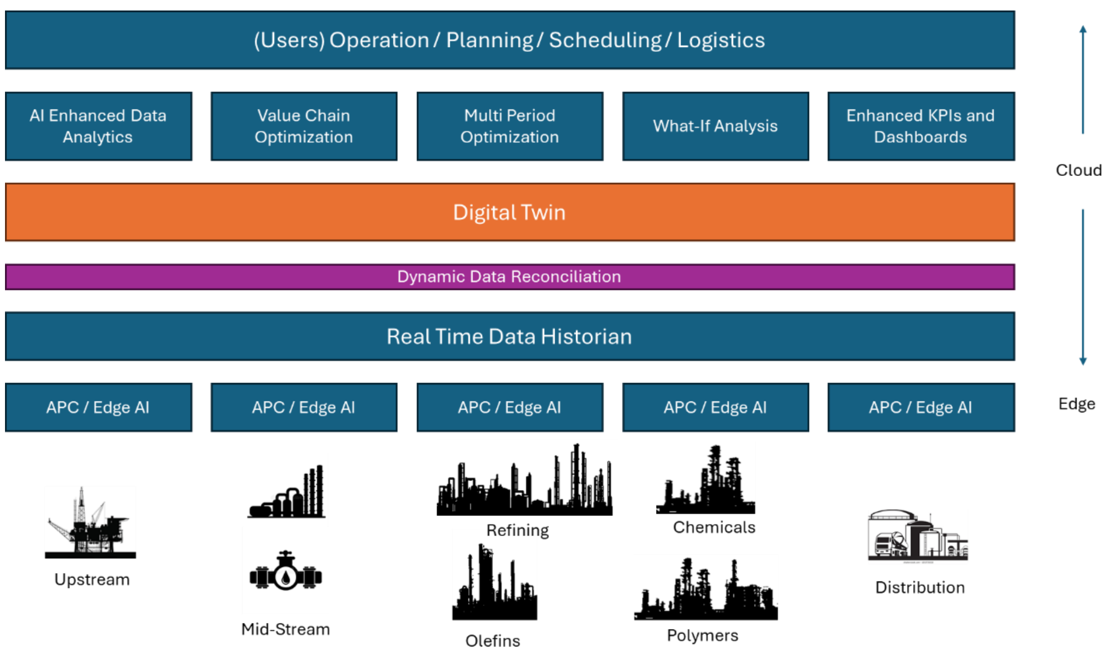
Summary

A digital twin is a real-time virtual model of a physical system that continuously collects data to simulate and optimize operations. This white paper explores how digital twins can be effectively applied to the energy value chain, addressing key challenges such as fluctuating market demands, operational inefficiencies, and environmental sustainability.

A digital twin of an integrated hydrocarbon energy supply chain, covering upstream, midstream, and downstream operations, facilitates real-time monitoring of operational conditions across the entire asset. By leveraging precise process models and thermophysical properties, it can track individual molecular components, such as hydrogen, methane, and CO2, from the wellhead to the end user or emission point.

By leveraging advanced simulation, AI, and machine learning, digital twins can improve performance, monitor environmental impact in real time, reduce costs, and strengthen supply chain resilience, ultimately increasing operating margins and optimizing return on capital employed.



Digital Twin and Edge AI in the Hydrocarbon Value Chain

Introduction

The energy value chain encompasses all stages from resource extraction, production, processing, distribution, and sales (upstream, midstream, downstream and distribution). Traditional models of supply chain management are often siloed and reactive, relying on outdated data and linear models. The introduction of digital twins transforms this approach by providing real-time insights, predictive analytics, and dynamic optimization.

Definition and Key Benefits

A digital twin is a comprehensive simulation model that mirrors the operations of physical assets and processes in real-time using live data. In the context of the energy sector, digital twins can optimize multiple facets of the value chain:

- Upstream: Resource extraction and production.
- Midstream: Pipeline management, transportation and intermediate storage.
- Downstream: Refining, distribution, and retail.

Key benefits include:

- Improved asset performance: By continuously monitoring operational conditions, digital twins can optimize flow rates, reduce energy consumption, and minimize production losses.
- Enhanced market orientation: The technology allows energy companies to dynamically adjust operations in response to market signals, improving customer satisfaction and operational efficiency.
- Cost reduction and increased capital efficiency: Real-time insights enable companies to minimize operational costs, enhance asset utilization, and improve profit margins.

Improvements Over Traditional Planning and Scheduling

In contrast to traditional linear planning methods, value chain optimization via digital twins offers a dynamic, integrated approach. Traditional models operate in silos, are static, and rely on historical data with limited scope for real-time adjustments. This leads to slower responses to market changes, increased inefficiencies, and missed opportunities.

Digital twins facilitate a non-linear, holistic optimization model, allowing energy companies to monitor and adjust processes in real-time. This results in a more agile and responsive system, capable of addressing unexpected disturbances in supply or demand with minimal delays. The ability to simulate multiple scenarios in real-time helps organizations not only prepare for disruptions but also capitalize on market opportunities.

Role of AI and Machine Learning in Value Chain Optimization

Digital twins can harness the power of AI and machine learning in several ways:

- Surrogate Models: AI-driven surrogate models combine machine learning with first principles, simplifying detailed simulation models to reduce computational load while maintaining accuracy in complex systems.
- Model adaptation: AI agents can adjust digital twin model parameters in real-time to improve model fit based on cumulative reward, optimizing performance under various conditions.
- Decision Support: AI enhances digital twin capabilities by running multiple scenarios, optimizing complex constraints, and presenting results in a user-friendly manner, aiding in better decision-making and scenario analysis.

These technologies enhance decision-making, automate workflows, and provide end-to-end visibility across the value chain, leading to better performance and increased resilience.

Challenges and Considerations for Implementation

The complexity of creating and maintaining digital twin models for large-scale energy operations presents significant challenges. The development of accurate and scalable models requires a robust foundation of integrated data sources and advanced analytical tools. Additionally, organizational readiness is critical. Successful implementation depends on the company's ability to integrate digital twins into their broader operational and IT infrastructure.

Furthermore, scaling digital twin technology requires a secure, cloud-based platform to ensure data integrity, accessibility, and system resilience. Data governance and cybersecurity are also major considerations, given the sensitivity of operational and market data in the energy industry.

Case Studies and Real-World Applications

Several case studies have demonstrated the effectiveness of digital twins in optimizing the energy value chain. For example, energy companies utilizing digital twins have reported significant improvements in incremental profitability, reduced downtime, and more efficient asset utilization.

In the chemical industry, value chain optimization through digital twins has resulted in more efficient feedstock selection and higher operational efficiency. Similar applications in oil and gas sectors show measurable gains in production rates and reductions in energy consumption.

Conclusion

Digital twins represent a pivotal advancement in energy value chain optimization, offering opportunities to improve operational efficiency, reduce costs, and enhance profitability. By integrating real-time data, AI, and machine learning into their operations, energy companies can build more resilient, agile, and efficient supply chains. The application of digital twins is not without challenges, but the potential rewards—ranging from better asset performance to higher capital efficiency—make it a worthwhile investment for forward-thinking organizations.

As digital twin technology continues to evolve, its impact on the energy sector will likely grow, transforming how companies manage their value chains and respond to ever-changing market conditions.