TECHNICAL PERSPECTIVE

Bi-Fuel Engine Generators

INTRODUCTION

As end users search for ways to improve the reliability of their standby power systems, increased interest has been directed toward the issue of on-site diesel fuel storage. How much fuel is enough? How much is too much? Generac has addressed this issue, through its bi-fuel powered generators.

A bi-fuel engine is a compression-ignited (diesel) engine that runs on the simultaneous combustion of diesel fuel and natural gas. Under normal operating conditions, Generac's bi-fuel generators operate on 90% natural gas and 10% diesel fuel. This greatly extends run times and limits the amount of diesel fuel that must be stored on site.

Why Bi-Fuel?

Diesel and natural gas fueled generators have been common solutions for industrial standby power applications for decades. Each has its advantages and disadvantages.

Natural gas generators, though common in the under 150 kW market, are limited in larger kW applications due to significantly higher capital costs. Even so, natural gas generators offer numerous advantages compared to diesel solutions. The most noticeable is the extended run time offered by an endless supply of natural gas. This is a huge advantage given that refueling conventional diesel generators can be quite challenging during long-term outages. Hurricanes and storms can close roads, and area-wide outages can totally cripple refueling infrastructures.

KEY POINTS

- Why Bi-Fuel?
  - – Greatly Extended Run Times
  - – Increased Generator Reliability
  - – Environmental Advantages
- Why Generac?
  - – Proven Product
  - – Single Source Responsibility

CONSULTING-SPECIFYING ENGINEER
Product OF THE *Year* 2005 WINNER

Figure 1

GENERAC®
POWER SYSTEMS, INC.

Diesel generators are the market norm above 150 kW, but system designers must plan for the limitations associated with utilizing on-site diesel fuel. Storing small amounts creates the risk of running out of fuel. Storing large quantities requires on-going maintenance to prevent contamination and degradation. In addition, fuel delivery from a main storage tank may require a system of pumps, solenoids, and isolation valves that can negatively impact the reliability of the generator during an outage.

Bi-fuel gensets offer the best of both worlds. At a cost that is only slightly higher than a diesel-only design, bi-fuel ensures the extended run time benefits of natural gas, plus a more manageable amount of on-site fuel.

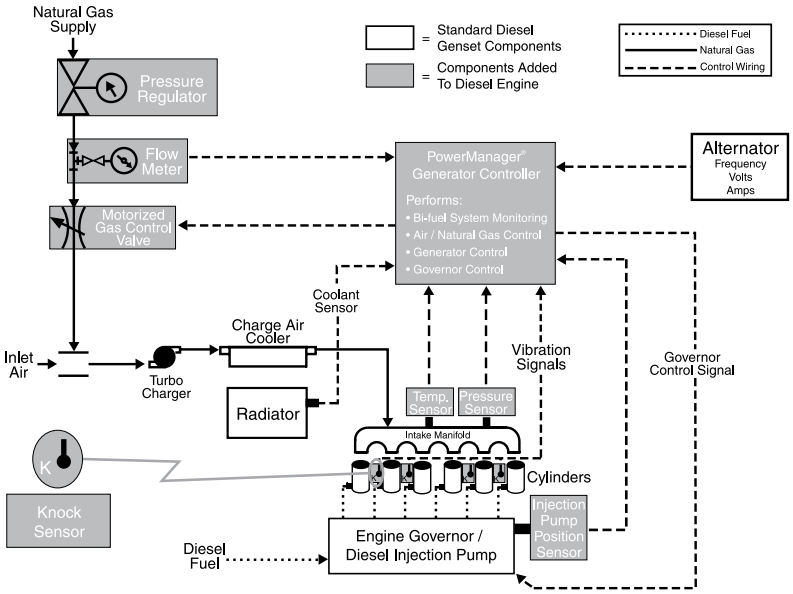

Figure 2

Bi-Fuel Implementation

The bi-fuel concept is not new. Rudolph Diesel, who invented the engine that bears his name, experimented with enriched air mixtures in the early 1900's and various forms of bi-fuel engines have been used in certain commercial applications for decades.

A diesel engine relies on the heat generated by compression of the intake air to ignite its fuel. Since the heat inside the cylinders can reach 1000° F and diesel fuel ignites at between 500 – 700° F, no spark is needed for normal diesel operation. The ignition point for natural gas is between 1150 – 1200° F. Therefore a diesel engine cannot run on natural gas alone.

Generac's bi-fuel generators use conventional, high-volume diesel engines that are modified for bi-fuel operation. The diesel fuel enters the engine through the injection system. As with a standard diesel engine, there are no spark plugs. The ignition of the diesel fuel provides the spark required by the natural gas.

Natural gas is metered into the air intake stream of the engine before it reaches the turbocharger. This allows the natural gas to enter at normal gas distribution pressures (2 psi).

With the Generac system, all critical factors are continuously monitored and the fuel mixture is instantaneously adjusted as needed. This process is controlled through Generac's integrated PowerManager® control system which provides a single point of control for all generator functions. The control system monitors various parameters such as engine coolant temperature, intake manifold temperature and pressure, kW load and engine speed (Figure 2). These inputs determine the ideal mixture of diesel fuel and natural gas.

Bi-Fuel Operation

During initial startup, the engine operates on 100% diesel fuel. As soon as the engine reaches its minimum coolant temperature and the generator accepts at least 10% of the electrical load, the PowerManager® control system begins bi-fuel operation. The system increases the amount of natural gas that is inserted into the intake air, and simultaneously decreases the amount of diesel fuel that is injected into the cylinders (Figure 3).

Generac has created comprehensive operational maps for all of its bi-fuel engines to determine the optimal and safe amount of natural gas for all operating conditions. Figure 3 shows fuel percentage versus load for a given intake air temperature.

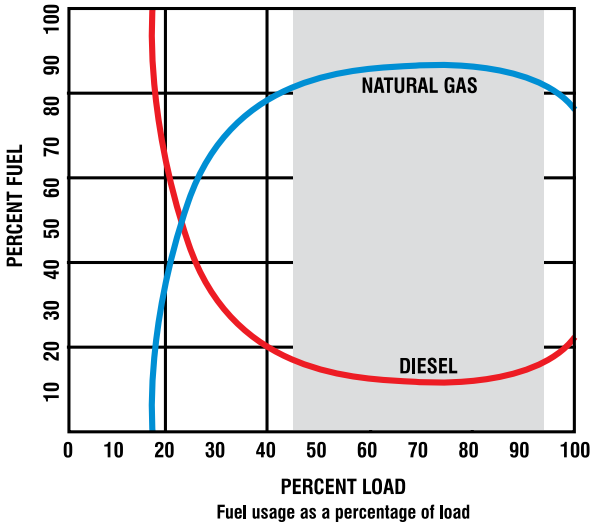

Figure 3

Similar curves have been developed across the full range of temperatures, creating a 3-dimensional curve. The controller uses this curve to maintain optimal fuel ratios as operating conditions change.

It's important to note that, the engine can operate on 100% diesel fuel if the natural gas supply is interrupted. The Generac control system automatically switches between bi-fuel and diesel mode as conditions dictate. The transition is both transparent and seamless, and there is no drop in power output at any point during the process.

Active Engine Protection

In a bi-fuel system, it is important to avoid admitting too much natural gas into the cylinder. A fuel mixture that is too high in natural gas can cause "pre-ignition". Pre-ignition occurs when a portion of the air/fuel mixture spontaneously ignites during the compression stroke, but prior to the desired moment of ignition. The result is a shock within the engine cylinder referred to as “knock”. When knock occurs, it can be very damaging to the engine. Engine knock occurs when three pre-ignition pressure waves collide.

These pressure waves are:

- The flame front from the spontaneously ignited fuel
- The flame front created by the normal ignition source
- The piston compressing the air/fuel mixture

With the Generac bi-fuel system, the PowerManager® control system provides two independent means to protect the engine from knock. As previously discussed, internal operational mapping limits natural gas admission to only safe levels. In addition, the PowerManager® controller senses the signature vibration signal created by conditions approaching, but prior to, pre-ignition. The controller immediately reduces the supply of natural gas. If the condition persists, the natural gas is simply shut off through an independent shut-off solenoid and operation continues on full diesel.

Bi-Fuel Benefits Summary

Extended Run Times

Comparison of Diesel vs. Bi-Fuel Run Times
300 kW Genset at 80% Load

Diesel Tank Size	Diesel Run Time	Bi-Fuel Run Time
12” tall / 183 gallons	8.9 hours	76.2 hours (3.2 days)
24” tall / 438 gallons	24.1 hours	182.5 hours (7.6 days)
36” tall / 693 gallons	33.8 hours	288.8 hours (12.0 days)

Reduced Fuel Storage

Because natural gas is the primary fuel, smaller diesel tanks are viable. Less fuel stored on site can lead to easier permitting

and lower fuel maintenance costs. In addition, indoor fuel installations with capacity limits per NFPA or local codes may become feasible.

Lower Cost

The cost of a midrange natural gas generator is approximately twice that of a comparable diesel unit. Bi-fuel offers many of the benefits of natural gas for only slightly more than a diesel-powered system. Bi-fuel also has a higher thermal efficiency than natural gas solutions. This may translate into operational fuel savings based on traditional fuel costs.

On-Site Fuel

For some applications, on-site fuel is required or strongly preferred. With the bi-fuel solution if there is ever a problem with the natural gas supply, the generator automatically switches to 100% on-site diesel fuel without affecting operation. This meets the on-site fuel requirements for emergency systems as referenced in NEC700 and NFPA110.

Reduced Exhaust Emissions

Bi-fuel generators emit about 30% less nitrogen oxides and 50% less particulate matter than comparable diesel-only units. This is consistent with the market's preference for environmentally friendly solutions.

Product Offerings

Generac offers 300 kW and 375 kW bi-fuel gensets. These units are available as stand-alone gensets and can be-con figured as a Modular Power System (MPS) for applications requiring up to 3750 kW of power. Both gensets are also avail able in a twin-pack arrangement as either a 600 kW or 750 kW Gemini®. Generac's bi-fuel generators are UL2200 listed and designed to meet the requirements of the National Electrical Code and NFPA standards.

CONCLUSION

The introduction of bi-fuel technology represents a tremendous advancement in the standby power industry. System designers have continually struggled with issues of fuel system reliability — too much fuel and it goes bad; too little fuel and it runs out. With tremendous increases in run time and the minimal use of diesel fuel, bi-fuel generators address these major fuel reli ability issues and offer environmental advantages.

The readers of *Consulting & Specifying Engineer* magazine recognized the importance of this technology in standby power applications by selecting Generac's bi-fuel generator as its 2005 Product of the Year Grand Award winner. This prestigious award honors the most significant new product in the engi neering field.

Bi-fuel standby emergency power is an idea whose time has come.

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