Dynamic Cross-Asset Data Fusion Digital Platform for CCUS Monitoring

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Abstract

Carbon Capture, Utilization, and Storage (CCUS) systems span a complex and highly interconnected set of assets across power plants to capture units, compression stations, transportation network, injection sites, and long-term storage. These assets operate under varying operational modes and generate large volumes of heterogeneous data at different temporal resolutions, including high-frequency operational measurements and periodic engineering, integrity, and monitoring data. Despite the system-level interdependencies across the CCUS value chain, digital solutions for CCUS operations remain largely asset-centric and siloed, limiting end-to-end visibility, cross-domain diagnostics, and proactive risk management.

This paper presents a comprehensive digital product architecture for CCUS that enables a dynamic, value-chain-level asset dashboard supported by cross-asset data fusion and advanced analytics. The primary objective of this research is to design and demonstrate a scalable digital platform that provides an integrated operational view of a connected CCUS value chain through dynamically configurable asset dashboards. The platform is intended to support diverse CCUS configurations and customer-specific requirements by allowing assets to be onboarded, configured, and monitored without rigid system redesign. A key goal is to enable continuous situational awareness by integrating real-time operational data with periodic contextual data, while supporting advanced analytics for asset health monitoring, anomaly detection, and root-cause analysis across surface and subsurface domains. The proposed solution is built on an integrated asset-centric digital framework in which every CCUS asset is represented as a configurable digital object. Each asset object encapsulates structural information, operational metadata, live and historical telemetry, calculated performance indicators, and data update characteristics. Assets are logically linked according to their functional relationships across the CCUS value chain, forming a connected asset network that reflects CO_2 flow paths and operational dependencies. Based on this connected asset definition, the system automatically generates a dynamic dashboard that represents a specific CCUS value chain as a single, coherent operational entity rather than a collection of independent assets. The dynamic dashboard is a central feature of the platform and is designed to adapt continuously as assets, data sources, or operational requirements evolve. Users can configure dashboard views by selecting assets of interest, defining key performance indicators, and specifying alerting and risk rules at both asset and value-chain levels. When new assets are introduced such as additional compressors, wells, monitoring equipment, or sensors their associated data models are dynamically integrated into the platform and immediately reflected in the dashboard.

This approach enables rapid customization for different CCUS projects and operating scenarios while maintaining a consistent digital backbone. A core capability of the platform is its unified data ingestion and fusion layer, which integrates both real-time and periodic data streams across all connected assets. Real-time data include operational measurements such as pressure, temperature, flow rates, equipment status, and energy consumption, while periodic data include inspection results, maintenance records, test outcomes, emissions reports, and subsurface assessment updates. These datasets are ingested through standardized interfaces, time-aligned, and contextualized within the connected asset framework. By combining data with different temporal resolutions, the platform enables joint analysis that accounts for both immediate operational behavior and longer-term system condition. Building on this unified data foundation, the platform incorporates a cross-asset analytics engine that supports correlated analysis across multiple assets and domains.