OPC Foundation Energy Initiative

Standardize and Simplify Connectivity and Semantic Information Models of Energy-related Systems, Services and Devices

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Founder and CEO, Hyviva

OPC Foundation Energy Initiative – The Future of Energy System Connectivity

The world of Energy is changing. There are multiple transitions in progress like the move from fossil fuels to renewable energy, and centralized energy generation to decentralized micro grids. Energy Systems are now more than ever considered critical infrastructure and must be resilient to any kind of malicious attacks – physically as well as cyber.

An energy eco-system has a core set of components that can be found in any size system – from large utility grade systems to small household microgrids:

Energy Production – the facility of devices that create the energy. Traditionally these are Gas, Nuclear or coal plants centrally located somewhere near a city or state. Renewable production sites using Solar, Wind or Hydro are located where their natural resource is located.

Energy Distribution – energy is very rarely used where it is produced and must be transported/distributed to the energy consumer. Even in microgrids, there will be power lines from i.e. solar panels to inverters.

Energy Transformation – sometimes it is more efficient to transform the energy into another media for better transport. Hydrogen is one of these media that can be transported via pipeline or trucks to locations where it is needed.

Energy Storage – a very important part of modern energy management is storing the energy either at the production site or the consumer site to balance out the so call "Duck Curve". This curve describes the mismatch between power generation (for example solar energy is most abandoned during midday) and power consumption (but during midday everyone is at and the energy consumption is low). Energy storage allows us to buffer this energy during high-production times and use it later when it's needed most.

Energy Consumption – this can be residential, commercial and industrial consumers. These consumers have different consumption curves and need to be balanced with the available production and storage options.

Traditionally energy systems have been developed and designed by large utility companies in almost black-box environments with proprietary connectivity and little focus on cyber security. With energy production moving closer to the energy consumer, more options for transportation and storage, traditional system design are in need of better connectivity solutions.

In 2024. OPC UA has started to look at the whole energy market to help simplify, standardize and improve the resilience of connection points. Not only among the five major energy components but also within.

One important standard that is widely used in substations, wind farms, solar array and other large utility size installations is the IEC 61850.

The OPC UA Wind and Solar PV Operations and Monitoring (SPOM) working group, together with the IEC 61850-20 working group has started mapping the 61850 models to OPC UA models.
Many other groups have started within the Energy Initiative and you can learn more about our activities in the following pages of this brochure.

We are planning many more working groups over the coming years with the goal to develop new energy systems – no matter large or small – in much shorter time and with much better resiliency against cyberattacks.

For more information please follow
http://opcfoundation.org/energy

Contents

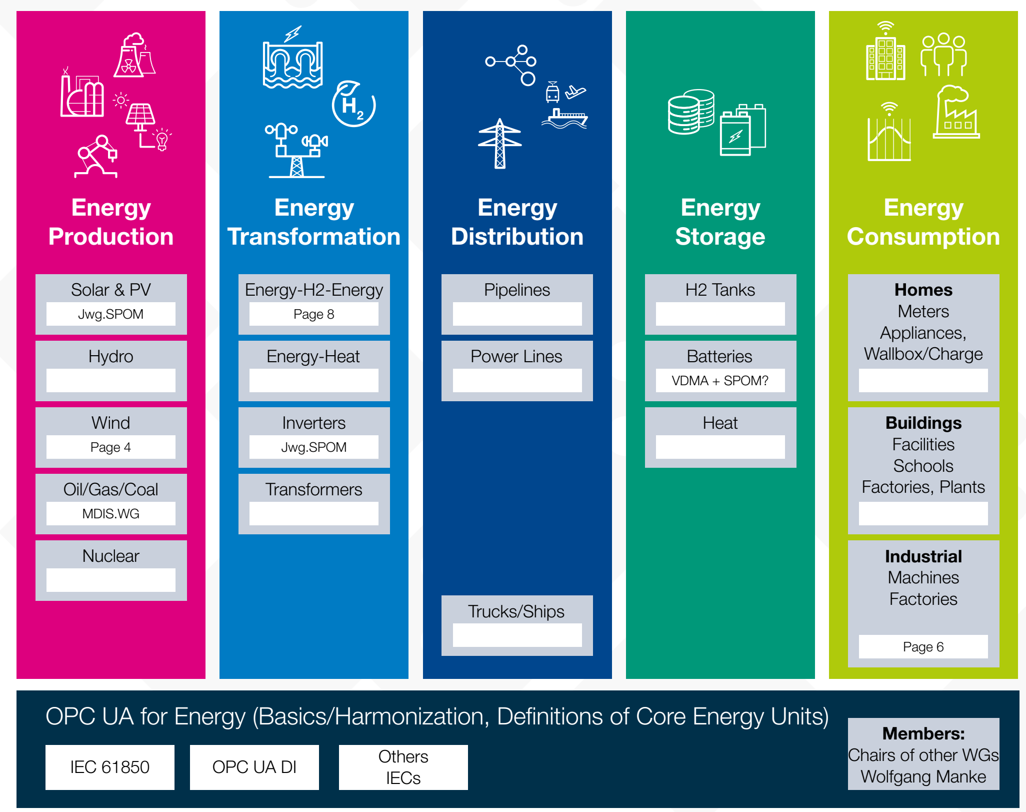

Figure 1: Outlook of future Working Groups

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Monitoring and controlling wind power plants

Significant work on establishing standards for an information model in the wind power domain has already been done within IEC 61400-25 – the wind power domain specific extension of IEC 61850.

Edition 2 of IEC 61400-25 already includes a mapping to OPC XML-DA. It is going to be replaced by the mapping to OPC UA in Edition 3.

IEC 61400-25 is based on the core and common parts of IEC 61850 (IEC 61850-7-3, IEC 61850-7-4, IEC 61850-7-40). Their mapping is required for the mapping of IEC 61400-25.

A wind power plant is not only wind turbines and the wind power plant control. It requires additional components like a substation. And an increasing number of wind power plants include additional systems like a battery energy storage system (BESS) or a solar systems (PV).

Information models for these additional components and systems are defined in the IEC 61850 series. Their mapping provides consistent modelling of a wind power plant.

The work on the mapping was driven by the requirement for a central gateway solution to the wind power plant and can also be used to directly access components having an OPC UA interface.

www.use61400-25.com

MEMBERS OF “USE 61400-25”

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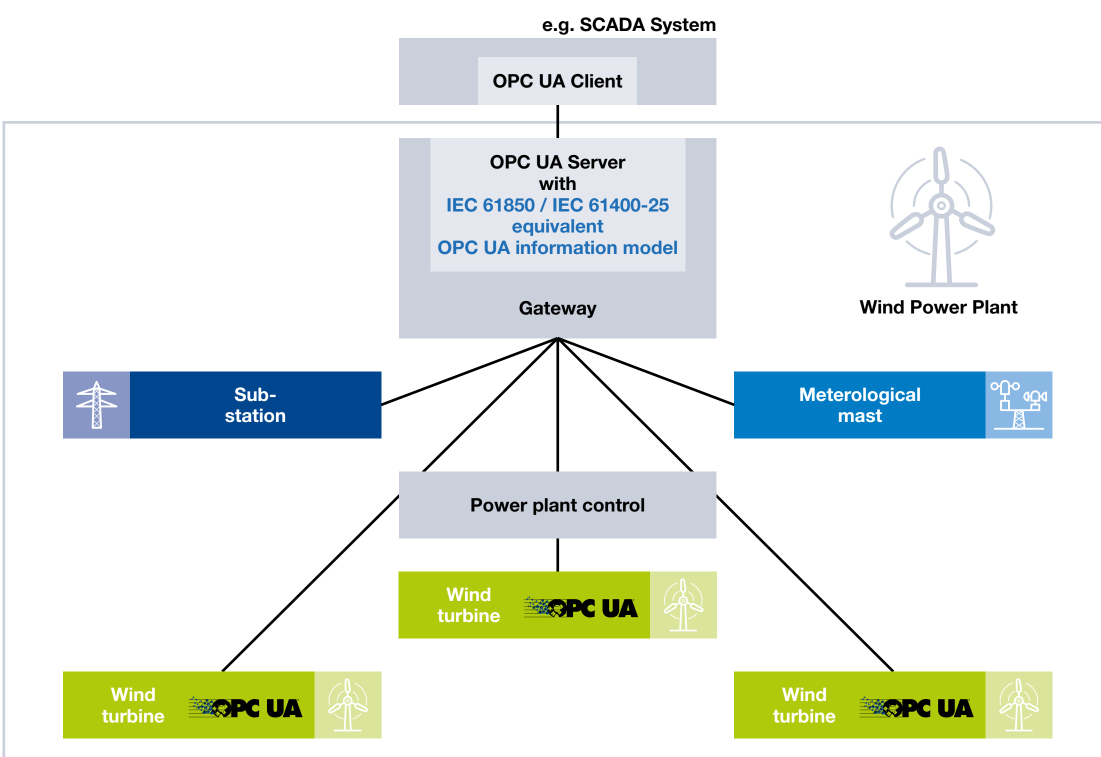
Siemens Gamesa
Vestas
Windey
RWE
Statkraft
Phoenix Contact
Toshiba
BIBA
Enercon
Q-Technology



TOM BERRY,
Distribution
Automation Architect,
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OPC UA for IEC 61850

IEC 61850 is a well-established and widely used standard covering communication networks and systems for power utility automation in multiple domains. These include substations, hydroelectric power plants, wind power plants and distributed energy resources (DER) like solar power (PV) and battery energy storage systems (BESS). It is used for monitoring and control, supervision, alarming and other use cases.

IEC 61850 provides an extensible information model that compliments very well the OPC UA approach and therefore allows easy mapping of the IEC 61850 information models to equivalent OPC UA information models.

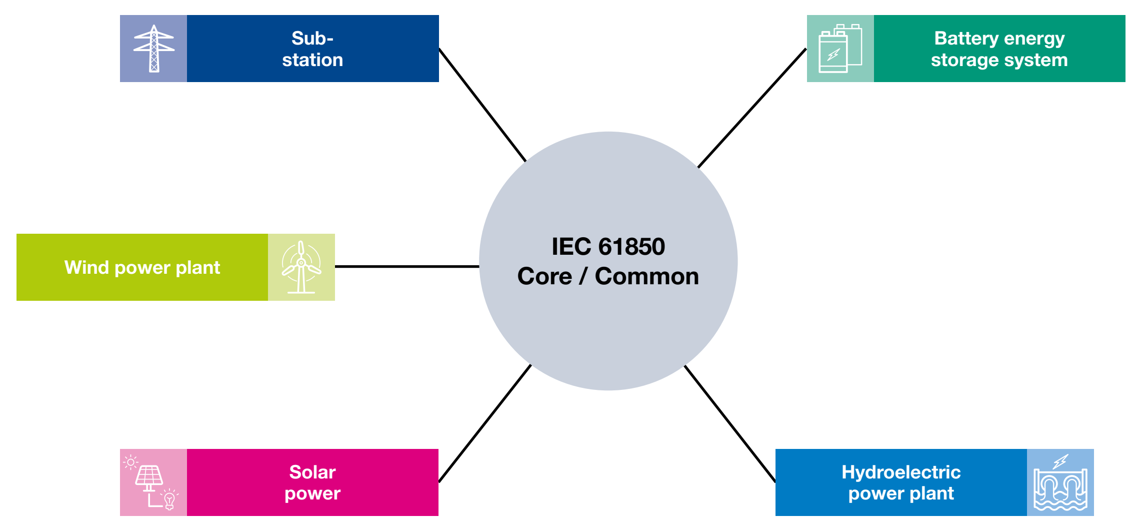
This companion specification applies to systems using IEC 61850 and can also be referenced by other OPC UA working groups in the energy domain like wind power and solar power.

BENEFITS OF OPC UA AND IEC 61850

By mapping the IEC 61850 to an OPC UA semantic information model, engineers, developers, and operators of energy systems will get many benefits such as:

- Standardized connectivity and data formats between many different energy components, even from different vendors
- Easy Integration with Process Control Systems (PCS), Energy Management Systems (EMS) and other high level control systems
- Simplified migration and integration of legacy systems with newer systems using gateways without losing the IEC 61850 information model
- Enhance and extend existing systems with new components and services
- Ready to integrate new energy components, systems, and services with energy production sources like wind turbines that have been traditionally hard to integrate with Battery- or Hydrogen Storage solutions

These benefits will reduce costs for installation, integration, commissioning, and maintenance of complex energy systems.



HEIKO HERDEN,
Heiko Herden,
Lead of VDMA
Harmonization, VDMA

Energy Consumption Management – Standardized Energy Management through Industry Collaboration

DRIVING SUSTAINABLE PRODUCTION
Climate-neutral production is becoming a key objective for industry. Initiatives such as the European Green Deal aim to make Europe climate-neutral by 2050, increasing the importance of transparent and efficient energy management in manufacturing.
To support this transformation, leading industry organizations – OPC Foundation, ODVA, PROFIBUS & PROFINET International, and VDMA – have jointly developed the **Energy Consumption Management** specification. The goal is to create a common, interoperable approach for managing energy data across industrial automation systems.

THE CHALLENGE: FRAGMENTED ENERGY DATA
Many factories lack a consistent way to collect and analyze energy data from machines, devices, and production systems. Different communication technologies and proprietary interfaces often prevent seamless integration of energy information.
Without standardized data structures and semantics, companies struggle to gain a clear overview of their energy usage. This makes it difficult to identify optimization potential, implement coordinated energy-saving measures, or comply with standards such as ISO 50001.

THE SOLUTION: STANDARDIZED ENERGY INFORMATION WITH OPC UA
The **Energy Consumption Management** specification defines a standardized information model based on OPC Unified Architecture (OPC UA). It enables interoperable communication of energy-related measurement and control data across machines, systems, and vendors.

The specification focuses on two key capabilities:
Energy Monitoring – Standardized reporting of energy consumption, including electrical energy as well as other energy sources such as compressed air or water. This provides the transparency needed to analyze energy usage across the production environment.

Energy Saving and Standby Management – Standardized mechanisms to communicate and control energy-saving states of machines and components, enabling coordinated standby strategies across production systems.
Together, these capabilities support the typical energy management cycle: analyzing energy consumption, identifying saving potential, and implementing efficiency measures.

THE BENEFITS FOR MANUFACTURERS
By adopting the Energy Consumption Management specification, manufacturers gain a powerful foundation for sustainable and efficient production.
Key benefits include:

- **Transparent energy monitoring** across machines, lines, and plants
- **Interoperability across vendors and automation systems**
- **Simplified implementation of energy management systems**

Standardization also accelerates innovation by enabling new digital services, analytics tools, and optimization solutions built on a common data foundation.

ERICH BARNSTEDT,
Senior Director & Architect
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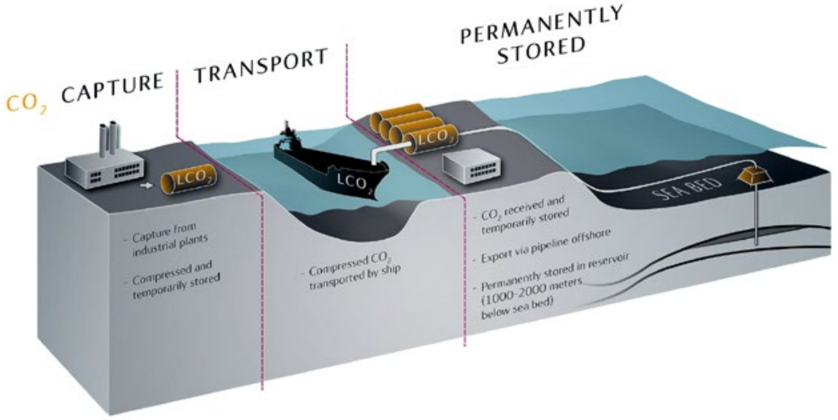
Carbon Capture and Storage (CCS): Why It Matters

CARBON CAPTURE AND STORAGE (CCS): WHY IT MATTERS
Carbon capture and storage (CCS) is a set of technologies designed to prevent carbon dioxide (CO_2) from reaching the atmosphere by capturing it at the source (or from air), transporting it, and permanently storing it deep underground. As the world races to cut emissions, CCS is increasingly viewed not as a single "silver bullet," but as a pragmatic tool, especially for industrial activities that are otherwise extremely hard to decarbonize. A flagship example of CCS moving from concept to real infrastructure is Northern Lights, Norway's cross-border CO_2 transport and storage project, developed as part of the Norwegian government's Longship value chain. Microsoft was part of this project from the start and initiated a working group within the OPC Foundation to standardize the data models used in equipment required for CCS.

WHY CCS IS USEFUL
Some industries emit CO_2 not only from fuel combustion, but also from core chemistry. Cement is the classic example: even with cleaner energy, the calcination process still releases CO_2. The International Energy Agency (IEA) notes that deep cuts in cement-sector emissions ultimately require a major scale-up of innovative technologies such as CCUS (carbon capture, utilization, and storage). This is why CCS is often framed as essential for sectors like cement, steel, chemicals, and waste-to-energy, where electrification alone may not eliminate process emissions.
Even aggressive decarbonization leaves residual emissions in aviation, heavy industry, and agriculture. Climate pathways that reach net-zero CO_2 generally include some form of carbon dioxide removal (CDR) to counterbalance these residuals. The IPCC emphasizes that CDR is required for net-zero targets, while also stressing it cannot substitute for immediate and deep emissions reductions. CCS is what makes several CDR methods durable at scale, particularly BECCS (bioenergy with CCS) and DACCS.
A key advantage of CCS is that it can be built as networks and hubs, multiple emitters sharing CO_2 transport and storage infrastructure, reducing duplication and making the economics more viable. Northern Lights is explicitly built around this "open access" model, designed to accept CO_2 from multiple companies and even multiple countries.



THE BIGGER PICTURE: CCS AS INFRASTRUCTURE, NOT A DETOUR
CCS is most valuable when it is deployed with discipline: targeted at hard-to-abate emissions, paired with rapid emissions reductions, and governed with strong measurement and permanence requirements. Northern Lights illustrates what that can look like in practice: public-private risk sharing to build first-of-a-kind infrastructure, an open-access commercial model, and a clear pathway from pilot-scale to multi-million-ton expansion. If Europe is to decarbonize industries like cement while keeping them globally competitive, projects like Northern Lights offer a concrete (and literally cement-connected) blueprint: build shared CO_2 transport and storage systems once, then connect many emitters to them over time. Since Northern Lights is meant as a blueprint for similar projects, it was important to all participants involved to make the data models of the equipment used available publicly through the OPC Foundation. The related OPC UA Companion Specification will be released in the next few months.

CHRIS M. MÜNCH,
Founder and CEO,
C-Labs and Hyviva

OPC UA for Hydrogen – The Fuel of the Future

Hydrogen plays a central role in the global energy transition to sustainable and renewable energy. It is the most abandoned element in the universe and in almost every material – including of course – water. With its very high energy density it can be used in many applications like mobility, energy storage and heating.

Hydrogen is a fuel! It can be stored, transported and used like traditional fossil fuels with one major advantage: It can be created anywhere in the world – even at home - with relatively simple processes like electrolyzes using water and solar energy. As a fuel it has many more use cases on the horizon once this "physical energy" is accessible more broadly.
There are many colors of Hydrogen, expressing the way hydrogen was formed. The most common ways of forming hydrogen are electrolyzes and methane reforming. The energy source used to form it determines the color. More about the colors https://www.nationalgrid.com/stories/energy-explained/hydrogen-colour-spectrum

With its very small molecular density it can be compressed, liquified or injected into other materials such as metal hydride and specialized liquids. Systems that manage Hydrogen, no matter if small or large, are complex and require many parts from different vendors. This automatically leads to compatibility issues with hardware and software creating overhead and excess costs that in many cases make hydrogen projects very expensive. The OPC Foundation has started to address important aspects around connectivity and modelling. The first working group for Electrolyzer has been established in 2024 with more to come.

The Hydrogen Initiative of the OPC Foundation is bound to achieve these major goals:

- Faster integration of different components to accelerate the development of Hydrogen systems
- Seamless connectivity across vendors to allow maximum flexibility for system integration
- Uniform access to operational, maintenance, and system data over the whole lifecycle

As figure 1 shows there are many components that need addressing. The orange parts are already in work and for the blue parts, the OPC Foundation will send out request for participation to the member companies shortly.

The journey started two years ago at the Hannover Messe 2024 and is now on its way with over 30 participating companies in our first companion specification for Electrolyzer. If you are interested in participating in our existing working group or forming one of the remaining groups, please contact the OPC Foundation or write me directly at chris@hyviva.com

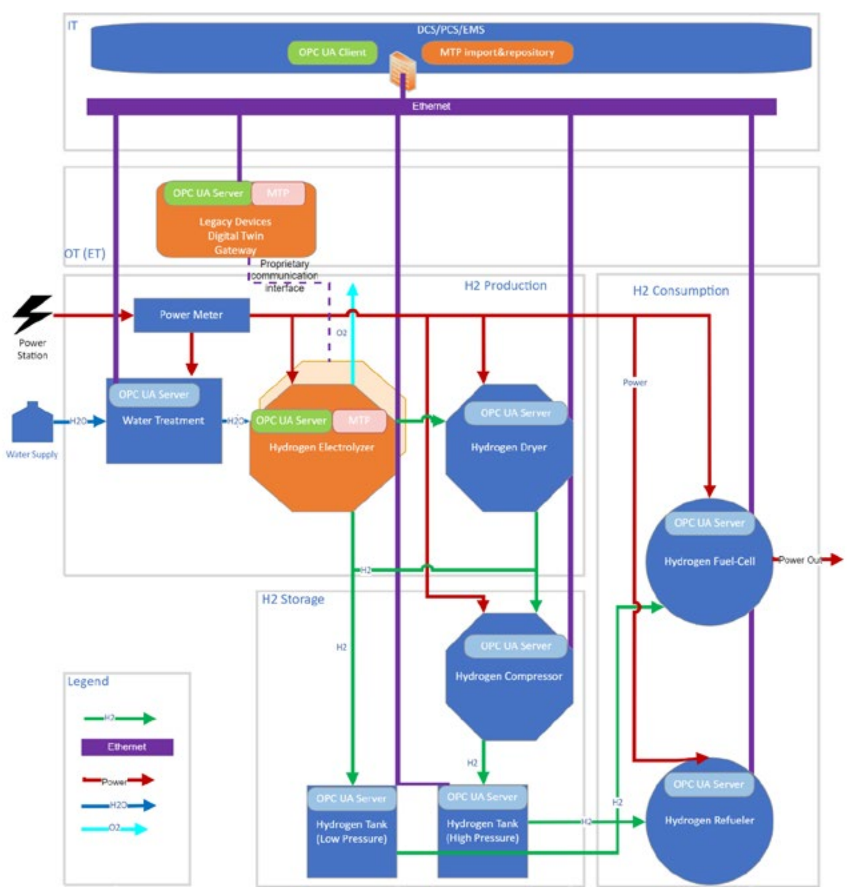


Figure 1 Hydrogen Eco-system components

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OPC for Hydrogen Electrolyzer

INTRO

Electrolyzer are the core production units enabling (green) hydrogen generation for I industrial, mobility, and energy domains.

As hydrogen plants scale from pilot projects to industrial production systems, seamless integration of electrolyzers into Distributed Control Systems (DCS), Process Control Systems (PCS), and Energy Management Systems (EMS) become critical.
The joint VDMA and OPC Foundation Working Group for Hydrogen Electrolyzer was founded to develop a standardized, manufacturer-independent information model to enable:

- Low-effort integration of electrolyzers into automation systems
- Interoperable communication across vendors
- Modular hydrogen system composition

The initiative covers all major Electrolyzer technologies: Alkaline, AEM, PEM, and SOEC and supports combinations of multiple technologies within a single hydrogen production system.

CHALLENGES

The hydrogen industry faces significant integration barriers that slow deployment and increase costs:

- Proprietary interfaces
- High integration effort
- No common data model
- Difficult system aggregation
- Legacy device challenges

OPC FOUNDATION SOLUTION

The Hydrogen Electrolyzer Working Group delivers a standardized OPC UA Companion Specification, a manufacturer-independent information model that all Electrolyzer vendors and system integrators can use.

Key elements of the solution include:

- **OPC UA Companion Specification for Hydrogen Electrolyzers:** A formal, machine-readable information model defining data structures, interfaces, and services for all major Electrolyzer types, published as a NodeSet file compatible with any OPC UA-compliant system.
- **Standardized Electrolyzer Information Model** defining harmonized digital nameplate data, structured system topology, relevant process values, operational states, alarm and maintenance information, as well as standardized control and service interfaces for seamless integration into DCS/PCS/EMS and MTP-based modular automation environments.
- **Legacy Device Support via Digital Twin Gateway:** A defined pathway to expose existing brownfield Electrolyzer devices through OPC UA gateways.
- **Harmonized approach:** Active alignment with OPC UA for Machinery, Device Information Model, Industrial Automation, MTP concepts according to International MTP guidelines and other VDMA companion specifications.
- **Vendor independence:** Customers can freely combine electrolyzers from different manufacturers and select the best control system, without proprietary lock-in.
- **Faster time-to-production:** With plug-and-play connectivity to DCS, PCS, and EMS, hydrogen plants can be commissioned and scaled much more quickly.
- **Energy system integration:** Uniform aggregation of OPC UA Servers enables higher-level energy optimization.
- **Regulatory and sustainability alignment:** Open, auditable data flows support compliance reporting and sustainability accounting for green hydrogen production.

FURTHER LINKS:

Working Group Hydrogen Electrolyzers
Wasserstoff-Leitprojekte: H2Giga: serial production

ACTIVE WG MEMBER COMPANIES:

ABB
C-Labs
Enapter
HSU
H-TEC
Phoenix Contact
PILZ
Semodia
Siemens Energy
Sunfire
TU Dresden
VDMA
Weidmann

Resources, Links, Contacts

LANDING PAGE

- OPC Foundation Energy Initiative
  www.opcfoundation.org/energy

OPC UA RELATED LINKS

- USE61400-25:
  www.use61400-25.com

- IEC 16850
  https://en.wikipedia.org/wiki/IEC_61850

- Working Group Hydrogen Electrolyzer
  https://profiles.opcfoundation.org/working-group/95

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- Chair of Energy Consumption WG:
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- Chair of Carbon Capturing WG:
  Erich Bernstedt erichb@microsoft.com

- Chair of Hydrogen Initiative:
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- Chair Electrolyzer WG:
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NICE TO KNOW

- Hydrogen Flagship Projects:
  H2Giga https://www.wasserstoff-leitprojekte.de/projects/h2giga

- Hydrogen Color Coding
  https://www.nationalgrid.com/stories/energy-explained/hydrogen-colour-spectrum

OPC UA: Much more than just a Protocol! Meta-Modelling Language + Transport + Security

OPC UA IS …
A RICH MODELING LANGUAGE
OPC UA delivers context-aware data, not just signals:

- Object-oriented information models
- For data and interfaces
- For devices and services
- Strong typing and validation
- 430+ free companion specifications across industries – free of charge available
- Extensible models for enterprise-specific needs

Semantics are embedded directly into the data stream – enabling scalable analytics, automated integration, and system-to-system understanding without custom mappings.

Models

– More than 430+ models (Industries, Catena-X, ..) available.
– Free of charge and commercial modelling tools available
– OPC UA library is an free of charge repository of OPC UA based information models (from OPC Foundation and worldwide contributors)
– UA Cloud Library allows to instance models, keep the instances in database and interact via Web UI and REST interface

Internationalization

– OPC UA is IEC62541 Standard
– OPC UA is local standard in China (GB/T 33863.x), Korea, Russia, Singapore

PROVIDING FLEXIBLE TRANSPORT
Native Integration with modern IT & Cloud Platforms
Support 2 communication mechanisms:
Client/Server & Publisher/Subscriber
OPC UA integrates seamlessly with enterprise and cloud ecosystems:

- Publish/Subscribe over MQTT, AMQP and Kafka for cloud ingestion
- Efficient or human readable encodings
- REST and WebSocket bindings for IT and web applications
- Filetransfer
- Compatible with event streaming, data lakes, and analytic platforms

This makes OPC UA a natural backbone for IIoT platforms, AI pipelines, and digital twin architectures.

DELIVERING SECURITY BUILT-IN BY DESIGN
Enterprise-Grade security, proven at scale
security is built-in from the ground up:

- Onboarding
- For accessing information
- For transport of information
- Fine-grained authorization down to data-point level
- Integrated audit concepts
- Verified/Validated by international experts
- Infrastructure certificate management

Based on proven IT security standards (TLS, AES), OPC UA fits naturally into zero-trust and cloud security architectures.

RELIABLE DATA FOR MISSION-CRITICAL DIGITAL SYSTEMS
OPC UA ENSURES INTEGRITY AND AVAILABILITY ACROSS UNRELIABLE NETWORKS:

- Automatic recovery and reconnection
- Data buffering to prevent loss
- Sequencing, retransmission, and redundancy support

This reliability makes OPC UA suitable for cloud-based monitoring, analytics, and operational decision-making.

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