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This document appeared in

Detlef Stolten, Thomas Grube (Eds.):
18th World Hydrogen Energy Conference 2010 - WHEC 2010
Parallel Sessions Book 6: Stationary Applications / Transportation Applications
Proceedings of the WHEC, May 16.-21. 2010, Essen
Schriften des Forschungszentrums Jülich / Energy & Environment, Vol. 78-6
Institute of Energy Research - Fuel Cells (IEF-3)
Forschungszentrum Jülich GmbH, Zentralbibliothek, Verlag, 2010
ISBN: 978-3-89336-656-9

Hydrogen Driven Municipal Vehicle (hy.muve) – Vehicle Concept Demonstration and Field Testing in Switzerland

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1 Motivation

Among others, hydrogen is discussed as future fuel for road vehicles [1]. After a more basic research oriented phase, several pilot and demonstration oriented projects are ongoing in Europe [2]. The overall targets of fuel consumption and CO_2 reduction as well as fuel diversification hasn't change.

Early practical experience with fuel cell systems is essential for research institutions, vehicle manufacturers and the vehicle supply industry. This experience is particularly important for issues relating to the development of market implementation strategies, sampling of experience in real world operation and the study of socio-economic aspects in a sensible market phase.

At present, fuel cell powertrains are primarily being tested in passenger cars and buses. In these sectors, successful market introduction faces tough challenges in view of high driving dynamics, packaging requirements in limited space and cost expectations. Therefore, market introduction is to be expected after 2015. The present project is aimed at the introduction of a fuel cell drivetrain into a municipal vehicle (road sweeper). Considering their driving profile (operation by trained personnel, fleet operation from a fixed refuelling point, modest driving dynamics, predominantly low part-load operation, smaller relative share of powertrain in total cost, possibility to operate such vehicles in pedestrian areas and even indoors), these vehicles appear to be particularly well suited for an early introduction and possible commercialisation of fuel cells in a niche market.

2 General Goals of the Project

The Swiss company Bucher Schörling, the worldwide market leader in the manufacturing of municipal vehicles, is the key industrial partner in this project. In collaboration with other industrial partners, a prototype fuel cell municipal vehicle has been developed and is now close to a pre-production series which will be delivered to four Swiss cities for testing. Municipal service vehicles with their hydrostatic powertrain and auxiliary drives are a new field in which fuel cell converters have rarely been tested in the past. As the relevant components differ in specifications from those of passenger cars, a chain of innovative Swiss component suppliers would be given an opportunity to participate in the market introduction of this product.

In parallel to the technical development and demonstration phases in several cities, non-technical challenges for the implementation of innovations will be identified and promising strategies will be expanded further.

On the technical side, the questions of the powertrain layout with respect to efficiency, consumption, cost and spatial, thermal and electrical integration into a commercial vehicle represent a first challenge. These questions require fundamental knowledge with respect to modelling, development and testing of hydrogen based fuel cell powertrains.

A second challenge is the performance in aging and durability studies of the fuel cell system as well as analysis of handling and operation. This part is actually one of the most important research fields in respect to the market entry of fuel cell vehicles. It includes the identification and quantification of factors which limit PEM fuel cell durability due to contamination in the market fuel, aspiration-air pollution and technology disaffection using property change analysis during long-term testing.

A third challenge is the development of an innovation implementation strategy for hydrogen powered vehicles, which is based on socio-technological analysis with the evaluation of all included parties and the identification of barriers and risks. There are few studies based on public long-term real world testing of fuel cell vehicles so the assumptions on these issues are presently rather based on expert’s estimations or are carried out by industrial partners without publication of the results. Therefore, the strategy would highly be of interest in other fields with hydrogen implementation plans.

We are planning, in addition to these findings and based on the technical development, to monitor inter- and intra organisational routines, collaboration and communication concepts. Mastering this potential for organisational innovation will prepare the participating partners for future technological opportunities.

3 Project Phases

a) <u>Model phase: Development of a longitudinal dynamics model</u>

The powertrain of the existing diesel-powered municipal vehicle (Bucher Schörling CityCat 2020) had to be modelled and the torque demand of the engine had to be investigated for different types of operation (road sweeping including auxiliary drives, vehicle transfer without auxiliary drives, uphill and downhill operations, etc.). Additionally, other important matters as range, starting time, operating temperature, maximum vehicle inclination, etc. had to be defined. Based on the results, a representative municipal driving cycle could be defined.

Based on the analysis of operation conditions, the specifications of the complete fuel cell powertrain were determined using a technical model of the complete drivetrain (fuel storage, fuel cell, electric motor, cooler, electric system, etc.) and basic requirements for the components were defined. The longitudinal dynamic model provided the scientific foundation for powertrain specifications, including efficiency, consumption, energy management, vehicle range, etc., enabling variation of the operating conditions and evaluation the effect of all individual specifications on practical use by means of a computer [4].

b) Concept phase: Powertrain integration, concepts and packaging

For integrating the fuel cell powertrain in the municipal vehicle to the stage of everyday use in customer hands, a 3-step development was required:

1st step: Integration concept:

To exploit the advantages of the combination of a fuel cell system with a hydraulic power train in the municipal vehicle, an adapted concept with respect to integration of the electric, thermal and control properties was required. Based on the results of the model phase, components in the electric and thermal loops could be defined based on the available technology.

This step included the design of the control architecture and functionality of the overall power management system and interface to the vehicle. Subsequently, the hardware as control unit, power management, sensors, actors, MMI were defined.

2nd step: Packaging study:

On the basis of the drivetrain specifications from the longitudinal dynamics model, a packaging study has been done, including 350 bar hydrogen storage and the complete drivetrain. The packaging study also had to include the possibility of capturing the unwanted reaction water of the fuel cell system. All possible modifications of the vehicle had to be done with a view to later serial production (Figure 1).

Besides the packaging study, the interfaces between vehicle and powertrain had to be evaluated and an overall control concept, including integration into the vehicle control system, had to be defined.

After approval of the whole vehicle concept by Bucher Schörling, a prototype vehicle was built (Figure 2).

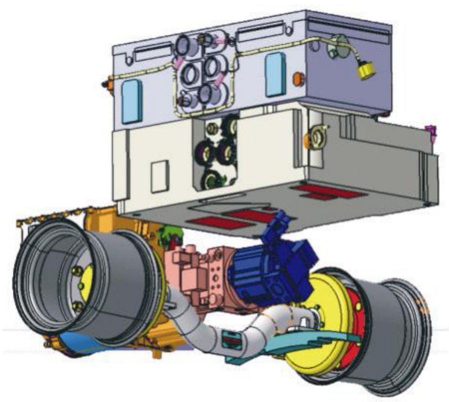

Figure 1: First packaging study of fuel cell system assembly.

Figure 2: Bucher Schörling CityCat H_2Project vehicle.

3rd step: Component testing:

Based on the results of concept and packaging study the main components as well as the control unit had to be tested prior to integration with respect to specifications.

c) Realisation phase: Prototyping, vehicle adaptation and control design

Implementation of the detailed control concept and strategy as well as the embedding in the overall vehicle control system needs extensive testing for adaptation of the thermal and dynamic behaviour of the complete powertrain. This includes the optimisation of the start/stop, the power, the thermal control strategies as well as certification and safety aspects for the operation in public.

d) Testing Phase: Vehicle laboratory and field tests

After the realisation phase, the vehicle was first tested in the laboratory with regard to system performance (max. power, torque, dynamics, powertrain efficiency) and ambient conditions before it could be used in the field.

This laboratory testing also included a comparison of the hydrogen-powered municipal vehicle with a diesel-powered vehicle regarding energy efficiency and consumption [5].

After laboratory testing, 18 months field testing under real world conditions are being performed in four Swiss cities equipped with a mobile hydrogen fuelling system. The field testing includes investigations regarding drivability, handling, technical reliability, fuel consumption and durability and aging studies (degradation, poisoning, etc.), using property change analysis.

After the field test phase a second laboratory test phase will give results with respect to aging and offers exploitation of parameters which have become apparent in the field test phase.

e) Evaluating learning effects, operating behaviour

Practical experience in an early implementation phase provides a unique opportunity for additional Swiss industrial partners to enter the developing fuel cell network with innovative solutions. Taking this research and implementation-project as an empirical case study, the socio-technological investigation will systematically identify relevant challenges and solutions. The recording and systematic evaluation of cooperation, communication and network contacts is of special interest for the development of the prototype vehicle and field testing. Also innovation and implementation costs and benefits of the involved partners will be evaluated both from a short- and long term perspective.

An adequate research design with well suited research instruments for monitoring and evaluating technology-induced organisational adaptation processes will be developed and applied. The interaction of humans with the new technology and its operation will be investigated (e.g. How do technicians with diesel experience respond to a hydrogen-powered vehicle with an electric powertrain? Do they feel safe working with it?). Also under investigation are strategies in use that have to be adjusted to the new technology within a company. These questions will be addressed within the whole supply chain affected by the technological innovation.

In parallel to these more organisational issues, the functionality of the technology in practice will be evaluated as well as a pragmatic and preliminary cost assessment will be conducted. Also, operators' acceptance, reactions of stakeholders as well as public awareness will be evaluated.

References

[1] J. Köhler et al.; Infrastructure investment for a transition to hydrogen automobiles; Technological Forecasting & Social Change xxx (2010) (Article in Press)

[2] P. Baptista et al.; Plug-in hybrid fuel cell vehicles market penetration scenarios; international journal of hydrogen energy xxx (2010) (Article in Press)

[3] F. H. Sobrino et al.; Critical analysis on hydrogen as an alternative to fossil fuels and biofuels for vehicles in Europe; Renewable and Sustainable Energy Reviews 14 (2010)

[4] *Early introduction of fuel cell vehicle in suitable niche markets on the example of municipal vehicles*, FISITA 2008 "Future powertrain solutions" or "Resources and ecology"

[5] Medienmitteilung "Positiv in der Energiebilanz aber technisch anspruchsvoll - «Sauberes» Kehrfahrzeug mit Anlaufschwierigkeiten", Empa 28.04.2010