GENERAC INDUSTRIAL POWER

WHITE PAPER

GASEOUS-FUELED GENSETS an Alternative to Diesel Solutions

INTRODUCTION

Traditionally, the choice between diesel-fueled and gaseous-fueled generators has been relatively straightforward. Power density as well as capital cost advantages in large-kilowatt applications typically favored diesel for standby power of 150 kilowatts of electricity (kWE) or more—large commercial and industrial standby applications.

However, technological innovations are making gaseous-fueled generators both more powerful and more cost effective. Additionally, issues of fuel storage and reliability in diesel-fueled generators are becoming a bigger challenge. Finally, as more and more companies seek to reduce their carbon footprints, they are more open to options that are more environmentally friendly.

As a result, standby generator system designers, electrical contractors and electrical engineers have significantly more gaseous-fueled choices than they had before.

DIESEL VS. GASEOUS-FUELED GENSETS: A TRADITIONAL PERSPECTIVE

Diesel and gaseous-fueled generators each offer advantages to consider when designing a standby power solution. The most noticeable advantage of a gaseous-fueled generator is the extended run time provided by a continuous supply of natural gas. The natural gas infrastructure has shown itself to be extremely reliable in situations that cause power outages; through four Florida hurricanes in 2004 and the Northeast grid failure of 2003, the natural gas supply was unaffected.

By comparison, diesel-fueled generators provide access to backup power in remote areas that do not have a gaseous-fuel infrastructure. When applied to standby power applications of 150 kW_E or more, a diesel-fueled generator delivers a lower capital cost per kilowatt of electricity than a gaseous-fueled generator. Attempts to lessen this disparity, such as converting industrial diesel engines to gaseous fuel, only add engineering costs to the project. As a result, diesel-fueled generators have an initial capital cost advantage over their spark-ignited counterparts in larger standby applications, making them the traditional market norm.

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Additionally, a significant part of the market—especially those segments with mission-critical applications like hospitals and 911 call centers—uses diesel-fueled generators because of code requirements for on-site fuel. While gaseous-fueled generators using on-site LP fuel can often meet such code requirements, as can systems designed to run in a dual-fuel configuration with natural gas as a primary fuel and LP as the secondary fuel, the capital cost advantage of diesel-fueled generators typically makes them the preferred solution when on-site fuel is a must.

Both diesel and gaseous-fueled units share applications below 150 kW_E. Gaseous-fueled generators are often chosen for residential and small commercial standby applications. The automotive-style engines used in these units are readily available in high volumes, making them extremely cost effective. The ready supply of LP and natural gas in these applications also makes them ideal.

DIESEL CHALLENGES

In spite of their widespread use for standby power in large-kilowatt applications, diesel-fueled generators can have some significant drawbacks that are often overlooked. Fuel storage and reliability considerations are foremost, as are environmental issues.

Fuel Storage

There is no question that the ability to store diesel fuel on site fills a critical need for backup power in remote areas without a gaseous-fuel infrastructure. However, because it is typically stored for long periods of time, contamination and breakdown are real concerns.

According to Exxon Mobil, diesel fuel can be stored for up to one year without a reduction in quality if it is kept clean, cool, and dry. Longer storage periods require periodic filtrations and the addition of fuel stabilizers and biocides[1]. In the case of a diesel generator set, however, it could easily take a diesel-fueled generator with a tank sized for 72 hours of full-load operation about 20 years to turn a single tank of fuel[2]. Without proper maintenance, the fuel will become contaminated with water and biomass.

Water enters the tank as humidity through the normal vent and condenses. Moisture binders in the fuel capture and contain the moisture, but as these binders become overloaded, water will drop to the bottom of the tank and begin accumulating. If pulled into the engine, it could result in loss of power, loss of lubrication, and corrosion. Water also creates an environment that will support biomass at the water/fuel interface. When these microbes are pulled into the engine, they clog the fuel filter, resulting in power loss and shutdown. To minimize these effects, fuel tanks require a well-defined low point where the water can collect, and monthly maintenance to drain the water. Periodic fuel polishing (filtering and water removal) may be required, as well.

In addition to contamination, fuel breakdown seems to be more prevalent with today's low sulfur fuels. The additional refining processes necessary to remove the sulfur may also be removing some of the fuel's stability elements. As diesel fuel gets older, a fine sediment and gum forms in it, brought about by the reaction of diesel components with oxygen from the air. Additives are helpful in treating common fuel breakdown issues when integrated into a fuel filtering preventive maintenance program. However, at some point the fuel may simply need to be replaced.

By contrast, natural gas is continuously supplied via the local municipal infrastructure, so storage is not an issue. As for LP, it can be stored on site for several years—more affordably and more safely than diesel fuel—providing an additional redundant backup to the already stable gaseous-fueled pipeline infrastructure.

Reliability of Fuel Delivery

According to the Edison Electric Institute, severe weather events account for 62% of unexpected power outages in the United States. These events can close roads and cripple municipal infrastructures, making it difficult or impossible to refuel the diesel generators used in so many standby applications. Designers who size fuel tanks more modestly to address the aforementioned issues of fuel contamination or breakdown run the risk of implementing a solution that will run out of fuel in an emergency.

1 "Diesel FAQ," last modified July, 2010, accessed September 8, 2010, http://www.exxon.com/USA-English/GFM/fuels_quality_diesel_faq.aspx

2 Assuming a 60% typical load level, weekly no-load exercising, and average power outages of only four hours per year.

Environmental Concerns

More and more companies are considering how their overall environmental footprint affects the world. This trend holds true in virtually all areas of business, and automatic standby generators are no exception. In this regard, diesel-fueled generators face significant challenges. Not only do diesel engines emit more nitrogen oxides and particulate matter than comparable spark-ignited units, but diesel engines are also being ever more scrutinized to minimize their environmental impact.

For example, diesel engines have been subject to intense emission level regulations, and have seen aggressive Environmental Protection Agency (EPA) tier changes. This additional oversight has increased the total cost of both diesel engines and fuel. Future governmental cap and trade regulations for emissions trading may cause diesel engines to be taxed at a higher rate due to higher CO_2 emissions.

Fuel containment and the environmental concerns surrounding large quantities of fuel stored on site are considerable issues, as well. Because quantities of fuel are typically kept in a main storage tank and then transferred to a smaller day tank at the generator for usage, fail-safe controls must be designed into the system to avoid spillage. Additionally, no single point of failure in the fuel delivery system should result in fuel spillage. Many localities have their own code requirements covering fuel containment and delivery—some of which include concrete-walled secondary containment, double-walled piping, fire-rated tanks, special fill and spill requirements, special permitting, etc. In fact, permitting costs for diesel storage also continue to rise as local governments attempt to control the environmental impact of accidental spills, odors and other factors. Thus, while diesel-fueled generators above 150 kW_E do offer significant capital cost advantages when compared to similar gaseous-fueled units, managing the fuel storage, reliability, and environmental concerns tends to flatten this cost differential.

TECHNOLOGY SHIFTS IN GASEOUS-FUELED GENERATORS

Thanks to advances in technology, gaseous-fueled generators are growing in popularity for larger applications. Key advancements include the optimization of engine speed (RPM), integrated approaches to generator paralleling, and bi-fuel (combined diesel and gaseous-fuel) operation. These technologies are reducing the historical cost advantage of diesel-fueled generators.

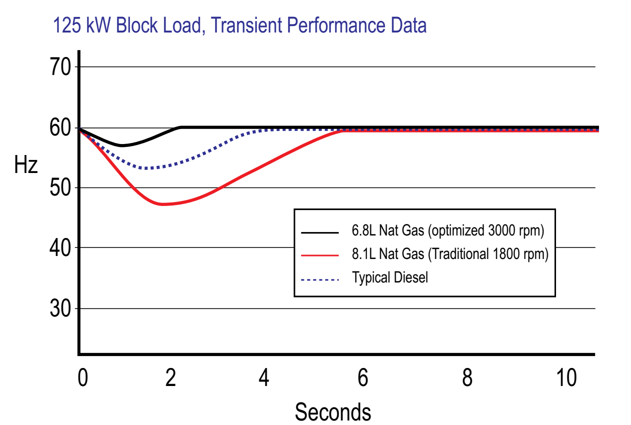
Optimizing Engine RPM

The AC frequency of the generator electrical output is a function of engine speed and alternator design. To achieve 60 Hz, the alternator rotor must revolve at a specific speed for a given alternator pole configuration. Fifty years ago, most generator engines operated at speeds below 900 RPM. Within the last 30 years, however, engine outputs have increased. As such, the diesel standby generator market has moved from 1200 to 1800 RPM.

This trend has affected gaseous-fueled generators in applications up to 150 kW_E, as well. Historically operating at 1800 RPM, current technology is optimizing these automotive-style engines for operation at 2300, 3000, and 3600 RPM. Some manufacturers utilize a simple gear reduction device between the engine and a four-pole alternator to achieve the optimal amount of mechanical power at a 60 Hz electrical output.

Increasing the operating speed of spark-ignited automotive-style engines offers many advantages, including improved transient performance, less stress on engine bearings, and increased power densities. The graph below illustrates the transient performance increase associated with optimizing the RPM of these engines.

Most importantly, though, this trend means more powerful engines and reduced capital costs.



Integrated Generator Paralleling

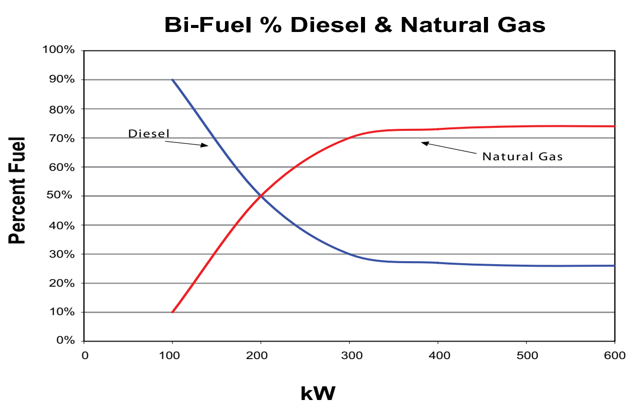
Using these speed-optimized, spark-ignited engines as building blocks, manufacturers are connecting smaller gaseous-fueled generators together and combining their output in an integrated approach to generator paralleling. In this way, they are able to provide a cost-effective alternative to single, large diesel-fueled units.

Parallel power solutions have always offered significant advantages, including application flexibility, scalability, and redundancy. However, the implementation of such solutions had been limited to mission-critical applications and large kilowatt projects largely because of panel board constraints including cost, space, and issues of single source responsibility. Traditional parallel power solutions were also extremely complex. Each generator in the system normally required four to six analog and digital micro-controllers from various manufacturers, all hardwired together. A typical two-generator system would have between nine and fourteen controllers (including the master control section) to manage the speed governor, load-share controller, synchronizer, voltage regulator, generator controller, and protective relay.

Today, manufacturers have mitigated cost and complexity by using one digital controller per generator to control all functions, significantly enhancing system performance and reliability. Some have also integrated the paralleling switch into the generator connection box, eliminating the cost and space requirements of external panel boards. Today, three 300 kW_E gaseous-fueled generators operating in parallel could replace a single large 1000 kW_E diesel-fueled generator at a more feasible cost—but with the added advantage of built-in redundancy. With a single 1000 kW_E unit, generator failure means the facility will be without backup power. In a parallel solution, however, if one of the 300 kW_E units doesn't run, the most critical loads will be distributed among the remaining two generators.

Bi-fuel Generators

Bi-fuel generators combine the power density and capital cost benefits of diesel engines with the extended run time of natural gas. Using mass-produced diesel engines as prime movers, bi-fuel generators start up on diesel fuel in a normal manner. As loads are added, natural gas is introduced to the combustion air while diesel fuel is reduced. Under typical load conditions, bi-fuel generators will operate on a ratio of 25% diesel and 75% natural gas, with no reduction in power. An example fuel mix for a 600 kW_E generator is illustrated below.



Only slightly more expensive than diesel-only designs, bi-fuel generators offer several important advantages. For one, the lower capital cost of a compression-ignited engine is retained while capitalizing on many of the advantages of gaseous fuel, such as an improved emissions profile.

Run times are significantly extended, as well, due to the reduced consumption of diesel fuel. This can be very important, since refueling may be difficult during emergencies that cripple municipal infrastructure. It can also allow for smaller diesel tanks, because natural gas is the predominant fuel. With smaller fuel tanks, the risk of fuel contamination and the cost of fuel maintenance is significantly reduced.

Finally, fuel redundancy is built into the system. If the natural gas supply is interrupted for any reason, or if there is a fault in the bi-fuel delivery system, the controls automatically revert to 100% diesel without interruption.

Combining fuel cost with environmental impact provides companies with a broader view to the true bottom line, and overall environmental impact, of their generator choice. For example, while a 100 kW_E diesel engine burns fuel 23% more efficiently than a similar-sized gaseous-fueled engine (column J), its fuel cost per kilowatt hour is almost double (column I) and its total CO_2 emissions are more than 16% greater (column O). Additionally, gaseous-fueled generators have historically cost less per installed kilowatt than their diesel counterparts in the smaller sizes (column K).

Given the new technologies associated with gaseous-fueled generators, and their advantages in terms of fuel reliability and cost, customers might be more willing to consider a gaseous-fueled solution where historically they would have purchased a diesel-fueled unit.

SUMMARY

Gaseous-fueled generators are becoming more attractive for standby applications above 150 kW_E. The capital cost and thermal efficiency advantages of diesel over gaseous fuels have been moderated by the maintenance and reliability challenges of storing diesel fuel over long periods of time. Additionally, a number of recent technological innovations in implementing high-kW_E gaseous-fueled solutions are allowing such generators to compete with their diesel-fueled counterparts on cost and power.

Additionally, the fact that spark-ignited engines offer improved emission profiles over compression-ignited engines—and that gaseous fuels do not pose the kinds of environmental risks inherent in diesel fuel storage—is making gaseous-fueled generators more attractive to the ever-growing number of companies looking to reduce their overall carbon footprint.

Diesel-fueled generators will most assuredly continue to serve the standby power market; no single solution is ideal for every application. Gaseous-fueled generators, however, are becoming more cost-effective and environmentally-friendly options for applications above 150 kW_E.

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EFFICIENCY AND CO_2 EMISSIONS

To evaluate the bigger environmental picture, it is important to compare the source-to-site cost of the fuel used in diesel and gaseous-fueled generators. This is the total cost associated with using the fuel. It includes such items as extraction and transportation costs, the current market price of the fuel, and the cost per kilowatt hour. Consideration of total CO2 emissions is critical, as well, in determining environmental impact. It is possible to quantify all of these items and bring them into the cost-benefit analysis regarding generator fuel choice.

The following chart shows efficiency and CO2 comparisons of gaseous-fueled and diesel generating sets.

Diesel vs. Gaseous-fueled Generators: Total Cost and Total CO2 Emissions

A	B	C	D	E	F	G	H	I	J	K	L	M	N	0
Unit kW_E	Fuel Type	Engine Volume (liters)	Engine RPM	Power (kW_E)	Nat Gas Fuel Flow (ft^3/hr)	Diesel Fuel Flow (gal/hr)	Cost/ Hr[1]	Cost/ kW-hr[1]	Btu/kW_E	Capital Cost/kW_E	CO_2 Emissions From Engine Exhaust Only (lbs/hr)	Energy use (mBtu/hr)	Total CO_2 Emissions from Engine and Processing (lb/hr)[2]	% CO_2 Increase vs Natural Gas
100	Gas	6.8	2300	100	1380	—	$13.11	$0.131	13,800	$205	168.4	1.380	328	—
100	Diesel	6.7	1800	100	—	7.9	$20.15	$0.201	10,490	$220	175.4	1.116	383	16.7%
200	Gas	13.3	1800	200	2750	—	$26.13	$0.131	13,750	$270	335.5	2.750	654	—
200	Diesel	8.7	1800	200	—	15.5	$39.53	$0.198	10,291	$180	344.1	2.189	751	14.9%

1 Based upon fuel usage and overall current price of fuel, 100% rated load. Natural gas: $0.95/therm. Diesel: $2.55/gal.

2 GREET Transportation Fuel Cycle Analysis Model, developed by Argonne National Laboratory, September 5, 2008.

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GENERAC INDUSTRIAL POWER: DIESEL AND GASEOUS-FUELED SOLUTIONS

Generac Industrial Power offers diesel and gaseous-fueled generators for every standby power solution.

- Diesel up to 25 MWE
- Bi-Fuel™ 600 kWE
- Gaseous up to 300 kWE
- Parallel power solutions up to 9 MWE using Generac's Modular Power Systems (MPS

Modular Power Systems (MPS)

Generac's Modular Power System (MPS) is a combination of the industry's most reliable generators and state-of-the-art integrated paralleling technology. Powered by either diesel or gaseous fuel, MPS is appropriate for numerous types of businesses, including hospitals, airports, office buildings, manufacturing plants, data centers, and retail superstores. Not only does MPS boast a reliability rate of up to 99.9999%, it is more cost effective and flexible than single generator sets with the same load capacity, making expensive stand-alone switchgear obsolete.

Gemini®

Generac's Gemini Twin Pack houses two generators within a single enclosure, providing the same amount of power in a footprint that is 20% smaller than many single engine units. Gemini provides built-in redundancy for superior system reliability and scalability along with load shedding capabilities. Parallel up to seven diesel or gaseous-fueled Gemini systems without additional switchgear.

Bi-Fuel™

Perhaps the solution that most effectively combines the power of diesel with the environmental friendliness of natural gas, Generac's Bi-Fuel system generators start on diesel fuel and add natural gas as load is applied. During an outage, each Bi-Fuel unit can optimize at a fuel mixture of 75% natural gas and 25% diesel. If the natural gas supply is interrupted, the generator automatically switches to 100% diesel without any power drop during the transition. At varying loads, the advanced fuel system maximizes the use of natural gas while closely monitoring the system for safe operation.

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