Chapter 1

*

DIESEL GENERATORS AS EMERGENCY POWER SOURCES

HRTD
Human Resources
Training & Development

Some Information on the Week Ahead…

- The bulk of this course focuses on technical and operational aspects of Emergency Diesel Generators (EDG's).
- To reinforce class material, you'll spend roughly half the week in a unique diesel training lab, observing demonstrations and also participating in hands-on exercises.
- Chapter 1 focuses on the regulatory basis for EDG's and key criteria for them. You may already be proficient in that area.
- NRC *requires* that we cover this basic material, as some course participants may be relatively new on the job.
- Even those with considerable experience may benefit from a brief review of the underlying documentation. Chapter 1 can be a convenient reference text, whatever your experience.

Chapter 1 Learning Objectives

This lesson sets the stage for all later Chapters by giving students a fundamental understanding of:

- The regulatory basis for nuclear power plants (NPPs) to have redundant power systems (onsite and offsite), and the key criteria applicable to those systems.
- Three fundamental *performance requirements* for EDG's.
- Why *diesel* engines are used instead of other engine types.
- An overview of the regs, codes, guides, and standards that establish the design basis for emergency power systems, and how they are used in the licensee's design and application.
- Major components of a diesel generator system (overview).

10 CFR 50…

- Successor document to the Atomic Energy Commission (AEC) General Design Criteria (GDC) of 10 JUL 1967, which was used for nuclear power plants starting construction before 1972.
- 10 CFR 50 Appendix A, General Design Criterion (GDC) 17 requires both off-site and onsite power systems "to permit functioning of structures, systems, and components important to safety."
- It further requires *independence, redundancy, and testability* of on-site power systems to assure they can perform their vital safety functions assuming a single failure…

Independence is the absence of shared components that could result in the simultaneous failure of both units. That includes physical and electrical separation, such that a transformer or cable tray fire, for example, would not impact operation of the other emergency diesel generator.

Redundancy is required to achieve the desired operational reliability, and also to accommodate "down time" for testing and maintenance. This means a dual EDG installation, where the required power is available with either EDG "unit" out of service.

Testability is somewhat self-explanatory. EDG qualification, site acceptance, and surveillance testing are discussed in Chapter 11.

Each power source must have the capacity and capability to assure that:

1. "Fuel design limits and design conditions of the reactor coolant pressure boundary are not exceeded" for any anticipated occurrences, and
2. The "core is cooled and containment integrity and other vital functions are maintained in the event of postulated accidents."

A Loss of Offsite Power (LOOP) event is one "postulated" accident. As will be discussed later, regulations require much more complex scenarios to be considered in selecting and designing EDG systems.

Key requirements for EDG's are in Regulatory Guide 1.9, Rev 4 (March 2007), "Application and Testing of Safety-Related Diesel Generators in Nuclear Power Plants" (*new title for this edition*)…

RG 1.9 Rev 4 (Appendix 2 of Student Manual)

This document, the successor to AEC Safety Guide 9, establishes *three fundamental performance requirements* that every EDG must meet to perform its design function. We will list and discuss them:

1. To "...start and accelerate a number of large motor loads in rapid succession while main-taining voltage and frequency within acceptable limits...."
2. To "...provide power promptly to engineered safety features if a loss of offsite power *and* an accident occur during the same time period...."
3. To "...supply power *continuously* to the equipment needed to maintain the plant in a safe condition...."

Why DIESEL Power?

Two considerations determine the choice of engines for this use:

1. Based on the plant-specific accident analysis, how fast must electrical power be restored to support Emergency Core Cooling System (ECCS) operation, to prevent core damage (i.e., to keep from exceeding peak fuel clad temperature)?

   ⇨ Many reactor designs needed ECCS power within 15-30 seconds. For a safety margin, 10 seconds was required.

2. What power supplies are readily available that could reliably pick up heavy step loads beginning in just 10 seconds?

   ⇨ Diesels had the needed fast start capability, the muscle to rapidly assume heavy loads, were of proven reliability, and had been accepted for the Naval Reactors program.

Early Plants Licensed under AEC Criteria

The primary design criteria applicable from early AEC regulatory requirements...those still being the GDC of record at many older nuclear power plants…are as follows:

Criterion 38: Reliability **&** Testability of Engineered Safety Features

Criterion 39: Emergency Power for Engineered Safety Features

Criterion 48: Testing of Operational Sequence of (ECCS)

The AEC had other criteria which also formed the basis for those currently appearing in 10 CFR 50 Appendix A. Some early plants have voluntarily adopted portions of the current requirements applicable to EDG's, such as IEEE 387 (discussed later). No further time will be spent on early criteria.

Plants Licensed by NRC to GDC of 10CFR50

Some key design criteria of 10 CFR 50 Appendix A are as follows:

***Criterion 17**: Electrical Power Systems…* To recap, it requires both on and off-site power, plus Independence, Redundancy, Testability.

***Criterion 18**: Inspection and Testing of Electrical Power Systems*… Requires provisions for assuring operability and for testing the full operational sequence and performance under conditions as close to design as practical.

Criterion 33, 34, 35, 38, 41, and 44… These establish the criteria for specific safety systems to be able to perform their required functions even assuming a Loss of Offsite Power (LOOP) and also the single failure of a source of onsite power (e.g. one EDG Train).

"Top Level" NRC Regs for NPP Licensing, Construction, Commissioning, Operation:

- **10 CFR 50.10** – License required
- **10 CFR 50.23** – Construction permits
- **10 CFR 50.34** – Details the contents of applications, technical information. Of particular significance to EDG selection:
  - *Preliminary safety analysis report*
  - *Final safety analysis report*

  These describes the facility, present the design basis and the limits on its operation, and provide detailed safety analyses of its structures, systems, components and the facility as a whole.
- **10 CFR 50.36** – Covers specifications intended to define safety system Limiting Conditions for Operation (LCOs).

"Top Level" NRC Regulations (continued)

- **10 CFR 50.54, 50.56, and 50.57** – Pertain to licensing
- **10 CFR 50.56** – Conversion of construction permit to license; or amendment of license
- **10 CFR 50.57** – Issuance of operating license.
- **10 CFR 50.63** – Loss of All Alternating Current Power (Station Blackout). This is an additional source of functional regulatory requirements involving Emergency Diesel Generators. Target EDG reliability is used to determine station blackout coping capability.

These criteria are implemented into *site-specific* system design, using NRC Reg Guides and their incorporated codes and standards developed by ANSI, IEEE, NFPA, etc., or by industry groups. ⇨

Selected Implementing Documents…

- **RG 1.6 –** "Independence Between Redundant Standby (Onsite) Power Sources and Between Their Distribution Systems"
- **RG 1.9, Rev 4 (March 2007) –** "Selection, Design, Qualification, and Testing of Emergency Diesel Generator Units Used as Class 1E Onsite Electric Power Systems at Nuclear Power Plants"

  This RG introduced 3 fundamental *performance requirements* for EDG's. It incorporates portions of **GDC 17** – Electric Power Systems, and **GDC 18** – Inspection and Testing of Electrical Power Systems. RG 1.9 also invokes several IEEE documents:

- **IEEE 308** – "Standard Criteria for Class 1E Power Systems for Nuclear Power Generating Stations."

continued…

- **IEEE 387 (1972, 1977, 1984, 1995) –** "IEEE Standard Criteria for Diesel-Generator Units Applied as Standby Power Supplies for Nuclear Power Generating Stations." Note: *Not all plants are committed to use IEEE 387, especially if licensed prior to 1972*.

  IEEE 387-1995 gives the design basis for nuclear service EDG's as 4000 starts and 6000 operating hours, over a specified service life of 40 years. Such intermittent duty is very different from typical commercial service! This course will point out the profound impact that has on EDG maintenance and testing, as well as some design implications. IEEE 387-1995 is Appendix 3.

- **RG 1.32 –** "Criteria for Safety-Related Electric Power Systems for Nuclear Power Plants." Implements portions of GDC 17.

- **IEEE 308 –** "Standard Criteria for Class 1E Power Systems for NP Generating Stations." (Criteria for independence, redundancy)

- **RG 1.75 – "**Physical Independence of Electric Systems." This is implemented via **IEEE 384, "**Standard Criteria for Independence of Class 1E Equipment and Circuits."
- **RG 1.93 – "**Availability of Electric Power Sources." *RG 1.93 provides guidance for application of **10 CFR 50.36,** particularly section 50.36(c)(2), "Limiting Conditions for Operation," (LCO) when less than the number of power supplies required by GDC 17 are available*.
- **RG 1.137 – "**Fuel-Oil Systems for Standby Diesel Generators." Implemented via **ANSI N195 / ANS 59.51 – "**Fuel Oil Systems for Emergency Diesel Generators."
- **Regulatory Guide 1.155 – "**Station Blackout**"** and **10 CFR 50.63,** "Loss of all Alternating Current Power." *Specified SBO duration shall be based on the redundancy and reliability of on-site EPS.*

Licensee Implementation of Design Criteria

The licensee's documentation of EDG System design will include:

- System drawings and isometrics
- System specifications
- Equipment specification
- Purchase specifications
- Installation and Test Criteria

Plant technical specifications are required to prescribe Limiting Conditions for Operation (LCO) for EDGs and other required safety systems. If any safety limit is exceeded, the reactor must be shut down. The LCOs, associated safety limits, limiting safety system settings, and limiting control settings are also covered in the plant Final Safety Analysis Report / Updated Final Safety Analysis Report.

Highlights of FSAR / UFSAR

FSAR/UFSAR Chapter 8, Section 8.3(4), Onsite Emergency (AC) Power Systems: The bulk of the plant-specific design criteria applied by the licensee to the EDGs is typically included here.

FSAR/UFSAR Chapter 9, Plant Auxiliary Systems: Typically includes design criteria for many of the major EDG support systems such as Fuel Oil, Jacket Water, Lube oil, and Starting Air.

FSAR/USFAR Chapter 14, Accident (Safety) Analysis: Addresses *generic plant design basis events or accidents* where Emergency Diesel generators are required to mitigate the resulting effects. They range from a Safety Injection Actuation Signal (SIAS), where the EDG simply receives a start signal and runs in standby mode in case it's needed, to much more complex and serious events.

Diesel Generator Fundamentals

Each EDG system is an independent, redundant electrical power plant within the nuclear power plant. It's the largest and most complex NPP safety system, and has a critical role.

EDG design criteria applied to each plant are listed or referenced, by revision date, in the licensee's design and equipment specs. **Note:** Subsequent updates of regulatory criteria may be difficult, or impractical, for a licensee to back-fit (and that is not required).

The major components of the **generator** are as follows:

- Generator housing and stator
- Generator rotor and exciter
- Voltage Regulator
- EDG emergency trip controls and relays

Major components of the **engine** and its support systems are:

- Governor
- Starting System (air or electric)
- Fuel Oil Delivery System
- Combustion Air Intake
- Exhaust System
- Lubrication System
- Cooling (Jacket Water) System
- Crankcase Ventilation
- EDG start logic controls and relays
- Emergency run controls and Relays

Figure 1-1 "Diesel Generator Systems" (RG 1.9, Fig. 1) illustrates an EDG system, including most of its support systems…

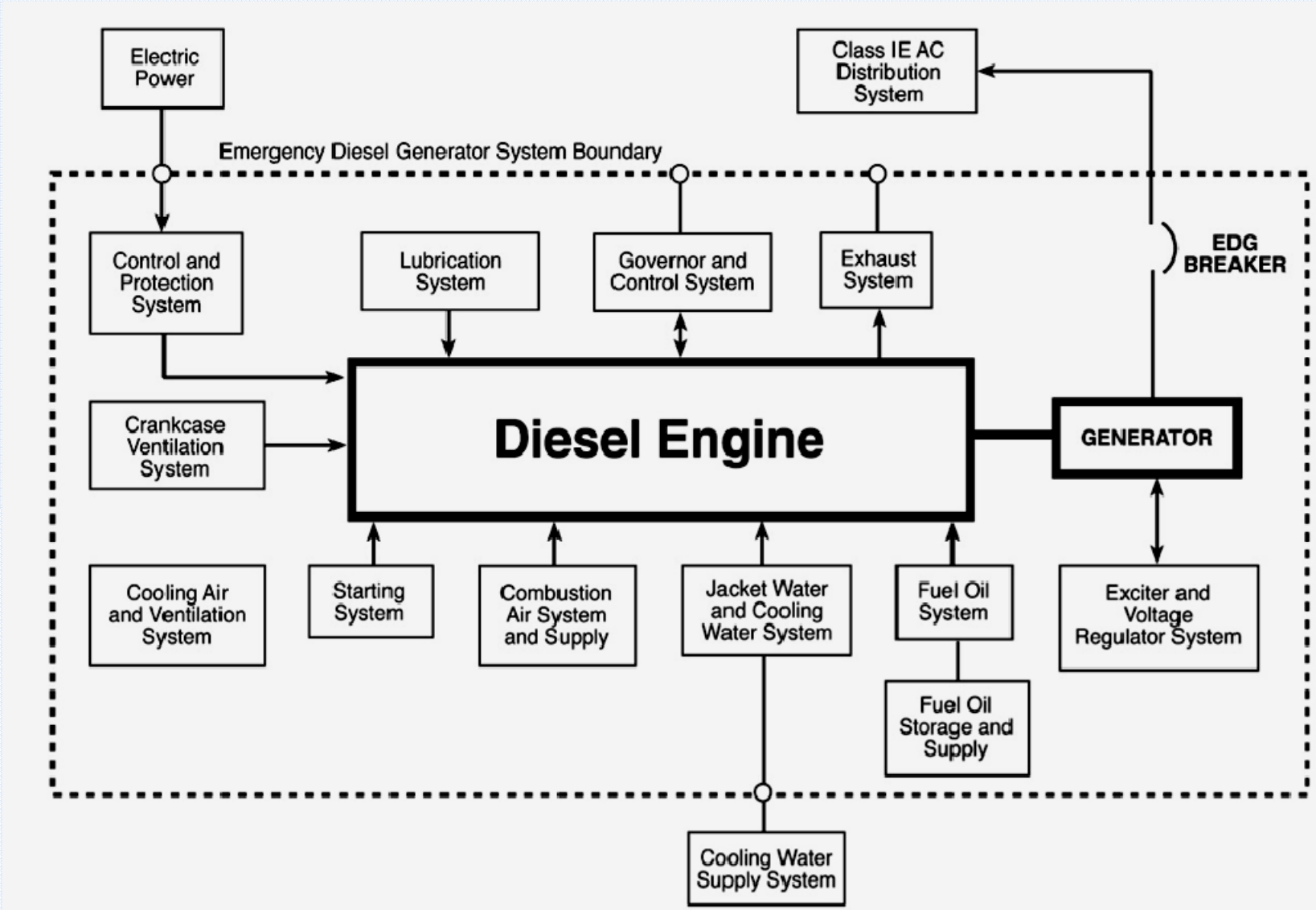

Figure 1-1 Diesel Generator Systems

In Summary…

1. Both offsite and onsite power systems are required by 10 CFR 50 Appendix A, Criterion 17.
2. Key regulations include NRC Regulatory Guide 1.9 Rev 4 (2007), IEEE Standard 387-1995, 10 CFR 50.xx, others.
3. Diesel engines are used principally for their fast start capability.
4. EDG systems must be redundant, independent, and testable.
5. EDG's must stay within electrical limits when subjected to heavy step loads, cope with loss of off-site power plus an accident, and carry full load for the safety design basis time (typically 7 days).
6. Licensee’s EDG System design basis and documentation are plant-specific. They prescribe the equipment and its LCO's.

END OF CHAPTER 1