

ENGINEERING  
TOMORROW

*Danfoss*

## Hydrogen

fuel cells for  
electric mobility

Case story | VACON® NXP DC/DC Converter  
VACON® NXP Grid Converter

# Fuel cells for **electric transportation of the future**

Nuvera Fuel Cells solutions successfully support many applications such as replacing battery packs of electric forklifts, converting big port trucks from diesel to hydrogen, and electrical mobility for buses.

In the innovative laboratory of Nuvera Fuel Cells, the Danfoss VACON® NXP series contributes to evaluating the performance of E-45 and E-60 fuel cell engines for electrical mobility under authentic conditions.





Paolo Zucchi, Engineering Manager of Nuvera Fuel Cells, explains:

*"In Nuvera, we have developed solutions for electrical mobility based on fuel cells with compact engines providing 45 kW and 60 kW net power output, making them very appealing for mobility applications. In order to optimize these products and guarantee a maximum level of reliability, we've decided to run long-term durability testing on our fuel cell engines in an experimental laboratory located inside the industrial site of SIAD S.p.A., near Bergamo, Italy, where hydrogen is produced. Our new lab infrastructure will give us the possibility to optimize our products on the basis of power cycles simulating the real vehicle application of our final customers."*

Fuel cells are heavily penetrating the electrical transportation market at different levels, in particular high-power vehicles such as buses, delivery vans, trucks and port equipment. These applications require high-reliability components and must be able to perform, even under the most demanding environmental conditions.

The aim to achieve maximum reliability and efficiency led Nuvera Fuel Cells to develop an innovative laboratory to

stress its fuel cell products designed for the mobility market.

Nuvera Fuel Cells is a subsidiary of the Hyster-Yale Group focused on power generation module development made from on PEM (Proton Exchange Membrane) fuel cells. Fuel cells based on metal bipolar plates rather than graphite ones guarantee better performance in terms of efficiency, robustness and volume.

#### **A laboratory in a container**

To create an experimental lab infrastructure directly connected to the SIAD hydrogen production plant, Nuvera Fuel Cells decided to engineer a container capable of hosting up to eight power generator engines during testing.

Paolo Zucchi says: *"It hasn't been an easy task to fit everything we needed inside a container. We wanted eight test benches, flexible and independent from each other, capable of safely running 24 hours a day, 7 days a week, under authentic conditions. The necessary hydrogen is taken through a dedicated piping from the SIAD production plant next to it, properly regulated and then distributed inside the container to the eight power generator engines, compliant with the applicable safety standards. The most demanding task of the project has been the one related to the power management.*

*We were looking for AC drives that were not only compact enough to fit inside the limited available space but also flexible and most importantly, suited for this application. In fact, since we had to fully test the behavior of our products, we didn't want to manage uncertainties or issues related to the electrical power equipment while running the tests. We found the solution in the Danfoss AC drives family, which had already been used with great satisfaction by our colleagues in Hyster-Yale in The Netherlands. They used AC drives to develop a solution for converting a diesel port truck into a fuel cell-powered one."*





## Sustainable test procedures thanks to energy recovery

The task of the power control within the Nuvera Fuel Cell experimental laboratory is twofold: on the one hand, it must adapt voltage level delivered by the fuel cells, which varies according to the power of the load and current delivered. On the other hand, it must guarantee the full energy recovery of the electricity generated during the test cycles, returning it to the grid. "Energy sustainability was another essential requirement of the project," underlines Fabio Nassi, who is the electrical engineer that followed the project for Nuvera, "therefore,

*thanks to the expert support of Danfoss Drives engineers, we have developed a configuration for maximum flexibility in defining the test cycles to which our generator modules are subjected as well as the complete recovery of the produced energy."* The same solution is replicated eight times, once for each fuel cell.

Each test station is independent from the others and the test equipment allows Nuvera to test both 45 kW and 60 kW generator modules, as well as any other Nuvera Fuel Cells developed in the future with the same class.

## Complete plug-and-play delivery

The electrical cabinets were supplied directly by Danfoss, who oversaw construction and commissioning together with its partners. "A single point of contact for the construction of the electrical panels was of great advantage. Danfoss Italy proved to be of great help during the optimization phase of the project, but they also took care of the practical implementation, delivering electrical cabinets already tested and installed in plug-and-play solutions to the construction site", comments Mr. Zucchi. "Furthermore, since all the AC drives are of the same range, we were able to use the same programming and management environment for their configuration and monitoring, with a clear saving in training time."

## A successful partnership

Nuvera Fuel Cells' new laboratory has been commissioned and as soon as the connection to the grid is completed, it will run continuously. The lab will perform tests on fuel cell engines solicited with power cycles typical of bus applications, in order to

evaluate their long-term performance under authentic conditions. The practical container concept makes this lab infrastructure usable for other purposes.

The same kind of solution can be used to test an energy accumulation system,

Dario Rudellin, Business Developer within energy in Danfoss says:

**"The system is really flexible and based on VACON® NXP drives platform architecture exploiting it in its entirety. A DC Bus was conceived for energy exchange between power users. The output of each fuel cell generator module is connected to a VACON® NXP DC/DC Converter, which boosts the output DC bus voltage around 670 V, regardless of the instantaneous output voltage level of the fuel cells. A VACON® NXP Grid Converter is connected to the same DC bus with the aim of regenerating towards the national electricity grid, according to the Italian grid code CEI 0-16. A third VACON® NXP DC/DC Converter has been selected for supplying a compressor used for the fuel cell".**

based on hydrogen as a vector. This system can be connected to an electrolysis production system powered by renewable energy, thus optimizing the electrical energy generation and achieving zero-emission distribution.

Mr. Paolo Zucchi concludes: "We know Danfoss VACON® NXP drives to be a robust product because of Danfoss' successful history in the electrification of naval applications and they have satisfied our expectations. Above all, the experimental lab project is concrete evidence that the excellent collaboration among all partners involved, also at a personal level, let us reach the expected results within the given time frame.

Thanks to this new lab infrastructure, we can show our customers the excellent performance and reliability of our fuel cell engines, which are developed with our most advanced patented technologies."





## A better tomorrow is **driven by drives**

Danfoss Drives is a world leader in variable speed control of electric motors. We offer you unparalleled competitive edge through quality, application-optimized products and a comprehensive range of product lifecycle services.

You can rely on us to share your goals. Striving for the best possible performance in your applications is our focus. We achieve this by providing the innovative products and application know-how required to optimize efficiency, enhance usability, and reduce complexity.

From supplying individual drive components to planning and delivering complete drive systems; our experts are ready to support you all the way.

You will find it easy to do business with us. Online, and locally in more than 50 countries, our experts are never far away, reacting fast when you need them.

You gain the benefit of decades of experience, since 1968. Our low voltage and medium voltage AC drives are used with all major motor brands and technologies in power sizes from small to large.

## NUVERA<sup>®</sup>

### Nuvera Fuel Cells

Nuvera Fuel Cells, LLC is a manufacturer of heavy-duty, zero-emission engines for mobility applications. With teams located in the U.S., Europe, and Asia, Nuvera provides clean, safe, and efficient products designed to meet the rigorous needs of industrial vehicles and other transportation markets.

As a subsidiary of Hyster-Yale Group, a global lift truck and aftermarket part manufacturer, Nuvera has a unique place in the fuel cell industry, with a worldwide presence and the capabilities of an established vehicle OEM.

A proprietary stack technology is at the core of Nuvera<sup>®</sup> fuel cell engines. Performance and efficiency result from unique technology innovations.

As a long-established and specialized PEM fuel cell systems developer, Nuvera's engineering teams bring extensive experience in both fuel cell stack design and hybrid fuel cell powertrain development. Its predecessor companies offer over 90 years of innovative electrochemical technology development background that Nuvera has built on to deliver competitive commercial products.

Nuvera Fuel Cells Europe is a division of Hyster-Yale Italia S.p.A. with engineering offices in san Donato Milanese (MI) and a laboratory inside the SIAD plant of Osio Sopra (BG).