Clean Energy Back-up Power Solutions:
The Role of Advanced Fuel Cell Technology in Protecting 21st Century Telecommunications Cable TV and Transportation Safety Networks

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Abstract

Organizations responsible for critical communications and trafflc safety networks invest millions of dollars annually to guard against power loss; increasingly business leaders are demanding reliable, clean energy back-up power solutions that provide continuous, on-demand power.

Fuel cells have long been envisioned as a potential source of clean, renewable energy, but have traditionally faced three seemingly insurmountable obstacles: high manufacture and catalyst costs, concerns regarding durability, and an inability to automate mass production.

Today, fuel cell technology has broken through all three barriers, and has effectively delivered reliable, low-cost, clean back-up power with solutions that meet the requirements of the most demanding Telecommunications, CATV and Transportation applications.

With recent advances, Proton Exchange Membrane (PEM) fuel cell technology has proven to be an economical alternative to diesel generators, and particularly well-suited to rooftop deployments. Altergy's PEM fuel cells have demonstrated superior total cost of ownership and durability, delivered uninterrupted clean energy during prolonged utility outages, and simplifled full compliance with EPA regulations.

Overview

Equipment failure is the leading cause of unanticipated power outages that can last hours or up to several days. Severe weather and operator error also cause power failures and widespread blackouts that affect thousands of homes and businesses every year. Organizations responsible for critical communications and trafflc safety networks invest millions of dollars annually to guard against power loss; increasingly business leaders are demanding reliable, clean energy back-up power solutions that provide continuous, on-demand power.

Valve-regulated lead-acid (VRLA) batteries have been used in the Telecommunications, Cable TV, and Transportation sectors for decades to provide uninterruptible back-up power for up to eight hours of runtime with predictable costs. VRLA battery technology has not changed signiflcantly since the 1980s.

The diesel engine (compression ignition) is the most commonly used source of back-up power for Telecommunications (wireless and landline) and CATV back-up power systems for outages lasting more than eight hours. For critical communications and trafflc-signal sites without stationary diesel generators, mobile diesel and spark-ignited gasoline or propane "generators on wheels" are the most common means used to provide prolonged back-up runtimes. Diesel generator technology has not changed signiflcantly since the 1970s.

Unavoidable size and weight limitations of batteries, as well as U.S. Environmental Protection Agency (EPA) regulations aimed at reducing greenhouse gas emissions, have motivated power industry professionals and end-users across sectors to seek alternative technology that can reliably and cost-effectively provide uninterruptible back-up power for extended runtimes while complying with increasingly stringent emission standards.

TABLE 1. Large Blackouts in the United States
Statistics For Outage Cause Categories

	% of events	Mean size in MW	Mean size in customers
Equipment failure	29.7	379	57140
Wind/rain	14.8	793	185199
Lightning	11.3	270	70944
Operator error	10.1	489	105322
Voltage reduction	7.7	153	212900

Source: Trends in the History of Large Blackouts in the United Sates
http://www.uvm.edu/~phines/publications/2008/Hines_2008_blackouts.pdf.

Climate Change and Diesel Emissions

The U.S. EPA regulates emissions from diesel engines in an effort to address climate change, and there has been a substantial reduction in atmospheric levels of nitrogen oxide, carbon monoxide and non-methane hydrocarbons since its regulations were enacted. As diesel emission regulations have become increasingly restrictive, the cost of modifying generators to maintain compliance has risen signiflcantly.

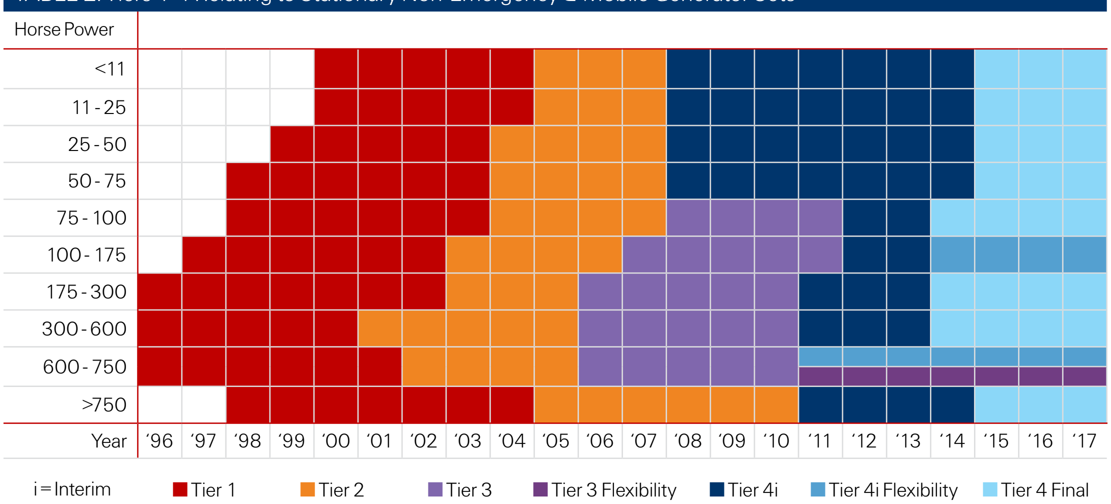
The EPA flrst regulated off-highway compression ignition diesel engines in 1996 and began enforcing limitations on exhaust emissions for stationary diesel generators in 2006. The regulations were introduced in steps known as Tier levels, and each tier specifles additional compliance requirements.

To meet EPA's more stringent emissions standards, diesel engine manufacturers have employed exhaust after treatment systems, such as selective catalytic reduction (SCR), diesel particulate fllters (DPF), exhaust gas recirculation (EGR) systems, which have signiflcantly increased the upfront capital costs of generators. Compliance modiflcations can, in some cases, double costs.

Stationary diesel-engine and gas-engine generator sets used strictly for emergency standby power (ESP) usually run less than 200 hours per year and are exempt from EPA Tier 4 Interim (2008) and Tier 4 Final (2014-2015) regulations in most of the United States. However, mobile diesel and spark- ignited generators used for temporary backup power (generator on wheels) usually are subject to Tier 4 emissions regulations.

Furthermore, many state and local municipalities set even stricter emissions limits than those established by the EPA, which often results in additional equipment modiflcation. Many "non-attainment" areas, particularly in and around dense or large population centers, set standards above and beyond EPA Tier 4 levels, which can inffiate back-up power costs. Examples of non-attainment areas include the State of California, many New England states, and the cities of Atlanta and Houston.

TABLE 2. Tiers 1-4 Relating to Stationary Non-Emergency & Mobile Generator Sets



Diesel Generator Cost of Ownership

Total cost of ownership for generators over a 10-year span is determined by more than the initial capital acquisition expense, and must factor in maintenance schedules and replacement part expenses. Also, when operating in municipalities that enforce noise ordinances that may require enhanced sound attenuated enclosures, additional costs may be incurred. Severe conditions" such as extreme temperatures, prolonged periods of inactivity, extended continuous runtime, and exposure to inclement weather or saltwater can further increase maintenance and operational costs.

As diesel fuel gets older a flne sediment and gum forms, caused by the reaction of diesel components with oxygen from the air. Fuel tanks and other storage systems are also thriving places for aerobic and anaerobic bacteria. The flne sediment / gum and bacteria will block fuel fllters, leading to fuel starvation and the engine stopping. Therefore frequent fllter changes are required to keep the engine operational while scheduled maintenance costs vary with generator size they can typically range from $1,000 to $2,500 annually for the life of the equipment.

Prohibitions on Diesel Rooftop Deployment

Fire risks and weight considerations often prevent diesel generators from qualifying for the permits required for rooftop deployment. There is a risk of secondary fire in the event of a fuel leak that pools below the generator and onto the roof surface, and many roof structures cannot safely support the weight of high-capacity diesel generators.

Most major metropolitan cities have little available ground-level real estate to house generators for existing cell sites or new small cell deployments, which makes rooftop deployments highly desirable. Batteries don't have the fire risk that diesel generators do, but batteries cannot produce enough power over sufficient runtimes to adequately back-up critical systems.

Wet Stacking and Longevity

"Wet stacking" is a term used to describe a diesel engine dripping a thick black gooey substance from its exhaust piping or "stacks." This serious condition is caused by operating the diesel engine at light load for extended periods sending unburned fuel and soot into the exhaust system. Wet stacking can seriously degrade diesel engine performance and useful life.

Wet stacking is not entirely uncommon given the standard operating procedures of diesel-powered back-up generators deployed in typical Telecom and CATV facilities. Many generators in the field are routinely tested at no load or at light loads instead of at or near full load. Also in telecom applications generators are typically oversized when initially specified to accommodate anticipated load growth that often does not materialize. In general diesel generators that are not regularly exercised or operated at 33% to 50% of the nameplate rating are at risk for wet stacking over the long term.

Runtime Impacts on Mechanical Failure

Even with established maintenance schedules, diesel generators are subject to wear and tear. Being pressed into extended duty can stress machinery that is often idle and features many moving parts. Such stress can lead to mechanical equipment failure in diesel generators.

During the 2003 grid outage that crippled the Northeastern U.S. there were numerous reports of diesel generators failing after running continuously for more than 24 hours. These failures were not due to lack of fuel, but to mechanical component failures in generators not adequately designed for continuous runtime duty.

Fuel Cell Technology Potential

Fuel cells have long been envisioned as a potential source of clean, renewable energy. Fuel cells produce energy – an electrical current – by creating a chemical reaction between hydrogen, the most abundant gas in earth's atmosphere, and air. The only byproduct of the process is water ($H2 + O = H2O$); there is no combustion and there are no greenhouse gas emissions.

NASA, the U.S. Navy, and other organizations have deployed fuel cell technology in limited applications since the 1960s. Until recently, however, high production costs, concerns regarding durability, and an inability to automate mass production were considered insurmountable obstacles to fuel cells realizing their dramatic commercial potential.

Fuel Cell Background

The origin of fuel cells can be traced to 1776, when Henry Cavendish, a renowned scientist of the time discovered that water is not an element, but a compound formed when hydrogen reacts with oxygen. In 1839, Sir William Robert Grove confirmed the theory that this reaction also generates an electrical current, earning him the esteemed title "The Father of Fuel Cells."

Fuel cells produce an electric current by means of an electro-chemical reaction between hydrogen and oxygen, not the combustion of fossil fuels as diesel generators do. Water is a natural by product of the electro-chemical reaction. There are no greenhouse gas emissions, and there is very little noise.

Charles Langer and Ludwig Mond coined the term "fuel cell" in 1889, and scientists developed fuel cell technology for another 60 years before it found its first practical uses in the 1950s in mobile applications that would eventually range from space missions to public transportation. Every Apollo and Space Shuttle mission by NASA since the early 1960s has had fuel cells aboard supplying power and drinking water to the astronauts.

Since the turn of the 21st century, fuel cells have seen widespread implementation in the U.S. and around the world, in stationary prime power electric only, and combined heat and power (CHP) applications.

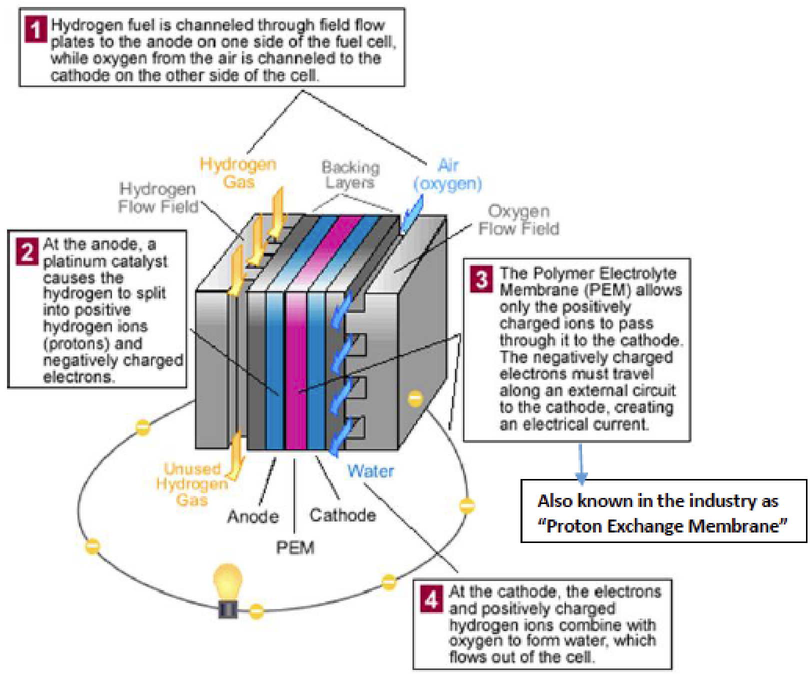
Reliability and Easy Refueling

Proton Exchange Membrane (PEM) fuel cell technology has been commercially proven in thousands of deployments and millions of reliable operational hours. Fuel cells have performed consistently even when subjected to wide temperature swings and harsh weather conditions experienced in telecommunications back-up power applications. PEM fuel cells have provided critical back-up power to hospital life-support systems when back-up batteries failed and have provided uninterrupted power through hurricanes earthquakes and desert sand storms.

Fuel cells provide Direct Current (DC) electricity without the emissions of diesel or gas generators and without the constant recharging batteries require. As long as there is a supply of hydrogen fuel the most widely used industrial gas in the world the fuel cell will produce DC power with unlimited runtime and zero emissions at the point of use.

PEM Fuel Cell Technology – How it Works

A PEM fuel cell produces DC power as the result of an electro-chemical reaction between hydrogen gas and oxygen from the air in the presence of a catalyst.



- Hydrogen is mixed (not burned) with air. In the presence of a catalyst, the chemical reaction converts the hydrogen and oxygen to electricity and water.
- PEM fuel cells can start-up in less than 30 seconds*, making them ideal for critical back-up power.
- There are no moving parts in cell stack, which makes for easy, low-cost maintenance.

** Altergy Freedom Power™ only.*

Altergy Breakthroughs

Altergy is the flrst company to successfully design, mass-produce, and commercially deploy rugged, reliable, low-cost fuel cells.

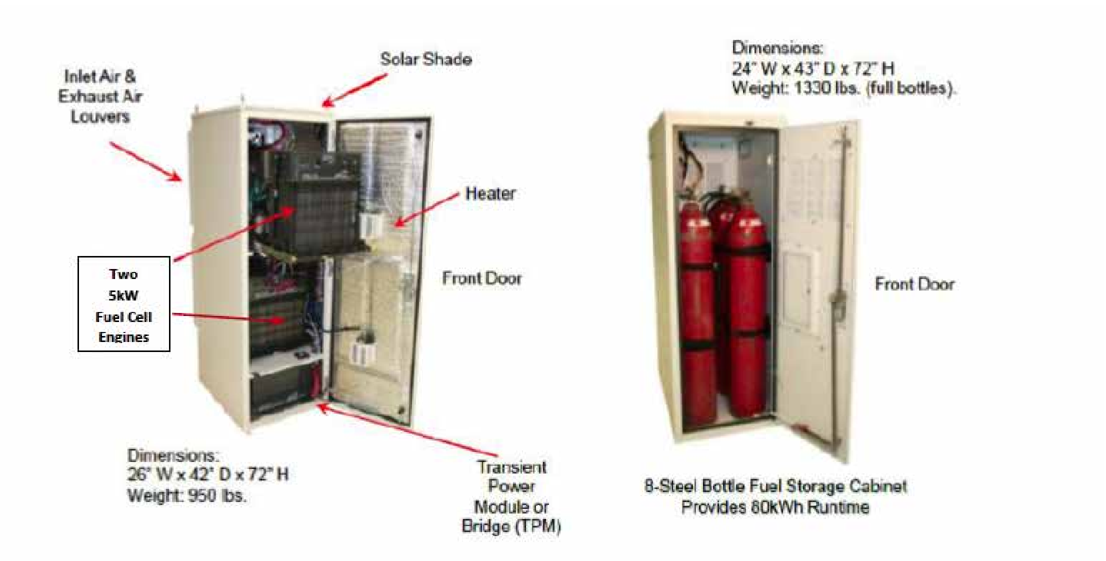
Altergy replaced the graphite plates and other fragile components used in traditional fuel cells with low-cost, highly durable components that withstand the severe conditions experienced in industrial use. Altergy fuel cells provided uninterrupted power when Hurricane Sandy knocked out grid power for extended periods of time in the Northeast in 2012.

Altergy also has overcome traditional cost and volume-production barriers, and made fuel cells more compact. Altergy fuel cells are made with readily available off-the-shelf materials on the world's flrst and only automated, high volume, fuel cell fabrication and assembly line. These breakthroughs translate to greater deployment fiexibility and lower costs.

Reduced Footprint

Altergy's products have the smallest footprint of any PEM fuel cell on the market, and often can be deployed in smaller spaces where other fuel cell systems, batteries, and generators cannot. One standard cabinet, for example, can provide 10kW of back-up power capacity, and another small cabinet can provide fuel storage for up to 80kWh runtime.

Altergy's lightweight, small-footprint fuel cells simplify rooftop deployment and are ideal for urban applications – rooftop permitting is easy because there are no weight limitations or flre risks to address.



A standard telecom grade OSP cabinet (26″x42″x72″) can house a 10kW PEM fuel cell solution.
A smaller cabinet (24″x43″x72″) can store fuel for 80kWh runtime.

Total Cost of Ownership

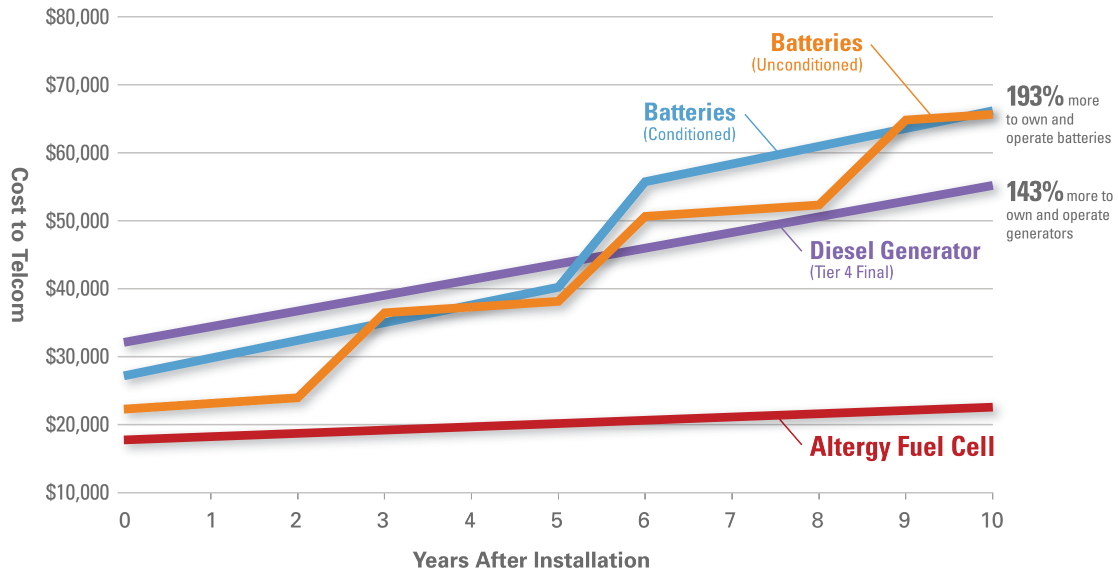
Altergy's innovative product design reduces critical component costs by more than 80%, and the use of readily available materials and automated manufacturing processes reduces costs further. Altergy fuel cell solutions are cost-competitive with traditional power sources and far more sustainable.

With no moving parts in the cell stack, maintenance is simply cleaning or replacing air filters once per year or every 1000 hours of operation, whichever comes first (~$100/year). The only other ongoing operating expense is the cost of H2 fuel and delivery, which is significantly less than the cost of diesel fuel and delivery.

Altergy fuel cell products have been zero-emission certified by the California Air Resources Board, and rebates and incentives that encourage the use of sustainable technology may be available in some states. An Investment Tax Credit (ITC) may be available at the federal level providing $3000/kW or 30% of the total project costs, whichever is less. This represents a dollar for dollar reduction in tax liability for system owners.

PEM fuel cells, depending on the design, cell stack components, balance of plant (BOP) material used, and manufacturing techniques employed, have a design life of greater than 15 years. Fuel cells also avoid the cost of diesel fuel theft.

Fuel Cells – The Best Value in Backup Power

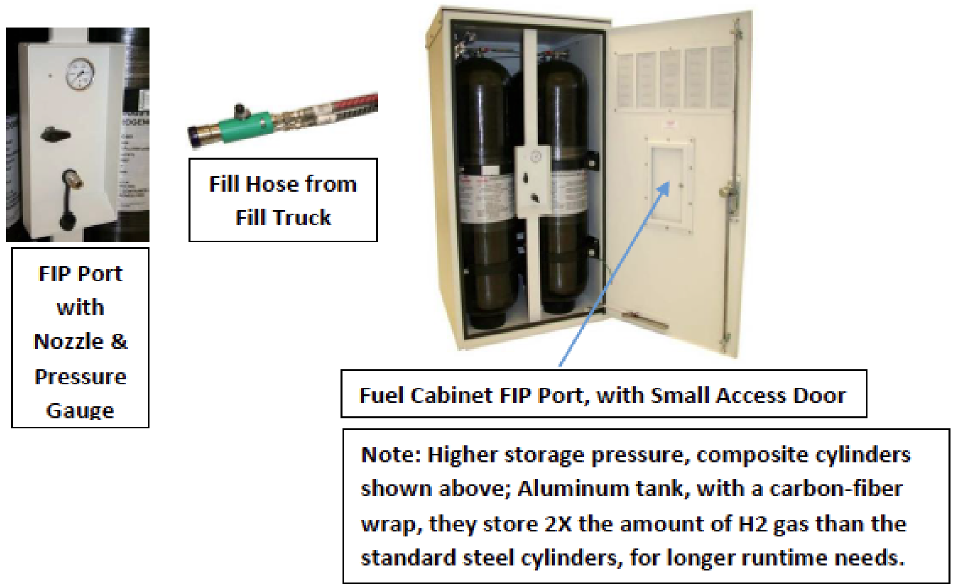


TCO based on a 5kW load, 8 hours of runtime. Battery quantities and size determined at end of the life (2.5 years). Generators are Tier 4 Final. Analysis includes, acquisition costs, plus permitting and installation costs, as well as ongoing maintenance (and battery replacement) costs for all three technology alternatives. Data sources for the analysis include research reports (Batelle, Battery Council International, etc.), Manufacturer data sheets, prices, white papers and Altergy Systems information.

Flexible Fueling Options

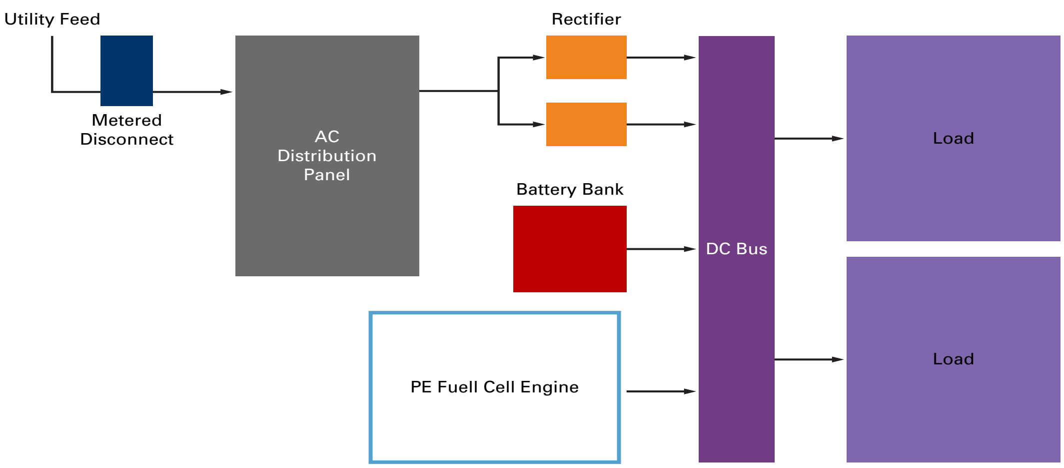
Hydrogen gas (H2) is readily available in most U.S. cities and municipalities and has an excellent safety record. For typical OSP applications, the H2 is stored in steel tanks or cylinders, and enclosed in a telecom grade OSP cabinet.

Re-fueling H2 "Fill" trucks today use "Fill-In-Place" technology (FIP) to re-fuel PEM fuel cell sites, replacing traditional "bottle swapping" practices. With FIP, a flll truck fltted with a Department of Transportation (DOT) certifled hose connects to a flll port located on the fuel cabinet front door. The hose simply connects to the flll port nozzle, and in minutes all cylinders are re-fllled in place, with no access inside the cabinet required.



Typical Telecom or CATV Application

For a typical Telecom or CATV OSP application the PEM fuel cell's DC output connects directly to the system DC bus just like the VRLA battery bank.



The PEM fuel cell will continuously monitor the DC bus. In a typical wireless telecom 48VDC application upon a utility or rectifler failure the batteries would provide the initial uninterruptible power to the critical telecom loads. As the battery power is used the DC bus voltage will start dropping with thresholds selectable in 0.1VDC increments. At the specifled threshold DC voltage level the fuel cell would move from the monitoring state (standby) to the start state and power the load for the duration of the outage. When utility power returns the fuel cell senses the return of the utility waits until stable (wait time is customer specifled) then returns to a standby mode.

Summary

Climate change and rising costs have motivated power industry professionals and end-users across sectors to seek alternative technology that can reliably and cost-effectively provide uninterruptible back-up power for extended runtimes while reducing emissions and complying with increasingly stringent emission standards.

Fuel cells have long been envisioned as a potential source of clean, renewable energy, yet conventional wisdom has held that cost and production obstacles once thought to be insurmountable would forever limit fuel cell development and deployment. Now, Altergy has broken through those barriers and delivered proven, reliable, low-cost, clean energy back-up power solutions that meet the requirements of the most demanding Telecommunications, CATV and Transportation applications.

Advanced PEM Fuel cell technology has proven to be an economical, rugged alternative to diesel generators, and particularly well suited to rooftop deployments. Altergy fuel cells have demonstrated superior total cost of ownership and durability, and delivered uninterrupted clean energy during prolonged utility outages in extreme conditions and diverse deployments.