

Optimizing Engine RPM for Standby Power Generation

From the introduction of reciprocating engines in generator set applications, the marketplace has continued to evolve and change. One significant area of change has been the operating rpm of the engine. With improving engine technology and better metallurgy, generator engine speed has steadily increased over the last 80 years. As an industry leader in standby power generation, Generac Power Systems fully embraces this market trend and produces various products that optimize engine rpm.

Engine RPM and Alternator Frequency

The AC frequency of the genset's electrical output is a function of engine speed and alternator design. In the North American market, 60 Hz power is required to operate virtually all electrical devices. To achieve 60 Hz, the engine must operate at a specific rpm for a given alternator configuration. An alternator's operating speed is determined by its main rotor, which is manufactured to a specific magnetic pole configuration. The table below outlines the basic relationship between engine rpm, alternator pole configuration and 60 Hz output frequency.

Alternator Poles	Engine RPM	Typical Application (historically)
2	3600	Small kW generators (<25 kW) Large utility generators (gas & steam turbines)
4	1800	Standby power generation (25 kW to 2000 kW)
6	1200	Standby power generation (+2000 kW) Prime power natural gas generators
8	900	Standby power generation (+4000 kW) Prime power natural gas generators

Note: Table corresponds to 60 Hz electrical output.

Market Trends

Fifty years ago most generators operated at speeds below 900 rpm. More recently, we have seen the large standby generator market move from 1200 to 1800 rpm as large engine outputs have progressed from 750 to 2700 kW. The prime power, natural gas driven generator market is also migrating from 900 to 1200 rpm with some recent offerings at 1800 rpm.

The smaller kW, automotive derivative engines have also moved from 1800 to 3000, and most recently to 3600 rpm. **The advantages of higher rpm are compelling: improved transient performance, less stress on engine bearings, increased power densities, and improved customer value.**

Improving Transient Performance

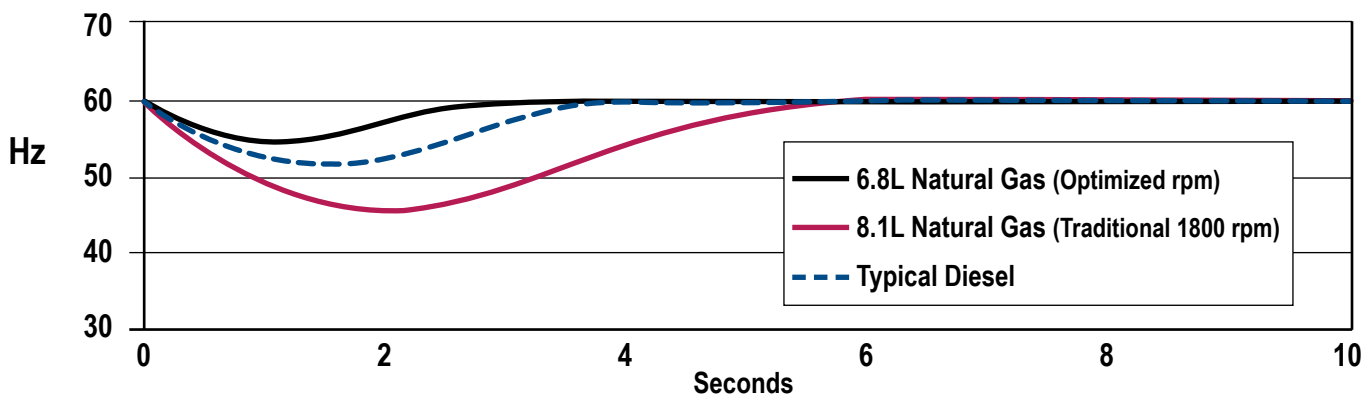
A generator's engine must quickly respond to constantly changing loads to prevent the generator frequency from dipping excessively. This transient performance characteristic is a function of the engine's fuel system, amount of turbocharger boost, and the rotating inertia of the genset.

Diesel generators typically provide better response than natural gas units due to the characteristics of the engine's fuel system. However, most diesel generators are heavily turbocharged. When large load changes occur, the turbocharger takes some time to "spin-up", thus leaving the engine temporarily under-powered.

In recognition of this effect, Generac has embraced optimizing engine speed instead of turbocharging for automotive derivative engines. As engine speed increases, inertia also increases at the square of speed. If engine speed is doubled, inertia increases by a factor of four.

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125 kW Block Load, Transient Performance Data



Using these principles, Generac offers natural gas generators that significantly outperform competitive natural gas systems and challenge the transient performance of diesel units. The graphic on the **previous page compares the data for an 8.1L turbocharged engine versus a smaller 6.8L, higher rpm configuration**. Generac offers both configurations but believes that the higher rpm unit is superior in all aspects. By all measures, the transient performance of the smaller 6.8L engine outperforms the 8.1L unit by a factor of two.

Engine Life: Reduced Bearing Stress

In today’s competitive standby generator market, the challenge is to produce more power with smaller engines. For diesel engines the market accomplishes this with increased turbo-boost: more air, more fuel, and more power. Generac embraces this common practice for high compression diesel engines that are designed for high bearing loading. However, turbocharging spark-ignited, automotive engines raises concerns about the high stresses placed on the engine bearings.

These concepts are intuitive to many of us based on our experiences using automobiles to tow loads. The previous comparison referenced a 6.8L engine sourced from Ford. This is the same type of engine found in the F250 pickup and the Excursion. If you were towing a 35 foot boat up a steep grade that required maximum power, would you:

- A) Leave the engine in overdrive and crawl up the hill at 1800 rpm with the accelerator tight to the floor
- B) Stop at the local garage and add a turbocharger for more 1800 rpm engine torque, or
- C) Increase engine rpm by coming out of overdrive

The obvious answer is to increase engine rpm. For a given power output, as engine speed increases, torque decreases proportionately. That is significant because engines produce torque by creating force on the pistons. That force is carried by the main engine bearings, connecting rod bearings, and wrist pin bearings. Turbocharging an automotive engine dramatically increases torque and significantly reduces engine life. The following table compares bearing loading for two different 125 kW configurations using automotive-based engines.

Engine Configuration	Engine RPM	BMEP (psi)	Bearing Load Peak (psi)
6.8L natural gas no turbocharger	3000	116	2850
8.1L natural gas, turbocharged, after-cooled	1800	168	4144

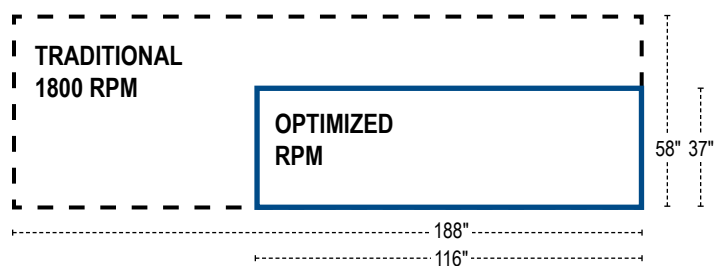
Note: Break Mean Effective Pressure (BMEP), is the average pressure on the piston.

The 8.1L engine, though 16% larger, experiences 45% greater bearing stress than the higher speed 6.8L engine. In this operating speed range, the engine bearings tend to be the limiting factor in engine life, not piston ring to cylinder wear. This is consistent with the design and power band of an automotive engine.

Increasing Power Density and Customer Value

In addition to improving transient performance and reducing bearing stress, optimizing rpm allows smaller engines to comfortably produce more power. In spark-ignited automotive engines, power increases of 50 to 100% are common, while in diesel models power increases tend to be a more modest 25%. The end result is generators that are lighter, smaller, and a better value to the customer.

Footprint Comparison 150 kW (Sound Attenuated Enclosures)



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Myths Versus Facts

As a market evolves and adopts new technology, it's not uncommon for confusion and misinformation to occur. Standby power generation and the use of optimized rpm is no exception to this rule. The following points are an attempt to create some clarity.

1. Generac is a supporter of market choice. The strongest case for optimizing engine speed exists with spark-ignited units, and this is the product category in which Generac has focused its efforts. Generac still offers 1800 rpm options, but we believe our optimized rpm units are a superior choice for standby power applications. Generac's diesel line-up is primarily 1800 rpm, matching the high torque characteristic of most diesel engines.
2. The practice of optimizing the generator's rpm is a proven solution. Generac has 25 years of experience operating standby generators at speeds above 1800 rpm. The proven reliability of those units is a very strong testimonial to the concept of optimizing rpm.
3. Full load fuel consumption rates are comparable between generators operating at a higher rpm and traditional 1800 rpm models as shown in the following graphic.

Engine	RPM	80 kW	100 kW	125 kW	150 kW	Average
Traditional	1800	1236	1440	1796	1850	
Optimized RPM	3000, 3600	1099	1374	1717	2061	
Comparison		-11.1%	-4.6%	-4.4%	11.4%	-2.2%

4. Sound levels are also comparable between optimized rpm generators and traditional models. Sound levels are significantly affected by enclosure design and operating modes. The data presented here is a good faith effort to present market norms. The optimized rpm units presented can be exercised in a Quiet-Test™ mode that reduces the sound levels an additional 10 dBA making Generac's QT Series generators the quietest in the industry.

Full Load Sound Levels @ 7m (dBA)

Engine	RPM	80 kW	100 kW	125 kW	150 kW	Average
Traditional	1800	76.6	76.6	78.3	78	
Optimized RPM	3000, 3600	74	77	74	76	
Comparison (dBA)		-2.6	0.4	-4.3	-2.0	-2.1

Conclusion

The facts are compelling. By optimizing the generator's rpm, manufacturers are able to improve transient frequency response, increase engine life by reducing bearing loads, increase the generator's power density, and offer more value to the customer. In addition to all these benefits, this technology is proven in the market with 25 years of in-field operational experience, does not negatively impact full load fuel consumption, and can be implemented without increasing sound levels. For these reasons, Generac offers both traditional and optimized rpm solutions, but we believe that the optimized rpm solution is the superior choice.



3125 Intertech Drive
Brookfield, WI 53045
262-790-6230
800-236-1625
wolterps.com

0719-0707

Generac Power Systems, Inc.
Highway 59 & Hillside Rd.
P.O. Box 8
Waukesha, WI 53187
1-888-GENERAC
generac.com