White Paper

Decentral Hydrogen Production from Renewable Energy for the Mobility Sector

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INTRODUCTION

Thoughts about infrastructure needs for the decentral production of hydrogen in fuelling stations with the use of electrolysers

To meet the climate targets of the Paris 2015 Agreement by further decreasing the CO_2 emissions, it is necessary to increase the renewable energy in the energy mix and to replace fossil fuels also in the mobility sector in a progressive rate.

The more energy from wind and solar power is in the energy mix, the more long-term storage is needed. Relevant publications forecast a demand of at least 20 Terawatt hours (TWh) of storage capacity in 2030 in Germany.

Hydrogen has the great advantage that it cannot only be used as a long-term storage of electric power but also as a fuel for mobility. Surplus renewable energy can therefore be converted to hydrogen by electrolysis, and stored before it is distributed to the mobility sector. 20,000 tons of hydrogen can be generated out of 1 TWh of electrical energy. This allows fuelling 100,000 cars driving 20,000 kilometres each.

In 2014, the surplus energy in Germany was 1.5 TWh. This amount of energy would have been sufficient to supply 150,000 cars!

The decentral production of hydrogen at the fuelling stations represents a rational supplement to the centralised generation and storage of hydrogen in large facilities which requires transportation and distribution over large distances in order to fuel cars, trucks and busses.

The concept of decentral production of hydrogen is presented within this white paper. Thereby, electrical energy and deionised tap water is supplied to the fuelling station in order to produce hydrogen with the use of an electrolyser. In several compression stages the hydrogen is then conditioned for both trucks and busses at 350 bar and cars at 700 bar.

For simplification purpose, the demonstration is scaled to an electrolysis capacity of 1 Megawatt at the fuelling station. Electrolysation is a proven technology since over 50 years. Assuming the electrolyser reaches just 2,000 full load operating hours per year, the fuelling station can convert 2,000 Megawatt hours in hydrogen and supply 200 cars driving 20,000 kilometres each.

The realisation of this idea requires the implementation of a smart grid and a tariff policy that allow surplus energy being offered at very low cost.

CONCEPT OF SURPLUS ENERGY UTILIZATION

Technological train

The block diagram of the technological train together with main equipment arrangement, for example electrolysis plant combined with hydrogen refuelling station, is presented below. Thereby, electrical energy and deionised tap water is supplied to the fuelling station in order to produce hydrogen with the use of an electrolyser.

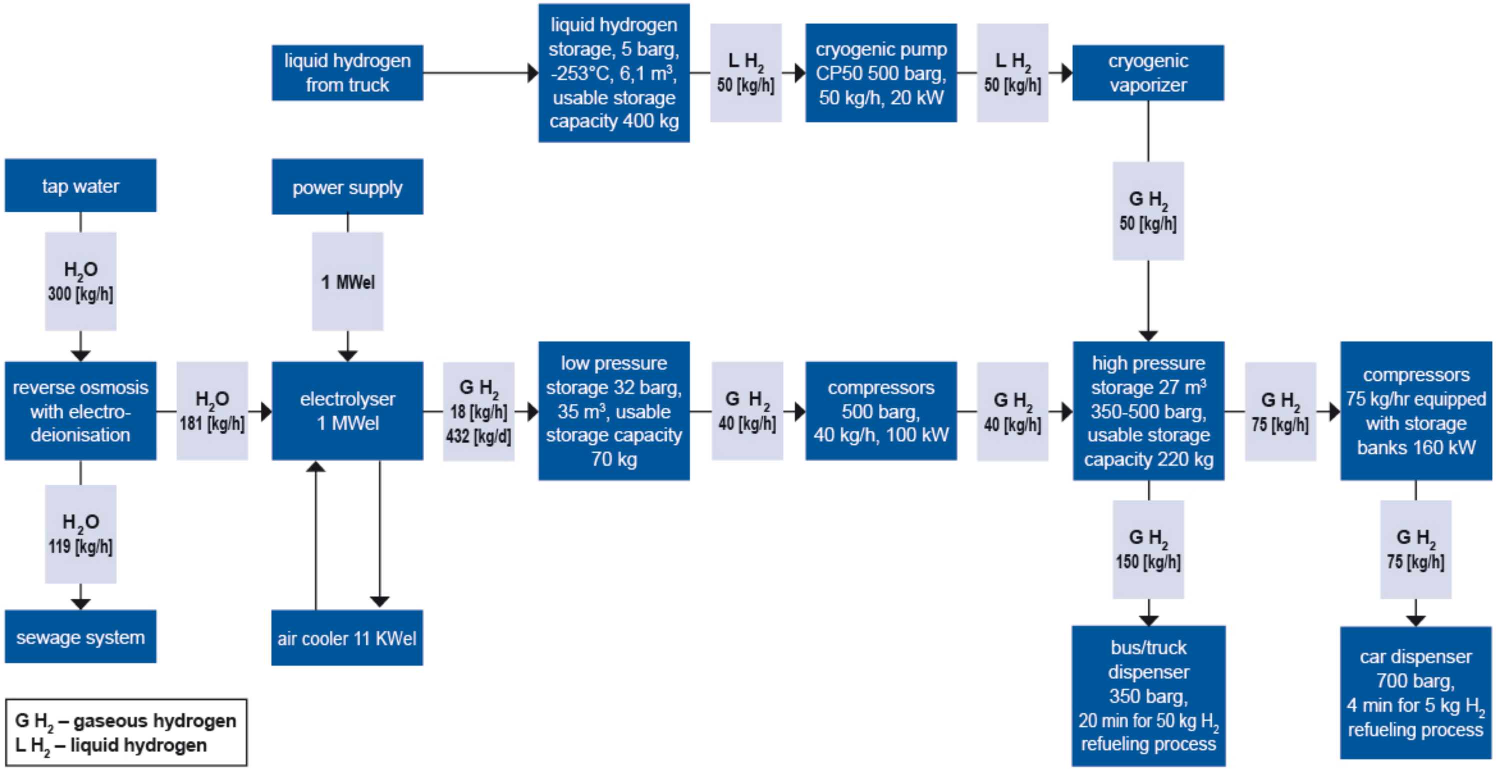


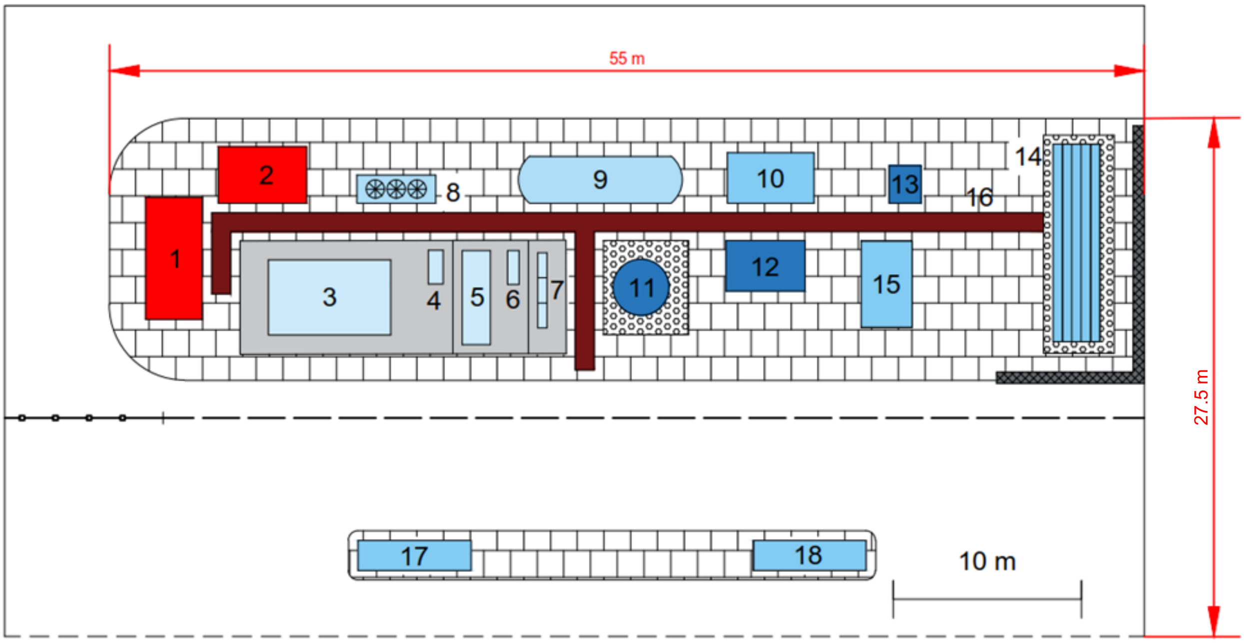
Figure 1 **Technological train together with main equipment arrangement**

Layout of Fuelling Station

The layout of the fuelling station consists of four major components:

1. Electrical energy equipment
2. Gaseous hydrogen equipment (in separate building)
3. Gaseous hydrogen equipment (high pressure)
4. Liquid hydrogen equipment

The different areas are connected through utilities. A protection wall separates the hydrogen high pressure storage from its surrounding.



1 Electrical grid connection
2 Transformer Station
3 Electrolyser 1 MW_{el}
4 Deoxo-dryed
5 Water treatment plant
6 Chiller
7 Control panel
8 Dry cooler
9 Hydrogen low pressure storage
10 Hydrogen ionic compressor
11 Liquid hydrogen storage
12 Cryogenic pump CP 50
13 Cryogenic vaporizer
14 Hydrogen high pressure storage
15 Hydrogen ionic compressor
16 Utilities
17 Bus/truck dispenser – 350 barg
18 Car dispenser – 700 barg

GASEOUS H2 EQUIPMENT
GASEOUS H2 EQUIPMENT (HIGH PRESSURE)
LIQUID H2 EQUIPMENT
ELECTRICAL ENERGY EQUIPMENT
UTILITIES
BUILDING
PROTECTION WALL
GRAVEL
PAVED SURFACE
ASPHALT SURFACE
GATEWAY
FENCE

Figure 2 Layout of a fuelling station with electrolyser

SHORT FUNCTIONAL DESCRIPTION

Grid Connection

The station is connected to a Medium Voltage (MV) network. Total station power demand will not exceed 2,000 kVA, including process equipment and lighting & small power.

Details of the grid connection depend on technical conditions obtained from the grid operator, however, redundant power supply shall be considered – two power supply lines connected to independent power supply stations. Battery limit between the grid and the station is assumed to be at MV switchgear incomers. Power consumption meters shall be provided with the possibility of multi-tariff metering with smooth tariff adjustment.

MV is transformed to 400 V to feed the electrolyser rectifier and other process related equipment, as well as lighting and small power consumers. MV consumers are not foreseen.

Water Treatment Unit

Softened and deionised water is required for the hydrogen generation in the electrolysis process. Depending on the electrolyser's type requirements regarding water quality are different - conductivity range between 1 and 5 µS/cm. Reverse osmosis with electro-deionisation allows achieving required water purity.

Electrolysis

There are two types of electrolysers available on the market for such applications – Proton Exchange Membrane (PEM), and Pressure Alkaline Electrolysers (PAE). Decision about the type of the electrolyser depends on various issues and needs to be taken after analysis of specific data for each project.

Electrolysers are available in a wide range of capacity so it can be easily adjusted to the project's needs. A 1 MW electrolyser with approx. 200 Nm^3/h of hydrogen production needs about 300 kg/h of deionised water. From the electrolyser hydrogen passes through a special purification system which ensures H2 quality 5.0 (which means the purity of H2 = 99.999%). The purification system consists of a deoxo-dryer device. Produced hydrogen pressure is within the range of 10 to 32 barg. Operating parameters are controlled by a dedicated control system. Besides water, the electrolyzer must be supplied with a cooling medium. Waste heat is dissipated by an air cooler.

Low pressure storage

Hydrogen from electrolysis feeds a low pressure storage horizontal tank with a capacity of 35 m^3. This is a buffer for the compressor but can be used also as low pressure storage. Usable storage mass considering pressure changes in the tank within range of 6 to 32 barg is 70 kg of hydrogen. Then it is compressed by an ionic compressor in a 5-stage Ionic compression process to 500 barg with a capacity 40 kg/h and routed to a high pressure storage facility.

High pressure storage

This high pressure storage facility consists of a bank of high pressure tubes with diameter 50 cm and a length of 11 m. Evaluated capacity of the high pressure storage is 27 m^3 and allows to store the hydrogen production at full electrolyser load through 12 hours. Assuming pressure changes in the storage from 500 barg to 350 barg the usable mass for hydrogen storage is approx. 220 kg. Then the hydrogen is available directly for buses and trucks refuelling at pressure of 350 barg with high flow rate up to 150 kg/h. Through the ionic compressors hydrogen is available for cars refuelling at 700 barg with a capacity up to 75 kg/h. The capacity of the high pressure storage, due to high investment costs, shall be optimized based on the project's needs (hydrogen generation plan versus number of refuelled cars).

Compression

Ionic compressors available on the market are innovative and much more efficient than conventional compressors (because hydrogen is compressed in an almost isothermal process) – according to some research the efficiency can reach even 80 to 85%. Ionic compressors dedicated for car refuelling at high pressure can be equipped with chillers which ensure proper temperature for dispensers according to hydrogen refuelling station regulations.

Liquefied hydrogen storage and vaporization – back-up system

The high pressure storage can also be supplied with vaporised hydrogen from the liquid storage tank. It shall function as back-up in case of lack of hydrogen generated by the electrolysis process – if there is a prolonged lack of energy over-production or high demand for refuelling cars and/or trucks and buses. Firstly, liquid hydrogen supplied by a road tanker is stored in a standardized 6.1 m^3 vessel (5 barg, -252 °C), from where it is taken by the cryogenic pump and transported to a cryogenic vaporizer (air-heated). After that, the vaporous hydrogen is provided to the above mentioned high pressure storage facility where it can be equally used.

ADVANTAGES OF THIS CONCEPT

Decentral production of hydrogen

The decentral production of hydrogen allows quicker market penetration and reduces losses by central production and long distance distribution of hydrogen. An adequate electrical grid and tap water is usually availble in Germany. Scaling up is much simpler due to the modular concept based on a manageable layout connected to a conventional fuelling station.

SERVICES AND CONTACT

Your trusted partner for consulting and engineering

ILF Consulting Engineers is capable to design the facilities required to implement the basic idea described above providing a tailor made solution for each individual fuelling station. Our scope of services includes but is not limited to:

- Consulting Services
- Engineering and Design
- Procurement Services
- Construction Supervision
- Commissioning
- Project Management

Special attention will be paid to an adequate grid connection and the selection of the electrolyser.

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