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Duration Tests of PEM Fuel Cells in a 50 kW Pilot Power Plant

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1 Introduction

Duration tests are performed in a 50 kW PEM pilot power unit at the Akzo Nobel chlor-alkali plant at Delfzijl, the Netherlands, since April 2007. The rated electrical peak power of the PEM fuel cell unit is 120 kW, but to extend lifetime and to attain high conversion efficiency the unit operates at partial load, feeding 50 kW into the local grid.

Chlor-Alkali plants are a perfect location for PEM fuel cells as they produce high quality hydrogen at low cost and require high power electricity for electrolysis. Chlor-Alkali plants produce the industrial chemicals chlorine and caustic soda (lye) by the electrolysis of brine. For every molecule of chlorine a molecule of hydrogen is produced. It is not always possible to sell the byproduct hydrogen as a chemical or as a fuel. Globally an average of 15 % of the produced hydrogen is vented to the atmosphere (ref 1). The hydrogen production of all chlor-alkali plants is about 1.5 million ton per year (16 billion m³/y) yielding 2800 MW of electric power with PEM fuel cells, if a conversion efficiency of 50 % is assumed. The 15 % of vented hydrogen could generate 400 MW annually, thus avoiding CO₂-emission of fossil fueled power stations. Another source of byproduct hydrogen is the chlorate industry usually associated with the paper industry. As they tend to be located in remote areas hydrogen is mostly released to the atmosphere. The annual electric power that could be generated from the hydrogen of chlorate production, at 50 % conversion efficiency, is 330 MW.

The 50 kW pilot PEM power plant in Delfzijl is a joint project of NedStack Fuel Cell Technology B.V. and Akzo Nobel Base Chemicals B.V. The Akzo Nobel chlor-alkali plant in Delfzijl came into operation in June 2006 and produces over 100 kton of chlorine and 3 kton of hydrogen per year. This quantity of hydrogen could generate 6 MW of electricity at 50 % conversion efficiency. Production of electricity from the 50 kW PEM power plant started in April 2007. In March 2010 after more than 14,000 hours of fuel cell operation about 700 MWh of electricity was delivered to the local grid.

2 The 50 kW Pilot PEM Power Plant

The basic building block of the 50 kW unit is a NedStack PEM fuel cell stack of 75 cells, each with an effective area of 200 cm².



Figure 1: Module with 12 stacks, with 75 cells each and an effective cell area of 200 cm².

At the stationary load of 50 kW a total of 12 stacks (figure 1), comprising 900 cells, is connected in series, generating 630 VDC at 80 A. At this operating point of 0.4 A/cm² the nominal stack power is 4.2 kW, while the rated peak power is 10 kW at 250 A. An inverter connected to the local grid converts the direct voltage to 400 VAC, 3 phase. Although an electrolysis plant uses direct power it turns out to be more economical to feed to the grid rather than to the electrolysers. The conversion efficiency of the fuel cells is 55 %. The balance of plant, including the inverter, reduces the overall efficiency to 45 % (LHV of hydrogen). The Pilot PEM Power Plant is located in a 20 foot sea container at the chlor-alkali plant Delfzijl (figure 2). More information is in ref 2-4.

3 Results

Since April 2007 several types of Membrane Electrode Assemblies were tested in the pilot plant in Delfzijl. Non-availability of the unit due to maintenance of the chlor-alkali plant, to diagnostic failure or to cell failure was relatively large as the maintenance team was located 200 km away in Arnhem. The PEM system however is very reliable and the few technical problems encountered so far could be solved satisfactorily. A drawback of the design with series connection of voltages is that the whole unit stops when the voltage of a single cell falls below a threshold. After such a trip the hydrogen is automatically replaced by nitrogen, reducing the relative humidity of the anode gas in this set-up. Subsequent desiccation is likely to cause shrinkage in the plane of the membrane (ref 5, 6). After start-up the humidity is restored and swelling will occur. It is found that the lifetime of reinforced membranes is a factor of two longer than that of normal membranes. An example of the voltage decay in a stack with 25 μm thick reinforced membranes, measured during 8155 hours on the grid, is given in figure 3.



Figure 2: Container with the 50 kW PEM Power unit at the Akzo Nobel chlor-alkali plant in Delfzijl.

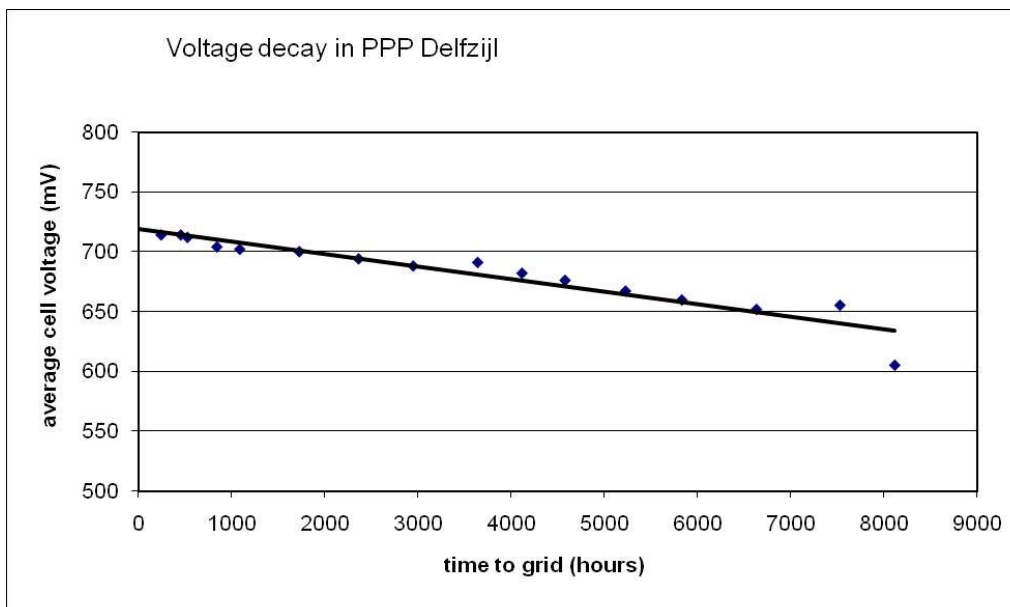


Figure 3: Decay of the voltage of a stack with MEA's (current 80 A, cell area 200 cm²) with reinforced membranes at PEM pilot plant Delfzijl. Failure occurred after 8155 hours on the grid.

4 Design of 1 MW Unit

Semi-mobile chlor-alkali-plants with a chlorine production of 15 kton/year, are foreseen in the near future. They are a perfect match for a 1 MW PEM fuel cell unit. All by-product hydrogen is then converted to electric power reducing the power consumption from the grid by 20 %.

For the present large chlor-alkali plants 1 MW is the minimum size to have a certain impact. At 1 MW the balance-of-plant can be reduced as to raise the overall conversion efficiency to 50 % (LHV of hydrogen). The problem of non-availability of a PEM power plant due to cell failure is solved by switching the power modules in parallel. For the 1 MW Solvay project 12 modules of 85 kW will be connected in parallel. Failure of a cell in a module will trip one module but the other 11 will compensate for the loss by automatically raising the current. Stack replacement is designed to be rapid and restoration of the original situation will occur within 1 hour.

An impression of the Solvay 1 MW PEM power plant is given in figure 4. It will fit a 40 ft container. Delivery to the Solvay chlor-alkali plant in Antwerp is planned by the spring of 2011.

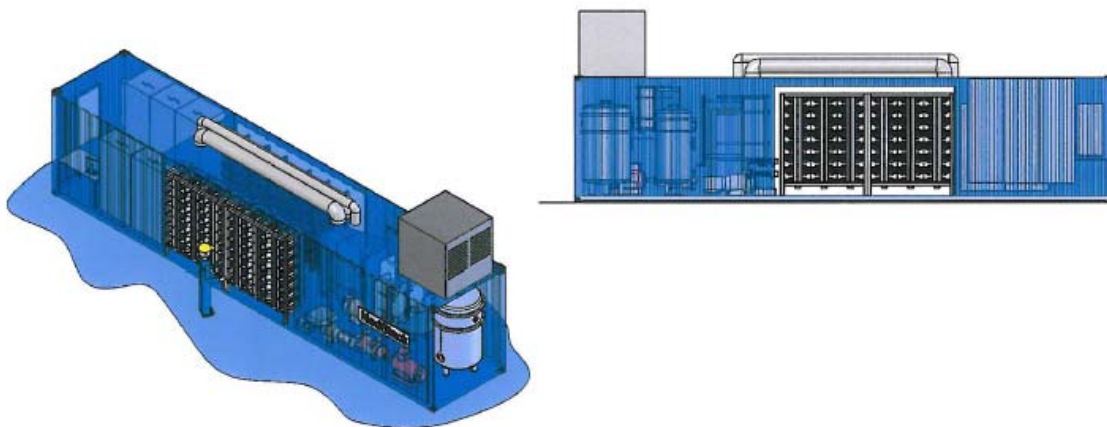


Figure 4: Design of the Solvay 1 MW PEM power plant.

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