Fuel Cell Characterization with LXI Instruments

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Renewable energy is one of the world's fastest-growing energy sources. In the automotive industry, the ever-increasing costs of gasoline and diesel, as well as growing environmental concerns from greenhouse gas emissions are driving the rapid deployment of alternative renewable energy sources such fuel cell technology.

Fuel cell technology utilizes hydrogen and oxygen to produce direct current (DC) electrical energy with very little or no harmful emissions and no need to recharge. Fuel cell vehicles can use pure hydrogen or extract it from a secondary fuel such as methanol, ethanol, or natural gas that contains hydrogen. Figure 1 is a block diagram of a Proton Exchange Membrane (PEM) fuel cell that uses pure hydrogen as fuel.

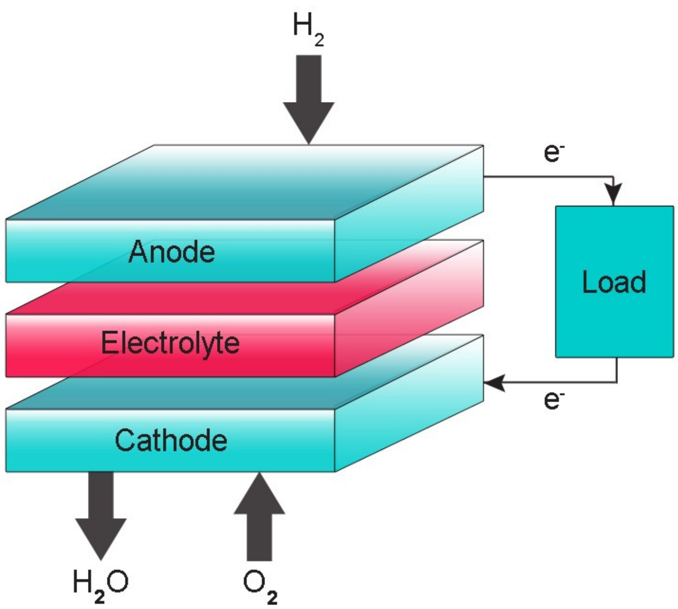

Figure 1 - Block Diagram of PEM Fuel Cell

Hydrogen (H_2) is provided to the anode while oxygen (O_2) is supplied to the cathode. At the anode, hydrogen breaks down into electrons and protons. The electrons pass through an electric circuit to provide power to a load while the protons pass through the electrolyte material to the cathode. At the cathode, electrons and protons combine with oxygen and produce water (H_20).

A single fuel cell produces a voltage of approximately 1 V. Therefore, to deliver the desired amount of energy, several fuel cells can be combined in series or parallel circuits. This is called a fuel cell stack. Figure 2 shows a diagram of GM’s HydroGen4 fuel cell vehicle using a fuel cell stack as the energy source.

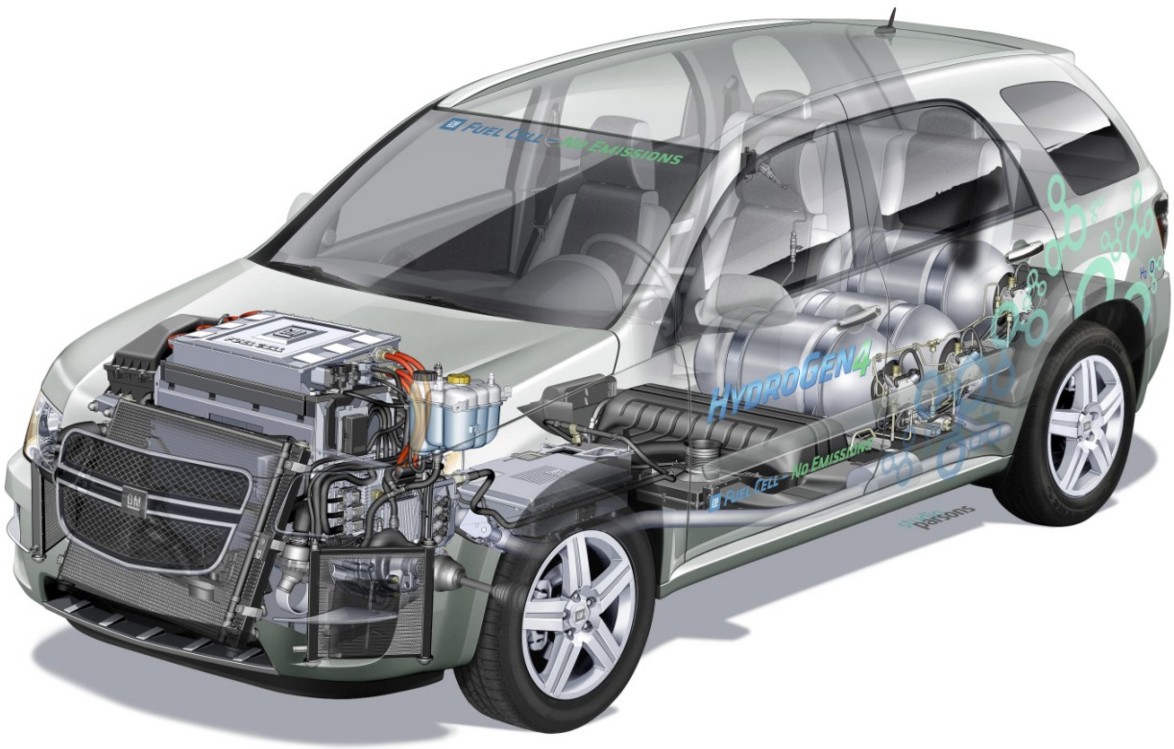

Figure 2 - Diagram of GM's HydroGen4 Fuel Cell Vehicle © General Motors

Fuel Cell Characterization Using LXI Instruments

During research and development, fuel cell testing is performed to characterize the fuel cell's energy output and optimize the design to maximize energy output and efficiency. Characterizing fuel cells involves applying a current or voltage input and observing the response. Characterization requires multi-channel measurements to be made under variable loads and controlled environmental and gas conditions.

LXinstruments fuel cell test system shown in Figure 3, uses Agilent's L4534A LXI (LAN eXtensions for Instrumentation) digitizer with four differential floating inputs to provide the multi-channel measurement capability required. The LXI digitizer provides 20 MHz simultaneous acquisition with floating AC coupled measurements for increased resolution. Agilent's N3302A electronic loads, modulated with the Agilent 33220A LXI arbitrary waveform generator, are used to provide synchronized, variable load conditions.

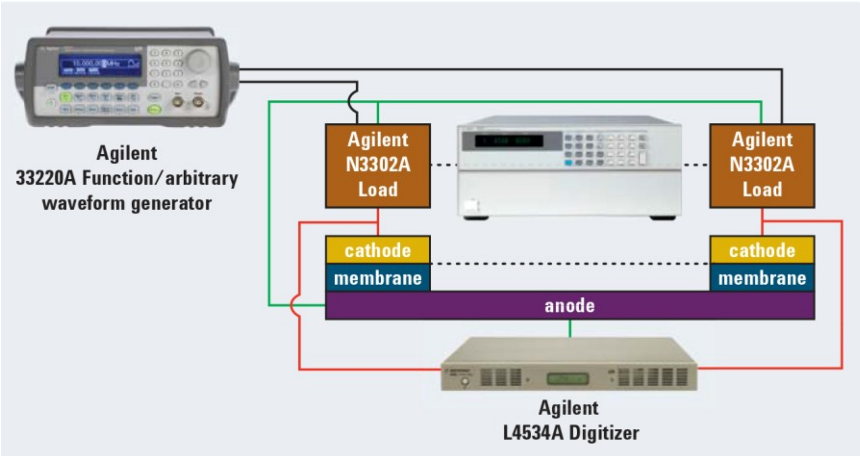

Figure 3 - LXInstruments Fuel Cell Test System with Agilent's LXI L4534A Digitizer Used to Test Segmented Fuel Cells

The LXI connectivity provided by the L4534A digitizer allows communication between the system and the controlling computer over industry standard Ethernet LAN. This supports the fast transfer of the large blocks of data necessary to calculate the frequency and phase response of the individual fuel cells.

Electrochemical Impedance Spectroscopy (EIS)

EIS is a method used to measure the complex impedance characteristics of fuel cells. EIS involves applying a small AC current to the cell, to ensure that the response is pseudo-linear, and measuring the resulting voltage and phase angle. The response is an AC voltage signal that is out of phase with the applied current and can be analyzed by calculating the complex impedances and plotting them against one another at different input frequencies. Figure 4 shows an example of the analysis of the impedance response displayed with NyQuist plots that provides insight into the cells characteristics.

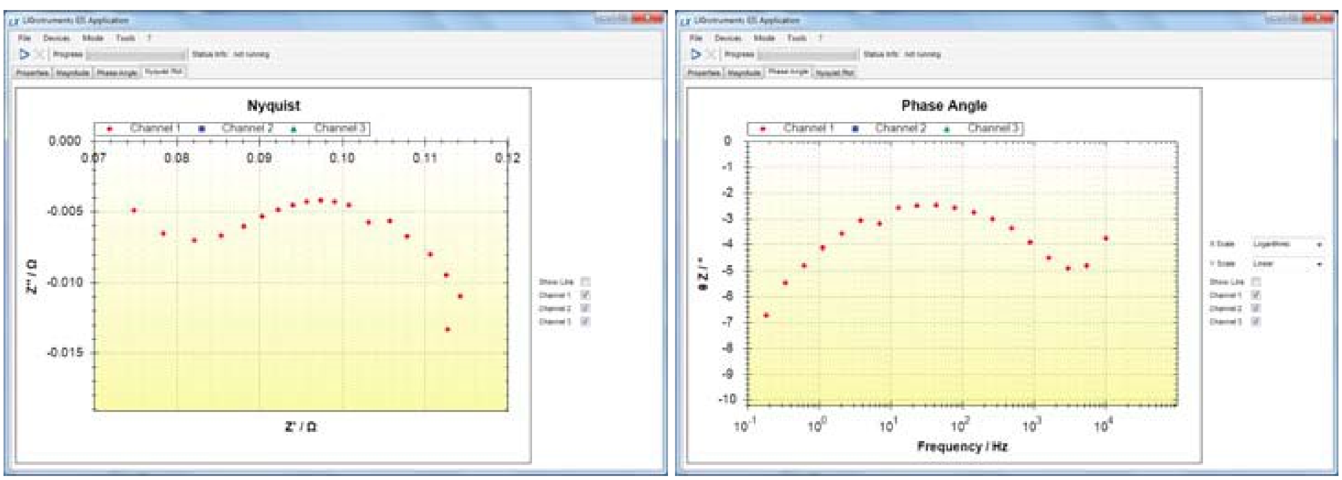

Figure 4 - NyQuist Plots of Complex Impedances from EIS Measurements

EIS measurements have traditionally required specialized test equipment that is high cost and limited in channel count. The LXinstruments fuel cell test system uses standard LXI instruments from Agilent Technologies together with proprietary software to provide a fully modular and affordable system for making electrochemical impedance spectroscopy measurements on fuel cells. By standardizing and extending LAN, LXI offers the advantage of remote testing capabilities and fast block data transfer rates for efficient analysis of measurement data.

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