Using Load Banks to Verify Engine-Generator Performance

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Diesel-powered generators are principal components in emergency backup power systems. Should they fail during an emergency, power for life-safety, non-critical, and operational loads could be disrupted. To ensure gen-sets perform as designed, periodic testing under load is required. This paper describes how load banks benefit backup power system testing programs.

CODE-REQUIRED ENGINE-GENERATOR TESTING

Emergency power generating systems must comply with various requirements that are based on National Fire Protection Association (NFPA) standards that prescribe backup power system testing practices. The Joint Commission Hospital Accreditation Standards is an example of an industry-specific standard that applies to hospital and healthcare facilities. This paper summarizes how backup power system testing is conducted to comply with key industry standards.

National Fire Protection Agency


NFPA 99: The Heath Care Facilities Code - Generators must be tested at least 12 times per year. Testing must be conducted according to Chapter 8 of NFPA 110 – Standard for Emergency and Standby Power Systems.

NFPA 110 - Standard for Emergency and Standby Power Systems - Emergency Power Supply Systems (including generators, paralleling gear, and transfer switches) must be inspected weekly and tested monthly according to the provisions of Chapter 8. The minimum testing provisions include running generators for a minimum of 30 minutes at a minimum of 30 percent of nameplate power capacity or at an exhaust gas temperature that meets or exceeds the manufacturer’s minimum specification.

NFPA 70 - National Electrical Code - This code specifies safeguards to protect persons and property from electrical hazards. Important sections of the code pertaining to Emergency Power Supply Systems include: (1) Article 700 – Emergency Systems, (2) Article 701 – Legally Required Standby Systems, (3) Article 702 – Optional Standby Systems, and (4) Article 708 - Critical Operations Power Systems. These articles are summarized as follows:

Article 700 - Emergency Systems requires that critical life-safety loads, such as equipment that enables people to safely exit buildings in an emergency, be powered by an emergency power system within 10 seconds of the loss of the normal power source. Examples of equipment regulated by this article include “…ventilation where essential to maintain life, fire detection and alarm systems, elevators, fire pumps, public safety communications systems, industrial processes where current interruption would produce serious life safety or health hazards, and similar functions.”

Article 701 - Legally Required Standby Systems specifies that legally required loads, such as equipment that enables responders to enter a building and operate building systems, be powered by an emergency power system within 60 seconds of the loss of the normal power source. Examples of these legally required systems include those serving “…heating and refrigeration systems, communications systems, ventilation and smoke removal systems, sewage disposal, lighting systems, and industrial processes, that, when stopped during any interruption of the normal electrical supply, could create hazards or hamper rescue or fire-fighting operations.”

Article 702 - Optional Standby Systems applies to standby power systems that support equipment to avoid economic loss or business interruptions. While disruption of power to these loads will not present life or safety implications, they nevertheless support functions that may be critical to the successful execution of a facility’s mission. Examples include “…heating and refrigeration systems, data processing and communications systems, and industrial processes that, when stopped during any power outage, could cause discomfort, serious interruption of the process, damage to the product or process, or the like.” Article 702 article does not specify timing or testing requirements; nevertheless, best practices include testing of these backup power systems.

Article 708 - Critical Operations Power Systems requires testing of standby power systems that support loads that are critical to public safety or national security. These systems “…require continuous operation for the reasons of public safety, emergency management, national security, or business continuity.”

Table 1 summarizes the application of each article.

<table>
<thead>
<tr>
<th>Article</th>
<th>Focus</th>
<th>Permanent</th>
<th>Temporary</th>
<th>Installation</th>
<th>Operation</th>
<th>Maintenance</th>
<th>Monitoring</th>
<th>Control</th>
<th>Equipment Typically Affected</th>
</tr>
</thead>
<tbody>
<tr>
<td>700</td>
<td>Emergency</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td>Lighting and controls needed for personnel safety</td>
</tr>
<tr>
<td>701</td>
<td>Legally-Required</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td>Systems or equipment needed to aid emergency responders</td>
</tr>
<tr>
<td>702</td>
<td>Optional</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td>Equipment that does not have a life safety function</td>
</tr>
<tr>
<td>708</td>
<td>Required for National or Public Security</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td>Equipment or systems that could impact public safety or national security, as indicated by code or a governmental agency</td>
</tr>
</tbody>
</table>

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4 Ibid. Article 700.2. p. 70-581.
5 Ibid. Article 701.2. p. 70-587.
6 Ibid. Article 702.2. p. 70-590.
7 Ibid. Article 708.2. p. 70-600.
The Joint Commission is a not-for-profit organization that evaluates and accredits healthcare organizations and programs in the United States. To promote safe and effective care, it issues standards that are used to audit healthcare practices and facilities. For example, its 2019 Hospital Accreditation Standards set forth Standards for the management and testing of emergency power systems together with Rationale for each standard and Elements of Performance that can be audited to demonstrate compliance. Auditors use these tools to assess compliance for accreditation.

Many Joint Commission elements reference requirements set forth in the NFPA standards. However, in the United States, healthcare facilities have a great incentive to comply with Joint Commission standards because reimbursements for medical services may be contingent on attaining and maintaining Joint Commission accreditation. Joint Commission requirement for testing backup power systems are summarized in Table 2.

<table>
<thead>
<tr>
<th>Standard</th>
<th>Description</th>
<th>Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>EC 02.05.07 EP 6</td>
<td>Transfer switches 12 times annually.</td>
<td>Monthly</td>
</tr>
<tr>
<td>EC 02.05.07 EP 7</td>
<td>Test generator for 4 continuous hours every 36 months.</td>
<td>36 months</td>
</tr>
<tr>
<td>EC 02.05.07 EP 8</td>
<td>36-month tests performed with a dynamic or static load of at least 30% of nameplate rating or the exhaust gas temperature during test meets manufacturer’s recommendations.</td>
<td>see EC 02.05.07 EP 7</td>
</tr>
<tr>
<td>EC 02.05.07 EP 9</td>
<td>If a required emergency power system test failed, measures are implemented to protect patients, visitors, and staff until repair or corrections are completed.</td>
<td>As applicable</td>
</tr>
<tr>
<td>EC 02.05.07 EP 10</td>
<td>If a required emergency power system test failed, a retest is performed after repairs are made.</td>
<td>As applicable</td>
</tr>
</tbody>
</table>

NOTE: Always consult source documents directly before selecting a compliance strategy.

THE CASE FOR LOAD BANK TESTING

To adequately test backup power systems, they must be run under load to verify adequate performance and reliability. This is especially important for diesel-powered gen-sets because diesel engines must be run at minimum power levels for minimum durations to avoid combustion by-product residue build-ups that could impair performance and reliability. Unless otherwise specified by a manufacturer, diesel systems must be run monthly for a minimum of 30 minutes at

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a minimum load of (1) 30% of generator nameplate rating or (2) the minimum exhaust temperature specified by the engine manufacturer.

At some facilities, building load can be used to exercise engine-generators. However, because building load is variable, and testing can sometimes be disruptive to power distribution systems and load equipment, building load may be insufficient to comply with testing requirements, particularly during “off-hours” when testing problems would be least likely to disrupt facility operations.

Test programs are usually better served by applying loads using loads banks. These offer users the ability to apply precise amounts of load for any desired duration. They also offer flexibility to schedule tests at any time of day, even during periods when building load is below 30% of generator nameplate value. As a result, load bank users can meet test loading requirements independent of a building’s real-time power usage.

THE ADVANTAGES OF COMBINATION RESISTIVE/INDUCTIVE LOAD BANKS

Load banks are available in models that apply different types of loads. The simplest designs apply resistive load to test power sources. The power factor of the applied load is 1, or unity. While this can be acceptable in many applications, most power distribution systems also supply other types of loads, such as inductive loads from motorized equipment, and typically present power factors near 0.8.

To best replicate the associated electrical stresses, a combined resistive/inductive load bank is required. A resistive/inductive load bank will provide a total impedance that simulates the loading that the engine and generator will experience together in actual service. To fully verify that a gen-set will perform as designed, it must be tested at generator nameplate value and an appropriate power factor using a resistive/inductive load bank. Additional information about load bank types is available in our document entitled Load Banks for Power System Testing.
LOAD TEST FUNCTIONS

Load testing verifies an engine’s ability to supply the amount of power required by the emergency backup power system. The following section describe addition functions that load testing can perform for users.

Verify Voltage Regulator Operation

A generator’s voltage regulator is a critical component that enables backup power systems to quickly stabilize line voltage following large changes in load. When large loads are applied, engine speed drops before the engine’s governor returns it to its prior steady-state condition. The recovery time is known as transient response. If a regulator is not functioning properly, recovery may not be possible, resulting in a sustained low voltage condition. In extreme cases, a generator’s magnetic field could collapse, rendering it useless.

Testing with a resistive/inductive load bank applies loads that simulate the characteristics of actual “real world” loads. When load banks are furnished with digital control systems, transient response tests can be executed and recorded automatically to verify proper voltage regulator operation. It is important to note that voltage regulator operation cannot be fully assessed using a load bank that applies only resistive load.

Verify Governor Operation

Governors are devices that monitor, adjust, and limit gen-set engine speed. Regardless of whether an engine is equipped with a velocity, mechanical, or electronic governor, gen-set engine governors respond to loading by adjusting engine throttle. Load banks are needed to setup and calibrate engine speed-regulating functions, including engine over-speed response.

Verify Cooling System Operation

Running a gen-set under load can identify weaknesses that may be present in an engine’s cooling system, included is coolant radiator, coolant thermostat, and oil cooler. Recording temperature data during load bank testing provides a basis for calculating temperature differentials between ambient air and radiator exhaust or other media. Temperature data can be used to verify that the load test complies with criteria in standards and can be used to identify when air restrictions are present that impede cooling performance. Load tests can also verify the operation of cooling system alarms for overheat conditions.

Verify Fuel System Operation

Diesel gen-set engines are often equipped with turbochargers. These engines can be prone to over-fueling and poor combustion when operated with insufficient load. Unless the load is enough to generate high exhaust temperatures and flow velocities, unburned fuel residues will coat internal engine surfaces including (1) turbocharger vanes; (2) surfaces inside exhaust pipes, mufflers, and silencers; and (3) post-combustion emission control equipment. Known as wet stacking, this condition can decrease turbocharger and engine performance, and, in extreme cases, present a fire hazard.

By applying adequate load using a load bank, periodic gen-set tests ensure that engines reach proper operating temperatures that are sufficient to burn off accumulated deposits of unburned combustion products. Minimum load requirements may vary by manufacturer, but typically range from 30% to 50% of a gen-set’s kilowatt rating. Testing at load levels close to the engine’s rated output can help identify potential points of failure such as clogged air and fuel filters, faulty fuel injection pumps, fuel overheating, and other conditions that could otherwise lead to poor performance or failure during emergency operation.
Verify Control Operation

Problems with circuit breaker trip settings, voltage and frequency adjustments, and loose or failed connections can be discovered during load tests. Resistive/inductive load banks simulate “real-world” conditions where voltage-drop, harmonics, and efficiency can be effectively analyzed. A resistance-only load bank test may not indicate problems with a power supply or control system, resulting in eventual operational problems during emergency operation.

Some gen-set controls are equipped with a dedicated backup power source capable power controls during these changes. Generator testing can verify proper operation of control system features during tests.

SUMMARY

Industry standards and codes specify that emergency power systems must be tested to verify their condition and performance. These standards specify the frequency and duration of tests and the output that must be achieved. Because building load can be highly variable, load banks offer advantages for predictable, repeatable, and compliant testing. Resistive/inductive loads banks most accurately simulate “real-world” loads. During testing, load banks verify a range of gen-set functions, including proper operation of voltage regulators, governors, and cooling, fuel, and control systems. Because they provide comprehensive, standard-compliant testing, load banks are a preferred solution for stressing electrical devices and systems under test.