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High- or Medium-Speed Generator Sets: Which Is Right for Your Application?

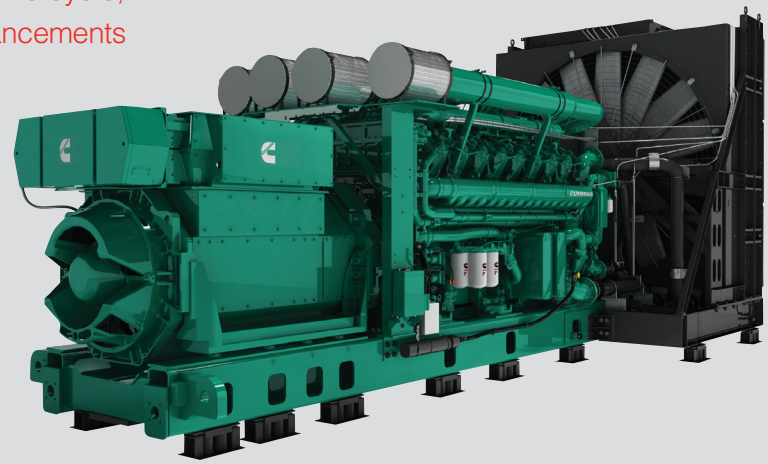
■ White Paper

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High-speed diesel generators offer considerable startup and operational benefits, but concerns about reliability, shorter maintenance intervals, and long-term durability leave many questioning whether they're right for prime applications. On closer examination, however, many of these concerns often prove to be based on anecdotal evidence rather than firsthand experience. In practice, high-speed generator sets used for prime applications not only deliver a significantly lower initial capital cost, they offer a comparable or lower total cost of ownership over the life cycle, along with noteworthy enhancements to operational efficiency.

High-speed Generator Sets — Ready for Prime Time?

While high-speed generator sets are most commonly associated with standby emergency power, they offer significant cost and efficiency benefits for prime applications—even when maintenance intervals are taken into account. These advantages can no longer be ignored, as the capacity of high-speed generator sets continues to grow, encroaching into nodes that could be supported only by medium-speed generators as recently as a decade ago.



The purpose of this paper is to address common concerns about the use of high-speed generator sets, particularly for prime applications. Exactly where the line between "high" and "medium" speed is drawn can vary between companies and even individuals. In this paper, we will be comparing high-speed generator sets operating at 1,500–1,800 rpm to medium-speed generator sets operating at 1,000 rpm or less.

The Business Case for High-speed Applications

Total cost models vary between high- and medium-speed generator sets, but four major economic components are central to any comparison of life cycle costs over time:

- Initial capital costs
- Fuel consumption costs
- Frequency of service intervals and associated costs per instance
- Frequency of major overhaul intervals and associated costs per instance

While high-speed generator sets are capable of continuous, indefinite operation, the practical application of these four factors suggests they are most cost-effective for prime power applications where annual run-time is limited to a range from hundreds of hours to a few thousand hours per year.

Specific examples where high-speed generator sets tend to offer superior economy and reliability include:

- Utility peaking, where generator sets augment base load power plants;
- Industrial and commercial peak shaving; and
- Temporary or short-term power installations
- Standby

Capital Cost

The most commonly cited advantage of high-speed generator sets is the significantly lower initial cost associated with their smaller, more efficient design. Depending on the application, capital costs alone can be as much as 50 percent lower than a medium-speed generator of comparable capacity. This is because power output is a function of speed. Medium-speed systems require a larger engine displacement, alternator and chassis to produce a comparable amount of power and thus are heavier, larger and more expensive.

For example, as shown in Table 1, an 1,800 rpm, 95 liter displacement machine is capable of delivering 3,000 kW (prime). A 900 rpm machine would need to be about twice as large to provide comparable 60 Hz power output.

Table 1: Medium- and High-speed Generator Set Size Comparison

Type	Engine RPM	Prime Rating	Engine Displacement	Footprint	Weight
Medium-speed	900 rpm	3,640 kW	222 liters	26 m^2	51,000 kg
Medium-speed	900 rpm	2,775 kW	175 liters	22 m^2	59,000 kg
High-speed	1,800 rpm	3,000 kW	95 liters	13.5 m^2	25,000 kg

In addition, the smaller size and weight of high-speed generator sets directly translates into installation, transportation and infrastructure cost savings because of smaller size and weight.

Operating Cost Comparisons

While the factors that reduce the up-front costs of high-speed generator sets are well understood, there is less recognition of the additional advantages that reduce their total cost of ownership over time.

Ease of Maintenance

Among the most common concerns regarding high-speed generator sets are the shorter intervals between maintenance and overhaul cycles, which are often believed to imply higher overall maintenance costs.

This is not necessarily the case in practice because the smaller size of high-speed engines makes them easier and less expensive to overhaul and maintain. In the case of prime applications, total operating and maintenance costs across the life cycle may not be significantly different compared to equivalent medium-speed systems.

Fuel Economy

Many popular medium-speed generator sets have seen no significant technological advancement in fuel economy in the last 30 years, thus fuel consumption is no better than modern high-speed generator sets. These older design generator sets typically deliver around 4.2 kWh per liter (15.9 kWh per U.S. gallon) of diesel at rated load, but fuel economy is considerably worse for loads of less than 100 percent. Fuel consumption for modern medium-speed generator sets can be 3–5 percent lower than older products.

By contrast, today's state-of-the-art, high-speed diesel engines are capable of providing up to 4.3 kWh per liter (15.5–16.3 kWh per U.S. gallon) of diesel from 75–100 percent load. One factor that makes this possible is the fuel injection system used on high-horsepower engines, capable of injecting fuel at up to 2,200 bar to provide a cleaner—and more efficient—combustion formula. Modern high-speed engines also use electronic control modules (ECMs) to continuously optimize engine performance and fuel efficiency.

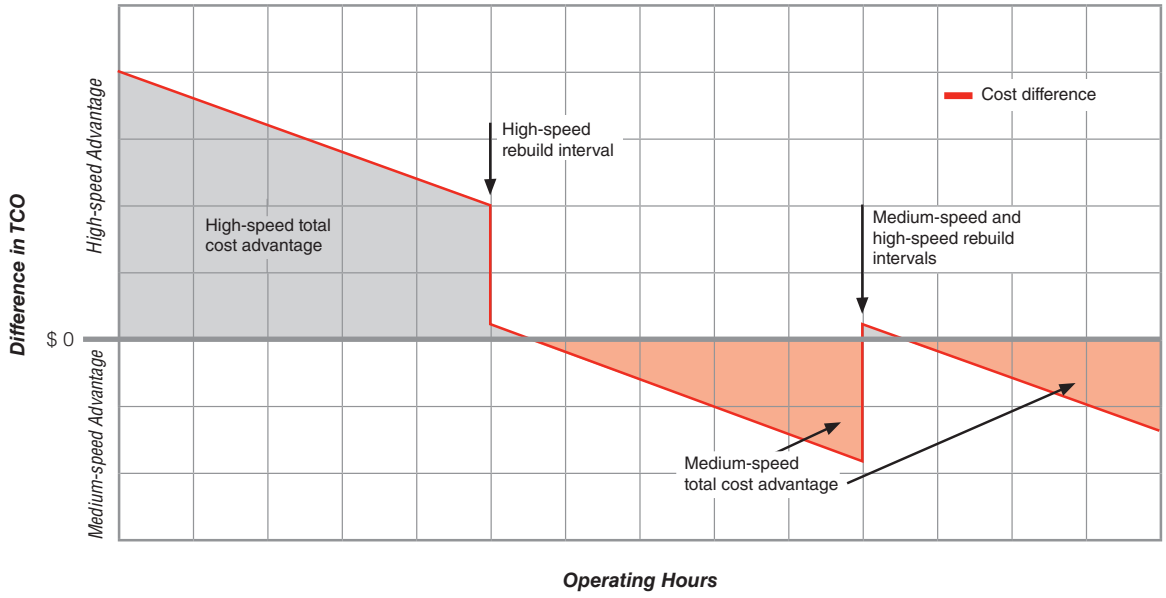
While a few of the newer medium-speed systems provide similar or slightly better fuel efficiency, fuel consumption of many high-speed generator systems across the full range of loads is comparable to most traditional medium-speed engines. However, fuel consumption is a consideration point when evaluating options for systems that consistently see very long hours of operation. In such cases, the cost premium associated with newer medium-speed designs could be recouped in only a few years. This is less of a factor for shorter-hour applications, where the same cost recovery can take many years.

Figure 1 illustrates the total cost of ownership difference between two comparable technology generator sets with similar output: one high-speed and one medium-speed. The chart shows the approximate cost benefits of both options over time, accounting for all the key components of life cycle cost — initial capital expense, fuel consumption, maintenance and rebuild.

This comparison illustrates that a high-speed generator set has a significant cost advantage until it requires a major overhaul, even though the medium-speed generator has lower fuel consumption and lower maintenance costs. The owner must decide whether the higher cost for a medium-speed generator can be justified based on the company's cost of capital and payback expectations.

Figure 1 — Operating Time-based Total Cost of Ownership Comparison

High-speed vs. Medium-speed Generator Sets



Emissions

High-speed engines are also preferable in countries where emissions are regulated. NO_X emissions are a function of the combustion temperature and time. Medium-speed engines require a longer combustion process, resulting in higher NO_X emissions.

Shifting, Adding or Reducing Capacity

The smaller size and modular design of high-speed generator sets make them highly flexible. They are relatively easy to move, and their capacity can be expanded or decreased in a reasonably short time. Similar changes are rarely practical or even possible for medium-speed systems because of their many accessories and dedicated facilities.

Built for Speed—and Durability

There is a common belief, often anecdotal, that high-speed generator sets are less durable than their medium-speed equivalents. Because modern high-speed engines are developed to work at faster speeds from the outset, they incorporate many features that significantly improve durability. In some applications, these features can produce an economic advantage over medium-speed engines. Over time, many notable features have been introduced to improve the durability of modern high-speed engines, including:

- Higher inherent strength in the engine block
- Single-piece forged steel pistons and counterweighted crankshafts
- Power cylinder architecture that combines the widest possible bore with the shortest possible stroke—the wider bore enables larger valves with better engine breathing and lower thermal loading, while a shorter stroke enables a lower piston speed that results in longer cylinder life

System Performance Considerations

Power Restoration Time

A high-speed generator set system can start up and be ready to take full load in 10 seconds from the power outage. Most medium-speed engines require much longer to start and accept full load, sometimes up to several minutes.

Block Loading

While medium-speed generator sets are effective for base and constant loads, they struggle to adapt to changing loads. In addition, their larger turbocharger compressors react slowly to changing operating requirements. The lower inertia of high-speed generator set systems ensures better load pickup and excellent transient response in general.

Redundancy

Because of the lower initial and installed costs of high-speed generator sets, it is very cost-effective and practical to add an additional high-speed generator set when additional redundancy is desirable. Adding a medium-speed generator set is more expensive.

Consider All Costs When Comparing Generator Sets

When analyzing whether to use high-speed or medium-speed generator sets in a power plant, it is important to analyze all components of the project cost, including initial capital cost, fuel consumption, annual operating hours, maintenance and rebuild costs, cost of capital, project net present value and company expectations for payback.

A high-speed generator set will have significantly lower capital costs. In addition, operating costs of modern high-speed engines have continued to improve due to fuel efficiency gains, durability improvements and increased time between maintenance intervals.

The initial higher cost of a medium-speed generator set could potentially take many years to recover — well beyond payback expectations — if in fact it is ever fully recovered.



About the author

Joel Puncochar is currently a marketing manager for Cummins, providing market input to design engineers for newly designed electric generator sets. He has worked in the generator set industry in design engineering, application engineering and marketing for 40 years, including generator sets for standby, prime power and continuous duty applications operating on diesel fuel and natural gas. He has a bachelor's degree in mechanical engineering from the University of Minnesota.

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