P21 WHITE PAPER

FUNCTIONAL DESCRIPTION
PREMION T FUEL CELL SYSTEM

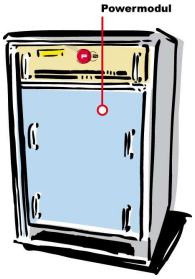
Introduction

Today's community entails that everyone wants to communicate always, everywhere and all the time without interruption. That's the reason why the Base Stations for mobile telecommunication are provided with uninterruptible back-up solutions with lead batteries to bridge small grid cuts.

The lead batteries need rooms with air-condition. Their bridge times are short. If there is a bad grid with a lot of grid cuts following each other, and the batteries gap to reload in the mean time, they can't deliver the requested power supply.
The batteries need reload systems, periodical maintenance, in critical stations, they have to be replaced every 3 Years, they are not environmental friendly (acid and lead) and they are hazardous waste after lifetime.
The solution for these problems is to replace the batteries with an environmentally friendly modern and flexible fuel cell system without batteries.

Founded in 2001 as a management buy-out spin-off from Mannesmann/Vodafone group, P21 GmbH had one major goal that is reality today: fuel cell products that fulfil the toughest requirements in the telecommunications industry and also expand the options in emergency power supply considerably.

P21 GmbH developed a fuel cell back-up system with hydrogen: **Premion T**.



Compared to batteries based back-up solutions Premion T shows clear advantages:

- **Robust against harsh climatic conditions**
- **Higher reliability**
- **Longer backup times**
- **Less space required**
- **Lower lifecycle costs**

The goal of the development was to retrofit or replace the lead batteries based UPS technology by the innovative and environmentally friendly fuel cell technology.

Premion T is the brand name of the fuel cell system of P21. It was designed to deliver the back-up power needs of the mobile base stations for telecommunications.

Fuel Cells and Premion T

The fuel cell is an electrochemical energy converter; it transforms chemical energy of fuel directly into DC current and heat.

The fuel cells can be grouped by the type of electrolyte they use:

PEMFC	**Polymer Electrolyte Membrane Fuel Cells**
AFC	Alcaline Fuel Cells
MCFC	Molten Carbonate Fuel Cells
SOFC	Solid Oxide Fuel Cells
PAFC	Phosphoric Acid Fuel Cells

Premion T uses PEMFC.

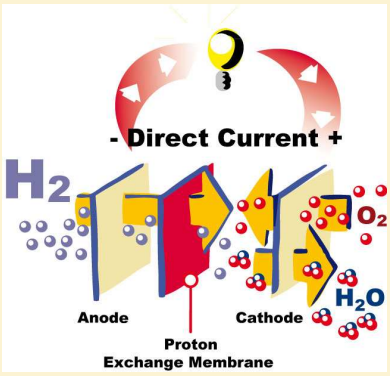
The PEMFC is composed by a proton exchange polymer membrane (perfluorsulfonic acid) as the electrolyte. The catalyst is platinum, supported on carbon. The cells operate between 20℃ and 70℃.

Functional Principle PEM

The heart of the PEM fuel cell is a Polymer Electrolyte Membrane with remarkable unique capabilities. It is impermeable to gases but it conducts protons. The membrane is layered with two catalyst coatings, where the chemical reactions take part. For the electrical connection, the membrane is embedded between two electro conductive electrodes. These are made of graphite material.

In the fuel cell the anode is the negative pole and the cathode is the positive pole. The anode is supplied with hydrogen and the cathode with oxygen out of the air. The gases are distributed in the system by special designed diffusion materials.

Functional Principle:



Hydrogen and oxygen react in the cell to water, heat and electrical current.

Hydrogen, chemical name H_2, is split at the anode catalyst into its primary constituents 2 protons (H+) and 2 electrons (e-). The protons (H+) are transported through the membrane to the cathode, the electrons (e-) travel through the electrodes and the external load to the cathode. At the cathode catalyst the electrons (e-) react with the protons (H+) and the oxygen (O_2) to water (H_2O) and

heat. The different potentials between the anode and cathode reaction is the driving force for the power conversion of the fuel cell.

Each cell generates about 0, 5 to 1 V. To generate some practical voltages more cells are needed in series. The cells are stacked up to form a fuel cell stack.

A fuel cell system needs a supporting system to handle the supply of reactant gases, take care of waste heat and regulate and condition power output and monitor the stack vital parameters.

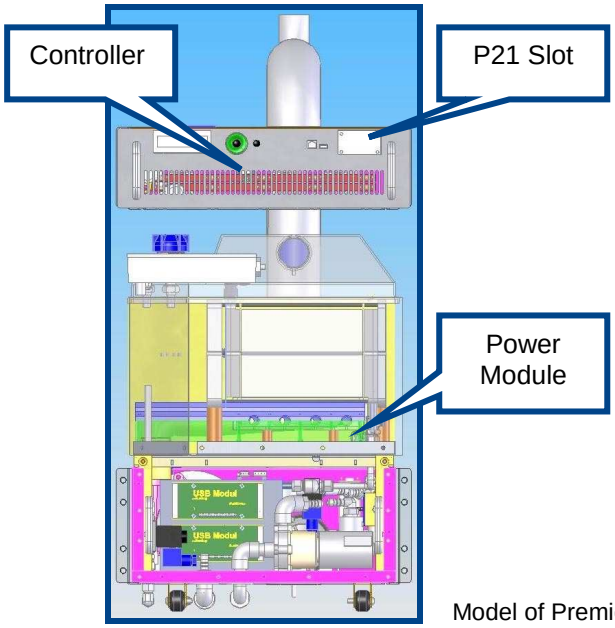
Premion T System

The power back-up system Premion T is composed of 3 building blocks:

1. **Controller** for monitoring and regulation of the system, with integrated super capacitors, as the energy store unit.

2. **Power module** containing the PEM-Stacks and the supporting system.

3. **External heat exchanger** to transport the heat out of the system.



Model of Premion T

Controller

The Controller Module is the brain of the fuel cell system. The electronic components and the software of the controller lead and monitor all processes in the system.
A 2-line LC illuminated display on the controller, shows the performance and the status of the system. A 5-key control panel helps to operate the system.
The Controller has an Ethernet and an USB Port for system initialization, service purposes and remote control.

The P21 Slot (optionally available) is upgradeable for specific customer requirements for connecting the Premion T to specific data transfer and telecommunication nets.

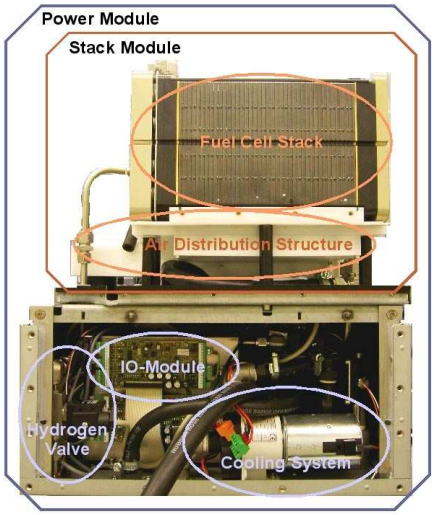
The super capacitors in the Controller Module provide an absolutely interruptible power supply until the fuel cells start producing energy.
The parameters of the fuel cell system, like status, hydrogen fill level, etc. can be called up by remote access and visualized by the GUI (Graphical User Interface).

Power Module

The heart of the Premion T is the fuel cell stacks. Each stack has 40 PEM fuel cells and an air distribution and cooling system, the bipolar plates (BPP).

The BPP allow electricity to be conducted between adjacent individual fuel cells. They are specially designed to channel the flow of gases and cooling liquid to and from the cell.

The MEA (Membrane Electrode Assembly) lies between the BBP and consists of a coated membrane with an electrode layer on each side. The membrane acts as an electrolyte, through which hydrogen ions pass and is an isolator to prevent electrical contact between anode und cathode.



Power Module

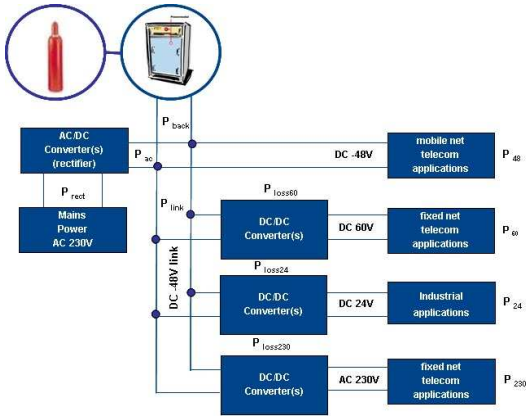
Further system components, like the internal cooling system, as well as all sensors (temperature and pressure measuring units) and actuators (pumps and valves) manage the process.

Heat Exchanger

The heat exchanger (not in the picture) is an outdoor air cooled system. It takes care of the transport of the waste heat out of the system.

Handling, Functionality

Premion T is connected in parallel to the power supply and to the load in a -48 VDC- net. The next figure shows how to connect the Premion T to the different power nets.



Examples for connecting Premion T to different power nets.

Depending on the input or output voltage required, different converters can be connected to Premion T.

In Standby Modus the system is supplied by the net power.
In case of a black out, the base station is supplied directly from the super capacitors, which are automatically reloaded by the fuel cells system in operation.

Premion T is triggered by the voltage of the super capacitors. When the output voltage of the capacitors falls below a predefined level, Premion T starts to work and delivers in just a few seconds the required energy to supply the load and for reloading the super capacitors. The load is always uninterruptibly connected to power.

The reachable bridge time depends on the available hydrogen quantity. With one hydrogen bottle (50l) the grid cut can be bridged without interruption over 8 h.

Once Premion T is in standby modus, the super capacitors are loaded. When they give their power to the load, Premion T starts operating.

The stacks are immediately provided with hydrogen by automatically opening the hydrogen valve. The ventilator starts providing the stacks with oxygen out of the air. The pump of the internal cooling system transports the heat out of the stacks. The external cooling system takes care of the transport of the heat out of the system.

The super capacitors are reloaded and Premion T stops working until the voltage of the capacitors falls below a defined level. Then Premion T starts producing energy again.

Process description

The input media of our system are:

- Hydrogen
- Air

The output media are:

- Electrical DC currency
- Water
- Heat

Premion T is triggered by the voltage level of the super capacitors. When the voltage reaches a predefined level, the fuel cells start working and transforming chemical energy directly to DC current.

Hydrogen

Hydrogen comes out of a bottle with a maximal compression of 200 bar, flows through a double step gas decompression system. In the stacks H_2 gets split into its components, protons and electrons.
The protons get through the PEMFC to the cathode where they react with the oxygen to water.
The electrons are transported to the cathode passing the load and delivering the requested power.
Hydrogen only can enter the Premion T when the system is operating, otherwise the hydrogen valves stay closed.

Air

The filtered environment air is pumped into the system.
The air enters the stacks by the cathode side. The exhausted air leaves the power module through a pipe connection and it is released to the environment.

Electrical Power

Premion T is connected in parallel to the power supply and to the load in a -48 VDC- net.
In the first 10 sec after a black out, the customer load is supplied by the super capacitors with the requested power until the fuel cells start working and delivering the power to the load and reloading the super capacitors.

Heat

The produced heat is transported out of the system with the help of two heat exchangers.
The first heat exchanger is part of the Power Module and it transports the heat out of the stacks.
The second heat exchanger transports the heat out of the complete system. It is an air cooling system, which is placed outdoor.

Water

The system produces water as steam and condensed water. The water gets out of the system with the exhausted air. The

cooling water is in a closed circuit and does not have to be refilled.

Process visualization

The GUI (Graphical User Interface) helps the customer and the service engineers getting clear information about the system and its status locally or via remote access.

Hydrogen logistic

The secure handling with hydrogen in industrial environments has been done over Years and Years and it is an approved technology.
P21 has a partnership and cooperation with Linde AG, a worldwide industrial gas supplier. Linde AG is our logistic partner concerning the hydrogen supply. Linde delivers, installs and refills the hydrogen when ever it is requested.

Example of an outdoor hydrogen installation

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