Industrial fuel cell technology made in the Netherlands

With the advance of hydrogen in the renewable energy domain, fuel cell technology has come into the spotlight more and more. Many fuel cell technology providers focus on mobility (personal vehicles) but very few target large-scale industrial or large transportation. Nedstack, located in the Netherlands, does just that.

By Lucien Joppen

Nedstack's small-scale production unit at its HQ in the Netherlands.

Valve World visited the company's headquarters in Arnhem, a small city close to the German border. Back in the 1990s, the company started as a business unit within AkzoNobel, at the time also located in Arnhem.

The company, at the time a major producer of many bulk chemicals, including chlorine, was looking for a way to utilize hydrogen, turning it from an unwanted byproduct into an energy carrier. In 1998, AkzoNobel decided to spin out Nedstack, turning it into an independent company.

Fast forward two decades later and Nedstack has managed to survive the valley of death and is busy commercializing its technology in various sectors. Jogchum Bruinsma, sales engineer/application manager maritime at Nedstack, is eager to go into detail on 'his' company and the fuel cell technology is used for large-scale applications.

Industrial applications

"Given our industrial background, Nedstack focusses on industrial applications", Bruinsma says. "Over two decades, we have developed, manufactured and tested reliable and robust fuel cell stacks that are able to operate over lengthy periods of time. We use PEM (proton exchange membrane) stacks. PEM has proven to be the superior and most versatile technology for industrial applications. They produce

PEM

A Proton Exchange Membrane (PEM) fuel cell consists of a membrane in between two cell plates containing gas channels. On one side of the membrane is hydrogen. The hydrogen reacts with a catalyst in the membrane, which splits it into protons and electrons. The protons pass through the membrane. The flow of remaining electrons becomes an electrical current. On the other side of the membrane is air. The oxygen in the air reacts with the protons and electrons to form pure water. This can be summarised with the following equation: $2H_2 + O_2 = 2H_2O$ + electricity + heat.

the most power for a given weight or volume of fuel cell. Because they are lightweight, have such high power-density, and cold-start capability, they qualify for many applications, such as stationary combined-heat-power, transport, portable power and even applications in space. Also, very important is the maturity of the technology and its CAPEX, compared to other fuel cell technologies."

Chlor-alkali plant

Over the years, Nedstack has managed to increase the capacity of a single stack to 13,5 Kw (peak 230A Ampere). This involved 'pushing' 96 individual fuel cells together in a single stack. "These individual stacks can be installed in series or parallel to operate as a unit. We already have three industrial units in operation for many years. We started with a 70 kW unit near a chlor-alkali plant in Delfzijl, located in the north of the Netherlands. At the time, in 2007, our stacks consisted of 75 fuel cells, so this unit contains 12 stacks, each with 75 cells. Over ten years in operation, this unit has generated over 2,5 GWh of electricity with an on-grid time of over 70,000 hours. During its lifetime, we have gained valuable insights regarding the operational conditions and how we can optimize the unit's performance in various ways, for example by tweaking MEA's."

In 2011, Nedstack installed an 1 MW fuel cell power plant to the Solvay chlorine plant in Lillo, Belgium, at the time the largest PEM stack unit in the world. Five years later, Nedstack installed a 2MW facility (grid connection) in Yingkou, China.

Stable performance

As the PEM-stack does not any moving parts, there is no friction-related wear and tear, Bruinsma says. "During its lifecycle of say 30,000 hours (design, in practice 24,000 hours), stack performance is affected, for example by polymer degradation, contaminants on the anode and cathode surface or corrosion due to demineralised water, that is used as a coolant. We have conducted extensive tests for our XXL stacks to measure their performance over time and also to determine which factors were at play. It was interesting to see that in the middle of its life cycle (17,000-23,000 hours), the performance was very stable and that the capacity only decreased marginally. We also have been working with refurbished stacks, based on selected, older MEA's to create second-life stacks that have been running for several thousands of hours. We are continuously working to improve the life cycle performance of our PEM stacks, for example by improving sealing materials and several other components."

Hydrogen-powered river transport as a viable option.

Australian project

As mentioned before, Nedstack has moved its technology from commercial-demo or reference plants (Delfzijl, Lillo) to commercially available units. Bruinsma mentions the installation of a 500 kW stack system at a solar plant in Australia. The company has established a joint-venture with the Australian company between LAVO Hydrogen Storage Technology Pty Ltd (green hydrogen) to further develop proton-exchange membrane (PEM) fuel cell technology in Australia to support the expanding hydrogen industry. The (local) government has identified green hydrogen and the development and production of PEM fuel cells as a means for municipalities and (energy-intensive) industries to reduce their carbon footprint. A similar development is taking place in the maritime sector, both in off and on-shore applications, Bruinsma says. "There is a clear momentum in the industry to adopt fuel cell technology."

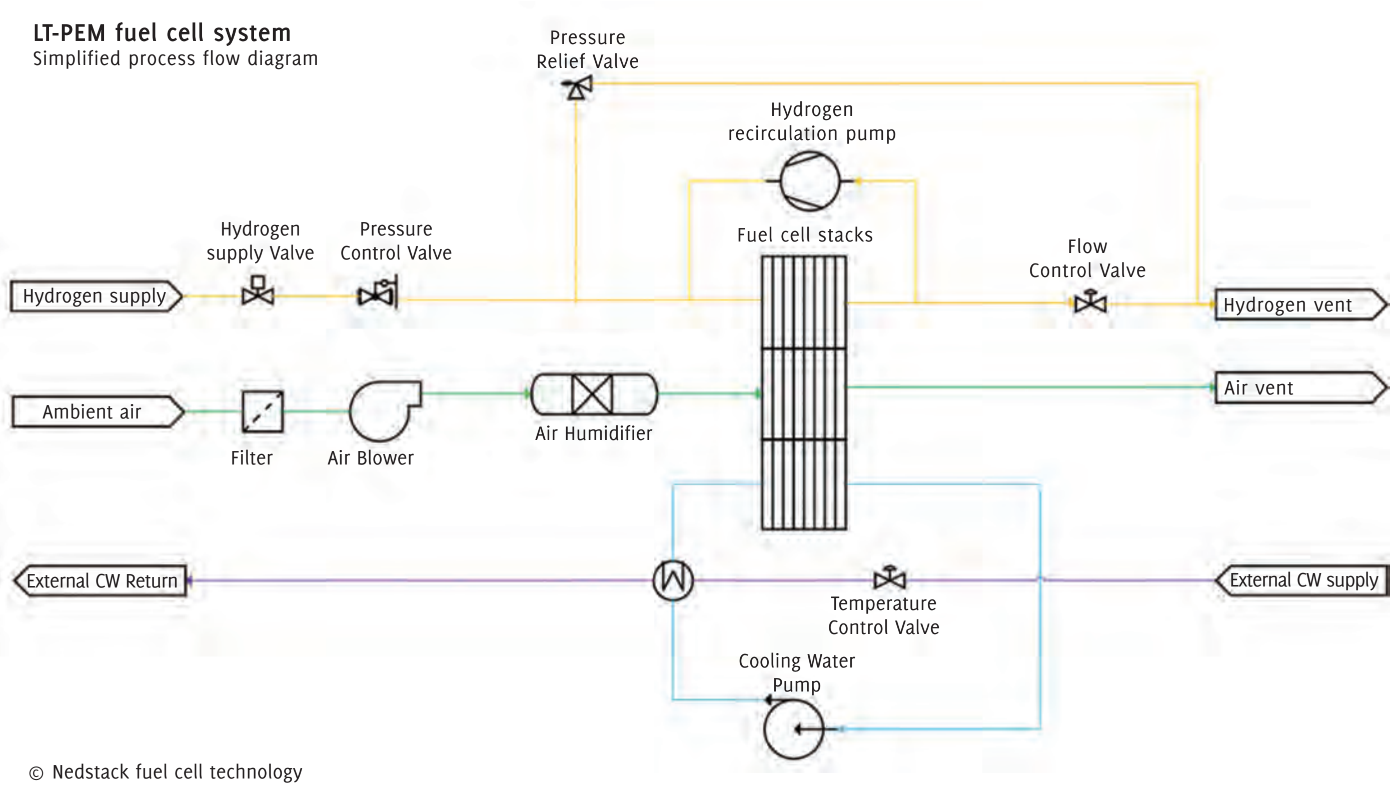
Efficiency

There has been an ongoing debate regarding the efficiency of hydrogen fuel cells versus battery-charged vehicles, most notably in the domain of personal mobility (vehicles). According to Elon Musk, the energy efficiency of hydrogen production involves more steps and leads to substantial larger energy losses during these stages.

Prof. Maximilian Fichtner, Dep. Director of the Helmholtz Institute Ulm for Electrochemical Energy Storage and designated expert in hydrogen research, was quoted in the magazine Wirtschaftswoche, the "very poor energy efficiency well-to-wheel" of the fuel cell car make sure that battery-powered e-cars "order a multiple of more efficient". "I'm not against hydrogen as an energy storage medium at all", Fichtner stated. "We just should make use of it where it makes sense – and that's not in the car, but in the stationary area."

When compared to conventional combustion-based technologies, fuel cells can operate at higher efficiencies than combustion engines and can convert the chemical energy in the fuel directly to electrical energy with efficiencies capable of exceeding 60 per cent (Source: US Department of Energy).

Jogchum Bruinsma, Nedstack sales engineer/ application manager maritime.



In the fuel cell stacks, hydrogen and oxygen from air react and produce electricity, heat, and pure water. The hydrogen supply is controlled by the pressure over the fuel cell stacks, which varies in off-take due to load variations. A flow control valve is used for purging any contamination that might build up in the hydrogen stream. A pressure relief valve ensures safe operation, as often high-pressure storage is used to feed hydrogen. The air is humidified to maintain the right circumstances a within the fuel cell stacks and is controlled by the actual load. As the electrochemical reaction between hydrogen and electricity is exothermic, heat is generated which need to be disposed to keep the fuel cell stacks at ideal operating temperatures. To prevent cross contamination with external cooling systems, the cooling circuit is split into a primary stack cooling circuit and a secondary external circuit.

Maritime applications

Last year, Nedstack received an order to supply and install - in conjunction with the company Koedood Marine Group - a complete PEM fuel cell system to retrofit an inland container vessel. The PEM fuel cell system, to be installed in the cargo space of the vessel, has a capacity of 900 kW capacity to supply propulsion and auxiliary power. The 110m x 11.45m inland container vessel has already been retrofitted and is planned to be zero-emissions and hitting the water powered 100 percent by hydrogen power by the end of this year.

Although this feat is an encouraging sign, it is too early to speak of a breakthrough in maritime applications. In several markets, for example in the tugboat market or in container shipping (pre-COVID), there is severe price competition. Only if certain solutions save on operational cost, shipping companies would be open to invest in new technologies, Bruinsma states. “Admittedly, seaports, which usually have public participation, have put carbon footprint reduction on their agenda which ideally should facilitate the uptake of low(er) carbon technology. However, in general the emphasis on price remains key so if shipping companies are allowed to run on the cheapest form of diesel they wouldn’t change to cleaner fuels.”

Technical challenges

As for even larger scale applications in the maritime domain, there are also technical and infrastructural challenges that need to be addressed, Bruinsma states. “Large bulk carriers or container ships require massive amounts of energy. Then you are talking about 15 MW fuel cell power and substantial amounts of hydrogen, which requires more frequent bunkering operations compared to fossil fuel powered vessels. Having stated this, fueling up could take place at offshore wind farms that are producing hydrogen. There are currently several pilots planned to produce green hydrogen generated by offshore wind electricity.”

Another issue is related to the supply of green hydrogen. At the moment, more than 95 per cent of hydrogen is produced via fossil fuels.

Offshore wind

Companies like Nedstack can develop fuel cell technology but the end users will need a steady hydrogen supply to power their fuel cell stacks in a sustainable manner. Bruinsma does see a role for offshore wind/hydrogen production. “When transporting large amounts of energy via a pipeline/cable over larger distances, hydrogen is more cost-competitive than electrons. This especially accounts for scaling up. In case of electrons, one needs to increase the cable diameter. In case of hydrogen, these adaptations are less costly.”

Bruinsma also sees opportunities for fuel cell technology on-site of offshore wind farms. “Wind farms tend to generate excess capacity which is difficult to store in batteries given their limited capacity. By storing hydrogen, one can harness this energy and convert it into highly valuable electricity during peak hours.”

Temperature and humidity are two important interconnected factors in the performance of PEMFCs (Proton Exchange Membrane Fuel Cells). As hydrogen is dry, it needs to be humidified and warmed and not compressed to facilitate an optimal process. Managing temperatures is also crucial for the PEM-process: roughly 90 per cent of the heat is being transferred to the cooling water, which is led through a heat exchanger, keeping the cooling stack water temperature at a constant.