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Extending EV Range with Direct Methanol Fuel Cells

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Abstract

Electric cars are the vehicles of the future, and there is a proven hybrid system for extending their mileage. Direct methanol fuel cells (DMFCs) provide safe, lightweight, onboard battery charging that can free car owners from worry about running out of power. The hybrid system includes a DMFC fuel cell, fuel cell cartridge and electric vehicle batteries. The fuel cell operates almost silently with virtually no exhaust, it is immune to extreme weather and the convenient fuel cartridges feature extremely high energy density, providing vehicle owners with a lightweight, efficient and onboard power source. When connected to a rechargeable battery, the fuel cell constantly monitors the battery's charge state. Once this drops below a predefined value, the fuel cell automatically starts recharging the battery. When the battery is full, the fuel cell returns to standby mode. This presentation will discuss the role methanol/battery hybrid systems can play in extending the range and operating time of electric vehicles. In addition, it will discuss the environmental merits of methanol, including its increasing production from biomass.

Keywords: Fuel cell, off-grid power, onboard charger, power generator, direct methanol fuel cell

1 Introduction

1.1 Problem

The wider distribution of alternative power concepts for electric vehicles is impeded by a logistical problem, which is also the reason why there are few hydrogen-powered vehicles on our roads. It really is a chicken-and-egg problem: no hydrogen cars without hydrogen gas stations, no hydrogen gas stations without hydrogen cars. As the hydrogen-vehicle discussion has quieted down, plug-in hybrid electric vehicles (PHEVs) have become popular. However, PHEVs face a similar problem: no PHEVs without public charge stations, no public charge stations without a certain amount of PHEVs on the road. Several small-scale projects have attempted to solve these problems, in London, for example, but a general solution has not been found yet.

1.2 Solution

A solution for the chicken-and-egg problem would be electric vehicles (EVs) with an onboard charge station. This solution is already on the road today with a direct methanol fuel cell (DMFC). Even though the power of the fuel cell is still too limited to directly power the motor, it is completely sufficient to recharge smaller EVs overnight or when they are parked for shorter periods. This creates an efficient bridge between public or private grid-charge stations and enables drivers to plan their routes much more freely. An EV equipped with a fuel cell is not bound to the electricity grid anymore.

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2 Overcoming battery limitations

2.1 Limited reach with batteries

Small EVs weighing less than 500 kg, with one to two seats and a maximum speed of 45 to 65 km/h, are usually equipped with batteries with a capacity of three to five kWh and a system voltage of 48V or 72V. At an energy demand of four to seven kWh per 100 km these vehicles have a reach of approximately 50 km. This, of course, varies considerably depending on the driving style, the traffic situation, and the terrain to be covered, with the result that in city traffic the reach usually is limited to 30 to 40 km. After that the vehicle has to have reached a location where it has access to a power socket or another charge station.

Figure 1: Start Lab EV powered by SFC's EFOY fuel cell

If lithium batteries are used, the reach can be extended by a factor of two or three. But even then a stop at a charge station or a power socket is imperative.

2.2 Reach extension with fuel cells

The DMFC solves this problem of grid-dependency. Hydrogen fuel cells are not a valid alternative, as their infrastructure is even more limited than that of publicly available power sockets. With the EFOY direct methanol fuel cell, however, EV operators have a commercially available solution that has successfully proven its reliability and functionality in many off-grid applications.

2.3 High energy density with fuel cells

A major advantage of the DMFC is the extremely high energy density this technology offers compared to batteries. A fuel cartridge weighing only 22 kg contains a capacity of 31 kWh. Batteries providing an equivalent amount of power would weigh 1,000 kg. With 31 kWh, a lightweight EV can cover more than 500 kilometers.

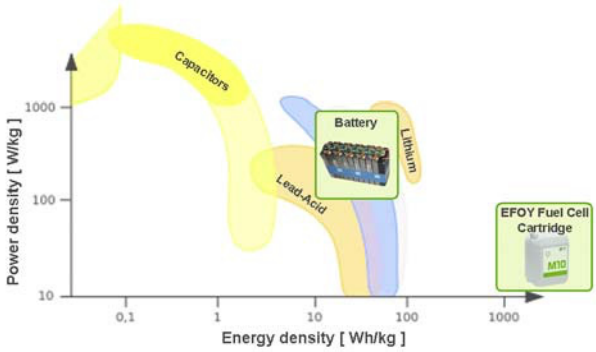

Figure 2: DMFC's superior energy density provides easier handling and greater efficiency

The energy density of batteries ranges from 30 Wh/kg of simple lead batteries to 110 Wh/kg for currently available lithium batteries. The energy density of DMFCs with 1,400 Wh/kg is much higher. In its liquid form methanol has a theoretical energy content of 5.500 W/kg. The DMFC transforms the methanol into power with an electric efficiency ratio of 25 percent.

Table 1: Comparing Power Solutions

Storage technology	Solution	Energy density
Battery	Lead Battery	35 Wh/kg
Battery	NiMh	70 Wh/kg
Battery	Lithium	110 Wh/kg
Hydrogen, PEM Fuel Cell	200 bar steel bottle, electric efficiency ratio 40%	160 Wh/kg
Hydrogen, PEM Fuel Cell	350 bar steel bottle, fibre reinforced electric efficiency ratio 40%	400 Wh/kg
Methanol, DMFC	Plastic cartridge, liquid fuel electric efficiency ratio 25%	1,400 Wh/kg

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The DMFC, however, has a much lower power density than a battery. Therefore it makes no sense to replace the battery with a fuel cell. In traction mode, charge changes ranging from a few hundred watts up to 15 kW are normal. The fuel cell would not meet peak-performance demands. It requires several minutes for start-up from standby to nominal power. Therefore, the hybrid solution of fuel cell and battery takes advantage of the best properties of both.

Figure 3: Flow of power in a hybrid fuel cell/battery system; from left: EFOY fuel cartridge, EFOY Pro fuel cell, battery, electric motor

An additional advantage of this hybrid combination is the fact that the fuel cell always performs at its full nominal value, and thus in the best possible operation mode, independent of the current energy requirements of the vehicle, which are covered by the battery.

2.4 Operating mode of fuel cells

The fuel cell is equipped with an automatic charge control that constantly monitors the battery's charge state. Whenever it drops below a predefined level, the DMFC automatically begins charging the battery. In this mode it produces environmentally friendly power with maximum efficiency. Once the battery is fully recharged, the fuel cell automatically returns to standby. This eliminates unfavorable operation modes like partial load operation and, in return, increases the total efficiency ratio.

2.5 Total efficiency ratio

This high total efficiency ratio enabled by the hybridization of fuel cell and battery significantly exceeds combustion engines on short distances. A modern combustion engine achieves an efficiency ratio of 25 percent and more in optimal operation mode at nominal rotation speed and nominal load. This, however, is only true for continuous driving without stopping and starting. In city traffic after cold start and on short distances of just a few kilometers, the efficiency ratio of vehicles powered by combustion engines falls dramatically to under 10 percent.

3 Advantages of methanol

3.1 Infrastructure

A fuel infrastructure for the fuel used in the EFOY fuel cells already exists: the EFOY fuel cell and EFOY fuel cartridges used for its operation are available at over 1,200 sales points in Europe.

3.2 Much power, low weight

The fuel is stored and transported in convenient lightweight plastic cartridges. As demonstrated in Table 1, methanol's excellent energy density enables the drivers of electric vehicles to take along large amounts of power at low weight and in the smallest space possible – a decisive advantage over transporting heavy hydrogen bottles or replacement batteries.

3.3 Methanol from renewable resources

Methanol is an excellent anti-freeze agent and an excellent solvent. It is used in large amounts by the chemical industry. End users know it as the anti-freeze liquid for their windshield cleaner in winter.

Today, methanol is still produced for the most part from natural gas that occurs as a by-product of oil production, in amounts too small to justify building a special natural gas pipeline. For many years, this gas was burned off, but that practice has been stopped due to environmental and resource-conservation reasons. This natural gas now is processed directly on-site into methanol.

Increasingly, methanol is also produced from renewable resources like second-generation biomass (bio-garbage) and even from household refuse. In this way, fuel cells can contribute to garbage recycling very efficiently.

4 Technical data of EFOY fuel cells and cartridges

4.1 EFOY fuel cells

The EFOY Pro series comprises the four models EFOY Pro 600, EFOY Pro 1200, EFOY Pro 1600 and EFOY Pro 2200.

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EFOY	Pro 600	Pro 1200	Pro 1600	Pro 2200
Charging capacity	600 Wh/day	1200 Wh/day	1560 Wh/day	2160 Wh/day
Nominal output	25 W	50 W	65 W	90 W
Nominal voltage	12 V / 24 V	12 V / 24 V	12 V / 24 V	12 V / 24 V
Nominal current @ 12 V / 24 V	2.1 A / 1.05 A	4.2 A / 2.1 A	5.4 A / 2.7 A	7.5 / 3.75 A
Weight	17.2 lbs	18.1 lbs	18.5 lbs	19.4 lbs
Noise emissions	23 dB(A) in 7 m distance 39 dB(A) in 1 m distance			
Operating temperature	-20 to +45 °C (-4 °F to +113 °F)			
Nominal consumption*	0.9 l/kWh			
Dimensions (L x W x H)	433 x 188 x 278 mm (17 x 8 x 11 in)			

*Effective consumption depends on operating conditions

Figure 5: Technical data of EFOY fuel cells
*effective consumption depends on operating conditions

4.2 EFOY fuel cartridges

EFOY fuel cartridges are available in three sizes with 5, 10 and 28 litres (28 litres for industrial applications only).

Fuel cartridge	M5	M10	M28*
Volume	5 liters (1.32 gallons)	10 liters (2.64 gallons)	28 liters (7.4 gallons)
Weight	4.3 kg (9.5 lbs)	8.4 kg (18.5 lbs)	22 kg (48.5 lbs)
Rated capacity	5.5 kWh	11.1 kWh	31.1 kWh

Figure 6: Technical data of EFOY fuel cartridges
*connection requires M28-interface adapter

5 Summary

In serial hybrid operation the DMFC offers a decisive added value for electric vehicles below the size of a car. It solves the problem of dependency on the grid and lack of available public power sockets and thus enables an EV to be independent of any power outlet for weeks on end. The methanol cartridges enable 20, 30 and more kWh to be easily stored even in small vehicles. The EFOY fuel cell and EFOY cartridges are available at 1,200 sales points in Europe.

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