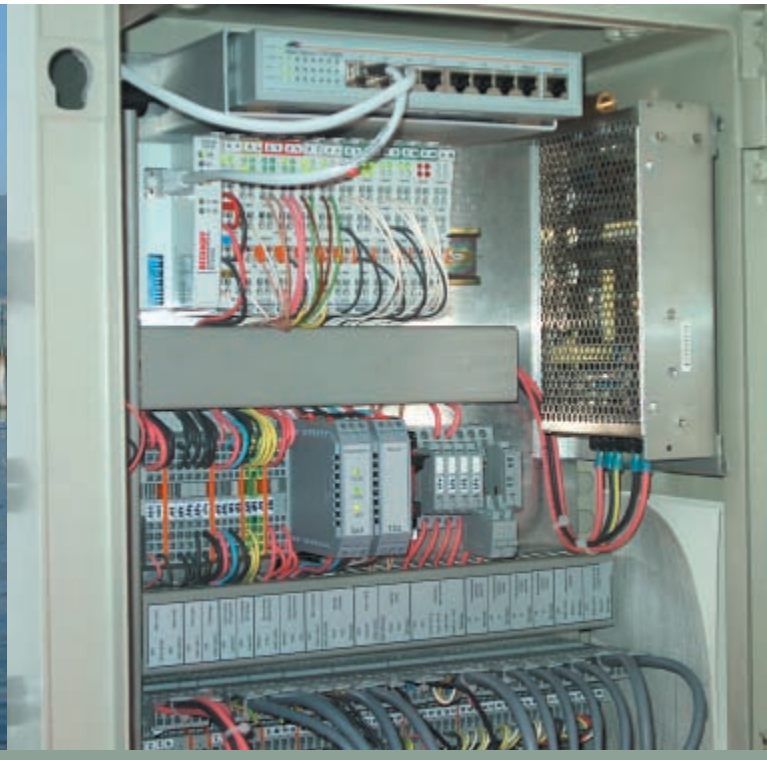
Environmentally-friendly technology for water transportation.

The BC9000 Beckhoff Ethernet controller controls the motor of the future.



The Institut Energie et Systèmes Electriques at FH Yverdon (EIVD) has been testing fuel cells under practical operating conditions since 1997. One interesting example is the Hydroxy3000 electric boat featuring a 3 kW fuel cell. The aim of this project is to test fuel cells for inland water transport and to examine whether they are a realistic alternative to the internal combustion engines currently used on lakes and canals.

Electric boat features hydrogen fuel cell

The Hydroxy3000 is a catamaran with a length of 7 m, a width of 2.5 m, and an unladen weight of 1.5 t. Both hull parts are equipped with a 3 kW electric motor. The fuel cell is the main source of energy. Batteries balance the energy supply and serve as an energy reserve in case of problems. The boat can carry seven passengers and travel at a speed of approx. 11 km/h.

The fuel cell is supplied from a 76-liter (200 bar) hydrogen bottle. It drives two propellers via two 48 V DC motors that are electronically controlled from the bridge. Since each hull is equipped with a control system, the boat is exceptionally maneuverable. The hydrogen bottle and the fuel cell are located in separate, naturally ventilated compartments. Vibration and hydrogen sensors can shut down the hydrogen system in the event of problems. In such an emergency, auxiliary batteries ensure that the boat remains maneuverable and can return to its base.

The boat features a display that is connected to a GPS device and shows the speed, the course, the motor output and the remaining energy supply. The complete system is controlled via two independent BC9000 Bus Terminal Controllers: one controls the fuel cell, the other controls the boat. All parameters controlled by the sensors are monitored via a laptop that can also carry out detailed data measurements.

The water-cooled 3 kW fuel cell consists of 73 individual cells supplying about 60 A at a variable voltage between 40 and 60 V. A heat exchanger dissipates the heat from the primary cooling system to the lake via a secondary system. The fuel cell supplies energy to the motors and to a 200 Ah/48 V auxiliary battery. This battery has such dimensions that it does not require control electronics. It is charged during times of low motor load. During times of high load, it supplies additional drive power.

Small controller monitors boat parameters and controls fuel cell

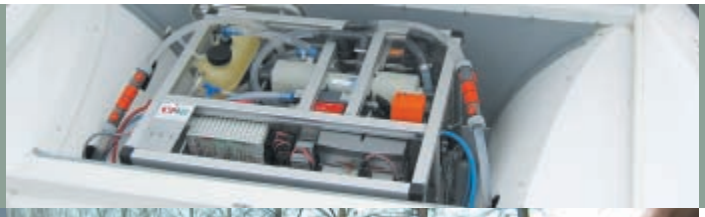
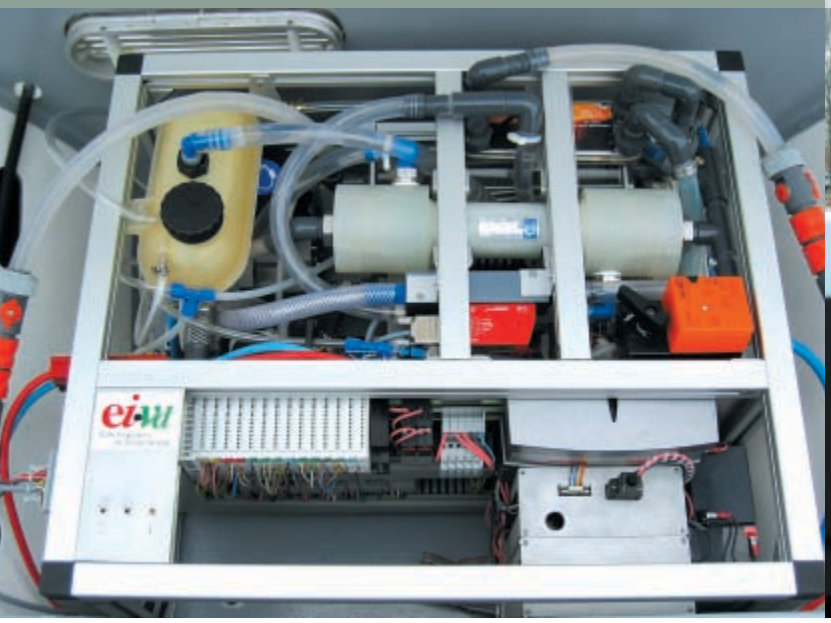
Separate Bus Terminal Controllers with associated I/O terminals are used for controlling the boat and the fuel cell. Both controllers are networked via an Ethernet connection.

A BC9000 Ethernet controller monitors the boat parameters. It provides safety parameters in the event of problems with the electrical system and alarms indicate malfunctions. The BC9000 also communicates with the boat control system. The following parameters are measured: Battery current and voltage, motor current, motor and battery temperature, speed, course and position of the boat (GPS). Hydrogen concentration in the fuel cell compartment, the bottle compartment and the cabin are also measured. These parameters inform the captain about the energy flow between the fuel cells, batteries and motors, the speed of the boat, any hydrogen leaks, etc. Via the control interface, the captain can switch over the power supply (fuel cell, motor), switch on the motor or the position lights, etc.

The second BC9000 controls all main fuel cell parameters, i.e. temperature, air and water supply and discharge, moisture content and pressure of the supply air, air and hydrogen flow, hydrogen pressure in the bottle and at the fuel cell inlet, overall voltage of the fuel cell, current generated, and voltage of the individual cells. Depending on these parameters, the Ethernet controller determines the optimum operating conditions for the fuel cell and influences the different components involved in the operation of the fuel cell, i.e. air compressor, hydrogen return flow compressor, cooling water valve and valve for controlling the moisture content of the supply air, cooling water pumps, main hydrogen supply valves, and outlet valves for the hydrogen circuit. The control voltage of the two compressors is modified via DC/DC converters.

Advanced, environmentally-friendly power generation via fuel cells has clear advantages in terms of energy efficiency and emissions reduction compared with "classic", thermal technologies. The technology points to a particularly promising future for inland water transport involving small to medium-sized boats, because it generates no water or air pollution/smells and creates relatively little noise. The technology will certainly become much more prevalent as the price of developing the technology continues to be reduced and as the rapidly evolving market begins to mature.

→ FH Yverdon, Institut Energie et Systèmes Electriques **www.eivd.ch**
→ Beckhoff Switzerland **www.beckhoff.ch**



Fuel cell with BC9000 for process control.