The Hydrogen Roadmap to Relevance

Industrial-grade Software for Digital Transformation

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HYDROGEN OVERVIEW

From industry to transport, many sectors are adopting hydrogen as a key pillar of their national and international energy system strategies aimed at taking on climate change by reducing greenhouse gas (GHG) emissions. By the beginning of 2021, over 30 countries had released hydrogen roadmaps, and announced more than 200 Hydrogen projects and ambitious investment plans. Governments worldwide have committed more than USD 70 billion in public funding. This momentum exists along the entire value chain, accelerating cost reductions for hydrogen production, transmission, distribution, retail, and end applications.

Hydrogen is already a commodity used as feedstock in different industrial applications, ranging from refineries to ammonia and methanol production. The global demand for pure hydrogen has tripled since 1975. Yet, current hydrogen demand is mostly supplied by fossil fuels, including natural gas and oil and coal, because they represent the cheapest pathway. However, hydrogen has also been proposed as a potential energy carrier to support a wider deployment of low-carbon energy, mainly produced from renewable energy sources.

WHY HYDROGEN NOW?

The universe's most abundant element has long been considered a potential alternative to traditional forms of fuel. However, until now, the cost barriers associated with hydrogen production were too high to make it a viable zero-carbon fuel source.

Three factors are giving rise to a renewed interest in hydrogen:

1. Introduction of favorable government policies
2. Technological improvements and scale driving down costs
3. Increase demand driven by sectors seeking to decarbonize

Varying waves of enthusiasm have supported the narrative of low-cost, clean hydrogen as an alternative to fossil fuels, mainly exploiting fuel cell applications in the transport sector, and heating as a lower-cost alternative to electricity. Scientific and industrial interest in the potential of hydrogen technologies first occurred during the oil crises of the 1970s, as the world was looking for alternative solutions to face potential oil shortages and tackling environmental problems such as local pollution and acid rains. Research programs on hydrogen were implemented, but they did not have significant effects since -- due to new oil discoveries -- the oil prices eventually decreased, and the fear of shortages disappeared.

Rising concerns over climate change and peak oil scenarios renewed interest in hydrogen in the 1990s and 2000s. Again, low oil prices limited the diffusion of hydrogen technologies, as did the economic and financial crisis at the end of the 2000s.

Today, a growing consensus is building up again on the potential of hydrogen, mostly due to a stronger climate agenda with more challenging targets. Clean hydrogen is part of a group of technologies that must be deployed across final uses to ensure a transition towards climate-friendly energy sources.

BLOCKERS TO OVERCOME

Sustainability is good for business – and has become a source of future competitive advantages. Yet turning initiatives like hydrogen into reality is the challenge.

With green hydrogen costing six times that of traditional production, and blue hydrogen costing two-to-three times as much, the transition to cleaner production through carbon capture and renewable energy must be strategic. To win in the future, operators must begin laying the foundation with OT data management and software solutions.

The infrastructure for a low/zero hydrogen economy consists of transport, storage, and distribution stations. This can be extremely costly compared to other decarbonization efforts, such as electrification.

Cheaper and more abundant renewable energy sources are integral to scaling low and zero-carbon hydrogen use. [There is a lack of proven applications at scale to date, though large-scale efforts are in planning phases].

Hydrogen's low density presents unique and costly distribution challenges that have yet to be solved. With over a million tons of clean hydrogen projected for transport starting in the next five years, those who invest in advancing storage and transportation infrastructure today will steer the sector's development, influence and standardize policy, and reduce administrative costs associated with import and export.

Industries and governments are focusing on 3 key areas to scale the hydrogen economy:

1. **Infrastructure development:** Hydrogen behaves differently to natural gas and will require new or adapted infrastructure.
2. **Hydrogen production:** Hydrogen can be produced in several ways, but if it is to help in the battle with climate change, the process will have to be decarbonized.
3. **Safety research:** The scale of the future hydrogen society will be determined by success in demonstrating safety.

Digital solutions for Hydrogen reduce both CAPEX and OPEX, driving innovation across all project phases from design, & build, to operate and optimize.

FASTER AND LEANER START UP: DESIGN & BUILD

A strong foundation of digital intelligence builds the critical infrastructure that enables reliable, autonomous operation.

Digital twin simulations enable engineers to create steady-state/dynamic models for plant design, performance monitoring, troubleshooting and operational improvements. Optimize equipment design before users make large capital investments and start operations.

- Simulate the entire hydrogen production from electricity supply to hydrogen storage with easy-to-use and comprehensive flow sheeting
- Achieve economic benefits via the lowest total cost of ownership
- Create a digital representation of a physical asset either in design or operation – a "process digital twin"

Comprehensive digital twin process models provide engineers with a complete view of heat and material balances for evaluating limiting design cases and other operating conditions. Additionally, simulation is used to perform feasibility studies, assess alternative process configurations, and identify risks. Engineers leverage this information to ensure designs are safe, meet environmental regulations and maximize the operational and business performance of the asset.

A steady-state digital twin can only provide a snapshot of the starting and end conditions, while a dynamic model can accurately predict intermediate process conditions during the transition. With the capability to replicate start-up, shut-down, the impact of equipment failures, and other abnormal conditions, a dynamic digital twin can better serve engineering design analysis, decisions and outcomes that otherwise may not be known or will be discovered far too late in the project lifecycle.

The early conceptual phase of a green hydrogen project will include sorting through numerous options with the following key process variables

- Electrolyzer technology: Alkaline, Proton exchange membrane (PEM) or Solid oxide
- Variability of electrical supply, if coming directly from a renewable source such as solar or wind
- Water quality at the source and that going into the electrolyzer stack
- Discharge water quality: in the case of an alkaline electrolyzer, potential need for purge or discharge of water/KOH electrolyte
- Main electrolyzer stack: Technology-specific parameters such as electrical voltage, current density, conversion efficiency, heat balance etc.
- Battery limit conditions of product streams such as hydrogen and oxygen

Digital twin process simulation is central to the analysis of the various options to determine the selected design's economic and operable feasibility.

Much near-term attention will be focused on modeling the electrolyzer stack. The process simulation tool needs to represent the overall performance of this stack and the overall balance of plant.

The process simulation needs to be validated for use in representation of the main electrolyzer stack as well as the balance of plant.

In addition, production management software orchestrates hydrogen production efficiency throughout the value chain and provides insightful production analytics & accurate production accounting.

The software maximizes throughput, is responsive to plan, improves capacity-asset utilization, and reduces inventory in hydrogen production units.

As a result, operators can plan, schedule, dispatch, track, store, ship, account, statistically reconcile, analyze & report while meeting stringent quality standards at single-plant or across the enterprise.

OPTIMIZED RELIABLE OPERATIONS

Asset performance management systems provide a real-time analytics solution that continuously monitors asset and process performance across the enterprise, detect impending health issues, and predict time to failure. APM provides a flexible platform to implement asset-model driven, templated calculations, logic rules, diagnostic events, and fault models. Capturing performance characteristics and templating enables the possible definition of all the asset relationships in the hydrogen production plant – from cells, related to a stack, to multiple stacks, related to a rectifier and onwards through the plant. A full engineering library can be used as a starting point for engineers to design and configure new templated asset models suitable for a green hydrogen plant and capture performance KPIs into one overarching view. The successful engineering surveillance of green hydrogen production units can lead to higher overall efficiencies, for longer periods of time, and therefore generate more hydrogen efficiently.

Advanced Process Control (APC) delivers maximized operating profitability by optimizing hydrogen production tradeoffs, managing product specifications, and pushing operating envelopes to constraints. APC technologies optimize operations across the entire production facility through advanced multivariable control. It also sustains performance and optimization benefits through adaptive control and real-time monitoring.

Operations management software enables standardized work process across clusters of hydrogen production units and drives informed decisions and operational compliance. End-to-end alarm lifecycle management helps hydrogen production units reduce console operator’s alarm load, improve situational awareness, and significantly reduce process upsets and shutdowns, turning control room noise into operational knowledge and rationalizing alarms to drive operator effectiveness.

Workforce competency solutions also promote the safety and effectiveness of operations personnel, enabling end-to-end management across departments. Immersive simulations instill staff with veteran-level understanding of green hydrogen processes and operations, guiding them to realize their full potential faster. The value from using dynamic simulation models for training is well established and contributes to a suite of safety, reliability and operator effectiveness, productivity, and performance benefits. Some of the best-run facilities have integrate OTS training interventions into their competency management system. Training investments can be optimized, targeted, and deployed to address specific competency gaps.

Extending Digital Twins from Design to Operations

Digital twin modeling offers what-if analysis and visualization of opportunities for improvement. Process engineers can confidently use the dynamic model to evaluate the impact and benefits of various process changes or upgrades in hydrogen production units, such as debottlenecking studies, fine-tuning operating procedures, resolving equipment constraints, etc. Whether during design or on an operating plant, hazard, and operability studies (HAZOP) can identify potential hazards that may arise from deviations from the intended design conditions. While subject matter experts (SMEs) typically hypothesize over various scenarios and outcomes, dynamic digital twins for green hydrogen can enhance a HAZOP by spotting high-risk probabilities, narrowing safe ranges of operation, and testing risk mitigation strategies. Dynamic simulation results improve the HAZOP process and operational safety by supplementing the SME discussion with a rigorous and credible engineering evaluation of the dynamic process response.

ROLE OF INDUSTRIAL-GRADE SOFTWARE

While less than 1% of global dedicated hydrogen production today is considered “green” hydrogen – we know that will change, but there is no easy way forward. The roadmap to relevance and sustainability calls for operational efficiency.

Digital intelligence connects awareness and understanding of assets, people, and processes across the plant, affording transparency and empowering operators with prediction to make data-driven decisions and optimize.

Successful digital transformation requires proven, industrial-grade software, delivered by operational domain experts who understand process industries.

Building sound, reliable data infrastructure and avoiding “proof of concept purgatory” is critical for supporting operators who are committed to putting hydrogen on a low carbon path to a net zero future.

REFERENCE

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