



GENCORE®5 FUEL CELL SYSTEM

System Fundamentals

GenCore 5T48
GenCore 5B48
GenCore 5U48
GenCore 5T24
GenCore 5U120

GENCORE DESCRIPTION

GenCore fuel cell systems are direct hydrogen fueled proton exchange membrane (PEM) fuel cell systems, designed specifically to provide back-up power to Telecommunications, Cable Broadband and UPS (Uninterruptible Power Supply) applications.

Designed to replace valve regulated lead acid batteries (VRLA) GenCore systems are a direct DC power source, which offer significant value to our customers.

The GenCore® 5 fuel cell system is a hydrogen fueled back-up DC power generator with a net power output of 5kW. The product is designed to provide back-up power for telecommunication, broadband, industrial, and utility applications. The following configurations are available:



- 5T48 - 48VDC output designed for direct DC buss interconnection in telecommunications wireline and wireless applications.
- 5B48 +48VDC output to interface with most widely available cable-broadband power nodes via battery DC link.
- 5U48 +48VDC floating ground output designed for industrial, utility, and backup applications.
- 5T24 +24Vdc output designed for direct DC buss interconnection in telecommunications wireline and wireless applications.
- 5U120 +120VDC output designed for industrial and backup applications. Available in both normal and floating ground configurations.

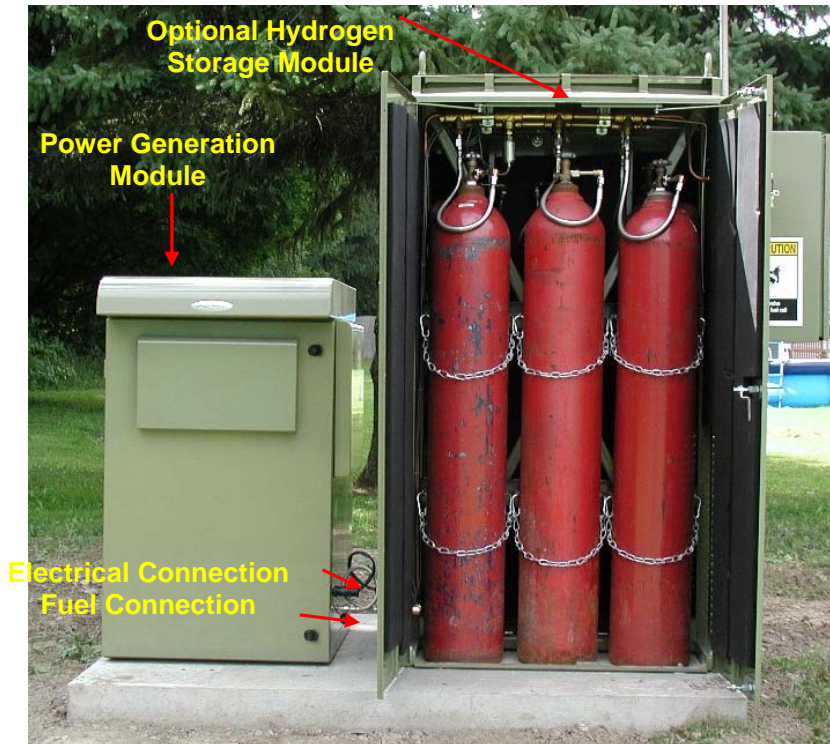


Figure 1: GenCore 5 Fuel Cell System with Optional Hydrogen Storage Module

GENCORE SPECIFICATIONS

Table 1 shows the specifications for the Gencore™ 5 fuel cell system.

Table 1: Fuel Cell System Specifications

PRODUCT CHARACTERISTICS			5T48	5B48	5U48	5T24	5U120	
Performance	Net Output ¹	0 to 5,000W	✓	✓	✓	✓	✓	
	Adjustable Voltage Output	- 46Vdc to -56Vdc	✓					
		+46Vdc to +56Vdc		✓	✓			
		+23Vdc to +28Vdc				✓		
		+125.9Vdc to 136.2Vdc					✓	
	Operating Range - Voltage	- 42Vdc to - 60Vdc	✓					
		+42Vdc to +60Vdc	-	✓	✓			
		+21Vdc to +30Vdc				✓		
		+125.9Vdc to 139.8Vdc					✓	
	Operating Range - Current	0 to 109 Amps	✓	✓	✓			
		0 to 218 Amps				✓		
		0 to 39.9 Amps					✓	
	Grounding	Normal	✓	✓		✓		
		Floating			✓		✓	
Fuel	Gaseous Hydrogen	99.95% (dry)	✓	✓	✓	✓	✓	
	Supply Pressure	80 +/- 16 psig	✓	✓	✓	✓	✓	
	Fuel Consumption	40 slm at 3,000W	✓	✓	✓	✓	✓	
		75 slm at 5,000W	✓	✓	✓	✓	✓	
Operation	Ambient Temperature	-40C to 46C	✓	✓	✓	✓	✓	
	Relative Humidity	0% to 95% non-condensing	✓	✓	✓	✓	✓	
	Altitude	-197ft to 6,000ft	✓	✓	✓	✓	✓	
Physical	Dimensions	44" x 26"W x 24"D	✓	✓	✓	✓	✓	
	Weight	500 lbs	✓	✓	✓	✓	✓	
Safety	Compliance	FCC Class A	✓	✓	✓	✓	✓	
		ANSI Z21.83	✓	✓	✓	✓	✓	
		UL	✓	✓		✓		
		Telcordia GR 63, 78,487, 1089	✓	✓		✓		
Emissions	Water	Maximum 2.0 liters per hour	✓	✓	✓	✓	✓	
	Co, CO2, NOx, SOx	<1ppm	✓	✓	✓	✓	✓	
	Audible Noise	60dba @ 1m	✓	✓	✓	✓	✓	
Sensors	Gas Hazard Sensor		✓	✓	✓	✓	✓	
	Pad Shear		○	○	○	○	○	
	Water Intrusion		○	○	○	○	○	
	Tampering		○	○	○	○		
Control	Microprocessor w/Diagnostics		✓	✓	✓	✓	✓	
	2 LED Alarm Panel		✓	✓	✓	✓	✓	
	Communication	RS-232		✓	✓	✓	✓	✓
		Digital Form "C" output		✓	✓	✓	✓	✓
		Modem		○	○	○	○	○
Multiple System Connection			○	○	○	○	○	

GENCORE CONSTRUCTION AND SUBSYSTEMS

The GenCore 5 fuel cell system is designed for outdoor installation and consists of a standard Power Generation Module and an optional Hydrogen Storage Module. The Power Generation Module may be

operated independently using an external hydrogen supply or can be operated using the Hydrogen Storage Module. The Hydrogen Storage Module is a self-contained unit that houses 6 hydrogen cylinders and provides all the required pressure regulation and valving. Block diagram is shown in Figure 2.

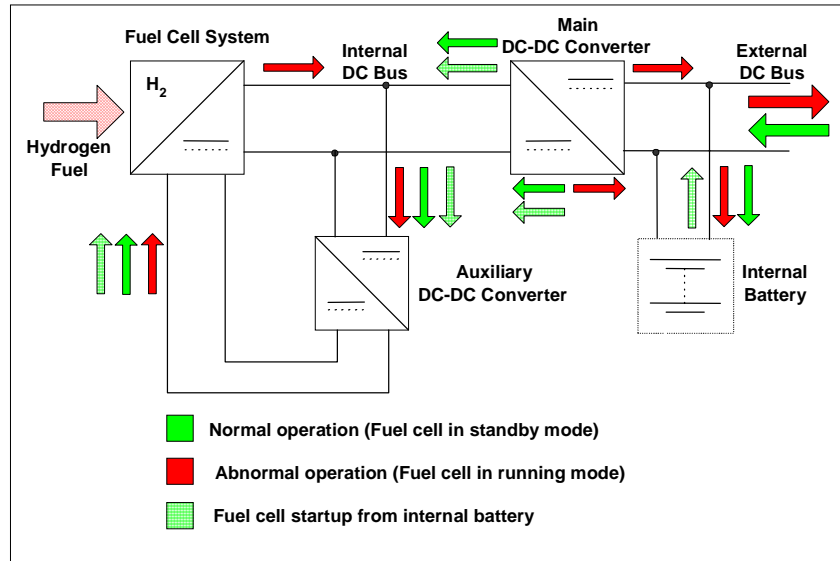


Figure 2: GenCore 5 Functional Diagram

Power Generation Module

The Power Generation Module contains the fuel cell stack, power conditioning electronics and auxiliary components. See Figure 3.

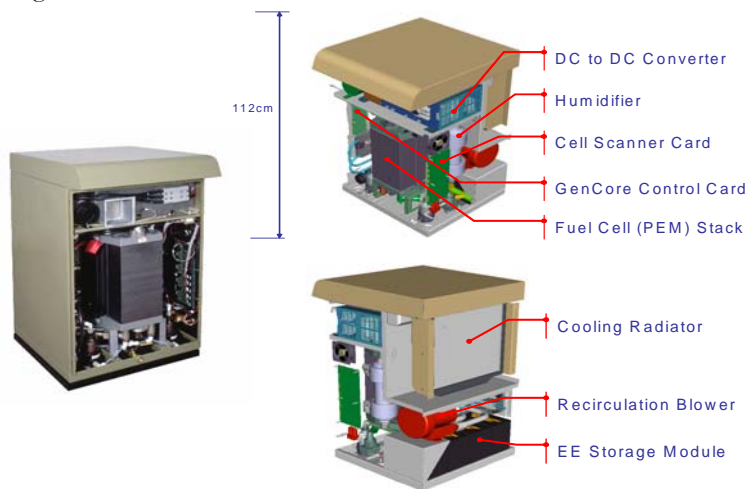


Figure 3: GenCore 5 Fuel Cell System and Sub-Systems

Fuel Cell Stack

The fuel cell stack is made up of individual fuel cells, each with a proton exchange membrane (PEM) between two plates. The cells are connected in series with a collector plate at the stack top and bottom providing high current connections to the external circuit. The electrochemical process produces DC electricity with heat and water as byproducts. The fuel cell stack is the heart of the system. Individual cell

voltages are measured and the fuel cell stack Cell Voltage Scanner Card provides inputs to the control subsystem. Refer to Figure 4.

There are no field serviceable components in the stack. If the stack requires corrective service it will be replaced with a new stack and the old stack sent back to the manufacturer for repair/refurbishment.

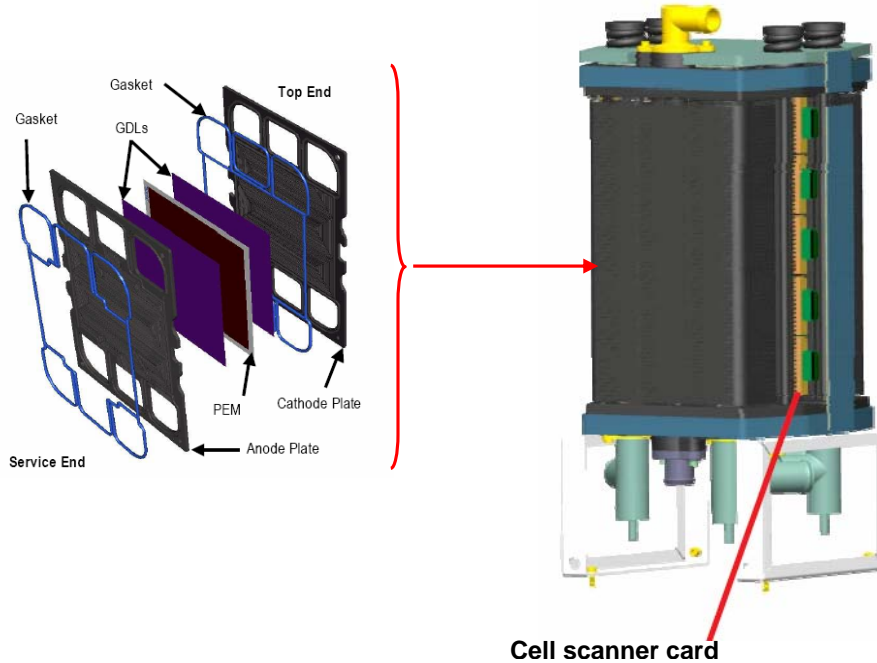


Figure 4: GenCore 5 fuel cell stack

Cooling Subsystem

The electro-chemical reaction that takes place inside the fuel cell stack is an exothermic reaction and therefore the generated heat needs to be managed. The primary function of the cooling system is to maintain stack coolant Inlet temperature within an acceptable operating range. The coolant temperature determines the stack temperature that is an important factor in PEM performance and gas stream relative humidity.

An automotive style radiator filled with a coolant consisting of a pure, uninhibited, Propylene Glycol/Deionized water mixture. Uninhibited Propylene Glycol is used because it is an environmentally friendly, a low cost heat transfer fluid and is highly resistive, ensuring minimal leakage current across the electrically charged stack plates. This coolant is non-flammable.

A thermostat at the top of the header directs the coolant down out of the coolant bypass port when the coolant temperature is low returning it directly to the pump. When the coolant heats up the thermostat opens allowing hot coolant to be directed to the radiator for cooling before returning to the pump suction.

Stack Anode Hydrogen Subsystem

The stack anode hydrogen subsystem provides the transport and control of the Hydrogen (H₂) to and from the fuel cell stack.

Stack Cathode Air Subsystem

The stack cathode air subsystem provides the transport and control of the air to the fuel cell stack from ambient and the process exhaust out of the fuel cell stack.

Humidifier

The humidifier functions to transfer heat and humidity from the cathode exhaust to the cathode inlet air stream.

Battery

The battery forms part of the power conditioning subsystem and is located in the bottom of the fuel cell system, accessible from the rear service panel. The battery consists of 4 series connected, 12VDC valve regulated lead acid batteries and is used to store energy to supply energy during fuel cell system power transients and for limited operation without the electrical grid when the fuel cell stack is not available, i.e. to start the fuel cell. The battery sits in parallel with the customer DC bus and is under normal operation kept in a charged state by the customer connection rectifying equipment.

DC-DC Converters

The converters forms also part of the power conditioning subsystem and consist of the main DC-DC converter, the auxiliary DC-DC converter and communications circuits for integration into the fuel cell system. During fuel cell system operation, the main DC-DC converter converts the varying fuel cell stack output voltage to a settable constant DC voltage for use by the fuel cell system auxiliaries and the connected load equipment. When the fuel cell system is in “Idle” mode it receives DC power from the customer rectifying equipment to power the fuel cell system auxiliaries.

The auxiliary DC-DC converter takes the power from the main DC-DC converter and converts it to 24Vdc that is used by the GenCore Control Card for control, communications and power functions. An RS485 bus is used for internal communications and the control card also receives inputs from a battery current sensor and a voltage signal from the customer DC bus.

Multiple System Operation

For higher output power needs, up to four GenCore 5 systems can be combined for outputs up to 20kW. Utilizing a factory-installed optional LAN card, multiple systems can be operated in a combined mode with one GenCore acting as the central controller with others following.

Hydrogen Storage Module

The Power Generation Module, shown in Figure 5 may be operated independently using an external hydrogen supply or can be operated using the Hydrogen Storage Module. The Hydrogen Storage Module is a self-contained unit that houses 6 hydrogen cylinders and provides all the required pressure regulation and valving as shown in Figure 1.

The Hydrogen Storage Module has a control panel that allows the user to select the primary cylinder bank, close supply valves and check pressures. The module is divided into 2 cylinder banks each consisting of 3 cylinders. This arrangement is necessary to ensure that cylinder replacement can be affected without interrupting fuel supply to the Power Generation Module. The selection between the 2 cylinder banks is done via the auto changeover regulator that serves as a pressure-reducing regulator and as an automatic bank selection valve. The bank selector valve sets the primary cylinder bank. Whenever the primary cylinder bank pressure drops below 85psi, the changeover regulator will automatically switch over to the secondary cylinder bank.

Each cylinder is equipped with a manual valve to isolate the bank during refueling and a main isolation valve which also acts as an emergency shutoff valve is located on the outside of the controls enclosure to shut off all fuel to the Power Generation Module. High pressure gauges are provided for each cylinder bank to indicate available fuel and a low pressure gauge is provided downstream of the regulator which displays the supply pressure to the Power Generation Module. An excess flow valve is provided as a safety device that shuts off flow in the event of a supply line breakage.



Figure 5: Hydrogen Storage Module

GENCORE OPERATION

The GenCore 5 fuel cell system is fully automated and requires no manual actions for normal operations. The controls automatically power up and enter the standby mode, once the DC power (internal or external) is applied to the system.

During the standby mode, the system monitors the DC bus voltage and the output current from the internal batteries. The fuel cell system enters the running mode whenever the DC bus voltage drops below the set nominal voltage by more than 2V (adjustable) or if a significant amount of current (12A+) is drawn from the internal batteries.

The control and monitoring of the fuel cell system is done via the Service Interface Software that is installed on the user's laptop or PC. A serial cable is connected to the laptop or PC's RS232 port and the RS232 port of the fuel cell system control card. The fuel cell system control card has an onboard data storage facility where it stores the last 30 days statistical data and the last 30 system events. Whenever the Service Interface Software communicates with the fuel cell system, service log files are created on the user's laptop or PC. The unit can also be connected via a modem for remote access. Figure 6 and Figure 7 show the startup screen and main window respectively for the Service Interface Software.



Figure 6: Service Interface Software Startup Screen



Figure 7: Service Interface Software Main Window

The fuel cell system can be manually started and shutdown from the main window shown in Figure 7. This window also displays all the operating parameters.

During the running mode, the fuel cell system opens the hydrogen inlet solenoid valve and the fuel cell exports power to maintain the DC bus voltage at the nominal voltage setpoint with an offset variation. As the load current requirement changes, the fuel cell adjusts its current output to match that. The fuel cell system goes into current limit if the required load current exceeds the maximum fuel cell system output current and the internal battery will source the extra load current. During this period the battery voltage and DC bus voltage will drop as the battery discharges and the fuel cell system will shutdown if the bus voltage drops below the DC-DC converter minimum operating voltage of approximately 39Vdc. The fuel cell system will then have to be manually reset.

The control system monitors various parameters and issue alarms for low fuel conditions (where the pressure sensors are installed and feature activated), minor and major alarms. The different operating modes are indicated with a LED at the rear of the fuel cell system with different color and flashing modes to indicate the applicable operating mode.

GENCORE MAINTENANCE

Planned maintenance is performed on an annual basis and divided into annual maintenance and 3-yearly maintenance as indicated below.

Maintenance item	Yearly	3-Yearly
Battery inspection	X	X
Hydrogen safety sensor replacement	X	X
Grounding inspection	X	X
Hydrogen Storage Module vent inspection	X	X
Hydrogen Storage Module inspection	X	X
Hydrogen system leak check	X	X
Site inspection	X	X
Coolant replacement	---	X
Battery replacement	---	X
Cathode air filter replacement	---	X
Converter air filter replacement	---	X

GENCORE FUEL USAGE

Figure 8 shows fuel consumption and run time as a function of power output. One standard hydrogen fuel cylinder will provide approximately nine-kilowatt hours of power. The Hydrogen Storage Module contains six cylinders; this amount of fuel will provide approximately 54 hours of operation at 1 kilowatt or 12 hours of operation at 5 kilowatts prior to refueling.

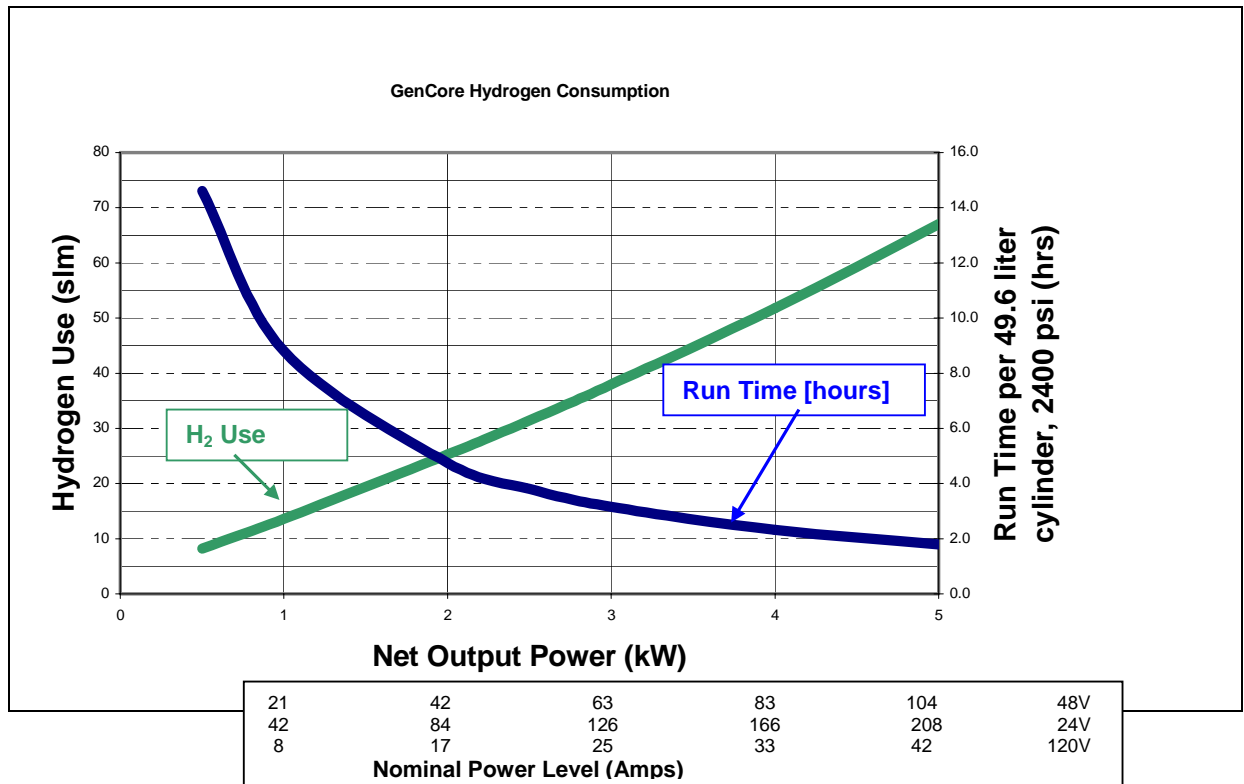


Figure 8: Hydrogen Fuel Consumption for the GenCore 5 Fuel Cell System