Hydrogenics Selected References

Grid Balancing, Power to Gas (PtG)

2016
In a nutshell

- Global provider of
  - On-site hydrogen water electrolysers
  - Energy Storage systems
  - \( \text{H}_2 \) fueling stations
  - Fuel cells systems
- Over 65 years experience
- 170 employees
- Own R&D and product development
- Over 2,000 projects deployed in >100 countries
- 145 Patent & Applications
- Listed on NASDAQ (HYGS) and TSX (HYG)
Production Hall (Belgium)

Final Skid & Container Integration

Oxygen cleaning

Welding area (certified)

Skid/System Assembly
Production Hall (Germany)
Production Hall (HQ Canada)
The Smart Energy Grid – Hydrogen to build bridges

Energy System

Current Tool

Advantage

Disadvantage

H₂ Link

Synergies

Heat

(BTU)

Natural Gas

Storage

Dependency

CO₂ emissions

H₂ Interchangability

Transport

(Litres)

Gasoline

Portability

Dependency

CO₂ emissions

H₂ range

over batteries

Power

(kWh)

Electricity

Speed

Storage

H₂ clean

conversion

H₂ link

interchangability

H₂ range

over batteries

H₂ clean

conversion
Hydrogen bridges the power, gas and transport sectors to unlock new options for energy storage.
Hydrogenics’ Power-to-Gas & Grid Balancing Expertise
Ontario, Canada

Ontario Grid Frequency Regulation

OBJECTIVES
• Investigate the reactivity of a HySTAT™ hydrogen generator.
• Provide frequency regulation by responding to real-time frequency regulation signals from the IESO on a second-by-second basis using an electrolyzer.

SOLUTION
• HySTAT™ S4000 Indoor solution producing 100Nm³/h H₂.
• Perfect ability to capture the overload and cope with the volatility of frequency regulation signals.
Galicia, Spain

Sotavento Grid Stabilisation

OBJECTIVES

- Research and technological demo centre aimed at improving the implementation of renewable energy systems.
- Production of H₂ from a wind farm featuring 24 wind turbines of 5 different technologies.
- Use the H₂ in an internal combustion engine to produce electricity.

SOLUTION

- HySTAT™ 60 Outdoor with all peripherals to produce 60Nm³/h H₂.
- H₂ compression & storage system and one HICE.
Glamorgan Smart Grid project

**OBJECTIVES**
- Improve interaction between renewable electricity, electrolytic hydrogen production and fuel cells at Baglan Energy Park.
- Use of 20 kW solar panels and a wind turbine to produce H₂.

**SOLUTION**
- HySTAT™ 10/10 Indoor electrolyzer to produce 10Nm³/h H₂.
- Compression, storage and dispensing system.
- HyPM™ 12 kW Fuel cell.
- 2 HyPM™ 12 kW (Integrated in a shuttle bus and an electric delivery vehicle).
Meckl.-Vorpommern, Germany

**RH₂ - WKA Grid Stabilisation**

**OBJECTIVES**
- Produce electricity coming from a 140MW onshore wind farm (some turbines are rated at 7.5MW) using hydrogen as energy storage. Have CO₂ savings of +/- 250.000 t/year.
- Use the H₂ in an internal combustion engine to produce electricity and retrieve the heat from the system for the building. In a further stage, use H₂ for transport and demonstrate the PtG (Power to Gas) solution by injecting the produced H₂ in the nearby pipeline.

**SOLUTION**
- 1MW HySTAT™ indoor solution with all peripherals to produce 210Nm³/h H₂.
- H₂ compression and storage system (4’500Nm³ H₂ at 310bar) with 90 + 150kW HICE.
Brisbane, Australia

Sir Samuel Griffith Center

OBJECTIVES

• Off-grid and energy independent building, the first zero-emission building in Australia.
• Solar cells installed on the roof and solar film on the windows. 85% of the generated solar power is used during the day and 15% is used to produce H₂, feeding a fuel cell to generate electricity in times when the sun is not out.

SOLUTION

• HyPM™ 30 electrolyzer to produce 30Nm³/h of hydrogen.
• Six 10KW HyPM™ fuel cells, fully integrated in two 30kW HyPM™ FC Racks.
Stuttgart, Germany

**Methanation process**

**OBJECTIVES**
- Demonstrate the PtG (Power to Gas) solution using methane.
- Produce H₂ from the surplus of electricity and combine it with CO₂ from a biogas plant to produce methane ($4H_2 + CO_2 \rightarrow CH_4 + H_2O$).

**SOLUTION**
- HySTAT™ 60 Outdoor with all peripherals to produce 60Nm³/h H₂.
- The electrolyzer combined with a methanation process produces bio-methane.
- Bio-methane is injected in the gas grid, leading to a carbon neutral process.
Falkenhagen, Germany

Greening of Gas

OBJECTIVES
• Demonstration of the process chain; converting excess wind power into hydrogen
• Optimize operational concept (fluctuating power from wind vs. changing gas feed).
• Gain experience in technology and cost.
• Feed $H_2$ into the high-pressure transmission natural gas pipeline at 55bar (ONTRAS).

SOLUTION
• 6 x HySTAT™ 60 with all peripherals in 20Ft. housings to produce 360Nm$^3$/h $H_2$.
• A 40 Ft container including 2 compressors to compress the hydrogen to 55barg.
• Power: 2MW
Puglia, Italy

INGRID (24Mio€ FCH JU project, 7 partners)

OBJECTIVES
- Allow increased penetration of highly fluctuating RE into the grid using electrolysis and supply-demand balancing.
- Improvement of distribution operation through active/reactive power control for optimal voltage regulation and power quality.
- Use $\text{H}_2$ for transport, industry, grid balancing and injection into the gas network.

SOLUTION
- 1MW HySTAT™ electrolyzer in a 40Ft. Housing to produce 200Nm³/h $\text{H}_2$.
- 60kW Fuel Cell backup system.
- 39 MWh, 1,000kg solid hydrogen storage system.
Mississauga, Canada

Enbridge invests 5Mio. CAD in Hydrogenics

OBJECTIVES
Develop utility scale energy storage in North America to:

- Bridge the electricity and natural gas networks.
- Demonstrate Load-Following of Renewables.
- Bring seasonal storage capabilities to electricity networks.
- Set Gas Inter-Operability Standards and Metering.
Herten, Germany

Herten Smart Grid System

**OBJECTIVES**
- Convert excess wind power (8600 kW turbine) into hydrogen to store surplus energy.
- The hydrogen will be used to provide backup power or to refuel vehicles.

**SOLUTION**
- HySTAT™ 30 Indoor electrolyser with all peripherals to produce 30Nm³/h H₂.
- 50bar compressor and 500kg H₂ storage.
Multi megawatt electrolyser

1,300Nm³/h • 2,800kg/day • +/-7MW

OBJECTIVES

• Convert excess renewable into hydrogen to store surplus energy.
• The hydrogen can be used for different application, like direct injection into the natural gas grid, vehicles refueling or for industrial applications.

SOLUTION

• HySTAT™ 1300 Indoor electrolyser with all peripherals to produce 1300Nm³/h H₂.
Rich and Diverse Business Models

• Only H₂ can provide long term seasonal storage
• Fast & dynamic response to load follow profile of RE
• Marketing of “Green Gas”
• Electricity transport whenever and wherever you want
• Energy Arbitrage up to seasonal and “unconstrained”
• Power to Hydrogen Fuel – zero emission transport
• Grid stabilization services
Multiple Revenue Streams

Benefits of Distributed Power-to-Gas Solution

- Integrate Renewables
- Shift Power
- Energy Storage & Transport

$M

Supply Response  Fast Frequency Regulation  Sale of Hydrogen  Banked Energy  Pipeline and Storage  Deferred Transmission Capex  Carbon Credits¹  Total Value

¹A 10MW Power-to-Gas plant running 2000 hours a year would reduce carbon emissions by 3225 tonnes CO₂ equivalent by displacing natural gas
Hydrogenics
Value Proposition
Hydrogenics’ product added value

- Complete turnkey solutions
- Flexible & fully-automated production
- Best offering according to project (PEM or Alkaline technology)
- 10barg (30barg) pressure without compressor
- Compact and highly efficient solution
- Adapted power management
- Robust & Safe design, high reliability (many units in operation)
- Reduced and simple maintenance (limited moving parts, No KOH pump)
- Hydrogen purity according to requirements (up to 99.999%)
- Compliant to all major international standards
- Customizable and easy to integrate solutions
Hydrogenics’ team added value

- Direct contact with the manufacturer
- Project Manager for each project
- Dedicated R&D and Technology team
- Team of highly skilled people
- Commitment to safety and reliability
- 65 years of experience
- ISO 9001, 14001 and OHSAS certified
- Worldwide start-up and after-sales service
- Recognized by major companies