European Data Centre Association's
Technical Committee

Diesel Generators: Striking a Balance for Readiness and Run Hours Minimisation

EUDCA Viewpoint

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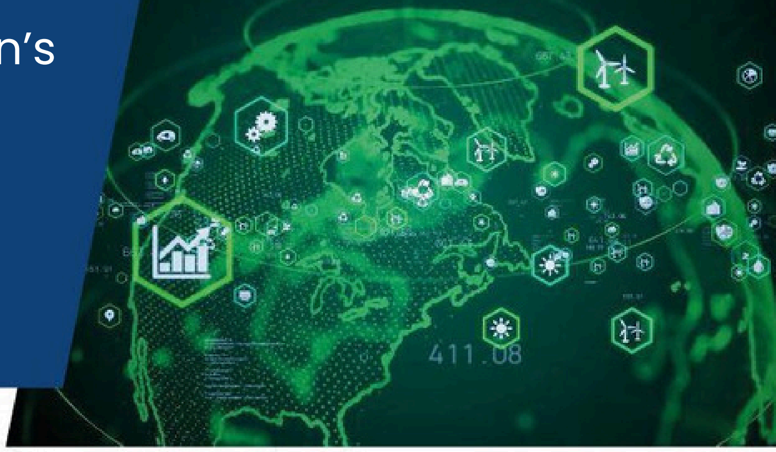

Setting a context for test regimens that minimise expense, operating hours, and emissions while maintaining reliability and readiness

Due to their power density, quick response time, and cost-effectiveness, diesel generator sets (gensets) have long been the primary choice for backup power in mission-critical applications. However, their reliance on fossil fuels presents significant challenges for air permitting and global warming. In addition to emitting greenhouse gases such as CO_2, diesel generators are also sources of criteria air pollutants including particulate matter (PM) or soot, sulphur oxide (SOx), and nitrogen oxides (NOx).

Data centres typically deploy large numbers of diesel generators for backup duty to protect the entire facility against utility power outages or other calamities, that could disrupt the regular power supply. Although backup generators rarely need to run in such circumstances, they must be maintained and ready to operate in case of an emergency.

To ensure readiness, data centre operators typically run their backup generators bi-weekly to monthly, with additional extended tests on an annual basis. Although maintenance run hours are relatively low, the sheer number of units requiring testing contributes to a substantial total volume of emissions.

At the same time, permitting authorities limit run hours to keep total annual site emissions below a mandated threshold, meaning for many data centres there is strong incentive to reduce engine testing regimes. Since there are currently no realistic, mature, and at scale alternatives for onsite backup power, it has become extremely important to reduce maintenance runtime to improve the overall sustainability of these backup generators.

This paper advocates for test regimens that will minimise expense, operating hours, and emissions while maintaining reliability.

Introduction

Historically, standby generator sets have been exercised monthly or bi-weekly to confirm that the system will work properly when called upon.

In North America, for example, National Fire Protection Association standard 110 (NFPA 110) requires diesel backup generators used for critical and life-saving infrastructure to be exercised at least once a month for a minimum of 30 minutes to verify generator readiness. Generators under test must be loaded either to a minimum of 30% of the genset standby rating, or to a level that maintains a minimum exhaust gas temperature as recommended by the manufacturer.

NFPA 110 does not generally apply to European data centres, except in certain specific circumstances, and where they are classified as critical infrastructure. As a rule, monthly or quarterly testing regimes tend to be either advised or imposed by local authorities.

It is important to understand that as a sector, European data centres have generally adopted testing regimes in line with critical infrastructure practices. However, over time, different testing practices have evolved due to differing OEM guidelines, genset configurations, operator-specific operational strategies, and comprehensive risk assessments. This has led to a proliferation of diverse testing methods across the market. At the same time, environmental incentives are prompting data centre operators to reduce their testing regimes.

Therefore, it has become essential to review the effectiveness of a range of regimes to ensure that diesel generators will start and run as and when needed.

In essence, the testing or exercise regimes that data centres adopt can be divided into two sub-categories:

- **No-load or loaded short exercise runs**: Typically performed weekly, bi-weekly, or monthly and usually last no longer than 10 to 15 minutes. When performed at load, tests are typically conducted against the load present in the data centre at the time of testing.
- **Yearly full-load exercise runs**: Typically last 1 to 2 hours at 70% to 100% of the rated output, and performed against a load bank.

This paper will predominantly focus on the effectiveness and alternatives for the no-load/ low-load exercise runs. It will also cover the yearly exercise runs, since reducing or removing low-load testing can also decrease the time required to test at full load.

No-load or loaded short exercise runs

Standby generator sets are often “exercised” by starting and operating them at rated frequency with no load - since non-critical load is not always available for testing - or at low load, as the overall critical building load is often well below 50%.

However, there are differences of opinion: for example, some manufacturers recommend testing at closer to 70% load; some clients prefer load banks for testing (considering this preferable to testing with a critical load given the consequences of a failure); some ops teams consider short runs as potentially doing more harm than good.

Low load or No-load runs

When diesel engines are operated repeatedly or extendedly at no load or loads below 30%, combustion related problems can accumulate. Risks of extended low load application include water contamination of lubrication oil, fuel dilution of lubrication oil, wet stacking, carbon buildup on piston rings and injectors, and combustion chamber detonation.

The wet stacking (unburnt fuel entering the exhaust system) and carbon buildup as a result of low load runs would require the yearly full load exercise run to be extended to generate sufficient operating temperatures to counter these effects, whilst the potential oil dilution would require more frequent replacement of the lubrication oil.

Although engines with more modern fuel systems are less prone to such effects, from an overall engine health perspective, low load runs are suboptimal for older technology fuel systems.

Selective Catalytic Reduction Aftertreatment

In some cases, Selective Catalytic Reduction (SCR) aftertreatment systems have been installed to reduce NOx emissions. As these systems are flow-through catalysts, they are not negatively impacted by testing regimes, however, they do require the catalyst temperature to rise above 300°C to begin operation.

When tested at low load, or for a short timeframe (10-15 minutes), the urea injection system will not be actuated and the engines will emit unregulated NOx, which, depending on the load, emissions factors and number of units installed, could contribute significantly to the overall NOx emissions of the site.

Therefore, frequent short-term exercising does not add any value in testing the operational readiness of SCR systems and is in fact, counterproductive to their purpose of reducing NOx emissions. Certain functional tests can be performed with the engine out of operation (cold maintenance activities), to safeguard the system reliability.

Diesel Particulate Filters Aftertreatment

Diesel Particulate Filters (DPF) are installed to prevent particulate matter, or soot, emitted in the diesel engine exhaust gas from entering the atmosphere. These filters trap soot in a ceramic filter until enough exhaust heat is produced to allow the soot to burn off during operation. This process is called DPF regeneration.

It is important to note that especially during engine start, an excess burst of soot is accumulated in the filters. If the engine is only started and not run for sufficient time or without sufficient load to properly regenerate, the filter will eventually clog after a number of start cycles. If the filter is clogged and a rapid load ramp is attempted, the system will either shut down the engine due to excess backpressure or the ceramic layer will develop leaks, or potentially worse, it will fault into an uncontrolled regeneration.

As DPFs are passive devices, frequently starting the engine to run briefly on low loads is not effective for ensuring its operational readiness. On the contrary, this sort of regime is detrimental and could require a premature need for a prolonged loaded run of the engine to regenerate the filter.

Oil Lubrication System

Engines generally require pressurisation of their lubrication systems to ensure sufficient circulation to ensure an oil film is present on all moving metal parts. When the engine is not in operation, this oil film will degrade over time.

To minimise wear on the engine, particularly the main bearings, an oil pre-lube system is often Installed. This system pressurises the oil at predetermined intervals, typically multiple times a day, ensuring the engine oil film is in optimal condition for starting, with minimal time to reach rated speed and minimal wear. In this configuration, frequent low-load or no-load runs bring no value to the operational readiness of the lubrication system.

In cases where no pre-lube system is installed, the monthly exercise runs will function to re-establish the oil film and negate degradation, although it may be less effective due to the long interval. It is important to note that aside from reestablishing the oil film, there is no additional benefit to the lubrication system, and thus prolonged running of the machine up to 10 to 15 minutes does not provide added value.

Cooling system

The engine cooling system is a closed-loop system with a mechanically driven engine pump. Generally, very little goes wrong with such systems, except for coolant leaks. Running the engine has some benefits, primarily because some leaks only become active when the system is at operating temperature or due to the heat cycling of the engine. However, this requires a loaded engine run for an extended period to ensure thermostats are opening and the engine is at operating temperature. Low-load or short runs cannot ensure the system is at full operating temperature and therefore have very little additional value in checking the cooling system for leaks not present when the engine is cold.

Additionally, any leaks present when the engine is cold can be detected without running the engine through the following methods:

- Low-level alarm on the radiator top tank.
- Leak detection devices in the genset enclosure or room bunded area.
- Frequent oil samples or oil level checks to detect minor or large leaks within the engine.
- Regular visual inspections.

If the radiator fans are driven by electric motors, operators typically check their function when accessible.

When the fans are powered by the building, they can be tested by manually actuating the motor contactors. If powered by the engine, a brief start-up to rated speed should be sufficient to confirm the fans are operational.

However, in many cases, the fans are not easily accessible, and if one is broken, running the engine at low load would not trigger any overheating alarm.

Batteries & Starting system

Standby generators for data centre applications are typically equipped with redundant batteries and starters in an N+1 or N+N configuration. A redundant starting system is deemed highly reliable, with the most common fault requiring frequent checks being a weak or faulty battery in the string.

It is important to follow the manufacturer's planned maintenance procedures, which typically include visual inspections, topping off battery fluids, and measuring open circuit voltages. Additionally, a battery management system can be installed to monitor battery health.

It should be noted that due to the high starting currents, there is no better test than to load up the battery to check its health and capability to start the engine. This can be done either with a battery load bank or by cranking the engine. The latter is the most common way to check the system periodically and is usually part of the monthly exercise regime.

Fuel system

Biological content in fuel can lead to filter plugging and other fuel system component issues, such as sticking actuators, especially if allowed to sit idle for prolonged periods of time. Biofuels are generally not recommended for standby applications; however, in some regions, all diesel fuels have some biological content. Where that is the case, fuel sampling and testing are required.

It should be noted that Hydrotreated Vegetable Oil (HVO) fuels are not to be regarded as biofuels. On the contrary, HVO fuels are superior with regard to stability and shelf life, making them an ideal application for standby generators with extended exercise intervals. HVO fuels also represent a substantial saving in CO_2 and SOx emissions, according to manufacturers.

Another important factor in potential failure to start is the fuel feed to the engine. If the fuel system is not designed with a system to ensure a constant positive head, there is a risk the fuel feed line will lose its vacuum, and fuel will drop back to the fuel tank. In such a case, when the engine is started, it might struggle to prime the fuel line and therefore start with more difficulty or fail to start altogether. Assuming the fuel system setup is not prone to this effect, it is still important to regularly check for leaks, as they can cause similar issues.

Overall, it can be stated that if fuel is of the right quality and stable, there is no benefit in exercising the engine on a monthly basis. With regards to the external fuel system, it is important to assess each specific setup for the risk of fuel drop-off in the feed line. However, even if the system is prone to this, there is no reason to start and run the engine for longer than 60 seconds.

Alternator

Overall, alternators are very reliable devices if maintained properly. It is important to have alternator heaters switched on when the alternator is not operated to ensure the windings stay dry and to avoid corrosion. During regular inspections, operators can additionally check for loose, broken, or corroded connections, as well as the good operation of the heater system.

To ensure the health of the Permanent Magnet Generator (PMG), stator, varistor, windings, Automatic Voltage Regulator (AVR), and other electrical components, resistance can be measured every 6 months according to the manufacturer's manual.

Re-greaseable bearings should be lubricated every 6-12 months, and they should be rotated at least once a year to avoid bearing flattening. Depending on the manufacturer, there might be a preference to rotate the alternator more frequently, which can be done manually, or by starting the machine for a 60-second run.

Yearly full-load exercise runs

Currently, most data centre operators run their engines on a yearly interval at 70 to 100% of their rated power for 1 to 2 hours on a load bank to test the backup system. This test duration and engine load are not necessarily needed to prove good operation of the engine - typically, it can suffice to run the engine above 30% load, long enough to bring it up to operating temperature.

Depending on the engine type and ambient temperatures, it can be more effective to run the engine at a higher load point to reach this operating point more quickly.

The load point and duration will need to be increased if there is a need to regenerate the DPF or remove potential wet stacking. Both will be heavily dependent on the engine type and the exercise regime exposure throughout the year.

Also, when SCR treatment systems are installed, there is typically a need to prove the aftertreatment to the authorities on a yearly basis. Such tests need to be conducted when the engine is at full operating temperature and at design load, and as such, are best paired with the yearly exercise run. This will easily extend the testing duration over 1 hour.

Impact overview

Table 1 **(see Appendix)** provides an overview of the relative impact of the discussed exercise methods on generator reliability. It also indicates the potential reliability implications when exercise intervals are extended.

Table 1: Effects of engine exercise methods to system reliability

	Wet stacking	SCR system	DPF system	Oil lubrication system	Cooling system	Starting System	Fuel system	Alternator
10-15min no load / low load run	-	0	--	+	0	++	++	++
30-60s no load / low load run	-	0	--	+	0	++	++	++
prolonged testing intervals (against the above testing methods)	0	0	0	-	0	--	-	0
1h high loaded run	++	++	++	+	++	++	++	++
loaded run up to operating temp	+	++	+	+	++	++	++	++

Table 1 indicates that frequent generator tests conducted under minimal load conditions for durations of 10–15 minutes offer no reliability advantage over equivalent tests limited to 60 seconds. Consequently, for test protocols involving low-load scenarios, it is advisable to optimise the procedure by reducing the runtime to 60 seconds.

Extending generator test intervals necessitates focused attention on three key subsystems: fuel delivery, lubrication, and starting mechanisms.

Lubrication System:

The integration of a pre-lubrication pump is considered the most robust solution to mitigate startup wear. Alternatively, operators should engage with engine manufacturers to evaluate the trade-off between oil film degradation and bearing wear. In certain configurations, reduced start frequency may be advantageous, though potential impacts on startup performance must be assessed.

Fuel System:

It is essential to verify that the fuel system maintains adequate fuel head pressure over extended idle periods. As testing intervals shift to quarterly or semi-annual schedules, fuel stability becomes a critical factor. The adoption of HVO fuel is recommended due to its superior storage characteristics and reduced degradation risk.

Starting System:

The starting subsystem, particularly battery integrity, becomes increasingly critical with prolonged intervals. Implementing battery health monitoring, redundancy strategies, or utilising a battery load bank to simulate starter motor load can enhance reliability.

A phased approach to extending test intervals allows for system-specific reliability validation and adjustment of supporting measures. With appropriate coordination and alignment with the generator OEM, test intervals may be extended to 6–12 months, contingent on the implementation of suitable maintenance protocols and system safeguards.

For annual loaded runs, it is essential to test the system and ensure the generator reaches full operating temperature. These tests can be optimised for time and fuel consumption, depending on several factors: whether the engine is prone to wet stacking during the year, whether electrical systems need to be tested at specific loads, and whether emissions aftertreatment systems require regeneration or validation.

Additionally, the engine configuration and ambient conditions will influence the optimal load point for the test.

Conclusion

In the data centre industry, diesel generator exercise protocols and their associated frequencies are shaped by a combination of OEM guidelines, genset configuration, operator-specific operational strategies, and comprehensive risk assessments. While current practices reflect industry norms, there remains significant potential for optimisation.

The analysis in the table below demonstrates that traditional, time-intensive testing regimens do not always translate to greater reliability. In fact, the data shows that shorter, targeted tests — when strategically implemented — can deliver equivalent assurance of system readiness, while dramatically reducing fuel use, emissions, and operational costs.

(See the test item table on the next page)

By reassessing exercise methods and intervals, operators can reduce generator run hours, minimise fuel consumption, and lower overall pollutant emissions without compromising the reliability of backup systems. Embracing this optimisation aligns operational excellence with the urgent global imperative for sustainability.

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Test Item Table

Test Item	Duration /Efficacy		
	Proposed (1 min)	**Standard Monthly (15 mins)**	**Standard Annual (60 mins)**
Voltage Stability	Medium	High	High
Frequency Regulation	Medium	High	High
Load Response	Medium	High	High
Fuel Consumption	Low	Medium	High
Noise Levels	Medium	High	High
Temperature Control	Low	Medium	High
Cooling system	Medium	Medium	High
Emissions / SCR	Low	Medium	High

Appendix

Table 1: Effects of Engine Exercise Methods to System Reliability

	Wet Stacking	SCR System	DPF System	Oil Lubrication System	Cooling System	Starting System	Fuel System	Alternator
10–15 min no load / low load run	–	0	--	+	0	++	++	++
30–60 min no load / low load run	–	0	--	+	0	++	++	++
Prolonged testing intervals (against the above testing methods)	0	0	0	–	0	--	–	0
1 h high loaded run	++	++	++	+	++	++	++	++
Loaded run up to operating temperature	+	++	+	+	++	++	++	++