"Green Hydrogen at DLR Lampoldshausen – Extension of the Existing H2 Infrastructure"

Andreas E. Haberzettl, Michael Füting, Dr. Daniela Lindner, Anja Frank, Holger Gernheuser

Institute of Space Propulsion , German Aero Space Center, Lampoldshausen, Germany
andreas.haberzettl@dlr.de , www.DLR.de

Abstract: At the site Lampoldshausen, the German Aerospace Center (DLR) operates on behalf of the European Space Agency (ESA) test facilities for rocket propulsion and their corresponding supply facilities for rocket engine testing for the Ariane launcher family. In addition DLR is operating test facilities for its own research and technology program.

An extensive media supply infrastructure for the test facilities is used for decades, the main aspects for the operation are here the supply with GN2, Helium, GH2, LH2 and LOX.

In the framework of the ongoing projects H2Orizon and Zero Emission, green hydrogen is produced using wind power. The integration of the new systems into the existing hydrogen infrastructure provides more flexibility without reducing the current performance characteristics. A new electrolyzer for additional GH2 production and new consumers will be established and this results in new additional requirements for the supply system. The installation of a liquefier is also planned as a future growth potential.

This paper gives information concerning the operational concept including the tailored extension of the existing hydrogen supply infrastructure adapted to the needs of the new systems and the development of the new systems, and the extension of the existing hydrogen infrastructure. The central responsibility and controllability of the processes should be retained.

1. Introduction

The DLR Institute of Space Propulsion in Lampoldshausen is operating test facilities for its own research and technology program as well as for development and qualification purposes for the European Space Agency. The fluid supply for these facilities is also part of these operations and facilities. Main aspects are here the supply with gaseous nitrogen (GN2), Helium, gaseous hydrogen (GH2), liquid hydrogen (LH2) and liquid oxygen (LOX).

In project "H2Orizon" a PEM-electrolyzer for the production of green GH2 has been installed.
With the project "Zero Emission" an additional electrolyzer for green GH2 production and a hydrogen test infrastructure for new consumers will be established and added to the existing system.

This paper gives an overview to the operational concept of the complete hydrogen infrastructure of DLR test site Lampoldshausen in order to be able to have a centralized responsible operation. The new concept has to ensure the security of supply in quantity, quality and in time for all connected consumers. It needs to provide transparent and reliable distribution which is "online" visible for the consumer. In short: an efficient hydrogen management on site has to be provided, which is less costly than the operation of the original system to date (status 2021).

2. Initial position

During the installation phase of the P5 test facility new propellant and gas supply systems were also fitted. Two tank depots for liquid hydrogen (T58, see figure 2) and liquid oxygen (T23, see figure 3) were set up on the test site (see test site Map figure 1 below).

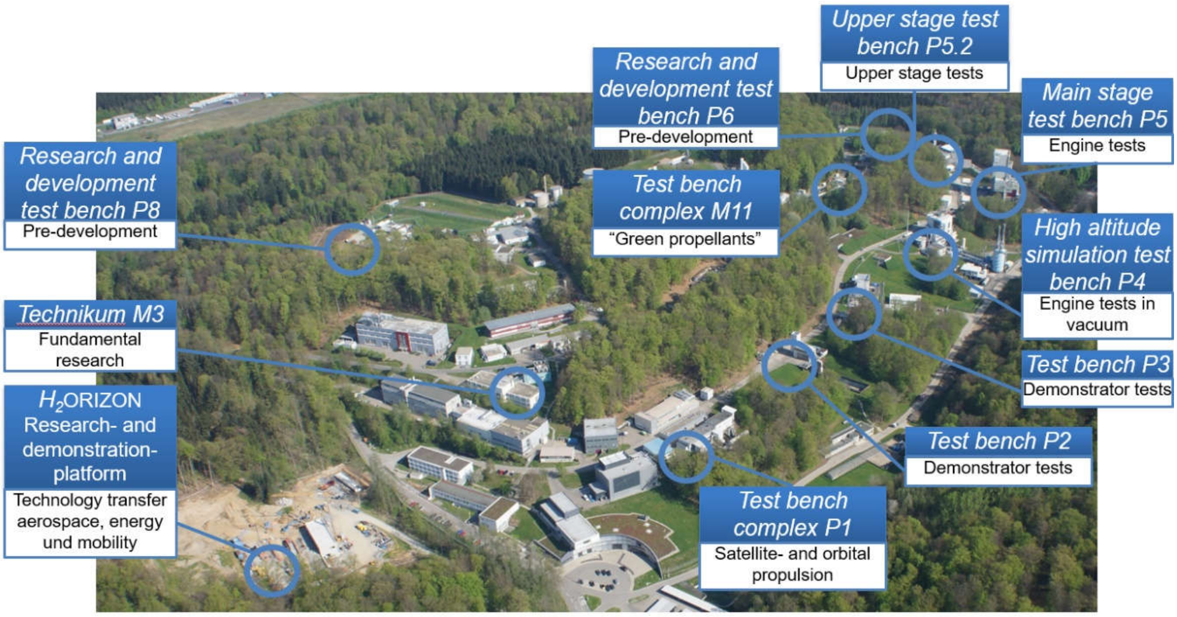

Figure 1: DLR Lampoldshausen – Today's capability

Both systems are jointly managed and monitored from the G56 control building. The T58 depot not only supplies the P5 test facility with liquid hydrogen but also P4.1 and the P5.2 European Upper Stage Test Facility.

Figure 2: LH2 storage area T58

The T58 hydrogen depot consists of the following
elements:

- Main storage tank, vacuum-insulated, 270 m³ capacity, storage temperature of 20 K
- Pilot tank, vacuum-insulated with a capacity of 55m³
- Two connections for tank vehicles
- Pressurization system
- Transfer line to P5 and transfer line (connected to the P5 line) to P4.1
- Safety equipment.

The extremely cold (20 K) liquid hydrogen is delivered by trailers with a capacity of up to 50 m³. Two vehicles can be discharged at once. An amount of approximately 200 m³ liquid hydrogen can be delivered in one day. The hydrogen from the storage tank runs during the preparation phases between the tests through pipes (approx. 350 m to P5 and approx. 500 m to P4.1) to the run tanks at the respective facility. These flexible, vacuum-insulated pipes enable a safe transfer of the hydrogen to the test facilities at a rate of about 100 m³ per hour.

Operation of the test facilities requires an adequate supply of hydrogen (GH2), helium (GHe) and nitrogen (GN2) gas under various pressure levels. The corresponding equipment is located in the upper section of the test site and consists of the D57 compressor station and the D22 nitrogen installation, operated from the G56 control building.

Figure 3: Control Building for Supply Facilities G56

Supply of Gaseous Hydrogen

The D57 hydrogen compressor station consists of

- Three membrane compressors for outlet pressures of up to 320 bar for possible flow rates of 175 Nm³ per hour
- Two membrane compressors for outlet pressures of up to 800 bar for possible flow rates of 175 Nm³ per hour.

D57 has connections to the following installations

- ➔ P5 test facility: five pressure tanks with a capacity of 8 m³ each for max. 320 bar
- ➔ P4.1 test facility P4.1: 320bar using the before mentioned P5 tanks too
- ➔ P3.2 test facility: two pressure tanks with a capacity of 15 m³ each for max. 800 bar and two pressure tanks with a capacity of 4 m³ each for 320 bar
- ➔ P8 test facility P8: one pressure tank with a capacity of 6,5 m³ for max. 630 bar
- ➔ One pressure tank with a capacity of 4 m³ for max. 320 bar near the compressor station itself as a buffer tank

Before compression the hydrogen gas is withdrawn either from a gas storage system consisting of 2 tanks(100 m³ with 25 bar and 50 m³ with 40 bar) or from the pilot tank in the liquid hydrogen depot. The suction pressure for the compressors is in the range of between 2 and 6 bar.

Figure 4: Gaseous hydrogen supply facility D57

3. Overview of the system and its locations

The existing Hydrogen System is distributed on different locations onsite DLR Lampoldshausen. The LH2 main storage (T58) is located in the north of the site.

In its direct surrounding several main facilities are placed, which altogether built the central media supply systems for the rocket engine test facilities. These are the GH2 production and compressor station, D57 and GH2 catch tank (return from P3), main control building G56, GHe trailer connection, D57A GN2 supply for P5.2, T21 one storage bottle for GH2 or GHe (Kourou bottle for flexible use). Connected are currently the test benches P3 and P8 (high pressure GH2 @ 800 bar, capacity actually used for P5.2 testing filled with GHe) as well as P4, P5 and P5.2 (GH2 @ 320 bar and LH2). A trailer connection station for the ZEAG trailer connection is established. An overview of the site and its main facilities is given in the following Figure 5.

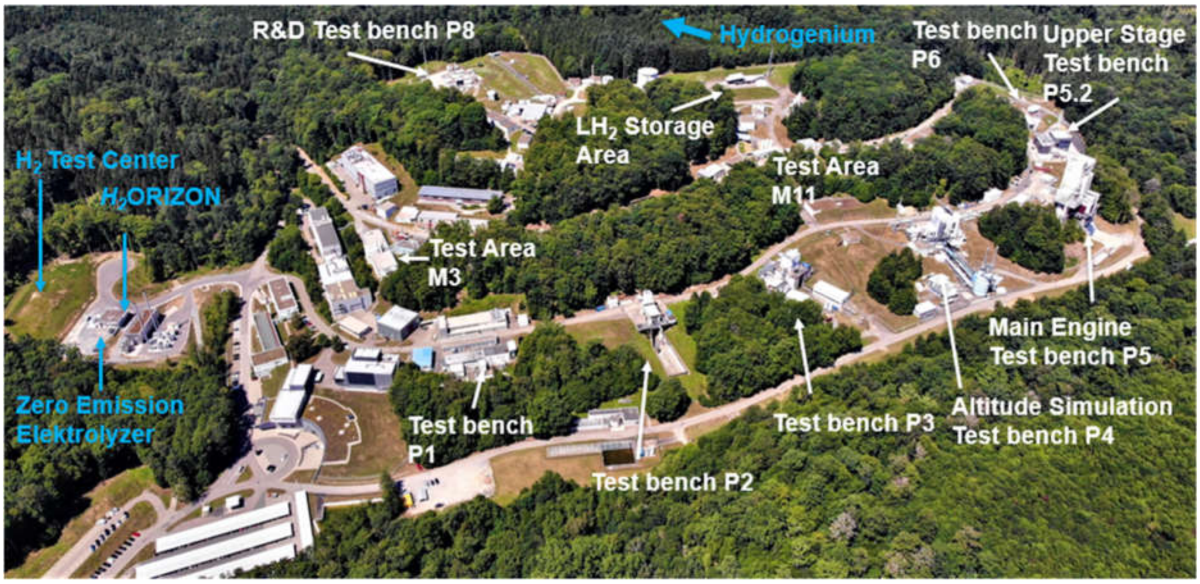

Figure 5: Overview of the Lampoldshausen Test Center with relevant facilities and plants (existing and planned)

4. Extension of the Hydrogen Infrastructure

The projects H2Orizon and Zero Emission extend the site's infrastructure by allowing green hydrogen production on site and creating new test infrastructure for hydrogen applications beyond space flight.
To connect the new and old infrastructures, a GH2-transferline will be installed.
The operation of the electrolysers depends on the operational acceptance of this pipeline. Hence two important milestones can be defined modifying the operational concept of the hydrogen systems:

- In 2022 the H2Orizon electrolyzer was taken into operation.
- Start of operation of Zero Emission electrolyzer and pipeline Mai/June 2023

Furthermore, in 2022 the H2-Container Technical Center (H2CT) shall be erected and go into operation in 2023.

As an outlook, the project "Hydrogenium" can be mentioned which will allow an expansion of the test infrastructure in the northern part of the DLR site. The detailed planning will start end of 2022.

As a future growth potential, the erecting of a hydrogen liquefier was identified to be integrated later in those infrastructures.

5. Project H2Orizon

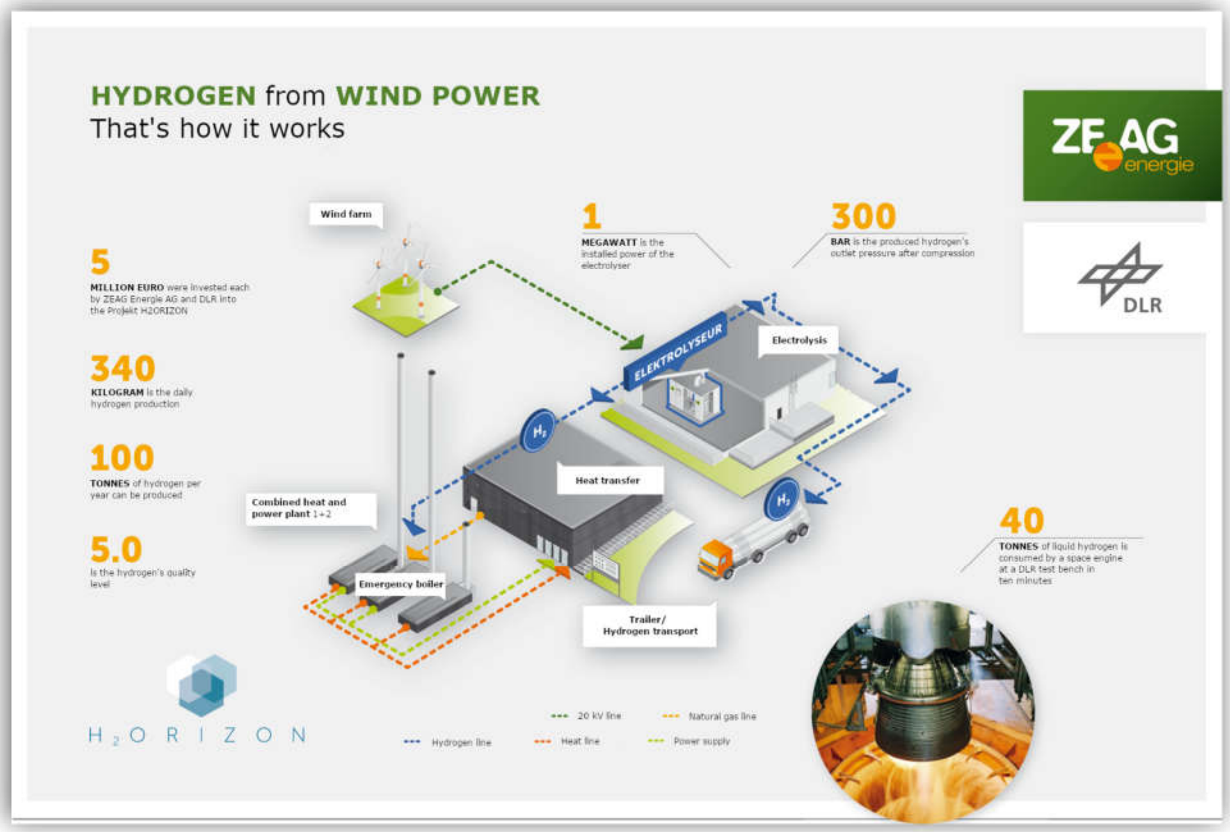

Figure 6: H2orizon Project at the Lampoldshausen Test Center

The DLR Lampoldshausen site offers a unique development and test environment for testing, further developing and applying hydrogen technologies and processes in practice. At the same time, the DLR in Lampoldshausen has decades of experience in handling large quantities of hydrogen - and needs it: Because the DLR Institute for Space Propulsion, with its engine tests for the European launch vehicle family Ariane, is one of the largest users of hydrogen in Europe. That know-how lead to the institute's first technology transfer project "H2Orizon".

DLR's hydrogen concept in Lampoldshausen is based on obtaining hydrogen from water by means of electrolysis and using 100% renewable energies without a connection to the public electricity grid as well as reducing the site's CO2-emissions.

Therefore, the system concept in the H2ORIZON project consists of two essential components. One is regenerative hydrogen production based on 100% wind energy. The polymer electrolyte membrane electrolysis (PEMEL) has an electrical load of around one megawatt and is connected directly to the "Harthäuser Wald" wind farm (Fig. 6).

The hydrogen is processed, compressed and filled directly into special transport vehicles, so-called tube trailers, for distribution. Up to 100 tons of gaseous hydrogen production per year are planned.
In addition, a new power supply system is being built to supply the DLR site with heat and electricity. The two gas engine- combined heat and power plants (CHP) with a total power output of 1.7 megawatts thermal and 1.4 megawatts electrical are also connected directly to the hydrogen production in addition to the conventional supply of natural gas. The project is executed together with ZEAG Energie AG as a project partner.

6. Zero Emission

Project "Zero Emission" is a continuation of the technology transfer activities that have started with project H2Orizon. It aims to supplying the DLR Lampoldshausen site with more green hydrogen and to test the entire hydrogen process chain under the special conditions of an energy-intensive site for testing space propulsion systems as well as to reduce the site's CO2-emissions even more (Fig. 7).

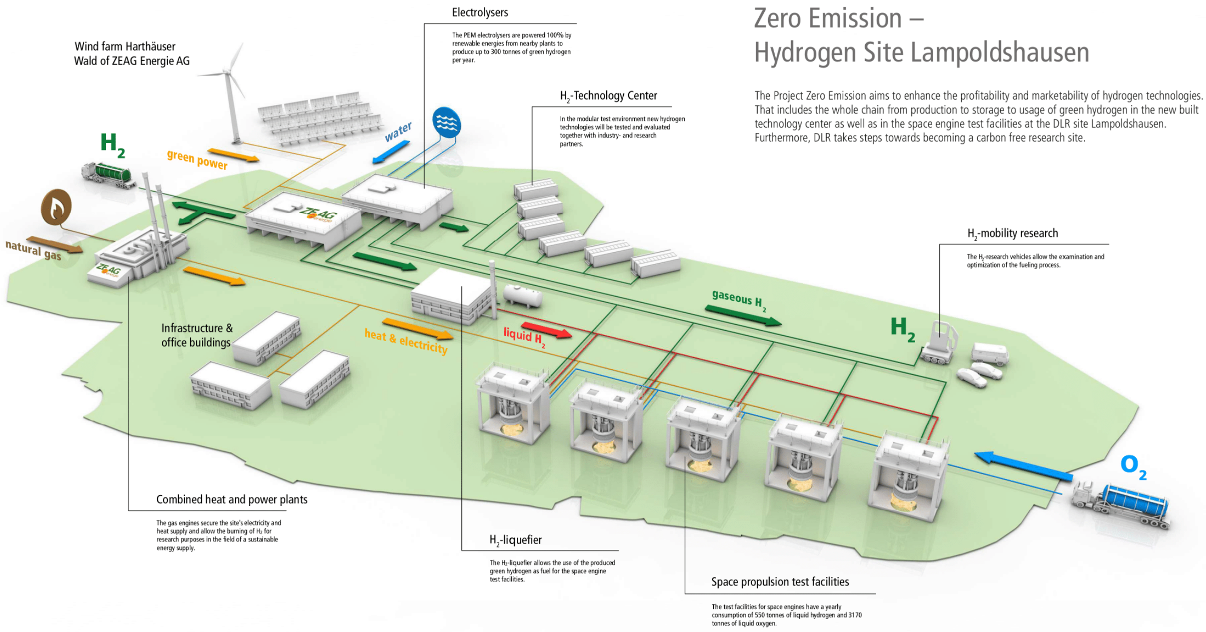

Figure 7: Project Zero Emission

On this basis, the DLR is now developing three further subject areas: "Green Spaceflight", "CO2-neutral Site" and "H2 technical center". The DLR Institutes for Vehicle Concepts and Networked Energy Research contribute their expertise together with industrial partners.

6.1 "Green Spaceflight"

In the "Green Spaceflight" topic, a 2.3 MW PEMEL is installed, again 100% powered by the nearby wind farm, to extend the site's green GH2 production. Also, the initial planning to install a H2-liquifier on site has started. The connection of the two electrolyzers to the existing as well as the newly build infrastructure by a GH2 transfer line is also part of this topic.

6.2 "CO2-neutral Site"

Another part of the project is the CO2 neutrality of the DLR site in Lampoldshausen which seeks to make DLR Lampoldshausen carbon neutral, with an emphasis on the sustainable supply of electricity and heat, and the use of fuel cell-powered vehicles inside and outside the 51-hectare site. With two research vehicles, issues related to an optimization of the fueling process are evaluated. Additional sensors provide a detailed understanding of the phenomena inside the hydrogen tank during the fueling and allow a parameter identification and validation of DLR's simulations in cooperation with the DLR Institute of Vehicle Concepts.

As part of DLR's research, a future energy supply system for Lampoldshausen is being designed and optimized with the aim of creating a sustainable, zero-carbon energy supply for the site while examining new optimization algorithms with regard to uncertain future climate predictions. The simulation and optimization are done by the DLR Institute of Networked Energy Systems.

Together with the project H2Orizon, a CO2-redutcion of about 9300 t/a, which is more than 65% of DLR's total CO2 emissions in Lampoldshausen, has already been achieved.[1]

6.3 "H2 Technical Center (H2CT)"

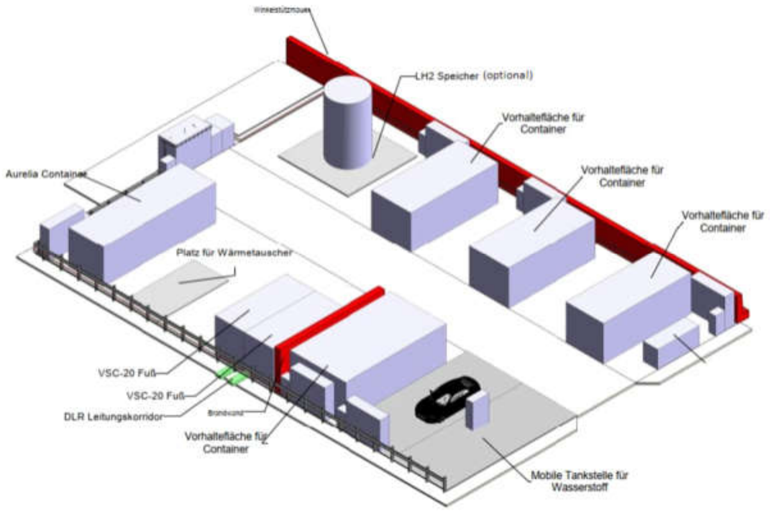

Figure 8: Schematic view of H2 Technical Center (H2CT)

The third core topic addresses the expansion of testing activities at the Lampoldshausen site beyond space flight: DLR uses its unique know-how in handling large hydrogen test benches and the existing safety infrastructure to create a research and development platform for hydrogen technologies. This H2 technical center should enable partners from industry and science to develop and test technologies for use in the hydrogen economy under real conditions. In this way, the project supports technology transfer to the economy (Fig. 8).

7. Needed Systems for operation, control concept for operation

The existing utilities management system (UMS) has to supervise the provision of a number of test stands with different media of different states and pressure levels. The distribution of the gases and process cooling water is managed by operators in building G56, or optionally from building M8.
The following table1 gives an overview:

Table 1: Media Information of the Utilities Management

Medium	**Pressure (bar)**	**Source**	**Destination**
GH2	320	D57	M11, P3.2, P5, P8, *P4.1*
	800	D57	
GHe	230	D57	P4.2, P5, *P4.1,* P5.2
GN2	200	D22	DLR-Net, M70, P3.2, P4.2, P5, P6, P8, *P4.1*
	800	D22	
LOX	-	T23	P5
LH2	-	T58	P5, *P4.1*
		P5	*P4.1*
Cool. Water	-	Water Towers	P4.2, P5, *P4.1*

[1] M. Füting "Zero Emission – Hydrogen Site Lampoldshausen", FAR 2022 - *2nd International Conference on Flight Vehicles, Aerothermodynamics and Re-entry Missions Engineering*

As can be seen in figure 9, the UMS system in its existing status features 16 PLCs of sufficient size as frontends in the major locations of supply and consumption, and I/O extensions in neighbored small locations. All system interconnections will be made by redundant fiberoptic network connections in order to guarantee an optimal galvanic isolation and a high availability. For a high level of security and availability , critical functions work directly in the front end PLCs.
Because major functions of the supply will be controlled centrally by automatic sequences partly in parallel and with long duration, reliability is a key element of the system. Therefore, the central operational part of the system in G56, consisting of backend workstations and graphic operator terminals, has to be laid out in hot redundancy. Also, the backend-frontend network connections will be redundant for safety reasons.

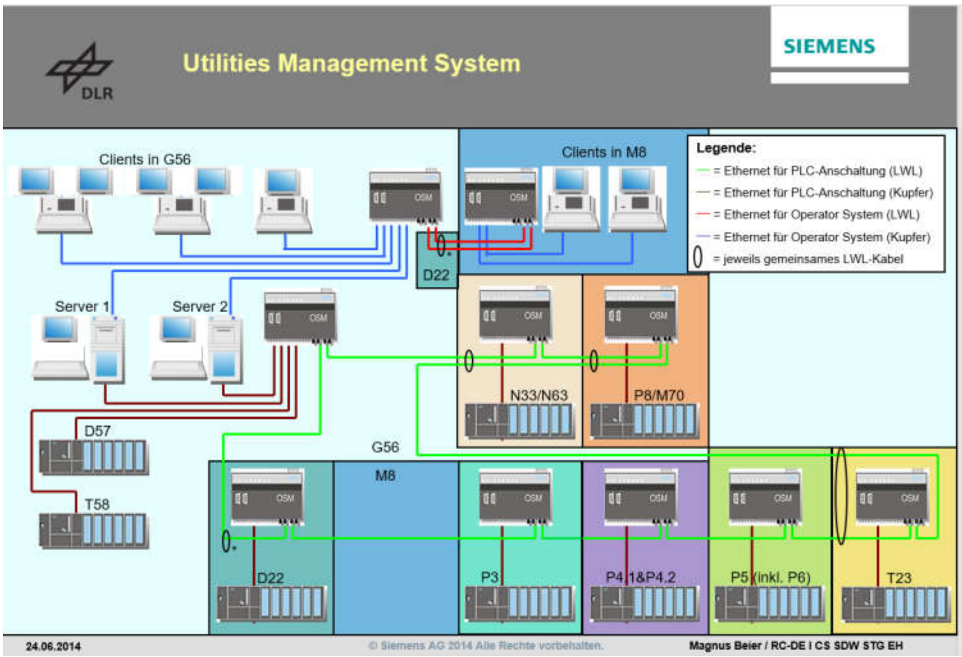

Figure 9: UMS Network plan

In order able to do justice to the expansion of the UMS system, a new PLC front end will be installed at H2CT test site. Therefor the redundant network ring also will be expanded. These new PLC supervises the gas transfer in the transfer line to the compressor station D57, communicates with the H2CT MCC and optional with an additional electrolyzer and hydrogen liquefier.

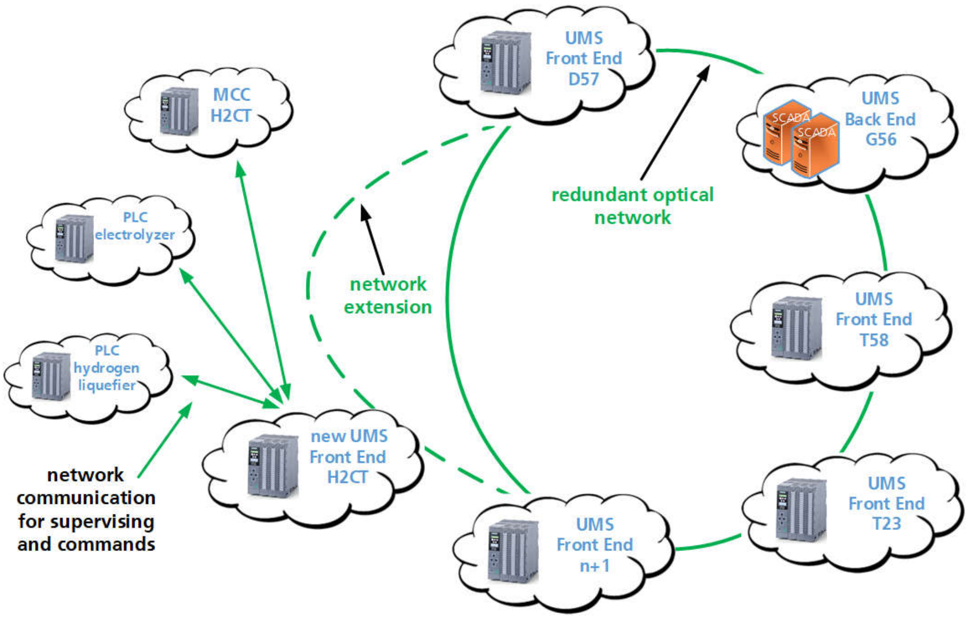

Figure 10: Adoption of UMS system to type Linde Electrolyzer