DEVELOPMENT OF HYDROGEN STORAGE FACILITIES FOR INCREASED RENEWABLE ENERGY EFFICIENCY

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Abstract. *Storage technologies are essential for the integration of fluctuating renewable energies. Large scale storage provides grid stability, which are fundamental for a reliable energy systems and the energy balancing from hours to weeks, time ranges to match demand and supply.*

Keywords: *Energy storage technologies, Hydrogen storage, Renewable energy, Grid stability.*

Introduction:

Wind and solar generation saw an increase of 10% in 2020. The Renewable Energy Directive sets rules for the EU to achieve its 32% renewables target by 2030. Higher wind and solar power penetration is possible, but several challenges remain if production is to meet demand. One solution is electrical energy storage.

Electricity from renewable sources of energy is plagued by fluctuations (due to variations in wind strength or the intensity of insolation) resulting in a lack of stability if the energy supplied from such sources is used in 'real time'. An important solution to this problem is to store the energy electrochemically (in a secondary battery or in hydrogen and its derivatives) and to make use of it in a controlled fashion at some time after it has been initially gathered and stored.

While a variety of technologies will be used to fulfill storage needs, hydrogen plays an essential role in different areas of the supply and distribution chain for renewably-sourced energy.

Hydrogen has the highest mass energy density of any fuel, making it an extremely effective medium for energy storage and distribution Fig. 1. As Europe deploys more renewable capacity, from vast wind farms to roof-top solar arrays, hydrogen is set to be an essential integrator, harnessing excess power generation, balancing intermittent supply and demand, and ultimately helping support a clean, efficient and sustainable energy system.

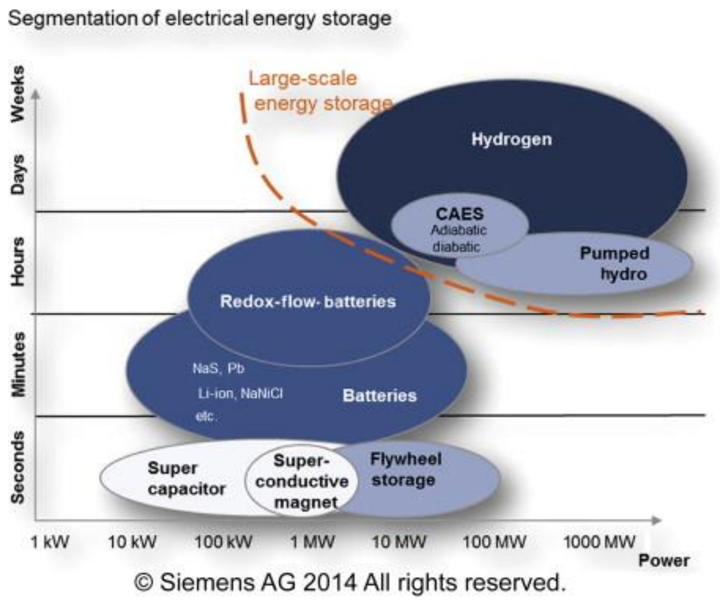

Figure 1. Hydrogen Storage Comparison

At wind and solar energy sites, excess electricity not supplied directly to the power grid can be used to perform electrolysis to split water molecules into oxygen and hydrogen, with the hydrogen stored for later reuse, ensuring that not a single kilowatt-hour is wasted. The hydrogen can be used directly as a clean-burning gas in power stations, pumped into the natural gas grid, reconverted into electricity using fuel cells, or used as a transport fuel for hydrogen fuel cell vehicles. Renewably sourced hydrogen can also help meet demand from metallurgical plants, refineries and electronics factories among other sectors looking to 'green' their industrial processes.

1. Hydrogen Storage

Hydrogen produced from electrolysis can be kept as a gas under high pressure or as a liquid at very low temperature, while hydrogen's stable chemistry also means it can hold energy longer than any other medium Fig. 2. Smaller amounts of hydrogen can be stored in above-ground tanks or pressurised bottles, while larger amounts can be pumped into the natural gas grid, even underground caves with a capacity of hundreds of thousands of cubic metres. Such large capacity storage has been evaluated by the HyUnder project, which assessed salt-cavern storage sites for renewably sourced hydrogen across Europe and looked at potential interactions with the transport sector and other markets.

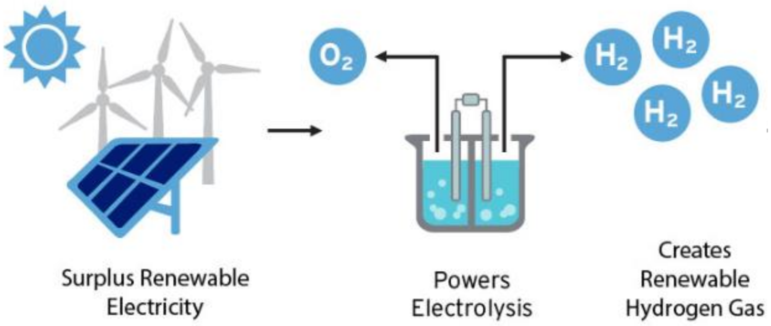

Figure 2. Hydrogen gas production through electrolysis

Batteries are not suitable in storing large amounts of electricity over time. A major advantage of hydrogen is that it can be produced from (surplus) renewable energies, and unlike electricity it can also be stored in large amounts for extended periods of time. For that reason, hydrogen produced on an industrial scale could play an important part in the energy transition.

Alongside other demand and supply measures, energy storage can play an important part in improved system integration. Short-term electricity storage in batteries for small plants is developing dynamically, however, longer-term storage of larger surplus amounts of electricity requires new types of storage, such as chemical storage in the form of hydrogen.

Hydrogen can be obtained by electrolysis from electricity produced with surplus renewables. If there is a corresponding energy demand, the hydrogen can fulfill it directly. However, it can also be stored in bulk tanks as pressurised gas and retrieved when supplies are low.

As energy carrier has by far the highest gravimetric energy density. The mass-based energy density of hydrogen is thus almost three times higher than that of liquid hydrocarbons however the volumetric energy density of hydrogen is comparatively low. Therefore, for practical handling purposes, the density of hydrogen must be increased significantly for storage purposes.

The most important hydrogen storage methods, which have been tried and tested over lengthy periods of time, include physical storage methods based on either compression or cooling or a combination of the two (hybrid storage). In addition, a large number of other new hydrogen storage technologies are being pursued or investigated. These technologies can be grouped together under the name materials-based storage technologies. These can include solids, liquids or surfaces.

2. Hydrogen from Water Electrolysis

Hydrogen can be produced from a large number of primary energy sources and by various technical processes.

Electrolysis is a promising option for hydrogen production from renewable resources. Electrolysis is the process of using electricity to split water into hydrogen and oxygen. This reaction takes place in a unit called an electrolyzer. Electrolyzers can range in size from small, appliance-size equipment that is well-suited for small-scale distributed hydrogen production to large-scale, central production facilities that could be tied directly to renewable or other non-greenhouse-gas-emitting forms of electricity production.

Hydrogen production via electrolysis may offer opportunities for synergy with variable power generation, which is characteristic of some renewable energy technologies. For example, though the cost of wind power has continued to drop, the inherent variability of wind is an impediment to the effective use of wind power. Hydrogen fuel and electric power generation could be integrated at a wind farm, allowing flexibility to shift production to best match resource availability with system operational needs and market factors. Also, in times of excess electricity production from wind farms, instead of curtailing the electricity as is commonly done, it is possible to use this excess electricity to produce hydrogen through electrolysis.

The electrolysis breaks down a feedstock, in this case water, into hydrogen and oxygen by electricity. The electrolyser consists of a DC source and two noble-metal-coated electrodes, which are separated by an electrolyte Fig. 3.

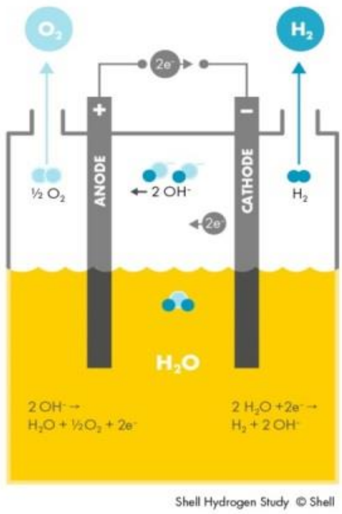

Figure 3. Electrolyser

The efficiency of electrolysis is determined by the amount of electricity used to produce an amount of hydrogen. Depending on the method used, the efficiency of water electrolyser is currently in the region of 60 to 80% (based on the calorific value).

3. Scalable renewable energy infrastructure

One of the biggest benefits of hydrogen is its scalability. A two-megawatt hydrogen electrolyser is roughly the size of a shipping container and can be easily installed next to a field of wind turbines or a distribution substation. This supports a wide variety of applications, including local and decentralised systems providing electricity and fuel for vehicles autonomous of other infrastructure except a clean water supply.

The Don Quichote project is testing the commercial viability of an integrated hydrogen storage system linked to a refuelling facility, directly connecting intermittent renewable electricity to transport applications.

With a complete hydrogen-based energy system established at a commercial site near Brussels, the Don Quichote team is using electricity from solar panels and a wind turbine to generate hydrogen through electrolysis that is then used for back-up power supply and to refuel fuel cell-powered forklift trucks and other vehicles.

Another project, Hybalance, is also planning to use an advanced PEM electrolyser in a large demonstration initiative. Deployed in Denmark, the more than one megawatt-capacity electrolyser will produce hydrogen from renewable energy for an industrial client, supply electricity to the grid, and provide hydrogen to a network of five refuelling stations supporting more than 60 fuel cell vehicles.

Electrolyser production is still in its early stages. Europe, the world leader, has a manufacturing capacity of 1.2 gigawatts (GW) per year, enough capacity in theory to power more than half a million fuel cell passenger cars with hydrogen from water. Production capacity is expanding rapidly. The world's largest electrolyser plant, under construction by the United Kingdom's ITM Power, is expected to produce 1 GW per year. In addition, NEL Hydrogen of Norway has announced plans to build a plant with a production capacity of 360 megawatts (MW) per year and the potential to expand to triple that amount.

The deployment of electrolysers has also picked up in recent years, both in terms of the number and the size of the projects. About 10 years ago, the majority of projects were smaller than 0.2 MW. Over the last three years, several projects were in the range of 1 MW to 5 MW, with the largest at 6 MW. In Japan, a 10-MW project just started operating, and a 20-MW project in Canada is under construction. Larger projects in the hundreds of megawatts have been announced.

As a result, the next two years could set new records, with announced projects bringing the global installation of electrolyser capacity from 170 MW in 2019 to 730 MW in 2021. To ensure that such momentum is kept up after the Covid-19 crisis, it will be important for governments to reassure investors about their continued commitment to hydrogen.

Conclusion:

Hydrogen storage is a key enabling technology for the advancement of hydrogen and fuel cell technologies in applications including stationary power, portable power, and transportation. Hydrogen has the highest energy per mass of any fuel; however, its low ambient temperature density results in a low energy per unit volume, therefore requiring the development of advanced storage methods that have potential for higher energy density.

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