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How technology can help advance green hydrogen initiatives

by Rajesh D. Sharma

Executive summary

New technologies will pave the way as the world moves away from fossil fuels and towards renewable energy sources. Green hydrogen is one of the emerging, enabling technologies that will facilitate the transition away from hydrocarbons. Still, it is in its infancy and determining how to achieve cost-effective production presents a formidable challenge.

Finding the forward path towards efficient green hydrogen production requires new technologies and new thinking. The solution is on the horizon, but for the industry to reach this ambitious objective, it must recognize the essential role digitalization will play in changing the status quo.

Introduction

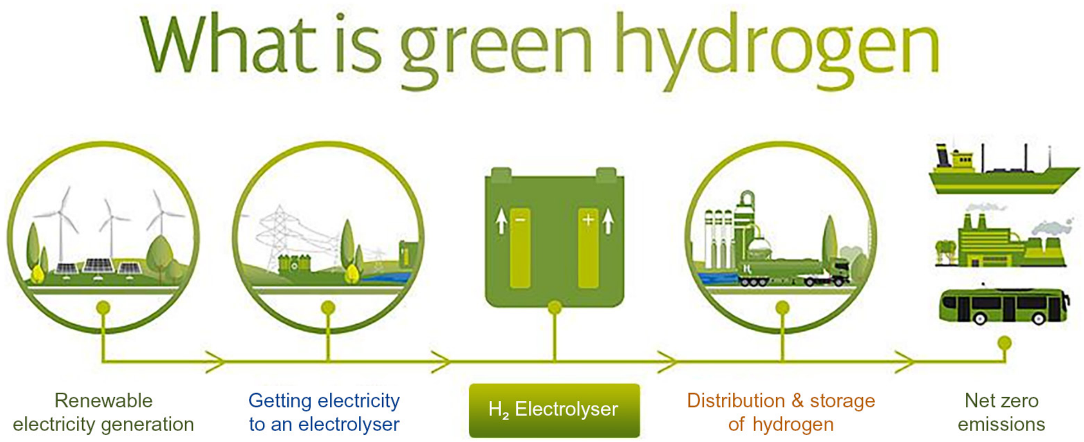
The world faces many challenges in making the transition from carbon-based to renewable energy. Green hydrogen, made with renewable energy, will be an essential contributor to effecting this change. Today, most hydrogen is produced with fossil fuels, and its use in the industry ranges from refining oil to producing ammonia, methanol, and steel. In addition, recent advancements in green hydrogen technology are broadening its appeal for other industry sectors.

Green hydrogen is produced by the electrolysis of water powered by renewable energy, and the hydrogen produced in this method has no carbon emissions. Oxygen is the other gas produced when hydrogen is made with electrolysis, and this oxygen can either be released in the air or used for other applications in the facility, see **Figure 1**.

Figure 1

What is green hydrogen

Photo courtesy of: Fuelcellworks



Currently, producing and using hydrogen for power is inefficient compared to directly using renewable electricity. According to the International Energy Agency, less than 0.1% of hydrogen today is produced through water electrolysis, but that could soon change.[1] Making green hydrogen competitive will take a lot of investment, but companies are rising to the challenge. An estimated $500 billion will be spent on research and development projects over the next decade, approximately 70% of which will target green hydrogen production. This investment is expected to push low-carbon hydrogen production capacity beyond 10 million metric tons annually by 2030.[2]

[1] IEA, The Future of Hydrogen, June 2019

[2] NS Energy: Global hydrogen investment pipeline surges to $500bn, By Andrew Fawthrop, 15 Jul 2021

Estimating the cost of green hydrogen

An investment decision for green hydrogen will start with establishing the cost to produce hydrogen.

The cost of green hydrogen is determined by the amount of energy required, the cost of energy supplied, the cost of the electrolyser and its system, and the OpEx required to operate the system.

Based on this simple formula, a pricing technique for electrolyser companies should offer developers and utilities a clear idea of how much it costs to manufacture one kilogram (kg) or an m3/h of hydrogen from each unique source. However, today's most common approaches do not give this estimate to a reasonable level. Instead, if we focus on the most critical variables that drive the total cost of green hydrogen, we can derive a better estimate for its:

- CapEx: capital expense for the electrolyser (including the balance of plant).
- OpEx: operating expenses for running the electrolyser. Primarily this is electricity, with some costs for maintenance of the system and water.
- Lifetime: to assess the total cost of hydrogen, lifetime must be considered. "Lifetime" refers to when it is optimal, from a system performance perspective, to replace the unit, rather than a statement that the system can no longer operate.
- Efficiency: the efficiency of the electrolyser is determined by how much electricity is needed to produce a certain amount of hydrogen. The higher the efficiency, the lower the operating cost.

A green hydrogen facility typically has electrolysers, high/medium/low-voltage electrical equipment, rectifiers, gas separation, gas drying, processing facilities, compressors, cooling fans, control, and safety systems. The facility can be divided into electrolyser stacks and balance of plant (BOP).

For a gigawatt scale hydrogen plant, the Institute for Sustainable Process Technology estimates the direct cost split between electrolyser stacks and balance of plant (BOP) equipment to be 23% and 76%, respectively for **Alkaline electrolyser**, and 48% and 52% respectively for Polymer Electrolyte Membrane **(PEM) electrolysers**.[3] As can be seen, BOP cost has a significant influence on the overall cost of the project.

Based on the above variables and cost factors, it becomes pertinent that to estimate, engineer, construct and operate a green hydrogen facility, one should have:

1. The knowledge of design and safe operations of a green hydrogen facility.
2. An understanding of factors affecting the efficiency of production.
3. The ability to run production with the least amount of downtime.

[3] Institute for Sustainable Process Technology

Challenges to increasing green hydrogen production

The desire to move towards green hydrogen is real, but making the transition will require three crucial things:

1. Improving knowledge to drive design and engineering results.
2. Ensuring safety and efficiency to optimize operations.
3. Developing and implementing requirements for green certification.

1. Improving knowledge to drive design and engineering results

Scientifically, producing hydrogen through electrolysis has been possible for a long time. Still, this technology has been implemented on a significantly smaller scale than the megawatt and gigawatt projects announced in the last year. The scaling-up process is one of the most significant obstacles to any new technology, not just green hydrogen. Transitioning from small-scale viability demonstrations to large-scale industrial processing necessitates a shift from strictly scientific and technological obstacles to logistical, economic, and, in certain circumstances, political challenges.

The lack of knowledge about installing and linking large-scale electrolyzers is a hurdle to designing an optimal electro-intensive facility of this size. There is little data that enables investors to gain insight into what the return on investment might be. In the absence of this information, investors find it challenging to move forward with confidence.

2. Ensuring safety and efficiency to improve operations

While there are acknowledged safety risks with hydrogen, and we should continue to stress hydrogen safety measures as it also possesses features that make it safer to handle, when used correctly, than conventional fuels like gasoline and diesel. Hydrogen's versatility and strength as an energy carrier allow it to be used directly to power fuel cells or to store excess energy from renewable sources. Large amounts of hydrogen can be stored in tanks as high-pressure gas, and even more, significant amounts of it can be stored as a liquid at low pressure and cryogenic temperature.

Hydrogen gas (H_2) is made of two hydrogen atoms with only one proton and one electron each and is flammable and relatively easy to ignite due to this simple chemical structure. As a result, the perception of risks associated with storing hydrogen impedes pursuing large-scale usage. Any system used to handle hydrogen must address the relevant safety hazards unique to its material properties.

While green hydrogen offers a solution for the hardest-to-abate sectors, we have little experience using it in those applications. This is why hydrogen safety research is critical to play a more significant role in our economy.

3. Developing and implementing requirements for green certification

Additional complexity is introduced when renewable energy is fed from the grid, as will be the case for many projects announced in Europe. The challenge for producers is to ensure all produced hydrogen is green and certified for off-takers.

Since handling hydrogen is similar to handling natural gas, these challenges can be solved with technology solutions that have a long and proven history in the oil and gas industry. Digitalization will play a significant role in resolving these challenges and, at the same time, will facilitate more efficient and immediate collaboration.

Technologies that can address the challenges of scaled green hydrogen production

The challenges in the scaled production of green hydrogen can be addressed to a large extent by using new digital technologies available today. We can leverage the experience we have gathered in the oil and gas industry to solve process safety and energy efficiency challenges.

Several key technology solutions will play a key role in green hydrogen production, including:

- Process modeling and integrated engineering using a digital twin
- A combined safety, power, and process control system
- Artificial intelligence and machine learning to improve analytics for optimized asset performance
- Blockchain to enable verifiable green certification

Dynamic process and power simulation:

The green hydrogen industry is racing from the pilot and small-scale production plants to large facilities. We are seeing the need to make larger electrolysers to meet the requirements of giga-scale production planned by some producers. The complete value chain of green hydrogen is gearing up for such scaled production, which includes the renewable power source, the water treatment facilities, gas treatment facilities, and further usage of hydrogen in downstream processes.

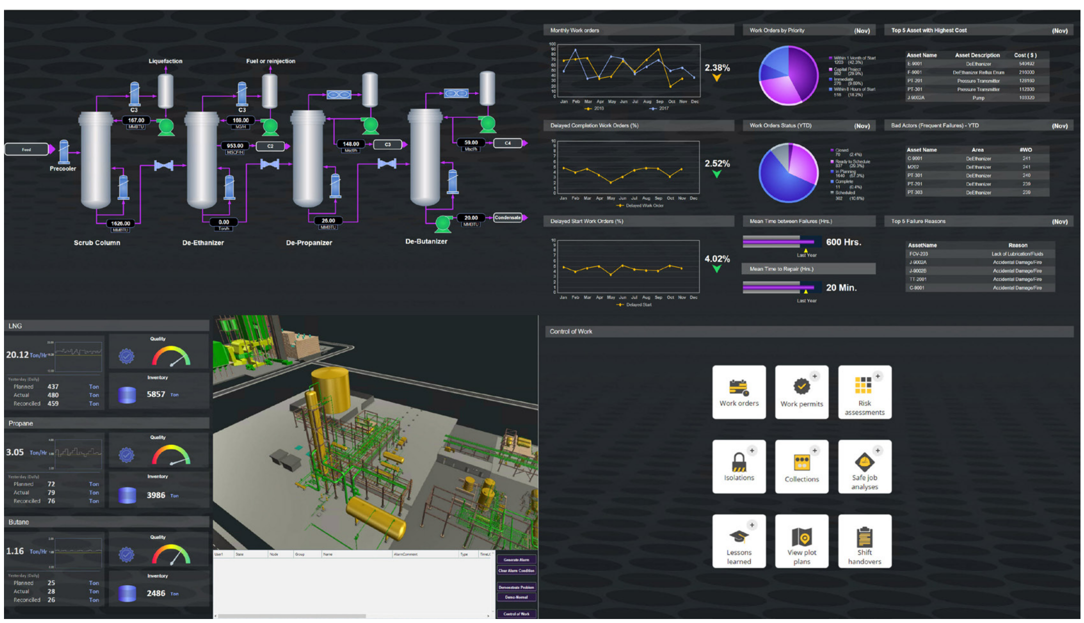


Figure 2

Example of dynamic process simulation model

Source: AVEVA

Using a dynamic process simulation model, see **Figure 2**, improves understanding and simplifies resolving the impediments to scaling up the size of electrolyzers and the connected processes for large facilities. Essentially, a simulation model or **digital twin expedites the conceptual stage of the project by streamlining the process for selecting the type and size of electrolyzer(s) needed and providing insight into requirements for associated static, process, and electrical equipment like pumps, motors, tanks, piping, etc**. The model uses available data to simulate renewable power generation, water treatment, and other process parameters to analyze the variations expected in operating a facility thoroughly. A complete model also includes storage considerations and downstream industrial usage simulation based on project development goals.

Because green hydrogen production is an electro-intensive process, system design also requires a robust power simulation model. Simulating the electrical equipment like breakers and transformers with current requirements based on the size of electrolyzers provides optimum sizing for equipment and related cabling.

Integrating the power and process simulation provides a complete end-to-end analysis of the facility's design. Further, it provides an opportunity to optimize any design aspects while maintaining design integrity between process and power equipment.

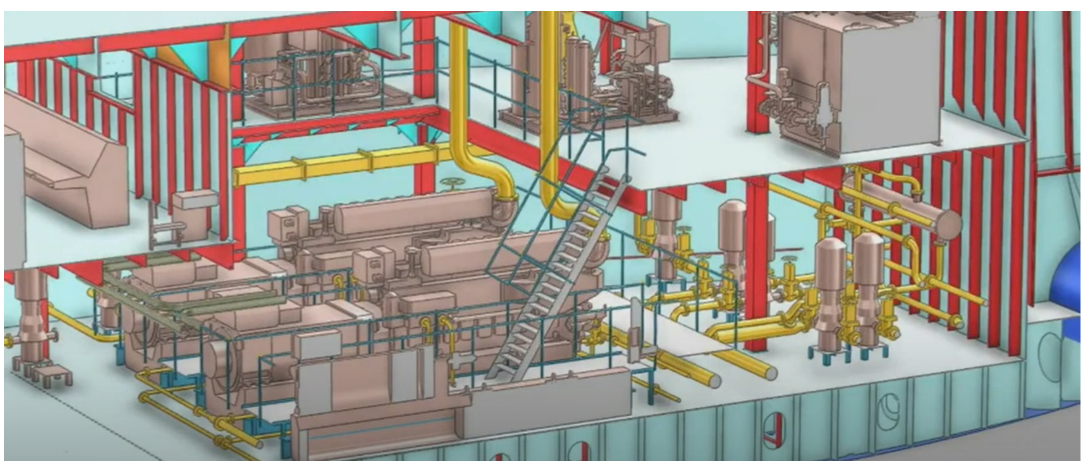
The digital twin – a virtual representation of the system built from real-time process and equipment data – enables developing a functional design that can be optimized for different business scenarios. Working with a digital twin to design a production facility allows power to be optimized and benchmarked using a complete asset database.

A 3D facility rendering, see **Figure 3**, enables data available from digital twin to be mapped to individual equipment providing a single source of truth that can be used for the complete lifecycle of the facility, moving from conceptual design to engineering and into operations and maintenance.

Figure 3

Example of a digital twin 3D rendering

Source: AVEVA



Leveraging the digital twin to integrate engineering:

Engineering tools help streamline the engineering processes across multiple stakeholders within the project team and facilitate interaction with external parties. These tools rely on digital twin technology for the complete lifecycle of the hydrogen production facility, from conceptual design to engineering to operation and maintenance. Working with a digital twin simplifies the design process by allowing designers to use all the available data and equipment information to create a 3D model of the facility and generate drawings like piping and instrumentation diagrams (P&IDs), process flow diagrams (PFDs), single-line diagrams (SLDs), and datasheets for design equipment.

Combined safety, power, and process control system

Benefits of the integrated system:

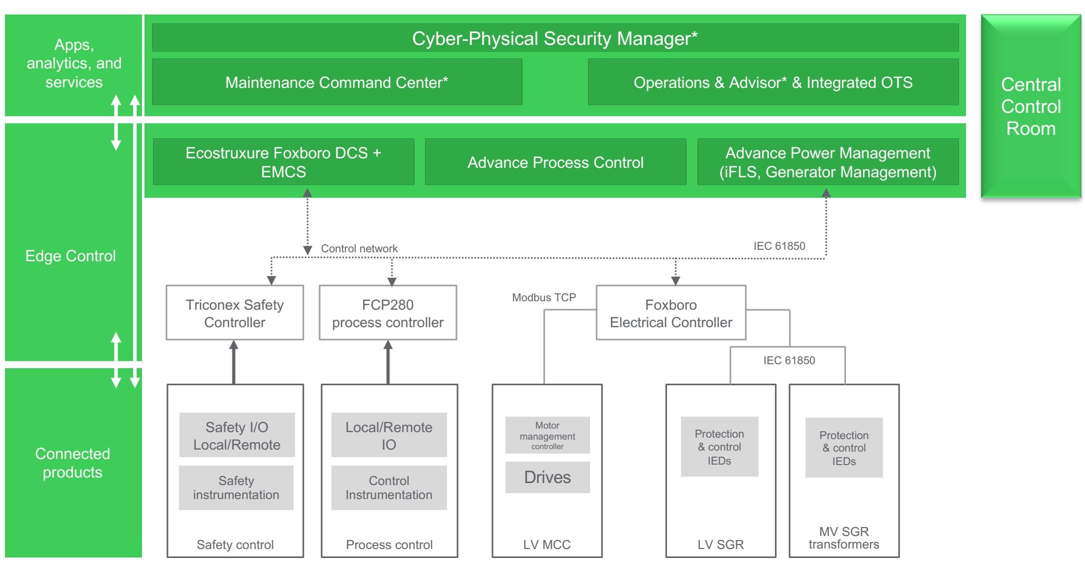
- Reduced CapEx by up to 20% of electrical and automation infrastructure
- Faster project design, startup, and commissioning

Green hydrogen production is unique because the power required for producing it is enormous, and the process is critically important in terms of safety. This makes hydrogen production a perfect candidate for a combined power and process system with integrated safety. A combined system which includes Distributed Control System (DCS), Energy Management and Control System (EMCS), and Safety Integrity System (SIS), can be used for improved control and safety of the facility, see **Figure 4**. Such a system can utilize the integrated digital twin used during the design stage more effectively. The combined system also saves cost by up to 20% in CapEx,[4] including reduced hardware, reduced time in engineering the system, faster testing, commissioning, and startup times.

This solution seamlessly integrates electrical equipment using industry-standard protocols like IEC 61850 on the same system, which controls process equipment with various devices and connections like OPC, Fieldbus, MODBUS, and wireless or wired instruments. Because safety is critical for hydrogen production, a SIL3 level safety system integration provides a complete safety, power, and process control system. Using a digital twin makes functional testing for the integrated system easier, allowing fully remote assessment during the design and engineering phase.

Figure 4

Example of DCS, SIS, and EMCS integration based on the Schneider Electric EcoStruxure *architecture*



[4] Eight Strategies to Drive Enterprise Profitability through Integrated Power Management and Process Automation

Asset performance and analytics

Considering some giga-scale projects' size and the level of electro-intensive processes involved, using analytics to optimize asset performance is obvious. The health of electrical equipment like transformers, switchgears, and rectifiers directly impacts production performance, and variables like temperature, water, and electrolyte flow can affect production efficiency and the quality of hydrogen produced. Electrodes within electrolyzer stacks are prone to wear caused by aging, water, and current quality, as well as the number of start-stop operations to which they are subjected.

CapEx and OpEx for Balance of Plant can be optimized by 15% to 20% with technologies like digital twin, combined safety, power, and process control system.

Using performance data simplifies asset management and ensures that essential components are performing per design. Continuous monitoring makes it possible to detect decreases in performance so maintenance can be scheduled to prevent efficiency declines and production loss. Asset performance management solutions can capitalize on the digital twin model to analyze and report equipment performance and measure it against design benchmarks. Subject matter experts with access to equipment data in the cloud can use machine learning based on predictive analytics to identify and anticipate issues for critical equipment like electrolyzers, transformers, switchgear, compressors, and pumps to eliminate unnecessary downtime and maximize production.

Blockchain traces end-to-end green production:

When grid power is used for green hydrogen production, the producer must validate that the produced hydrogen is generated from green electrons and demonstrate that fact to end-users. Any rebate issued to hydrogen users from authorities will require this level of tracing.

It is difficult to prove that hydrogen has been generated from green electrons using traditional tools. This is why **Blockchain** – a list of records, called blocks, linked together using cryptography to make it impossible to cheat the system – will be essential to providing evidence of end-to-end green energy production. To do so means power utility companies, hydrogen producers, and users will need to embrace this new technology.

Conclusion

The massive consumption of power for hydrogen production makes power efficiency critically important. Tools like predictive analytics and advanced process control can help producers achieve maximum plant uptime and efficiency. Combining the technologies and solutions outlined here will allow green hydrogen project design and operations to be optimized from design through operations and expedite the transition to renewable energy.

According to the technical study by the Institute for Sustainable Process Technology, a typical hydrogen project cost ratio between electrolyzer and balance of plant is 23%-48% and 76%-52%, respectively.[5] The production cost optimization of electrolyzers is driven by equipment manufacturers who rely on digitalization to improve their own production quality and cost reduction. Balance of plant, which includes process and electrical equipment, can be optimized by up to 15% to 20% in TotEx,[6] a combination of CapEx and OpEx using the technologies and solutions discussed in this paper.

About the author

Rajesh D. Sharma is the Global Marketing Director for the Schneider Electric Oil, Gas, and Petrochemicals segment. He is responsible for developing strategies, marketing tactics, and new business models around Integrated Digitized Solutions for the Schneider Electric Oil & Gas portfolio offerings. Rajesh has over 30 years of experience in the energy sector and has previously acted as Managing Director for Telvent Energia SA branch, Abu Dhabi for the Middle East region, and General Manager in Reliance Industries, India. Rajesh has published articles and papers on various topics, including integrated technologies, digitalization, sustainability, and energy transition. He holds a bachelor's degree in Instrumentation Engineering from India.

[5] Institute for Sustainable Process Technology

[6] Eight Strategies to Drive Enterprise Profitability through Integrated Power Management and Process Automation

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