ELECTROLYSER-BASED HYDROGEN SYSTEMS FOR FCEV REFUELLING AND POWER-TO-GAS
15 DEC 2014, H2FC SUPERGEN
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ENERGY STORAGE AND CLEAN FUEL

Drivers for Change

- Decarbonisation
- Increasing renewables penetration in the power sector (greener power, excess power)
- Transport and heat sectors causing vast emissions (hydrocarbon and combustion dependency)
- Biomass sources will be insufficient (importing waste, food versus fuel debate)

Fundamental Problems

- Temporal mismatch between energy demand and renewables availability (needs energy storage)
- Energy efficiency and DSM not enough on their own (needs fuel switching)
- How to switch fuels $C_xH_y \rightarrow CH_4 \rightarrow H_2$

Hydrogen systems based on electrolysis can provide low/zero-carbon clean fuel and energy storage for electricity supply/demand matching

POSITIONING ELECTROLYSIS
RAPID RESPONSE PEM ELECTROLYSER

Scalable | Rapid Response | Self pressurising
TOWARDS HIGH RENEWABLES

- Demanding decarbonisation targets
- Increasing onshore and offshore wind farms
- Increasing buildings-integrated PV and solar farms
- Falling costs of renewable power sources due to high volume production

Results in:

- Lower-carbon electricity
- Excess energy in the power system
- Low, zero or negative price power
- Wasting captured renewable energy
- Increased grid balancing requirements (frequency and voltage)
POWER PRICES IN A HIGH RES POWER SYSTEM

- Increasing periods of low cost electricity
- Emerging opportunity for energy storage

THE NEED: GRID BALANCING
ENERGY STORAGE | CLEAN FUEL
BALANCING SUPPLY AND DEMAND IN THE UK:

- A total of £725m paid for balancing services in 2010-11
- Estimates in 2020 are: circa £1.9bn - £5.9bn p.a.
- Tariffs already operational in the UK
UK TSO (NATIONAL GRID): PAYMENT STRUCTURE

Four Grid Balancing Payment Tariffs:

• Short Term Operating Reserve (STOR)
• Fast Reserve
• Firm Frequency Response
• Frequency Control by Demand Management (<2s response)
POWER-TO-GAS

GRID BALANCING TOOL
EU Hydrogen Limits for Injection into the Gas Grid
Covered by a range of local rules
Note: interpretation of these rules is complex

Limit falls to 2% if there is a CNGV station downstream
SNG POWER-TO-GAS

Inputs: Electricity, Water, CO₂

Storage: Transformer

Electrolysis: Heat, O₂ → H₂

Storage: Methanation Plant

Methanation: Heat

Outputs: Gas Grid, Electricity, O₂, CH₄

METHANATION

ITM POWER
Energy Storage | Clean Fuel
P2G: ELEMENTS OF VALUE

- Value to the power grid
- Value to the gas grid
- Value to the economy

**Value to the Power Grid**
- Avoided wind curtailment
- Avoided infrastructure upgrades
- Reduce CO₂ impact of OCGT’s
- Help manage voltage and freq.

**Value to the Gas Grid**
- Decarbonising gas
- Providing renewable heat
- Reducing GHG emissions from gas transportation

**Value to the Economy**
- Reducing fuel imports
- Reducing emissions
- Improving energy security
- Creating jobs in manufacturing
A RAPID RESPONSE P2G PLANT

THUGA, FRANKFURT
FIRST P2G SALE: THÜGA GROUP

Won competitive tender on cost, price & performance

- One of the world’s largest utility groupings
- 18,200 employees
- 5.7m customers (electricity, 3.6m, gas 2.1m)
- Sales of €21.3bn
- Plant located at Mainova AG in Frankfurt
- Commenced operation December 2013

360KW POWER-TO-GAS MODULE
ENERGY STORAGE | CLEAN FUEL
PEM ELECTROLYSER PLATFORM

Rapid response on-site electrolysis

- Modular design
- Input water clean-up
- Power conversion
- Pressurised electrolysis
- Thermal management system
- Hydrogen purification
- PLC control and data comms
- Remote operation
- CE Marked

A MODULAR OFFERING
HYDROGEN ENERGY SYSTEMS
CORE TECHNOLOGY

PEM Stack Platform | BoP Integration

- Modular
- Rapid response
- Self pressurising

0.5MW Stack Configuration

STACKS PLATFORM
HYDROGEN ENERGY SYSTEMS
LOAD FOLLOWING

Rapid response Electrolysis

- Full system test program
- Set Point v’s Actual (blue)
- EIFER & DVGW-EBI.
- Multiple start/stop tests
- Load modulation for full range
- Challenge system reliability
- Validate system to assimilate intermittent renewable power

PERFORMANCE
HYDROGEN ENERGY SYSTEMS
Ensuring compliance with the gas grid

- Hydrogen is injected directly into the gas distribution network
- Hydrogen concentration must not exceed 2%
- Controlled mixing of gases
- Dew point of $\text{H}_2$/natural gas mix must be <200mg/m$^3$
- Compliance: DVGW-ABG260 | TUV
- ITM have a partnership with NRM
THE SCHEDULE

A challenging time frame

- Discussions April 2011
- Competitive tender process
- Order placed March 2013
- On site September 2013
- CE marked December 2013
- TUV permit December 2013

- 5 boxes of compliance paperwork!

THE SCHEDULE

HYDROGEN ENERGY SYSTEMS
PERMIT TO OPERATE

TUV Hessen

- Germany requires more than a CE mark
- 3 on-site audits
- Verify plant matches documentation
- Assess integration into wider system
- Permit to operate received
- Significant learning – partnerships established
THUGA P2G PLANT & VISITOR CENTRE
HYDROGEN ENERGY SYSTEMS
HYDROGEN MOBILITY

FCEV REFUELLING
FUEL CELL ELECTRIC CARS

An EV drive train that’s refuelled rather than recharged

- Refuel in 3 minutes
- Range 400 miles
- Managed export of electricity from the grid

**Diagram:**
- **Electric Motor:** Stores the electricity, uses the electricity to move the vehicle forwards, requires less maintenance and runs almost silently.
- **Battery:** Converts the hydrogen and oxygen into electricity.
- **Fuel Cell:** Stores compressed hydrogen gas to enable increased mileage.
- **Hydrogen Tank:** The only emission from the vehicle is water vapour.

FUEL CELL CARS
HYDROGEN ENERGY SYSTEMS
ON-SITE ELECTROLYSER-HRS

Water electrolysis, hydrogen and the fuel cell electric vehicle

• Utilises the existing water and electricity infrastructures
• Key enabling technology for hydrogen infrastructure development
• Meets multiple policy goals incl. clean air, sustainability and GHG targets
• No disruption to normal social/business routines
• Satisfies fleet duty cycles and return-to-depot refuelling
ON-SITE ELECTROLYSER-HRS

- Generate → dry → compress → store → chill and dispense on-demand
ON-SITE ELECTROLYSER-HRS

- Hydrogen generation process (self-pressurising PEM electrolyser)
- Compression for storage at elevated pressure
- Drying and chilling processes to ensure purity, safety and reliability
- Refuel, on demand, vehicle tanks to 700b in 3 minutes
- Conform to ISO 14687-2 hydrogen purity
UK Government has committed £500m to ULEV

- Called for an initial roll out of 65 x 80kg/day HRS in the UK
- Called for 1150 HRS by 2030 | 51% electrolysis
- 75% CO₂ saving relative to diesel cars by 2030
- £11m of UK government & industry investment in 2015
- Aiming for 15 HRS by end 2015
HRS IN THE UK

M1 Refuelling Station | AMP Sheffield

- ITM Power’s latest public station
- Opening in March 2015
- Currently operating at ITM Power
• 100 FCEVs from 5 OEMs
• ITM to build 3 HRS in London
Hyundai, Chino, California: 100% Renewable Hydrogen Station

- Fund of $200m for 100 HRS across 10 years in California
- Aiming for 51 HRS by end 2015
NEXT STEPS

- Agree a policy framework for enabling P2G and electrolyser-HRS across the EU
- Agree balancing services provision and payment levels for P2G and electrolyser-HRS with electricity TSO's
- Agree Feed-in-Tariff levels for injecting hydrogen or SNG
- Agree hydrogen concentration targets for HP and LP gas networks, standardise across countries where possible
- Ease the permitting process across the EU for electrolyser-HRS and P2G plant
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