Proton Motor Fuel Cell GmbH

Manfred Limbrunner

Director Sales & Marketing / Member of the Board

Fuel Cells · Power Systems

Proton Motor Power Systems PLC

Only European manufacturer of long life time PEM fuel cell stacks and fuel cell systems for high power applications

Proton Motor Fuel Cell GmbH:

Located:	Puchheim (Munich area)
CEO:	Dr. Faiz Nahab
Founded:	1998
Employees:	102
Space:	6.000 m^2 (development and production)

Proton Motor Power Systems PLC:

Located:	Newcastle upon Tyne (UK)
Chairman:	Mr. Helmut Gierse
Board:	Dr. Faiz Nahab (CEO PM) Mr. Roman Kotlarzewski (CFO PM) Mr. Sebastian Goldner (CTO/COO PM) Mr. Manfred Limbrunner (CSO PM)
Founded:	2006
WKN:	A0LC22 @ London Stock Exchange

High Power Capable Types of Fuel Cells

FC Types	Fuel	Temp.	Pros	Cons
AFC Alkaline Fuel Cell	H2	≤ 80°C	• Dynamic operation • Start/Stop capability • High el. Efficiency • Emission free	• High H2 purity • High O2 purity • Low lifetime
PEFC Polymer Electrolyte Fuel Cell	H2	≤ 80°C	• Dynamic operation • Start/Stop capability • High el. Efficiency • High lifetime • Emission free	• High H2 purity
PAFC Phosphoric Acid Fuel Cell	Reformate	≤ 200°C	• Low H2 & O2 purity	• Low Dynamic operation • Start/stop capability • Low el. Efficiency • Low lifetime • Emissions
MCFC Molten Carbonate Fuel Cell	Reformate	≤ 650°C	• Low H2 & O2 purity	• Low Dynamic operation • Start/stop capability • Low el. Efficiency • Low lifetime • Emissions
SOFC Solid Oxide Fuel Cell	Reformate	≤ 1000°C	• Low H2 & O2 purity • High Lifetime • High el. efficiency	• Low Dynamic operation • Start/stop capability • Emissions

Hydrogen Storage Systems for PEFC Applications

On-Board H2 Storage Systems		Automotive		Rail	Maritime
		Passenger Cars	Utility Vehicles		
Compressed Gaseous Hydrogen (CGH)	350 bar		X	X	X
	700 bar	X			
Liquid Hydrogen (LH2)					X
Metal Hydride Storage					X
Liquid Organic Hydrogen Carrier (LOHC)		To be developed			
Ammonia		To be developed			

Proton Motor Fuel Cell GmbH

Start development of Fuel Cell Technology

1994

Bayernbus set into operation

2000

Fuel Cell Ship “Alsterwasser” in operation

2008

Road approval Newton with HyRange®

2011

EPS-System BOS Application

2016

75 kVA Fuel Power plant Surf’n’Turf

2017

1998

Foundation Proton Motor Fuel Cell GmbH

2001

World first Fuel Cell Fork Lift

2009

World first Triple Hybrid City Bus

2012

EPS System installed in Bachhausen

2016

Presentation of FC REEV vehicle

2018

FC-EPS System at DB Netz AG

Modular Fuel Cell Stack & System Approach

- Stationary
- Automotive
- Rail
- Maritime

PM200 Stack Modules

FC Power Range: 2,1…14,8 kW_{el} (2 kW steps)

Current range: 0…150 A

PM400 Stack Modules

FC Power Range: 14,2…71,0 kW_{el} (7 kW steps)
85…213 kW_{el} (20 kW steps)
Cascadable into MW_{el} power range

Current range: 0…500 A

Efficiency:	47…67%	Ambient Temp.:	-35 to +45 °C
Life time:	> 20.000 operating hours	H2 pressure:	3,5 / 8,0 bar_g
Protection class:	IP65	Conformity:	CE, EN 62282-2

Freeze storage and freeze start capable (since 2010)

No need for humidification

Liquid cooled

Modular System Approach for OEM Products











Package Components

H_2

Air

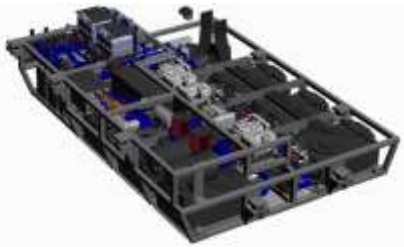
PM Stack Module inside

2–16 kW / 15–75 kW

Electricity

Cooling

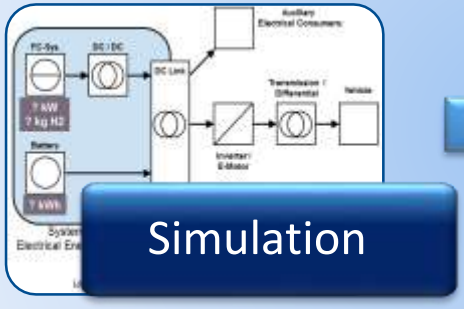
Controls




From Concept to Application

Fuel Cells · Power Systems

Feasibility Studies



Simulation

Development

Engineering

(Serial-)Produktion

Stack Manufacturing

System Manufacturing

FAT

Customer Support

Integration

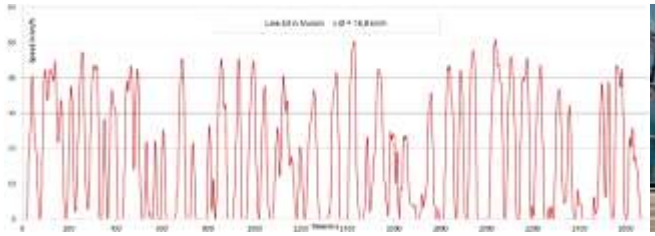
Commissioning

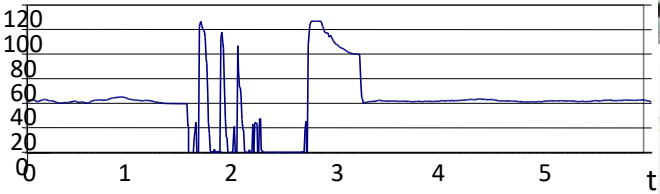
Service

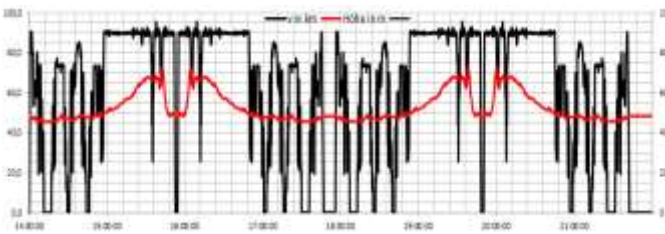
Fuel Cell Hybrid Concept

Demand of application defined through:

- Drive/Load Cycle
- Energy Autonomous Operation
- Stand By Time Between Operation
- Payload







Design & Dimensioning Principals:

Target: Refilling **NOT** Recharging

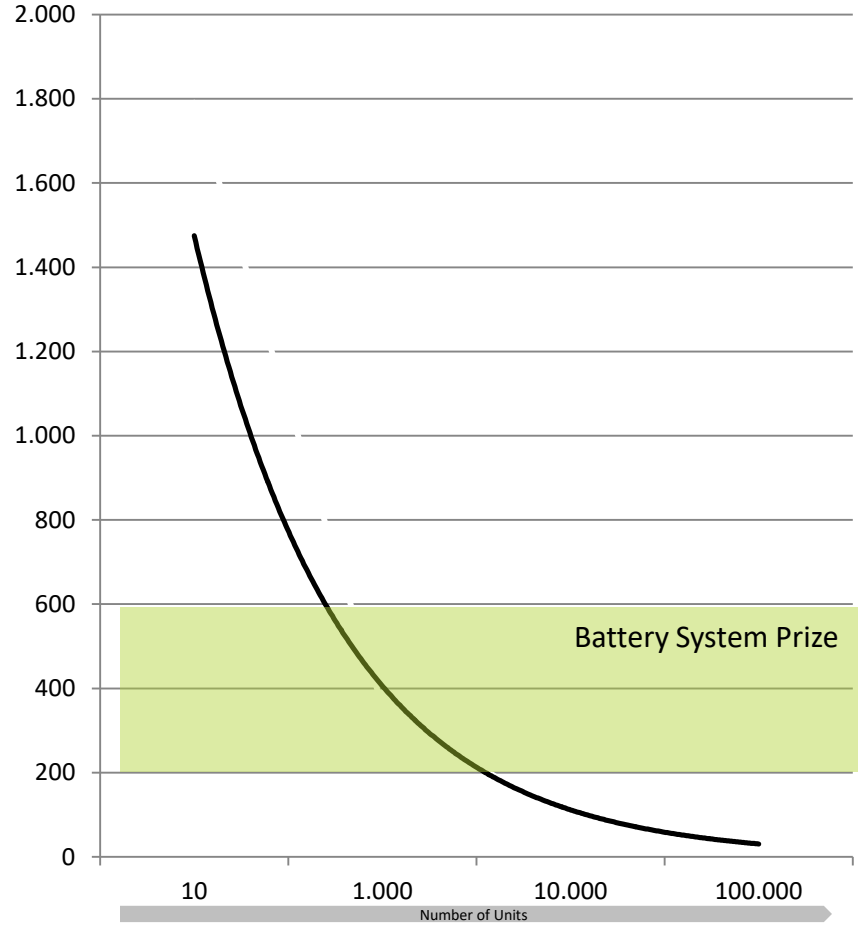
Peak Power and/or Breaking Power	→	Battery Size [kWh]
Average Power	→	Fuel Cell Size [kW_{el}]
Energy Autonomous Operation	→	H2-Storage Size [kg H2]

Definition within Proton Motor:

FC Range Extender: Fuel cell power less than average power of application
➔ refilling **AND** recharging

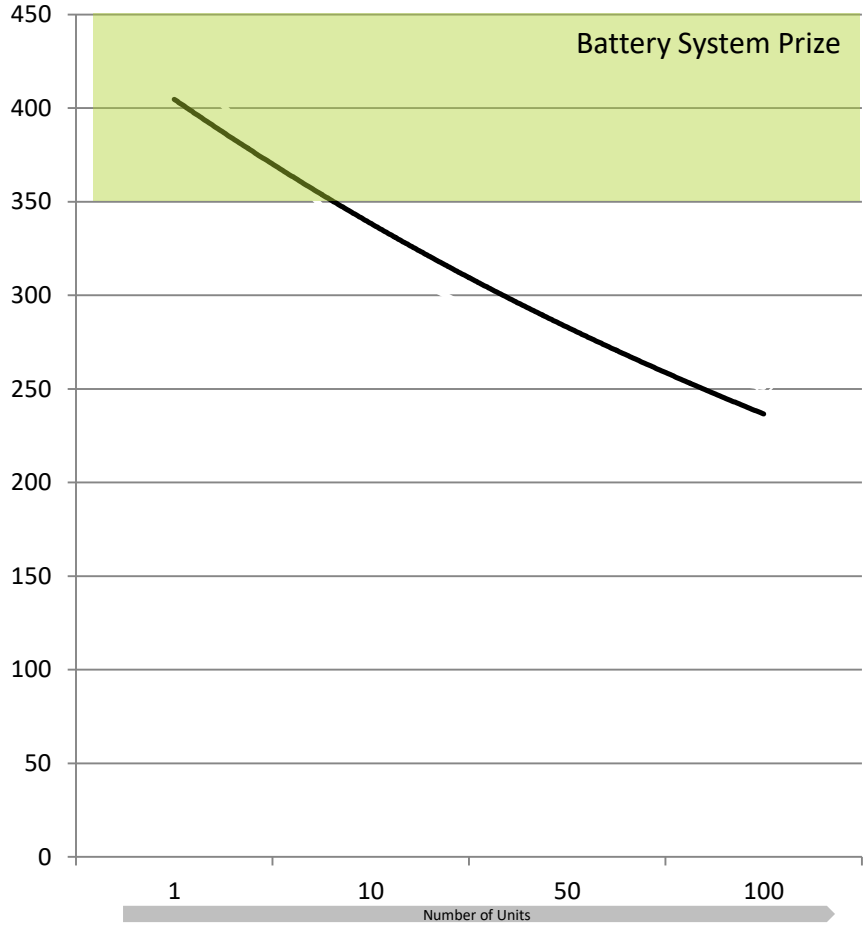
FC Hybrid: Fuel cell power higher than average power of application
➔ refilling **NO** recharging

Price Development Fuel Cell System



Included in specific price:

- Fuel Cell System 67 kW (w/o H2 Storage & DC/DC)
- Voltage Supply FC Auxiliaries

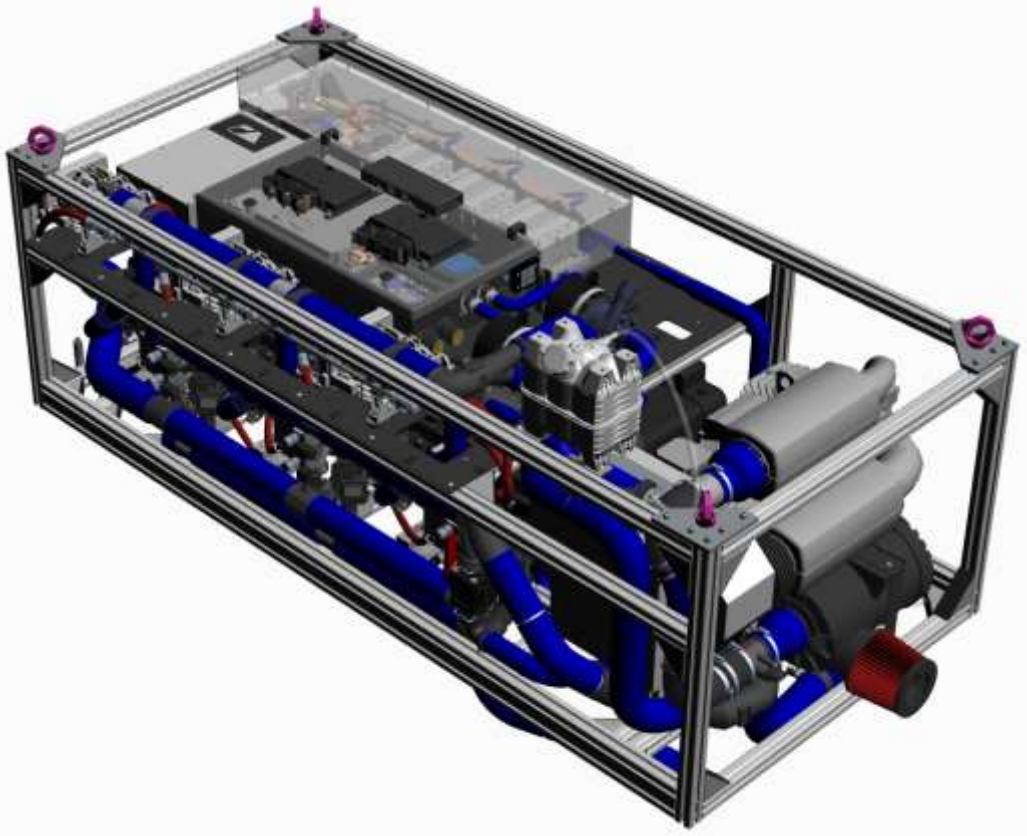


Included in specific price:

- Fuel Cell System 67 kW
- Voltage Supply FC Auxiliaries
- DC/DC Converter and Voltage Supply Auxiliaries
- H2 Storage System 30 kg @ 350 bar

Fuel Cell System (Multi Stack System)

Power Levels: 85…213 kW_{el} (20 kW steps)



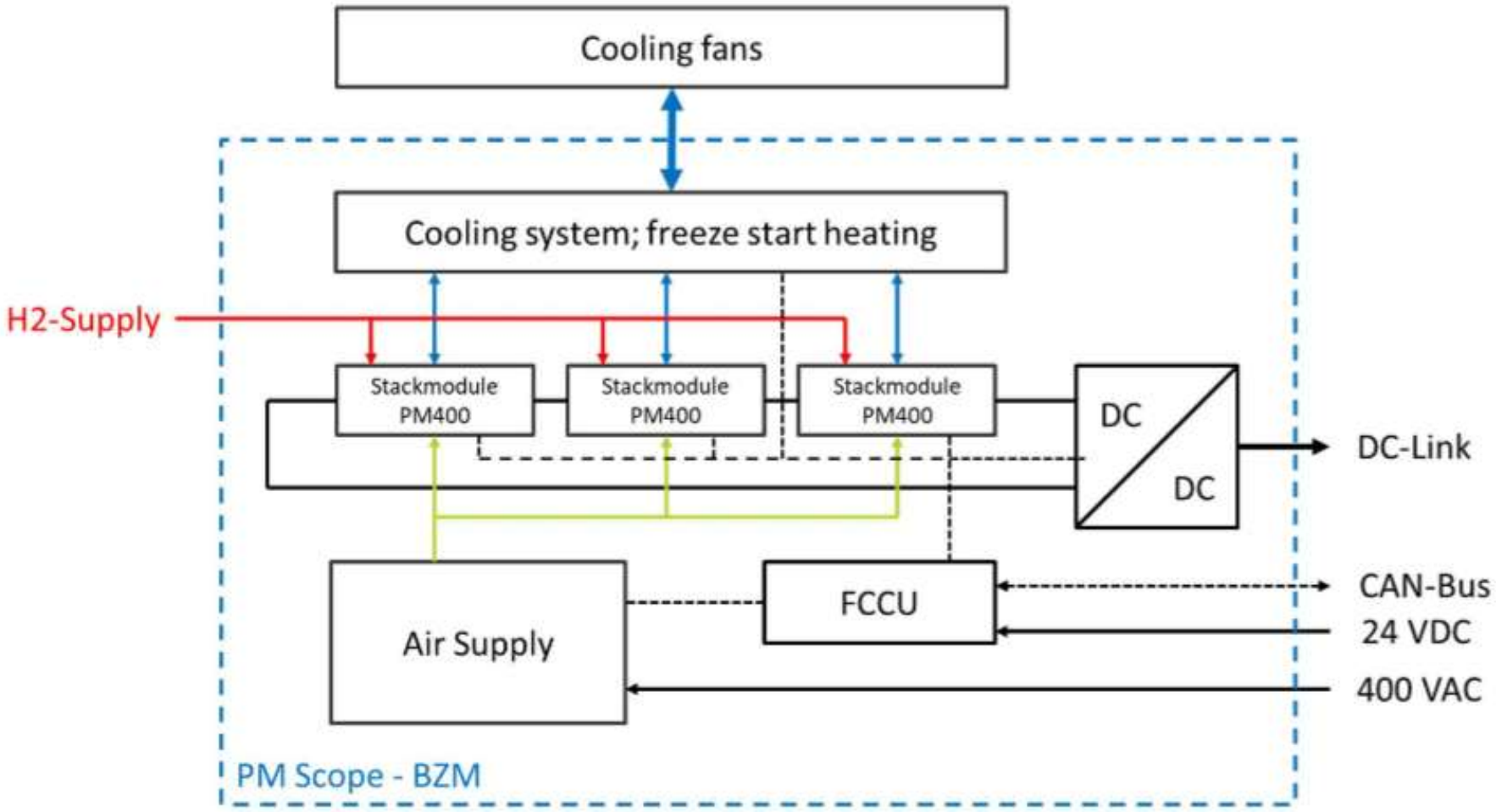
Fuel Cell System 213 kW :

FC Power:	31…213 kW_{el}
Output Voltage:	30…770 VDC
	820 VDC (shut down limit)
H2 Interface:	3,0…7,5 bar_g
	1,5 bar_g (adaptable)
Weight:	881 kg
Volume:	1.500 l

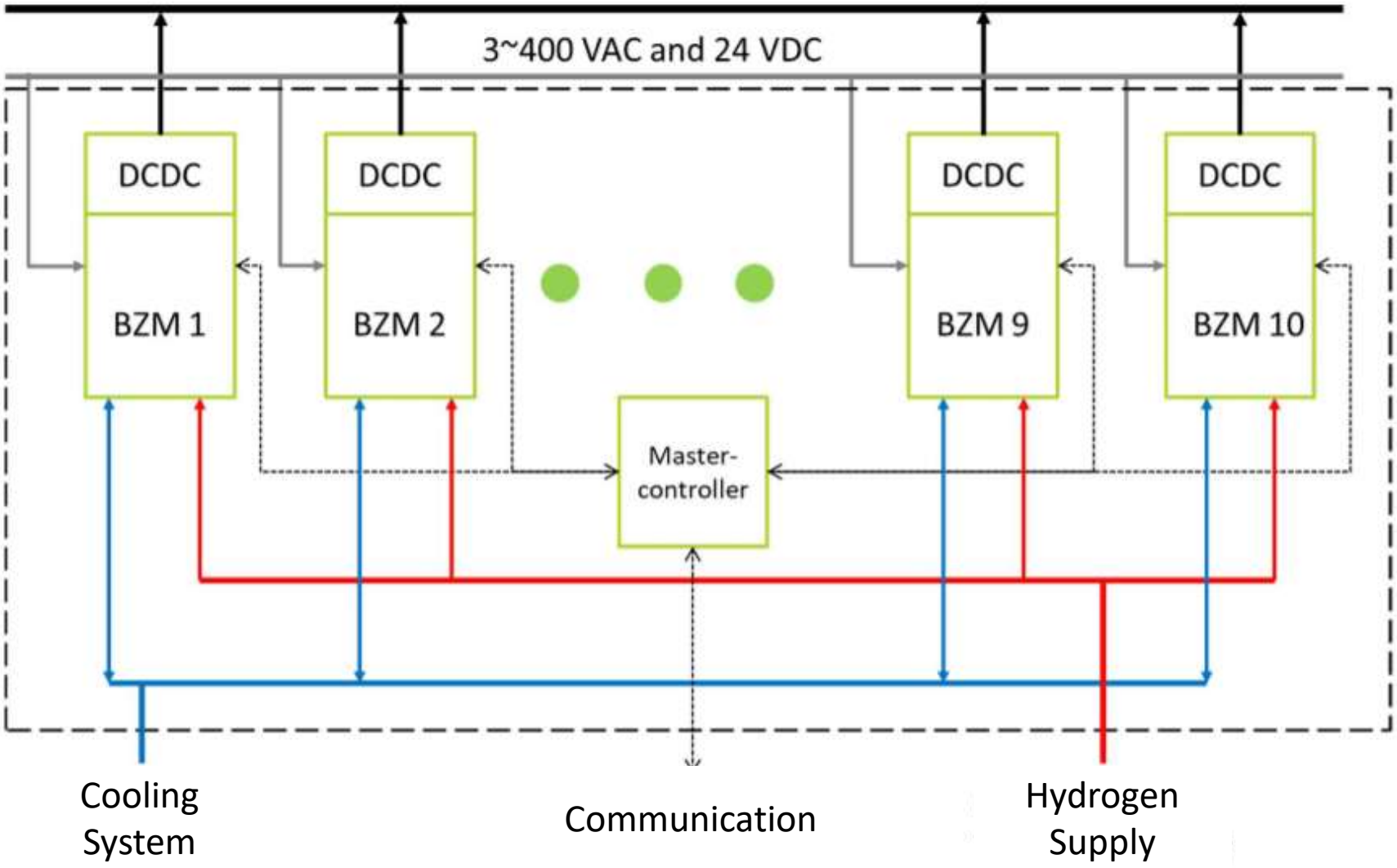
Complete Balance of Plant & DC/DC converter integrated

Internal power/voltage supply & distribution from DC link available

Fuel Cell System (Multi Stack System)



Cascaded Fuel Cell System



Hydrogen Storage Systems for PEFC Applications

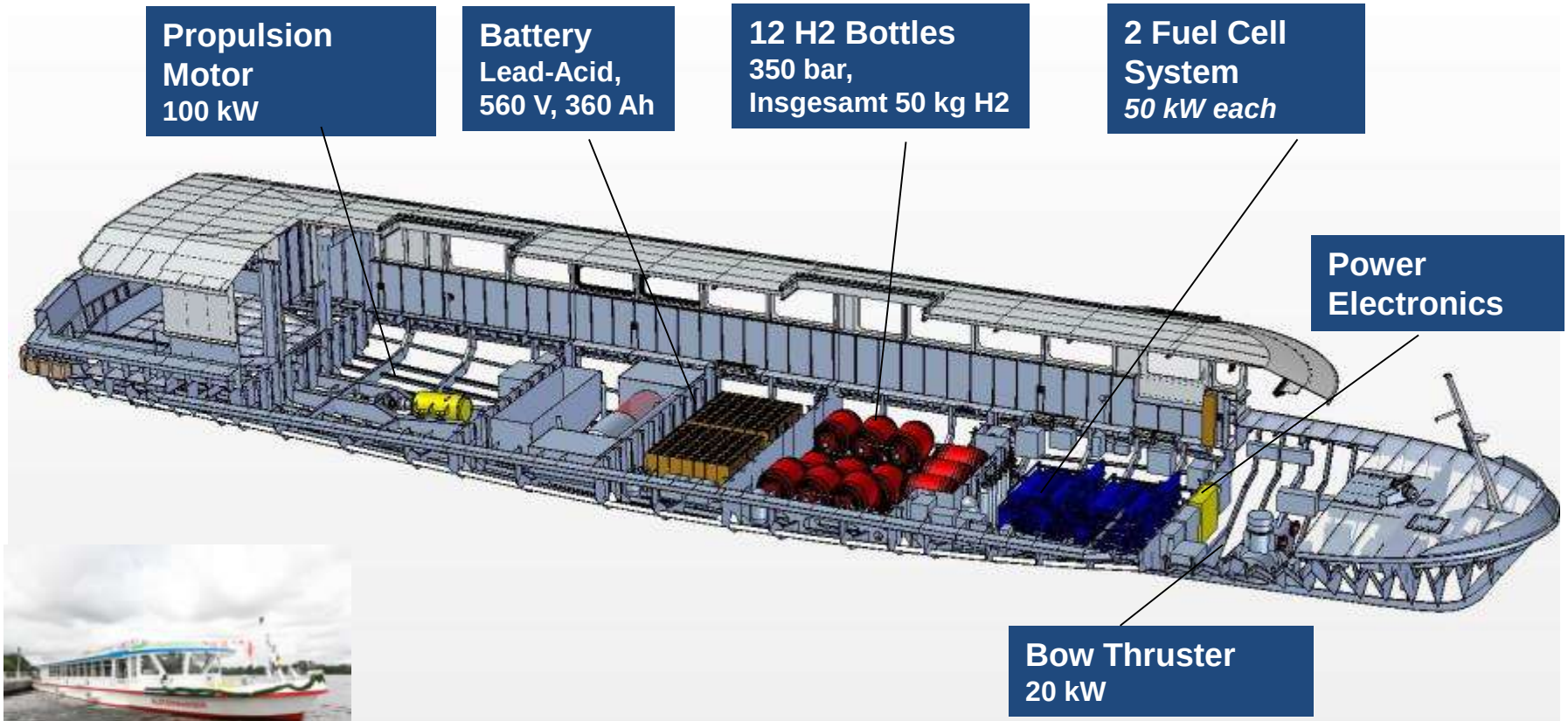
On-Board H2 Storage Systems		Automotive		Rail	Maritime
		Passenger Cars	Utility Vehicles		
Compressed Gaseous Hydrogen (CGH)	350 bar		X	X	X
	700 bar	X			
Liquid Hydrogen (LH2)					X
Metal Hydride Storage					X
Liquid Organic Hydrogen Carrier (LOHC)		To be developed			
Ammonia		To be developed			

FCS Alsterwasser

ZEMSHIPS project, Hamburg

- Zero Emission Fuel Cell Ship.
- Capacity for approx. 100 passengers.
- ZEMSHIPS project partner: ATG, Linde, German Lloyd, Stadt Hamburg, Proton Motor.
- Proton Motor was responsible for the complete propulsion system of the Ship.
- In use since summer 2008. In approx. 4000 operating hours more than 50.000. passengers were transported (01/2014).
- 1,7 kg hydrogen consumption per operation hour.

FCS Alsterwasser



Safety Concept

Packaging and System Layout

Avoiding H2 Leakage

- Welding instead of screwing
- Depressurizing high and mid pressure pipes if not in use
- Inerting mid and low pressure pipes if not in use
- Double-walled pipes

Ex-Zone Concept

- Sectional classification in ship
- Forced air ventilation of areas with possibility of H2 leakage
- Monitoring gas concentration

Control

Micro Controller and CVMU‘s

- Keep System in normal parameters
- Normal shut down if first level switching points are reached
- Prevent system from getting damaged
- Prevent hydrogen from leaving the system

Safety Circuit

Hard wired safety circuit

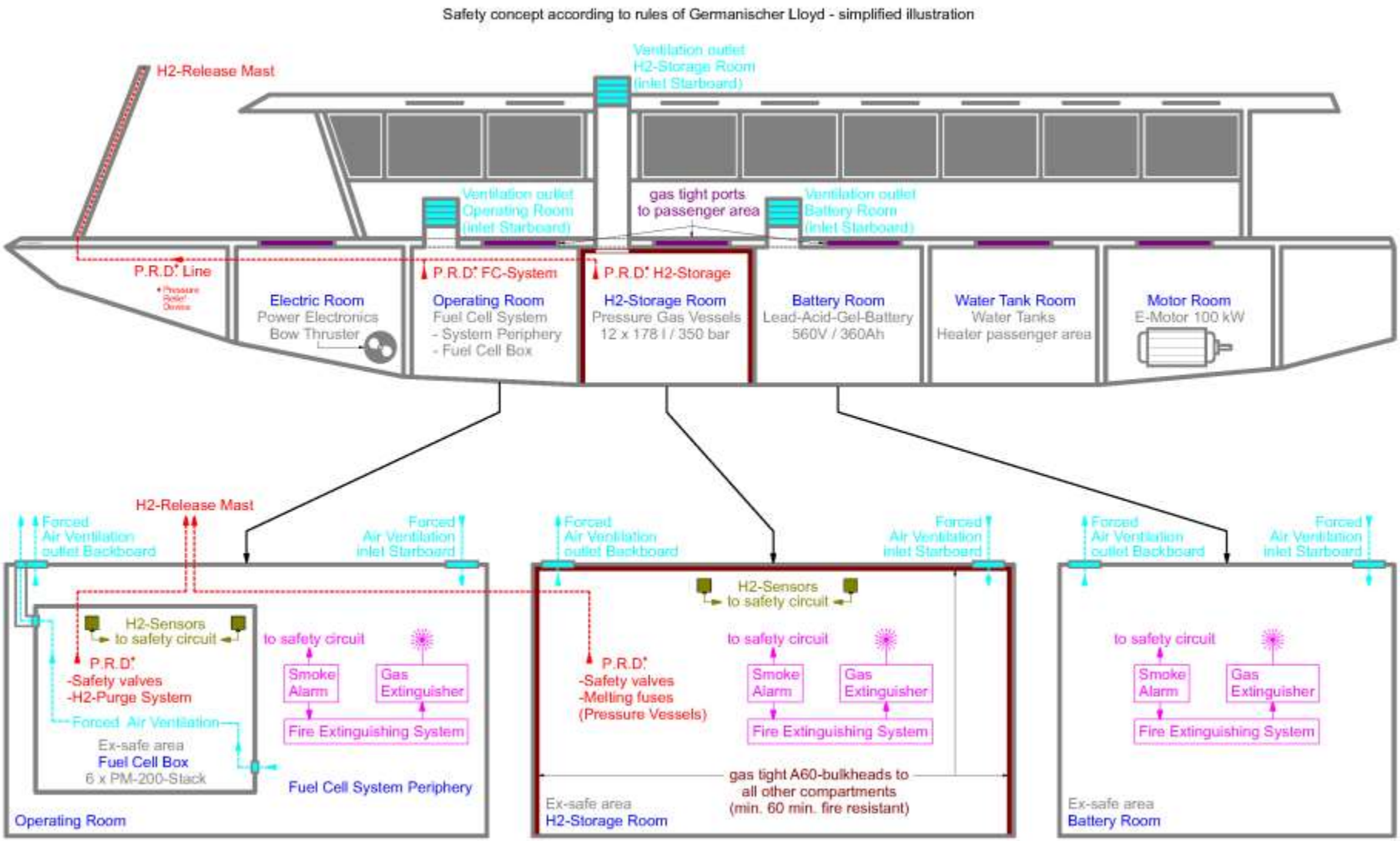
- Switches for temperature, pressure and flow
- Emergency Shut Down if switching points are reached
- Preventing system from getting damaged
- Preventing hydrogen from leaving the system

PRD‘s

Pressure Relief Devices

- Safety valves
- Melting fuses
- Preventing the system from getting damaged
- Releasing hydrogen to surrounding if set pressure points or temperatures of melting fuse are reached

Safety Concept Packaging



Reference Mobility Customers/Orders

Fuel Cells · Power Systems

Automotive

Etrucks europe

Application:	**Garbage Truck**
FC Power:	**43 kW**
H2 Storage:	**20/30 kg 350 bar**
Battery:	**136 kWh**
Delivery:	**6 Systems in 2020**

Rail

Application:	**Rail Milling Train**
FC Power:	**2 x 107 kW**
H2 Storage:	**To be announced 350 bar**
Battery:	**To be announced**
Delivery:	**1st Qu. 2021**

Maritime

FINCANTIERI
The sea ahead

Application:	**Marine Vessel**
FC Power:	**144 kW**
H2 Storage:	**50 kg Metal-Hydride**
Battery:	**To be announced**
Delivery:	**1st/2nd Qu. 2021**

References Stationary Applications

Grid Stabilisation / Peak Shaving (decentralized hydrogen production)

FC Power: 178kW
Voltage: 400 VAC (Grid dependent)
Customer: APEX
Location: Rostock (Germany)

Power Supply Grid Independent (hydrogen supply)

FC Power: 129 kW
Battery : 180 kWh
Voltage: 400 VAC (Grid independent)
Customer: Shell
Location: Munich (Germany)

References Stationary Applications

UPS / Emergency Power Supply (hydrogen supply)

UPS Telecom

Customer: DB Bahnbau

FC Power: 6 & 9 kW

UPS Road Tunnels

Customer: To be announced

FC Power: 23, 28, 36, 43 kW

Seasonal Energy Shift / Peak Shaving (decentralized hydrogen production)

Houses & Appartments

Projects: Hy2Green (I)

Brütten (CH)

FC Power: 9 kW

Housing Block

Customer: Vonovia

FC Power: 36 kW

Going to Market Strategy

Market Growth

- 1st target market Europe
- Development site Puchheim (Munich)
- Manufacturing site Puchheim (Munich)
- Target system production capacity 5.000 per Year
- Target Fuel Cell Stack production capacity 10.000 per Year
- European JV's serial Fuel Cell Stack production

Mass Markets

- World wide market
- Development site Puchheim (Munich)
- Lead Factory in Puchheim (Munich)
- System and Fuel Cell Stack production capacities > 5.000 Systems
- World wide licensees & strategic partnerships

Fully Automated Fuel Cell Stack Manufacturing

Status Quo

FC capacity 215 MW_{el}:

- 5.850 pcs. 37.0 FC Stacks
- 7.150 pcs. 30.0 Stacks

Increasing Market Demand

FC capacity 1.110 MW_{el}:

- 30.000 pcs. 37.0 FC Stacks
- 37.000 pcs. 30.0 FC Stacks

Increasing capacity and value at PM e. g.:

- Using roll material
- Sealing integrated
- Gluing integrated

Fuel Cells · Power Systems

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