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Nuclear Maintenance Applications Center: Emergency Diesel Generator Single Component Vulnerability Review Guidance

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PRODUCT DESCRIPTION

This report provides guidance to owners and operators of nuclear power plants on performing emergency diesel generator (EDG) system single component vulnerability reviews. This guidance was developed based on a recommendation from the nuclear industry's EDG Technical Advisory Committee (TAC) that plants perform a single component vulnerability review as discussed in the Institute of Nuclear Power Operations' Industry Experience Report 13-21.

Background

Through a common-cause analysis of 200 EDG Mitigating System Performance Index (MSPI) failures from 2007 through 2011, it was determined that 35.5% of the failures were attributed to preventive maintenance deficiencies. Some of these failures were attributed to EDG components that were not included in any maintenance or monitoring program. Based on this information, a few plants performed single component vulnerability reviews that identified components not covered in EDG maintenance programs and therefore left the EDG vulnerable to failure. Because of these issues, the EDG TAC recommended that EDG single component vulnerability studies be performed at each station to improve overall industry EDG reliability.

Considering the recommendation to perform EDG single component vulnerability reviews, the EDG TAC concluded that a guide should be developed to assist plants in performing this review. This report is intended to provide detailed guidance to personnel performing an EDG single component vulnerability review.

Single component vulnerability reviews consider subsystems that constitute and support the EDG as well as functions of the EDG room fire suppression system that can prevent the EDG from performing its safety functions. The review process consists of a system-by-system, in-depth review of EDG components within the plant to ensure that sufficient monitoring, maintenance, and design provisions are in place to prevent functional failures.

Objectives

The objective of this single component vulnerability review is to identify components that do not have sufficient monitoring, maintenance, and design provisions in place and—if they fail—could result in a failure of the EDG to perform its safety function. Once components are identified that are not addressed in current programs, actions to mitigate or eliminate the associated risks should be taken to reduce the system vulnerability to failures.

Approach

EPRI's Emergency Diesel Generator Technical Advisory Committee developed a draft document, which was sent out to the EDG TAC for review and comment. The draft material was reviewed and modified by EDG TAC members several times. Input was obtained from plant personnel and independent contractors who had previously performed single component vulnerability reviews.

Results

Detailed guidance is provided in a step-by-step process to perform EDG single component vulnerability reviews, including beneficial practices.

Applications, Value, and Use

The intended audience for this report is nuclear station engineering and maintenance department management and senior personnel who will lead the effort to perform these reviews. It is recommended that sites consider the guidance in this report when developing their own approach to performing EDG system single component vulnerability reviews.

Keywords

Emergency diesel generator (EDG)
Maintenance
Single component
Vulnerability review

ABSTRACT

This report provides guidance to owners and operators of nuclear power plants on performing emergency diesel generator (EDG) system single component vulnerability reviews. This guidance was developed based on a recommendation from the nuclear industry's EDG Technical Advisory Committee (TAC) that plants perform a single component vulnerability review as discussed in INPO's Industry Experience Report 13-21. The objective of this single component vulnerability review is to identify components that do not have sufficient monitoring, maintenance, and design provisions in place and—if they fail—could result in a failure of the EDG to perform its safety function. Once components are identified that are not addressed in current programs, actions to mitigate or eliminate the associated risks should be taken to reduce the system vulnerability to failures.

Single component vulnerability reviews consider subsystems that constitute and support the EDG as well as functions of the EDG room fire suppression system that can prevent the EDG from performing its safety functions. The review process consists of a system-by-system, in-depth review of EDG components within the plant to ensure that sufficient monitoring, maintenance, and design provisions are in place to prevent functional failures.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

1
INTRODUCTION

Purpose

This report provides guidance for the performance of a single component vulnerability review of the emergency diesel generator (EDG) system. The intent of this review is to identify EDG system components not included in a current EDG maintenance program that could cause the EDG to fail to perform its safety function. The review should ensure that these components have appropriate maintenance, monitoring, and/or design provisions in place to preclude an EDG failure.

Background

In October 2010, the Institute of Nuclear Power Operations (INPO) issued Topical Report 10-73 [1], which identified an adverse trend in EDG start, load, and run failures at U.S. nuclear power plants. In July 2011, the industry formed an EDG Technical Advisory Committee (TAC) to focus on correcting this adverse trend. The EDG TAC is a cooperative effort to ensure that there is an industrywide, cohesive, and coordinated effort to improve EDG performance.

Both short- and long-term goals and actions have been developed by the EDG TAC in an effort to identify not only those items that may have immediate benefit, but also those deep-rooted issues that take longer to produce improvements in EDG reliability and availability. Problems in control systems and system fluid (water, oil, and fuel) and air leaks associated with EDGs were determined to be two of the leading causes of EDG Mitigating System Performance Index (MSPI) failures. Some of the causes of these problems have been reported to the industry in the form of INPO Event Reports (IERs).

Through a common-cause analysis of 200 EDG MSPI failures from 2007 through 2011 [1], it was determined that 35.5% of the failures were attributed to preventive maintenance (PM) deficiencies. Some of these failures were attributed to EDG components that were not included in any maintenance or monitoring program. Based on this information, a few plants performed single component vulnerability reviews that identified additional components not covered in these EDG programs and left them vulnerable to failure. Because of these issues, the EDG TAC recommended that, to improve overall reliability, an EDG single component vulnerability study should be performed at each station. Accordingly, IER L4 13-21 [2], “EDG Review Visit Summary,” Corrective Actions for Consideration #2 was issued as follows:

> Perform an EDG preventive maintenance gap analysis that compares station PMs to vendor and owners group recommendations for PMs. Also, perform an EDG Single Component Vulnerability review to ensure the PM strategy addresses this component group appropriately. Identify critical components that currently do not have a unique identifier for inclusion in the PM program. Close any identified gaps.

Based on the specific recommendation to perform an EDG single component vulnerability review, the EDG TAC determined that a guide should be developed for plants to follow when performing this review. This report provides detailed guidance to personnel performing an EDG single component vulnerability review.

2
SINGLE COMPONENT VULNERABILITY REVIEW SCOPE

EDG Single Component Vulnerability Review Boundary

To ensure the completeness of the review, it is important to first clearly define the EDG systems included in the review. For the purpose of this report, the EDG system, as shown in Figure 2-1, includes the following:

- Diesel engine
- Lubrication system
- Jacket water and cooling water system
- Combustion air system and supply
- Exhaust system
- Fuel oil storage and supply system
- Crankcase ventilation system
- Governor and control system
- Generator
- Exciter and voltage regulator system
- Starting system
- Cooling air and ventilation system
- Fire suppression system (functions that render the EDG unavailable)
- Control and protection system

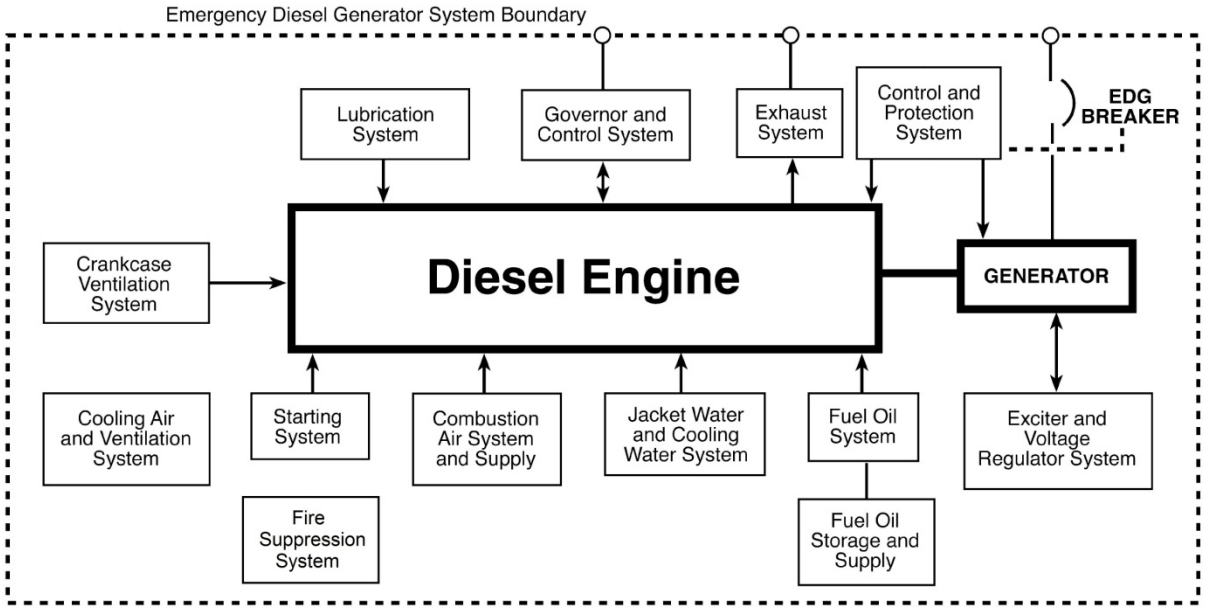

Figure 2-1
Emergency Diesel Generator System Boundary Diagram

These components and subsystems included in the single component vulnerability review boundary, in addition to the fire suppression system, are consistent with those identified in Regulatory Guide 1.9, Rev. 4 [3]. Stations not licensed to Regulatory Guide 1.9, Rev. 4 are encouraged to use the same boundary because it encompasses systems affecting EDG operation. The systems identified also match those defined in IEEE 387-1995 [4] except that the fuel oil storage and supply and fire suppression system are outside the scope of that standard. A malfunction of the fire suppression system could result in a functional failure of the EDG at some stations (for example, some plants draw engine intake air from the EDG room, and CO_2 or Halon injection could starve the engine of combustion air, causing it to shut down). All of these systems should be considered within the scope of an EDG single component vulnerability review.

3
SINGLE COMPONENT VULNERABILITY REVIEW GUIDANCE

This section describes the fundamental steps and a suggested order for performing the single component vulnerability review.

Gap Analysis of EDG Owners Group or Vendor Maintenance Programs

This comprehensive line-by-line review should be done to ensure that station procedures and mechanisms are in place to implement the owners group or vendor-recommended maintenance program. This ensures that all engine internal components and standard external components are maintained or monitored in a way that precludes engine-generator set failures in nuclear application. These programs are based on several years of vendor experience and analysis as well as many years of industry experience. Any exceptions taken to the program should have a strong technical justification, and any gaps identified should be addressed in an expeditious manner.

Gap Analysis of Vendor 10 CFR Part 21 Reports, Service Information Memos, and Product Improvements

This comprehensive line-by-line review should be done to ensure that the station has evaluated and implemented applicable vendor product improvements, service information memos, and 10 CFR Part 21 reports that relate to single component vulnerabilities.

Reviews of Plant EDG System Piping and Instrumentation Diagrams and Electrical Schematics

Thorough reviews of each EDG system piping and instrumentation diagram (P&ID) and EDG system schematic should be performed to identify any components whose failure could lead to a functional failure of the EDG. The electrical schematic review, where appropriate, should address subcomponents in devices such as voltage regulators and governors. Electrical components should be identified to the relay and contact level. This is likely to produce results of items not individually identified as station components that may not have been addressed in station maintenance programs or practices.

EDG Walkdowns

Thorough line-by-line walkdowns of each EDG system should be performed to identify any components that exist on the engine piping or engine skid that may not be included in system drawings whose failure could potentially result in an EDG failure.

Component and Station Program Gap Analysis

A gap analysis of identified components from the review of P&IDs, schematics, and EDG walkdowns and existing station maintenance, monitoring, and design provisions can then be performed to ensure that appropriate actions are in place to preclude EDG failures. Components not addressed in these programs whose failure could lead to an EDG functional failure will be identified as *single component vulnerabilities*.

Actions to Address Single Component Vulnerabilities

An assessment should be completed for components identified as *single component vulnerabilities* to ensure that the appropriate maintenance, monitoring, and design provisions are put in place to preclude failures. Recommendations to address these vulnerabilities should include the following:

- Developing preventive or periodic maintenance to prevent failure of the component in accordance with vendor recommendations and/or industry standards.
- Developing monitoring practices for the component so that adverse trends can be identified and action can be taken prior to component failure.
- Considering a design change to address the single component vulnerability, such as using a more robust component or, in some cases, adding redundancy.
- Considering a design change to address vulnerabilities that are based on obsolescence.
- Increasing margin (for example, between operating conditions and alarm or trip setpoints) in design basis documentation for high-risk components (if possible).

Implementation

The first step for implementation of actions identified to address vulnerabilities should be the timely entering of these actions into the plants' corrective action program. Implementation schedules for actions to address vulnerabilities may vary depending on the complexity of the action. Some may be addressed with timely changes to EDG condition monitoring practices; others may require approval from the plant health committee. In either case, implementation of actions recommended to address single component vulnerability failures needs to be timely, but based on the vulnerability. For example, a component vulnerability identified with no failure history would receive a lower priority than a component vulnerability that has a recommended 10-year replacement and has been in service for 20 years. Implementation schedules may vary from addressing known vulnerabilities within weeks to addressing vulnerabilities at the next EDG maintenance opportunity or even longer to address the vulnerability through implementation of a design change. Station management and operations need to be made aware that the EDGs will be vulnerable to failure until these actions are addressed and implemented. A bridging strategy may be used to minimize risk during the waiting period.

4
BENEFICIAL PRACTICES

Single Component Vulnerability Review Team Composition

An EDG single component vulnerability review team should be composed of knowledgeable personnel—preferably engineers—from the plant organizations having the most involvement with the EDGs (that is, engineering, maintenance, and operations). Each of these groups should be represented on the review team. One person on the team should lead the effort, but work should be distributed so that no one individual or group is overburdened or displaced. This review will require a significant amount of time for the station personnel involved, and plant management should be prepared to allocate resources and distribute workloads accordingly.

The following is a summary of the suggested level of involvement for each identified group:

- **Team Leader**. A project manager or a system or design engineer with knowledge of the EDGs and their systems should lead the single component vulnerability review team and be prepared to devote a significant portion of his or her time to the project. The leader should **not** be the plant's current EDG system engineer. The EDG system engineer should provide information and answer questions but should not be the review team leader. Station management should recognize the value of limiting the role of the EDG system engineer in the review team because the system engineering responsibilities are burdensome enough.
- **Team Members**. Recommended personnel could include those with existing responsibilities or a former EDG background (in engineering, operations, or maintenance) or those who work on similar, related, or connected systems. Team members with electrical/controls experience or knowledge are critical to the usefulness of the review.
- **Management**. Plant management should assign an executive sponsor for the single component vulnerability review effort. This person should not participate in the detailed review work; rather, he or she should manage/align plant resources as needed to support the review.

The members of the EDG single component vulnerability review team should be identified to their supervisors, and plant management must ensure that the selected individuals have access to the necessary resources to support the review and that their workloads are adjusted to accommodate participation in the review.

If practical, it is recommended that this review be performed with in-house personnel. The knowledge gained by site personnel through involvement with this review is expected to prove invaluable in the future. Site personnel will be better prepared to address EDG issues, including performing operability reviews, optimizing maintenance, and troubleshooting failures. If outside support is considered, ensure that the provider has significant experience with diesel engines, auxiliary equipment, regulatory exposure, and system functionality. The site should maintain guidance, control, and oversight of the project through the team leader.

Performance of the Review

Industry experience has shown that the following beneficial practices can help with the performance of the review:

- Compile large-size hardcopy drawings (P&IDs and electrical schematics) of the EDG's skid auxiliary and control systems ahead of time.
- Use color-coded markers to mark off each component reviewed in the P&IDs and electrical schematics. For electrical relays, mark off each coil and in-service contact. This is an efficient way to track progress and keep the review moving forward, without duplication.
- Compile the results into a table (Microsoft Excel spreadsheet or equivalent). An example table is provided in Appendix A. Consider adding the following detail:
  - The component name; its equipment ID (if any; gaps noted); a short description and function; single component vulnerability status (and why it is considered a single component vulnerability); whether its failure rendered the EDG inoperable or unavailable; what PM, testing, or inspection activity covered it; and compliance with Owner's Group PM recommendations.
  - Note open questions, gaps, and follow-up actions by tracking number. Color-coded boxes and the Excel "comments" feature can be used to track these during the review before they are compiled into the final report.

Component Review

The review results should be documented to show a separate evaluation for each failure mode of the identified single component vulnerabilities. For common components such as relays or valves, existing industry guidance (that is, EPRI templates) can be used. The following information should be presented for each component failure mode:

- Applicable operating experience (OE)
- Consequence of failure
- Comparison of plant to industry/vendor O&M practices
- Whether a replacement is available or can be obtained in time to prevent the EDG from exceeding its limiting condition for operation (LCO)

Report Preparation

The results of the single component vulnerability review should be presented to plant management in the form of a report. The report should include an executive summary that clearly identifies the approach of the review, the single component vulnerabilities identified, and the recommendations for correcting the vulnerabilities. The report recommendations and proposed corrective actions should be entered into the plant's corrective action program.

The review report may be formatted in accordance with standard plant practices, but the following information should be included as a minimum: the single component vulnerability review scope, the approach, vulnerabilities identified, and recommended actions developed.

Management Review

Once the initial single component vulnerability review is completed and documented, a plant management review board should be convened to review the results and implementation plans, including cost and schedule.

Implementing Recommendations

Items requiring extensive resources or special management attention should be submitted to the appropriate plant committee. Plant management should focus on correcting problems identified during this review and not just acknowledge that the review was completed.

5
REFERENCES

1. INPO Topical Report 10-73, Emergency Diesel Generator (EDG) Start, Load, and Run Failures and Events Affecting Power Generation (January 2007–June 2010), October 2010.
2. INPO Event Report L4-13-21, Emergency Diesel Generator (EDG) Review Visit Summary, May 14, 2013.
3. USNRC Regulatory Guide 1.9, Rev. 4, Application and Testing of Safety-Related Diesel Generators in Nuclear Power Plants, March 2007.
4. IEEE STD 387-1995, IEEE Standard Criteria for Diesel-Generator Units Applied as Standby Power Supplies for Nuclear Power Generating Stations.

A
SAMPLE OF A SINGLE COMPONENT VULNERABILITY REVIEW TABLE

A sample of an EDG system single component vulnerability review table is shown in Table A-1.

Table A-1
Sample of an EDG System Single Component Vulnerability Review Table

System	Component	Component ID	Function	SCV = Loss of Operability	SCV Comment	Available	Testing Pm (Freq)	Inspection PM (Freq)	Replacement PM (Freq)	References
Governor	EGB - Governor Booster	Needs an ID	Provides Oil Pressure upon engine start	Y	Failed or slow start to to loss of EGB contol pressure	N	Functionally tested (EDG Run)	General Maintenance (PM219845 (730))		
Governor	CCCR - Cross Current Control Relay	CCCR	Swap Governor and voltage regulator between Isochronus and droop modes	Y	Inability to swap between Isochronus and droop	Y	Functionally Tested (EDG Run and (PM219841 A10)	Check PU voltage and contact resistance (PM219841 A09)		
Voltage Regulator	K1 Relay	K1	Self Excitation and removes excitation on engine shutdown	Y	Unable to maintain field excitation	N	Functional (PM215083)	Visual (PM215083)		
Voltage Regulator	VR1	VR1	Surge Suppression in case of an overvoltage	Y	Loss of Generator Field	N		Inspect (730) Thermography (180)		
Generator	Generator Space Heaters	GSH	Keeps Generator above ambient temp to prevent condensation	N	N/A	Y	Functionality operate (PM219843) (A11)	Visual Inspection (PM219843; A01)		
Engine Controls	Start Relay	4A	Permissive to start the engine	Y	Needed to start engine	N	Functions on monthly run			
Fuel Oil	Basket Strainer	BS-020-120	Strains Fuel Oil from outside fill connection	N	N/A	Y				1433187-25
Lube Oil	Engine Driven L/O Pump suction strainer	Needs an ID	Entrap dirt	N	N/A	Y		NO PM		1433187-33
HVAC	Temp Control Switch	TTICSHL-081-101A	Controls EDG cell fans	Y	If room drops below TS temp	Y	Functional (PM222830 (1825))			

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