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Hydrogen Powered Fuel Cell Forklifts – Demonstration of Green Warehouse Logistics

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Abstract

An Austrian consortium of industry and research partners demonstrates a system solution for renewable hydrogen powered fuel cell range extender vehicles applied in intralogistics. The core element of this development, the “HYLOG Fleet Energy Cell” by Fronius International, replaces the lead-acid battery in conventional battery-electric propulsion systems for warehouse logistics. In collaboration with Linde Material Handling a warehouse truck fleet of 10 class-3 vehicles has been adapted accordingly at an Austrian site of the global logistics company DB Schenker. Renewable hydrogen is supplied by the oil and gas company OMV using a decentral biomethane steam reformer, installed onsite at the logistic facility. The warehouse trucks are fuelled indoors for the first time in Europe. Operation experiences show that warehouse logistics is in particular attractive for hydrogen and fuel cell technologies due to increased productivity, reduced maintenance and reduced life-cycle Greenhouse gas emissions.

Keywords: Fuel cell, material handling, renewable hydrogen, indoor hydrogen fuelling

1 Introduction

In intralogistics, the world’s largest market for electric propulsion systems, the productivity of battery electric lift trucks and logistic vehicles is often limited, particularly in multi-shift operation with high energy demand. Limiting factors are the time involved in charging or changing batteries, but also the battery's limited service life and relatively high maintenance costs.

A fuel cell range extender as propulsion system for warehouse trucks replaces time consuming battery handling by hydrogen refuelling in less than 3 minutes. Continuous power supply of fuel cells versus decreasing performance at low state of charge of lead batteries is an additional advantage of a fuel cell range extender.

Warehouse logistics with fleets of more than 10 vehicles in multi-shift operation with high energy and power demand could become an early market for fuel cell technologies, justifying the installation of technology- and cost-intensive hydrogen infrastructure.

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The core element the "HYLOG Fleet Energy Cell" developed by Fronius International replaces the lead-acid battery in conventional battery-electric propulsion systems for warehouse logistics. In collaboration with Linde Material Handling a warehouse truck fleet of 10 class-3 vehicles has been adapted accordingly at an Austrian site of the global logistics company DB Schenker.

Renewable hydrogen is supplied by the oil and gas company OMV using a decentral biomethane steam reformer, installed onsite at the logistic facility. The warehouse trucks are fuelled indoors for the first time in Europe.

Development, certification, installation and approval of the above described system have been achieved in the Austrian research and demonstration project E-LOG-BioFleet.

2 Demonstration of green warehouse logistics

2.1 Hydrogen powered fuel cell range extender – HYLOG Fleet Energy Cell

The fuel cell range extender system developed by Fronius International combines a PEM fuel cell with a high power lithium ion battery and a 200 bar hydrogen tank in one housing - the Fronius HYLOG Fleet Energy Cell. It has been designed for class-3 warehouse trucks, replacing a 24 V / 500 Ah lead battery in a 4PzS tray, here of a Linde T20 truck (figure 1).

The specification of the energy cell is based on real-life driving cycle measurements of battery vehicles at operating conditions of a logistic site. Average power during a 6-hour shift operation was measured to be 1.7 kW, peak power up to 11 kW. The hydrogen tank supplies 6 kWh electrical energy enabling 4 hours operation at 1.5 kW average power. The high power lithium ion battery supplies peak power (max 11 kW) and the fuel cell the average continuous power of the driving cycle (2.6 kW) (table 1).

Figure 1: Class-3 warehouse truck (Linde T20) with HyLOG Fleet Energy Cell

Table 1: Fronius HYLOG Fleet Energy Cell

/ Peak Power (continuous): 11kW (2.6kW)
/ Peak Current: 450A
/ H2 Tank: 25L, 200bar, 6 kWh(el)
/ Onboard/Indoor Refuelling: <3min
/ Onboard Battery: High Power Lithium Ion
/ Nominal System Voltage: 26.4V
/ Operating Temp. Range: +2 to +60°C
/ Dimension L/W/H: 786/310/630 mm (4PzS Tray)
/ Weight: 180kg
/ Certification:
EN 62282-5-1:2007 (Portable FC Systems),
97/23/EC (PED),
EMC 2004/108/EC,
EN 61508 Ed. 2.0 (functional safety)
IEC 62133 Ed. 2.0 (secondary cells)

Replacing long charging times for the lead battery by hydrogen refuelling within few minutes is the main advantage of the innovative range-extender technology. With 200 bar hydrogen pressure in the vehicle tank the driving range is currently about 30% lower compared to the lead-battery.

Hydrogen pressure could be increased up to 350 bar, however due to the short hydrogen refuelling time as well as due to the resulting higher energy demand, driving range equivalence with the battery solution may not be required.

Another advantage of the Energy Cell HyLOG Fleet is the increased lifetime compared to the lead battery. Currently 5,000 hours are confirmed (4,400 hours of the lead battery at 2.6 kW nominal capacity), with 10,000 to 15,000 hours lifetime expected.

The operating temperature range is currently +2°C to +60°C. By using the waste heat in the system, midterm operation will also be possible at freezing conditions down to -10°C with constant performance, thus increasing the operating temperature range and productivity compared to battery-electric vehicles.

The weight of the Energy Cell HyLOG Fleet with 180kg is half the weight of a comparable lead-battery. The missing weight has to be compensated depending on the vehicle application to guarantee traction and vehicle stability.

2.2 Renewable hydrogen infrastructure

An overview of the hydrogen supply infrastructure in the E-LOG-BioFleet project is shown in figure 2.

Renewable hydrogen is produced in a decentral methane steam reformer installed onsite at the Austrian logistic site of DB Schenker (figure 3). The steam reformer is fed by biomethane which is produced at regional biogas stations and supplied via the natural gas grid in Austria. The steam reformer has a production capacity of 10.8 kg hydrogen per day. The hydrogen is compressed and stored onsite in a 350 bar storage bank.

The warehouse trucks are refuelled indoors inside the logistic centre (figure 4), the storage bank is designed for refuelling three vehicles in series. An indoor hydrogen refuelling station has been realised and approved by the authorities for the first time in Europe.

Operation of the infrastructure as well as the first fuel cell vehicles at the logistic site of DB Schenker started in June 2013.

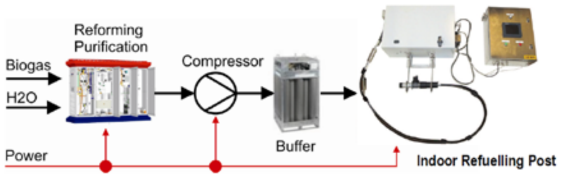

Figure 2: Renewable hydrogen infrastructure in the “E-LOG-BioFleet” project

Figure 3: Reforming unit with concrete steel container for hydrogen compressor, natural gas compressor and cooling unit

Figure 4: Indoor hydrogen refuelling station

2.3 Life-cycle Greenhouse gas emissions

The E-LOG-BioFleet project is accompanied by technical, economic and ecological assessments, proving the potential benefits and sustainability of the developed propulsion system and hydrogen infrastructure. Assessments are still ongoing, robust results will be available at the symposium. Preliminary results for the Greenhouse gas (GHG-) emissions already show the potential benefits of the developed solution. Results are based on full-life-cycle calculations.

Figure 5 shows the life-cycle GHG-emissions per hour operation of a class-3 electric logistic vehicle. The hydrogen for the fuel-cell vehicle is produced by biomethane reforming. The primary energy carriers for biomethane production are 85% energy crops and 15% livestock manure, the materials most commonly used for biogas production in Austria.

The results show that the life-cycle GHG-emissions of the fuel cell vehicle at least equal the life-cycle GHG-emissions of the battery-electric vehicle with electricity from hydropower. With the increase of confirmed life-time of the HYLOG-energy cell from 5,000 hours up to 12,000 hours, the GHG-emissions can be reduced by about 10%. Additional biomethane production paths are assessed which may result in even higher reduction potentials of life-cycle GHG-emissions of the developed system. Results will be presented at the symposium.

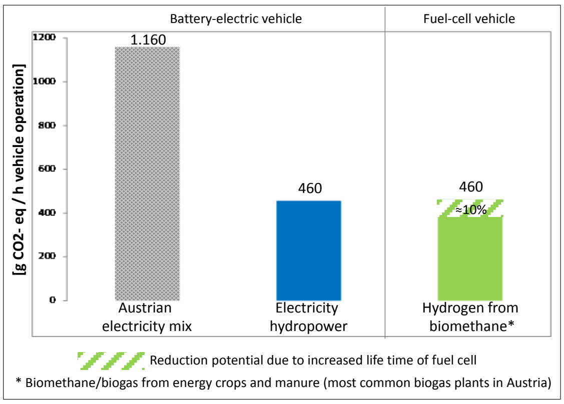

Figure 5: Life-cycle GHG-emissions of battery-electric versus fuel-cell logistic vehicles

3 Conclusions

The operation of 10 class-3 warehouse trucks at the Austrian logistic site of DB Schenker as well as operation of the onsite hydrogen infrastructure demonstrate the technical maturity of the developed technologies and system. Warehouse logistics with multi-shift operation and high energy and power demand is in particular an attractive field for hydrogen and fuel cell technologies as it offers the potential for increased productivity and sustainability. Further refining and necessary cost reductions of this still young range-extender technology and the hydrogen infrastructure will be pushed by the wide range of potential applications and related scaling effects.

The main benefits of the hydrogen powered fuel cell range extender vehicles compared to conventional battery-electric vehicles are summarized below:

- Increased productivity and flexibility of the vehicles:
    - Faster refuelling
    - Constant performance
    - Maximised life-time
    - Increased availability
    - Reduced maintenance intervals
    - Increased operating temperature range
    - Monitored operating status
    - Recovery of warehouse area
- Vehicle energy management capability
- Diversification of renewable energy carriers used (electrical power / biomethane / hydrogen) with high potential for decreased life-cycle emissions

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