KOHLER

Performance and Rating of *Hydrogen Fuel* Cell Applications

AUTHOR
BEN CRAWFORD
Manager–Business Development at
Kohler Power Systems

Kohler Co.
Kohler Energy Division

INTRODUCTION

While conventional fossil fuel-based generators remain the preferred solution for energy resilience, interest in alternative fuels such as hydrogen has increased dramatically for stationary emergency and prime applications.

For operators especially focused on solutions that provide zero emissions at the point of use, fuel cell technology can be designed and manufactured to the same operational standards of conventional generators.

SYSTEM TOPOLOGY—FUEL CELL TECHNOLOGY

A fuel cell is an electrochemical cell that converts the chemical energy of a fuel and an oxidizing agent into electricity through a pair of reactions. Fuel cells continuously produce a DC voltage for as long as fuel and oxygen are supplied, and there is no combustion.

Fuel cells are classified primarily based on the electrolyte used. As a result, different types of fuel cells use different catalysts, operate at different temperatures, and accept different fuels. These differences determine the suitability of a particular fuel cell type for a given application.

SOLID POLYMER ELECTROLYTE MEMBRANE FUEL CELL

For stationary emergency and prime power applications, start-up time is most critical. Solid polymer electrolyte membrane fuel cell (PEMFC) technology is most suitable because of the ability to start quickly. While PEMFC has been available in the market for several years in on-road applications, the use of the technology in stationary power generation is just beginning. Additionally, this fuel cell requires pure hydrogen.

PEMFC are typically manufactured as self-contained systems that include components for air supply, hydrogen supply, cooling, and power control into a single compact module. For reference, this module would be considered the engine in a conventional generator.

Modules currently available on the market are typically less than 100 kW each, so to increase the total power output of the fuel cell power system, the modules can be aggregated to the desired scale. When used in stationary power applications, the fuel cell module is integrated with other components to ensure the power system provides energy on demand.

The similarities and differences of system topologies between a conventional generator and a fuel cell generator are shown in Figures 1 and 2.

Figure 1

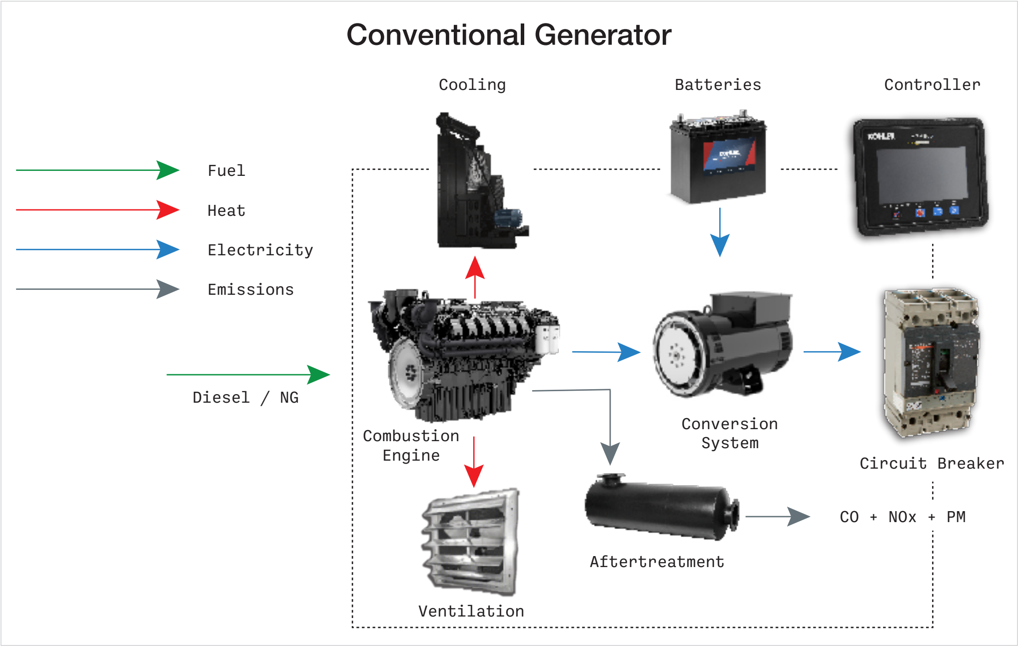
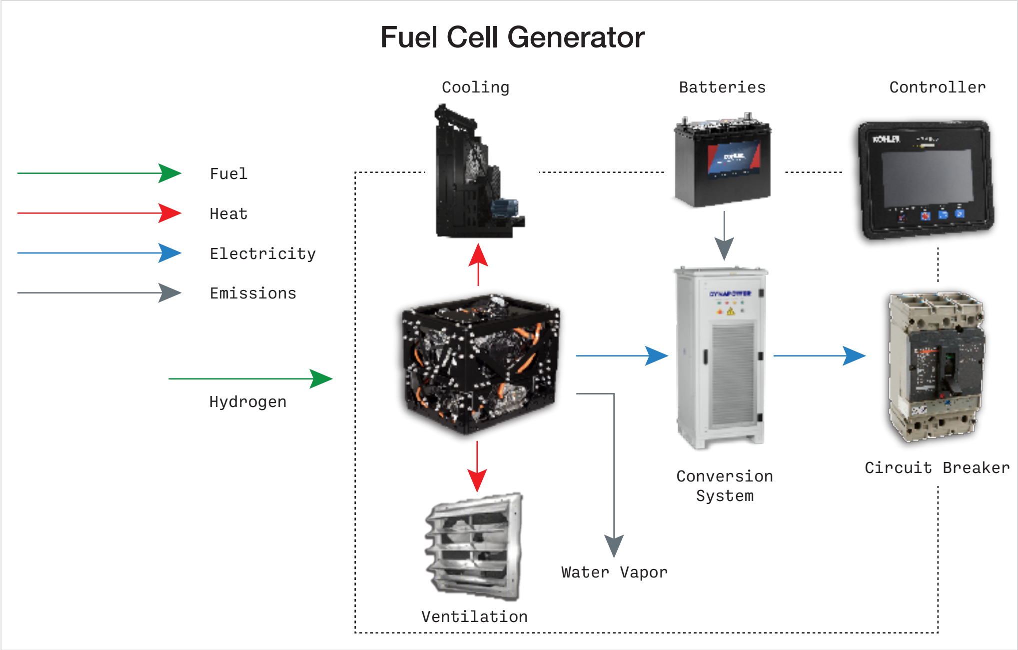


Figure 2



COOLING

ELECTROCHEMICAL PROCESS GENERATES HEAT

A fuel cell's electrochemical process of using hydrogen and oxygen to produce electricity generates heat. (For PEMFC, the heat generated is of low efficiency and not beneficial combined heat and power (CHP) applications.)

Like an internal combustion engine, the fuel cell modules contain a cooling circuit in which a liquid coolant circulates to cool the module. The cooling connections from the fuel cell modules are then connected to a heat exchanger, also known as a radiator. To maintain optimal operating conditions, a fan is sized appropriately to discharge the heat into the atmosphere.

For cold weather conditions, an enclosure heater may be installed to maintain optimal performance for components within the power system enclosure. Kohler adheres to the standards set by NFPA 110, which requires temperatures in outdoor enclosures to be at least 40°F (4°C).

BATTERIES

DC POWER TO START

Internal-combustion engines require DC power from batteries to rotate (crank) the engine via a starter solenoid. Similarly, a fuel cell module requires DC power to start the various components that allow the electrochemical process to begin producing electricity. To provide adequate DC power, a starting battery is used. Conventional lead-acid batteries are an inexpensive and proven starting power solution, but advancements in lithium-ion batteries provide an alternative solution.

POWER-CONVERSION SYSTEM

PEMFC PROVIDE DC OUTPUT

Like a conventional generator, the fuel cell or engine is not the only component required to deploy a reliable source of power. PEMFC modules output a DC voltage, so a series of power electronics components such as a DC-DC converter, DC-AC inverter, and transformer are integrated to output the desired voltage and frequency for the region of installation.

SUPERVISORY CONTROL

METERING, CONTROL, AND DIAGNOSTICS

A supervisory control system provides metering, control,and diagnostics for the fuel cell power system. The controller uses software logic to manage start-up, shut down and fault conditions.

Additional features often include tactile buttons or a touch screen to provide access to local data and manual operation as well as MODBUS / TCP-IP to transmit data from a building management system (BMS).

ADVANCED LOGIC

Advanced logic can be included that allows the fuel cell power system to parallel with a utility connection or export power.

Kohler uses tested and proven controller technology originally built for conventional generators.

SAFETY

SAFE DISTRIBUTION OF OUTPUT POWER

A circuit breaker is included in the fuel cell power system to provide electrical protection and safe distribution of the output power. Like conventional gaseous generators, safety shutoff valves are included in the fuel cell power system to stop the flow of hydrogen. Additionally, PEMFC modules contain sensors for detecting unexpected hydrogen release.

CODES AND STANDARDS

There are codes and standards for the safe design and installation of fuel cell power systems. NFPA 853 specifies installation criteria while NFPA 2 provides provisions for the generation, installation, storage, piping, and handling of liquid and gaseous hydrogen. Similar to how UL2200 applies to conventional stationary engine generator assemblies, CSA/ANSI FC1 specifies the safe design and operation of stationary fuel cell power systems.

MAINTENANCE

Maintenance of fuel cell systems is considerably less than conventional systems because there are fewer mechanical components that can fail.

SERVICE POINTS

There are two primary components that require interval service: the air filter and the ion exchange filter. Like combustion engines, the fuel cell air filter keeps dirt and debris out of the system.

To ensure a robust running system and to avoid electric shorts, the electrical conductivity in the fuel cell stack must be kept low. By using an ion exchange filter, ions, which are released by several components in the fuel cell coolant circuit, are separated. After several hundred hours, the ion exchanger filter must be replaced.

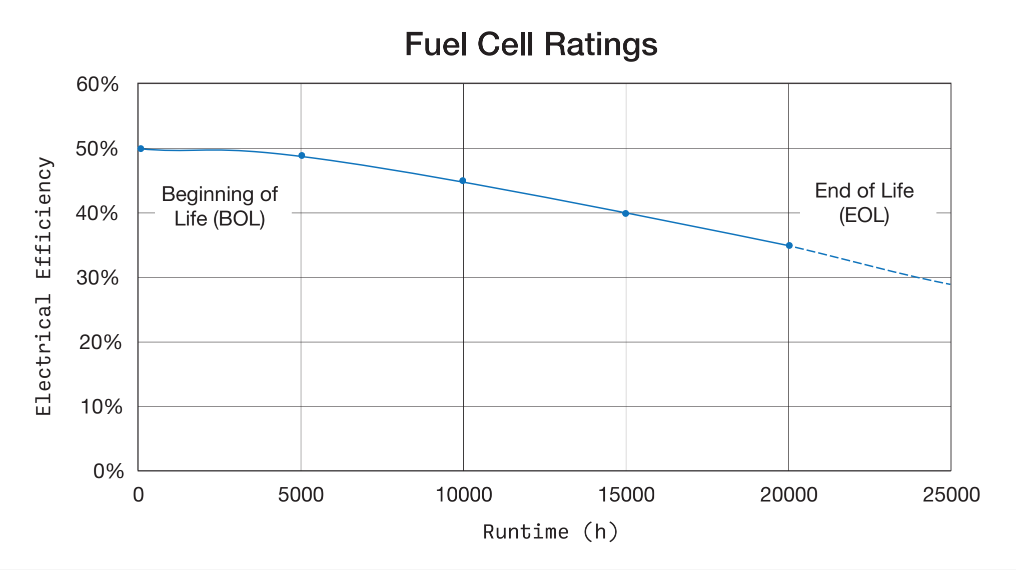
FUEL CELL STACK DEGRADATION

Internal-combustion engines lose efficiency as fuel deposits develop on injectors and as mechanical components age. While fuel cells do not have injectors, the stack, or the series of plates that generate electricity, degrades over time lowering electrical efficiency.

FUEL CELL LIFE SPECIFICATIONS

As shown in Figure 3, this degradation is correlated with the hours of operation of the power system, with a loss of total output power of approximately 15% every 20,000 hours. Therefore, fuel cell systems specify beginning-of-life (BOL) and end-of-life (EOL) power ratings.

Figure 3



FUEL CELL RATINGS

Given the degradation of the fuel cell stack and the load required by the balance of plant (BOP) components, power system specifiers should be aware of actual lifetime output power.

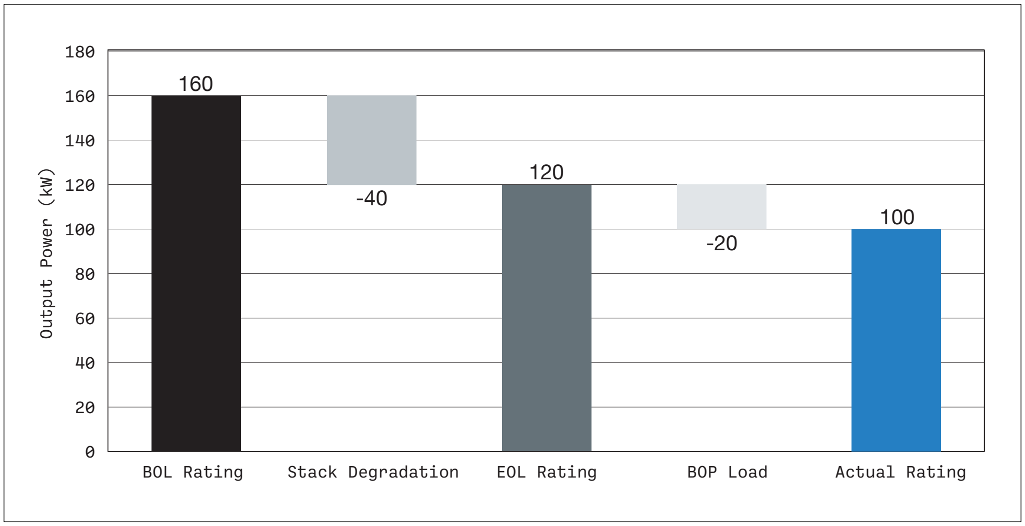
PARASITIC LOAD

As shown in Figure 4, the parasitic load on an example system must be considered in addition to the stack degradation. An accurate rating of a 160 kW fuel cell system is 100 kW.

Furthermore, transparency from manufacturers is important for system sizing. A fuel cell power system may be rated with the combined battery and module power, which would only be the system rating for a short period of time.

At Kohler, the power rating for our hydrogen fuel cell-based power systems is the actual (net) power throughout the total life of the product, so you can be sure that you receive the power you require from the first hour to the last.

Figure 4



ECONOMICS

Fuel cell technology is currently more expensive than conventional power generation solutions, but as the market expands and economies of scale develop, prices will decrease.

ECONOMICAL APPLICATIONS

Today, the most economically attractive applications for hydrogen fuel cell modules are in material handling, such as forklifts.

Mobility applications such as buses, trains, medium and heavy-duty trucks, and even some larger consumer vehicles such as SUVs are starting to adopt this technology.

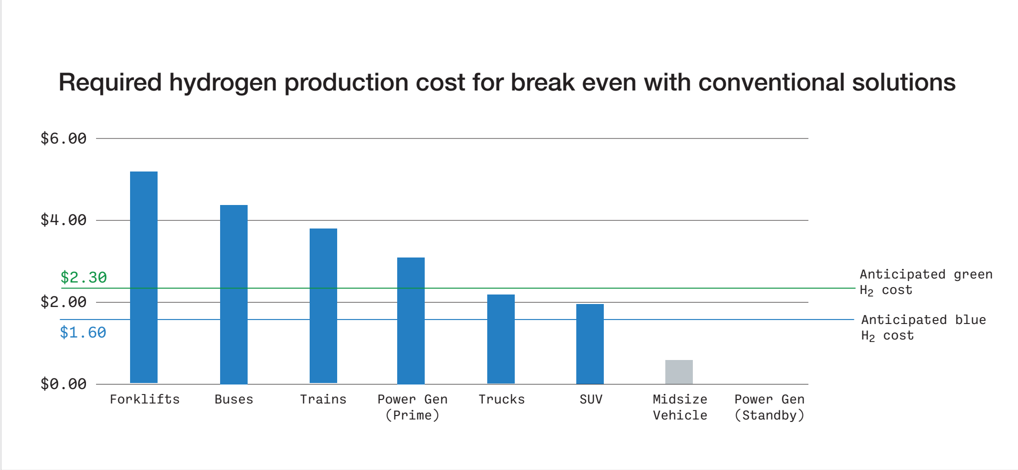
NEW APPLICATIONS

Hydrogen fuel cell modules used for power generation are more nascent, but like mobility applications, a duty cycle in which the system is operated more frequently (such as prime) is more economical.

Figure 5 illustrates the applications in which hydrogen fuel cell technology are more economical (shown in blue) and less economical (shown in gray) based on the price of hydrogen per kilogram.

When fuel cell technology is combined with an attractive price for hydrogen fuel, the total cost of ownership of a fuel cell-based system is competitive with conventional solutions apart from midsize consumer vehicles and fuel cell power generation limited to emergency-only operation.

Figure 5



ECONOMICS CONT.

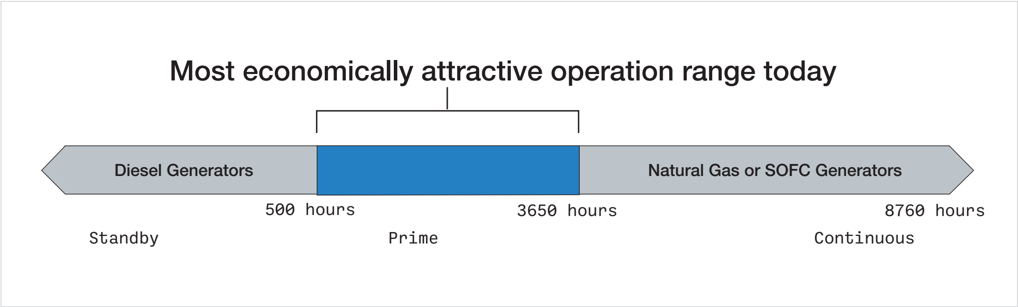
When comparing conventional and hydrogen fuel cell technology for power generation, some options are more economically attractive than others depending on the intended runtime. Diesel generators remain the economically preferred solution for applications operating for less than 500 hours annually, however, the majority of standby diesel generators do not operate more than 100 hours per year. Above 100 hours requires Tier 4 emissions in the U.S. and Canada.

Conversely, for applications operating more continuously up to 8,760 hours per year, solid oxide fuel cell (SOFC) technology is preferable in addition to its benefits in combined CHP applications.

PEMFC AS AN ECONOMIC SOLUTION

As shown in Figure 6, PEMFC fills the gap between the two technologies and provides an economically viable solution for applications that require more frequent and flexible operation.

Figure 6



ENVIRONMENTAL IMPACT

While it's important to understand the economics of fuel cell technology, the main driver of adoption today is the environment. Many customers are willing to pay a higher acquisition cost over conventional solutions to receive a hydrogen fuel cell-based solution that produces no emissions at the point of use.

FUEL CELL APPLICATIONS

Market segments currently most interested in the environmental benefits that hydrogen fuel cell-based power systems have to offer are mission-critical, utility grid support, ports, and electric vehicle (EV) charging.

DATA CENTERS

Data centers are leading market adoption as they attempt to decarbonize their operations, including the replacement of diesel generators for emergency backup. Health care organizations, water treatment plants, and manufacturing facilities, among others, can all benefit.

ADDED MICROGRID CAPACITY

Hydrogen fuel cell-based power systems can support the utility grid by replacing and expanding peaking plant capacity and as a distributed energy resource (DER) within microgrid networks. Due to the scale required in these applications, regions where there is access to high volumes of cheap, renewable hydrogen will especially benefit from using fuel cell-based technology.

SEAPORT OPERATIONS

Ports are also focused on the decarbonization of their operations because of their proximity to city centers. Adoption of fuel cell-based port equipment such as gantry cranes, top pick handlers, and forklifts has already begun, but shore power is another beneficial use case.

As vessels become larger, the ability for the existing utility grid connection to provide the required energy capacity while at berth is becoming challenging. Investments in infrastructure to support additional energy capacity at ports require significant funding and time, often protracted beyond emissions targets. Therefore, hydrogen fuel cell-based shore power systems can provide peak capacity that cannot be provided by the utility grid. The output power is routed through new or existing electrical shore power connections that provide power to a vessel while at berth.

EV CHARGING CAPACITY

Energy capacity challenges with the utility grid are also impacting EV charging stations. Organizations that operate a large fleet of EVs are constrained by the available capacity from the utility grid, so fuel cell technology can complement the existing infrastructure by providing peak capacity power on demand.

SUMMARY

While there are significant differences in how a combustion engine and a fuel cell convert fuel to energy, an integrated power system using either component is similar. Despite the economic and hydrogen fuel supply constraints that exist today, fuel cells offer a reliable source of power generation that has zero emissions at the point of use.

KOHLER'S FUEL CELL SYSTEM

As a global leader in conventional power generation solutions, Kohler has applied its world-class manufacturing and component integration expertise to develop a 100-kW stationary fuel cell generator, shown in Figure 7, with intentions to scale the systems to larger power ratings in the future. Combined with the extensive global network of distributors and dealers, Kohler can provide end-to-end support to ensure the system is designed and maintained to perform.

Figure 7

KOHLER 100-kW fuel cell

ABOUT THE AUTHOR

Ben Crawford is Manager—Business Development at Kohler Power Systems. He holds a bachelor of science degree in mechanical engineering from Iowa State University and an MBA from the University of Michigan Ross School of Business.

Ben has been with Kohler since 2016 and specializes in emerging energy technologies.

ABOUT KOHLER ENERGY

Kohler Energy, a global leader in energy resilience solutions, brings bold design and powerful impact to the energy systems that sustain people and communities everywhere around the world. It is an integral part of Kohler Co., with solutions across home energy, industrial energy systems, and powertrain technologies. With more than a century of industry leadership, Kohler Energy leverages the strength of its portfolio of brands – Power Systems, Home Generators, Kohler Uninterruptible Power, Clarke Energy, Heila Technologies, Curtis Instruments, and Engines.

Kohler Energy builds resilience and goes beyond functional, individual recovery to create better lives and communities. For more details, please visit please visit KohlerEnergy.com.

For more information, contact your KOHLER source of supply.
Or call toll-free in the U.S. and Canada 800-544-2444.

KohlerEnergy.com

PRINTED IN U.S.A. WF495691 G26-51 KPS 140 11/23