

Mobile Hydrogen Laboratory for Experimental Research and Engineering Education

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Osaamista energiamurroksen johtamiseen -hanke

INTRODUCTION

The hydrogen economy offers enormous potential to reduce CO₂ emissions, yet its large-scale deployment appears to be progressing slowly.

- Requires energy policies that penalize the use of fossil fuels, an area in which the European Union has long acted as a global frontrunner.
- Hydrogen is currently the key solution for reducing greenhouse gas emissions in sectors of heavy industry, aviation, and energy.

Production of **green hydrogen** requires the splitting of water molecules into hydrogen and oxygen by utilizing renewable electric energy (wind, solar, hydro).

- Wind and solar power, with their varying output power due to weather, will mainly be utilized.
- To maintain power system balance, hydrogen production must be flexible in accordance with the needs of the power grid.
- The flexibility of H₂ production is still somewhat unclear. This represents one clear technical challenge of hydrogen economy.
- Many aspects of the hydrogen economy still require further technical development. From the energy system viewpoint, the flexibility of H₂ production is one of the most interesting ones.

HYDROGEN ECONOMY AND ENGINEERING EDUCATION

Engineering education must keep pace with the technological development.

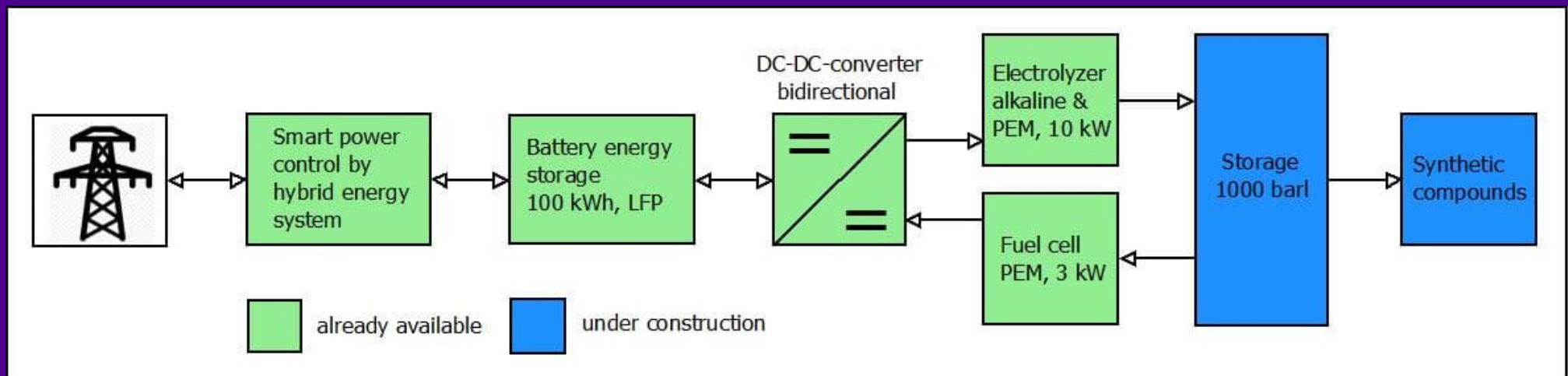
- H₂ technologies represent a key area that needs to be incorporated into engineering curricula.
- In addition to the substance development, laboratory infrastructures must also be updated to ensure the development of hands-on engineering skills.
- We present the mobile hydrogen laboratory that has been designed and built at Tampere University of Applied Sciences in Finland. The mobile hydrogen laboratory will be utilized in experimental research, and in the development of engineering education in electrical engineering, automation engineering, and process engineering.



HYDROGEN PRODUCTION SYSTEM (1/3)

The hydrogen production system was designed and implemented component by component in-house.

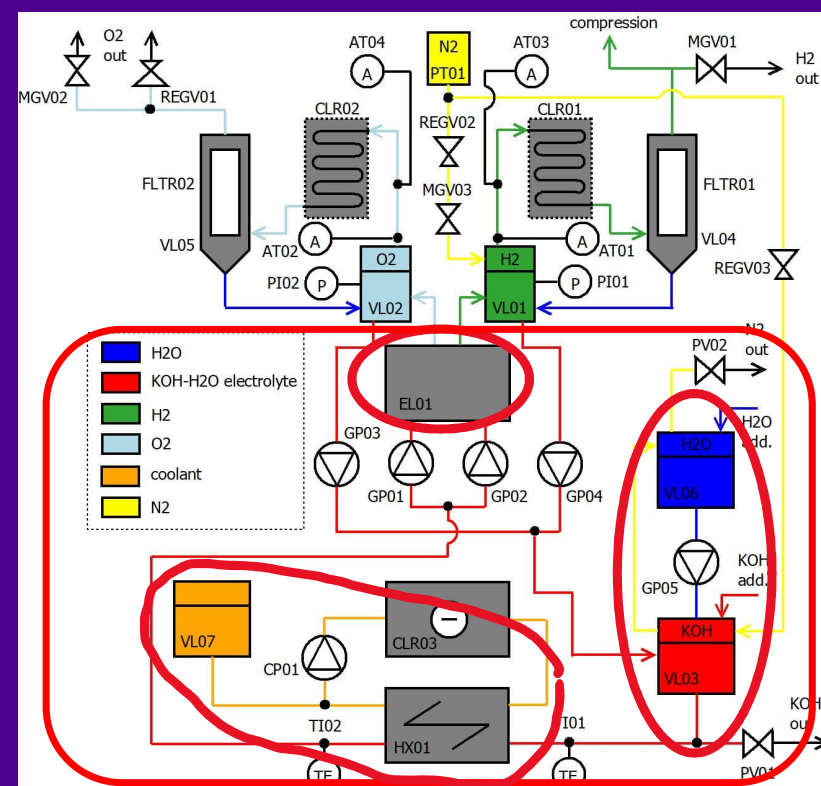
- Our aim was to maximize the educational and experimental research potential of the system.
- The in-house implementation of laboratory systems on a component-by-component basis provides university staff with valuable expertise that would be largely unattainable if the systems were acquired as ready-made plug-and-play solutions.
- The equipment is technically complex, which provides extensive opportunities for experimental research and for the development of engineering education.



HYDROGEN PRODUCTION SYSTEM (2/3)

Hydrogen production is based on an electrolyser that splits water into hydrogen and oxygen using electrical energy.

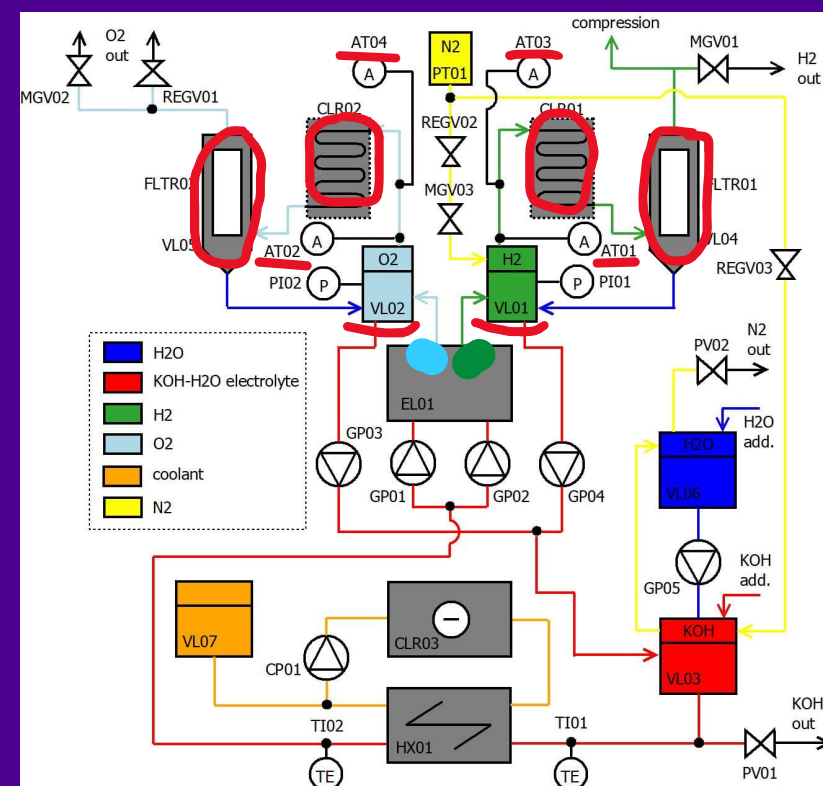
- H₂ production is implemented with an alkaline-type electrolyser (EL01), but the system also allows the use of a PEM-type electrolyser.
- The electrolyte of the alkaline electrolyser is a mixture of potassium hydroxide (KOH) and water, with the KOH concentration maintained in the range of 25–30%.
- The lower half of figure shows the electrolyte circulation loop, which consists of concentration control as well as cooling and feeding of the electrolyte to the electrolyser.
- Maintaining the concentration requires periodically adding water (VL06) to the electrolyte tank (VL03) using the purified-water dosing pump (GP05).
- Electrolyte cooling is implemented using a heat exchanger HX01. Coolant is circulated by a circulation pump CP01, and VL07 serves as the coolant reservoir.



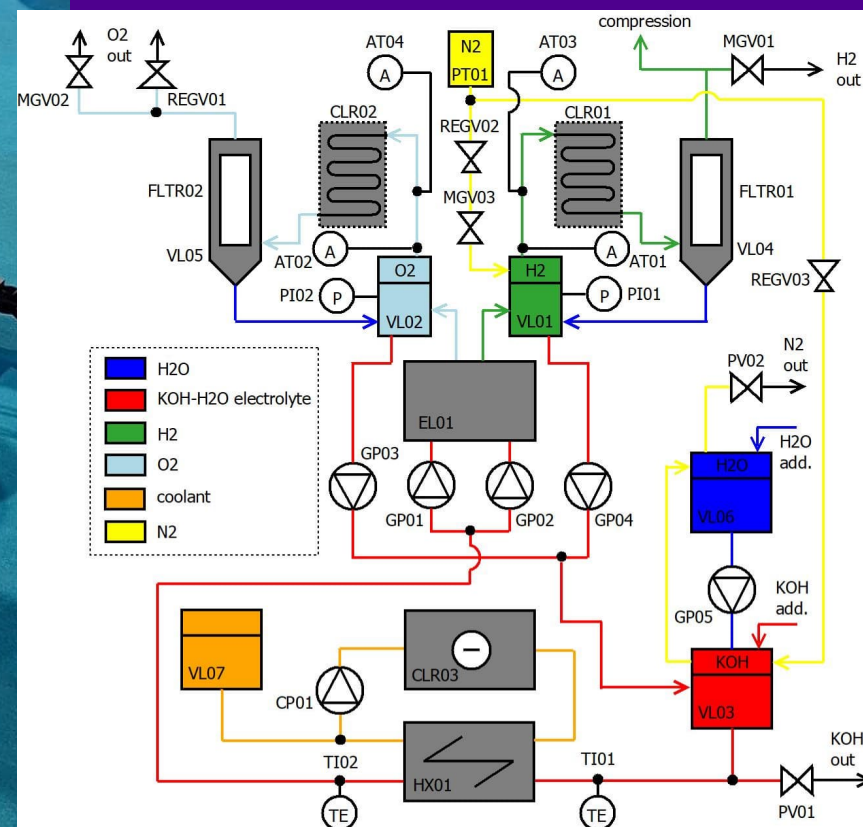
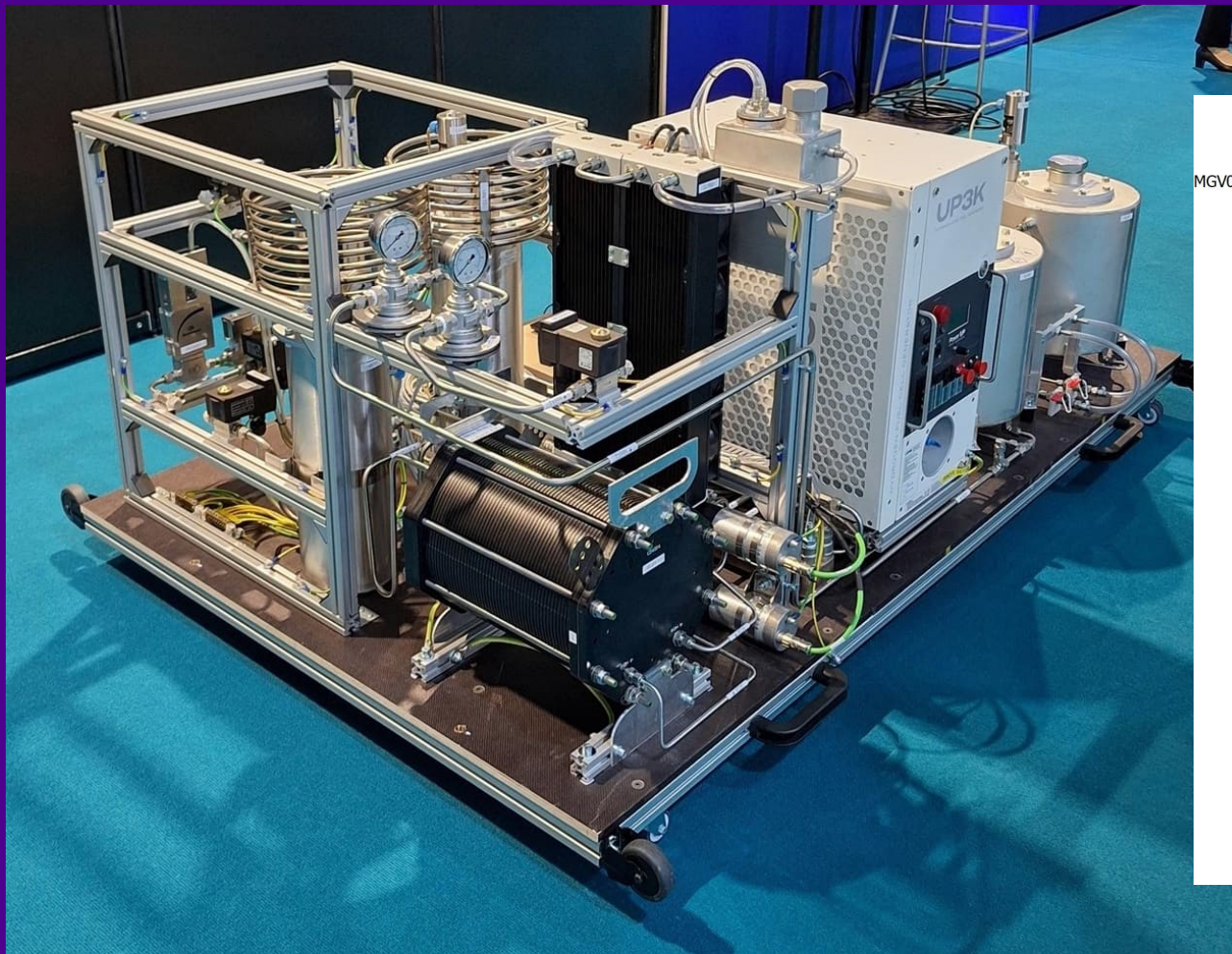
HYDROGEN PRODUCTION SYSTEM (3/3)

Pressure control between the hydrogen and oxygen sides is crucial.

- Excessive pressure difference can lead to gas crossover and even damage the membrane.
- Both reaction gases, H_2 and O_2 , have their own outlets.
- To monitor gas crossover, hydrogen (AT01, AT02) and oxygen sensors (AT03, AT04) are installed after separation tanks VL01 and VL02.
- H_2 and O_2 gases are not obtained directly from the electrolyser. Instead, the outlets deliver electrolyte solution containing H_2 bubbles and O_2 bubbles.
- Gas bubbles need to be separated from the electrolyte.
- First, gravitational separation (VL01, VL02) is utilized.
- To condense moisture from H_2 and O_2 gases, cooling coils CLR01 and CLR02 are utilized.
- Finally, coalescing filtration (FLTR01, FLTR02) is utilized to remove the remaining impurities.



PRACTICAL IMPLEMENTATION OF THE SYSTEM



MOBILE HYBRID ENERGY SYSTEM FOR MODERN DRIVES OF SMART ENERGY TRANSITION



POLAR
NIGHT
ENERGY



caruna



Vipuvoimaa
EU:lta
2014–2020
10/7/2026 9

MOBILE HYBRID ENERGY SYSTEM

Technically versatile mobile hybrid energy system has been designed and built to demonstrate a great variety of modern electric drives of smart energy transition.

- Includes sophisticated power electronics system, 100 kWh energy storage (Li-ion) and high-power charging station for electric vehicles.
- Mobile solution to two trailers was designed and implemented at Tampere University of Applied Sciences.



TECHNICAL PROPERTIES

Enables a great variety of modern electric drives utilizing energy storage.

- Offers 3-phase isolated network with 70 kW maximum power and 100 kWh storage capacity.
- Includes intelligent power control system: when hybrid energy system is connected to a building's network via 3-phase plug, comprehensive power flow control of electricity connection can be carried out. <https://doi.org/10.1007/s40866-023-00162-5>
- Numerous possibilities: mobile 3-phase isolated network, peak shaving, eco-friendly reserve power, mobile charging station for electric vehicles, demand response, zero-energy buildings (integrated to pv), balancing the grid, supporting weak grid, ...

