U.S.NRC

United States Nuclear Regulatory Commission

Protecting People and the Environment

Chapter 11

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QUALIFICATION, SITE ACCEPTANCE, AND SURVEILLANCE TESTING

HRTD
Human Resources
Training & Development

Learning Objectives

Upon completing this lesson, students will better understand:

1. How EDGs are type-qualified for nuclear power plant service.
2. Installation, break-in, inspection, and full load run by supplier.
3. The licensee's pre-operational test program to verify EDG performance and establish critical baseline data.
4. The licensee's ongoing surveillance testing of their EDG's.
5. A typical EDG surveillance run by the licensee, including control of KW and KVAR loading when on the grid.
6. Comments on the relevance of this material to EDG selection/operation.

EDG "Type Qualification" Tests for Nuclear Service

- All diesel generators used as on-site emergency power sources at NPPs must be type qualified for that service.
- RG 1.9 Rev 4 has the basic requirements and IEEE 387-1995 Clause 6 provides detailed guidance. (Clause $\leftrightarrow$ Chapter)
- Prior qualification of an EDG of similar design is permitted to be used to reduce the testing and analysis required.
- Analysis used when testing is seen as unneeded/impractical.
- Testing may be by manufacturer or independent third party. The latter most likely if the manufacturer is not maintaining an approved 10 CFR 50 Appendix B Quality Assurance program
- For some early 1970's plants, part or all of EDG qualification testing was on-site, as IEEE 387-1972 was not yet adopted.

Three Basic Type Qualification Tests for EDG's

Load Capability Tests:

- Carry the continuous rated load until engine temperatures have stabilized.
- Carry short-time rated load for 2 hours and continuous rated load for 22 hours (in either order).
- Complete load rejection test at the short-time rating. Engine speed increase must be < 75% of the Δ between nominal RPM and the over-speed trip set-point, or 15% over nominal (60Hz) RPM, whichever is less.
- Complete light/no-load test equal to the design light load, for allowed duration. Note: Follow with ≥50% load for ≥0.5 hour.

Three Basic Type Qualification Tests (continued)

Start and Load Acceptance Tests:

- Start and achieve specified voltage and frequency within the required time (typically 10 seconds).
- Immediately accept a single step load equal to or greater than 50% of the continuous kilowatt (KW) rating.
- At least 90 of these tests shall be with the EDG initially at warm-standby.
- At least 10 of these tests shall be with the engine at its normal operating temperatures for the load ("hot start").
- Any failure requires a design review, corrective action, and continuation of the tests until reaching 100 consecutive starts *without failure*. (Note: See qualifiers in Student Manual.)

Three Basic Type Qualification Tests (continued)

Margin Tests:

Extra high stress tests to demonstrate the EDG has a performance safety margin for that plant's design. Requires at least two tests applying loads typically 110% of the most severe single step load in the plant design profile, including steps above a base load.

- Demonstrate ability of the generator, exciter, and automatic voltage regulator to accept the margin test load without voltage collapse or inability of the voltage to recover.
- Demonstrate the ability of the engine and its speed-regulating governor to accept that load without stalling, and to recover to normal operating speed.

Note: Hz and V excursions may exceed values specified for loads.

Additional EDG Evaluation by Test or Analysis

Aging of Components and Assemblies:

IEEE 387-1995 introduced comprehensive evaluation of ageing. Components and assemblies required for the unit to meet its design capabilities were deemed "safety-related." Their age-related failure mechanism potential must be evaluated and, if significant, qualified by test (preferred), analysis, or both. Those with a qualified lifetime less than the EDG system life objective must have a maintenance/replacement interval defined. $Q_T \downarrow$

Seismic Qualification Requirements

IEEE 344-1987 seismic qualification is required for safety-related components. Nonsafety-related items require analysis/test to show they will not degrade the EDG during a seismic event. $S_T \rightarrow f$

Analysis/Test of EDG Design Changes

IEEE 387 now requires that design changes to previously qualified EDGs be analyzed, to determine if major or minor.

Major Changes, such as a difference in the number of cylinders, stroke, bore, BMEP, running speed, or how the engine-generator is configured shall require requalification (as if a new design).

Minor Changes, such as component parts substitution, shall be qualified by analysis, or testing, or both.

The category given a (proposed) design change or modification is influenced by the use of that part or design feature in other EDGs and by experienced engineering judgment.

"Factory" Production Testing

- An initial "break-in" run as specified by the manufacturer.
- Load the engine as follows, using dynamometer or generator. These load tests may be run in any order. *Engine performance data must be logged as required by 5.2.1 of IEEE 387-1995:*
  - 1 hour each at 50% and 75% of the continuous rating
  - 2 hours each at 100% and 110% of the continuous rating
  - Set and check engine-mounted alarms and shutdowns. The points of activation must be recorded in the test logs.
  - Perform and document post-test inspections as specified by the manufacturer. Document results in test report.
- Test the generator in accordance with NEMA MG 1-1993

Initial On-Site Set-Up of EDG

FPT ↓

(Covered in much more detail by 11.3 of the Student Manual…)

- Anchor EDG, align with generator, check web deflection
- Engine internal checks, inspections (coatings, clearances, etc.)
- Governor, over-speed governor set-up and inspection
- Engine trip and alarm relay calibrations
- Generator internal checks (electrical and mechanical)
- Generator output breaker alignment and calibration
- Generator load sequencer checks and calibration
- Engine air start system inspection and tests

Initial On-Site Set-Up of EDG (continued)

- Fuel storage-transfer system function, integrity, capacities, gauge and alarm calibration, filters, fuel oil verified by analysis
- Lube oil system function, integrity, capacity, gauge and alarm calibration, filters, lube oil verified by analysis
- Cooling system function, integrity, capacities, gauge and alarm calibration, coolant quality verified by analysis
- Engine room ventilation system function, fan phase rotation, hi/low switch calibration, air flow (cfm) verified

All of this serves the same purpose as a pre-flight inspection…

At this point the EDG is ready for initial Site Acceptance Tests, and subsequent transfer to utility ownership.

Table 3—Site testing

Reference	Tests	Site acceptance tests (7.2)	Pre-operational tests (7.3)	Availability tests (7.4.2.1)		System operation tests—shutdown/refueling (7.4.2.2)	Independence tests 10 years (7.4.2.3)
				Monthly	6 Monthly		
7.2.1.1	Starting	X		?			
7.2.1.2	Load acceptance	X		?			
7.2.1.3	Rated load	X		?			
7.2.1.4	Load rejection	X					
7.2.1.5	Electrical	X					
7.2.1.6	Subsystem	X					
7.3.3	Reliability		X				
7.5.1	Start		?	X			
7.5.2	Load run		?	X	X		
7.5.3	Fast start		?		X		
7.5.4	LOOP		X				
7.5.5	SIAS		X				
7.5.6	Combined SIAS and LOOP		X			X	
7.5.7	Largest load rejection		X			X	
7.5.8	Design load rejection		X			X	
7.5.9	Endurance and load		X[a]			X	
7.5.10	Hot restart		X			X	
7.5.11	Synchronizing		X			X	
7.5.12	Protective trip bypass		X			X	
7.5.13	Test mode override		X			X	
7.5.14	Independence		X				X

[a]Instead of 2 h and 6 h, use 2 h and 22 h.

Figure 11-1

Site Testing of EDGs
IEEE 387-1995, Table 3

Site Acceptance Testing

These are full scope tests to demonstrate capability of the unit to perform its intended function, as installed. They are described in Clause 7 and Table 3 of IEEE 387. (See Figure 11-1 of Manual).

Starting Test: Demonstrates capability to attain and stabilize rated frequency and voltage within limits, in the time specified.

Load Acceptance Test: Demonstrates ability to accept individual loads that make up the design load at that NPP, in the desired sequence and time duration, maintaining V and Hz within limits.

Rated Load Test: Demonstrates ability to carry: (1) Continuous rating, until engine temperatures reach equilibrium plus 1 hour, followed by (2) Short-time rating, for 2 hours (typically 110%…).

Site Acceptance Testing (continued)

Electrical Tests: Verify characteristics of the generator, excitation system, voltage regulation system, engine governor, and the control and surveillance systems.

Subsystem Tests: Demonstrate control, protection, and surveillance systems are in accordance with requirements.

Site Acceptance tests are the basis for declaring the EDG ready for initial use, and for making final payment to the manufacturer.

The Pre-Operational tests which follow are the first *regulatory-based site tests in which the licensee must legally demonstrate and document EDG performance*. As "Pre-Operational" implies, they are a prerequisite to declaring the EDG system operational.

Pre-Operational Testing **(See Figure 11-1)**

Unlike Qualification, "Factory" and Site Acceptance testing, Pre-Operational tests confirm proper functioning of all logic circuits and controls programming. (Generic Letter 96-01 addresses that.)

All starting modes will be demonstrated: Local manual, Control Room manual, LOOP, SIAS from the RPS, combined SIAS and LOOP.

Steps should be taken to reduce engine wear during ALL testing, including keep-warm, pre-lube, and cool-down at reduced power. Some licensees are still subjecting EDGs to unnecessary stress...

Reliability Test: This demonstrates acceptable reliability has been achieved to place the new EDGs in service. It requires a minimum of 25 valid start and load tests without failure, on each EDG.

Pre-Operational Testing (continued)

Slow-Start Test: This simply verifies design Hz and V obtained.

Load-Run Test: Slow-start test demonstrating basic load-carrying capability, equivalent to 90- 100%, for not less than 1 hour.

Fast-Start Test: From standby conditions, without loading, just to verify EDG achieves the required V and Hz within limits, and time.

From this point forward, the Pre-Operational tests become much more demanding, to simulate various emergency demand- start scenarios and verify control systems are properly set up.

Loss-of-Offsite Power (LOOP) Test: A LOOP event is simulated by de-energizing the emergency buses. EDG must start, attain req'd V-Hz within acceptable limits and time, energize auto-connected shut-down loads through load sequencer, and operate 5 minutes.

Pre-Operational Testing (continued)

Safety Injection Actuation Signal (SIAS) Test: This demonstrates that upon an SIAS signal the EDG will start to a running standby mode, at acceptable V and Hz, ready to accept ESF bus loads in the event a LOOP event occurs (more likely with the main turbine off-line). That places the EDG in the best status to immediately accept loads upon breaker closure due to a LOOP, minimizing disruption of SI reactor cooling.

Combined SIAS and LOOP Test: This combines the two previous tests, and applies the same pass/fail criteria.

Largest-Load Rejection Test: When the largest single load is shed the EDG must stay within acceptable voltage-frequency limits and also not trip out on over-speed.

Pre-Operational Testing (continued)

Design Load Rejection Test: EDG must not trip on over-speed when it sheds a load of 90-100% of design loads. This assures subsequent fast availability. (See IN 93-96) No limit on V / Hz Δ.

Endurance and Load Test: Demonstrates ability to carry heavy loads for at least 24 hours, of which 2 hours is the short-time rating, and 22 hours is 90-100% of the continuous load rating.

Hot Restart Test: Demonstrates capability to restart immediately after a run at full load has stabilized engine temperatures at their full load values. This test can reveal one potential failure mode…

Design Load Rejection Test: EDG must not trip on over-speed when it sheds a load of 90-100% of design loads. This assures subsequent fast availability. (See IN 93-96) No limit on V / Hz Δ.

Pre-Operational Testing (continued)

Synchronizing Test: Demonstrates ability to transfer emergency loads from the EDG back to normal (offsite) power. It involves synchronizing EDG with the grid, then transferring its load back to offsite power, isolating the EDG from the grid, restoring standby.

Protective Trip Bypass Test: This verifies protective trips are bypassed in emergency operation as designed…

Test Mode Override Test: Demonstrates that with the EDG operating in automatic test mode while connected to its bus, a simulated SIAS overrides test mode and EDG responds properly.

Independence Test: This demonstrates that simultaneously starting and running redundant EDG units does not result in any potential common failure modes undetectable in single-unit tests.

Periodic Testing **(See Figure 11-1)**

At this point the EDGs are operational. These Periodic Tests are to demonstrate continuing capability to start and accept loads:

Availability Test: Each EDG unit shall be slow started and loaded at least once in 31 days. Every 6th month, a combined Fast-Start and Load-Run test shall be done, simultaneously satisfying the Availability Test and that one semi-annual test requirement. **RG 1.9**

System Operation Tests: This is a series of tests to verify the ability of the EDG to perform its intended function under simulated accident conditions. These tests shall be performed at shutdown/refueling outages (typically once every two years). They have all been described previously. See Figure 11-1 list.

Periodic Testing **(See Figure 11-1)**

Independence Verification Test: Following any modifications where the independence of EDG units may have been affected, or at least every 10 years during plant shutdown or refueling outage, an independence verification test shall be performed. It consists of starting all redundant units simultaneously.

.....**CAUTION** .....

The preceding discussion of EDG testing was based on Table 3 of IEEE 387-1995. The variances recently discovered between it and the corresponding Table 1 of RG 1.9 Rev 4 (3-2007) are awaiting resolution/explanation. The "regulatory positions" contained in RG 1.9 are uncharacteristically silent on those variances, so they may not be intentional. Follow official NRC guidance. The next printing of the EDG Course Manual will be revised as necessary.

Table 3—Site testing

Reference	Tests	Site acceptance tests (7.2)	Pre-operational tests (7.3)	Availability tests (7.4.2.1)		System operation tests—shutdown/refueling (7.4.2.2)	Independence tests 10 years (7.4.2.3)
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7.2.1.3	Rated load	X		?			
7.2.1.4	Load rejection	X					
7.2.1.5	Electrical	X					
7.2.1.6	Subsystem	X					
7.3.3	Reliability		X				
7.5.1	Start		?	X			
7.5.2	Load run		?	X	X		
7.5.3	Fast start		?		X		
7.5.4	LOOP		X				
7.5.5	SIAS		X				
7.5.6	Combined SIAS and LOOP		X			X	
7.5.7	Largest load rejection		X			X	
7.5.8	Design load rejection		X			X	
7.5.9	Endurance and load		X[a]			X	
7.5.10	Hot restart		X			X	
7.5.11	Synchronizing		X			X	
7.5.12	Protective trip bypass		X			X	
7.5.13	Test mode override		X			X	
7.5.14	Independence		X				X

[a]Instead of 2 h and 6 h, use 2 h and 22 h.

Figure 11-1

Site Testing of EDGs
IEEE 387-1995, Table 3

Records for Each EDG Unit

Extensive records shall be *maintained and retrievable* for each EDG unit for performance analysis, to verify assumptions made, and to extend or shorten equipment maintenance intervals/replacement schedules. The records must include the following, as a minimum:

- All start attempt, maintenance, repair, and out-of-service data, cumulative operating and maintenance data, statistical analysis of EDG test results as well as actual demand runs.
- Critical failure mechanisms, human errors, and common mode failures, with causes and corrective actions included.
- Test parameter data in accordance with IEEE 387-1995, Table 4, which lists the minimum engine operating data that must be maintained. (See Figure 11-2.)

Table 4—Test parameters

Parameter[a]	Pre-start	During test	Post-test
Pressures			
Lube oil: engine - inlet	X	X	
Lube oil: turbo - inlet	X	X	
Lube oil: engine - filter differential		X	
Lube oil: turbo - filter differential		X	
Lube oil: engine header		X	
Lube oil: filter differential		X	
Crankcase		X	
Starting air	X		X
Temperatures			
Lube oil: engine - inlet and outlet	X	X	
Jacket water: engine - inlet and outlet	X	X	
Exhaust: each power cylinder		X	
Exhaust: turbo outlet		X	
Exhaust: exhaust manifold (if applicable)		X	
Electrical			
Frequency		X	
Power		X	
Reactive		X	
Current: generator - all phases		X	
Voltage: generator - all phases		X	
Current: field		X	
Level			
Lube oil: engine generator crankcase	X		X
Lube oil: generator bearing	X		X
Jacket water: standpipe or expansion tank		X	X

[a]These parameters are considered the minimum requirements for this standard. Additional parameters may be added for performance measurements.

Figure 11-2

Test Parameters
IEEE 387-1995, Table 4

Concerns about the Adequacy of Licensee Testing

Refer to Temporary Instruction (TI) 2515/176 issued May, 2008:

- Addresses concerns regarding adequacy of EDG surveillance (Endurance and Margin) testing.
- Catalyst was a finding that endurance tests at Dresden NPS did not adequately verify EDG operability because test loading did not envelop the predicted design-basis event (DBE) loading.
- This inconsistency was subsequently found at other sites. Other issues were identified in test loading criteria, peak design-basis loading values and durations, and EDG ratings.
- This TI issued to assess the extent of these issues and evaluate the adequacy of EDG tests per plant-specific TS and design.

Concerns about the Adequacy of Testing (continued)

- EDG loading is generally designed for a concurrent loss-of-offsite power and a loss of cooling accident (LOOP+LOCA). The loading profile for a concurrent LOOP and large-break (LB) LOCA is typically high. However, at some sites the calculated load values were greater for a LOOP coincident with a small-break (SB) LOCA or a main steamline break (MSLB) than they were for the presumptive LOOP-LBLOCA.
- The timing of these events can also impact the load, depending on which one occurs first and the time interval between them.
- The definition of "short-time rating" is subject to interpretation, as engine manufacturers typically have several ratings higher than "continuous" for run intervals of 2000, 4, 2, and 0.5 hours.

Concerns about the Adequacy of Testing (continued)

- TI 2515/176 requested the collection of extensive data for every EDG used as an onsite standby power supply, as the first step in addressing this general concern.
- This will be a current topic for years, until completion of data analyses, follow-up, and needed corrective action by licensees.
- No follow-up report has been identified to date. If any course participant has updated information on the status of this very important effort to improve EDG reliability, please share it with the class…

NRC Position on the Use of EDGs for Peaking

Reference: Branch Technical Position ICSB-8 (PSB), "Use of Diesel Generator Sets for Peaking."

This concluded: "…the potential for common mode failure modes should preclude interconnection of the onsite and offsite power sources except for short periods for the purpose of load testing."

Clearly, the use of EDGs for peaking is strongly discouraged, if not prohibited. Both EDG systems should never be run in parallel with the grid at the same time, as a power line drop, a plant substation fault, or transient could take out both standby power systems at the same time, leaving the station very vulnerable to a subsequent LOOP event or other emergency.

EDG Operation on the Grid for Test

Three brief statements summarize this subject, which is discussed in more detail in 11.10 of the Student Manual for this course:

1. The engine "feels" KW load and is not affected by KVAR load except to the extent power factor impacts generator efficiency. KW load is increased by the governor attempting to increase RPM (generator frequency) by adding more fuel. Of course it can't, as the engine-driven generator is locked in sync with the grid as long as connected to it, so the result is the EDG picks up more KW load.

   Steadily reducing engine power, as if attempting to slow down, takes off KW load, eventually to where power flow reverses and the generator becomes a motor driven by the grid.

EDG Operation on the Grid for Test (continued)

2. The generator "feels" KVA and, as a result, KVAR load. The KVAR load is increased by the voltage regulator attempting to increase the generator output voltage (via the field). Of course, it can't raise grid voltage so that simply results in the generator picking up more KVAR load.

   The reverse is also true, such that if the voltage regulator tries to lower generator output voltage below line voltage it will eventually get the field so low a loss-of-field trip occurs.

3. To prevent problems, the EDG operator will always connect to the grid with the generator synchronized (but rotating at a slightly higher frequency than the grid) and with the generator output voltage slightly higher than grid voltage. (continued)

EDG Operation on the Grid for Test (continued)

The subsequent disconnect will be made before getting too close to no load. Of course the EDG must be in "droop" mode whenever on the grid, to prevent inadvertent overload.

NOTE: Clause 4.5.2.2 of IEEE 387-1995 requires that upon receipt of an emergency start-diesel signal, the EDG's automatic control system shall provide automatic start-up and adjustment of the speed (frequency) and voltage to a ready-to-load condition in the *isochronous mode*. This is to prevent reduced EDG performance in an emergency, from being left in "droop" mode at the conclusion of the licensee's monthly surveillance testing on the grid.

Observations on EDG Surveillance Runs

Chapter 11 contains a rather detailed technical description of an EDG surveillance run, along with information on the selection and operation of generators for particular loads. The impact of sudden load application or rejection on generator voltage and frequency are also discussed.

This material is just for information and reference, as it exceeds what can reasonably be covered in class during the allotted time.

The following slides contain information relevant to a typical EDG surveillance run. Rather than getting deep into technical details, the focus is on practical "nuts and bolts" items that help assure a successful test.

Observations on EDG Surveillance Runs (continued)

As-Found Documentation: Make a full "as-found" inspection of the EDG and its supporting systems before each surveillance run. Record all parameter values, switch/valve positions, alarms, trips. Compare "as-found" to previously recorded "as-left" conditions.

Pre-Op General Walk-Around: If any leaks in starting air, lube oil, jacket water, or fuel oil systems, verify they have been tagged, reported, and the reports accepted for EDG operation.

Verify EDG Support Systems Operational, including the following:

- Proper fuel and lube oil quality and quantity
- Pre-lube and lube keep-warm operating
- Jacket water keepwarm operating

Observations on EDG Surveillance Runs (continued)

- 125 V dc control and field flash operable
- Starting air and control air at proper pressure and dry
- Fire protection system is operational
- Combustion air intake and exhaust plus room cooling intake and exhaust are clean and clear of obstruction

All EDG shutdown trips and lock-outs cleared including:

- Shutdown relay trip reset
- Overspeed trip reset
- Output circuit breaker trips reset

Observations on EDG Surveillance Runs (continued)

All alarm windows cleared/accepted. Additional checks:

- Governor actuator oil level
- Engine barred over with cylinder cocks open
- All cylinder cocks closed…
- All governor fuel rack linkages operate freely
- All fuel racks engaged and operate freely
- Confirm governor is in droop ("parallel") mode
- Switch local EDG control from local to remote (for Control Room manual start)

Observations on EDG Surveillance Runs (continued)

Confirm availability of offsite power systems

Notify shift supervisor and get approval for start and loading onto the electrical power grid

Turn EDG mode selector switch to manual test position

Engage START switch to initiate operations run…

Engine starts, comes up to nominal 60 Hz speed

- Record starting time
- Allow to stabilize and take a set of readings
- Verify from local operator all conditions normal

Observations on EDG Surveillance Runs (continued)

At electric control panel, turn on synchronizing circuit:

- Synchronize with the grid, with both the EDG voltage and speed (frequency) slightly higher than grid.
- Gradually increase engine KW and KVAR load in steps.
  - Allow to run a few minutes at each step.
  - Make observations and take readings.
- Increase KW and KVAR load to their proper test values.
  - Continue to make observations and take readings.

Observations on EDG Surveillance Runs (continued)

- Allow to run for at least 1 hour. Take complete set of stabilized readings. Note any abnormal or unacceptable conditions. Take action if needed.
- Over a period of several minutes, unload EDG to approximately 10% of rated KW and KVAR.
- Trip the EDG output circuit breaker.
- Run the EDG for a few minutes to cool down.
- Shut down the EDG unit.
- Set electric governor mode to isochronous 60 Hz

Observations on EDG Surveillance Runs (continued)

Post-Operations Phase:

- After 15-30 minutes, open the cylinder cocks, bar engine over to check cylinders for water, oil, and noise. Correct any problems noted and close cylinder cocks.
- Align the EDG for its standby mode and switch local EDG control to remote and control room switch to auto.
- Reset all trips and clear alarm panels.
- Ensure that all EDG support systems are operable and aligned for standby operations.
- Document all Post-Op actions, surveillance, and parameter data for the "as-left" condition of the EDG.

END OF CHAPTER 11