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WHITE PAPER

Standby Power Generation Fuel Security – Diesel vs. Natural Gas

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INTRODUCTION

As natural gas continues to gain market share over diesel fuel for emergency power system (EPS) applications, those who once perceived the security and reliability of onsite diesel fuel have started to question the maintenance requirements and operational risks associated with maintaining a consistent and dependable diesel fuel supply.

With several practical benefits — including reduced maintenance costs and emissions as well as enhanced accessibility — natural gas is quickly becoming the fuel of choice for a variety of industrial power applications.

REGULATORY & OPERATIONAL CONSIDERATIONS

According to a 2007 study by the U.S. Department of Energy, there are approximately 12 million emergency generators in the United States with an installed capacity of approximately 170 gigawatts (GW).[1] Historically, units larger than 100 kW — which still account for the majority of installed emergency power systems — have been powered by diesel engines.

Cost effectiveness, ease of fuel management, reliability and availability have been traditionally rooted in diesel fuel economics. Diesel has also historically met onsite fuel supply regulatory requirements. Even if a specific fuel supplier was unable to make a delivery, the perception was — until recently — that delivery arrangements could be made quickly in the event of an emergency.

Two Things Happened to Change Diesel Fuel Reliability in EPS Applications:

- Ultra-low sulfur diesel (ULSD), which contains less than 15 ppm sulfur, was introduced nationwide in 2010 for non-road use in response to new U.S. Environmental Protection Agency (EPA) emissions requirements.[2]
- Hurricanes Irene (2011) and Sandy (2012) impacted diesel fuel supplies along the East Coast for weeks, while natural gas supplies suffered only localized short-term outages.[3]

ULSD was a prerequisite for engine exhaust aftertreatment systems introduced after 2006, enabling engines to achieve exhaust emissions more than 99% cleaner than engines manufactured prior to 1996. Diesel engine emissions from stationary sources are part of a larger group of EPA air quality regulations known as RICE-NESHAP.[4] Implementing cleaner diesel engines is estimated to reduce annual emissions from stationary engines as follows:

- 1000 tons per year of air toxics
- 2800 tons per year of fine particulate matter
- 14,000 tons per year of carbon monoxide
- 27,000 tons per year of volatile organic compounds[5]

However, ULSD has a substantially shorter shelf life compared to its high-sulfur predecessor. Fuel polishing[6] is required between six and 24 months. This is driven by changes in the fuel as well as the engines:

- The catalytic cracking processes used to increase per-barrel yield and remove sulfur results in a less stable finished fuel compared to product from a distillation process.
- Sulfur in diesel fuel acts as a biocide, slowing the growth of algae and other bacteria that would otherwise begin to break down the fuel. While high-sulfur diesel fuel was not completely immune to fuel degradation, it could be stored reliably for one to two years in most environments before fuel polishing might have been required.
- The high-pressure fuel systems (>30,000 lb./in^2 on the latest generation of engines) required to meet today's strict emissions requirements increase fuel temperature and the rate of fuel oxidation. Fuel oxidation leads to the formation of gums that can clog filters and fuel injectors.[7,8]
- Fuel systems on older diesel engines were more tolerant of degraded fuel.

With ULSD requiring more rigorous maintenance of the fuel itself and the EPA's mandate for cleaner burning diesel engines requiring a higher quality fuel, diesel fuel is no longer the low-cost, low-maintenance emergency power fuel it had been.

The environmental risk related to diesel fuel leaks, spills and the associated costs of cleanup also weigh heavily on the continuing use of diesel fuel for emergency power. EPA regulations require reporting of oil spills, which includes diesel fuel — even in very small quantities.[9]

As if the environmental risk, maintenance challenges posed by ULSD and more complex — albeit cleaner-burning — engines weren't enough, Hurricanes Irene and Sandy destroyed the long-standing conventional wisdom that diesel fuel delivery was assured even during the most severe emergencies. Both storms caused enough damage to the petroleum supply networks as to make diesel refueling a challenge.

For owners and operators of emergency power systems, the changing fuel landscape had them looking for alternatives. Natural gas appeared to address all their concerns: cleaner exhaust emissions, equal or better fuel availability, reduced fuel maintenance and reduced environmental liability.

NFPA 110 §5.1 specifies energy sources for emergency power systems. Natural gas is permitted as a fuel source, but carries with it the following exception:

> *For Level 1 installations in locations where the probability of interruption of off-site fuel supplies is high, on-site storage of an alternate energy source sufficient to allow full output of the EPSS to be delivered for the class specified shall be required, with the provision for automatic transfer from the primary energy source to the alternate energy source.*

Unfortunately, NFPA 110 does not define certain things, such as a high probability of interruption or a reliable fuel supply. NFPA forces this decision to the local Authority Having Jurisdiction (AHJ).

It is incorrect to conclude that diesel fuel, simply by its on-site presence, is more reliable than natural gas. For the purposes of an EPS, a reliable fuel supply is one that is consistently available in sufficient quantity and quality to provide emergency power. It is necessary to holistically examine external factors influencing the relative reliability of natural gas and diesel as EPS fuel sources.

Natural Gas Delivery Infrastructure

Even in cases where the AHJ has approved natural gas for life-safety EPS, there are owners and operators that are not comfortable being fully reliant on pipeline natural gas delivery to power their life safety and mission-critical systems. There is a perception of trading off one utility supply for another — electric power from the utility for natural gas to run a generator.

According to a 2013 report by Massachusetts Institute of Technology's (MIT's) Lincoln Laboratory, natural gas distribution systems operate at a reliability rate exceeding 99.999%,[10] with the exception of seismically active areas. Incidentally, that makes the natural gas distribution system approximately three orders of magnitude more reliable than a single-engine generator set.

The same MIT report notes that many of the compressors on the transmission network are powered by natural gas, using approximately 3 percent of the natural gas produced. The distributed nature of the natural gas production and transmission networks result in an exceedingly low probability of cascading failure.

From an end user's perspective, natural gas is delivered on demand, and it is easy to overlook more than four-trillion cubic feet of storage capacity in the continental United States.[11] If all natural gas production in the United States ceased simultaneously, it would still take anywhere from two to nine weeks to fully deplete the natural gas in underground storage.

Each individual location has its own unique risk profile, but an illustrative example is helpful:

- Assume 99 percent availability on the electric utility (87.6 hours of outage time per year).
- Hypothetically, a particular city has older natural gas infrastructure and availability is only 99.9 percent (two orders of magnitude less reliable than that cited by the MIT report, corresponding to 8.76 hours of outage time per year).

$$P\ (\text{utility power fail}) = 0.01$$
$$P\ (\text{natural gas supply fail}) = 0.001$$

For the purpose of maintaining electrical power to a facility using a natural gas generator, a natural gas supply failure is a problem only if utility power is in a simultaneously failed state:

$$P\ (\text{natural gas supply fail} \mid \text{utility power fail}) = 0.0001 \times 0.01 = 0.00001$$

Expressed in terms of availability, there is a 99.999 percent probability that utility power or the natural gas supply will be available at any given time. This "five nines" availability equates to an average of five minutes and fifteen seconds per year in which both electric and natural gas service are simultaneously unavailable. This analysis is only valid if the probability of failure for either utility can be treated as independent events. Since history and simulation[12,13] show there is a low correlation between electric utility and natural gas supply failures, both can be treated as independent events.

A number of facility management professionals believe maintaining an on-site supply of diesel fuel will mitigate the few minutes annually that utility power and natural gas could be simultaneously unavailable each year. However, managing a diesel fuel supply isn't as simple as it may seem.

Diesel Fuel Maintenance and Delivery Risks

Many facility managers dismiss the inherent challenges and risks of maintaining a stable, on-site diesel fuel supply. The perception is that simply because there is a fuel tank on site, any risks to the EPS suddenly dissipate.

However, without regular diesel fuel testing and fuel polishing, it is virtually certain the fuel quality will degrade before it is fully consumed. As mentioned earlier, today's ULSD fuel is more prone to oxidation and microbial growth. Furthermore, the majority of emergency power systems see an insignificant number of commercial power outages per year. This isn't a problem for natural gas engines; they simply burn less gas. For a diesel engine, though, it means a single tank of fuel could take years to consume.

Testing diesel fuel once every six months until a fuel quality pattern is established — and then at least annually thereafter — is critical to maintaining diesel fuel reliability. In hot and humid environments, diesel fuel polishing is often required annually. In cooler, less humid environments, the fuel maintenance interval may be longer, but the end result is the same: if the fuel is not used, it will have to be polished and/or replaced at some point. At between $1 and $2 per gallon for fuel polishing services, the cost to provide regular preventive maintenance to diesel fuel is a significant operational cost. Moreover, diesel fuel has a finite shelf life that varies from as short as six months in a harsh environment to a maximum of two years under the most benign environmental conditions.[14,15]

A frequent cause of diesel EPS failure is clogged fuel filters due to inadequate fuel maintenance. Weekly unloaded exercise burns very little fuel, and even clogged filters can usually provide enough fuel flow to keep the unloaded engine running. However, when a load is applied, as in the case of an actual power failure, the engine fuel demand increases dramatically. That's when system owners are most likely to discover fouled fuel filters — as the engine shuts down and the facility goes dark.

Responsible facility managers can mitigate the risk of poor diesel fuel quality through an aggressive fuel maintenance program, provided they have an adequate maintenance budget. System owners that lack the operational capability or budget to maintain diesel fuel properly are at a significantly higher risk of fuel system-related failures.

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The supply of diesel fuel is another external factor that can be difficult to control. The greatest reliance on emergency power systems is correlated with severe weather events and the subsequent impact to fuel transportation; timely fuel deliveries are most critical when it is most difficult to get a truck to the location. Due to infrastructure damage or government rationing of limited supplies, a supplier's ability to obtain diesel fuel for regular delivery can also be seriously challenged following major natural disasters, which is the same time an EPS may have to run continuously for days or weeks on end.

Hurricane Irene (2011) and Hurricane Sandy (2012) are two recent examples where diesel fuel supplies were seriously impacted for extended periods following initial landfall.

Hurricane Irene was a distributed impact along most of the East Coast. While damage to diesel fuel distribution infrastructure was widespread, problems were relatively minor and repaired in several days. Although limited damage to roads caused localized diesel fuel delivery problems, there was virtually no impact to natural gas supplies.

Comparatively, Hurricane Sandy devastated fuel terminals across the Northeast. Even if a delivery truck was able to get to a terminal, it was unlikely it would be able to obtain fuel. The available fuel and trucks within the region were redirected by the government to hospitals and emergency response facilities. Here are a few factors that illustrate the criticality of the situation in the Northeast following Hurricane Sandy:[16]

- The EPA relented on ULSD rules and allowed emergency vehicles, pumps and generators that could tolerate the higher sulfur fuel to burn 500 ppm home heating oil (a majority of the non-road engines in service at the time could handle fuel with a higher sulfur content). In New York and New Jersey, the waivers extended to December 7, 2012, until the fuel supply infrastructure had finally stabilized — more than a month after the storm made landfall on October 29.
- While not uncommon in disasters, hours-of-service regulations for fuel truck drivers were waived in the aftermath of Sandy, which was especially critical for fuel transportation. Fuel truck drivers could work as long as they could stay awake. The driver qualification and maintenance waivers, however, are only granted in the most desperate situations. Following Sandy, if a truck could carry fuel, the driver was qualified and the vehicle had a reasonable chance of getting to a destination without a major failure, they were subsequently deployed for delivery.
- For the first time since its inception in 1920, the Jones Act, which normally prohibits foreign-flagged vessels from transporting cargo — including petroleum — between U.S. ports, was waived, enabling foreign vessels to deliver some 2.7 million barrels of product into the NYC area until the supply infrastructure was stabilized.

Keeping a diesel fueled generator running suddenly became a very uncertain proposition. Even large businesses, with robust business continuity plans, experienced problems maintaining a steady diesel supply. Meanwhile, with only isolated exceptions, generators fueled by natural gas ran continuously for days to several weeks with no fuel supply interruption.

Capital and Operational Costs

Facility managers and owners considering natural gas as a fuel source for their EPS should not be discouraged by the higher capital cost for a natural gas generator. In cases where a design-build firm will be selling a finished project to another entity for management, there may be less concern for operational cost on the EPS. The actual fixed and operational costs will vary based on installation conditions and regional variations in operational costs. However, when total cost of ownership (TCO) is considered, natural gas is a better option.

Table 1: A single engine 200 kW diesel generator set compared to a 200 kW natural gas generator set using Generac Industrial Power's ROI Calculator[17]

Total Cost for 25 Years (-4% Inflation)	Diesel $148,542.00	Natural Gas $142,157.00
Total NOx Emissions	919 (lb)	25 (lb)
Total CO Emissions	596 (lb)	124 (lb)
Total PM Emissions	37 (lb)	0 (lb)

Over the life of the machine, the diesel and natural gas options have a nearly equal cost. The natural gas engine offers additional benefits, including the following:

- No fuel quality risk or the associated costs of diesel fuel polishing
- Reduced fuel delivery risk associated with natural gas, especially following natural disasters
- Lower fuel cost per kW produced – In the example above, 20 hours of exercise and 25 hours of actual runtime are assumed. If actual runtime is greater, the natural gas option becomes less expensive overall compared to diesel
- Significantly reduced exhaust emissions
- Opportunity to participate in utility demand response (DR) programs at a substantially lower cost than a diesel alternative – This is attributable to the lower fuel cost of natural gas and the lower cost of meeting non-emergency emissions limits with a natural gas engine

SUMMARY

No single fuel source is infallible. In this whitepaper, we addressed the external factors that can impact diesel fuel reliability — maintenance for fuel quality, delivery for continuous supply and the environmental risk of accidental spills during refueling.

Natural gas has demonstrated its resilience twice in recent years against two major hurricanes in an area of the country that is highly reliant on natural gas.

For facility managers that are confident in their maintenance programs and business continuity plans, diesel will continue to play an important role in emergency power systems.

For applications where the owner's ability to aggressively maintain diesel fuel is less robust, natural gas is a better choice for long-term fuel reliability and availability.

AUTHOR BACKGROUND:

Mike Hainzl is a power solutions manager for Generac Power Systems' Industrial Division, supporting the Northeast U.S. and Atlantic Canada.

Prior to joining Generac in 2015, Hainzl spent over 23 years in the telecom industry, where he held positions in RF and facilities engineering, field operations, and business continuity management. He has managed fixed and mobile generator fleets for national telecom providers and coordinated emergency power restoration following major events like Hurricanes Katrina, Irene and Sandy.

Hainzl developed techniques to improve operational readiness of telecom emergency generator assets through remote monitoring, automated reporting and triage. Failure mode and risk analysis provided quantitative data for capital and maintenance budgeting.

Hainzl has a BSEE, MS in engineering management and an MS in emergency management from New Jersey Institute of Technology. He is also a Certified Business Continuity Professional (CBCP).

Endnotes

[1] https://www.ferc.gov/legal/fed-sta/exp-study.pdf US Department of Energy, 2007. The Potential Benefits of Distributed Generation and Rate-Related Issues That May Impede Their Expansion, pp.34-35

[2] https://www.epa.gov/diesel-fuel-standards Diesel Fuel Standards, EPA web page.

[3] https://energy.gov/sites/prod/files/2013/04/f0/Northeast%20Storm%20Comparison_FINAL_041513b.pdf, US Department of Energy, Office of Electricity Delivery and Energy Reliability. Comparing the Impacts of Northeast Hurricanes on Energy Infrastructure.

Specifically, Table 3 on page 11 notes the number of natural gas compressor stations impacted during Hurricane Sandy (1) in contrast to the number of petroleum terminals (62).

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[15] Diesel Fuel Storage and Handling Guide, CRC Report #667. https://crcao.org/reports/recentstudies2014/CRC%20667/CRC%20667.pdf

[16] DOE Northeast Storm Report.

[17] Generac Industrial Power ROI Calculator. http://www.generatorROI.com

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